Technical Readiness for A-USC Plant Deployment – a B&W Perspective

IEA Clean Coal Centre Workshop
Advanced Ultra-Supercritical Coal-fired Power Plants
Vienna, Austria; 19-20 September 2012

Kevin McCauley
Dir. Strategic Planning Global Technology

A Global Business: B&W Corporation

"Energy Technology Solutions"

Global Reach

Headquartered in Charlotte, NC, USA with major operations:

- **Beijing, China**
- **Pune, India**
- **Barberton, OH, USA**

B&W Power Generation Group

- **$1.6 B sales. $2.7 B backlog. ~9,500 employees (including JV employees) worldwide**
- **Headquartered in Barberton, OH, USA**
- **Installed 38% of boilers in North American coal-fired power plants**
- **Supplied worldwide capacity of more than 300,000 MW in 800+ utilities in 90+ countries**
- **Full suite of environmental control products and solutions for any application or need**

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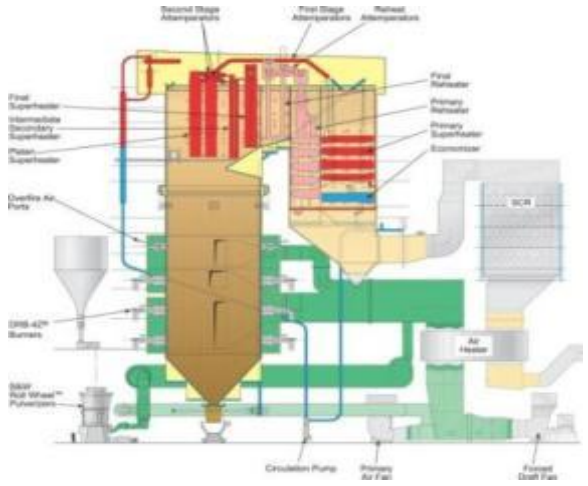
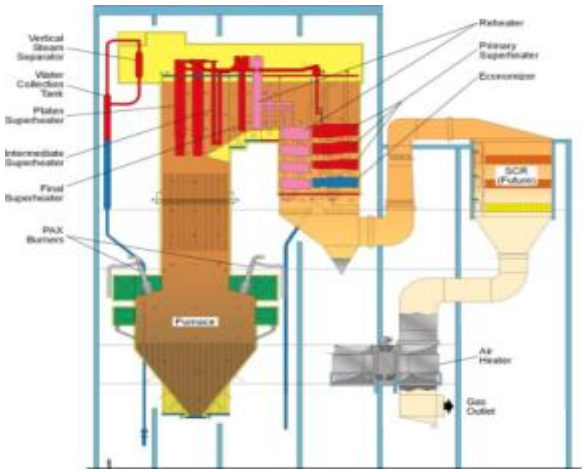
Proven History…Constant Advancement

- Over 80 years of research and development, and applications… in steam generation
- Variable and constant pressure furnace designs…since 1957
- Applicable with wide range of coals (and solid fuels)…with reliability
- Highest efficiencies at 600-620C currently, developing >700C for the near future
- Fuel flexibility with development of supercritical circulating fluid bed (CFB) boilers

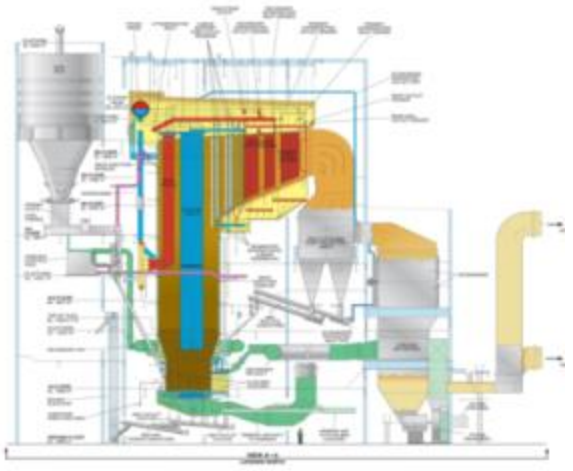
Vertical Tube Universal Pressure Boiler (VTUP™)



Downshot Universal Pressure Boiler (VTUP™)



Circulating Fluidized Bed Boiler (CFB)



