TECHNICAL INFORMATION

ABOUT

UNDERGROUND STORAGE RESERVOIRS FOR NATURAL GAS

Underground Storage Reservoirs for Natural Gas

1 Fields of Application

Underground storages (UGS) for natural gas are used

- for balancing of the gas supply and demand over a defined period such as
  - to compensate season-related fluctuations (summer / winter periods)
  - to ensure that natural gas is available without delay for diverse consumers
- to provide gas to the customers under optimum economic conditions between buying and selling
- to ensure gas supply in the event of failures or malfunctions at production sites or in transportation systems.

Considering several possible geological storage formations, there are different demands on the technological surface facilities. The general layout of underground storages depends on geological conditions as well as on demands of the connected pipeline or network.

Fig. 1 - UGS - Surface facility

The decision to utilize an underground reservoir for storing natural gas involves corresponding geological characteristics and extensive studies with regard to the relevant technological and economic conditions.

Process stages to be implemented are selected primarily based on gas composition, gas flow rates and pressure ratios between reservoir/cavern and pipeline.

It goes without saying that it is also possible to provide additional subsurface (geological, reservoir-engineering) expertise within bigger projects.

2 Principle of Process

2.1 General

An underground storage of natural gas is built for balancing between gas supply and demand. When the gas demand is low, natural gas is taken from the pipeline to be injected into the gas storage reservoir and supplied back to the system in times of high demand.
The natural gas that is injected into the underground storage and supplied back to the gas grid has to meet all requirements of the applicable standards (e.g. DVGW standard G 260) for marketable natural gas.
Depending on the changing gas flow rates and the pressure ratios between pipeline and gas storage, the following operating modes may arise:

- feed-in into the UGS with or without gas compression
- feed-out of the UGS with or without gas compression

In addition to these modes, diverse special and combined operating modes can be implemented. The scope is geared to the specific requirements of the gas storage facility and the connected pipeline network.

2.2 Storage of natural gas

The natural gas taken from the pipeline system is monitored regarding quantity and quality and it is injected into the storage reservoir using a compressor station.
The need to apply gas compressors depends on the pressure ratio between pipeline and gas reservoir and the gas flow rates to be stored. Both piston compressors and turbo-types may be used for gas compressing. The compressor drive can be achieved by gas engines, gas turbines or electric drives, the most favorable for the specific application has to be determined and evaluated under consideration of the general conditions.

2.3 Production of natural gas

The process stages for withdrawing gas from the UGS mainly depend on the type, the location and the conditions of the gas reservoir and have to be evaluated for each specific case.

Basically, the procedure is as follows:

Natural gas from the gas reservoir is directed to a separator to remove free fluids and is then supplied to gas treatment in order to ensure that the natural gas quality is in accordance with the relevant guidelines (i.e. DVGW G260).

The following processes might be used to treat the natural gas:

- absorption processes with triethylene glycol (TEG) or other substances such as silica gel
- low temperature separation using the Joule-Thomson effect or an external refrigeration plant

The following factors help to determine the most suitable processes:

- analysis of the gases to be withdrawn,
- pressure ratios between UGS and pipeline system,
- necessary gas rates for the feed-in and feed-out,
- economic aspects.

These factors should be evaluated as part of a feasibility study.

3 Plant Concept

3.1 General

The primary parts of the surface facilities are mainly independent from the kind of underground storage (salt cavern, porous rocks, …). They usually consist of:

- separation of solids and condensate
- gas flow measurement
- gas compression
- station piping and field lines
- pre-heating and pressure control
- drying and treatment.

