Progress on High Efficiency Coal Power Plants

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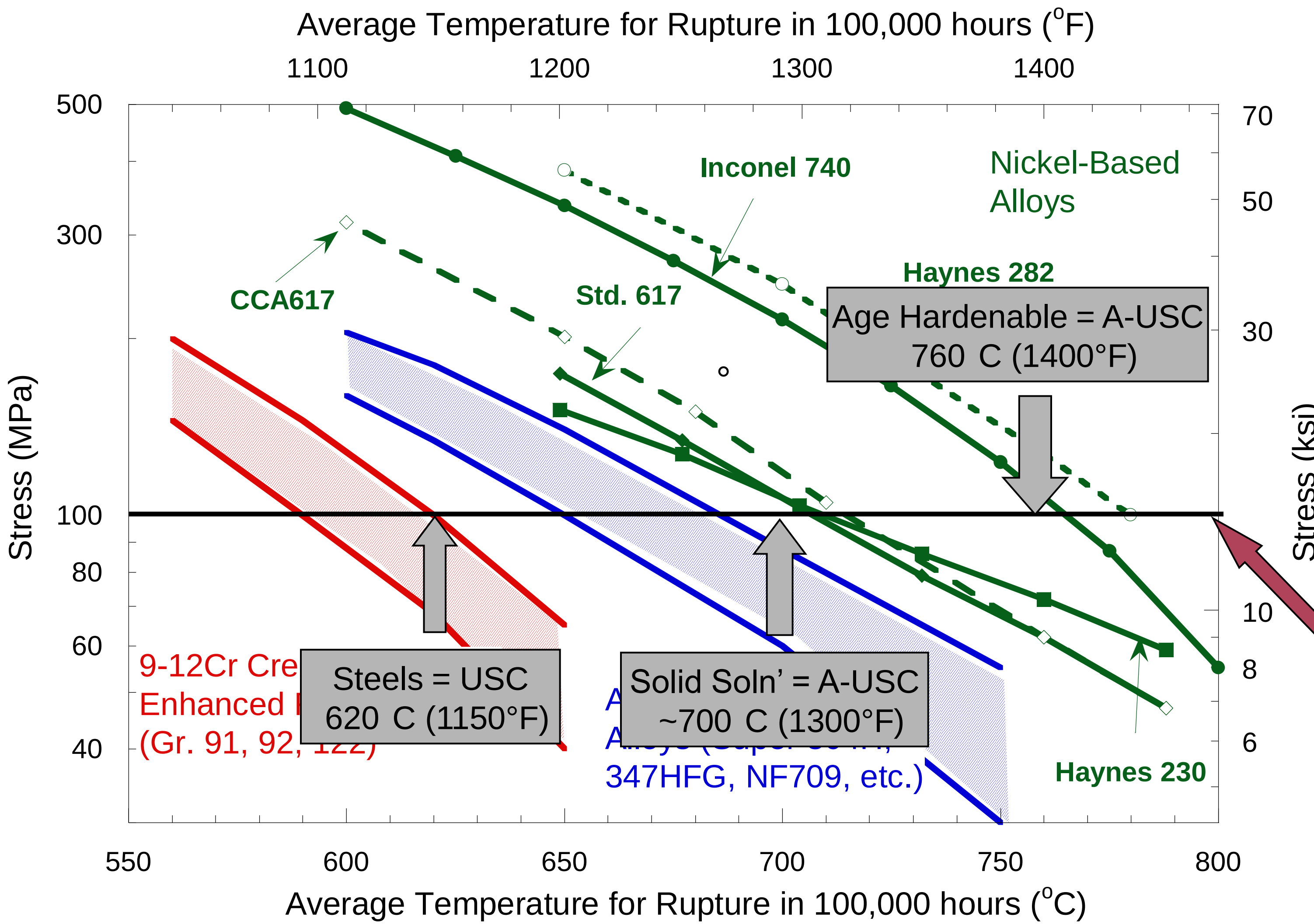
McIlvaine Webcast
March 1, 2012