Waste Coal Lignite Sub-Bit Bituminous Anthracite PetCoke

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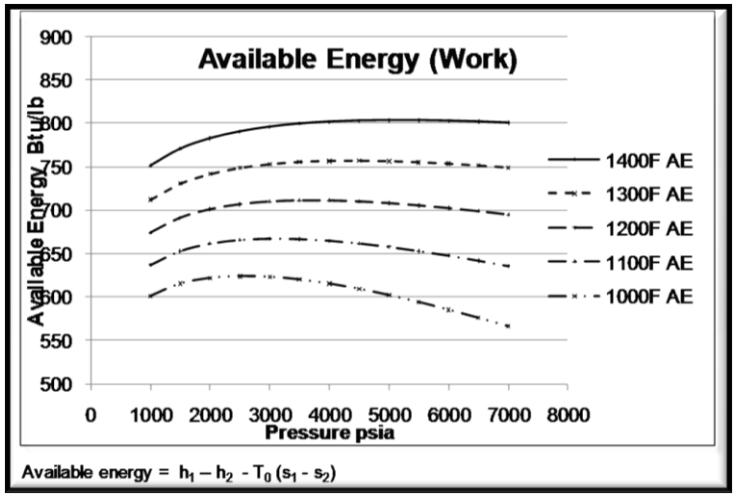
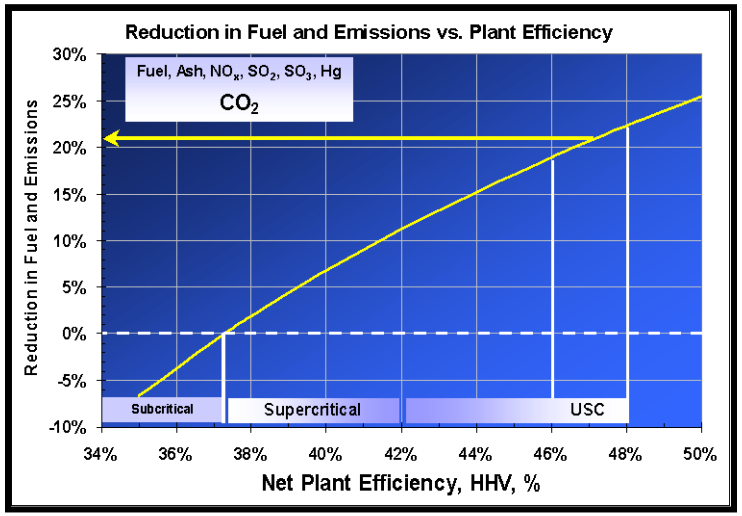
"Advanced" Ultra Supercritical Power Plant

Operating up to 5,000 psi and 1,400 F





- Ultrasupercritical (USC) US-DOE goal for higher efficiency and much lower emissions, materials capable of:
  - 760 °C (1400 °F)
  - 34.5 MPa (5,000 psi)
  - Future oxygen firing
- Plant efficiency can be improved to 45-47 % (HHV) Ultra-supercritical (USC)
- CO_2 Emissions are reduced by 28 to 31%
- Lower balance of plant cost means smaller coal handling and emission controls for the same net plant output
- Meeting these targets requires:
  - The use of new materials
  - Novel uses of existing materials

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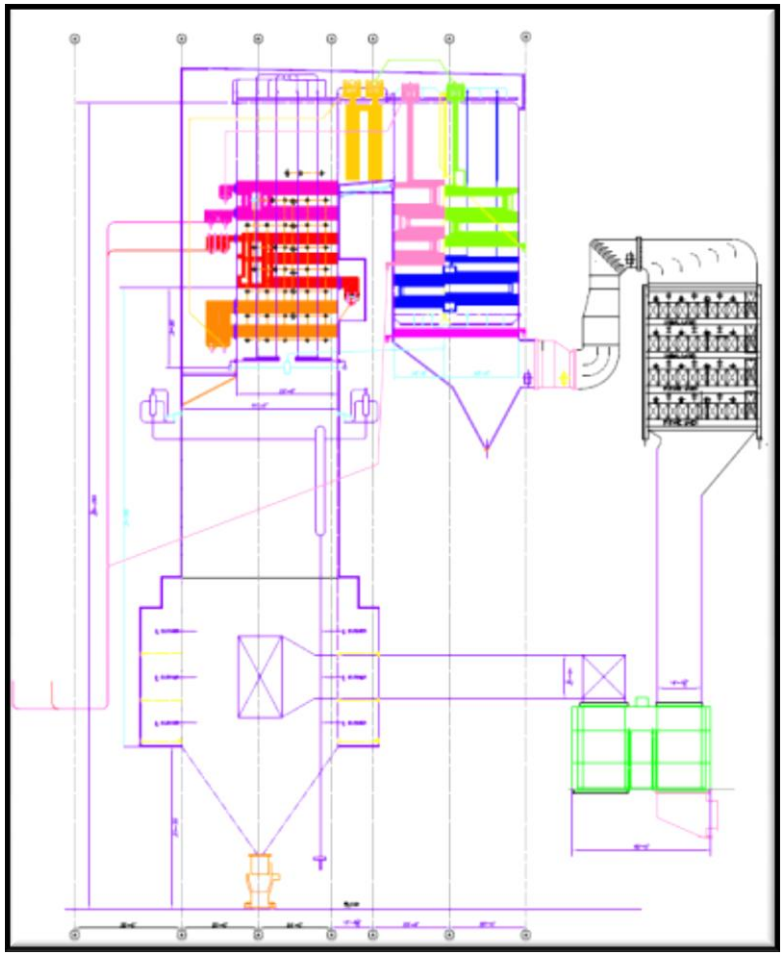
Design for Boiler/Turbine Joint Studies

