Rectisol® Wash Units
Acid Gas Removal for Polygeneration Concepts
downstream Gasification

Ulvi Kerestecioğlu, Thomas Haberle
GTC Conference, Washington DC, USA, November 3rd, 2010
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Agenda of the Presentation

1. General Information about the Rectisol® Process
   - Products downstream Acid Gas Removal Systems
   - The Rectisol® Process

2. Basic Schema of the Rectisol® Process
   - Block Flow Diagram and Simplified Process Flow Diagram
   - Achievable Product Quality of the Rectisol® Process

3. Polygeneration Concepts with the Rectisol® Process
   - Multi Products with one Acid Gas Removal System

4. CO2 Emissions & Clean Energy
   - CO2 Capture with the Rectisol® Process

5. Polygeneration & IGCC Projects in the USA
   - TCEP & HECA Project

6. Miscellaneous
Polygeneration Concepts using Linde’s Rectisol® Wash Process

General Information about the Rectisol® Process

RWU in Shanghai, China
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Acid Gas Removal is an Essential Process Step in the entire Gasification Unit.

**Raw Material**
- Coal
- PetCoke
- Asphalt
- Residual Oil
- Naphtha
- LPG
- Natural Gas

**By-Products**
- CO2 for EOR
- CO2 for UREA
- H2S Frac. for SRU

**Synas Conditioning**

**Downstream Process**
- IGCC Syngas
- NH3 Syngas.
- H2 Product
- CO Product
- Syngas for...
- Methanol / DME / SNG / FT / OXO
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Acid Gas Removal is an Essential Process Step in the entire Gasification Unit.

- CO₂ for UREA
- CO₂ for EOR
- Syngas for FT
- H₂S Frac.
- Syngas for SNG
- Syngas for DME
- Syngas for SNG
- Syngas for IGCC
- Syngas for OXO Gas
- Syngas for Methanol
- Syngas for CO Prod.
- Syngas for NH₃ Prod

Syngas Purification = Rectisol Wash Unit
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Rectisol® Offers lots of Benefits for Polygeneration Concepts Downstream Gasification Units.

Requirements for plant and products

- Highest product quality
- Simultaneous production of several products
- Flexible switches between different products and product flow rates
- Stable in operation
- Safe for operators and environment

The Rectisol® Process meets above requirements and offers lots of benefits for polygeneration concepts downstream Gasification Units.
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Rectisol® is a Well Proven Wash Process.

What is Rectisol®?

- The Rectisol® process is a physical wash process where acid gas compounds are solved in methanol and thus removed from the syngas.
- Rectisol® was developed jointly by Linde and Lurgi in the late 50th.
- Methanol is cheap, readily available and thermally and chemically stable.

![Methanol Molecule](image)
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Linde is Well Experienced in Rectisol® due to its Own Running Plants.

Experience with Rectisol®

- More than 60 Linde Rectisol® Units are engineered world wide by Linde
- Linde is owning and operating three plants (Singapore and the United States)
- Each Rectisol® Wash Unit is developed hand tailored for customers needs and requirements
- Linde is well experienced in handling of different feed gas compositions and production of different products.
- Improved trace component handling guarantees a safe and stable operation.

Methanol Molecule
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Linde has Rectisol® Wash Unit References all over the World.

62 references worldwide
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Linde has Rectisol® Wash Unit References Downstream of a lot of Different Gasification Types.

- Downstream GE (Texaco) Coal Gasification
  - max. capacity 997,000 Nm³/h
- Downstream Shell Coal Gasification
  - max. capacity 544,000 Nm³/h
- Downstream other Coal Gasific.
  - e.g. Koppers, HTW Lignite, ECUST, Chinese Fixed Bed, ConcoPhillips E-Gas, etc.
  - max. capacity 1,070,000 Nm³/h
- Downstream Heavy Fuel Oil, Residuals or Asphalt Gasification
  - max. capacity 448,000 Nm³/h
- Others
  - e.g. Natural Gas
  - max. capacity 235,000 Nm³/h
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Basic Schema of the Rectisol® Process

RWU in Yunnan, China
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Rectisol® is a Flexible Process to Achieve a Wide Range of Products and By-Products and Qualities.

Block Diagram of a Rectisol® Wash Unit with Nitrogen Stripping

Rectisol® is a Flexible Process to Achieve a Wide Range of Products and By-Products and Qualities.
Polygeneration Concepts using Linde’s Rectisol® Wash Process

The Wash Process consists of Four Major Sub-Units.

Absorption

H2S Enrichment

Regeneration

Miscellaneous

Feed Gas

MeOH Injection

CO2 Product

Syngas

Nitrogen

H2S Fraction

Wash Water

Tailgas

Waste Water

Steam

Cooling

Refr.
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Highest Product Qualities can be Guaranteed.