Materials Limit the Current Technology



Minimum Desired Strength at Application Temperature

Primary Technical Goals of US A-USC Materials Programs

- Materials Technology Evaluation
  - Focus on **nickel-based alloys**
  - Development of fabrication and joining technology for new alloys
- Unique Conditions for US Program Considerations
  - Higher-temperatures than European Program (760 C versus 700 C) means **additional alloys** are being evaluated
  - Corrosion resistance for **US coals**
  - Data for **ASME code** acceptance of new materials
  - Phase II Boiler work includes **Oxycombustion**

Acknowledgements: U.S. Department of Energy (US DOE) / Ohio Coal Development Office (OCDO) A-USC Steam Boiler and Turbine Consortia

U.S. DEPARTMENT OF ENERGY

Ohio | Coal Development Office

NETL

Federal – State – National Laboratory
Non Profit – For Profit
Cost Sharing Consortium

Energy Industries Of Ohio

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GE imagination at work

Babcock Power Inc. RILEYPower A Babcock Power Inc. Company

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U.S. DOE/OCDO: A-USC Steam Boiler Consortium

1: Conceptual Design

2: Material Properties

3: Steamside Oxidation

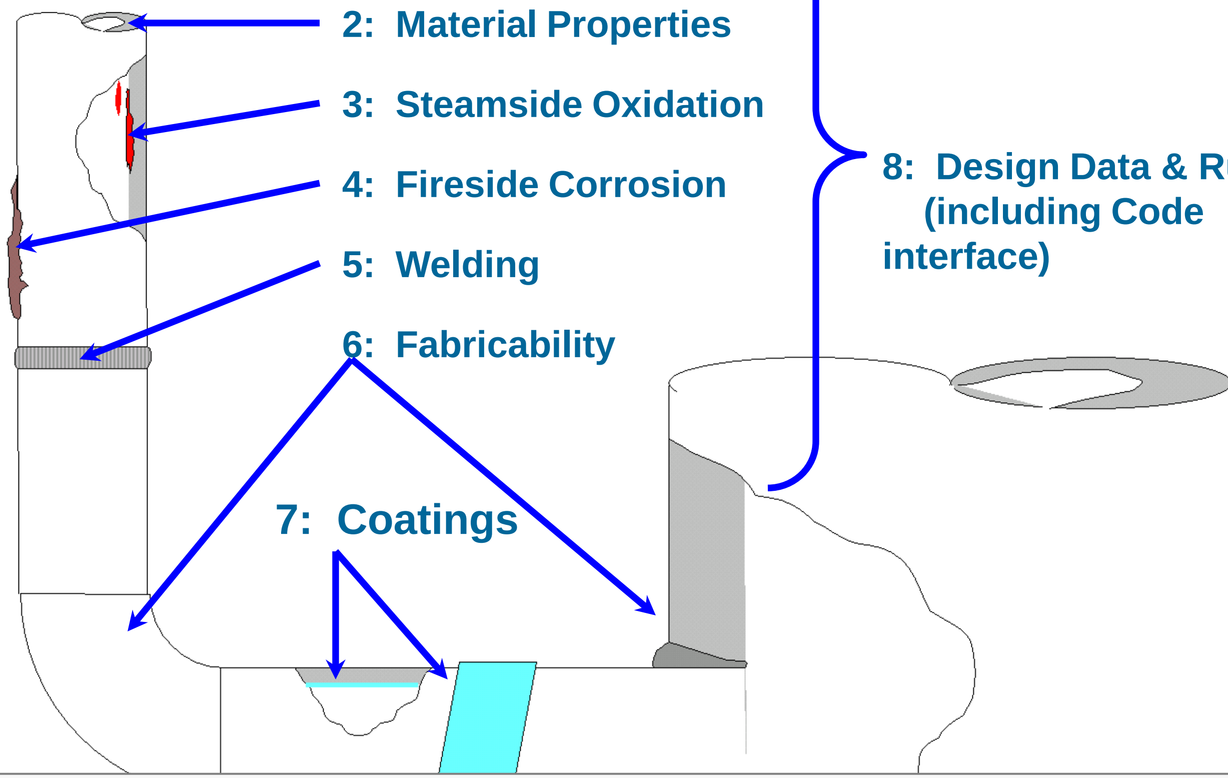
4: Fireside Corrosion

5: Welding

6: Fabricability

7: Coatings

8: Design Data & Rules (including Code interface)



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Develop the materials technology to fabricate and operate an A-USC steam boiler with steam parameters up to 1400 F (760°C)

Major Step: Code Case 2702 (Inconel®740) now Approved for Use in Section I

- Approved: Sept. 26, 2011
- Maximum Use Temperature: 800°C (1472°F)
- Rules for:
  - Chemistry
  - Heat-treatment
  - Welding
  - Post-weld heat-treatment
  - Cold-forming
  - Weld strength reduction factors

CASES OF ASME BOILER AND PRESSURE VESSEL CODE

CASE
2702

Approval Date: September 26, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case 2702
Seamless Ni-25Cr-20Co Material
Section I

Inquiry: May precipitation-hardenable Ni-25Cr-20Co alloy (UNS N07740) wrought sheet, plate, rod, seamless pipe and tube, fittings and forgings material conforming to the chemical requirements shown in Table 1, the mechanical properties listed in Table 2, and otherwise conforming to the applicable requirements in the specifications listed in Table 3 and in this Case be used in welded construction under Section I rules?

