ThyssenKrupp Uhde’s commercially proven PRENFLO® and HTW™ Gasification Technologies
Halle (Saale), June 13, 2013
Claudio Marsico – Director Sales – Gas Technologies Division

2. ibi Fachsymposium

ThyssenKrupp Uhde
Presentation Outline

- ThyssenKrupp and Uhde
- Uhde’s experience and expertise in gasification
- PRENFLO (PSG / PDQ)
- High Temperature Winkler (HTW)
- Updates on Projects and Alliances
- Summary
ThyssenKrupp Group

Workforce: ~150,000

ThyssenKrupp AG

Steel Europe

Elevator Technology

Industrial Solutions

Components Technology

Material Services

TK Uhde

TK Polysius

TK Fördertechnik

Marine Systems
<table>
<thead>
<tr>
<th>From the idea to operation of a chemical plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Research phase</td>
</tr>
<tr>
<td>- Concept development and assessment</td>
</tr>
<tr>
<td>- Execution of R&amp;D projects</td>
</tr>
<tr>
<td>- Acquisition of technologies / companies</td>
</tr>
<tr>
<td>o Bid phase</td>
</tr>
<tr>
<td>- Project development / market study</td>
</tr>
<tr>
<td>- Feasibility study</td>
</tr>
<tr>
<td>- Project financing</td>
</tr>
<tr>
<td>o Project implementation phase</td>
</tr>
<tr>
<td>- Licence award or procurement</td>
</tr>
<tr>
<td>- Basic / detail engineering</td>
</tr>
<tr>
<td>- Procurement / inspection / shipping</td>
</tr>
<tr>
<td>- Project execution</td>
</tr>
<tr>
<td>- Construction</td>
</tr>
<tr>
<td>- Commissioning</td>
</tr>
<tr>
<td>o Operation and service phase</td>
</tr>
<tr>
<td>- Training of operating personnel</td>
</tr>
<tr>
<td>- Plant maintenance and operation</td>
</tr>
<tr>
<td>- Materials management and spare parts</td>
</tr>
<tr>
<td>- Plant optimisation and upgrading</td>
</tr>
</tbody>
</table>
Site-Seeing

More than **2,000** plants built by Uhde on all continents

<table>
<thead>
<tr>
<th>Category</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilisers</td>
<td>130</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>185</td>
</tr>
<tr>
<td>Refineries</td>
<td>380</td>
</tr>
<tr>
<td>Aromatics</td>
<td>75</td>
</tr>
<tr>
<td>Hydrogen, ammonia, methanol</td>
<td>120</td>
</tr>
<tr>
<td>Org. Chemicals/petrochemicals</td>
<td>375</td>
</tr>
<tr>
<td>Plastics, synthetic fibres</td>
<td>115</td>
</tr>
<tr>
<td>Polyester / polyamides</td>
<td>400</td>
</tr>
<tr>
<td>Electrolysis</td>
<td>150</td>
</tr>
<tr>
<td>Coke Plant Technologies</td>
<td>500</td>
</tr>
<tr>
<td>Tank storage facilities</td>
<td>105</td>
</tr>
<tr>
<td>Industrial plants</td>
<td>150</td>
</tr>
</tbody>
</table>
Overview of our Product divisions

- Ammonia & Urea
- Hydrogen & Nitrates
- Electrolysis
- Refining Technologies
- Gas Technologies
- Org. Chemicals/Polymers
- Polyester
- Coke Plant Technologies
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### Market drivers for gasification of solids

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Technology</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>fossil fuel prices</td>
<td>proven technology</td>
<td>polygeneration</td>
</tr>
<tr>
<td>fossil fuel availability</td>
<td>clean technology</td>
<td>CCS</td>
</tr>
<tr>
<td>fossil fuel flexibility</td>
<td>ideal for low rank fuel</td>
<td>sellable by-products</td>
</tr>
</tbody>
</table>
Synthesis Gas as a Central Part of Uhde’s Process Chain

Gasification: Feedstock - Process - Product

**Feedstock**
- Gas, Naphtha
- Oil/Residues
- Petroleum Coke
- Hard Coal
- Biomass

**Gasification**
- Steam Reformer/ATR
- Oil Gasification
- PRENFLO Gasification
- HTW Gasification

**Syngas**
- CO + H2

**Further processing**
- Methanol
- Ammonia
- Fischer Tropsch Synthesis
- CO-Conversion
- Methanation
- Power Plant (IGCC)
- Synthetic Natural Gas
- Hydrogen
- Electricity

**Product**
- MTO
- MTG
- Urea
- Fertilizer
- Diesel
- Petrol + LPG
- Diesel, Naphtha
- Lubricants
- Synthetic Natural Gas
- Electricity
- Diesel
- Petrol + LPG
- Fertilizer
- Diesel, Naphtha
- Lubricants
- Synthetic Natural Gas
- Electricity
Various Materials require various Gasification Technologies
Uhde's Gasification Portfolio

