Introduction of Korean 1000MW USC Boiler

February 2013
Doosan Boiler BU
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1. General Introduction – Doosan Boiler Technology History

- **1977**: License Agreement of Alstom’s Boiler Tech.
- **1987**: License Agreement of Sulzer’s Once-Through Boiler Tech.
- **1989**: License Agreement of FW’s CFB Tech.
- **2001.03**: Termination of Lurgi’s CFB License Agreement
- **2006.09**: Acquisition of Doosan Babcock
- **2006.11**: Foundation of DB E&S in India
- **2007.02**: Termination of Alstom License Agreement
- **2007.10**: Acquisition of DCW
- **2008.9**: Foundation of Doosan VINA in Vietnam
- **2008.12**: PCC: License Agreement of HTC Technology
- **2011.3**: Start Manufacturing in Doosan VINA, Vietnam

**Tech. Licensee Period**

**Doosan Own Boiler Tech. Period**

* PCC: Post Combustion Carbon Capture
1. General Introduction – Doosan Babcock Overview

- Incorporated in 1891 as Babcock & Wilcox Ltd
- Progressive establishment of Associates & Subsidiaries
  - Deutsche Babcock (Germany)
  - B & W Espanola (Spain)
  - Babcock Hitachi (Japan)
  - Babcock Africa (RSA)
  - B & W Mexico (Mexico)
  - and some 15 other Licensees
- HQ is in Crawley, Europe Service HQ is in Renfrew
- Employees: 5,000 (Engineers: 1,000)
1. General Introduction - Supply Capability

- Unit Type: Drum Type, Once - thru Type Wall Firing, Downshot, CFB Boiler
- Fuel: Coal (Bituminous, Sub-Bituminous Anthracite, Lignite), Oil and Gas
- Scope: Design and Engineering, Manufacturing, Erection, Supervision and Training, After Service and Retrofits for Boiler Island, DCS, SCR, FGD, ESP
1. General Introduction - Product Line

**Boiler**
- Pressure Part
- Non-Pressure Part
- Pulverizer
- Burner
- Structural Steel
- DCS / APH

**AQCS**
- FGD
- SCR
- ESP
- Ash Handling System

**BOPs**
- Condenser
- Heater
- Dearator

**Key Products**
- P.P
- Non-P.P
- Pulverizer
- Burner
- Structural Steel
- DCS / APH

- FGD
- SCR
- ESP
- AHS

- Condenser
- Heater
- Dearator

- Market Share of SC & USC Boiler excluding China domestic market in recent 10 years
- Total ordered capacity: 121 GW

Source: McCoy Power Report 2010

- Etc.: Ansaldo, MHI, B&W, BWE, Foster Wheeler, Kransny
- Chinese: Dongfang, Shanghai, Harbin
- Hitachi: Hitachi Europe and BHK

Doosan: 15.75%
Hitachi: 22.92%
Chinese: 26.40%
BHEL: 6.60%
L&T: 5.51%
IHI: 4.14%
Etc.: 10.48%
1. General Introduction - Manufacturing Capacity

Advanced boiler manufacturing facilities of 8.5GW/Yr in Korea, Vietnam, India

- **Doosan HQ, Korea**
  - Capacity: 5,500MW/year

- **Doosan VINA, Vietnam**
  - Capacity: 2,000MW/year

- **Doosan Chennai Works, India**
  - Capacity: 1,000MW/year
  - To be expanded to 2,100MW in 2012
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I General Introduction Doosan Boiler

II Doosan USC Boiler Design Features
1. General of Ultra Supercritical Boiler
2. 1000MW USC Boiler Design Features

III Doosan Experience List
## 2. Doosan USC Boiler - Definition of USC Boiler

<table>
<thead>
<tr>
<th>Pressure Level</th>
<th>USC (Ultra-Supercritical)</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 bar</td>
<td>Subcritical Pressure Plant</td>
<td>- Operated under 221.2 bar of steam pressure</td>
</tr>
<tr>
<td>221 bar</td>
<td>Critical Pressure</td>
<td>- Or Operated over 600 °C of SH/RH temperature</td>
</tr>
<tr>
<td>250 bar</td>
<td>Supercritical Pressure</td>
<td>- Operated over 221.2 bar</td>
</tr>
<tr>
<td>265 bar</td>
<td>ASC / HSC</td>
<td>- Typically operated up to 250 bar, 569°C/596 °C</td>
</tr>
<tr>
<td>300 bar</td>
<td>USC(Ultra-Super Critical) Plant</td>
<td>- Operated over 250 bar, 569°C/596 °C</td>
</tr>
</tbody>
</table>
2. Doosan USC Boiler - USC Advantage

