CO-GENERATION POWER PLANTS IN CHEMICAL INDUSTRY

Event:

Presented By
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Cogeneration System
What is Cogeneration?

- **Cogeneration** is the simultaneous production of Heat & Power from the same fuel source.

- **Cogeneration** plants are also called as **CHP** Plants (Combined Heat & Power).
Why need cogeneration?

• There are number of reasons why cogeneration is needed in a process industry and is summarized under the following three categories.

- Economic Benefit
- Environmental Benefit
- Energy Security
Energy Utilization in a Conventional Process Plant

Fuel – 1 (Coal)

Electrical Energy
Power from Coal Based Thermal Power Station

Thermal Energy
Steam from the Coal based Process Boiler

Process Plant Which required Both electrical & Thermal Energy

Steam Generation
83% is output as Steam

Power Generation
35% is output as Power

Fuel – 2

- 48% Condenser Losses
- 15% Boiler Assoc. Losses
- 2% Other
- 15% Boiler Assoc. Losses
- 2% Other
Limitations in the Conventional System

- Dependence on the State Electricity Grid
- High Power Cost
- High Demand Charges and Peak Hour Charges
- Quality of Power available from the grid
- Low efficiency of the process boilers
- High Steam Cost

Need for cogeneration system
Co-generation Plant
Energy Utilization - Cogeneration system

Co-generation Power Plant, Which supplies the required Power & Steam

Fuel - Coal

Process Plant

84% is Output as Power and Process Heat

15% Boiler Assoc. Losses

1% Other
Conventional Plant Vs Cogeneration Plant

**Power from State electricity Grid**

**Steam from the Process Boiler**

**Fuel – 1 (≈6.0TPH)**

**Fuel – 2 (≈10TPH)**

**Process Plant**

10MW Power & 52TPH Steam @ 6ata, 170°C

**Co-generation System**

(10MW of Power & 52TPH of Steam)

Boiler steam generation 66TPH, 110ata & 540°C

TG – Back pressure with 7ata exhaust pressure

**Conventional System**

Steam Cost – 800Rs/Ton
Power Cost – 6.0Rs/Unit + MD charges + Tax

Assumption
Coal Cost is Rs 4000/Ton

**Cogeneration System**

Steam Cost – 600Rs/Ton
Power Cost – 2.5Rs/Unit

Assumption
Coal Cost is Rs 4000/Ton
Efficiency of Generating Units

- Coal Based Thermal Power Plants - 32-40%
- Gas Turbine Based Power Plants - 25-30%
- Combined Cycle Power plants - 55-60%
- Co-generation Power Plants - 60-92%
Benefits of Cogeneration?

Facilities that are more likely to benefit from cogeneration are those that use large quantities of Thermal Load and Electricity simultaneously.

- Reduced Energy Cost (Both Electrical & Thermal)
- Improved Plant Efficiency / Heat Rate
- Reduced CO₂, SOₓ and NOₓ emissions
- Reduced Transmission & Distribution Losses
- Increased Energy Security
Potential Sectors for cogeneration

- Sugar Plants
- Distillery Units
- Textile Units
- Chemical Industries
- Pharmaceutical Units
- Paper Industries
- Refineries
- Tyre Industries
- Food Industries
- Wood Processing Industries
- Fertilizer Units, etc.
Types of Cogeneration System
Types of Cogeneration

• Steam Turbine Based Cogeneration system
  - With Back Pressure Turbine
  - With Extraction cum Condensing Turbine

• Gas Turbine based cogeneration system

• Engine based cogeneration system
Steam Based Cogeneration System

The selection of the steam based cogeneration scheme depends on the Electrical energy and the Thermal Energy required in any industry.
Gas Turbine & Engine Based Cogeneration System

Gas Turbine Based Cogeneration System

Engine Based Co-generation System
Cogeneration - Topping & Bottoming Cycle

- **Topping Cycle**
  - Fuel
  - Prime mover burns fuel
  - Generator
  - Electricity
  - Unusable waste heat
  - Waste heat
  - Heat exchanger
  - Thermal technology for heating/cooling applications
  - Controls and operating strategy

- **Bottoming Cycle**
  - Emergency stack cap
  - Project battery limits
  - Quench tower and dust chamber
  - Boiler bypass
  - Alternator
  - Economiser
  - Condensate precipitator
  - Future SO₂ scrubber
  - After burner chamber
  - Dust settling chamber
  - Boiler
  - Dust recycle conveyor
  - Aux. burner
  - Dust collection
  - Existing dust recycle conveyor
  - 110 m stack

