Advanced Ultra-Supercritical Technology Developments and Update on ComTest Project

DOE Contract DE-FE0025064

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2020 NETL High Performance Materials Project Review Meeting
Virtual Meeting

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Goals: The A-USC ComTest Project will lead to...

- **Higher efficiency** for new and existing fossil fuel plants
  - 10% above today’s new state-of-the-art coal power plants, and
  - 25% above that of the average power plants in the U.S. existing fleet
- **Lower emissions** (NOx, SOx, CO₂)
- **Minimized risk** for utilities desiring to build A-USC plants
- Support for design of **A-USC boiler & steam turbine** at 760°C
- Accelerated development of U.S. domestic **supply chain** for advanced materials and components
- **Validation of technology** applicable to fossil, nuclear, sCO2, and renewable power generation options, all targeted by the U.S. DOE NETL Cross-Cutting Research Technology Program
### Pathway to Increased Efficiency of Rankine Cycle

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Steam Conditions</th>
<th>Net Plant Efficiency (HHV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcritical</td>
<td>2400psig 1000 to 1050°F</td>
<td>35%</td>
</tr>
<tr>
<td>Supercritical (SC)</td>
<td>&gt;3600psig ~1050°F (550°C) and above</td>
<td>38%</td>
</tr>
<tr>
<td>Ultrasupercritical (USC)</td>
<td>&gt;3600 psig ~1100°F (600°C) and above</td>
<td>&gt;42%</td>
</tr>
<tr>
<td>Advanced-Ultra Supercritical (A-USC)</td>
<td>4000-5000psig 1300-1400°F (700-760°C)</td>
<td>&gt;45%</td>
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</table>

Materials are the limiting factor to achieving higher efficiency
History of the United States A-USC Program
Background of US A-USC Materials Programs

Present work builds upon 15-year effort, administratively managed by Energy Industries of Ohio, with technical management by EPRI, supported by U.S. Department of Energy, Ohio Coal Development Office, and industry participants

- Boiler Materials for Advanced Ultra-supercritical Coal Power Plant
  - DOE Contract: DE-FG26-01NT41175
  - OCDO Grant: CDO-D-05-02(A)

- Materials for Advanced Ultra-supercritical Steam Turbines
  - DOE Contract: DE-FE0000234
  - OCDO Grant: CDO-D-05-02(B)
Primary Technical Goals of US A-USC Materials Programs

- Evaluate materials technology for A-USC
  - Focus on **nickel-based alloys**
  - Develop fabrication and joining technology for new alloys
- Consider the unique conditions for US program
  - Higher-temperatures than other international programs (760°C versus 700°C) means **additional alloys** evaluated
  - For boiler:
    - Corrosion resistance for **US coals**
    - Data for **ASME BPV Code** acceptance of new materials
    - Impact of combining A-USC with other CO₂ capture technologies such as **Oxy-combustion**
    - Design for cycling operation to maximize flexibility
Accomplishments of ComTest Phase I

- Completed Pre-FEED and FEED tasks
- Prepared preliminary capital cost estimates
- Worked with suppliers to develop supply chain
- Developed test plan for Producing Components
- Selected suitable supply chain candidates for making full scale components
- Identified U.S. foundry, forge, extrusion and fabrication capability which is now competing with Defense needs.

Phase II work plan to build upon Phase I results
Tasks Completed in A-USC Materials Programs

General design studies show favorable economics

Welding Technology Developments

Fabrication Processes

Steam-Side Oxidation

Fireside Corrosion (High-Sulfur Coal & In-Plant Testing)

Turbine Component Scale-up
Next Step… Building Upon Prior Work

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

ComTest

15 Years

New Materials
Castings
Forging
Fabrication
Field Test
Forging
Welding

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## ComTest Phase II Project Team