◆ Main Advantage

- Higher Plant Efficiency
- Lower Operating Costs Coming from Coal Consumption Reduction, Smaller Power consumption, etc)
2. Doosan USC Boiler - USC Advantage

◆ Higher Plant Efficiency

* Main steam pressure (bar) / SH Temp. (°C) / RH Temp. (°C)
2. Doosan USC Boiler - USC Advantage

◆ Saving Coal Consumption

✔ Operating (Fuel) cost comparison

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>SC</th>
<th>USC</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator output</td>
<td>MW</td>
<td>1000</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Steam pressure</td>
<td>bar</td>
<td>250</td>
<td>269</td>
<td>at Boiler Outlet</td>
</tr>
<tr>
<td>Steam temperature</td>
<td>°C</td>
<td>541/541</td>
<td>613/624</td>
<td>at Boiler Outlet</td>
</tr>
<tr>
<td>Plant Efficiency</td>
<td>%</td>
<td>Base</td>
<td>+6.02%</td>
<td></td>
</tr>
<tr>
<td>Coal consumption</td>
<td>Ton/hr</td>
<td>350.2</td>
<td>330.3</td>
<td>Note 1.</td>
</tr>
<tr>
<td>Coal consumption difference</td>
<td>Ton/year</td>
<td>Base</td>
<td>-130,743</td>
<td>Note 2.</td>
</tr>
<tr>
<td>Coal cost saving per year</td>
<td>USD</td>
<td>Base</td>
<td>13 Million$</td>
<td>Note 3.</td>
</tr>
<tr>
<td>Coal cost saving for 30 years</td>
<td>USD</td>
<td>Base</td>
<td>390 Million$</td>
<td>Note 3.</td>
</tr>
</tbody>
</table>

(*) Note 1. Import coal : HHV = 5,970 Kcal/kg
2. Operation hours per year = 365 days x 24 hours/day x 0.75(capacity factor) = 6570 hours
3. Coal price = 100 USD/Ton (fixed over 30 years)
2. Doosan USC Boiler – USC Boiler Steam Condition

- **USC Steam Condition**: 1,000 MW x 269 bar x 613 °C / 624 °C

  ✓ Regarding Steam Condition of Ultra Supercritical Boiler,
  - 630~650°C class is hard to be realized because the proven material is not available up to now
  - 700°C class has a long way to go before securing engineering confidence and meeting economic conditions
  - 269bar 613°C /624°C is the maximum steam condition considering the available material with sufficient margin for safe operation

  ✓ DHI - Doosan Babcock successfully finished the development and verification of the USC boiler model for the steam condition of 269 bar x 613 °C / 624 °C at boiler outlet
## 2. Doosan USC Boiler – Main Specification of USC Boiler

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation (MWe)</strong></td>
<td>2 x 1000</td>
</tr>
<tr>
<td><strong>Name of Plant</strong></td>
<td>Sinboryeong #1/2</td>
</tr>
<tr>
<td><strong>Customer</strong></td>
<td>KOMIPO</td>
</tr>
<tr>
<td><strong>Contract (Completion)</strong></td>
<td>2012. 03 (2016. 06)</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
<td>Sub-bituminous Coal (5,600 kcal/kg)</td>
</tr>
<tr>
<td><strong>Type of boiler</strong></td>
<td>Ultra Supercritical Two pass Opposed wall firing Balanced Draft</td>
</tr>
<tr>
<td><strong>Steam Condition</strong></td>
<td>3,010 ton/hr 269 bar/613°C/624°C</td>
</tr>
</tbody>
</table>
Doosan firing system can control combustion air flowrate into each burner for air balance. - minimizing tube metal temperature deviation by even gas temperature

Control of combustion air for individual burner

Verification of the effect of individual control with operating data
Utilizing orifices to reduce steam temperature variations

→ Can prevent a metal failure in SH and RH tubes
2. Doosan USC Boiler – Steam Temperature Control

◆ Flue Gas Bias Damper

◆ Steam Temperature Control System
The direct entry type stub header configurations to reduce header thickness and thermal stresses

- Direct connection of stubs to header
- Thick header (124mm)
- Disadvantage of fatigue-creep life at high temperature and pressure
- Slow erection by difficult welding due to complex configuration

- Stub header between header and stubs
- Thin header (86.5mm)
- Advantage of fatigue-creep life at high temperature and pressure
- Faster erection by easy fielding welding due to simple configuration
## Pressure Part Material

