Coal Fired Boilers
Technologies for Improved Efficiency & Reduced Emissions

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Thermal Power - Market Requirements

- Low cost of generation
- Minimum emission of Pollutants
- Suitability for different quality of fuel
- Suitability for differing modes of operation and grid conditions
- High Reliability & Availability
- Increased use of IT
- Low life cycle cost
- Plant Life Extension & Capacity upgrades
- Higher size Units
- Shorter Delivery time

Power Plant Equipment Manufacturers to respond by employing the right technologies

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Thermal Power- Choice of fuel

- **Sustainable, economic power generation thru efficient use of locally available fuels, in an environmentally friendly fashion.**

- **India - Coal the desirable choice – abundantly available, low cost**

- **Coal Based Generation- Emissions/Pollutants to be minimised**
  - ✓ **Particulates**
  - ✓ **Carbon Dioxide**
  - ✓ **Oxides of Nitrogen**
  - ✓ **Sulfur dioxide**
Indian Coals
Challenges in Boiler Design

- Widely varying properties – makes equipment selection costly and sub-optimum
- High Ash with high Quartz; highly abrasive – Erosion/wear reduces boiler component life
- Low Sulphur content - high electrical resistivity of Ash
- Low Heating Value – more coal burnt for the same output
Indian Coals – Properties

- Ash: 25 - 50%
- SiO2+ Al2O3 in Ash: 80 - 92%
- Moisture: 8 - 20%
- Volatile Matter: 18 - 30%
- Sulphur: 0.2 – 1.0%
- Heating Value (HHV): 2500 - 5000 Kcal/Kg
## Indian coal Vs Average International Coals

### Coal/Ash Quantity For 500 MW Unit

<table>
<thead>
<tr>
<th></th>
<th>INDIAN COAL</th>
<th>INT. COAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat Duty</strong></td>
<td>MKcal/h</td>
<td>1080</td>
</tr>
<tr>
<td><strong>Fuel Fired</strong></td>
<td>MKcal/h</td>
<td>1250</td>
</tr>
<tr>
<td><strong>HHV</strong></td>
<td>Kcal/Kg</td>
<td>3800</td>
</tr>
<tr>
<td><strong>Quantity of Coal</strong></td>
<td>t/h</td>
<td>329</td>
</tr>
<tr>
<td><strong>Average Ash Content</strong></td>
<td>%</td>
<td>40</td>
</tr>
<tr>
<td><strong>Quantity of Ash</strong></td>
<td>t/h</td>
<td>132</td>
</tr>
</tbody>
</table>

The 8 fold increase in the ash passing thru an Indian coal fired boiler, warrants incorporation of special design features for high availability.
Coal Fired Boilers
Design for Eco-friendly Power Generation
Towards Eco-friendly use of coal

- **Burn less fuel**
  - Improve Plant efficiency
- **Minimise generation of pollutants**
  - Choice of appropriate combustion system, fuels
  - Choice of boiler technologies like Fluidised Bed combustion
- **Capture pollutants before leaving the boiler**
  - Dust Collectors, De-sulfurisation plants, De-Nox plants.
Plant Efficiency Improvement

Efficiency Development of power plants in Europe

Year


Efficiency, %

30 35 40 45 50 55

BHEL CC+ Units

175 bar / 540 °C / 540 °C

240 - 280 bar evaporator pressure

280 bar / 620 °C

 Efficiency Improvement of Steam power plants

Turbine Efficiency
Condenser Pressure
Process Optimisation (FWT, feed heater arrangement)
Steam Parameters
Feed Water Temperature
Measures on Steam generator

Basis 38 %

7.2 %

2.0

1.5

0.4

2.0

0.7

0.6

Source: VGB Power Tech 11/2003

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Plant Efficiency Improvement

Boiler Side Measures

- Designing for Supercritical Steam Parameters

- Designing for minimum:
  - RH spray
  - SH spray (if tapped off before feed heaters)
  - Flue gas temperature at AH outlet
  - Excess air at AH outlet
  - Unburnt Carbon loss
  - Fuel oil support for coal flame stabilisation
  - Auxiliary power consumption
Heat Rate Improvement
Steam Parameters Vs Cycle Efficiency

Cycle efficiency with:
175 bar and 538/538 °C = 38.0 % (BASE)
241 bar and 538/566 °C = 38.0 x 1.0264 = 39%

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Steam Power plant efficiency increases with increase in steam pressure and temperature.

Power plant  Cycles operating above critical pressure (221.2 bar) are classified as Supercritical cycles

With higher cycle efficiency, the supercritical cycle offers the advantage of ‘burn less fuel for the same output’ and lower emission.