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Funder</th>
<th>Role</th>
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</thead>
<tbody>
<tr>
<td>US DOE NETL</td>
<td>✓</td>
<td>Funder</td>
</tr>
<tr>
<td>OCDO (Ohio)</td>
<td>✓</td>
<td>Funder</td>
</tr>
<tr>
<td>EIO</td>
<td></td>
<td>Prime Contractor &amp; Administration</td>
</tr>
<tr>
<td>EPRI</td>
<td>✓</td>
<td>Technical Lead</td>
</tr>
<tr>
<td>GE</td>
<td>✓</td>
<td>Supply of Fabrications and Valve</td>
</tr>
<tr>
<td>RILEY POWER</td>
<td></td>
<td>Welded Fabrications</td>
</tr>
<tr>
<td>METAL TEK &amp; McCONWAY &amp; TORLEY</td>
<td>✓</td>
<td>Supplier of Turbine Casting (10-ton Nozzle Carrier)</td>
</tr>
<tr>
<td>SPECIAL METALS</td>
<td>✓</td>
<td>Wye Forging and Header</td>
</tr>
<tr>
<td>SCOT FORGE</td>
<td></td>
<td>Steam Turbine Rotor Forging</td>
</tr>
<tr>
<td>AECOM</td>
<td></td>
<td>EPC Contractor</td>
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ComTest Utility Advisory Committee

- Help to shape and guide the project
- Prioritize work scope
- Ensure key technical needs are met
- Collaborate
- Provide utility perspective

Current Members

- Southern Company
- AEP
- Duke
- FirstEnergy
- Tri-State
ComTest Phase II – Project Organization Chart
ComTest Phase II Work Plan

- Fabrication of components identified as being outside of the proven capabilities of the existing supply chain, including:
  - Steam turbine rotor forging and Haynes 282 nozzle carrier casting
  - Superheater and reheater header and tube assemblies
  - Large diameter pipe extrusions and forgings
  - Test valve articles to support ASME Code approval
- Key fabrication steps will also be done including boiler weld overlays and simulated field repairs
- Extensive inspection and quality assurance testing of the components
- ASME Code approval for key components

Significant fabrication work will be done with lessons learned provided
ComTest Phase II Project Scope Superheater and Valves

- GE concluded that the operational testing of a pilot scale A-USC superheater was not necessary to confidently design a commercial scale A-USC boiler

- GE recommended alternative focus for boiler components
  - Construction of full-scale SH/RH assembly and membrane panels
    - Thick-wall headers, pipes, tube stubs and tubes
    - Welding, simulated field erection, inspection, repair
  - Additional supply chain development on valves (long lead time)
    - PRV and PARV safety valves
    - National Board qualification testing for ASME Code approval
ComTest Phase II Project Scope Steam Turbine

- GE concluded that the operational testing of an A-USC ComTest turbine was not needed to confidently design a commercial scale A-USC steam turbine, but
  - Want to verify that full-scale castings and forgings can be constructed
  - Have provided drawings of full-scale **800MW** equivalent components
  - Have provided test/inspection criteria to validate successful completion
ComTest Phase II Current Activities

- Developing procurement specifications for **full-scale components**
- Identifying **supply chain** firms capable of producing nickel super alloy components
- Negotiating sub-awards, acquiring materials, maintaining a technical liaison with suppliers thru all phases of production
- Completing the **fabrication and production** of components
- Performing **materials testing** to ensure specifications achieved
- Validating **supply chain** fabrication methods
- Documenting testing and evaluations and **reporting results**
ComTest Phase II - Major Component Activity

Extrusion

Welding
Steam Turbine Assembly – Nozzle Carrier
A-USC Steam Turbine Nozzle Carrier Casting
(10 tons Haynes 282)
Note: Trial casting is upper section
Solidification Modelling of Nozzle Casting Component
Feeders with exothermic sleeves and lids

Gating system

Steel chills

Gating system
ComTest Schedule

- **Phase I**
  - Pre-FEED
  - NEPA
  - FEED
  - Detailed Engineering

- **Phase II**
  - Turbine Rotor Forging
  - Nozzle Carrier Casting
  - Valve Testing / NB Qualification
  - Superheater Component Fab.
  - Pipe Forgings and tube trials
  - Metallurgical Testing Plan
  - Evaluation & Reporting

Based upon July 23, 2020
Project Management Plan
Important Because… Cross-cutting Applicability to sCO2 Power Cycles, Solar Applications and others

- sCO2 power cycles share common materials, forgings and castings with A-USC technology.
- Synergies exist between ComTest and DOE’s Supercritical Transformational Electric Power (STEP) project that will demonstrate a large-scale supercritical CO2 (sCO2) power plant.
- The STEP program will use a main stop and control valve that is essentially the same as the MSCV contemplated for the A-USC ComTest project.
  - Demonstrate manufacture of large Haynes 282 alloy valve body
  - Operate valve in sCO2 environment, at similar temperatures to A-USC
ComTest Support Acknowledgement

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