Introduction of the state-of-the-art technology of IHI for Ultra-SuperCritical power plant

2009.7.27

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Power Plant Division

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1. Improvement of steam conditions
Improvement of steam conditions

Development of Steam Conditions in Japan

STEAM TEMP. (°C)

STEAM PRESS. (MPa)

Sub Critical

Super Critical

Year of Initial Operation

STEAM TEMP.

STEAM PRESS.

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Coal Fired USC Power Plant in Japan

21 USC Coal Fired Power Plant is under commercial operation
Development of Coal Fired Power Plant in Japan

Half of total electricity is now generated by USC unit in Japan.

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Thermal Efficiency Improvement by Applying USC Steam Condition

- **Base**: 566/566 C

- **Isogo New No.1**: 26.6 MPa, 600/610C
- **Isogo New No.2**: 26.3 MPa, 600/620C
- **Tachibana-Wan**: 25.0 MPa, 600/610C

**Developing Tech. Level**:
- 750/760 C (USA DOE Target)
- 700/720/720 C (EU AD700 Target)

**Present Tech. Level**:
- 630/630 C
- 610/610 C
- 600/600 C
- 593/593 C

**Main Steam Pressure (MPa)**:
- 24.1
- 24.5
- 29.4
- 34.3

**Thermal Efficiency Improvement (Relative %)**:
2. Development of USC technology
The core factors in USC technology are …

1. **Enlarge the capacity** (600MW --> 1000MW)
   - Large-scale Boiler (Furnace, Piping, HDR, Steel structures…)
   - Large-sized auxiliary equipment (Pulverizer, Fans, Burners, Sootblower…)
   - Imbalance of heat absorption in FUR and HRA (Heat surface arrangement)

2. **Improve the steam conditions** (566°C --> 620°C)
   - Development of new material
     (High temp. strength, Steam side oxidation, High temp coal ash corrosion)
   - Optimize the heating surface arrangement

3. **Advanced combustion technology** (Reduction of emission)
   - Develop the low-emission burner together with boiler
   - Firing with wide range coal characteristic
   - Stabilized combustion system

4. **The cutting edge control technology** (Automatic reliable operation)
   - Sliding Pressure Operation
   - Dry / Wet Conversion
   - Start-up / Shut-down Operation
### Development of USC technology

#### Tech. Development of Boiler Material

<table>
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<th>ITEMS</th>
<th>YEAR</th>
<th>Remark (milestone)</th>
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<td>'81</td>
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<td>• Boiler design</td>
<td>'82</td>
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<td>Conceptual and basic design of USC</td>
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<td>• Practical application of advanced materials</td>
<td>'84</td>
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<td>Study of coal ash high temp. corrosion</td>
<td>'85</td>
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<td>Superheater, re heater materials</td>
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<td>'88</td>
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<td>'89</td>
<td>(5)TP310 NbN</td>
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<td></td>
<td>'90</td>
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<td>'91</td>
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<td>'92</td>
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<td></td>
<td>'93</td>
<td>Delivered 1st</td>
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<td>'94</td>
<td>593°C Coal Fired USC in JAPAN</td>
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<td>• Development of new valves</td>
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<td>COD 1993.4</td>
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<td>&amp; Boiler Circulation Pump</td>
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<td>• International USC research project</td>
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<td>project (EPRI RP1403)</td>
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</table>

Up to 1993
Development details for austenitic steels for boiler application

Reference:
Development of USC plants (Phase-2), The thermal and nuclear power, vol.52, 2001, Prepared by EPDC/BHK/MHI/IHI/HITACHI/TOSHIBA

Material selection of USC boiler

Figure in ( ) shows creep rupture strength at 600°C × 10^5 hours
Development details for ferritic steels for boiler application

Material selection of USC boiler

35MPa

2.25Cr-1Mo
ASME T22
STBA24

2.25Cr-1MoV
+V + Nb
STBA24

9Cr-2Mo
HCM9M
(METI-STBA27)

9Cr-2MoV Nb
EM12
(NFA49213)

9Cr-1Mo
ASME T9
STBA26

9Cr-1MoV Nb
TEMPALOY F-9

12Cr
AISI 410

12Cr-0.5Mo

12Cr-1MoV
HT91
(DIN X20CrMoV121)

12Cr-1MoW
HT9

60MPa

+V + W
Mo + Nb

12Cr-1MoV
HT91
(DIN X20CrMoV121)

12Cr-1MoW
HT9

100MPa

140MPa

180MPa

Creep rupture strength at 600°C × 10^5 hours

12Cr-0.5Mo-1.8W
NF616
ASME T92
METI-STBA29

9Cr-0.5Mo-1.8W
NF12
ASME T122
METI-SUS410J3TB

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-0.5Mo-1.8
NF616
ASME T92
METI-STBA29

