ComTest “Superheater”
for
Advanced Ultrasupercritical (A-USC)
1400F (760C) Steam Conditions
increase temperature to improve efficiency

Pittsburgh Pennsylvania - 2015 April 29
DOE-FE-00242067

Paul Weitzel
Technology, New Product Development
B&W will perform the pre-front end engineering design (Pre-FEED) of an A-USC steam superheater for a component test program achieving 760°C (1400°F) steam temperature. The steam generator superheater would subsequently supply the steam to an A-USC prototype scaled intermediate pressure steam turbine.

In the 3\textsuperscript{rd} quarter of a 5 quarter project (15 months)
“New” Design Technique by General Electric (bolted GT discs) for steam turbine

Test 1400F blade path integrity for erosion (steam side oxidation)
OBJECTIVES
The technical goal of the project is to perform the pre-front end engineering design (Pre-FEED) of a gas fired A-USC steam superheater capable of operating at 760 deg C steam temperature.

-expected results: completed Pre-FEED package for design, procurement, manufacturing, construction, and installation.
ComTest A-USC Superheater

TASKS and SUBTASKS TO BE PERFORMED

Task 1.0 – Project Management and Planning

Task 2.0 – Scope Interface Engineering

Task 3.0 – Product Engineering

Subtask 3.1: Perform pre Front End Engineering Design Studies

Subtask 3.2: Develop Preliminary Commissioning and Testing Plan

Task 4.0 – Mechanical Design of the A-USC Steam Superheater
  mechanical engineering design
  stress analyses (ASME Code calculations by rule)
  general arrangement and layout drawings.

Task 5.0 – Manufacturing Engineering of the A-USC Steam Superheater

Task 6.0 – Construction Engineering of the A-USC Steam Superheater

Task 7.0 – Cost Estimate for A-USC Steam Superheater
A-USC ComTest Superheater Youngstown Thermal
T-92 Membrane Enclosure, field welding, PWHT, initial service, high temperature operation
2 walls 11ft x 60ft
2 walls 4 ft x 60ft
740H nickel tubes, header, thick piping

Supply chain- nickel valves, accessories
STRINGERS T92  
2.00" x 0.230"

ECONOMIZER 210A1  
2.50" x 0.180"

PSH T92  
2.50" x 0.330"

PSH TP310 HCbN  
2.50" x 0.360"

ECONOMIZER 210A1  
2.50" x 0.180"

STRINGERS TP310 HCbN  
2.25" x 0.240"

PSH TP310 HCbN  
2.25" x 0.300"

740H 2.25" x 0.280"

STRINGERS TP310 HCbN  
2.00" x 0.240"

PSH 740H  
2.25" x 0.280"

PSH 740H  
2.25" x 0.350"

PSH 740H  
2.25" x 0.390"

STRINGERS TP310 HCbN  
2.00" x 0.240"

FSH 740H  
1.75" x 0.515"

1.75" x 0.470"

1.75" x 0.430"

STRINGER PLATENS  
TP310HCbN  2.00" x 0.380"

740H 2.00" x 0.180"

740H 2.00" x 0.150"
T-92 Test Wall Panel

Have not operated the T-92 panel. Can not weld panel into existing wall enclosure and operate at needed conditions. Need to do that in ComTest.

Fabricate install, PWHT, Repairs accomplished
# Candidate Steam Generator Materials

<table>
<thead>
<tr>
<th>Grade or Short Name</th>
<th>Specification</th>
<th>Composition</th>
<th>Application</th>
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</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>SA-210C</td>
<td>Carbon Steel</td>
<td>Economizer Tubes, Piping, Headers</td>
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<td>SA-106C</td>
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<td>T-12, P-12</td>
<td>SA-213</td>
<td>1Cr-.5Mo</td>
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<td>SA-335</td>
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<td>T-22, P-22</td>
<td>SA-213</td>
<td>2.25Cr-1Mo</td>
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<td>SA-335</td>
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<td>Superheater Tubes, Piping, Headers</td>
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<td>SA-213</td>
<td>2.25Cr-1.6W-V-Nb</td>
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<td>SA-213</td>
<td>9Cr-1Mo-V</td>
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<td>TP347 HFG</td>
<td>SA-213</td>
<td>18Cr-10Ni-Nb</td>
<td>Superheater Tubes</td>
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<tr>
<td>Super 304H</td>
<td>UNS 30432</td>
<td>18Cr-9Ni-.3Cu-Nb-N</td>
<td>Superheater Tubes</td>
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<tr>
<td>TP310 HcbN</td>
<td>SA-213</td>
<td>25Cr-20Ni-Nb-N</td>
<td>Superheater Tubes</td>
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<td>617_</td>
<td>UNS N06617</td>
<td>55Ni-22Cr-9Mo-12Co-Al-Ti</td>
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<td>UNS N06230</td>
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<tr>
<td>740H</td>
<td>S/B N07740</td>
<td>50Ni-25Cr-20Co-2Ti-2Nb-V-Al</td>
<td>Superheater Tubes, Piping, Headers</td>
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<tr>
<td>282_</td>
<td>non-ASME</td>
<td>58Ni-10Cr-8.5Mo-2.1Ti-1.5-Al</td>
<td>Future Potential for Tubes, Piping, Headers</td>
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</tbody>
</table>
ASME I Allowable Stress for Materials

