MHPS’s State of Art AQCS Technologies for Indian Power Plants
New Environmental Regulation announced on 7th Dec 2015

<table>
<thead>
<tr>
<th>Capacity</th>
<th>TPP installed before 31 December 2003</th>
<th>TPP installed after January 2004 up to 31st December 2016</th>
<th>New install from 1st January 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
</tr>
<tr>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
</tr>
<tr>
<td>Smaller than 500MW</td>
<td>500MW &amp; Above 500MW</td>
<td>Smaller than 500MW</td>
<td>Any Size</td>
</tr>
<tr>
<td>Particulate</td>
<td>100mg/Nm³</td>
<td>50mg/Nm³</td>
<td>30mg/Nm³</td>
</tr>
<tr>
<td>SO2</td>
<td>600mg/Nm³</td>
<td>200mg/Nm³</td>
<td>100mg/Nm³</td>
</tr>
<tr>
<td>NOx</td>
<td>600mg/Nm³</td>
<td>300mg/Nm³</td>
<td>100mg/Nm³</td>
</tr>
<tr>
<td>Mercury</td>
<td>-</td>
<td>0.03 mg/Nm³</td>
<td>0.03mg/Nm³</td>
</tr>
</tbody>
</table>

- The new regulation may require application of state of art technologies
- MHPS has enough experience to comply with severe requirements in Japan, and MHPS can supply reliable technologies to meet Indian regulation.
MHPS Delivered AQCS units all over the world

- SCR: 1,023 Units (20 Countries)
- ESP: 3,276 Units (32 Countries)
- FGD: 323 Units (26 Countries)

※2015年現在: SCR 1,023 Units (20 Countries), ESP 3,276 Units (32 Countries), FGD 323 Units (26 Countries)
Air Quality Control System (AQCS) for Coal Fired Plant

One-stop AQCS solution by MHPS
Latest MHPS SCR Technology
NOx control technologies

- Combustion Technology
  - OFA (Over Fire Air)
  - Gas Recirculation
  - Low NOx PM Burner (Pollution Minimum)
  - In-Furnace NOx Removal System (MACT)
- Post-Combustion Technology
  - Selective Catalytic Reduction (SCR)
  - Selective Non-Catalytic Reduction (SNCR)

NOx control technologies:
- SNCR
- MACT
- OFA
- PM Burner
- SCR
- AH

Catalysts:
- Honeycomb Catalyst
- Plate Catalyst
Harmful NOx is decomposed into harmless N2 and H2O by catalytic action.

\[
4\text{NOx} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}
\]
Typical System Configuration & Main Reaction

REACTION FORMULA

- \(4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}\)
- \(\text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}\)
- \(6\text{NO}_2 + 8\text{NH}_3 \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O}\)

NH\(_3\) injection → SCR Reactor → Catalyst → NO\(_x\) Analyzer

BOILER → ECO → Catalyst → \(\text{NH}_3\) Storage & Supply

STACK

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In-house ‘Knowledge’ and ‘Expertise’ built over 45+ years.
- Understand complete “Power Island”
- Understand gas path management
- Catalyst selection
- Catalyst management plan
- Proven track record (1,023 units)

Pioneers and patent holders for SCR systems and catalyst technology.
- (Plate & Honeycomb type)
### Honeycomb/Plate Catalyst Type

- **Honeycomb Catalyst**
- **Plate Catalyst**

<table>
<thead>
<tr>
<th>Application</th>
<th>Dust Level</th>
<th>DeNOx Level</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Cover all applications.**

*Best selection of catalyst provides benefit on plant operation and maintenance costs.*
Flue Gas Path Management

NH3 Distribution

- NH3 Profile
- Velocity Profile
- Large Particle Ash
- Ash Erosion
- Ash Accumulation

‘Flue Gas Path Management’

Flue Gas Flow Distribution

SCR Component

- Ammonia Injection Grid
- Static Mixer
- Turning Vane
- Rectifier (Flow Straightener)
- Duct, Ash Hopper
- LPA Screen
- Turning Vane
- Rectifier (Flow Straightener)
- Turning Vane
- Rectifier (Flow Straightener)
**CFD Analysis**

- Understand flue gas profile.
- Minimize gas angle entering SCR catalyst.
- Minimize velocity maldistribution at catalyst inlet.
- LPA (Large Particle Ash) simulation by CFD.