AVANT-GARDE
Potential Sectors – Bottoming Cycle

- Cement Plants
- Sponge Iron Plants
- Coke Oven plants
- Glass Manufacturing Plants
- Carbon Black Plants
- Iron Melting Industries
- Sulfuric acid plants
- Refineries
- Other Steel Plants, etc...
Tri-generation System

- **Fuel (natural gas/biogas)**
  - COGEN UNIT
  - Waste heat
  - HEAT EXCHANGE
  - Hot water/steam

- **Electric Chiller**
  - Electricity
  - Chilled water
### HEAT TO POWER RATIO AND OTHER PARAMETERS OF COGENERATION SYSTEMS

<table>
<thead>
<tr>
<th>Cogeneration System</th>
<th>Heat-to-power ratio (kWₜₕ/kWₑ)</th>
<th>Power output (as percent of fuel input)</th>
<th>Overall efficiency per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back-pressure steam turbine</td>
<td>4.0-14.3</td>
<td>14-28</td>
<td>84-92</td>
</tr>
<tr>
<td>Extraction-condensing steam turbine</td>
<td>2.0-10.0</td>
<td>22-40</td>
<td>60-80</td>
</tr>
<tr>
<td>Gas turbine</td>
<td>1.3-2.0</td>
<td>24-35</td>
<td>70-85</td>
</tr>
<tr>
<td>Combined cycle</td>
<td>1.0-1.7</td>
<td>34-40</td>
<td>69-83</td>
</tr>
<tr>
<td>Reciprocating engine</td>
<td>1.1-2.5</td>
<td>33-53</td>
<td>75-85</td>
</tr>
</tbody>
</table>

Source: Taken from internet
Efficiency Improvement in Steam Based Cogeneration System
Co-generation Plant - Efficiency Improvement at concept stage

• Higher steam cycle pressure and temperature

• Lower condenser pressure

• Higher feed water inlet temperature to Boiler

• Addition of Feed Water Heaters (HP & LP heaters)
History of Power Cycle Parameter – Towards efficiency Improvement

• There is a gradual increase in the power cycle parameters across the globe

• Today there are many small capacity power plants operating at 110ata.

• We are presently marching towards 125ata & 145ata Plants.

• Recently we have commissioned one small capacity (70MW) Re-heat based Power plant in a Chemical Industry
Condenser Parameter – Towards Efficiency Improvement

- The turbine exhaust parameter depends on the ambient conditions and water availability.
- Normal Operating range 0.22ata to 0.09ata
  - ACC (0.22 to 0.16ata), which depends on the ambient temperature.
  - WCC (0.12 to 0.09ata), which depends on the wet bulb temperature.
- Every 0.01ata reduction in vacuum will improve the power output by 0.2% corresponding to the steam flow quantity to condenser.

- 0.22ata
  - 1.0TPH of steam when expanded from 105ata & 535°C to
    - 280kW
- 0.18ata
  - 285kW
- 0.14ata
  - 292kW
- 0.10ata
  - 301kW
## Increase in Plant Efficiency with Feed Water Heaters

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Description</th>
<th>Unit</th>
<th>Deaerator</th>
<th>LP Heater + Deaerator</th>
<th>LP &amp; HP Heater + Deaerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Feed water inlet temperature</td>
<td>ºC</td>
<td>130</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>2.0</td>
<td>Fuel Input to boiler (Rice Husk)</td>
<td>Kg/h</td>
<td>10940</td>
<td>10719</td>
<td>10530</td>
</tr>
<tr>
<td>3.0</td>
<td>Circulating water quantity</td>
<td>m³/h</td>
<td>2419</td>
<td>2367</td>
<td>2289</td>
</tr>
<tr>
<td>4.0</td>
<td>Plant Heat Rate</td>
<td>kcal/kWh</td>
<td>3446</td>
<td>3376</td>
<td>3317</td>
</tr>
<tr>
<td>5.0</td>
<td>Plant Efficiency</td>
<td>%</td>
<td>24.9</td>
<td>25.5</td>
<td>26.0</td>
</tr>
<tr>
<td>6.0</td>
<td>Fuel Saving</td>
<td>Tons/year</td>
<td>Base</td>
<td>1759</td>
<td>3247</td>
</tr>
<tr>
<td>7.0</td>
<td>Savings (Rs 2500/ton)</td>
<td>Rs in Lakhs</td>
<td>-</td>
<td>44</td>
<td>81</td>
</tr>
</tbody>
</table>

Source: The above working is for a typical 10MW Independent Power Plant with Rice Husk as the fuel. The Power Cycle pressure and temperature considered is 67ata & 485°C
Consultant’s Role in the Co-generation Plants
To Provide tailor-made cogeneration solutions...