Temperature F vs. Allowable Stress ksi

Materials:
- 210C
- T12
- T22
- T23
- T24
- T91
- T92
- 347HFG
- 310HCbN
- S 304H
- 617
- 230
- 740
- 282
**ComTest Demonstration Aspects**

Validation of the supply chain for nickel components
4500 psi design pressure for fabrication at prototype component sizes
Design and fabrication of nickel (740H) superheater tubes, headers, connection piping and attemperator with nickel liner
Membrane panel (T92) shop welding, field welding and PWHT
Membrane panel corner and buckstay restrained loads at prototype temperature, 750F to 950F steam
Mitigate early life cracking of CSEF (T92) materials
Chemical cleaning and steam blowing start up operations of pressure parts
Thermal load cycling of the A-USC Superheater
A-USC ComTest Purpose

* reduce the economic risk of the first A-USC demonstration plant

* exercise the complete project execution process for placing into service the A-USC plant (the design, procurement through the supply chain, manufacturing, delivery, site construction and commissioning is contained in the ComTest project)

* smaller quantities of expensive materials will be tested in the ComTest phases rather than in a larger first of a kind power plant that must serve the electric grid while using components that have not been placed in first practice

The risk of sacrificing the expensive nickel alloy components in a plant that may not be able to shut down to protect the ComTest materials is averted by this form of test facility design.
ComTest A-USC Superheater

Project Status

Preliminary performance loads for up to 133,800 lb/hr and set tube metals for 1400F steam outlet – need higher pressure drop than initially desired

Final Superheater Outlet Header - 740H  12”OD x  2.875” thick

Determined that a duct burner can be used

Decision to not use an inlet steam heat exchanger from turbine exhaust

Using a two part economizer to provide hotter spray attemperation water & cool the flue gas

Developed initial control system functional process & P&ID’s

Started mechanical engineering design and developed 3D SolidWorks model of ComTest A-USC Superheater arrangement

Started sourcing materials, components and accessories
ComTest A-USC Superheater

Design and supply-chain exercise with a project that attracts response and participation by vendors

Follow-on phases would demonstrate the delivery steps in the same manner of US practice for power plant projects.
Why A-USC +1300F (704C) Operation

- **+11% reduction** in fuel consumption and CO₂ emissions vs. 600C plant heat rate
- **+29% reduction** vs. the current fleet average heat rate and CO₂ emissions – **could replace existing units** with new A-USC plants and meet EPA CO₂ goal without carbon capture

- Lower flue gas handling equipment size and fan power
- Lower plant fuel handling
- Lower fuel transportation system impact
- Lower water consumption and condenser heat duty

- **Lower CO₂ emitted and auxiliary power consumption for capture**

16% better heat rate and lower CO₂ emissions

@ nominal 600 MW_{NET} Average heat rate 8858 Btu/kWh in 2013

US Fleet Average 10,555 Btu/kWh

* Power Engineering July 2014
# Steam Cycle Evolution

<table>
<thead>
<tr>
<th>Future Consideration?</th>
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<table>
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<tr>
<th>Type</th>
<th>Xcel-Sherco 3</th>
<th>FE-Sammis 7</th>
<th>AEP-Turk</th>
<th>Advanced Ultrasupercritical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Press/SH/RH</td>
<td>2640/1005/1005</td>
<td>3785/1005/1005</td>
<td>3789/1114/1126</td>
<td>5000/1356/1401</td>
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<tr>
<td>Heat Rate</td>
<td>10,700</td>
<td>9500</td>
<td>8860</td>
<td>7500</td>
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<tr>
<td>Net Efficiency</td>
<td>32</td>
<td>36</td>
<td>38</td>
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<td>Relative CO₂ Reduction</td>
<td>Base</td>
<td>11.2</td>
<td>17.2</td>
<td>29.9</td>
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</tbody>
</table>
Thank You!

psweitzel@babcock.com
330-860-1655