**Cold Flow Model Test**

- In-house capability of CFD analysis and cold flow model test.
- Minimize gas angle and velocity maldistribution by guide vane and rectifier (MHPS patented technology).
Latest MHPS Technology to Remove Particulate Matter
**Low-Low Temp. ESP System**  
*(High-performance System)*

- Gas Temp. (deg.C): 130
- Dust Conc. (mg/m³N): 20,000
- Gas Temp. (deg.C): 90
- Dust Conc. (mg/m³N): 20,000

**SCR**: Selective Catalytic Reduction  
**A/H**: Air Heater  
**GGH**: Gas-Gas Heat Exchanger  
**DESP**: Dry Electrostatic Precipitator  
**FGD**: Flue Gas Desulfurization
1. **SO$_3$ removal**: SO$_3$ gas is condensed on fly ash
2. **Opacity reduction**: No plume caused by SO$_3$ mist at stack
3. **High PM removal performance at ESP**: Gas temperature reduction
4. **Water consumption saving at FGD**: Gas temperature reduction
Effect of Gas Temperature on PM Removal

- Decrease of ESP Inlet Gas Temp.
- Decrease of Dust Electric Resistant
- Decrease of Gas Volume
- Improve of ESP Performance

Effect of Gas Temperature on PM Removal:

- Low Low Temp. ESP System
- Conventional System

Graph showing the relationship between gas temperature and dust electric resistant for different coals (A and B).
Latest MHPS FGD Technology
Wet Limestone-Gypsum process ; DCFS-type Absorber

DCFS ; Double Contact Flow Scrubber

Single Tower DCFS

Twin Tower DCFS
Wet Limestone-Gypsum process; Open Spray-type Absorber

Spray Header

Spray Nozzles

Oxidation Agitator

Air Dispersion
Seawater FGD reference
Client: Tata Power Company Limited.
Plant: Trombay #8, India
Fuel: Coal
Capacity: 250 MW x 67%
Efficiency: 91%
Start-up: 2009
Build by BHEL (MHPS as subcontractor)

FGD License Agreement with BHEL
Agreed in April 2013

Signing Ceremony in Feb., 2013
Advantage of integrated design: ESP Downsizing

Separate Contracting

Supplier A

Boiler

ESP

Particulate matter conc. (mg/Nm³)

16,000

MHPS

DeSOx

Particulate matter conc. (mg/Nm³)

50

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

Integrated Design

Boiler

ESP

Particulate matter conc. (mg/Nm³)

16,000

MHPS

DeSOx

Particulate matter conc. (mg/Nm³)

100 (*)

50 (*)

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

Overall system purchasing achieve …

- Installation cost and space decrease 10-20%.
- Prevention of trouble at the interfaces

(*) AQCS system dust removal efficiency depends on coal type and dust particulate distribution. Considering dust removal performance at DeSOx, ESP can be downsized.
Retrofit to Existing Boilers (SCR)

**SCR Retrofit Project Outline**

- Plant: Poland
- Fuel: Coal
- Plant Power: 220MW x 2
- DeNOx: 80%
- Slip MH3: 2 ppm
- Start up: U2 Oct. 2015
  - U1 Mar. 2016

**Before installation**

**After Installation**

- Boiler
- ESP
- SCR
- Reactor A
- Reactor B
Retrofit to Existing Boilers (FGD)

FGD Retrofit Project Outline

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

Newly installed single FGD treating flue gas from 4 boilers
MHPS technology to capture Mercury in AQCS
Form of vapor phase mercury (Speciation)

Elemental Mercury - Hg⁰
Oxidized Mercury - Hg⁺⁺

The form of mercury in the flue gas is critical to performance of emissions control systems.

- Elemental Mercury: Hard to remove from flue gas
- Oxidized Mercury: Easier to remove from flue gas (downstream ESP, FGD)

To achieve higher Hg removal, Hg oxidation is indispensable.
Mercury Removal Technology
~ Hg removal in TRAC® with NH₄Cl Injection~

SCR with higher Hg oxidation and lower SO₂ conversion (TRAC®)

NH₄Cl Injection for both NH₃ and Cl supply

Element Mercury (Hg⁰) is suppressed by controlling Oxidation-Reduction Potential (ORP)

ORP*: Oxidation-Reduction Potential

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Mercury Removal Technology
~ TRAC® Catalyst ~

Conventional

SO₂ Oxidation Rate

Low

High

Mercury Oxidation Activity

Low

High

- High De-NOx Activity
- High Mercury Oxidation Activity
- Low SO₂ Oxidation Rate

TRAC®
(High Mercury Oxidation Catalyst)

TRAC® = Triple Action Catalyst
Effects of TRAC™ and Gas Cooler on Hg Removal

US Bituminous Coal
Hg: 0.11mg/kg
In-house Test Facility

Conventional Catalyst
- 150°C
- 19.5%

TRAC™ Catalyst
- 90°C
- 75.0%
- 4.7%

Boiler
SCR
A/H
Gas Cooler
DESP
FGD
Stack