Reply: It is the opinion of the Committee that precipitation-hardenable Ni-25Cr-20Co alloy (UNS N07740) wrought sheet, plate, rod, seamless pipe and tube, fittings and forgings as described in the Inquiry may be used in welded construction complying with the rules of Section I, provided the following rules are met:

(a) Material shall be supplied in the solution heat treated and aged condition. Solution heat treatment shall be performed at 2,010°F (1100°C) minimum for 1 hr per 1 in. (25 mm) of thickness but not less than ½ hr. Aging shall

(d) Postweld heat treatment for this material is mandatory. The postweld heat treatment shall be performed at 1,400°F to 1,500°F (760°C to 815°C) for a minimum of 4 hr for thickness up to 2 in. (50 mm), plus an additional 1 hr per additional 1 in. (25 mm) of thickness. If a longitudinal weld seam is required in the construction of a component, a weld strength reduction factor of 0.70 shall apply in accordance with rules in PG-26 for applications at temperatures above 1,112°F (600°C).

(e) After cold forming to strains in excess of 5%; after any swages, upsets, or flares; or after any hot forming of this material, the component shall be heat treated in accordance with the requirements specified in (a). No local solution annealing may be performed. The entire affected component or part that includes the cold-strained area and transition to unstrained material must be included in both heat treatments. The calculations of cold strains shall be made as described in Section I, PG-19.

(f) The maximum use temperature is 1,472°F (800°C).

(g) S_u and S_y values are listed in Tables 5 and 5M and Tables 6 and 6M, respectively.

(h) *Physical Properties.* See also Tables 7 and 7M,

Currently in process for B31.1 – Additional Research Underway to Extend the Maximum Use Temperature

Highlights: World's First Inconel®740 Pipe Extrusion

- Special Metals (Huntington, WV) & Wyman-Gordon (Houston, TX) Project

not consortium funded

- 15-inch (381mm) O.D. X 8-inch (203mm) I.D. X 34-1/2 feet (10.4m) long
- Larger forging window for Inconel 740 compared to CCA617 (same size pipe extrusion was shorter, 8.9m)