Typical Product Qualities

<table>
<thead>
<tr>
<th></th>
<th>Purified Gas</th>
<th>CO2-Product</th>
<th>H2S-Fraction</th>
<th>Tailgas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO2</strong></td>
<td>&lt; 5 vppm</td>
<td>≥ 98.5 mol%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>up to 5 mol%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H2S + COS</strong></td>
<td>&lt; 0.1 vppm</td>
<td>2 – 10 mg/Nm³</td>
<td>Suitable for SRU/Claus</td>
<td>5 - 25 vppm</td>
</tr>
<tr>
<td><strong>H2O</strong></td>
<td>&lt; 0.1 vppm</td>
<td>&lt; 1 vppm</td>
<td>&lt; 1 vppm</td>
<td>&lt; 1 vppm</td>
</tr>
<tr>
<td><strong>Methanol</strong></td>
<td>15 – 30 vppm</td>
<td>250 – 300 vppm</td>
<td>100 – 200 vppm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 vppm *)</td>
<td>20 vppm *)</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>Δp ~ 2 bar</td>
<td>1.7 – 3.3 bar(a)</td>
<td>1.5– 3.0 bar(a)</td>
<td>1.05 bar(a)</td>
</tr>
</tbody>
</table>

*) with Additional Water Wash Column
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Lowest and Stable Sulphur Contents in the Treated Syngas are Achieved.

Representative 3-months Plot of Outlet Sulfur Concentration (H2S)
(Inlet Sulphur Concentration ~ 8000 - 9000 ppmv)

Polygeneration Concepts using Linde’s Rectisol® Wash Process

Polygeneration Concepts with the Rectisol® Process

RWU in Ube City, Japan
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Linde’s Rectisol® Process can favourably be combined with several further purification steps.

Block Diagram of a Rectisol® Wash System for Polygeneration Concepts

*) One common regeneration system for both Rectisol Wash Units
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Linde’s Rectisol® Process can favourably be Combined with Downstream Units.
Polygeneration Concepts using Linde’s Rectisol® Wash Process
The Nanjing Plant in China – Successfully in Operation with Fluctuations in the Product Quantity.

Products
- Methanol Syngas
- CO Product downstream CO Cold Box

Operational Flexibility
- Switch between the product types
  CO Product ↔ Methanol Product
- Switch between the product flow rates
  * Part load operation only for unshift section (w/o CO Product)
  * Part load operation only for shifted section

Successful in operation since 2008.
Polygeneration Concepts using Linde’s Rectisol® Wash Process

CO2 Emission & Clean Energy

RWU in Berrenrath, Germany
Polygeneration Concepts using Linde’s Rectisol® Wash Process
CO2 Emission is Nowadays an Upcoming Issue.

CO2 Emission

➢ Today and in the near future CO2 emission is getting a more and more important issue.
➢ “Clean Energy” is an upcoming market.
➢ Nowadays the whole world is looking for reduced CO2 emission.

Carbon Capture means capture of mainly CO and CO2

The carbon capture rate can be increased:
➢ by a deeper shift (CO converted to CO2)
➢ by nearly 100% CO2 removal within the Rectisol® Process

⇒ Rectisol® Plants can be designed for nearly 100% CO2 capture, and therefore for a nearly CO2 emission free plant.
CO2 Product

- The CO2 can be recovered without Nitrogen stripping and is fulfilling pipeline and product specification
- The captured CO2 can be used for UREA and/or EOR
- The CO2 is free of water and nearly free of sulphur

The design of the required CO2 capture rate within the Rectisol® Wash Unit is driven by the overall required carbon capture rate.
Polygeneration Concepts using Linde’s Rectisol® Wash Process

IGCC/Polygeneration Concepts in the USA

RWU in Nanjing, China
Polygeneration Concepts using Linde’s Rectisol® Wash Process
The Texas Clean Energy Project (TCEP)

Key Figures for the TCEP:

Polygeneration Concept:
- Power, UREA, CO2 for EOR, Sulphuric Acid
- 400 MW IGCC Project, 1,350 MTD UREA (= 1,485 STPD)

FEED launched to Linde, Siemens, Fluor

Overall: 90% Carbon Capture ≈ 2.9 million t/year CO2 capture
- Nearly 100% sulphur removal
Polygeneration Concepts using Linde’s Rectisol® Wash Process
TCEP – Overall Process Integration.

