Wyoming / JCOAL Workshop 2017

Advanced Coal Fired Power Generation Technologies

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Vice President - Director of Operations
IHI INC. Power Plant Engineering Division
IHI Corporation
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2. Overview of IHI Boiler Business

3. Advanced Coal Fired Power Generation Technologies

4. Summary
1. Introduction of IHI Group Business
1-1. Company Profile

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Founded</td>
<td>1853</td>
</tr>
<tr>
<td>Head Office</td>
<td>Tokyo, JAPAN</td>
</tr>
<tr>
<td>Capital</td>
<td>JPY <strong>107.165 mil</strong> (USD <strong>975 mil</strong>)</td>
</tr>
<tr>
<td>Net Sales</td>
<td>JPY <strong>1,486,332 mil</strong> (USD <strong>13,512 mil</strong>)</td>
</tr>
<tr>
<td>Employees</td>
<td>29,659</td>
</tr>
<tr>
<td>Works in Japan</td>
<td>7</td>
</tr>
<tr>
<td>Branches / Sales offices in Japan</td>
<td>16</td>
</tr>
<tr>
<td>Overseas offices</td>
<td>14</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://www.ihi.co.jp">www.ihi.co.jp</a> (IHI Corporation)</td>
</tr>
</tbody>
</table>

Information is on consolidated basis as of March 2017.
1-2. Business Areas

- **General-Purpose Machinery**
  - Compressor, Separator, Turbocharger, etc.
  - Jet Engine, Rocket

- **Industrial Systems**
  - Steel Manufacturing Furnaces, Heat/Surface Treatment Equipment, Logistics Systems, Material Handling Equipment, etc.
  - Compressor, Separator, Turbocharger, etc.

- **Resources, Energy & Environment**

- **Social Infrastructure & Offshore Facilities**

- **Aero Engines, Space & Defense**

- **Industrial Systems & General-Purpose Machinery**

- **Bridge, Transportation System, Security, etc.**
2. Overview of IHI Boiler Business
2-1. Project Sites in USA

- Orange Grove Energy (SCR)
- Elk Hills Power (HSRG/SCR)
- Bosque Power (HSRG/SCR)
- Nebraska City #2 (PC Boiler/SCR)
- Holcomb #2 (PC Boiler/SCR)
- Plum Point (PC Boiler/SCR)
- Sandy Creek (PC Boiler/SCR)
- Plant Washington (PC Boiler/SCR)
- W.A. Parish (SCR)
- Cedar Bayou (SCR)
- P.H. Robinson (SCR)
2-2. IHI Reference in USA

<table>
<thead>
<tr>
<th>Client</th>
<th>Sandy Creek Energy Associates, L.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Sandy Creek</td>
</tr>
<tr>
<td>Turbine Output</td>
<td>998.5MW (net)</td>
</tr>
<tr>
<td>Boiler Capacity</td>
<td>6,295 klb/h (2,852 t/h)</td>
</tr>
<tr>
<td>Steam Conditions</td>
<td>3,908 psia, 1086/1082F (26.9 MPa, 585/583°C)</td>
</tr>
<tr>
<td>Fuel</td>
<td>Pulverized coal 100% Sub-bituminous Coal (PRB Coal)</td>
</tr>
<tr>
<td>Commercial Operation</td>
<td>2013</td>
</tr>
</tbody>
</table>
### 2-2. IHI Reference in USA

<table>
<thead>
<tr>
<th>Client</th>
<th>Nebraska City Power Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>OPPD Nebraska City No.2</td>
</tr>
<tr>
<td>Turbine Output</td>
<td>660MW (net)</td>
</tr>
<tr>
<td>Boiler Capacity</td>
<td>4,750 klb/h (2,155 t/h)</td>
</tr>
<tr>
<td>Steam Conditions</td>
<td>2,612psia, 1056/1052F (18.0MPa, 569/567°C)</td>
</tr>
<tr>
<td>Fuel</td>
<td>Pulverized coal</td>
</tr>
<tr>
<td></td>
<td>100% Sub-bituminous Coal (PRB Coal)</td>
</tr>
<tr>
<td>Commercial Operation</td>
<td>2009</td>
</tr>
</tbody>
</table>

**- BEST of the BEST -**

IHI's steam generator was praised as one of the six innovative top coal fired plants by “POWER” and was featured on the October 2009 cover.