New Designs Developed

- Steam outlet at side of boiler more cost effective for steam leads
- Helps mitigate effects of steam-side exfoliation with horizontal surface
- Air-fired configuration utilizes parallel backend for better RH control
- Modified tower reduces overall height of unit for capital cost savings
- Two-passes allows for parallel erection sequences reducing schedule
- Oxy-fired configuration
  - Can have series backend, use recycle for RH control
  - No SCR required

Modified Tower Design



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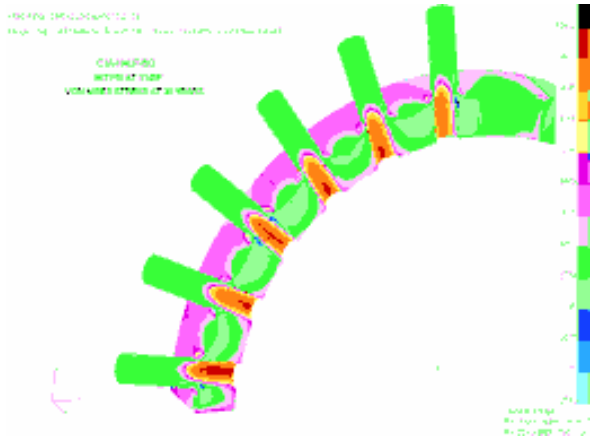
Pushing the Envelope…for A-USC Readiness

B&W Leading the Understanding



- **Fireside Corrosion – Air and Oxy-fired environment tests**
- **Steam-side Oxidation - Testing**
- **3D-FEA - Thick Walled Components**
- **T23 and T92 Waterwalls - Fabrication of full scale panel & field repair heat treat trials**
- **Stainless Steel - Thick-section weld development**
- **Alloy 740 and 282 – Added weld development**
- **Cladding and coating - Development**
- **Stress Relaxation Cracking - Evaluation**

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Fireside Corrosion

Further Development by B&W

- *Laboratory tests simulating waterwall and superheater and reheater conditions. Various coals tested*
- *Field tests performed consisting of steam loops and air-cooled probes*
- *Corrosion is a function of Cr level - decreases rapidly as Cr increases to 22 to 27% and then levels off*
- *IN-740 showed greater resistance than Haynes 230 and CCA617*
- *Oxy-fired data looks better*
- *Overlays and coatings will be necessary on WWs in units burning some coals because 9-12Cr ferritic steels do not have adequate resistance*

Consortium funded initial testing

Isothermal, 1000-hour tests

Able to predict corrosion rates…implement solutions

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Steamside Oxidation

Key additional research by B&W

- *Autoclave tests at 620C, 650C, 750C and 800C to 10,000 hrs*
- *Austenitic steels ranked and show good resistance to oxidation and exfoliation up to 700C*
- *Ni base alloys show the least oxidation and absence of exfoliation*
- *Parabolic kinetics exhibited enabling prediction*
- *Evaluated many coatings and surface treatments*
- *Several outstanding ferritic and austenitic alloys were identified.*