Inconel®740 Pipe after Extrusion at Wyman-Gordon

1022036 (A-USC Steam Turbine) Highlight: Large Step Casting Produced

- Research by NETL & ORNL led to selection of key turbine cast alloys for casings & valve bodies
  - Haynes 282 (primary) & Alloy 263
  - Numerous trial plates produced for welding repair studies
- Scale-up Efforts (Haynes 282)
  - 300 lb step casting (Manufacturer 1)
  - 600 lb *finished weight* step casting (Manufacturer 2 – EIO Project)

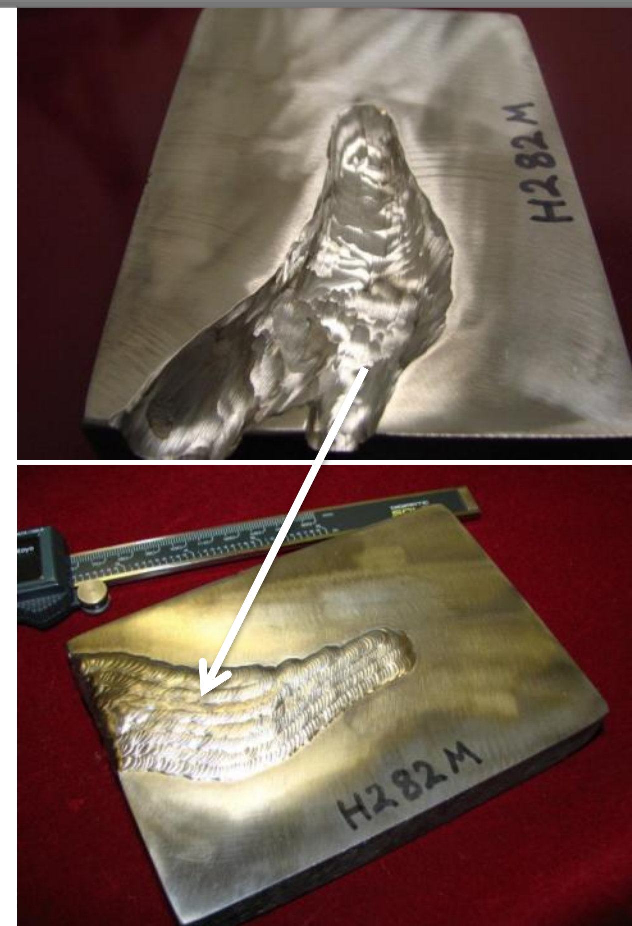
Largest cross-section = ~180mm (7inch) cube

1022036 (A-USC Steam Turbine) Highlight: Cast Nickel-based Alloy Welding Development

- 50.4mm (2”) thick cast plates produced
  - 282 and 263
  - Test Plan = tensile, creep, LCF, & impact

Cast Plate During Welding

Simulated Casting Defect & Subsequent Casting Repair



1022037 (A-USC Steam Boiler) Highlight: Fireside Corrosion – Steam Loop

- 1st Steam Loop was completed in Phase 1
  - Aggressive high Sulfur coal
  - Did not meet intended temperatures (less than 760°C/1400°F)
- 2nd Steam Loop now installed and operating
  - Future press release with more details
  - Goal: 12-18 months of operation
  - Maximum Temperature:
    - 760°C (1400°F)