**Actual Operating Situation**

- **Successful Operation over 97% Availability with Full Load in 2011.** *(Actual Result)*
3. Advanced Coal Fired Power Generation Technologies
IHI supplies the world with state-of-the-art coal-fired boilers, utilizing Clean Coal Technology (CCT), which we developed through years of extensive research.

**IHI USC/SC Boiler**
- World’s Highest Reheat Temp. (630°C(1166°F)) USC Boiler
- Highly Flexible Operation
  - Min. Load - CAPS

**IHI’s Proven Boiler Design**
- Over 95% Availability, over 19 years operation
  - Hekinan No.3
    - (First USC Boiler in Japan)

**IHI Clean Coal Technology**
- High Plant Efficiency
- High Availability
- Low Rank Coal Application
- Eco-Friendly
- CO2 Reduction

**CCS Technology**

**Biomass**

**Low NOx System**

**DeNOx**

**DeSOx**

**CCTF (Test Facility)**

**Sub-bitu. fired boiler**
As a leading company in this field, and a pioneer in Ultra Supercritical (USC) coal-fired boilers, we have achieved the world’s highest pressure and temperature steam conditions, and we continue to look for ways to improve plant efficiency.
### 3-3. IHI USC Boiler Reference

#### Client
Electric Power Development Co., Ltd. / J-POWER, Japan

#### Unit
Isogo New No.1 and 2

#### Turbine Output
2 x 600MW (Gross)

<table>
<thead>
<tr>
<th></th>
<th>No.1</th>
<th>No.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Capacity</td>
<td>1,710 t/h (3,770 klb/h)</td>
<td>1,670 t/h (3,682 klb/h)</td>
</tr>
<tr>
<td>Steam Conditions</td>
<td>27.5MPa, 605/613°C (3,987psi, 1121/1135°F)</td>
<td>27.2MPa, 605/623°C (3,945psi, 1121/1153°F)</td>
</tr>
<tr>
<td>Commercial Operation</td>
<td>2002</td>
<td>2009</td>
</tr>
</tbody>
</table>

Photo is provided by J-POWER(EPDC)
We are currently participating in the joint development of the Advanced USC (A-USC) 700degC-class boiler in order to achieve a plant efficiency of 46% (net HHV) and further reduce CO2 emissions.
3-5. Highly Flexible Operation

**Customers Needs on Current Plant Operation**

- Minimization of Load Retention for Mill Start/Stop Operation
- Minimization of Time Lag for Load Change Demand
- EDC/ELD(*) Operation at Minimum Load by Coal Firing

(*) EDC/ELD: Economic Load Dispatching Control

**Current Plant Operation (Typical)**

- **Load Retention**
- **Small Load Fluctuation**

**IHI Advance Technology respond to Customers Needs**

- Application of Wide Range Burner
- Expansion of Recirculation Operation Range (Wet Mode)
- Constant-pressured Wet Operation
- Optimized Boiler Control System

**Constant-pressured Wet Operation**

**Advanced Operation with 2 Bands (15%L to 100%L)**

- EDC Operation with 2 Bands
  - Lower Band
  - Upper Band
- 3%L/min. with 5 Mills
- 2%L/min. with 2 Mills

**Wet Operation**

**Dry Operation**
3-6. Highly Flexible Operation - CAPS

**Coal Adaptive control system for Power Stations**

- Adjust the control parameters automatically depend on the difference of heat absorption and combustion characteristics in case of coal brand change.
- Keep the optimum plant performance without any additional adjustments by long-term commissioning.