- PRENFLO
- PSG, PDQ
- entrained-flow gasification

- HTW (High Temperature Winkler)
- fluidized-bed gasification

Various Materials:
- Wastes
- Wood
- Peat
- Brown Coal
- Lignite
- Hard Coal
- Petcoke
- Residues
- Orimulsion
- Oil Naphtha
- Natural Gas
Gasification Technologies

- **Fixed Bed**
  - Temperature: 550 °C
  - Feedstock: 3 - 30 mm
  - Oxidising Agents
  - Syngas
  - Ash / Slag

- **Fluidised Bed**
  - Temperature: 800 – 1100 °C
  - Feedstock: 1 - 5 mm
  - Oxidising Agents
  - Syngas
  - Ash

- **Entrained Flow**
  - Temperature: 1350 – 1600 °C
  - Feedstock: 0.1 mm
  - Oxidising Agents
  - Syngas
  - Slag
Uhde’s Gasifiers

<table>
<thead>
<tr>
<th>PSG</th>
<th>PDQ</th>
<th>HTW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Entrained-flow gasification</strong></td>
<td><strong>Fluidized bed gasification</strong></td>
<td></td>
</tr>
</tbody>
</table>
Presentation Outline

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- Updates on Projects and Alliances
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**Developments**

**From Koppers-Totzek to PRENFLO**

- **PRENFLO burner test rig**
  - Start Up: 1978
  - Scale Up Factor: 8
  - 6 t/d (450 m³/h syngas)

- **PRENFLO Fürstenhausen**
  - Start Up: 1985
  - Scale Up Factor: 50
  - 48 t/d (3,500 m³/h syngas)

- **PRENFLO Puertollano**
  - Start Up: 1998
  - Scale Up Factor: 8
  - 2,400 t/d (180,000 m³/h syngas)

- **Shell-Koppers pilot plant Hamburg**
  - Start Up: 1978
  - 150 t/d coal

- **Koppers-Totzek**
  - Start of development 1941

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Koppers-Totzek gasification plant in Modderfontein, S. Africa
(Design capacity: 1,000 t/d of ammonia)
Koppers-Totzek gasification plant in India
(Capacity: 900 t/d of ammonia)
PRENFLO with Steam Generation (PSG)
1000 MWth, 40 bar

Features
- dry coal/pet coke powder feed
- 4 horizontal co-annular burners
- membrane wall
- waste heat boiler (PSG)
PRENFLO Plant in Fürstenhausen, Germany
Dry-fed, single train IGCC with CCS Pilot Plant at Elcogas, Spain
300 MW net based on petcoke / coal feedstock

PRENFLO Gasification
Coal Preparation
ASU
Combined Cycle
Gas Treatment
New CO₂ capture Pilot Plant implemented
Features

- dry coal/petcoke powder feed
- 4 horizontal co-annular burners
- membrane wall
- direct water quench
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Developments
The HTW Process

KoBra IGCC
RWE, Hürth
3700 t/d Lignite 27 bar

HTW-Pilot Plant (WVV)
Rheinbraun Wesseling
185 t/d Lignite, 25 bar

HTW-Peat Gasification, Kemira

HTW- Demonstratoin Plant
Rheinbraun Berrenrath
720 t/d Lignite, 10 bar

HTW- Pilot Plant
Rheinbraun Wachtfberg
40 t/d Lignite, 10 bar

HTW Laboratory Plant
RWTH-Aachen
12 t/d Coal, Atm.

Atmospheric Winkler generators
1956 – 1964 260 t/d Lignite

Start Up: 1978
Start Up: 1986
Start Up: 1988
Start Up: 1989
Engineering: 1994

Scale Up Factor: 5
Scale Up Factor: 18

>20 Years
HTW High Temperature Winkler - Gasifier
HTW- Laboratory Plant (PDU)
RWTH Aachen
approx. 50 kg/h
1974
HTW Pilot Plant
RWE-Plant-Wachtberg
Frechen / Germany
1,6 t/h
1978 - 1985
HTW Plant
WVV- UK-Wesseling
Wesseling / Germany
7,7 t/h Lignite
10 – 25 bar
1988 - 1990
HTW Syngas Plant
Kemira Oy
Oulu / Finnland
30 t/h Peat
≈ 300 t/d NH3
1988 - 1991
HTW Commercial Scale Demo Plant
Berrenrath/Germany

25 t/h dried lignite – 140 MWth
34,000 m³/h of syngas
≈ 300 t/d Methanol
67,000 total operating hours
84 % availability (last 10 years)
1986 - 1997
HTW-Precon-Gasification
Niihama / Japan
48 t/d Municipal Waste
1999 - 2002

Sumitomo Heavy Industries Ltd.
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ICM’s 18,000 bbl/d CTL Plant in Mongolia
Coal-to-Gasoline (CTG) plant *

Applying TK Uhde’s PRENFLO Gasification Technology

1. Coal Preparation
2. Coal Gasification
3. CO-shift Reactor
4. Acid Gas Removal
5. Methanol Synthesis
6. Methanol-to-Gasoline
7. Gasoline Storage

