SHELL COAL GASIFICATION PROCESS

An integrated solution for efficient coal-to-products value chains

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Shell Projects & Technology

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Shell Gasification technology portfolio

**SHELL GASIFICATION PROCESS (SGP)**

- with natural gas feedstock e.g. for GTL
- with residue feedstock e.g. for refineries

**SHELL COAL GASIFICATION PROCESS (SCGP)**

- with solid feedstock (coal, petcoke and biomass) e.g. for chemicals, hydrogen and power generation

“One proven technology, two line-ups”
Residue gasification: from the bottom-of-the-barrel to light products

- Proven track record since 1950s
  >125 gasifiers in operation

- Wide residue feedstock range from vacuum residue to highly viscous residues, such as thermal cracked residue, solvent de-asphalter residue; later retrofit to heavier feedstock possible

- Safe and reliable operation: automated and fully safeguarded heat-up, start-up, shutdown sequences; reliability >99.5%

- Extensive experience in start-up, operation and maintenance of own units and licensed units.
SCGP – A proven technology on an ever-increasing scale

Coal feed ton/day

1976 Pilot unit, Amsterdam, NL
1978 Demo unit, Harburg, Germany
1987 SCGP-1 Houston, USA
1993 NUON IGCC Buggenum, NL
2000 Onwards Coal gasification licensees

6 t/d
150 t/d
250 t/d
2000 t/d
3200 t/d

Lu’an (3200 t/d)
YTH, Datang (2700 t/d)
Datong (2400 t/d)
Yueyang JV (2000 t/d)
Guangxi Liuzhou (1200 t/d)
YTH Jinxin (1100 t/d)
Wison Nanjing BQ (1000 t/d)
Hubei Shuanghuan (900 t/d)

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SCGP licensing reference in China

- >15 years of commercialisation in China
- 22 license projects, 24 gasifiers in operation, 5 gasifiers to start-up

- 17 gasifiers with >2000t/d coal intake capacities
- Largest gasifier delivered 3,200t/d, start-up Q1 2017
Mature core of the technology: reactor and burners

Protection against high operating temperatures via a slag layer on a membrane (water) wall

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Shell Coal Gasification: a single proven technology, two line-ups

- Industrially proven, mature technology
- Carbon efficiency >98-99%
- Highest energy efficiency, lowest consumption
- High-level steam as a very useful ‘byproduct’
- Low water consumption, less wastewater to treat: environmentally friendly

- Same basic design as syngas cooler line-up
- Carbon efficiency >98-99%
- Simplified line-up, reduced Capex
- Even wider coal flexibility
- Easier operation and maintenance (less equipment)
Bottom Quench technology: a simplified line-up

- Syngas cooler replaced with a mature, ‘industry-standard’ water quench technology
- Same membrane wall
- Same multiple burner
- Same dry feed system
SCGP line-up with Syngas Cooler (SGC) offers high efficiency and small environmental footprint
Performance and reliability: wide coal suitability

**FEED FLEXIBILITY**
- Handled over >150 different kinds of coal incl. challenging feedstocks like lignite and petcoke
- Four projects successfully used petcoke blended with coal, with one reaching 328 days at full operation load
- Based on extensive operating experience, several modelling tools were developed to confidently assess novel coals and optimise coal blends

**Property range of feedstocks operated in SCGP**

```
<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Ash + flux (MF) wt%</th>
<th>Moisture wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>38.6% - 8.2%</td>
<td>35.0% - 3.8%</td>
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<td>Sub-bituminous</td>
<td>&gt;1500°C</td>
<td>100%</td>
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<td>Bituminous</td>
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<tr>
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**Broad operating experience on many different kinds of coal**

**FEED FLEXIBILITY**
- Handled over >200 different kinds of coal covering the whole reactivity spectrum from lignite to anthracite, ash contents from 6-37%
- Four projects successfully used petcoke blended with coal, with excellent operational results

DEEP INSIGHT IN PROCESS
- Based on extensive operating experience, several modelling tools were developed to confidently assess novel coals and optimise coal blends

Operational data from a Chinese customer
Example of actual operation of a Chinese customer

Operational data from a Chinese customer

Ash content, %

DESIGN WINDOW

January 2017
Rich operational experience on petcoke/coal blends

Tianfu was the first dry-feed gasification plant in China that successfully demonstrated petcoke/coal blending.

Now four SCGP plants in China have operational experience on petcoke.

1987

Gasified 100% petcoke in SCGP-1 plant in Houston US.

2010

Petcoke blending gives good operational performance and reliability: YZH operated continuously for 291 days and Tianfu for 186 days. Annual longest accumulated running days: 341.

NOW

Petcoke blending gives good operational performance and reliability: YZH operated continuously for 291 days and Tianfu for 186 days. Annual longest accumulated running days: 341.

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<tr>
<th>Characteristic</th>
<th>Unit</th>
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<td>Ash</td>
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January 2017
### RELIABILITY DATA 2016

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<td>300</td>
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<td>77*</td>
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| 15 | 140,000 | 96%  | 300 | 254 | 77*|

* Limited by downstream demand
SAFE OPERATION
- Dongting JV achieved 10 million man-hours without LTI on December 25, 2015 (since 9th Feb 2006)

HIGH RELIABILITY
- Overall SCGP plant reliability in 2016 is 96.3%.
  14 plants clocked more than 300 accumulative running days, the longest one 348 days

LATEST START-UP: ANOTHER SCGP-BQ
- Jinxin coal to ammonia/fertilizer plant in Inner Mongolia successfully started up in June 2016, reached 90% load, and produced on-spec end-use product within the first month of operation. First BQ operation on lignite
The first IGCC project in South Korea, located in Taean, approximately 150 km south-west of Seoul, started-up end of 2015.

IGCC is supported as new energy under the Korean government Renewable Portfolio Standard.

Gasification (a single SCGP unit)
- Feedstock: 2,650 ton/day sub-bituminous coal
- Syngas capacity: 175,000 Nm³/hr CO+H₂

IGCC power output 380 MW (gross), net efficiency 42% HHV, with good air quality emissions of
- SOx < 15 ppm
- NOx < 30 ppm
- Dust < 1 mg/Nm³
Looking to the future

- **Shell’s world-class gasification technologies** can contribute to a cleaner energy future.
- **Continuous improvement** has seen the reliability of Shell’s gasification technologies steadily improve in recent years.
- Shell has a **strong, global reference list** in gasification.
- **Coal gasification offers a single proven technology in two line-ups**: SCGP syngas cooler and bottom water quench depending on your business objectives.
- Our **dedicated gasification technical and services team** offers comprehensive and experienced support.
Thanks for your attention