Up-gradation of Boilers to Implement New Pollution Norms
### Key Regulatory Drivers: Power Plants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit*</th>
<th>TPPs installed before December 31, 2003 (Refer Note 1)</th>
<th>TPPs installed after 2003 to December 31, 2016 (Refer Note 1 &amp; 2)</th>
<th>TPPs to be installed from January 1, 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter</td>
<td>mg/Nm³</td>
<td>100</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>SOx</td>
<td>mg/Nm³</td>
<td>600 (&lt;500 MW)</td>
<td>600 (&lt;500 MW)</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200 (&gt;=500 MW)</td>
<td>200 (&gt;=500 MW)</td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td>mg/Nm³</td>
<td>600</td>
<td>300</td>
<td>100</td>
</tr>
</tbody>
</table>

**Note 1:** TPP’s (Units) shall meet the limits within two years from date of the notification.
**Note 2:** Includes all the TPP’s (Units) which have been accorded environmental clearance and are under construction.

*Corresponding to 6% O₂ Dry Volume.

NDA: Non-degraded Airshed, DA: Degraded Airshed (Poor Air Quality)

_Emission Norms for Industrial Boilers are individually governed by various states._
Total Portfolio Under Emission Control

1. NOx Control
   i. Combustion Modifications
   ii. Post Combustion Measures
      a. SNCR
      b. SCR
      c. Hybrid of SCR & SNCR

2. SO\textsubscript{2} Control
   i. Limestone injection in the combustor of AFBC & CFBC Boilers
   ii. FGD
      a. Dry FGD
      b. Wet FGD

3. SPM Control
   i. ESP modification
      a. HFPS
      b. Hybrid Filter (ESP + Bag Filter)
   ii. Flue Gas Conditioning: SO\textsubscript{3}, NH\textsubscript{3} and Dual injection in flue gas upstream of ESP
1. NOx Control

   i. Combustion Modifications: Up to 60% reduction potential for older units where low NOx burners / OFA were not originally provided.

   ii. Post Combustion Measures

      a. SNCR: 20 - 40% reduction potential for large PC fired units & upto 75% for small industrial units.

      b. SCR: 85 - 90% reduction potential.

      c. Hybrid of SCR & SNCR: Up to 60% reduction potential for large PC fired units.
SO$_2$ emission Control

1. SO$_2$ Control

   i. Limestone injection in AFBC & CFBC boilers: Up to 70-75% reduction potential for AFBC boilers & up to 90-95% reduction potential for CFBC boilers.

   ii. FGD
      a. Dry FGD
         - DID: Hydrated lime injection in flue gas downstream of boiler: Up to 60% reduction potential (max 75% with high grade lime).
         - RDS: Hydrated lime injection in flue gas downstream of boiler: Up to 95% reduction potential.

      b. Wet FGD using Limestone: Up to 99% reduction potential.
**SPM emission Control**

1. SPM Control

   i. ESP modification

      a. HFPS: Upto 50% reduction potential depending upon existing emissions.

      b. Conversion from ESP to Hybrid Filter (ESP + Bag Filter): 80 - 90% reduction potential depending upon existing emissions from ESP

Typical Power Plant

- Combustion Technologies
- SNCR
- SCR
- ESP Modification and Flue Gas Conditioning Systems

Advanced Modeling Services – All Technologies
DeNOx Technologies
Primary Measure – Combustion Modifications
Primary Measure – Combustion Modifications

1. Low NOx Burner – For T-Fired and Wall Fired units
2. OFA (Over Fire Air) - For T-Fired and Wall Fired units
3. Mill Modification for Pulverized Coal Fineness Improvement
4. Low Capex, Negligible Opex
5. 4 – 8 weeks shut down required depending on existing configuration and modification required.
Primary Measure – Combustion Modifications

- Base: 1.0
- 20% OFA: 0.70
- Low NOx Burner: 0.50
- Low NOx Burner and 20% OFA: 0.30
- SCR: 0.10

Combustion Technology

Post Combustion
SNCR “Right Side of Slope” Injection

**Low Temperature Issues**
- Slow Droplet Evaporation
- Slow Kinetics
- Low OH Concentration
- Ammonia Slip Increase

**High Temperature Issues**
- Rapid Droplet Evaporation
- Fast Kinetics
- Increased OH Concentration
- Urea Oxidation to NOx
SNCR – Why Urea

Urea droplets formed by FTI injectors are characterized in test facilities using laser Doppler techniques.
Selective Catalytic Reduction (SCR) Technology
SCR Arrangements

**High Dust**

- Boiler → NH3 → SCR → Air Heater → Air → ESP → Stack

**Low Dust**

- Boiler → NH3 → Hot-Side ESP → SCR → Air Heater → Air → ESP → Stack

**Tail End**

- Boiler → Air Heater → Air → ESP → FGD → Regenerative Gas-Gas Heat Exchanger → Duct Burner → Fuel or Steam → NH3 → SCR → Stack
SCR Reactors