<table>
<thead>
<tr>
<th>No</th>
<th>Section</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Economizer</td>
<td>SA213T1a</td>
</tr>
<tr>
<td>2</td>
<td>Evaporator</td>
<td>Spiral SA213T12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical SA213T12 / T23</td>
</tr>
<tr>
<td>3</td>
<td>Superheater</td>
<td>Primary SA213T23 / T91 / T92 / Super304H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Secondary SA213T91 / T92 / Shot blasted Super304H / HR3C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Third Shot blasted Super304H / HR3C</td>
</tr>
<tr>
<td>4</td>
<td>Reheater</td>
<td>Primary SA213T12 / T22 / T91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Final Shot blasted Super304H / HR3C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No</th>
<th>Section</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Separator</td>
<td>SA335P91</td>
</tr>
<tr>
<td>2</td>
<td>Header</td>
<td>SH Outlet SA335P92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RH Outlet SA335P122</td>
</tr>
</tbody>
</table>
2. Doosan USC Boiler - Optimized Furnace Design

◆ Lower Furnace Design

• Project Target: < NOx 150 ppm, UBC 5% max.

• Total 48ea burners (8ea/1mill)
  - 3 row x 8 column x 2 walls

• Total 40ea OFA
  - 2 row x 10 column x 2 walls

• BNR & OFA arrangement are optimized for NOx and UBC under the condition of even gas temperature distribution
  - CFD Results: NOx 130 ppm, UBC < 3.0%
2. Doosan USC Boiler – Coal Burner

◆ D-NOx™ Burner

Test Facility of Full Scale (~90MWt) Burner in Doosan Babcock

Measured NOx Performance

<table>
<thead>
<tr>
<th>FR (=FC/VM)</th>
<th>1.1 Performance Coal*</th>
<th>1.7 Range Coal1***</th>
<th>2.1 Range Coal2*</th>
<th>2.4 Worst Coal**</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPR 1&amp;2 Guarantee Value</td>
<td>170</td>
<td>150</td>
<td>130</td>
<td>110</td>
</tr>
</tbody>
</table>

* YH 5&6 Performance coal
** YH 5&6 Worst coal
*** CCTF test standard coal
2. Doosan USC Boiler – Summary

- **Recommended USC Coal Boiler is** 1,000 MW x 269 bar x 613 °C / 624 °C

- **Optimized furnace design**
  - Optimization for low NOx, UBC and even gas temperature

- **Low NOx & UBC**
  - Low NOx burner
  - Adequate furnace volume
  - Optimized OFA arrangement

- **Fuel flexibility**
  - Flame Stable Burner
  - Reliable Loesche mill

- **Optimized heating surface arrangement**
  - Optimization for effective heat transfer and low metal temperature

- **Metal temperature reduction design**
  - Even gas temperature distribution in furnace
  - Minimizing by orifice

- **Header thickness reduction design**
  - The direct entry type stub stub header configurations

- **Proven material selection**
  - Proven oxidation and creep resistant materials