2nd Steam Loop Installation

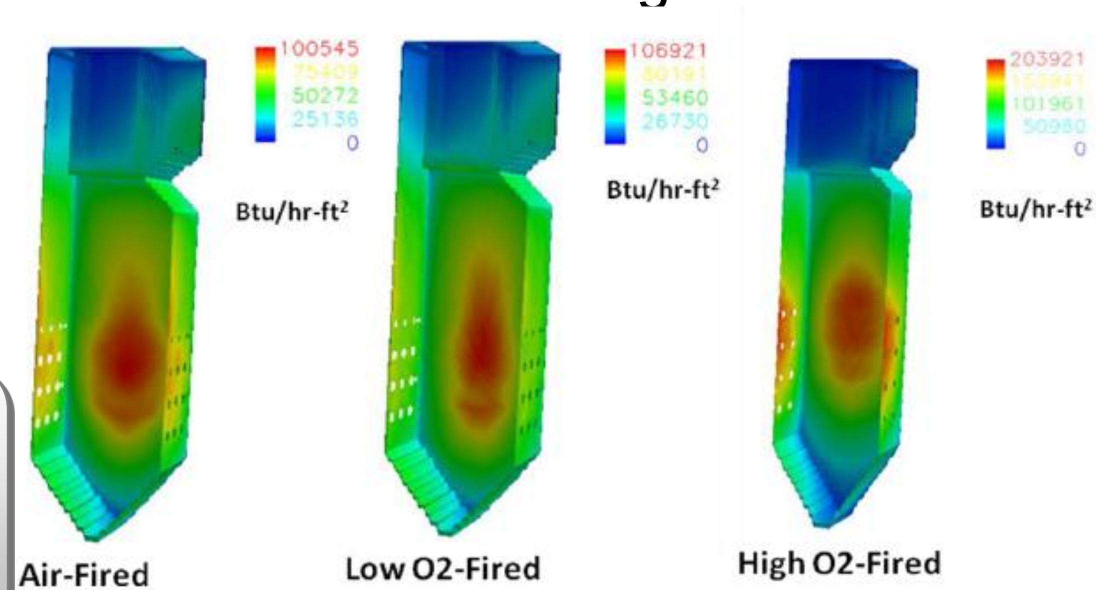
Summary: Excellent Progress in 2011

- Approval of ASME Code Case 2702 (Inconel ®740)
- Worldwide interest in program results and materials has spurred commercial interest
- Steam-turbine has selected key alloys, extensive testing has started, and scale-up activities have begun
- A utility workshop has helped focus future EPRI and Consortium efforts → AGAG & weld repair studies in boiler & turbine programs

300 lb Haynes 282 Step Casting

More to Come in 2012

- Additional field fireside corrosion testing (steam loop)
- Completion of oxycombustion design studies
- Fireside corrosion in oxycombustion enviroments
- Scale-up activities on turbine to include a larger rotor/disc forging
- Performance of weld repairs