- Higher Capex & Moderate Opex.
- Relatively longer installation time.
- SCR may not be necessary for retrofit units in view of relaxed emission norms.
Comparison Plate – Honeycomb Catalyst

Plate Type Structure

- Flexible Plates With Notches to Maintain Pitch
- Large Rectangular Openings
- High Void Fraction (>
50%)
- Pitch: ~5 to 7 mm

Honeycomb Structure

- Rigid Structure
- Square Openings/Increased Surface Area
- Void Fraction >75%
- Pitch: 7 to 10 mm (for coal-fired applications)

Plate type catalyst with conservative pitching is recommended for High Ash Indian Coal
ASCR Technology Presentation

NOx Reduction Technology
Optimized SNCR/ASCR

- **Low Temperatures**
  - Slow Droplet Evaporation
  - Slow Kinetics
  - Low OH Concentration
  - Ammonia Slip

- **High Temperatures**
  - Rapid Droplet Evaporation
  - Fast Kinetics
  - Increased OH Concentration
  - Urea Oxidation to NOx

- **Moderate Capex & Opex**
- **Relatively high shut down time as compared to SNCR.**
China Light & Power – Castle Peak “B”

Project Overview
• Project to reduce NOx emissions and increase operating efficiency in an existing coal fired power generating facility in Hong Kong

Problems and Challenges
• Complicated duct run that involved numerous sharp turns
• Limited space for Ammonia Injection Grid (AIG) and mixing devices.
• Limited space for reactor requires very high velocity through the catalyst, increasing chance of erosion failure and requiring extremely even and vertical gas flow.
• System needed to be designed to handle a range of coals with variable ash loading, sulfur content and NOx baselines

Fuel Tech Solution / Approach
• Utilized CFD modeling to predict gas flows, operating temperatures, velocities and other critical variables
• Single layer SCR installed in the existing ductwork, and an AIG was installed and located in the cavity of the economizer
• Patented Graduated Straightening Grid was used to provide optimally distributed and uniform gas velocities into the catalyst

Fuel Type
<table>
<thead>
<tr>
<th>Bituminous coals</th>
</tr>
</thead>
</table>

Boiler Type and Size
4 x 685 MW tangential-fired boiler

Results
• Single layer of catalyst provides ~8,000 hours of catalyst lifetime
• NOx removal efficiency varying from 40% at the beginning and 30% at the end of life
• Reactor is designed for 7.5 m/s catalyst face velocity

Computational and Experimental Fluid Dynamics Models
Next step – ASCR feasibility

- Evaluate Ductwork and Spacing between Economizer Outlet to Air Heater Inlet
- Evaluate Operating and Ash Conditions
- Space Available for Single Layer of High Performance Catalyst
DeSOx Technologies
DeSOx Technologies – AFBC/CFBC Boilers
Lime Stone Feed System

Crushed Limestone is fed either pneumatically or mechanically into the CFB and AFBC boiler.

- The pneumatic system feeds the Limestone directly into the furnace through furnace openings.
- In the mechanical system, the Limestone is fed along with fuel through fuel feeders into the furnace.
System Requirement for Lime Stone Feeding

- Limestone Preparation – To ensure required particle size.
- Conveying system from Bunker to Furnace, as applicable.
- Opening in Furnace
- SOx analyzers (part of CEMS)
- Control Logics – to be incorporated in existing DCS
Wet Flue Gas Desulphurization Technology
Wet Limestone based FGD

- Bi-Directional Spray Nozzles
- Wall Ring
- Absorber Inlet and Inlet Awning
- Reaction Tank forced oxidation with agitator
- 2-Stage Internal Mist Eliminator
- Absorber Design Greater Than 500 MW
- Experience with Designing Systems to Treat Flue Gas from Multiple Units
Dry Injection Desulphurisation (DID) Technology
# Case Study 1 – 2x210 MW PC Boilers

### Existing ESP

<table>
<thead>
<tr>
<th>ESP</th>
<th>Field Inlet Dust (kg/hr)</th>
<th>Recovered Dust (mg/Nm³)</th>
<th>Recovered Dust (kg/hr)</th>
<th>Field Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70.000</td>
<td>7.884</td>
<td>13.946</td>
<td>70%</td>
</tr>
<tr>
<td>2</td>
<td>21.000</td>
<td>3.914</td>
<td>3.914</td>
<td>70%</td>
</tr>
<tr>
<td>3</td>
<td>6.300</td>
<td>1.002</td>
<td>1.002</td>
<td>60%</td>
</tr>
<tr>
<td>4</td>
<td>2.500</td>
<td>0.369</td>
<td>0.369</td>
<td>55%</td>
</tr>
<tr>
<td>5</td>
<td>1.134</td>
<td>0.105</td>
<td>0.105</td>
<td>55%</td>
</tr>
<tr>
<td>6</td>
<td>737</td>
<td>0.09</td>
<td>0.09</td>
<td>35%</td>
</tr>
<tr>
<td>7</td>
<td>479</td>
<td>0.08</td>
<td>0.08</td>
<td>35%</td>
</tr>
<tr>
<td>8</td>
<td>479</td>
<td>0.08</td>
<td>0.08</td>
<td>35%</td>
</tr>
</tbody>
</table>