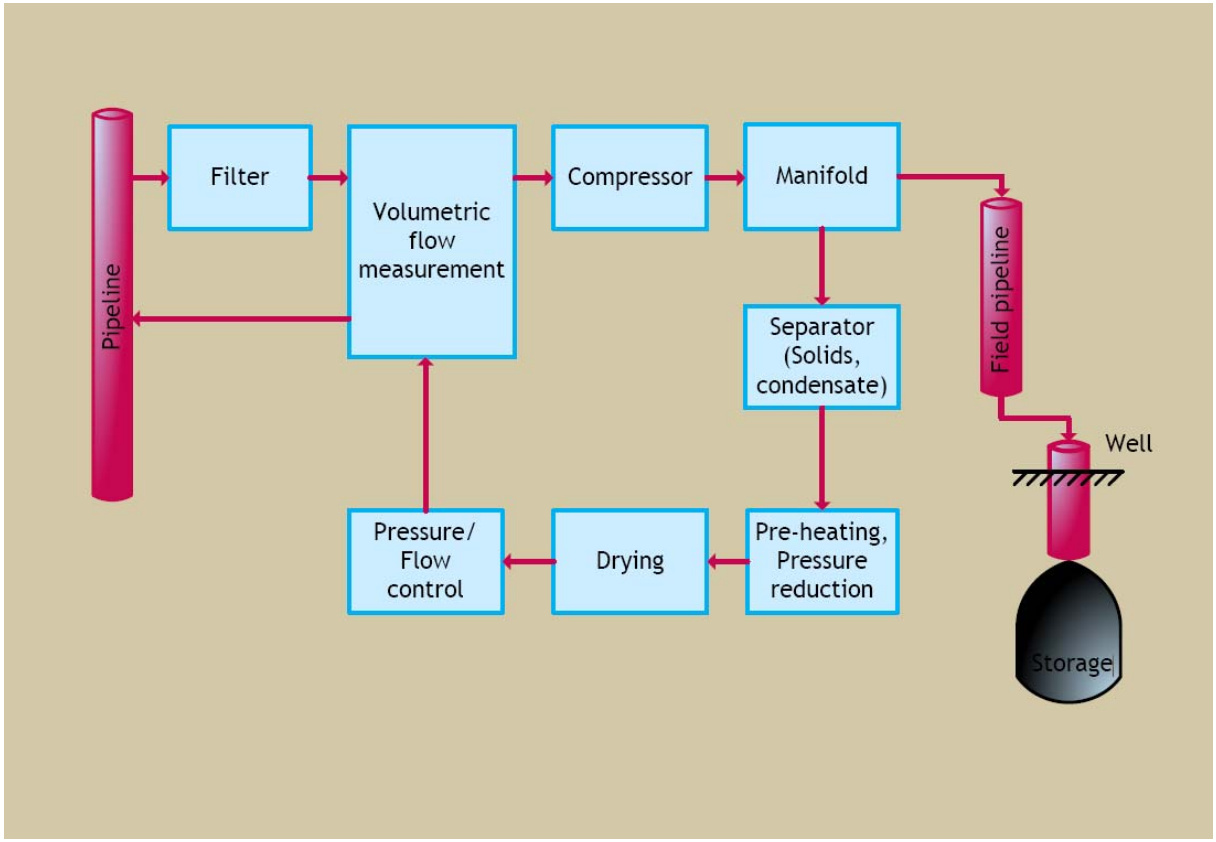

Fig. 2 - Plant scheme

The secondary and ancillary equipment depends on the plant concept and usually includes:

- the hot water boiler system for preheating the natural gas in order to prevent mechanical stress or hydrate formation during pressure reduction,
- the fuel gas and heating gas system,
- expansion systems,
- air supply for instrumentation,
- Injection stations for hydrate and/or corrosion inhibitors,
- collecting systems for reservoir fluids.

In addition to technological aspects, the plant concept also focuses on environment-related requirements. In this case, particular attention is paid to noise control and to minimize gaseous emissions.

The gas storage facilities are designed with respect to control and automation technology, so that they can be operated by means of simultaneous remote control from a central control room without personnel being directly on site. Redundant safety systems ensure automatic shutdown of the plant in case of abnormal operating conditions.

3.2 Surface facilities

3.2.1 Separators

Depending on the place in the technological flow line, fluid or solid particle separators or combined types with several construction principles (vortex, edge types, cartridge filters) can be used.

3.2.2 Gas flow measurement

The amounts of gas to be handled in an UGS are very huge, up to millions of cubic meters per day. Therefore, it is very important to be able to measure both the quality of the gas (calorific value, components, moisture etc.) and its quantity.
This needs special equipment approved by authority as there is also a tax-related issue. Several types of flowmeters (ultrasonic, turbine, vortex types) are used in combination with several flow computers and gas chromatography equipment.

