Research, Development, and Field Testing of Thermochemical Recuperation for High Temperature Furnace

DE-FG36-08GO18130

American Iron and Steel Institute/Gas Technology Institute
09/30/2008 – 12/31/2013

Joseph Vehec, American Iron and Steel Institute

U.S. DOE Advanced Manufacturing Office Peer Review Meeting
Washington, D.C.
May 6-7, 2014

This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Project Objective

- Substantiate technical feasibility of Thermochemical Recuperation (TCR) concept and economic viability including identification of technical scale up and manufacturability concerns
  - Increase furnace thermal efficiency to 61%
  - Reduce Natural Gas usage ~ 21%
  - Reduce Carbon footprint ~ 21%
  - Reduce NO$_x$ > 21% (due to flue gas recirculation)
Technical Approach

• Current Industry Practice: Recouping of sensible heat from waste gas to combustion air

• TCR Approach: Recouping both sensible heat from waste gas and endothermically converts fuel to higher calorific value
  • Current optimum TCR System is equivalent to preheating combustion air to 1700°F

• Innovation: TCR System consists of a non-catalytic reformer and air pre-heater in one integrated system
Technical Approach

- Project team included a leading R&D organization; three major steel companies; a major burner manufacturer; and a major recuperator manufacturer:
  - Gas Technology Institute [GTI]
  - ArcelorMittal USA
  - Republic Steel
  - United States Steel Corporation
  - Bloom Engineering
  - Thermal Transfer Corporation
  - Steel Manufacturers Association
  - Union Gas Limited
Transition and Deployment

- Domestic Steel Industry competition drives reductions in costs and new regulatory requirements drives Greenhouse Gas reductions
- Initial end users - Steel Reheat Furnaces
- Future end users
  - Electric Arc Furnaces; indirect heating systems; hybrid heat recovery-and-hydrogen production
- Commercialization Approach:
  - A revised Commercialization and Market Acceptance Plan (CMP) provides details regarding natural gas price sensitivity to return on investment (ROI) success; market population, etc.
Measure of Success

- Based on an EIA projected natural gas price of $5.91 per MMbtu, the table below represents a typical range of economic paybacks for three Reference Reheat Furnace (RRF) cases.
  - Note that for Case III to have a satisfactory payback the natural gas price will need to exceed $6.03 per MMBtu.
- Reference Reheat Furnace (RRF)

<table>
<thead>
<tr>
<th>Description</th>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Retrofitting an Air Recuperator on RRF</td>
<td>Retrofitting a Three-unit TCR System on RRF without recuperation</td>
<td>Retrofitting a three-unit TCR System on RRF with existing recuperation</td>
</tr>
<tr>
<td>CAPEX</td>
<td>$4.3 million</td>
<td>$18.3 million</td>
<td>$14 million</td>
</tr>
<tr>
<td>Fuel Savings</td>
<td>$6.0 million</td>
<td>$9.4 million</td>
<td>$3.3 million</td>
</tr>
<tr>
<td>Simple ROI</td>
<td>8.6 months</td>
<td>23.4 months</td>
<td>50.2 months</td>
</tr>
<tr>
<td>NPV *</td>
<td>$19.1 million per year</td>
<td>$18.8 million per year</td>
<td>($0.25) million per year</td>
</tr>
</tbody>
</table>

*NPV at a 7% discount rate over six years of cash flow
Project Management & Budget

- Phase I - Feasibility Study *(October 2009)*
  - Economic evaluation for reheat furnaces
  - Established design parameters
- Phase II - R&D *(March 2012)*
  - Transition concept to a prototype for field testing
- Extended Testing *(July 2013)*
- Phase III - Prototype Field trial *(terminated December 2013)*
  - Design, fabrication and field testing of prototype at a steel company site

<table>
<thead>
<tr>
<th></th>
<th>Phase 2.5</th>
<th>Phase 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE Investment</td>
<td>1,910,649</td>
<td>2,675,573</td>
<td>4,586,222</td>
</tr>
<tr>
<td>Cost Share</td>
<td>818,849</td>
<td>1,146,675</td>
<td>1,965,524</td>
</tr>
<tr>
<td>Project Total</td>
<td>2,729,498</td>
<td>3,822,248</td>
<td>6,551,746</td>
</tr>
</tbody>
</table>
Results and Accomplishments

- Project work ended with Phase II - Extended Testing (Task 2.5)
- A 21% fuel reduction was validated for the reference reheat furnace (RRF) specification provided by a steel company partner
- A CAPEX was developed for both a non recuperated RRF and a recuperated RRF
- The CMP contains a sensitivity analysis of ROIs based on the above with respect to a range of natural gas prices