Materials for Advanced Ultra-supercritical Steam Turbines - Advanced Ultra-supercritical Component Demonstration

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2018 Crosscutting Research Portfolio Review
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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
- Fabrication of **full scale components** (850 MWe) for 760ºC
- Accelerated development of domestic **supply chain** for advanced materials and components (greenfield & retrofit)
- **Validation of technology** applicable to multiple fossil, nuclear, and renewable power generation options, all targeted by the U.S. DOE NETL Cross-Cutting Research Technology Program
Presentation Outline

- Background
- ComTest Project Overview
  - Project Objective
  - Phase I
  - Phase II
- Status and Schedule
Background
Increasing Steam Conditions to Dramatically Improve Efficiency

Plant Efficiency (HHV) as a Function of Steam Temperature

- Studies: Sub-Bit/Lignite
- Studies: Bit.
- Plant Data: Sub-Bit/Lig.
- Plant Data: Bit.
- US Fleet Average 2010 (NETL)

Notes: Studies are a summary for DOE/NETL, EPR, and IEA Reports (pulverized coal with no carbon capture and storage)

Efficiency is plant design, location, and site specific

Factors include: temperature, pressure, cycle configuration, plant size, cooling water temperature, auxiliary loads, environmental requirements

- <600°C (SC)
- 600-650°C (USC)
- 700-760°C (A-USC)
Materials Limit the Current Technology

Today’s State-of-the-Art (USC) Coal-Fired Power Plants are defined by steel technology

- Steels = USC
  - 620°C (1150°F)

- Solid Soln’ = A-USC
  - ~700°C (1300°F)

- Age Hardenable = A-USC
  - 760°C (1400°F)

Minimum Desired Strength at Application Temperature
Background of A-USC Materials Programs

- Present work builds upon 15-year effort 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)
History of A-USC Materials Programs in U.S. ComTest is the Next Step for A-USC Technology
Tasks Completed in Prior 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
ComTest Project Overview
Main Objective of ComTest Project

U.S. Department of Energy (DOE) funded consortium, industry, and other partners, together with EPRI technical leadership, have concluded that the primary remaining step necessary to prepare A-USC technology for demonstration in a commercial-scale power plant (new or retrofit) is to build full-scale (800-850 MWe) versions of selected components.
Accomplishments – Phase I

- Evaluated host sites for test facility
- Identified viable host sites (Ohio and Alabama)
- Completed Pre-FEED and FEED tasks
- Prepared preliminary capital cost estimates
- Worked with suppliers to develop supply chain
- Determined that operational testing of the steam turbine and AUSC superheater were not required
- Revised scope of Phase II to focus on demonstrating production capability readiness (fabrication & supply chain)
- Completed Detailed Engineering effort for new scope
Materials to be Included – Phase II

- Inconel 740H (tubes, pipes, forgings)
- Haynes 282 (tubes, pipes, castings, forgings)
- Grade 91/92 (membrane panels)
- SAVE12AD (pipe/header)
- HR6W (tubes, pipe/header)
- Sanicro 25 (tube)
- TP347H, and Super 304H for lower temperatures
- Inconel 617 for safe ends on HR6W tubing
Boiler Component Scope – Phase II

- Procure materials for fabrication into A-USC components and sub-assemblies
- Fabricate A-USC boiler and superheater components and sub-assemblies (membrane panels, SH/RH tubes, headers, pipes)
- Fabricate forged components for
  - AUSC steam piping system – Wye and Tee (Inconel 740)

A-USC Superheater / Reheater Assembly
(Image provided by Alstom Power / GE)
Steam Turbine & Valve Component Scope – Phase II

- Procure materials for fabrication into A-USC components and sub-assemblies
- Fabricate a cast steam turbine nozzle carrier casing (Haynes 282)
- Fabricate steam turbine rotor forging (Haynes 282)
- Fabricate pressure relief and steam turbine bypass valves (Haynes 282)
  - Include testing, intended to obtain ASME Code approval for these valves.

Nozzle Carrier Casting
(Image provided by GE Power)
Testing and Analysis Scope – Phase II

- Perform mechanical properties tests and metallurgical analyses of specimens obtained from the A-USC components and sub-assemblys
  - Tensile, fatigue, creep rupture, creep-fatigue, notch sensitivity, fracture toughness, impact testing, and microstructural evaluation
- Perform a techno-economic analysis (TEA) of an A-USC power plant
  - Update the capital costs and Cost of Electricity
Fabrication Processes to be Developed – Phase II

- Bending of a heavy wall nickel alloy pipe
- Field erection simulation
  - Waterwall panel butt welds (with PWHT) and longitudinal seam welds (without PWHT)
- Field repair simulation
  - Inconel 740H and Haynes 282 thick wall piping – circumferential welds of fittings and plugs
  - Grade 92 tube membrane panel repair – simulated “Dutchman” repair when inserting panel openings
  - Evaluation of strength of PWHT vs non-PWHT welds in 740H
  - Determine ability to weld repair and to use innovative repair options such as weld overlay cladding of water walls as a field weld repair
ASME Code Case Development – Phase II

- Overpressure protection that would allow an alternative to a spring activated PRV at the superheater outlet
- Expand ASME B16.34 to allow bolted flange design at high temperatures
- Revision of the Case 2902 for Inconel 740H, to permit the use of SMAW as a permissible welding process
- Permit use of wrought forms of H282 in AUSC power plants
- Develop an ASME Code Case for the cast version of H282
## ComTest Project Team – Phase II

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<thead>
<tr>
<th>Team Member</th>
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<tr>
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ComTest Project Organization – Phase II
Status and Schedule
Current Status and Next Steps

- Phase I work has been completed
- Prepared draft of Final Report for Phase I
- Phase II Decision Point Application being evaluated
- Awaiting Phase II award
- Establish subcontracts
- Procurement of materials for components and sub-assembly fabrication
- Fabricate full scale components
- Confirm supply chain and fabrication methods
- Metallurgical testing and techno-economic analysis
ComTest Schedule (Revised March 2018)

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

**Phase II**
- Negotiations, Subawards & POs
- Turbine Rotor Forging
- Nozzle Carrier Casting
- Valve Testing / NB Qualification
- Superheater Component Fab.
- Pipe Forgings and tube trials
- Techno-Economic Study
- Metallurgical Testing
- Evaluation & Reporting

Key:
- Milestone (i.e. meeting, presentation)
- Deliverable (i.e. report)
A-USC ComTest Project Support Acknowledgement

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