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

9Cr-1MoVNb
ASME T91
METI-STBA28

# Development of USC technology

## Material Selection

<table>
<thead>
<tr>
<th>Turbine Throttle Steam Temperature (°C) (25MPa)</th>
<th>538</th>
<th>596</th>
<th>593</th>
<th>625</th>
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<tr>
<td><strong>ECO</strong></td>
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<td><strong>Furnace</strong></td>
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<td><strong>Separator / Separator Drain Tank</strong></td>
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<td><strong>Final SH (Heated Tubes)</strong></td>
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<tr>
<td>A213T91</td>
<td>A213TP347H</td>
<td>CC2328 (or HR3C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X10CrMoVNb9-1</td>
<td>19Cr11Nb(TP347FG)</td>
<td>18Cr9Ni3CuCbNi(Super304H)</td>
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<td></td>
</tr>
<tr>
<td><strong>Final SH (Unheated Tubes)</strong></td>
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<tr>
<td>A213T91/1792(T122)</td>
<td>A335P22/1792(P122)</td>
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</tr>
<tr>
<td>X10CrMoVNb9-1/1792</td>
<td>X10CrMoVNb9-1792</td>
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<tr>
<td><strong>Final SH Outlet Header</strong></td>
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<tr>
<td>A335P22</td>
<td>A335P91/12P(P122)</td>
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<tr>
<td>10CrMoVNb9-10</td>
<td>X10CrMoVNb9-12P</td>
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<tr>
<td><strong>Main Steam Pipe</strong></td>
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<tr>
<td>A335P22</td>
<td>A335P91/12P(P122)</td>
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<td>10CrMoVNb9-10</td>
<td>X10CrMoVNb9-12P</td>
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<td><strong>Final RH (Vertical: Heated Tubes)</strong></td>
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<tr>
<td>A213T91</td>
<td>A213TP347H</td>
<td>CC2328 (or HR3C)</td>
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<tr>
<td>X10CrMoVNb9-1</td>
<td>19Cr11Nb(TP347FG)</td>
<td>18Cr9Ni3CuCbNi(Super304H)</td>
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<td><strong>Final RH (Vertical: Unheated Tubes)</strong></td>
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<tr>
<td>A213T91</td>
<td>A213T91/1792(T122)</td>
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<tr>
<td>10CrMo9-10</td>
<td>X10CrMoVNb9-1792</td>
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<tr>
<td><strong>Final RH Outlet Header</strong></td>
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<tr>
<td>A387-22 cl2</td>
<td>A387Gr9/12P(P122)</td>
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<tr>
<td>11CrMo9-10</td>
<td>X10CrMoVNb9-12P</td>
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<tr>
<td><strong>Hot Reheat Pipe</strong></td>
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<tr>
<td>A387-22 cl2</td>
<td>A387Gr9/12P(P122)</td>
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</tr>
<tr>
<td>11CrMo9-10</td>
<td>X10CrMoVNb9-12P</td>
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</tbody>
</table>

- **Low-Cr Alloy (Ferritic steel)**
- **9-12 Cr Alloy (Ferritic steel)**
- **Austenitic steel**

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3. IHI USC PC firing boilers
IHI USC PC firing boilers

◆ Market Backgrounds
- IHI has full knowledge right in USC technologies.
- The first USC unit in Japan, Hekinan No.3, was started commercial operation in 1993.
- We have accumulated various technologies and experience through about 20 years.
- The biggest market share of USC plant in Japan. (43%)
- The largest capacity unit in Japan. (1,050MW Tachibana-Wan No.1)
- The highest steam conditions unit in Japan. (620°C Isogo NEW No.2)
- We can put together with different turbine supplier. (GE, Siemens, TSB, HTC, etc.)

◆ IHI Design Features
- FURNACE : Spiral pass with smooth tubes
- COMBUSTION : Wall (Opposed) firing with IHI low-NOx burners
- PARALLEL PASS : STC damper controls RH steam temperature
- BOUNDARY AIR : Minimize the slagging and corrosion on furnace wall
- STARTUP SYSTEM : We have various designs with and without BRP
- MATERIAL : Fit to use CC2328 (Super304H) in Final SH and RH
# IHI’s Existing USC Boiler

