INTRODUCTION

During the Gasification Technologies Conference 2000 the development of the gasification technology and the subsequent erection of a turnkey plant for utilizing nitrogen organic residues from the BASF plc Seal Sands plant in UK was presented. Last year BBP Power Plants commissioned the plant and improved plant performance based on experience during startup and commissioning.

Utilization of nitrogen-organic compounds

At BASF’s Seal Sands plant approx. 110,000 t/a of residual products are generated from various stages of the Acrylonitrile-synthesis, which are gasified. The residues are liquid, ashfree mixtures, which essentially contain nitriles, amines, ammonia-sulfates and prussic acid, which exist in 4 feedstock groups as shown in Table 1. There is a content of up to 24 Ma-% of organic bonded nitrogen. The syngas produced is used for power production and must meet the following specification:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Groups of feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>wt.%</td>
<td>62.5 36.5 18.9 25.3</td>
</tr>
<tr>
<td>H</td>
<td>wt.%</td>
<td>7.4 8.5 9.4 6.6</td>
</tr>
<tr>
<td>N</td>
<td>wt.%</td>
<td>23.8 19.8 7.1 11.0</td>
</tr>
<tr>
<td>S</td>
<td>mg/kg</td>
<td>90 &lt; 50 690 46,500</td>
</tr>
<tr>
<td>Cl</td>
<td>mg/kg</td>
<td>&lt; 50 &lt; 50 &lt; 50 125</td>
</tr>
<tr>
<td>Ash</td>
<td>wt.%</td>
<td>&lt; 0.05 &lt; 0.05 &lt; 0.05 0.68</td>
</tr>
<tr>
<td>Moisture</td>
<td>wt.%</td>
<td>6.1 27.4 62.6 35.3</td>
</tr>
<tr>
<td>Calorific value</td>
<td>kJ/kg</td>
<td>30,730 21,230 8000 8205</td>
</tr>
<tr>
<td>Feedstock rate</td>
<td>kg/h</td>
<td>2200 2000 6600 2500</td>
</tr>
</tbody>
</table>

Table 1

Dust content < 10 mg/m³ i. N.
Sulfur (H₂S, COS) < 25 mg/m³ i. N.
Nitrogen (NH₃, HCN) < 20 mg/m³ i. N.
Pressure ≥ 26 bars

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All 4 groups of feedstock shall be gasified simultaneously in any ratio between 0 and full capacity as per Table 1, if feasible.

The fact that only 2 out of the 4 groups of feedstock are miscible with each other required a special design of the burner and implementation of advanced control logic. The burner was designed according to the pressure atomization principle.

Due to the very low ash content and based on the experience gained during testing at our R&D facilities in Freiberg Germany: a reactor type with cooling wall according to picture 1 with the reaction chamber being enclosed by a high aluminum refractory lining was selected. The design is based on temperature equilibrium of 1400 °C. The oxygen demand is 4500 m³ i.N./hr.

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Due to the very low ash content a partial quench is used. This allows for high pressure steam generation a valuable by-product, which is used for power generation. The individual parameters are listed in the general system schematic as per picture 2.

A hot gas filter upstream of the COS/HCN hydrolysis reactor will protect the catalyst bed from dust settlement. In the hydrolysis stage, which operates in a temperature range of 220 °C to 240 °C the COS is reduced by 95 % and the HCN is completely eliminated. Following LP steam generation and cooling, where ammonia is removed together with the large condensate quantities, the pre-cleaned raw gas enters the desulphurisation unit. To simplify matters with respect to the relatively low sulfur output of 100 to 170 kg/h, the SulFerox process was chosen for direct oxidation of hydrogen sulfide to elemental sulfur.

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The approx. 14,000 Nm³/h of clean gas at a pressure of 26 bars is blended with natural gas for use in a gas turbine.

COMMISSIONING

Commissioning was started in January 2001. During cold commissioning of the plant the following functions were tested to the actual operating conditions as nearly as possible.
- Excess oxygen
- Oxygen control to the main burner during shutdown of feedstock (transition into part load operation)
- Switch over of the feedstock supply from circulating operation to gasification
- Shutdown of the combination burner
- Step chains of DCS to start/stop feedstock supply
- Emergency shutdown of the plant
- Tested newly developed burner with water at operating pressure and flow

After successful completion of the test program the refractory lining required drying and heating in accordance with the supplier’s recommendation and before gasifying feedstock. The drying and heating of the refractory was accomplished by using the pilot burner applying a defined natural gas, oxygen and nitrogen ratio.

Due to mechanical problems of rotating equipment the drying and heating of the refractory was extended from planned 7 days to 35 days.

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The refractory supplier’s recommendation required holding periods at a given temperature for a specified period of time prior to proceeding to the subsequent temperature level. Throughout this drying and heating phase the pilot burner met or exceeded all expectations.

During design phase of the process several operating modes (Table 2) were determined for the simultaneous gasification of the varying feedstock depending on the flow rate and the calorific value to ensure reliable plant operation and syngas quality. The first syngas was successfully produced on 11.07.2001 in operation mode B with only one start trial.

### Operational Modes

![Diagram of operational modes](diagram.png)

Table 2
Following successful syngas production and during stable operation of the gasifier downstream systems and components such as heat recovery system, hot gas filtration, raw gas and waste water treatment were optimized.

Initially it was dispensed with the application of other operation modes to get familiar with the behavior of the total plant and to establish the first heat and material balances. Due to the low sulfur content of the feedstock within operation mode B the operation of the desulfurisation plant was not required. After successful initial commissioning additional operation modes were run in accordance to specified commissioning program. Unexpected problems with the quench sump water level became apparent. The quench water outlet was clogged up by the unexpected formation of large coke particulates. These coke particulates were formed in the gasifier, during startup, when the feedstock is atomized without presence of oxygen.

