Gas Storage Bergermeer

Petroleum Geologische Kring

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TAQA Energy en EBN werken hier aan Gasopslag Bergermeer.

www.gasopslagbergermeer.nl
Contents presentation

- TAQA at a glance
- Why a Gas Storage
- Boekelermeer & Bergermeer Sites
- Subsurface
- Drilling / Completion Challenges
A GLOBAL ENTERPRISE

TAQA at a glance

- Oil and Gas E&P – Pipelines – Power Generation – Water Desalination
- 2013 revenue: $7.0 Bn
- Assets 31 Dec 2013: $33.2 Bn
- Employees: 2800
- Operating in North America, Europe, Middle East, North Africa and India

- Founded 2005
- Abu Dhabi Government 75% / Public Shareholders 25%
- Power generation capacity: 16,395 MW
- Water desalination capacity: 887 MIGD
- Oil & gas production: 142,400 boe/d (North America 63% - UK 32% - NL 6%)
Why a Gas Storage?
Use of UGS to Balance Supply and Demand
Bergermeer Gas Field

North Sea

Holland

Vlieland

Altena

Germanic Trias

Zechstein

Rotliegend Sandstone (Reservoir)

Water

(Source Rock)

Carboniferous

Gas filled

Bergermeer Gas Field

SW

NE
Underground gas storage in caverns

Diameter of cavern:
- Depth about 1200 m.
- Height 100-200 m.
- Width 50-100 m.

Gas volume:
- about 140,000,000 m³

As a comparison:
- Domtoren, Utrecht (112.3 m.)

Pipelines take the gas in and out of the caverns.

Thickness of salt layer:
- 400 – 600 m
“Gas-roundabout Netherlands”
GIIP = 16.8 BCM

Bergermeer GIIP, UR, CG and WG Volumes (BCM)

GIIP = 16.8 BCM
Gas demand in the Netherlands – Capacity BGM

- Average cold winterday: 500 MCM/d
- Record 7-Feb-2012: 545 MCM/d

![Graph showing gas demand decline rate and plateau rate.]

- Plateau rate 57 MCM/d for 30 days
- Decline rate 57 – 27 MCM/d for 62 days
Boekelermeer & Bergermeer Sites
TAQA Bergen Concession
Op deze kaart ziet u hoe de gasleiding van de puttenlocatie ondergronds naar de gasbehandelinstallatie zal gaan lopen. Uiteindelijk zal er vanaf de grond niets meer te zien zijn van zowel de gasleiding als van de puttenlocatie.
Key figures Bergermeer construction

- Total costs: €850 million
- Of which drilling: €183 million

- 3300 man years work, 2650 in NL
- Long term jobs: 50 in TAQA + 100 indirectly
Injection and Production of Gas
- Max 20 new wells (in cellars), injectors/producers
- Work-over existing wells
- Water Injection
- Seismic Monitoring

Bergermeer Well Location
Pipeline crossing Alkmaar – Egmond road
Beeld van de boring van de gastransportleiding onder het Heilooerbos.
Bergermeer reservoir pressures and induced earthquakes

Original reservoir pressure: 228 bara

Average reservoir pressure:
- 200 bara
- 150 bara
- 133 bara
- 100 bara
- 77 bara

Operational Range Gas Storage Project
77 bara < operations < 133 bara

- Tremors 1994:
  - 6 Aug: M=3.0
  - 21 Sep: M=3.2
  - ΔP = 170 bara
- Tremors 2001:
  - 9 Sep M=3.5;
  - 10 Sep M = 3.2
  - ΔP = 203 bara

Depleted average reservoir pressure: 14.4 bara

Time years:
- 1/1/1971
- 1980
- 1990
- 2000
- 2010
- 2014
Subsurface
Cross section
SOUTHERN PERMIAN BASIN

Bergen / Middelie Area
Present-day distribution and facies map of the Upper Rotliegend Group (late Middle to early Late Permian) in the Southern Permian Basin
Overall facies distribution at the onset of deposition of the Upper Slochteren Member.
Artist impression of Southern Permian Basin
Modern Analogue of Transverse Dunes in Moroccan Desert

Dromedary for scale
Fig. 12. *In-situ* soft-sediment deformation and sandy gravity flows are the main mechanisms forming the Weissliegend facies. Mass flows transport material into interdune areas (A) and create a more symmetrical topography, with the Weissliegend facies thinner on the dune crests and thicker in interdune hollows. *In-situ* soft-sediment deformation formed deposits (B) are present within the dune crests. UAU, Upper Aeolian Unit. Modified after Glennie & Buller (1983) and Howell (1992).
Rotliegend reservoir BGM: Weisliegend and Rotliegend