3.2.3 Station piping and field lines

Station piping and field lines are similar to a chemical plant and are one of the basics in a modern storage. Nevertheless, piping and corresponding valves, sensors and special components have to withstand pressure and corrosion over a long time and have to be reliable for smooth operation of the whole storage.

Fig. 3 - Station piping UGS Nuettermoor

3.2.4 Compressors

Since the pressure level of the feed pipelines is much lower than the storage pressure, the natural gas has to be pressurized with big compressor equipment. The working principle (turbo- or piston-type) is essential for the operation behavior and operation range of the compressor.
The special layout considering the possibilities of the compressor – driver combination and the demands of the storage structure is one of the special experiences of a storage planning engineer. A bad design at this point would waste big amounts of energy, money and time. Big compressors with some megawatt power are required for this special purpose.

3.2.5 Pre-heating and pressure control

This part of a storage is designed to provide the required amount of gas at the right time at the suitable pressure level for feeding the pipeline as needed.
In this respect special know-how is also necessary, since a severe drop in temperature (caused by Joule-Thomson effect) may cause damage to constructions or will support forming hydrates in the pipes and equipment.

3.2.6 Drying plant, treatment

To be able to deliver natural gas with the appropriate properties to the pipelines, it has to be dried or treated according to the content of several components. Only well cleaned gas is suitable for a natural gas supply at a high technical level of reliability.
De-hydration plants, based on glycol absorption are very common. When there are higher demands, special solid bed absorption or pressure swing technologies are needed.
Also cold frac or low temperature separation are proofed technologies for the UGS application.

3.3 Subsurface facilities

3.3.1 Types of underground storages

There are several kinds of underground storage types, depending on the geological formation:

- salt caverns,
- storage facilities in porous rocks (aquifers and depleted oil/gas fields),
- unminable coal seams,
- tubular storage facilities.

3.3.2 Caverns

Caverns are leached by pumping fresh water through wells in thick rock salt layers and pumping out the more or less salt-saturated brine.
DBI has gained experience in the field of engineering, construction optimisation and operation of gas cavern storage facilities for more than 30 years and deals with geology (analysing geological exploration data), cavern design, the leaching process up to gas filling and the way of operation.