The start of the gasifier without oxygen is required to insure a safe operation. Only after safety check of the control system an optimum gasification with smallest soot and coke formation can be achieved by tracking the lambda value.

To solve the problem technical solutions were researched
- To reduce the coke formation
- To keep the still formed coke in the gasifier

During the presentation the results will be reported, which have been achieved with the changes.

As expected the raw gas contains small amounts of soot and solids, which are separated from the raw gas by the hot gas filter and filled into Big-Bags via a lock hopper system and a cooling screw. During further treatment the dust ability of self-heating had to be considered when contacting with air.
This ability was suppressed during discharging through a proper nitrogen purge. Table 3 summarizes operating parameter reached during the initial operation periods, which confirm that:

- The carbon conversion is > 99.5%, 95% is specified
- Sulfates are reduced to sulfides
- The organic nitrogen compounds are degraded

<table>
<thead>
<tr>
<th>Input</th>
<th>Mode E</th>
<th>Output</th>
<th>Mode E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock 1 kg/hr</td>
<td>2100</td>
<td>HP Steam kg/hr</td>
<td>4790</td>
</tr>
<tr>
<td>Feedstock 2 kg/hr</td>
<td>700</td>
<td>Clean Gas Nm³/hr</td>
<td>9150</td>
</tr>
<tr>
<td>Feedstock 3/4 kg/hr</td>
<td>4500</td>
<td>Analysis GCH Lab</td>
<td>9750</td>
</tr>
<tr>
<td>Natural Gas Nm³/hr</td>
<td>100</td>
<td>H₂</td>
<td>34,30</td>
</tr>
<tr>
<td>O₂ Pilot Burner Nm³/hr</td>
<td>110</td>
<td>CO</td>
<td>32,90</td>
</tr>
<tr>
<td>O₂ Main Burner Nm³/hr</td>
<td>2520</td>
<td>CO₂</td>
<td>37,50</td>
</tr>
<tr>
<td>Lambda Combi Burner</td>
<td>0,426</td>
<td>CH₄</td>
<td>28,10</td>
</tr>
<tr>
<td>N₂ to Reactor Nm³/hr</td>
<td>450</td>
<td>N₂</td>
<td>16,00</td>
</tr>
<tr>
<td>N₂ to Quench Nm³/hr</td>
<td>135</td>
<td>H₂S</td>
<td>18,90</td>
</tr>
<tr>
<td>Quench Water Nm³/hr</td>
<td>4,56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Considering the sensitive feedstock quality from the BASF production plants the following facts are to be inspected and technically to be adjusted if necessary:

- Separation of the feedstock in the feed systems at special conditions
- Short termed large variations of the calorific value and the water content as well as quick tracking of the oxygen demand for a constantly high gasification temperature.
- Formation of the low amount of unconsumed carbon as swim coke with the said gating problems.
PROSPECTS

Based on the positive results we are transferring the plant into commercial operation. Together with our Partner BASF we will continue to monitor and collect valuable operating data.

With respect to thermodynamics it makes no fundamental difference to the gasification process whether we gasify conventional fuels, industrial residues and domestic wastes. The experience gained from coal and oil gasification could be easily applied toward the conversion and recovery of valuable products from residues and waste streams.

BBP Power Plants objective is to convert residues and waste streams into a raw syngas by customizing the entrained-flow gasifier for each specific task or project requirements, while maintaining compliance with the highest environmental standards. The generated raw syngas can be processed to valuable byproducts or power production.

BBP Power Plants owns and operates the largest gasification test facility in the world located in Freiberg (Germany). This plant is capable of gasifying a large variety of conventional and non-conventional feedstocks under different operating conditions, as accomplished for:

- more than 15 Chemical Companies world wide
- more than 20 different sewage sludges

To increase our capabilities to handle a wider variation of feedstock that differ in chemical composition, ash content, and calorific value we have developed several types gasification reactors that meet the challenges of large and divergent characteristics or feedstock. Picture 4 contains a summary of the types of gasification reactors.
The highly-tested Noell entrained-flow Gasifier reactor with “Cooling screen” is highly suited for gasification of all ash containing and homogeneous feedstock such as.

- Homogeneous solids: such as coal and petcoke. These feedstock are fed into the gasifier with a unique dense phase pneumatic conveying technology.
- Liquids: such as oil tars and sludges

On the other hand heterogeneous waste streams such as domestic waste is not suitable for entrained-flow gasification reactor. These streams require extensive pretreatment and process, which combines Pyrolysis and Gasification we have experience in dealing with this type of waste stream.

A cooling wall, refractory lined gasifier reactor is best suited for ashfree or feedstock such as fuel oil, synthesis residues or hydrocarbon containing gases.

Together with Chemrec AB of Sweden we developed gasification technology for gasifying Black Liquor (a wood pulping solution from the power process for pulp manufacturer) and tested the refractory lining. Amongst thermal resistance a specially chemical resistance of the reactor lining material is required because of the high aggressiveness of the liquid salt smelt from sodium hydroxide, carbonate and –sulfide.
LIST OF GRAPHICS

Table 1  Seal Sands Feedstock Analyses
Table 2  Operational modes
Table 3  Input / Output values during operation mode E

Picture 1  Reactor with cooling wall
Picture 2  Generalised system schematic of the Seal Sands gasification island
Picture 3  The plant during commissioning
Picture 4  Noell entrained-flow gasification

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