Lurgi FBDB Coal Gasification Co-Products: A High Value Economic Asset
Outline

- Air Liquide Global E&C Solutions Perspective
  - One Stop Shop

- Lurgi FBDB™ Coal Gasification Evolution
  - Towards the Lurgi FBDB™ Mk Plus™ Gasifier

- Lurgi FBDB™ Coal Gasification Island
  - Co-products recovery to ZLD (Zero Liquid Discharge)

- Summary
  - A One Stop Shop for fitting syngas
The Air Liquide Group: Key Facts

THE WORLD LEADER IN GASES FOR INDUSTRY, HEALTH AND THE ENVIRONMENT

Air Liquide at a Glance

- Present in 80 countries
- €15.3 billion of revenue
- 50,000 employees
- 4,000 employees in Engineering & Construction

Hydrogen
Carbon monoxide
Nitrogen
Oxygen
Argon & rare gases
Helium
Acetylene
... and more
Technologies to Offer – A One-Stop-Shop

Air Liquide – Lurgi offers not only the Gasification Block but “The Complete Gasification Island”

- FBDB™ Gasification
- Air Separation Unit
- Rectisol® Unit
- OxyClaus® Unit
- Methanation Unit

- Liquid Nitrogen Wash
- CO Cold Box
- Phenosolvan® Unit
- CLL™ Technology
- GTL.F1 Fischer-Tropsch Technology
Lurgi FBDB™ Coal-to-X Syngas <> A One-Stop-Shop

2 operation modes possible:
- Co-products recovered
- Co-products gasified
Evolution of the Lurgi FBDB™ Coal Gasifier

1st Generation from 1932
- Capacity: up to 10,000 Nm³/h
- Design Pressure: 20 barg
- Inner Diameter: 1600-2600 mm
- Height: 6000-8000 mm

Mark 0 (29 MW<sub>HHV</sub>)

2nd Generation from 1952
- Capacity: 13,000-20,000 Nm³/h
- Design Pressure: 20-30 barg
- Inner Diameter: 2600-3660 mm
- Height: 6800-8400 mm

Mark 1-3 (117-147 MW<sub>HHV</sub>)

3rd Generation from 1969
- Capacity: up to 65,000 Nm³/h
- Design Pressure: 30-34 barg
- Inner Diameter: 3848-3862 mm
- Height: 12,500 mm

Mark 4 (240 MW<sub>HHV</sub>)
Mark 5 (340+ MW<sub>HHV</sub>)

4th Generation from 2010
- Capacity: 120,000 Nm³/h
- Design Pressure: 60 barg
- Inner Diameter: 4700 mm
- Height: 15,716 mm

Mark Plus™ (450 MW<sub>HHV</sub>)
Countercurrent operation:
Coal moving down  Gas moving up

Temperature profiles and operating zones
The Lurgi FBDB™ Gasification Island >> Condensation Path

Gasification --->
Waste Heat Boiler

----->
Pre-Cooler

Gas Cooling
Waste Heat

----->
Air Cooler

Rectisol
Final Cooler

Pre-Wash / Extractor

Dusty Tar GL *)

Tarry GL

Oily GL

Oily GL

Naphtha

GL = Gas Liquor = Water + Condensates

Typical

°C

0 100 200 300

15.10.2013 Gasification Technologies Conference

Air Liquide, world leader in gases for industry, health and the environment
Lurgi FBDB™ in One Slide – Case Study

**Pressurized Fixed Bed**
- Screened coarse coal (5 to 50 mm) with minimum mechanical strength properties
- Counter current gives high thermal eff.
- Coal is pyrolyzed before being gasified
  - Co-products
  - Eff. drying for high moisture coal

**Low O2 consumption**

- Coal
  - 1260 t/h (ar)
  - 920 t/h (daf)
- HP Steam
  - 1000 t/h

**O2**
- 243 kNm3/hr
- 260 Nm3/tdaf

**Dry Bottom**
- Highest Temp. below ash fusion of the ash (no slag)
  - Efficient for high ash coal and/or high AFT coal (low O2 consumption)
  - High consumption of HP steam as moderator

**Syngas**
- High energy content syngas
- High carbon conversion (> 99%)
- High CH4 concentration (8% to 16%)
- Pre-shifted Gas; H2/CO between [1.5 – 2.7]
- Co-productions
  - Complex extractions from Gas Liquor
  - Remaining impurities to AGR
  - Substantial credits in the economics

**APLICATIONS**
- SNG
- Syngas for DRI
- NH3 with CH4 as co-product
- CTL

**Dry Syngas**
- 1800 kNm3/hr
- 1950 Nm3/tdaf
- H2/CO : 1.65
- CH4 : 14%
- 25700 MJ/tdaf

**Gas Liquor Separation**

**Gas Cooling**

**Gas Liquor**

**Phenols recovery**

**Lurgi CLL™ NH3 Recovery**

**Waste Water Treatment**

**Tar / Oil**
- 42 t/hr

**Phenols**
- 9 t/hr

**Liquid NH3**
- 11 t/hr

**Reuse**
- 990 m3/hr

**Cryogenics**

Air Liquide, world leader in gases for industry, health and the environment
FBDB Gasification Island >> Valuable Co-products