**Example of CAPS effect**

- MST (Main Steam Temp.) / RST (Reheat Steam Temp.) optimum control
- NOx Control coped with various coal kinds

<table>
<thead>
<tr>
<th>No.</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Superior SH spray control</td>
</tr>
<tr>
<td>2</td>
<td>RH temperature control</td>
</tr>
<tr>
<td>3</td>
<td>Emission (NOx) control</td>
</tr>
<tr>
<td>4</td>
<td>Optimized sootblower control</td>
</tr>
</tbody>
</table>
3-7. Woody Biomass Utilization

**Woody Pellet High Ratio Co-firing**

- CO2 reduction according to number of pellet mill can be achieved
- Achievable of CO2 negative with CO2 capture technologies such as Oxyfuel and PCC
- Possible utilization of both coal and woody pellet with minor modification

### Verification with 149MW Power Plant in Japan (2015)

- One coal mill (total 4 mills) was retrofitted to a pellet mill equipped with a “flow acceleration ring”.

Kamaishi coal fired power plant : 149MW (Nippon Steel & Sumitomo Metal Corporation)
Deference between Coal /Oil and Gas Fuel

Heat absorption at furnace will be reduced due to flame brightness.
Coal / Oil : Brighter Flame
Gas : Blue colored flame

Item to be modified

<table>
<thead>
<tr>
<th>Mandatory Items</th>
<th>Depend on Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burner Replacement</td>
<td>Gas Supply System</td>
</tr>
<tr>
<td>Flame Detector Replacement (UV to IR)</td>
<td>Logic Change</td>
</tr>
<tr>
<td>Fire Fighting System (Gas Detection System)</td>
<td>Commissioning</td>
</tr>
<tr>
<td></td>
<td>Heating Surface Modification</td>
</tr>
<tr>
<td></td>
<td>Spray System Modification</td>
</tr>
<tr>
<td></td>
<td>SCR Re-Tuning (if available)</td>
</tr>
<tr>
<td></td>
<td>BOP (fuel oil system, SCAH etc.) Preservation</td>
</tr>
<tr>
<td></td>
<td>Gas Supply System</td>
</tr>
<tr>
<td></td>
<td>Logic Change</td>
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</tr>
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<td></td>
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<td>BOP (fuel oil system, SCAH etc.) Preservation</td>
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Rich Experiences

IHI has rich experiences of boiler fuel conversion; oil to gas, coal to gas.

Oil to Gas Fuel Conversion Project in Japan

Boiler OEM : IHI
Fuel : Fuel Oil → Natural Gas
Capacity : 350MW
Scope of Modification
1) Burner System Modification
2) Pressure Parts Modification
3) Control System Modification
4) Additional SH Spray and Upgrade of Primary & Secondary SH Spray
5) Replace or Modification of each Fan System
3-9. Oxyfuel Combustion

Oxyfuel Combustion

- Lower CO2 capture cost for full capture
- Byproduct reuse such as N2 resulting from air separation for O2
- Achievable of CO2 capture rate up to 98%
- Applicable to both existing and new power plants

Callide Demonstration Project in Australia (2012 - 2015)

- The world’s only-one oxyfuel power plant for CO2 capture from coal fired power plants.
- Achieved over 10,000 hours oxyfuel operation without serious technical barrier
- Ready for large scale commercial plant

Callide A Power Station
Owned by CS Energy
4 x 30 MWe
Steam :136 t/h at 4.1MPa, 465°C
(300 klb/h at 595psi, 869F)
Commissioned :1965 – 69
Refurbished :1997/98
Placed in storage in 2002
4. Summary
We are confident that IHI’s coal fired power generation technologies will fit to the best-mix for the world wide energy requirements and also will be the best solution to promote effective utilization of existing assets related coal.
IHI
Realize your dreams