*) Photo Courtesy TransgasDevelopment

PREFLO Gasifiers
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Presentation of Feasibility Study

Ulaanbaatar, Mongolia, June, 2008
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Mongolia and Germany sign co-operation agreement

CTL project is of strategic importance
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Signing of agreement between Gov’t of Mongolia and TK Uhde in presence of Mongolian President Elbegdorj

ThyssenKrupp Schloss Landsberg, Essen, Germany, March 31, 2012
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Signing of PRENFLO licence agreement between ICM and TK Uhde in presence of Mongolian President Elbegdorj

ThyssenKrupp Schloss Landsberg, Essen, Germany, March 31, 2012
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Minister Battulga at ThyssenKrupp’s Reference Plant

Elcos, Puertollano, Spain, April 08, 2013
JAM Project in China – Commissioning in 2009
Converting Coal into Gasoline

Pilot Plant
100,000 tpa of gasoline

Commercial Plant
1,000,000 tpa of gasoline

Basic Engg. for MTG concluded
TransGas Coal-to-Liquids complex (18,000 bbl/d)
PRENFLO with MTG based on coal

Mingo County, West Virginia
Applying TK Uhde‘s PRENFLO Gasification Technology

Permto to Construct
R13-2791

Issued to
TransGas Development Systems, LLC
TransGas Coal to Gasoline Plant
969-00392

John A. Benedict
Director

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TransGas Coal-to-Liquids complex (18,000 bbl/d)
Ground Breaking Ceremony, 09 May 2011, West Virginia Plant Site

U.S. Senator Joe Manchin III. and WV Governor Earl Ray Tomblin
**BioTfueL – integrated process chain**

**PRENFLO with FT based on solid and liquid feedstock**

**Target**
Development and commercialisation of integrated process chain for production of 2nd generation biofuels

**Applying**
TK Uhde‘s PRENFLO Gasification Technology
BioTfueL – integrated process chain
PRENFLO with FT based on solid and liquid feedstock

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Pretreatment</th>
<th>Gasification</th>
<th>Gas Treatment</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>Torrefaction</td>
<td></td>
<td>CO-Shift</td>
<td>Gasel™</td>
</tr>
<tr>
<td>Straw etc.</td>
<td>Milling</td>
<td></td>
<td>AGR</td>
<td>Fischer-Tropsch</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td></td>
<td></td>
<td>Synthesis and Product Upgrading</td>
</tr>
<tr>
<td>Petcoke</td>
<td></td>
<td></td>
<td></td>
<td>Biodiesel; Biokerosene</td>
</tr>
<tr>
<td>Liquid Residues</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Life-cycle analysis for optimum equilibrium between technical-economical performance and environmental demands
Applying TK Uhde’s PRENFLO Gasification Technology
Biomass-to-Methanol Plant, Hagfors / Värmland / Sweden

Artist View

Applying TK Uhde’s HTW Gasification Technology

Photo courtesy VärmlandsMetanol AB
C.GEN – 450 MWe IGCC with CCS, Killingholme, UK
PRENFLO PDQ selected

- Optional hydrogen production
- Carbon capture & storage
- Synergies due to maximum integration into existing industrial network
- High level of standardization – beneficial for future plants
- Feedstock: hard coal, petcoke and biomass

Applying TK Uhde’s PRENFLO Gasification Technology
Alliances and ThyssenKrupp to co-operate in the field of coal gasification

JV KEPCO-Uhde Inc. founded in July 2011 in Seoul, South Korea
Alliances in the field of Coal-to-Liquids

A) Coal-to-GASOLINE via Methanol (MTG)

ExxonMobil Research and Engineering + ThyssenKrupp

B) Coal-to-DIESEL via Fischer-Tropsch

Axens IFP Group Technologies + ThyssenKrupp
Co-operations
Lessons learnt from operators

A) PRENFLO entrained-flow Gasification Technology

B) HTW fluidised-bed Gasification Technology
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Summary
Gasification is a proven technology, a vast number of gasifiers are operating since decades successfully on commercial basis.

Gasification allows flexibility in feedstock and polygeneration of products.

Gasification is environmental friendly.

Uhde has more than 70 years of experience in gasification based on 8 different gasification technologies.

… received more than 100 contract awards for gasifiers.

… has proven single sourcing capability.

… is a process oriented EPC contractor and not only licensor.

… has built the world’s largest solid fuel based, single train IGCC.

… has built more than 2,000 plants worldwide.
Gasification Uhde „Site“-Seeing

Koppers-Totzek gasification
Modderfontein, South Africa
carbon-to-ammonia/fertilisers

HTW coal gasification
Berrenrath, Germany
carbon-to-methanol

GE (Texaco) coal gasification
Oberhausen, Germany
carbon-to-hydrogen & oxochemicals

PRENFLO coal gasification
Fürtenhausen, Germany
carbon-to-methanol

HTW MSW gasification
Niihama, Japan
waste-to-energy

PRENFLO IGCC
Puertollano, Spain
pet coke/carbon-to-power
Summary
Uhde is Technology Provider and EPC Contractor
Thank you for your attention