<table>
<thead>
<tr>
<th>BGM Block-I (East)</th>
<th>Formation Top (m TVD NAP)</th>
<th>Gross Thickness (m)</th>
<th>N/G (fraction)</th>
<th>Porosity (fraction)</th>
<th>Sw (fraction)</th>
<th>Permeability, mD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weisliegend</td>
<td>2066 (±15m)</td>
<td>±50</td>
<td>0.99</td>
<td>0.13 – 0.20</td>
<td>0.18 – 0.45</td>
<td>20-80</td>
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<tr>
<td>Rotliegend to TD@2175m TV NAP</td>
<td>±2116</td>
<td>5</td>
<td>1.00</td>
<td>0.20 – 0.24</td>
<td>0.18 – 0.37</td>
<td>100 - 5000</td>
</tr>
</tbody>
</table>
Drilling / Completion Challenges:

- Depleted Reservoir (50-80 bar)
- Wellbore Stability (overburden and reservoir)
- Sand Control
3D-View
Existing Wells
New Wells
MPD Two Phase System Overview

N2 is pumped into the drilling annulus via a downhole choke. N2 expands in the drilling annulus displacing drilling mud by volume.

BHP is controlled automated MPD chokes receiving data from MWD and a downhole gauge.

N2 is removed from the drilling mud and vented. Drilling mud is metered and returned to the rig mud pits.
Baracarb

Depleted reservoir

reservoir

wellbore

OBM + Baracarb
Bergermeer Well Designs version 4

- 20” Surface Casing (into top Vlieland Shale)
- 13 ¾” Production Casing (into top Lower Bunter Main Clay Stone)
- 9 ¾” Production Liner (into top Weissliegend)
- 7” SAS in 8½” Slanted Hole
- 7” SAS in 8½” Sub-horizontal Hole
- 7” x 9½” Tubing

North Sea
Holland
Vlieland Shale
Triassic Formations
- Aalburg & Sleen
- Keuper
- Muschelkalk
  - Muschelkalk Evaporite (salt?)
  - Upper Röt Claystone
  - Main Röt Evaporite (salt?)
  - Sollingen Claystone
  - Sollingen Sandstone
  - Bunter Volpriehausen
  - Lower Bunter Rogenstein
  - Lower Bunter Main Claystone

Zechstein Z1 – Z3
- Z3 Salt
- Z2 Salt

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Quaternary
- Swell Packer
- Production Packer
- Uniflex Liner Hanger
- Denotes Cr13 steel

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Open Hole Completion-Sand Control
BGM-10 ST2
Permeability Log
**Swellpacker #1**
3222m or higher
195m

**Swellpacker #2**
3090m or higher
132m

**Swellpacker #3**
2985m or higher
105m

**Swellpacker #4**
2932m or lower
53m

51m blank pipe

53m

105m

132m

195m
Wellbore stability problems in Vlieland and Altena Shales

- Lost 2 holes
- Suspended well
- Acquired and interpreted geomechanical logs in next well BGM-11
- Maximum inclination in Vlieland and Altena: 50 degrees
Exchange down hole targets of BGM-10 and BGM-18
Inferred fracture zone causing total losses

BGM-17 cross-cutting mid field fault

Block 1A

Block 1B

Block 1C

Block 2
<table>
<thead>
<tr>
<th>Plan/Description</th>
<th>Plan</th>
<th>Actual</th>
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<tbody>
<tr>
<td>Drilling reservoir section</td>
<td>MPD</td>
<td>Single phase OBM</td>
</tr>
<tr>
<td>ECD reservoir section (p_{res} 80 bar)</td>
<td>0.57</td>
<td>1.15</td>
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<tr>
<td>Non-horizontal wells</td>
<td>S-shaped</td>
<td>Slanted</td>
</tr>
<tr>
<td>Horizontal wells</td>
<td>Weissliegend</td>
<td>Land on 2200 TVNAP</td>
</tr>
<tr>
<td>Number of non-horizontal wells</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Number of horizontal wells</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Number of sidetracks</td>
<td>1 (water injector)</td>
<td>1 + 3</td>
</tr>
<tr>
<td>Deliverability horizontal wells</td>
<td>3.2 x 10^6 m^3/d</td>
<td>&gt; 5 x 10^6 m^3/d</td>
</tr>
<tr>
<td>Deliverability non-horizontal wells</td>
<td>5 x 10^6 m^3/d</td>
<td>&gt; 5 x 10^6 m^3/d</td>
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<tr>
<td>Drilling costs</td>
<td>182.6 million €</td>
<td>164.6 million €</td>
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19th of June 2015: PGK excursion to Boekelermeer and Bergermeer
Questions ???