The selection and the operating scheme of the cogeneration system are site / Industry specific and depends on the following factors:

- Thermal Load Matching
- Base Thermal Load Matching
- Electrical Load Matching
- Base Electrical Load Matching
- Thermal & Electrical load Matching
- Quality of Thermal Energy Needed
- Electrical Load Pattern
To Provide tailor-made cogeneration solutions...

- Fuels Available / Supply at site
- Independent / Grid Dependent system
- Utilizing Existing Equipments
- Environmental Regulations
- Efficiency & Technology Maturity
- Initial Investments and other financial aspects
For proper selection of Power Cycle Parameter ....

- Capacity of Power Plant
- Type of Power Plant
- Value of the Fuel Used
- Operation with the existing Facility
- Initial Investment
- Limitation in the technology
- Characteristics of Fuels and Ash
# Fuel & Ash Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Fixed Carbon</th>
<th>Volatile Matter</th>
<th>H2O</th>
<th>S2</th>
<th>Ash</th>
<th>GCV (kcal/kg)</th>
<th>FC/VM ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagasse</td>
<td>10.0</td>
<td>38.5</td>
<td>50.0</td>
<td>0.0</td>
<td>1.5</td>
<td>2272</td>
<td>0.26</td>
</tr>
<tr>
<td>Imported Coal</td>
<td>43.7</td>
<td>45.0</td>
<td>07.0</td>
<td>0.3</td>
<td>4.0</td>
<td>5200</td>
<td>0.97</td>
</tr>
<tr>
<td>Slop</td>
<td>8.0</td>
<td>32.5</td>
<td>40.0</td>
<td>1.5</td>
<td>18.0</td>
<td>1729</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Indian Coal</th>
<th>Bagasse</th>
<th>Slope</th>
<th>MSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>55-65</td>
<td>40-55</td>
<td>8-10</td>
<td>45-60</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>03-06</td>
<td>03-08</td>
<td>01-03</td>
<td>03-12</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>08-20</td>
<td>05-10</td>
<td>00-05</td>
<td>06-12</td>
</tr>
<tr>
<td>CaO</td>
<td>01-03</td>
<td>05-08</td>
<td>10-15</td>
<td>07-16</td>
</tr>
<tr>
<td>MgO</td>
<td>01-02</td>
<td>01-04</td>
<td>Traces</td>
<td>01-02</td>
</tr>
<tr>
<td>Na₂O</td>
<td>00-01</td>
<td>00-02</td>
<td>00-01</td>
<td>02-15</td>
</tr>
<tr>
<td>K₂O</td>
<td>00-01</td>
<td>00-08</td>
<td>25-40</td>
<td>05-20</td>
</tr>
<tr>
<td>SO₃</td>
<td>00-03</td>
<td>Traces</td>
<td>1.5 - 3</td>
<td>00-05</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>00-02</td>
<td>01-04</td>
<td>5 - 10</td>
<td>10 -25</td>
</tr>
<tr>
<td>Cl</td>
<td>00-0.1</td>
<td>Nil</td>
<td>&gt;0.1</td>
<td>00-02</td>
</tr>
<tr>
<td>IDT</td>
<td>1400</td>
<td>1100</td>
<td>700 - 800</td>
<td>700 - 800</td>
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</table>
For proper selection of Major Equipments ....

