Introduction of
MHPS & Air Quality Control Systems

January 2017
AQCS Business Dept.
MITSUBISHI HITACHI POWER SYSTEMS, LTD.

1. Company Profile
2. MHPS AQCS
3. Application in India
   3-1. AQCS on Field Test in 2016
   3-2. Application for New MHPS Generation
   3-3. Existing AQCS Upgrading
4. High Efficiency System
5. Summary
1. Company Profile: History of MHPS

MITSUBISHI HITACHI POWER SYSTEMS
Capital: 1 Bil USD
Employees: app.22,000 (incl. 7,600 outside Japan)

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1. Company Profile: Product Portfolio

1. Company Profile: AQCS Related Overseas Bases

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1. Company Profile
2. MHPS AQCS
   3. Application in India
      3-1. AQCS Retrofit
      3-2. SCR Catalyst for High Dust Application
      3-3. Existing AQCS Upgrading
4. High Efficiency System
5. Summary

2. MHPS AQCS: Configuration for Coal Fired Plant

One-stop AQCS Solution Provided by MHPS
2. MHPS AQCS: Product Portfolio

MHPS covers wide ranged AQCS products to offer systems which match the needs of customers.

- Flue Gas Denitrification (SCR)
- Flue Gas Desulfurization (FGD)
- Electrostatic Precipitators (ESP)

Honeycomb Catalyst
Plate Catalyst
Double Contact Flow Scrubber (DCFS) Tower
Spray Tower
Moving Electrode
Conventional

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2. MHPS AQCS: Supply Records

Japan
For Utility
Others 4%

A Co. 26%
DeNOx Hitachi 25%
MHI 45%

B Co. 20%
ESP Hitachi 29%
MHI 49%

Others 2%

B Co. 14%
DeSOx Others 5%
MHI 47%

Others 5%

A Co. 16%
Hitachi 18%

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2. MHPS AQCS: FGD Competitiveness

MHPS Ranked the WORLD NO.1 in 2014 and 2015 two years

G5: 12M’15 CAP. SHARE

<table>
<thead>
<tr>
<th>TECH</th>
<th>12M’15</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHPS</td>
<td>5,770</td>
<td>37.66%</td>
</tr>
<tr>
<td>ALSTOM</td>
<td>4,875</td>
<td>31.88%</td>
</tr>
<tr>
<td>BOOSAN</td>
<td>1,985</td>
<td>13.19%</td>
</tr>
<tr>
<td>DOOSAN</td>
<td>1,200</td>
<td>7.90%</td>
</tr>
<tr>
<td>FORMOSA</td>
<td>565</td>
<td>3.79%</td>
</tr>
<tr>
<td>AMEC FW</td>
<td>430</td>
<td>2.84%</td>
</tr>
<tr>
<td>WGW</td>
<td>388</td>
<td>2.61%</td>
</tr>
<tr>
<td>VALMET</td>
<td>338</td>
<td>2.26%</td>
</tr>
<tr>
<td>OUTFIT</td>
<td>40</td>
<td>0.33%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15,380</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

3. MIPs & up. Source: McCoy Surveys.

Secured 100% project wins (*) in tenders of FGD in 2014 in S.E. Asia.
1) Malaysia 1000MWx1
2) Indonesia 1000MWx2
3) Philippines 400MWx1
4) Vietnam 660MWx2 (First Refusal Right)
3-1. AQCS Retrofit: ESP Outline

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
</tr>
<tr>
<td>Dust</td>
<td>100mg/Nm³</td>
<td>50mg/Nm³</td>
<td>30mg/Nm³</td>
</tr>
<tr>
<td>SOx</td>
<td>600mg/Nm³</td>
<td>200mg/Nm³</td>
<td>600mg/Nm³</td>
</tr>
<tr>
<td>NOx</td>
<td>600mg/Nm³</td>
<td>300mg/Nm³</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>-</td>
<td>0.03mg/Nm³</td>
<td>0.03mg/Nm³</td>
</tr>
</tbody>
</table>

The new regulation may require investment to Air Quality Control Systems. New TPP Tenders started including AQCS Challenge for AQCS Retrofit to Existing/Under Construction TPPs
3-1. ESP Retrofit: ESP Outline

MHPS has supplied over 3,200 units of dry and wet ESP worldwide. Feature and highlights of our ESPs are:

- **High dust reduction efficiencies** to meet the required emissions by MEEP(*)
- **Superior cost value** as a result of compact design, easy maintenance and energy savings.
- **High durability** due to well-designed robust structure.