<table>
<thead>
<tr>
<th>Plant</th>
<th>MW</th>
<th>Evaporation</th>
<th>Steam conditions</th>
<th>COD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hekinan No.3</td>
<td>700MW</td>
<td>2,250 t/h</td>
<td>24.6MPa/538/593C</td>
<td>1993</td>
</tr>
<tr>
<td>Noshiro No.2</td>
<td>600MW</td>
<td>1,860 t/h</td>
<td>24.6MPa/566/593C</td>
<td>1994</td>
</tr>
<tr>
<td>Nanao-Ohta No.2</td>
<td>700MW</td>
<td>2,120 t/h</td>
<td>24.6MPa/593/593C</td>
<td>1998</td>
</tr>
<tr>
<td>Tachibana-Wan No.1</td>
<td>1050MW</td>
<td>3,000 t/h</td>
<td>25.0MPa/600/610C</td>
<td>2000</td>
</tr>
<tr>
<td>Hekinan No.4</td>
<td>1000MW</td>
<td>3,050 t/h</td>
<td>24.1MPa/566/593C</td>
<td>2001</td>
</tr>
<tr>
<td>Hekinan No.5</td>
<td>1000MW</td>
<td>3,050 t/h</td>
<td>24.1MPa/566/593C</td>
<td>2002</td>
</tr>
<tr>
<td>Tomato Azuma No.4</td>
<td>700MW</td>
<td>2,040 t/h</td>
<td>25.0MPa/600/600C</td>
<td>2002</td>
</tr>
<tr>
<td>Isogo NEW No.1</td>
<td>600MW</td>
<td>1,710 t/h</td>
<td>26.6MPa/600/610C</td>
<td>2002</td>
</tr>
<tr>
<td>Isogo NEW No.2</td>
<td>600MW</td>
<td>1,670 t/h</td>
<td>26.3MPa/600/620C</td>
<td>2009</td>
</tr>
<tr>
<td>Maizuru No.2 (Erect. Stage)</td>
<td>900MW</td>
<td>2,570 t/h</td>
<td>24.5MPa/595/595C</td>
<td>2010</td>
</tr>
</tbody>
</table>
4. A-USC Technology (700°C Research)
A-USC Technology (700°C Research)

Advantage of A-USC Technology

A-USC
Net Thermal Efficiency
46~48% (HHV)

USC
Net Thermal Efficiency
42% (HHV)
A-USC Technology (700°C Research)

A-USC Technology Development

Source: http://www.meti.go.jp/committee/materials2/data/g90617aj.html
A-USC Technologies is suitable for coal with higher ash fusion temp.

IGCC Technologies is suitable for coal with lower ash fusion temp.
A-USC Technology (700°C Research)

Usability of existing system at Application of A-USC Technologies

<table>
<thead>
<tr>
<th>Cost of Thermal Power Unit</th>
<th>Coal Handling</th>
<th>Water Prep.</th>
<th>Boiler</th>
<th>AQCS</th>
<th>DUCT Stack</th>
<th>Turbine Generator</th>
<th>Cooling Water</th>
<th>Electrical Equip.</th>
<th>Ash Handling</th>
<th>Control</th>
<th>Building</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8%</td>
<td>7%</td>
<td>19%</td>
<td>14%</td>
<td>5%</td>
<td>15%</td>
<td>5%</td>
<td>5%</td>
<td>6%</td>
<td>3%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Usable Existing Property for A-USC

- A-USC technologies achieve economical replacement of existing old unit due to wide range of usable property
A-USC Technology (700°C Research)

Structure of 700°C Research

METI

Coordination

NIMS

Material Analysis

IHI

Boiler

Sumitomo Metals

Material

Toshiba

Turbine

Babcock Hitachi

Boiler

Hitachi

Turbine

Fuji Electric Systems

Turbine

Mitsubishi Heavy Industries

Boiler, Turbine

ABB Japan Bailey

Valve

METI: Ministry of Economy, Trade and Industry
NIMS: National Institute for Materials Science
# Development Plan for National Project

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<td><strong>Boiler Technology</strong></td>
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<td>Large Steam Pipe, High Temp. Tube</td>
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<td>Welding, Pipe Bending etc</td>
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<td>Material Test, Trial Manufacturing</td>
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<td>Rotor, Casing, Bolt etc</td>
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<td>Long Term Test (30000~70000 hour)</td>
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<tr>
<td><strong>Boiler Components &amp; Small Turbine Test</strong></td>
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<td>Manufacture</td>
<td>Test</td>
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5. Conclusion
Conclusion

- Thermal efficiency has been increased by improvement of steam conditions as application of USC conditions with outstanding performance and high availability.

- The Coal fired units having with USC steam condition are going on successful commercial operation over 15 years and now 620 °C reheat unit is in the commercial operation.

- We have already launched on new research for actual work of 700 °C class steam unit which will contribute to saving our environment for future generations.