- **Low stress supporting structure**
  - Advanced corner bracket design
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<tr>
<th>Location</th>
<th>No. of boilers</th>
<th>MWe</th>
<th>Steam Flow/te/hr</th>
<th>S/H Outlet Press kg/cm²g</th>
<th>S/H Outlet Temp °C</th>
<th>R/H Outlet Temp °C</th>
<th>Fuel</th>
<th>Order Date (Yr)</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINBORYEONG</td>
<td>Korea</td>
<td>2</td>
<td>1000</td>
<td>3010</td>
<td>274</td>
<td>613</td>
<td>624</td>
<td>C</td>
<td>2012 KOMIPO</td>
</tr>
<tr>
<td>KUDGI &amp; LARA</td>
<td>India</td>
<td>5</td>
<td>800</td>
<td>2550</td>
<td>252</td>
<td>568</td>
<td>596</td>
<td>C</td>
<td>2012 NTPC</td>
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<tr>
<td>HONGSHAN</td>
<td>China</td>
<td>1</td>
<td>600</td>
<td>1962</td>
<td>259</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2010 HBC FOR FUZHOU COAL GROUP</td>
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<tr>
<td>GUOJIAO</td>
<td>China</td>
<td>1</td>
<td>600</td>
<td>2000</td>
<td>259</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2010 HBC FOR SHANXI LOCAL POWER GENERATION</td>
</tr>
<tr>
<td>DENGFENG</td>
<td>China</td>
<td>1</td>
<td>600</td>
<td>1970</td>
<td>259</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2010 HBC FOR CHINA RESOURCES</td>
</tr>
<tr>
<td>YEOUNGHEUNG 5, 6</td>
<td>S.Korea</td>
<td>2</td>
<td>870</td>
<td>2664</td>
<td>246</td>
<td>566</td>
<td>593</td>
<td>C</td>
<td>2010 KOREA SOUTH-EAST POWER CO., LTD</td>
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<tr>
<td>AIN SOKHNA</td>
<td>Egypt</td>
<td>2</td>
<td>650</td>
<td>2065</td>
<td>270</td>
<td>569</td>
<td>567</td>
<td>MZ/NG</td>
<td>2010 EEHC</td>
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<tr>
<td>RAIPUR - CHHATTISGARH</td>
<td>India</td>
<td>2</td>
<td>685</td>
<td>2126</td>
<td>255</td>
<td>570</td>
<td>597</td>
<td>C</td>
<td>2010 GMR ENERGY</td>
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<tr>
<td>CHONGXING</td>
<td>China</td>
<td>2</td>
<td>600</td>
<td>2140</td>
<td>255</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2009 HBC FOR LANZHOU LOCAL</td>
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<tr>
<td>PINGLIANG</td>
<td>China</td>
<td>2</td>
<td>600</td>
<td>2070</td>
<td>255</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2009 HBC FOR HPI</td>
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<tr>
<td>RAYONG (GHECO-One)</td>
<td>Thailand</td>
<td>1</td>
<td>700</td>
<td>2191</td>
<td>255</td>
<td>569</td>
<td>569</td>
<td>C</td>
<td>2008 GLOW FOR EGAT</td>
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<td>NANJI</td>
<td>China</td>
<td>2</td>
<td>600</td>
<td>1965</td>
<td>255</td>
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<td>569</td>
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<td>2008 HBC FOR CHINA RESOURCES</td>
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<td>YUXIAN</td>
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<td>2008 HENAN LOCAL POWER</td>
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<td>YAOMENG 2</td>
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<td>300</td>
<td>950</td>
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<td>545</td>
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<td>2007 YAOMENG POWER GENERATION LIMITED</td>
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<td>GREIFSWALD (not built)</td>
<td>Germany</td>
<td>2</td>
<td>810</td>
<td>2084</td>
<td>281</td>
<td>603</td>
<td>605</td>
<td>C</td>
<td>2007 DONG ENERGY</td>
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<tr>
<td>ZHENXIONG</td>
<td>China</td>
<td>2</td>
<td>600</td>
<td>1913</td>
<td>254</td>
<td>571</td>
<td>569</td>
<td>LV/AF</td>
<td>2007 HBC FOR CHINA HUADIAN</td>
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<tr>
<td>TRIMBLE COUNTY 2</td>
<td>USA</td>
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<td>750</td>
<td>1998</td>
<td>271</td>
<td>583</td>
<td>580</td>
<td>C</td>
<td>2006 LOUISIANA GAS &amp; ELECTRICITY</td>
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<td>KANGPINJ</td>
<td>China</td>
<td>2</td>
<td>600</td>
<td>1900</td>
<td>254</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2006 HBC FOR GUODIAN</td>
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<td>600</td>
<td>1900</td>
<td>254</td>
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<td>569</td>
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<td>600</td>
<td>1913</td>
<td>254</td>
<td>571</td>
<td>569</td>
<td>C</td>
<td>2006 HBC FOR CHINA GUODIAN</td>
</tr>
</tbody>
</table>

**TOTAL No. UNITS**: 123  
**TOTAL MWe**: 64,681
3. Boiler Experience – Major Projects

Egypt
- Ain Sokhna / Gas (650MW x 2 unit)

Saudi Arabia
- Rabigh PP2 / Oil (700MW x 4 unit)
- Marafiq #5,6 / Oil (275MW x 2 unit)

Thailand
- Gheco-one / Coal (700MW x 1 unit)
- Glow CFB / Coal (115MW x 2 unit)

South Korea
- Youngheong #5,6 (870MW x 2 unit)
- Siboryeong #1,2 (1000MW x 2 unit)

Taiwan
- Hsinta #1,2 / Coal (500MW x 2 unit)

Vietnam
- Mong Duong II / Coal (600MW x 2 unit)

Libya
- Al-Khalij / Oil (350MW x 4 unit)
- Tripoli West / Oil (350MW x 4 unit)

India
- Mundra / Coal (800MW x 5 unit)
- Sipat / Coal (660MW x 3 unit)
- Raipur / Coal (685MW x 2 unit)

Indonesia
- Cirebon / Coal (700MW x 2 unit)

Philippines
- Cebu CFB / Coal (100MW x 2 unit)

Chile
- Nueva Ventanas / Coal (240MW x 1 unit)
- Angamos / Coal (240MW x 2 unit)
- Campiche / Coal (240MW x 1 unit)
Power & Water For Tomorrow

Thank You