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Fuels</td>
<td>• Power / Steam requirement.</td>
<td>• Water Pollution Aspects</td>
</tr>
<tr>
<td>• Boiler Capacity</td>
<td>• Process Steam Variation</td>
<td>• Water Availability</td>
</tr>
<tr>
<td>• Efficiency</td>
<td>• Eff. Improvement (Heaters)</td>
<td>• Cost of water &amp; chemicals</td>
</tr>
<tr>
<td>• Emissions</td>
<td>• Investment</td>
<td>• Ambient Conditions</td>
</tr>
<tr>
<td>• Load Fluctuations</td>
<td>• Proven Experience</td>
<td>• Guide Line of water consumption</td>
</tr>
<tr>
<td>• Investment</td>
<td>• Load Fluctuations</td>
<td></td>
</tr>
<tr>
<td>• Proven Experience</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Proper Selection of the main plant equipments and the design of the Boiler & auxiliaries, have a direct bearing on the co-generation plant performance
Co-generation Plant Layout Preparation

- Safety Aspects.
- Operation & Maintenance aspects.
- Equipment Erection Point of View.
- Optimum Routing of piping, Cables and conveyors.
- Location of Cooling Tower, Air cooled condenser, etc
- Site Topography
- Switch Yard Location
- Fuel Storage Yard Location
- Future Expansion
# Latest Pollution Norms

## NEW REGULATIONS ON EMISSION

<table>
<thead>
<tr>
<th>Date of Installation</th>
<th>PM</th>
<th>SO₂</th>
<th>NOₓ</th>
<th>Mercury (Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 31-12-2003</td>
<td>100 mg/Nm³</td>
<td>600 mg/Nm³ for &lt;500MW</td>
<td>600 mg/Nm³</td>
<td>0.03 mg/Nm³ for &gt;=500MW</td>
</tr>
<tr>
<td>After 01-01-2003 &amp; Upto 31-12-2016</td>
<td>50 mg/Nm³</td>
<td>600 mg/Nm³ for &lt;500MW</td>
<td>300 mg/Nm³</td>
<td>0.03 mg/Nm³</td>
</tr>
<tr>
<td>On or after 01-01-2017</td>
<td>30 mg/Nm³</td>
<td>100 mg/Nm³</td>
<td>100 mg/Nm³</td>
<td>0.03 mg/Nm³</td>
</tr>
</tbody>
</table>
The values are calculated for a 100TPH, 110ATA & 540°C imported coal fired boiler with 0.7% sulfur in fuel. Fuel GCV is 5950kcal/kg. The fuel consumption is 11.5TPH. The purity of lime stone considered is 70%.
Few Cogeneration Plant Scheme / HMBD’s prepared and executed by AVANT-GARDE
HMBD – 70MW with 145bar(a) cogeneration plant

Note: The values indicated are tentative and may undergo minor variation. Exact values will be confirmed after finalizing the TG vendor.
HMBD – 50MW with 125ata cogeneration plant
HMBD – 45MW with 110ata cogeneration plant
HMBD – 10MW with 110ata back pressure cogeneration plant
HMBD – 35MW with 110ata Injection Turbine
HMBD – 23MW with 110ata cogeneration plant
HMBD – 3.7MW with 87ata cogeneration plant
HMBD – 12.5MW with 87ata cogeneration plant
HMBD – 3.7MW with 67ata cogeneration plant
HMBD – Gas turbine based cogeneration plant
HMBD – 1.9MW with 47ata cogeneration plant
HMBD – 1.8MW with 45ata back pressure cogeneration plant
HMBD – Bottoming cycle in cement plant (16ata & 14.2MW)
HMBD – Bottoming cycle in carbon black industry
HMBD – Bottoming Kalina cycle in Cement Plant
HMBD – Conventional power plant with waste heat utilization from cement plant
HMBD – Organic Rankine Cycle with waste heat utilization from cement plant
Best Practices to be Followed in the existing cogeneration system
Best Practices ..... 

- Energy Audit to be carried out once in a year and necessary corrective actions to be carried out based on the report.

- Plant critical operating parameter of the plant, to be closely monitored. Any deviation in the parameters to be discussed with plant in-charge and corrective action if any, need to be taken.

- Walk down inspection of the boiler, TG, and other equipments, shall be carried out by all the shift in-charge and observations if any, to be recorded in a separate register.

- Fuel proximate analysis, LOI in the ash have to be analyzed in the in-house lab and record to be maintained. Fuel consumption also requires close monitoring.

- Cleaning of heat transfer tubes to be carried out during the off season shut down time of the boiler. More focus to be carried out in the air-heater assembly. It is recommended to engage a third party to study the boiler during the off season shut down and take corrective actions for the trouble free operation.

- Water audit to be carried out along with the energy audits.
Thank You