GPU Process

Downstream oxy-boiler and FGD the flue gas is treated to reach the necessary CO2 purity

Process steps:
- Direct Contact Cooling reduces H2O to <5%
- Multi Stage Flue Gas Compression to >28 bar
- Purification and Drying
- Regeneration Gas System
- Chilling and CO2 Separation
- Off-gas System
- CO2 Recompression
GPU Concepts

• Autorefrigerated GPU for yields of 90% and above
  – Component solutions for
    • Saline Aquifer,
    • Enhanced Oil Recovery CO2 qualities

• Externally refrigerated GPU for yields of 80% and above
  – Component solutions for
    • Saline Aquifer,
    • Enhanced Oil Recovery CO2 qualities
Auto-rerefrigerated GPU for SA Quality

Without use of additional refrigerants
Produced CO2 provides the required duty for condensation

Yield >90%
CO2 in product >95%
O2 in product <1%

Flue gas compressor → Mercury adsorber → Dryer → Cooling by CO2 evaporation → CO2 flash separation → CO2 compressor → Pump → CO2 product → Vent gas
Auto-refrigerated GPU for EOR Quality

Without use of additional refrigerants
Produced CO2 provides the required duty for condensation
CO2 recycle provides the additional duty to operate the distillation

Yield >90%
CO2 in product >99%
O2 in product <0,01%
Externally Refrigerated GPU for SA Quality

External refrigerant system to optimize energy demand in hot climates

Flue gas compressor → Dryer → Refrigeration System → CO2 flash separation → CO2 product

Yield >80%
CO2 in product >95%
O2 in product <1%

Vent gas

Pump
Externally Refrigerated GPU for EOR Quality

External refrigerant system to optimize energy demand in hot climates
Distillation ensures CO₂ quality for EOR

Yield >80%
CO₂ in product >99%
O₂ in product <0.01%

CO₂ product

Flue gas compressor

Dryer

Cooling by refr. evaporation
CO₂ distillation

Refrigeration System

Pump

Vent gas
Energy Consumption

![Graph showing energy consumption vs. cooling medium supply temperature.]

Feed Conc./Scheme/Product

- 82% SA C/P
- 82% EOR C/P
- 82% Refr
- 82% Refr EOR

Cooling Medium Supply Temperature [°C]

Feed: Conc. Vol-%CO2 dry basis
Scheme: Saline Aquifer / Enhanced Oil Recovery / Refrigeration system
Product: handling by Compressor with Pump system or pumping only
Conclusions

• Autorefrigerated GPU for recovery rates of 90% and above
  – CO2 as refrigeration media
  – SA and EOR quality CO2
  – Not too high cooling water temperatures (SA < 25°C EOR < 28°C)
  – More sensitive to trace substances, e.g. Hg reaction with Aluminum

• Externally refrigerated GPU for yields of 80% and above
  – Separate refrigeration media
  – SA and EOR quality CO2
  – Less sensitive to cooling water temperature
  – No mercury removal required
  – Robust design using mainly simple materials like carbon steel
ALSTOM GPU Pilot
Compression and Purification Units

- Commissioned with synthetic flue gas at ALSTOM Technology Center, Växjö (Sweden)
ALSTOM GPU Pilot – Main Features

- Capacity equivalent to 300 kW\textsubscript{th}
- Synthetic flue gas capabilities
  - Aux systems: gas mixing station, humidifier, exhaust system
  - Ability to simulate various flue gas compositions including transients
- 4 stage reciprocating compressor (max 40bar), inter coolers and separators after each stage)
- 8 channel on-line gas analyser
- Pilot installed in two containers
- Third container for analyser
- Fourth container with synthetic gas mixing equipment
GPU Arrangement at ALSTOM Windsor (US) BSF Site

- Gas Mixing
- Purification Pilot
- Compression Pilot
- Operator Trailer
- Analyzer

Diagram showing the arrangement of various components at the ALSTOM Windsor (US) BSF Site.
GPU Pilot Test Boundaries

- Two different types of coals tested, low sulfur sub-bituminous and high sulfur bituminous

- Variation of the inlet concentration for key components

<table>
<thead>
<tr>
<th>Component</th>
<th>Low Limit</th>
<th>High Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>70 Vol%</td>
<td>86 Vol%</td>
</tr>
<tr>
<td>SO₅</td>
<td>60 ppm</td>
<td>145 ppm</td>
</tr>
<tr>
<td>NO₅</td>
<td>100 ppm</td>
<td>365 ppm</td>
</tr>
<tr>
<td>Mercury (upstream Adsorber)</td>
<td>&gt;9.9 µg / Nm³</td>
<td>25 ng/Nm³</td>
</tr>
</tbody>
</table>
Targeted recovery rate of >90% reached at CO2 inlet concentrations of 80%.

Design point regarding CO2 inlet concentration is 82%.

Commercial unit performance higher due to reduction of heat losses.
SO2 Removal in DCC

High performance SOx scrubbing ensures relaxed operating conditions in the compression section and reduced corrosion risks.
NO$_x$ Removal in GPU

Graph showing the relationship between Inlet NO$_x$, ppmv dry and Outlet NO$_x$, ppmv dry for CO2 product and Vent gas.
Hg Removal in Activated Carbon Bed

Hg at Carbon bed inlet
Hg at Carbon bed outlet

Inlet Hg (ng/Nm3)

Outlet Hg (ng/Nm3)

Test #
Conclusions

• Successfully demonstrated operation of GPU pilot with oxy coal combustion flue gases

• Main targets for CO2-capture and purity achieved
  – CO2 purity > 95%
  – CO2 capture > 90%

• SO2 is efficiently removed in the DCC

• NOx may need special attention depending on CO2 product specification

• Required Hg-removal achieved (< 10 ng/Nm3)