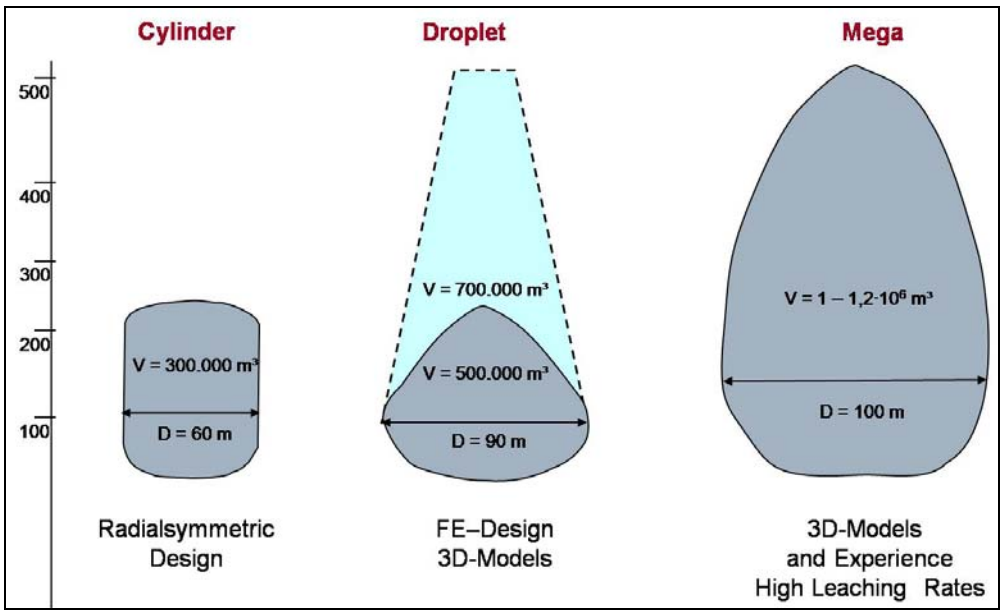

Fig. 4 - Examples of different shapes and sizes of salt caverns

3.3.3 Aquifer structures

Furthermore, DBI has gained experience in the field of building gas storage facilities in aquifer structures (via water displacement out of the pore space of reservoir rock) and in totally or partially depleted gas and oil fields. DBI deals with exploration and screening of suitable locations, generation of an optimal displacement front and contemplations about the mixing of e.g. storage gas with inert reservoir gas. Properties of potential reservoir - and cap rocks for calculating the effective storage capacities like pore space characteristic or frac gradient as well as the optimal storage operation are also within the fields of activity of DBI.

3.3.4 Tubular storage facilities

To store small quantities of gas in close proximity of gas consumers (e.g. towns or industrial areas) tubular storage facilities are designed by DBI. Storage facilities in abandoned mines are an exception on which DBI has also relevant experience.

4 Business Areas

4.1 General

DBI performs engineering services and research work in the field of engineering and construction of gas storage facilities in salt caverns, storage facilities in porous rocks (aquifers and depleted oil/gas fields) and in tubular storage facilities – surface and subsurface.

Business areas in oil/gas production and gas storage include the following issues:

- exploration and production of natural gas and oil reservoirs
- construction, operation and safety of the aboveground and underground gas storage facilities (UGS), also special CO_2 – UGS cases
- geologic, reservoir engineering and economic expertise of gas and oil fields as well as underground gas storage facilities
- computer simulation and software development with 3D geological and reservoir modelling as well as production simulation
- feasibility studies, business plan development and approval procedures
- engineering and operation of surface and sub- surface facilities
- engineering and application of enhanced recovery measures for oil and gas (EGR/EOR)
- special services
- research and development in the range of oil and gas production, gas storage and CO_2 sequestration

4.2 Oil and gas reservoirs

DBI is active in the field of the development of new oil/gas fields and in efficiency enhancement for the oil and gas production in depleted fields.

This work is based on:

- geology with evaluation of geological and geophysical exploration data and analysis of productivity tests
- production history with analysis of production data

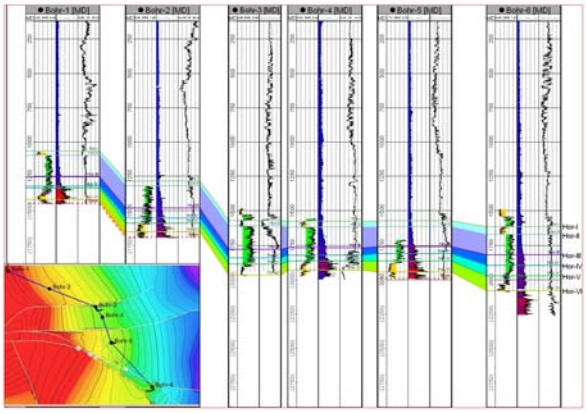

Fig. 5 - Cross section with geophysical well LOGs

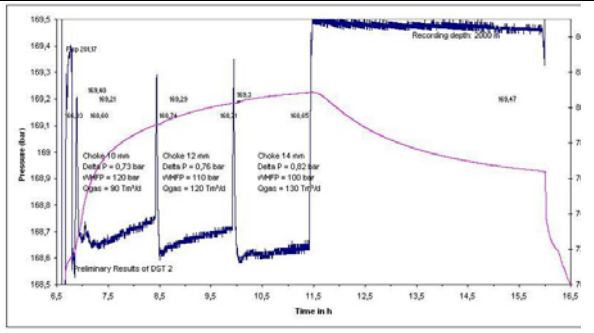

Fig. 6 - Example for a DST - drillstem test

The following methods are used:

- data preparation and analysis
- 3D geo-modelling
- 3D reservoir modelling
- production simulation