38 Reference for coal fired boiler since after 1981

(*) MEEP: Moving Electrode type ESP

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3-1. ESP Retrofit: MEEP Reference in India, Rihand TPP

NTPC Rihand ESP Upgrading Project

- NTPC Rihand Power Station 2x500MW
- Upgrading by Moving Electrode (MEEP)

Reduce dust emission from 500mg/Nm³ to 50mg/Nm³

*Applied for Indian high ash coal*

No Space for existing ESP Expansion!

By MHPS MEEP technology, dust removal efficiency increased within the original space!
3-1. ESP Retrofit: MEEP Reference in India, Rihand TPP

Conventional technology requires huge space to install additional ESP!

Dust removal efficiency improved within the original space by MEEP!

3-1. FGD Retrofit: FGD Outline

**FGD Absorber**

**Chemical Reaction in Absorber**

SO₂ + CaCO₃(limestone) + 2H₂O → CaSO₄·2H₂O(gypsum) + CO₂

**Features**

More than 95% SO₂ removal efficiency is achievable.
Efficient and highly reliable system.

**Two Major FGD Process**

1. Limestone Gypsum Process
2. Seawater Process
3-1. FGD Retrofit: Reference Project

FGD Retrofit Project Outline

- No available area nearby the existing stack
- Newly installed single FGD treating flue gas from 4 boilers
- Stack is integrated to the FGD absorber tower.

Plant : Poland  
Fuel : Coal  
Plant Power : 800MW  
Inlet SO₂ : 1,120ppm(d)  
DeSOx: 93.75%  
Start up : 2006

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3-1. FGD Retrofit: Normal Practice in AQCS Industry

Majority of MHPS FGD reference is Retrofit

<table>
<thead>
<tr>
<th></th>
<th>Total N of units</th>
<th>Retrofitted Units</th>
<th>Retrofit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>32</td>
<td>26</td>
<td>81%</td>
</tr>
<tr>
<td>Europe</td>
<td>102</td>
<td>72</td>
<td>71%</td>
</tr>
<tr>
<td>Japan</td>
<td>131</td>
<td>70</td>
<td>53%</td>
</tr>
<tr>
<td>China</td>
<td>18</td>
<td>6</td>
<td>33%</td>
</tr>
<tr>
<td>Korea</td>
<td>14</td>
<td>4</td>
<td>29%</td>
</tr>
<tr>
<td>Others</td>
<td>26</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>323</td>
<td>178</td>
<td>55%</td>
</tr>
</tbody>
</table>

FGD retrofit has been required in many countries as emission regulation established after the power plant operation.

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3-1. FGD Retrofit: Various Applications

**Option 1**
- No FGD & sufficient space case

**Option 2**
- No FGD & Insufficient space & Near the existing facilities case

**Option 3**
- No FGD & Insufficient space & Far from the existing facilities case

**Option 4**
- Existing FGD case

Most of retrofit units are categorized to Option 2 or Option 3.

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### 3-1. FGD Retrofit: Typical Installation Schedule

<table>
<thead>
<tr>
<th>Plant Operation</th>
<th>Operation</th>
<th>Periodical Maintenance approx. 1-2 months</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGD Installation</td>
<td>Construction Work</td>
<td>Absorber, Duct, Piping and other auxiliaries</td>
<td>Duct Tie-in Work</td>
</tr>
</tbody>
</table>

- FGD installation can separately proceed during boiler operation.
- Duct tie-in work to the existing duct could be done within maintenance period.

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3-1: AQCS Retrofit: Integrated design FGD+FGD

Separate Contracting

Boiler

Supplier A

Particulate matter conc. (mg/Nm³)

16,000

MHPS

DeSO₂

50

Approx 20-25%
Downsized by MEEP+FGD dust removal function (for installation area)

16,000

ESP

100

(*) AQCS system dust removal efficiency depends on coal type and dust particulate distribution.
Considering dust removal performance at DeSO₂, ESP can be downsized.

