EU-GCC Seminar:
“Natural Gas Technologies – Realities & Prospects”
Doha, Qatar, 7-8 February 2005

STREAM A:
“Advanced Technologies for Natural Gas Processing,
Transport, Storage and Distribution”

SESSION A.6:
Storage Technologies – GTL - LNG

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Gas Storage

Why?  How?  Evolutions?

UE / GCC – Seminar on « Natural Gas Technologies – Realities & Prospects »
Doha Qatar, 7-8 February 2005

GDF - DIRECTION DE LA RECHERCHE
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Agenda

✓ Aims of storage
✓ Design conditions
✓ Solutions
✓ Future

For Gas and for LNG

Montoir de Bretagne - France
23 February 2005
Aims (gas)

Represent a fundamental aspect of the development of the gas industry in a receiving country:

- In smoothing the flow of supply / consumption
- In ensuring the supply safety

The impossibility of gas storage can be a brake to this development.

Design conditions (gas)

- **Reservoir**:
  - **Tightness** of the cap rock
  - **Influence** between gas and the hydrogeology
  - Capacity
  - Porosity

- **Acceptance** of the on grounds facilities:
  - Compression
  - Gas treatment
There are three main techniques:
- Depleted gas reservoirs
- Salt caverns
- Aquifers

Solution (gas): Salt caverns

1. Salt deposit
2. Caverns
3. On ground facilities
Solution (gas) : Salt caverns

Salt cavern leaching

Water injection

The water dissolves salt

Brine draining

Solution (gas) : Salt caverns

Radius (meters)

Height (meters)

CONCRETE CASING

ROOF

SALT MASSIF

CAVERN

INSOLUBLE S RESIDUES

<table>
<thead>
<tr>
<th>Height (meters)</th>
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<tbody>
<tr>
<td>130 125 120 115 110 105 100 95</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Radius (meters)</th>
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<tbody>
<tr>
<td>0 10 20 30 40 50 60</td>
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Solution (gas) : Aquifer

1. Reservoir
2. Caprock
3. Control (upper) aquifer
4. Central station
5. Operating wells
6. Control well in upper aquifer
7. Control wells in reservoir
8. Gas-bearing zone

Examples in France (operated by Gaz de France)

<table>
<thead>
<tr>
<th></th>
<th>Aquifer 9 sites</th>
<th>Cavern 3 sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top depth m</td>
<td>600 à 1200</td>
<td>900 à 1400</td>
</tr>
<tr>
<td>Total capacity</td>
<td>18 605</td>
<td>2 200</td>
</tr>
<tr>
<td>Working volume</td>
<td>7 800</td>
<td>1 200</td>
</tr>
<tr>
<td>Peak flow rate</td>
<td>115</td>
<td>75</td>
</tr>
</tbody>
</table>
Gas Storage - Europe

Source: CEDIGAZ

- Aquifers 27.7%
- Old Mines 1.2%
- Salt Caverns 28.9%
- Depleted gas reservoirs 42.2%

Total Europe: more than 80 storages

Aims (LNG)

- Buffer storage
- Seasonal storage

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Design conditions (LNG)

- Storing LNG
- Performance of the chain
- « Social » acceptance of the tanks

- Behaviour of the LNG (tools like: predicting roll over LNG-Master®,...)
- Operating conditions
- Exceptional loads (earthquake, mechanical impacts...)
Solution (LNG)

Past:

- Metallic single containment tank

New design (step 1)

- Double containment

Avon mouth peak shaving plant - GB
Dudzelle peak shaving plant - Belgium
Solution (LNG)

New design (step 2):
- Full containment
- With dike

Membrane tank
Membrane tank

Marmara - Turkey
Solutions (LNG)

State of the Art:

European standardization effort

= No retention area for full containment tanks neither membrane tanks

Solution (LNG) – EN 1473 – pr-EN-14620

- Reinforced concrete raft
- Insulation on inside of secondary container
- Loose fill insulation
- Base insulation
- Primary container
- Prestressed concrete secondary container
- Elevated concrete raft
- Insulation on inside of secondary container
- Primary membrane
- Elevated concrete raft
- Suspended deck (insulated)
Solution (LNG) – EN 1473 (pr-EN-14620)

- Primary container
- Secondary container (impounding area)
- Base insulation
- Bund wall
- Bottom heating
- Outer shell
  - (not able to contain liquid)
- Suspended deck
  - (insulated)
- Loose fill insulation
- Elevated concrete raft
- Reinforced concrete secondary container
- Earth embankment
- Bottom heating

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Future (gas)

New design due to the geology:

Line Rock Cavern (LRC)

Future (gas - LRC)

Rock cover 100-200 m
Maximum pressure 15-30 Mpa
Diameter 25-45 m
- **Rock mass**: pressure absorption
- **Concrete layer**: Pressure transfer, Deformation distribution, Smooth basis for liner
- **Steel liner**: gas tightness

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Future (gas - LRC)

Demonstration cavern

- Geometrical Volume: 40,000 m³
- Diameter: 35 m (115 ft)
- Height: 50 m (160 ft)
- Gas Pressure: 200 bar (2900 psi)
- Total Gas Volume: 10x10⁶ m³ (360 MMcf)
- Working Gas Volume: 8.5x10⁶ m³ (300 MMcf)
- Base Gase Volume: 1.5x10⁶ m³ (60 MMcf)

Future (LNG)

Acceptance of the tanks:

- Underground cavern
- Offshore
Future (LNG)

Offshore

Gas Storage

Conclusion / Research challenges

- Industry / Market
- Price, unit capacity, environment
- Acceptance
- Underground storage: gas industry is in environnement's service (CO2)
Thank you for your attention