Progress on High Efficiency Coal Power Plants

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McIlvaine Webcast
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Materials Limit the Current Technology

**Average Temperature for Rupture in 100,000 hours (°F)**

**Stress (MPa)**

- **9-12Cr Creep-Strength Enhanced Ferritic Steels** (Gr. 91, 92, 122)
- **Nickel-Based Alloys**
- **Advanced Austenitic Alloys** (Super 304H, 347HFG, NF709, etc.)
- **Inconel 740**
- **CCA617**
- **Std. 617**
- **Haynes 282**
- **Haynes 230**

**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
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

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)
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 (7 inch) 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

Simulated Casting Defect & Subsequent Casting Repair

Cast Plate During Welding
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)
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 environments
- 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

153 meter (466 feet) tall cooling tower

- Flue gas to cooling tower
- Turbine hall
- Steam Generator
- Fans
- Blowers
- Air heaters
- Low-temp. heat exchanger
- Bypass Economizer
- ESP
- Ash handling

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Particulars

100% MCR Design Conditions

<table>
<thead>
<tr>
<th>Particular</th>
<th>Value 1</th>
<th>Value 2</th>
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</thead>
<tbody>
<tr>
<td>SH Flow</td>
<td>2,860 klb/hr</td>
<td>361 kg/s</td>
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<tr>
<td>SH Pressure</td>
<td>3989 psig</td>
<td>275 bar</td>
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<tr>
<td>SH Temperature</td>
<td>1040 F</td>
<td>560 C</td>
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<tr>
<td>RH Flow</td>
<td>2,424 klb/hr</td>
<td>306 kg/s</td>
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<tr>
<td>RH Pressure</td>
<td>798 psig</td>
<td>55 bar</td>
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<tr>
<td>Cold RH Temperature</td>
<td>599 F</td>
<td>315 C</td>
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<tr>
<td>Hot RH Temperature</td>
<td>1076 F</td>
<td>580 C</td>
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<tr>
<td>Feedwater Temperature</td>
<td>554 F</td>
<td>290 C</td>
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Permitted Emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Concentration mg/Nm³ (6% O₂, dry)</th>
<th>Yield lb/MMBtu</th>
<th>Primary control</th>
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</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>200</td>
<td>0.14</td>
<td>Limestone @ Ca/S of 2.0-2.4: 94% capture</td>
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<tr>
<td>NOₓ</td>
<td>200</td>
<td>0.14</td>
<td>SNCR - Aqueous NH₃ to cyclone inlets</td>
</tr>
<tr>
<td>Particulate</td>
<td>30</td>
<td>0.02</td>
<td>ESP</td>
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Bituminous coal from many local mines

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
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<tbody>
<tr>
<td>LHV</td>
<td>7700-9900 Btu/lb</td>
<td>18-23 MJ/kg</td>
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<tr>
<td>Moisture</td>
<td>6-23%</td>
<td></td>
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<tr>
<td>Ash</td>
<td>10-25%</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.6-1.4%</td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>&lt; 0.4%</td>
<td></td>
</tr>
</tbody>
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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

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
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</thead>
<tbody>
<tr>
<td>Gross Plant Output</td>
<td>460 MWe</td>
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<tr>
<td>Auxiliary Power</td>
<td>21 MWe (4.6% gross)</td>
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<tr>
<td>Net Plant Output</td>
<td>439 MWe</td>
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<tr>
<td>Net Plant Heat Rate</td>
<td>8,204 Btu/kWh (HHV)</td>
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<td>41.6% net efficiency</td>
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Together…Shaping the Future of Electricity