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Project Description and Objectives

DOE Goal Statement: Power Plant Efficiency Improvements
Develop cost-effective, reliable technologies to improve the efficiency of new and existing coal-fired power plants

Crosscutting R&D: High-Performance Materials Program

R&D conducted under the Advanced Structural Materials platform advances development and demonstration of the production and functionality of key process equipment required to withstand the harsh environments of high-efficiency advanced ultra supercritical (AUSC) coal-fired power plants
Project Description and Objectives

• A key driver for commercializing AUSC coal-fired power plants is reducing the high costs associated with process equipment containing high-Ni advanced alloys, which are needed to withstand AUSC conditions
  ◦ Reduction in the total quantity (lbs.) of advanced alloys needed in the plant
  ◦ Reduction in the cost ($/lb.) of installed advanced alloys components

• OEMs have developed preliminary designs and cost estimates for AUSC plant equipment that minimizes the need for high-Ni advanced alloys through the DOE/OCDO AUSC Consortium

• By leveraging this previous work, NETL seeks to understand the magnitude of cost of electricity (COE) improvements from reductions in installed advanced alloy component costs in PC AUSC plants through sensitivity analyses
Project Description and Objectives

Understand magnitude of COE reductions from lowering the cost of installed advanced alloy components ($/lb)

Source: NETL
Project Update

Sensitivity Reference Case

- NETL has developed baseline performance and cost results for PC plants with various AUSC steam conditions both with and without CO₂ capture
  - Aspen Plus® modeling was conducted using the design basis developed as part of the 2015 Cost and Performance Baseline for Fossil Energy Plants report [1]
    - Illinois #6 bituminous, Midwestern ISO conditions, 550 MWe-net output
  - Three steam conditions were assessed
    - 3500, 4250, and 5000psig/1350°F/1400°F

- Capital cost estimates for conventional plant equipment (e.g. non-advanced alloys) were scaled from the supercritical PC cases in the baseline report
Project Update

Sensitivity Reference Case

- Reference capital costs for plant equipment containing advanced alloys were developed through AUSC consortium reports and conversations with OEMs. [3],[4]
  - 825 MWe-gross “flange-to-flange” General Electric (GE) AUSC steam turbine package design
  - 898 MWe-gross Babcock & Wilcox (B&W) conceptual “inverted tower” boiler
  - 150 foot nominal length of main and reheat steam piping; reduced from a “conventional tower” boiler

- Scope adjustments and scaling factors were applied to the reference capital costs and incorporated into the overall plant capital cost estimates

- Sensitivity will be performed on the 3500psig/1350°F/1400°F case
  - COE - $79.2/MWh
Project Update

Assumptions

• The sensitivity analysis will represent a greenfield build
• The sensitivity analysis will consider fixed equipment designs
  ° The quantity of advanced alloy material does not change
  ° Cost reductions are assumed to occur through improvements in the advanced alloy supply chain
• AUSC equipment designs and concepts considered represent those developed under DOE cooperative agreement DE-FE0000234
  ° Changes to equipment designs (e.g. steam turbine rotor) are not considered, but may be incorporated as additional information is made available through future cooperative agreements
Project Update

Data Gap Analysis

• NETL conducted a data gaps analysis and defined cost breakouts for each advanced alloy (e.g. Inconel 740H, Haynes 282) currently unavailable from the reference equipment costs

  ◦ “Reference fractional cost” = \[
  \frac{\text{Total alloy cost ($)}}{\text{Total equipment cost ($)}}
  \]

  ◦ “Reference bulk cost” = \[
  \frac{\text{Total alloy cost ($)}}{\text{Total alloy weight (lb.)}}
  \] ← adjusted sensitivity variable

• The “reference bulk cost” breakout will provide the program with a cost reduction metric that encompasses the installed costs of all components (e.g. turbine blades, boiler tubes) for each advanced alloy within the boiler, steam turbine, and steam leads
Project Update

Data Acquisition

- NETL is currently consulting with resources who were involved in development of the reference equipment cost estimates (GE and formerly of B&W) to obtain the cost breakouts.

- If cost breakouts are obtained, NETL will perform sensitivities on the inverted tower boiler, steam turbine, and piping leads by adjusting the “bulk cost” term for each alloy using relationships such as the example below:

\[
\text{Equipment Cost (\$)}_{ST-G, Adj} = \text{Equipment Cost (\$)}_{ST-G, Ref} \left[ \left( \frac{A}{A'} \right)^{\alpha} + \left( \frac{B}{B'} \right)^{\beta} + \left( \frac{\Gamma}{\Gamma'} \right)^{\gamma} + \delta \right]
\]

\[
\begin{align*}
A & = \text{Adjusted bulk cost} \left( \frac{\$}{lb} \right) \text{ for individual alloys} \\
B & = \text{Reference bulk cost} \left( \frac{\$}{lb} \right) \text{ for individual alloys} \\
\Gamma & = \text{Reference fractional cost} \left( \frac{\$}{total} \right) \text{ for individual alloys}
\end{align*}
\]
Two primary challenges exist in obtaining the cost breakouts. An approach towards meeting each challenge is currently underway:

- **Challenge #1** – Material specifications for the inverted tower design do not currently exist.
  
  **Approach** – Through collaboration with the designer (formerly of B&W), materials specifications from the conventional air-fired AUSC boiler design developed through the AUSC Consortium will be used as a proxy. [5]

- **Challenge #2** – Cost breakouts must be calculated from the current AUSC steam turbine cost estimate.
  
  **Approach** – Through collaboration with the designer (formerly of GE Power), the cost breakouts will be calculated from the original cost estimate for the bolted rotor turbine design.
Preparing for the Next Steps

• The AUSC Consortium has made the following observations regarding the cost premiums of advanced alloys: [4]

  “Large [cost] increases are mainly the result of the high cost of the nickel alloys, which currently represent an increase in cost for a delivered casting or forging of close to 8 times compared to advanced 9-12Cr ferritic steels. Add to this the difficulty for machining super-alloys and the nickel alloy multiplier reaches 10 times”

• Cost multipliers such as this may aide in establishing the equivalent cost of 9-12Cr ferritic steels as the lower bound for the sensitivity analysis
  ° A maximum COE benefit from reducing the delivered costs of advanced alloys through R&D can be obtained

• Further analysis exploring the potential areas for cost reduction in the advanced alloy supply chain, as well as a downstream market deployment analysis, is needed to assess the potential impact of R&D
Concluding Remarks

- Current understanding of the designs and delivered costs of equipment containing advanced alloys (e.g. Inconel 740H, Haynes 282) capable of AUSC operation is expected to evolve through additional collaborative R&D efforts such as the ComTest Phase II project. [6]

- However, COE sensitivity analysis can provide valuable insight into the potential economic benefits that reducing the costs of these expensive alloys may have based on current understanding of designs and costs.

**DOE Goal Statement: Power Plant Efficiency Improvements**

*Develop cost-effective, reliable technologies to improve the efficiency of new and existing coal-fired power plants*
References

[1] “Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity, Revision 3,” July 2015