A-USC Steam Oxidation – 750C Test

Understanding of the kinetics…ready to apply to new units

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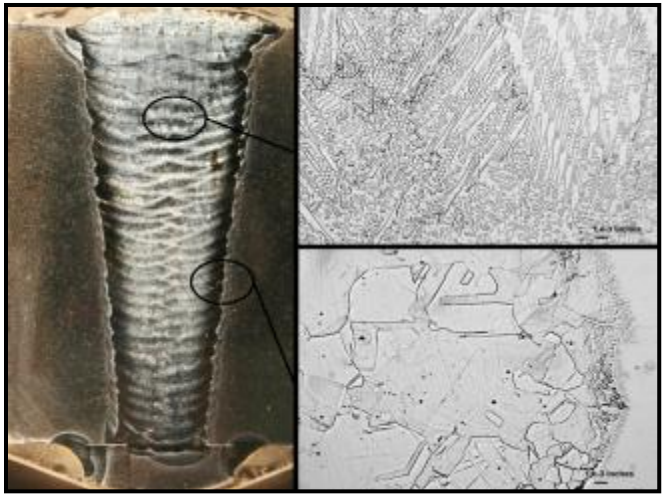
Weldability – Tubes and Pipes

Key B&W Leadership in Code Cases

- *Welding of small diameter candidate alloys very successful*
- *Narrow groove welding successful*
- *Alloy 740 tubes and pipe, both now Code approved in US*
- *Butt welding processes using 2 and 3 inch thick products qualified*
  - *Haynes 230:*
    - *Pulsed GMAW using matching filler.*
  - *Alloy 740:*
    - *Hot wire GTAW using matching filler*



Tremendous effort and great success…capable of all groove sizes

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Fabricability

Translating theory to practice

- *Tube cold U-bend trials up to 35% strain successfully completed for all USC project alloys: (740, 230, CCA617, S304H, HR6W, & SAVE12)*
- *Hot bending trials successfully completed*
- *Machining trials successful*
- *Tube swaging trials*
- *Controlled cold strain / recrystallization / precipitation studies completed for all USC project alloys*

B&W Beijing

Grade 92 Panels Successfully Manufactured

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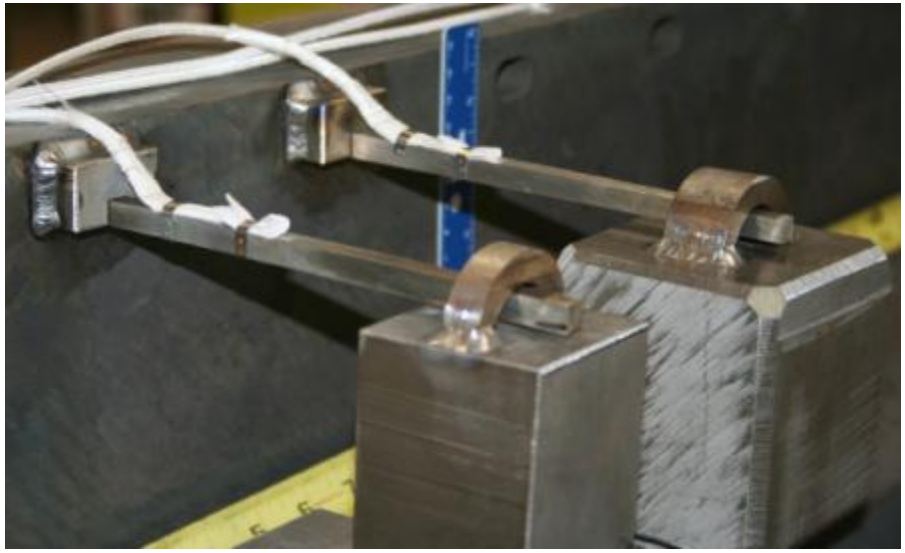
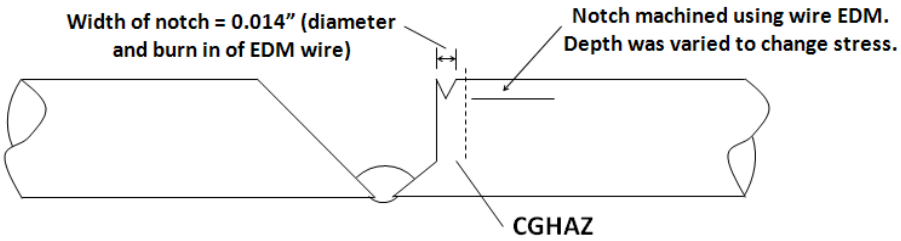
Weldment lifecycle analysis

B&W Development

- *Allows simultaneous testing several material conditions at a given temperature:*
  - *Stress-relieved*
  - *As-welded*
  - *Effect of filler metal*
  - *Stress*
- *Capable of inducing the same failure mechanism observed in service*
- *Strain-aged cracking*