### Hybrid Filter + DeSOx

<table>
<thead>
<tr>
<th>ESP</th>
<th>Field Inlet Dust (kg/hr)</th>
<th>Recovered Dust (mg/Nm³)</th>
<th>Recovered Dust (kg/hr)</th>
<th>Field / BF Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70.000</td>
<td>7.894</td>
<td>13.946</td>
<td>70%</td>
</tr>
<tr>
<td>2</td>
<td>21.000</td>
<td>3.934</td>
<td>3.934</td>
<td>70%</td>
</tr>
<tr>
<td>3</td>
<td>6.300</td>
<td>1.002</td>
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<tr>
<td>4</td>
<td>2.500</td>
<td>0.369</td>
<td>0.369</td>
<td>55%</td>
</tr>
</tbody>
</table>

- **Low Capex & Higher Opex as compared to Wet FGD technology.**
- **Best suited for units where space is a constraint.**
- **No need for wet stack**
- **SO3 can be controlled efficiently.**

(*) Ca(OH)₂ Injection (worst case)
Redecam Dry Scrubber (RDS) Technology
Redecam Dry Scrubber (RDS)

MAIN FEATURES

- Circulating fluidized bed principle
- Separate water spraying
- Low fineness hydrated lime
- Molar ratio Ca/S 1.3 to 1.5
RDS: Major Components

1. REACTOR
2. REAGENT INJECTION SYSTEM
3. WATER INJECTION SYSTEM
4. BAG FILTER
5. DUST RECIRCULATION SYSTEM
6. DUST EVACUATION SYSTEM
7. FLUE GAS DUCTING
8. COMPRESSED AIR SYSTEM
Case Study: 2x20 MW AFBC Boilers

- Suitable for higher SOx capture efficiency with respect to DID.
- Minimum modification in existing chimney as wet stack is not necessary.
- Best suited for units where wet FGD cant not be installed due to space constraint.
Particulate Matter Emission Control Technologies
ESP Performance Improvement by Flue Gas Conditioning
Flyash Resistivity vs. Sulfur in Coal

- Cold side ESPs are primarily affected by sulfur content of the coal being burned.
- Other constituents can also play a role in affecting ESP performance (i.e. flue gas temperature, moisture in ash, % ash in coal, and carbon in fly ash).
- Injection of SO3 in to flue gas reduces ash resistivity and thereby improves capture efficiency.
Dual Flue Gas Conditioning

A dual flue gas conditioning system simultaneously and independently injects two conditioning agents, $\text{SO}_3$ and $\text{NH}_3$, into the flue gas upstream of ESP.
Dual Flue Gas Conditioning

Why Add NH$_3$ to the Flue Gas?

The injection of NH$_3$ promotes improved utilization (uptake) of the SO$_3$, resulting in more effective resistivity control.

*DFGC will require least shut down time.*
ESP Performance Improvement by HFPS Implementation
PowerPlus™ vs. TR Sets

POWERPLUS

- Low Capex and Opex.
- Low installation time.

TR SETS
FGC+HFPS – Feasibility Studies Conducted on Indian Plants
Case Study of 5x660 MW

Numerical ESP Performance Model Projected Performance
1 T/R Out of Service Per Each Gas Pass (Chamber)

<table>
<thead>
<tr>
<th>Particulate Collections Efficiency, %</th>
<th>Emissions, mg/Nm³, dry</th>
<th>Combined Eff.</th>
<th>Outlet Emissions Limit: 50 mg/Nm³, dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Eff.</td>
<td>98.88</td>
<td>99.57</td>
<td></td>
</tr>
<tr>
<td>w/o SO3</td>
<td>98.88</td>
<td>99.57</td>
<td></td>
</tr>
<tr>
<td>w/SO3 FGC</td>
<td>295.84</td>
<td>113.58</td>
<td></td>
</tr>
<tr>
<td>w/Dual FGC</td>
<td>99.86</td>
<td>99.86</td>
<td></td>
</tr>
<tr>
<td>All Fields HFPS w/o FGC</td>
<td>99.25</td>
<td>99.25</td>
<td></td>
</tr>
<tr>
<td>mg/Nm³, dry</td>
<td>36.98</td>
<td>198.11</td>
<td></td>
</tr>
</tbody>
</table>
Case Study - 140 TPH CFB Boiler
Thanks!!!!

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