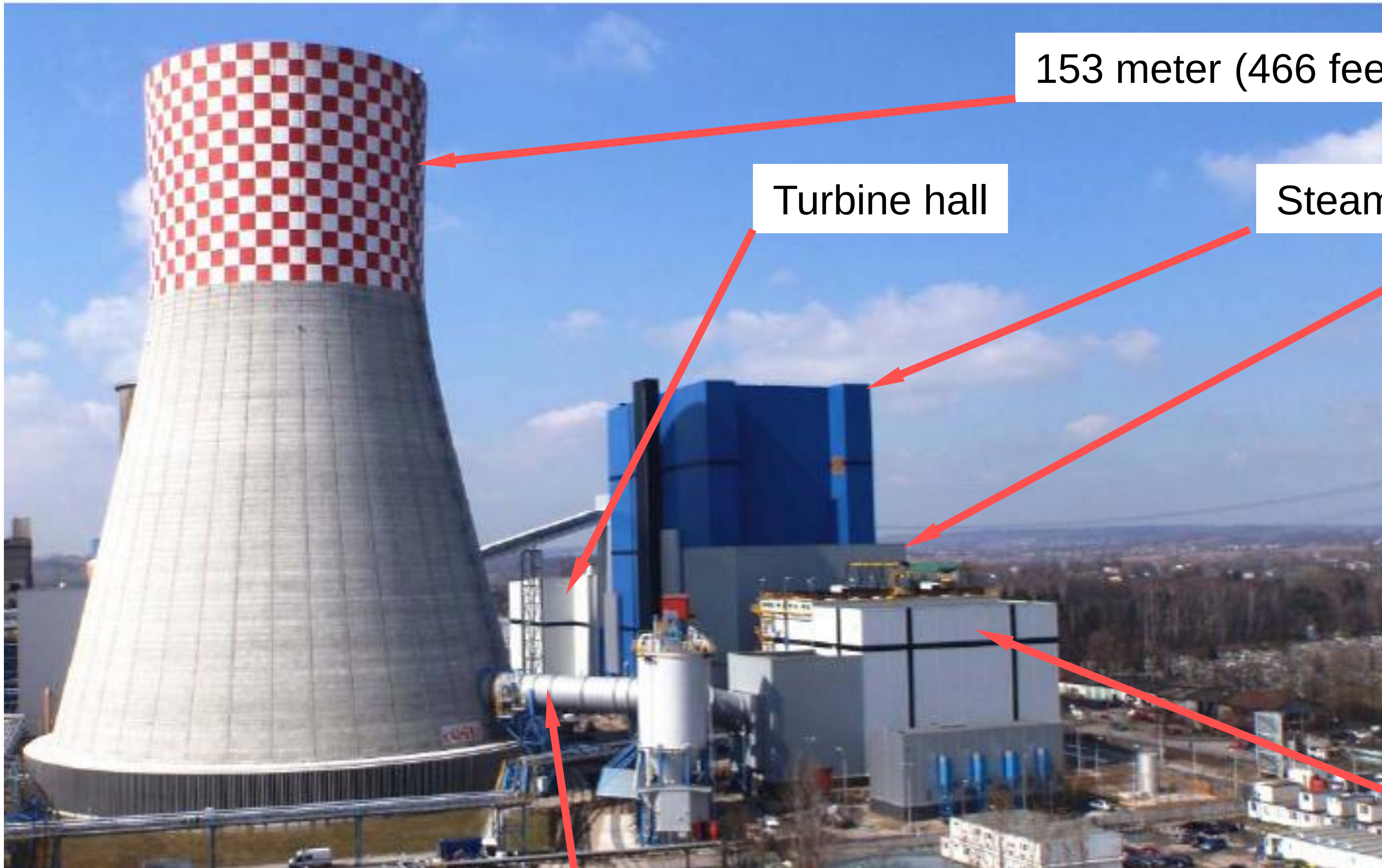
Calculated combustion microclimates for different firing conditions

Supercritical CFB

Katowice, Poland

PKE 460 MWe Supercritical CFB, Łagisza, Poland

PKE Łagisza 460 MWe CFB Power Plant



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Particulars

100% MCR Design Conditions

SH Flow	2,860 klb/hr	361 kg/s
SH Pressure	3989 psig	275 bar
SH Temperature	1040 F	560 C
RH Flow	2,424 klb/hr	306 kg/s
RH Pressure	798 psig	55 bar
Cold RH Temperature	599 F	315 C
Hot RH Temperature	1076 F	580 C
Feedwater Temperature	554 F	290 C

Permitted Emissions

	Concentration mg/Nm^3 (6% O_2, dry)	Yield lb/MMBtu	Primary control
SO_2	200	0.14	Limestone @ Ca/S of 2.0-2.4: 94% capture
NO_X	200	0.14	SNCR - Aqueous NH_3 to cyclone inlets
Particulate	30	0.02	ESP

Bituminous coal from many local mines

LHV	7700-9900 Btu/lb	18-23 MJ/kg
Moisture	6-23%	
Ash	10-25%	
Sulfur	0.6-1.4%	
Chlorine (dry)	< 0.4%	

Steam generator is also designed to burn:

- Up to 30% (by energy) coal slurry
- High ash washery wastes
- Up to 10% (by weight) biomass

Plant Performance

Gross Plant Output	460 MWe
Auxiliary Power	21 MWe (4.6% gross)
Net Plant Output	439 MWe
Net Plant Heat Rate	8,204 Btu/kWh (HHV) 41.6% net efficiency

Together…Shaping the Future of Electricity