Lesser Pollutants - SOX, NOX & CO2
### Plant Efficiency Improvement

#### Steam Parameters - Global Trends

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Pressure (bar)</th>
<th>Temp  ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>1991</td>
<td>250</td>
<td>540 / 540</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td>290</td>
<td>580 / 580 / 580</td>
</tr>
<tr>
<td>Germany</td>
<td>1995</td>
<td>285</td>
<td>545 / 560</td>
</tr>
<tr>
<td></td>
<td>1999</td>
<td>270</td>
<td>580 / 600</td>
</tr>
<tr>
<td>Japan</td>
<td>1991</td>
<td>246</td>
<td>538 / 566</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>246</td>
<td>566 / 593</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>246</td>
<td>593 / 593</td>
</tr>
</tbody>
</table>

- 255 bar 568/596 Deg C commonly used presently
- Ultra super critical units (parameters up to 375 bar & 700 ºC) with plant efficiency approaching combined cycle plants (50%+) are in development stage with parallel development in Materials
## Steam Generators – Design Parameters

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>UNIT</th>
<th>500 MW</th>
<th>800 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam Pressure</td>
<td>ata</td>
<td>170</td>
<td>247</td>
</tr>
<tr>
<td>Main Steam Temp</td>
<td>°C</td>
<td>537</td>
<td>565</td>
</tr>
<tr>
<td>Main Steam Flow</td>
<td>t/h</td>
<td>1515</td>
<td>2400</td>
</tr>
<tr>
<td>Reheat Pressure</td>
<td>ata</td>
<td>40.5</td>
<td>54</td>
</tr>
<tr>
<td>Reheat Temperature</td>
<td>°C</td>
<td>537</td>
<td>593</td>
</tr>
<tr>
<td>Reheat Flow</td>
<td>t/h</td>
<td>1335</td>
<td>1990</td>
</tr>
<tr>
<td>Cold Reheat Pressure</td>
<td>ata</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Cold Reheat Temp</td>
<td>°C</td>
<td>336</td>
<td>343</td>
</tr>
<tr>
<td>FinalL FW Temp</td>
<td>°C</td>
<td>253</td>
<td>290</td>
</tr>
<tr>
<td>BMCR</td>
<td>t/h</td>
<td>1625</td>
<td>2575</td>
</tr>
</tbody>
</table>
### Supercritical Units

#### Environmental Benefits

<table>
<thead>
<tr>
<th>Station Cap (No.x MW)</th>
<th>Units</th>
<th>MS Pressure (kg/cm²)</th>
<th>MS/RH Temp 0°C</th>
<th>Efficiency (%)</th>
<th>Coal Consumption (MMT/Yr)*</th>
<th>CO₂ Emissions (MMT/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000 8x500</td>
<td>169</td>
<td>538/538</td>
<td>38.6</td>
<td>15.61</td>
<td>22.90</td>
<td></td>
</tr>
<tr>
<td>4000 5x800</td>
<td>246</td>
<td>566/593</td>
<td>40.24</td>
<td>14.98</td>
<td>21.97</td>
<td></td>
</tr>
</tbody>
</table>

**Savings in coal consumed:** 0.63 MMT/Yr (about 4% Saving)

**Savings in CO₂ emissions:** 0.93 MMT/Yr

Source: CEA
Boiler Design for Supercritical Steam Parameters

Subcritical – Drum Type boiler

Supercritical – Once thru Boiler
Supercritical Boilers

- Once thru Boiler technology facilitates adoption of Supercritical parameters
- Higher pressure & temperature stress the boiler components at a high level
- New materials in use/trial operation to withstand the demanding service conditions
  - T 91/P91
  - T 92/P92
  - T 23/T24
  - TP347HFG
  - Esshete 1250

Well established, mature technology
Availability on par with subcritical boilers
Plant Efficiency Improvement - Boiler Side Measures

Flue Gas Temperature at Boiler outlet

GAS TEMP. LEAVING AH Deg.C

EFFICIENCY %

1980s 2000
Plant Efficiency Improvement

Boiler Side Measures

- Optimum design of furnace, Reheater & Superheater – minimises the spray for maintaining rated SH&RH steam temperature

- Optimum design of combustion chamber, pulverising system, firing equipment - minimises the need for high excess air at boiler outlet & reduces the unburnt carbon in fuel.

- Coal specific design of firing equipment – reduces the quantum of fuel oil support for coal flame stabilisation
Plant Efficiency Improvement - Boiler Side Measures

Auxiliary Power Consumption Reduction

- Use of High efficiency Boiler Auxiliaries
  - Axial Reaction fans
  - Bowl Mills
  - ESP with Intelligent operating systems
  - Use of High Efficiency Drives like VFD
- Reduction in the duty of the auxiliaries by system design optimisation
Towards Eco-friendly use of coal......