Integrated Design

Boiler

MHPS

Particulate matter conc. (mg/Nm³)

16,000

DeSO₂

50

(*) Overall system purchasing achieve
• Installation cost and space decrease 10-20%.
• Prevention of trouble at the interfaces

3-1. SCR Retrofit: SCR Outline

Harmful NOx is decomposed into harmless N₂ and H₂O by catalytic action.
3-1. SCR Retrofit: Reference Project

**Project Outline**

Plant: Poland  
Fuel: Coal  
Plant Power: 220MW x 2  
DeNOx Efficiency: 80%  
Slip NH₃: 2 ppm  
Start up: U2 Oct. 2015  
U1 Mar. 2016

Before installation  
After Installation

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3-1. SCR Retrofit: Normal Practice in AQCS Industry

About half of MHPS SCR reference is Retrofit

<table>
<thead>
<tr>
<th></th>
<th>Total N of units</th>
<th>Retrofitted Units</th>
<th>Retrofit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>21</td>
<td>13</td>
<td>62%</td>
</tr>
<tr>
<td>Europe</td>
<td>24</td>
<td>16</td>
<td>67%</td>
</tr>
<tr>
<td>Japan</td>
<td>85</td>
<td>21</td>
<td>25%</td>
</tr>
<tr>
<td>China</td>
<td>32</td>
<td>9</td>
<td>28%</td>
</tr>
<tr>
<td>Korea</td>
<td>12</td>
<td>12</td>
<td>100%</td>
</tr>
<tr>
<td>Taiwan</td>
<td>42</td>
<td>22</td>
<td>52%</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>4</td>
<td>67%</td>
</tr>
<tr>
<td>Total</td>
<td>222</td>
<td>97</td>
<td>44%</td>
</tr>
</tbody>
</table>

SCR retrofit has been required in many countries as emission regulation established after the power plant operation.
3-2. SCR Catalyst : Catalyst Manufacturing Facility

Japan
MHPS Akitsu Factory
Operation start: 1987
Location: Hiroshima, Japan

China
Mitsubishi-Hitachi (Hangzhou) Environmental Equipment Co., Ltd. (100% Subsidiary)
Operation start: 2012
Location: Hangzhou, China

India
Under Feasibility Study
3-2. SCR Catalyst: Catalyst Erosion Problem at Same Plant

Same SCR reactor
MHPS: Top layer, Company A: Bottom layer
Dust: Less than 20g/m³N

MHPS
Operation 2009/1~2015

Company A
Operation 2013/5~2015

3-2. SCR Catalyst: Catalyst Erosion Problem in China

Company B: Operation 2012/6~2014/5
## 3-2. SCR Catalyst: MHPS Reference of High Dust Coal

<table>
<thead>
<tr>
<th>No.</th>
<th>Project</th>
<th>Capacity</th>
<th>Dust conc g/m³N</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>青岛山 Unit 1-4</td>
<td>200MW x 4</td>
<td>46.6</td>
<td>2008</td>
</tr>
<tr>
<td>2</td>
<td>淮南下邽 Unit 1,2</td>
<td>660MW x 2</td>
<td>41.0</td>
<td>2011</td>
</tr>
<tr>
<td>3</td>
<td>临州 Unit 1,2</td>
<td>350MW x 2</td>
<td>43.6</td>
<td>2011</td>
</tr>
<tr>
<td>4</td>
<td>寧海 Unit 1,2,3,4</td>
<td>1000MW x 2 + 300MW x 2</td>
<td>41.2</td>
<td>2012</td>
</tr>
<tr>
<td>5</td>
<td>海口 Unit 1,2</td>
<td>600MW x 2</td>
<td>53.7</td>
<td>2012</td>
</tr>
<tr>
<td>6</td>
<td>湖南南部 Unit 3,5,6,7,8</td>
<td>300MW x 2</td>
<td>68.9</td>
<td>2012/2013</td>
</tr>
<tr>
<td>7</td>
<td>南山东 Port 1.2</td>
<td>600MW x 2</td>
<td>55.0</td>
<td>2013</td>
</tr>
<tr>
<td>8</td>
<td>湖南南部 Unit 3,4,5,6,7,8</td>
<td>250MW x 2 + 250MW x 2</td>
<td>57.5</td>
<td>2013</td>
</tr>
<tr>
<td>9</td>
<td>海口 Unit 1,2</td>
<td>350MW x 2</td>
<td>64.3</td>
<td>2013</td>
</tr>
<tr>
<td>10</td>
<td>江南 Unit 1,2</td>
<td>350MW x 1</td>
<td>48.2</td>
<td>2013</td>
</tr>
<tr>
<td>11</td>
<td>南山东 Unit 1,2</td>
<td>300MW x 2</td>
<td>48.7</td>
<td>2013</td>
</tr>
<tr>
<td>12</td>
<td>淮南下邽 Unit 1-4</td>
<td>200MW x 4</td>
<td>43.5</td>
<td>2013-2014</td>
</tr>
<tr>
<td>13</td>
<td>南山东 Unit 1,2</td>
<td>300MW x 2</td>
<td>40.0</td>
<td>2013</td>
</tr>
<tr>
<td>14</td>
<td>牡丹江 Unit 1,2</td>
<td>300MW x 1</td>
<td>50.6</td>
<td>2013</td>
</tr>
<tr>
<td>15</td>
<td>哈尔滨 Unit 1,2</td>
<td>300MW x 4</td>
<td>53.8</td>
<td>2013</td>
</tr>
<tr>
<td>16</td>
<td>汉南 Unit 3</td>
<td>300MW x 1</td>
<td>40.0</td>
<td>2013</td>
</tr>
<tr>
<td>17</td>
<td>江南 Unit 2</td>
<td>630MW x 1</td>
<td>41.0</td>
<td>2013</td>
</tr>
<tr>
<td>18</td>
<td>佳木斯 Unit 1,2</td>
<td>300MW x 1</td>
<td>48.2</td>
<td>2013</td>
</tr>
<tr>
<td>19</td>
<td>江南 Unit 5</td>
<td>130MW x 1</td>
<td>41.4</td>
<td>2013</td>
</tr>
<tr>
<td>20</td>
<td>江南 Unit 6</td>
<td>130MW x 1</td>
<td>41.4</td>
<td>2013</td>
</tr>
</tbody>
</table>