Chinese market conditions

<table>
<thead>
<tr>
<th>Co-Product</th>
<th>Market Price RMB/t</th>
<th>Case Study t/h</th>
<th>Case Study 10^3 RMB/h</th>
<th>Case Study USD/h</th>
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<tbody>
<tr>
<td>Clear Tar + Oil</td>
<td>3,800</td>
<td>42</td>
<td>159.6</td>
<td>26000</td>
</tr>
<tr>
<td>Rectisol Naphtha</td>
<td>3,800</td>
<td>11</td>
<td>41.8</td>
<td>6810</td>
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<tr>
<td>Liquid NH₃</td>
<td>2,300</td>
<td>11</td>
<td>25.3</td>
<td>4130</td>
</tr>
<tr>
<td>Crude Phenols</td>
<td>2,400</td>
<td>9</td>
<td>21.6</td>
<td>3520</td>
</tr>
</tbody>
</table>

40,500 USD/h

Together with the value of the recovered Sulphur, this accounts already to 25% of the feedstock and utilities cost!
From Gas Liquor to Zero Liquid Discharge

- Full chain of purification of the water

See: GTC 2012

Diagram:
- Coal → Lurgi FBDB™ Gasification → CO Shift & Gas Cooling → Raw syngas
- Steam
- Acid Gas (CO2, H2S, HCN)
- Gas Liquor
- Gas Liquor Separation
- Phenosolvan® Phenols Recovery
- Lurgi CLL™ NH3 Recovery
- Waste Water Treatment
- Zero Liquid Discharge
- Mud liquor
- Clear Tar / Oil
- Crude Phenols
- Liquid Ammonia
- CO2, H2S, solvent
Lurgi Phenosolvan® process

1. **Coal** → **FBDB™ Gasification** → **CO Shift & Gas Cooling** → **Raw syngas**
2. **Gas Liquor Separation** → **Gas Liquor**
3. **Phenosolvan Phenols Recovery** → **Dephenolized Gas Liquor**
4. **CLL / NH₃ Recovery** → **Stripped Gas Liquor**
5. **Waste Water Treatment** → **Effluent Water**

- **Clear Tar / Oil**
- **Crude Phenols**
- **Liquid Ammonia**
- **Mud liquor**
- **CO₂, H₂S, HCN**
- **Organics**

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**Gas Liquor tanks** → **Filtration** → **Extraction**

- **Mud liquor**
- **Solvent DIPE**
- **Extract**

- **Dephenolized Gas Liquor** (Raffinate to CLL)
- **Crude phenols** (Heavy organics)

- **< 50 ppm TSS**
- **Eta > 99%**
- **< 20 ppm m-phenols**
- **> 85% p-phenols rec.**
Lurgi Phenosolvan® unit with 1432 m³/h gas liquor throughput
Lurgi CLL™ Ammonia Recovery process

1. **Coal** → **FPDB™ Gasification** → **CO Shift & Gas Cooling** → **Raw syngas**
2. **HP Steam**
3. **Gas Liquor Separation** → **Gas Liquor**
   - **Mud liquor**
   - **Clear Tar / Oil**
4. **Phenosolvan Phenols Recovery**
   - **Crude Phenols**
5. **Dephenolized Gas Liquor**
6. **CLL / NH₃ Recovery**
   - **Liquid Ammonia**
   - **< 50 ppm free NH₃**
7. **NH₃ purification & liquefaction**
8. **CO₂ / H₂S absorption**
9. **Waste Water Treatment** → **Effluent Water**
10. **Acid gas and solvent stripping**
11. **Stripped Gas Liquor**
12. **NH₃ stripping**
Sasol Secunda – Lurgi Phenosolvan® / Lurgi CLL™

480 t Ammonia Recovery per day
Lurgi Waste Water Treatment – Zero Liquid Discharge

- **Bio – Treatment**
  - Particular care of high Chemical Oxygen Demand (COD) and high m-Phenols concentration

- **Complete re-use of waste water in the process → Zero Liquid Discharge**
  - Bio-treatment followed by reverse osmosis technology

- **Specification of water effluent to country standards**

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**Part of the LURGI FBDB™ Coal Gasification Island**

- **Stripped Gas Liquor**
  - COD 3200 mg/l

**Bio-treatment**
- Dual sludge system with recycle and proprietary carrier material
  - COD 320 mg/l
- Sludge excess

**Post-treatment**
- Special reverse osmosis crystallization unit
  - COD 80 mg/l
- Sludge excess
- Salts
  - ~99 % Recovery

**Cooling water Make-up**
Unique offer of Zero Liquid Discharge (ZLD)

- Based on very experienced technology providers in the field of Waste Water: Single point integrated solution

- Referenced plant working with very similar water quality and designed with the same process scheme

- Unique and advanced technologies for Waste Water treatment

- Competitive cost of final treatment of the SGL integrating a ZLD solution
  - < 9 RMB / m3 SGL (@ PRC)
  - Impact of approx. 2% on the final syngas price
Summary

A one-stop shop for fitting syngas
Summary

- Our tool-box of technologies gives operational reliability and safety
- Based on a long industrial operation experience. Significant Improvements achieved by the Lurgi FBDB™ Mark Plus™
- Improved Environmental Footprint
  - A New Waste Water Treatment Unit: Complete Process Water Re-Use → Zero Liquid Discharge
- Recovered Co-products are adding significantly to the plant economy
- A real One-Stop-Shop
  >> Proven technologies integrated into a single package
Thank you for your kind attention!

Questions?

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4,000 Air Liquide Global E&C Solutions Colleagues Thank You!

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- Cryogenic equipment centers