NOx generation reduced by:

- Use of Fluidised bed combustion Technology
- Use of Low NOx Burners/ firing systems
- Use of techniques like air staging/fuel staging/re-burning
- Separate Over Fire Air (SOFA) system

Capturing the NOx in DeNOX plants located at tail end of the boiler
Fluidised Bed Combustion Boilers

Technologies in vogue:

- Bubbling Fluidised Bed Combustion (BFBC)
- Circulating Fluidised Bed Combustion (CFBC)

✓ Ideally suited for Low Grade fuels, Lignite, Pet coke ...
✓ Does not need coal pulverisation system
✓ Keeps SOx & NOx emissions low
Integrated Gasification Combined Cycle (IGCC)

The emerging technology to utilise coal with the maximum efficiency

6.2 MWe capacity coal based combined cycle demonstration facility at BHEL, Trichy

BHEL is now setting up a 125 MW plant jointly with a customer
Integrated Gasification Combined Cycle (IGCC)

- Coal
- Air
- Gasifier
- SynGas
- Combustor
- HRSG
- Air
FETF, a fire side boiler simulator for study of complex inter-related effect of fuel characteristics. Rated for heat input of 756,000 kcal/h (880 KW).
Fuel evaluation test facility
Solid Fuel Burning Test Facility

SFBTF of 10 Mkcal/h capacity is used for coal burner/nozzle development, evaluation of flame stability, combustion efficiency & turndown.
Existing Power Plants
Performance Improvement
Focus area for improvement in existing plants:

- Availability
- Reliability
- Output
- Efficiency
- Environment
Availability & Reliability improved by

- Adoption of appropriate Operation & maintenance practices – special focus on tube failure prevention, maintaining proper combustion regime

- Use of early warning systems:
  - Tube leak detection system, Operator alarms
  - Sophisticated Controls & Instrumentation
  - Vibration monitoring systems for high speed equipment
  - Equipment trip provisions

- Operator Training
- Renovation of Boilers
- Use of well proven equipment & design practices, Redundancy for Critical equipment

Results in lesser number of plant outages, start ups
Minimises fuel oil consumption
Boiler Operating Modes for Improved Efficiency

- Base Load
- Cycling
- Two-shift
- Sliding pressure
- Trip to house load

Designing to operate in different modes:
- Improves part-load efficiency
- Less number of plant start-ups
- Quicker plant start-ups
- Minimises fuel oil consumption
IT for Power Plant Applications

Increasingly used for:

- Performance Optimisation
- Residual Life Assessment
- Emission analysis
- Operator Training
- Expert systems & Root cause analysis
- Maintenance
IT for Boiler Performance Improvement

Introduction of smart systems:

- **Performance Analysis, Diagnostics, Optimisation (PADO)**
  - System - provides operator guidance for optimised performance

- **Smart wall blowing system** – improves heat rate, minimises steam erosion

- **Emission analysis**

- **Expert systems & Root cause analysis**
Performance Improvement
Optimised Operation

- **Improved Plant Efficiency by maintaining:**
  - Minimum spray in Superheater/Reheater - use temperature control mechanisms
  - Rated steam parameters
  - Optimised combustion regime
  - Rated pulverised coal fineness
  - Minimum/zero oil support for coal flame stabilisation

- **Minimum Auxiliary Power consumption:**
  - Optimum number of mills in service
  - Prevent air ingress into boiler

- **Minimise Down time:**
  - Boiler maintenance techniques – plan for shortest time
  - Reduce plant start up time

- **Minimise Emissions:**
  - Maintain appropriate combustion air regimes
  - Flue gas conditioning for reduced emissions
Renovation & Modernisation of boilers

- Regain of lost capacity / Capacity augmentation
- Reduced forced outages
- Lesser maintenance requirement and time
- Enhanced operational Efficiency
- Improved Boiler Availability & reliability
- Performance improvements
- State-of-the-art upgrades
- Reduced support fuel requirement
- Enhanced life for Wear prone components
- Reduced emissions
Future Outlook

- Coal & Lignite will continue to be main fuels for Power Plants for some more decades

- Economics will decide the optimum power plant cycle parameters to be adopted.

- Increasing focus on minimising Emissions, improving efficiencies, fuel flexibility, enhanced Availability & Reliability

- Pulverized coal firing will continue to be the mainstay, till other technologies mature into commercially viable options

- Boiler technology will continue the advance towards increased efficiencies.
Thanks

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Tiruchirappalli

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