Above 50g/m³N: 20 Projects
Above 60g/m³N: 4 Projects

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3-3. Existing AQCS Upgrading: Global Regulation Trend

CLEAR TREND toward more and more stringent emission regulation. The AQCS is required to be upgraded to comply with the new regulation.

<table>
<thead>
<tr>
<th>Country</th>
<th>India</th>
<th>Japan</th>
<th>US</th>
<th>China</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>N</td>
<td>E</td>
<td>N/Exist</td>
<td>N</td>
<td>E</td>
</tr>
<tr>
<td>SO₂/NOx</td>
<td>100</td>
<td>200</td>
<td>115 (12)</td>
<td>144</td>
<td>288</td>
</tr>
<tr>
<td>NOx</td>
<td>100</td>
<td>300</td>
<td>70 (60)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Dust</td>
<td>30</td>
<td>50</td>
<td>5 (5)</td>
<td>12</td>
<td>39</td>
</tr>
</tbody>
</table>

N: New Built, E: Existing, Japan: Most stringent case
BREF: Best Available Reference Document

3-3. Existing AQCS Upgrading: Case Study in China

1000MW Chinese Power Station AQCS: Before MHPS Modification

- **Client’s efforts before MHPS Modification**
  - ESP: 5 sections
    - In 2014, Modification of ESP
    - Guaranteed ESP outlet dust: 30mg/Nm³
  - FGD: Limestone Slurry Process with 5 stages
    - In 2014, added 6th stage
    - Guaranteed FGD outlet SO₂: 30mg/Nm³
  - GGH: Rotating Type, 3.54% leakage

Client already made modifications such as ESP and 6th stage of FGD but still far from the required emission level.

- **Emission before MHPS Modification**
  - Dust: 14 mg/Nm³
  - SO₂: 330 mg/Nm³

- **Client Target**
  - Dust: 5 mg/Nm³
  - SO₂: 35 mg/Nm³
3-3. Existing AQCS Upgrading: Case Study in China

Scope of AQCS Modification by MHPS

1. New Gas Coolers
2. FGD Inlet Duct Modification
   Flue Gas Distribution plate Modification
3. FGD Internals Upgrade
   New EKATO and New Recirculation Pumps
4. Removal of Rotating GGH
   New Mist Eliminator
   New Re-Heater