Diagram:
- Raw Coal
- Gasification
- Sour Shift
- Rectisol
- Nitrogen Wash Unit
- Ammonia-Synthesis
- UREA-Synthesis
- Power
- Combined Cycle
- Air Separation Unit
- Oxygen
- Natural Gas
- Sulfuric Acid
- Tail Gas
- H₂ S-Fraction
- CO₂ - Compress.
- LP-CO₂
- MP-CO₂
- CO₂-EOR Compress.
- CO₂ for Enhanced Oil Recovery
- Facility Infrastructure
- Linde scope
- Linde scope

Polygeneration Concepts using Linde’s Rectisol® Wash Process
TCEP – The Plant Concept offers a lot of Special Features.

Special features realised for TCEP

Flexible product switch from max. Ammonia to max. Power
⇒ the Rectisol® Wash Unit is only marginal affected by the product switch
⇒ the Nitrogen Wash Unit is very flexible in plant load fluctuation
⇒ the SRU is not affected by the product switch

High ammonia production and high efficiency of the power plant
High H2 recovery rate for the Nitrogen Wash Unit (99.5% vs. ~ 90% for PSA)
⇒ more high pressure syngas available

High carbon capture rate within the Rectisol® Wash Unit
⇒ the CO2 capture rate within the Rectisol® Wash Unit is about 98.5%
   driven by the overall plant carbon capture rate of 90%.
Benefits realised for TCEP

No COS hydrolysis is required

No CO2 purification for CO2 to EOR is required

Very low sulphur content in CO2 is minimizing the cleaning effort on CO2 to UREA

No drying of CO2 streams is required (CO2 Products are free of water)
  ⇒ carbon steel material for CO2 compression is possible

Inert free NH3 loop
  ⇒ no NH3 purge gas treatment is required.
Polygeneration Concepts using Linde’s Rectisol® Wash Process
The Hydrogen Energy California Project (HECA) – Ground Plan

Courtesy of HECA
Polygeneration Concepts using Linde’s Rectisol® Wash Process
The Hydrogen Energy California Project (HECA)
- Key Figures

**Key Figures for HECA:**

- IGCC Concept:
  - Power, CO2 for EOR, Sulphur
- net 250 MW Power
- > 90% Carbon Capture
Polygeneration Concepts using Linde’s Rectisol® Wash Process
Benefits using Rectisol®:

- Sulphur specifications can be met without COS hydrolysis
  * Sulphur content in hydrogen is less than 1 vppm
  * Sulphur content in CO2 for EOR is less than 10 vppm
- Electrical equivalent is better than with PEGE
Polygeneration Concepts using Linde’s Rectisol® Wash Process

Summary

RWU in Nanjing, China
Polygeneration Concepts using Linde’s Rectisol® Wash Process
The Rectisol® Plant is Suitable to Produce a Wide Product Range.

<table>
<thead>
<tr>
<th>Product</th>
<th>H2/CO Ratio</th>
<th>Sulphur</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2 Product</td>
<td>maximum</td>
<td>0.1 vppm (if required)</td>
<td>vppm – mol%</td>
</tr>
<tr>
<td>NH3 Product</td>
<td>maximum</td>
<td>0.1 vppm</td>
<td>10 vppm</td>
</tr>
<tr>
<td>IGCC Plant with CC</td>
<td>maximum</td>
<td>5 vppm</td>
<td>0 to 2%</td>
</tr>
<tr>
<td>SNG Syngas</td>
<td>~ 3.0</td>
<td>0.1 vppm</td>
<td>0.5 mol%</td>
</tr>
<tr>
<td>MeOH Syngas</td>
<td>~ 2.05</td>
<td>0.1 vppm</td>
<td>0.5 mol%</td>
</tr>
<tr>
<td>FT Syngas</td>
<td>~ 2.0</td>
<td>0.1 vppm</td>
<td>0.5 mol%</td>
</tr>
<tr>
<td>Oxo Syngas</td>
<td>~ 1.0</td>
<td>0.1 vppm</td>
<td>100 vppm</td>
</tr>
<tr>
<td>CO Product</td>
<td>minimum</td>
<td>0.1 vppm</td>
<td>10 vppm</td>
</tr>
</tbody>
</table>
Polygeneration Concepts using Linde’s Rectisol® Wash Process


Rectisol Wash Unit

- Syngas for Methanol
- Syngas for FT
- Syngas for OXO Gas
- CO2 for UREA
- CO2 for EOR
- H2S Frac.
- SRU
- PSA
- Fuelgas for IGCC
- Syngas for SNG
- Syngas for DME
- Nitrogen Wash Unit
- Syngas for NH3 Prod
- Syngas for CO Prod.

CO2 for UREA

CO2 for EOR

CO2 for H2 Prod.
Thank you for your attention.

Ulvi Kerestecioğlu, Thomas Haberle