Studying and Understanding Component Lifecycle

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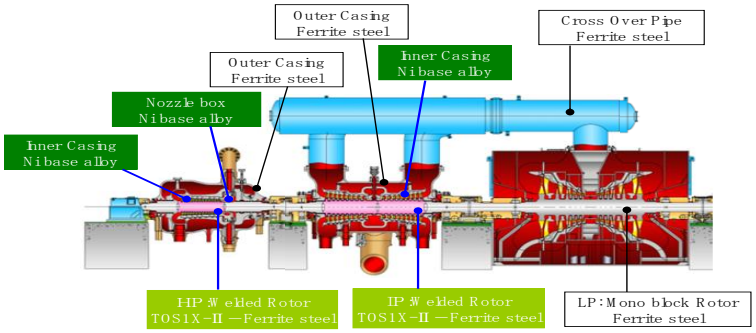
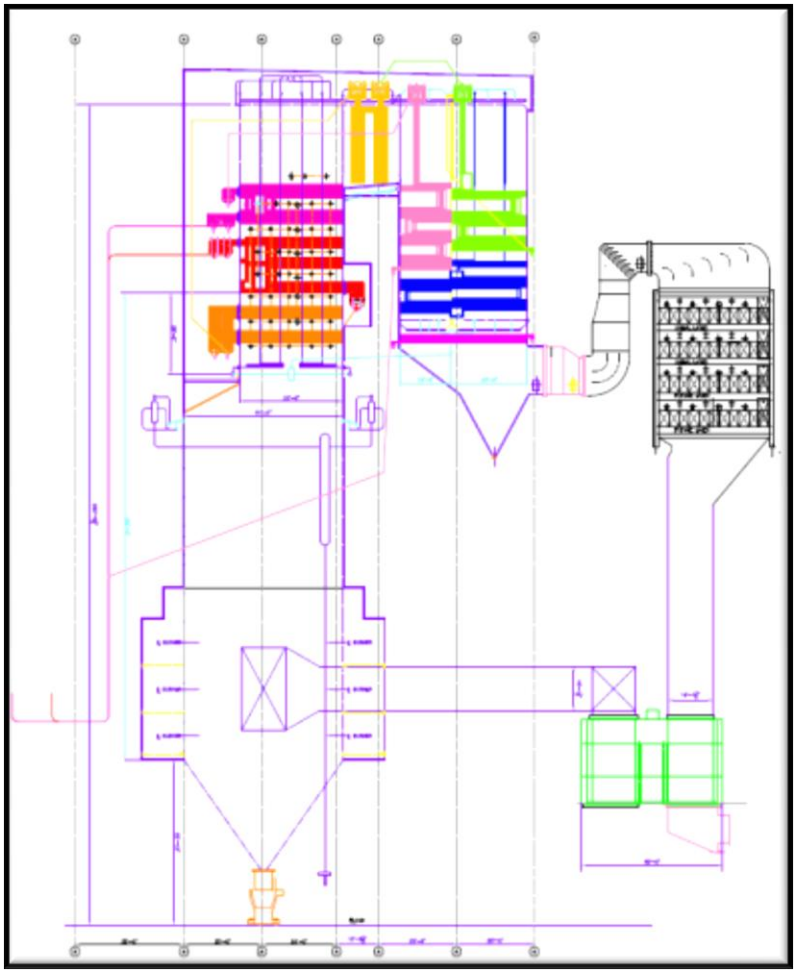
A-USC Boiler-Turbine – Performance

- Cycle Heat Balance for A-USC
- Single vs. Double Reheat
- Capacity, MWe
- Steam Turbine Configuration – Steam piping connections
- Operations:
  - Starting conditions (cold, warm, hot)
  - Turndown cycling (Grid Integration)
  - Considerations for BFP drives (TD and VFD)
  - Sliding pressure, pure or throttle reserve, pressure "shelf" at minimum load
- Rate of Load Change
- Carbon Capture Considerations:
  - Condensate heat exchangers for oxy-combustion heat recovery
  - Turbine steam extraction for post-combustion solvent regeneration





TOSHIBA
Leading Innovation

B&W
power generation group

Technical Readiness…Combination of expertise, technology and proven history

- **Suitable pressure boundary materials…have been characterized**
  Candidates identified and screened, Code approvals
- **Corrosion and oxidation…extensively tested and predictable**
  Improved materials, coatings/ claddings and design
- **Weldability of the highest strength alloys in heavy sections**
  Extensively investigated, B&W a leader
- **Designs have been analyzed…alternatives weighed**
  Concepts and optimization continue with turbine manufacturer

Ready for 700C (1290F) main steam and 730C (1350F) for reheat ; Confident at 760C

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“We are passionate about innovation and technology leadership”

Thank-you

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