Comprehensive Modifications by MHPS from the Air Heater Outlet to the Stack

<table>
<thead>
<tr>
<th>FGD Outlet Before Upgrading</th>
<th>FGD Outlet After Upgrading</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SO_2$</td>
<td>$SO_2$</td>
</tr>
<tr>
<td>$330$ mg/Nm$^3$</td>
<td>$\leq 35$ mg/Nm$^3$</td>
</tr>
<tr>
<td>Mist</td>
<td>Mist</td>
</tr>
<tr>
<td>$86$ mg/Nm$^3$</td>
<td>$\leq 40$ mg/Nm$^3$</td>
</tr>
<tr>
<td>Dust</td>
<td>Dust</td>
</tr>
<tr>
<td>$14$ mg/Nm$^3$</td>
<td>$\leq 5$ mg/Nm$^3$</td>
</tr>
</tbody>
</table>

Achieving ultra low emission by Comprehensive Modification of GGH, ESP & FGD

$Dust \leq 5$ mg/Nm$^3$   $SO_2 \leq 35$ mg/Nm$^3$
3-3. Existing AQCS Upgrading: Case Study in China

MHPS Modification Result
Output: 1000MW
Inlet Dust: 24.82g/Nm³
Dust Emission (Design): 5mg/Nm³
(Actual): 2mg/Nm³
SO₂ Emission (Design): 35mg/Nm³
(Actual): 10~23mg/Nm³
Outlet Flue Gas Temp: 80°C

Achievement of ultra low emissions by the comprehensive modification from Air Heater outlet to the stack

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4. High Efficiency System (HES)

HES is the advanced technology for strict dust restriction

**Conventional System under Current Regulation (Dust 30mg/Nm³)**
- Boiler
- DeNOx → L-Temp ESP → DeSOx → Stack

Current Regulation
- Dust: 30mg/Nm³
- SOx: 100mg/Nm³
- NOx: 100mg/Nm³

**Conventional System under Strict Regulation (Ex. Dust 5mg/Nm³)**
- Boiler
- DeNOx → L-L-Temp ESP → Rotary GGH → DeSOx → Stack

Future Regulation
- Dust: 5mg/Nm³
- SOx: 100mg/Nm³
- NOx: 100mg/Nm³

**High Efficiency System under Strict Regulation (Ex. Dust 5mg/Nm³)**
- Boiler
- DeNOx → Non Leak GGH → L-L-Temp ESP → DeSOx → Non Leak GGH → Stack

Future Regulation
- Dust: 5mg/Nm³
- SOx: 100mg/Nm³
- NOx: 100mg/Nm³

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4. High Efficiency System (HES)

Comparison of Life Cycle Cost (1000MW x 2 New Boiler)

Assumption: Outlet Dust is regulated to 5mg/Nm³ after 10 years

Scenario: Initially the Conventional system for 30mg/Nm³. 10 Years Later: Conversion for 5mg/Nm³

HES is the most economical way under severe emission limit.

Further, Japanese Government loan can be applied under very favorable conditions e.g., 0.3% interest rate, 40 years repayment period including 10 years grace period

![Graph of Life Cycle Cost Comparison]

[Mil. US$]

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4. High Efficiency System (HES)

The HES has been pilot tested by using Indian coal

1. Project : HES Pilot Test with Indian Coal in Japan
2. Place : MHPS Akitsu R&D Centre
3. Term : FY2015
4. Fund : Clean Coal Fund by Japanese Government

<table>
<thead>
<tr>
<th>Schedule in FY2015</th>
<th>1Q (Apr-Jun.)</th>
<th>2Q (Jul-Sep.)</th>
<th>3Q (Oct-Dec.)</th>
<th>4Q (Jan-Mar.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Planning/Contract</td>
<td>Planning</td>
<td>Bid Contract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Import of Indian Coal</td>
<td>9/19 Import to Akitsu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Preparation of Test</td>
<td></td>
<td>Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Test</td>
<td></td>
<td></td>
<td></td>
<td>Report</td>
</tr>
<tr>
<td>5. Analysis/Reporting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The performance of ESP was improved by reducing inlet flue gas temperature

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Summary of MHPS AQCS Business

1. MHPS's AQCS total solution covers SCR, FGD and ESP.

2. The novel AQCS technology has been developed to meet the restricted emission limit in World Bank, Japan, EU and US standards. MHPS has huge amounts of the worldwide delivery records.

3. Extensive experiences for retrofitting AQCS to the existing boilers within the limited area and the limited period.

4. Experiences of various type of coal enables us to design the most optimized Catalyst under Indian high ash condition.

5. MHPS is also aware of the importance of cost competitiveness, therefore the local supply chains would be applied for further cost reduction.