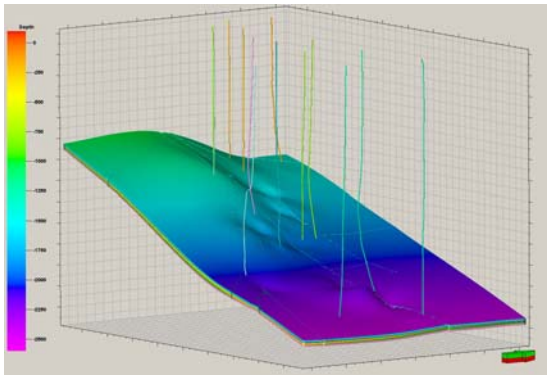

Fig. 7 - 3D-geo-model with data wells

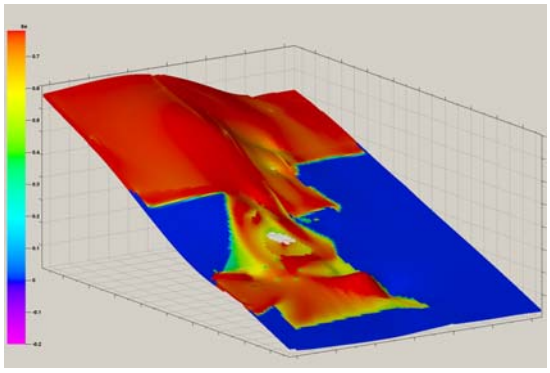

Fig. 8 - 3D-reservoir model with oil saturation

The aim is to enhance the production coefficient and the efficiency in oil/gas production by defining and adapting adequate methods to field conditions:

- support and increase of production of long produced fields
- development and adaption of methods for well treatment and stimulation (frac, polymer plug)
- development and adaption of secondary and tertiary production methods (EOR/EGR) - flooding with water, steam, polymer, gas, CO_2 and biogenic flooding.

4.3 Computer simulations and software development

- complex 3D-reservoir simulation of gas – oil – water with data bases
- complex 3D-Cavern leaching models with Log-data bases
- simulation for stress and deformation behaviour of pipelines, casings and cavern cavities
- development and implementation of management models of cavern and underground porous storage facilities
- systems for archiving and analysis of production and operational data bases

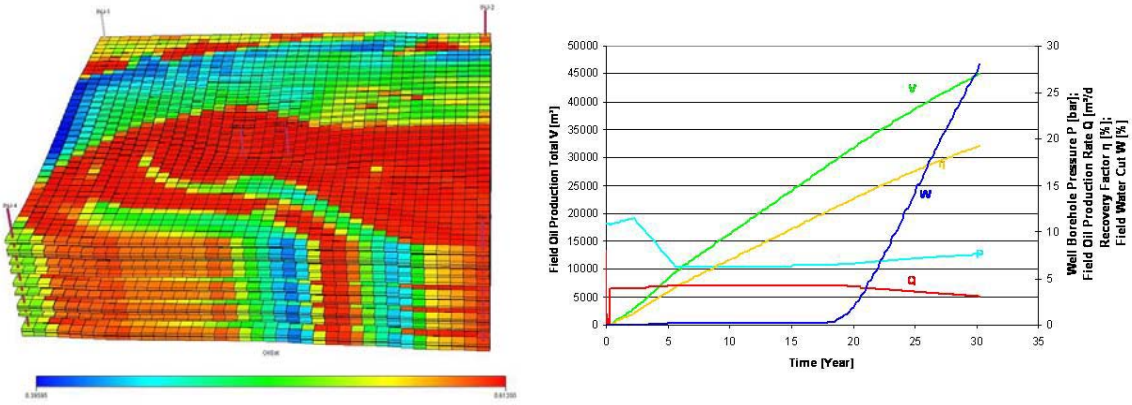

Fig. 9 - 3D-reservoir model and diagram with production curves of a production for water flooding

4.4 Sub-surface facilities

- Reservoir management
- Deposit and production technologies
- Drilling and completion of wells
- Leaching technology of salt caverns
- Rock mechanics
- Soil mechanics
- Montane technologies and soil technologies
- Engineering of cavern and underground porous facilities (aquifers, exploited deposits)

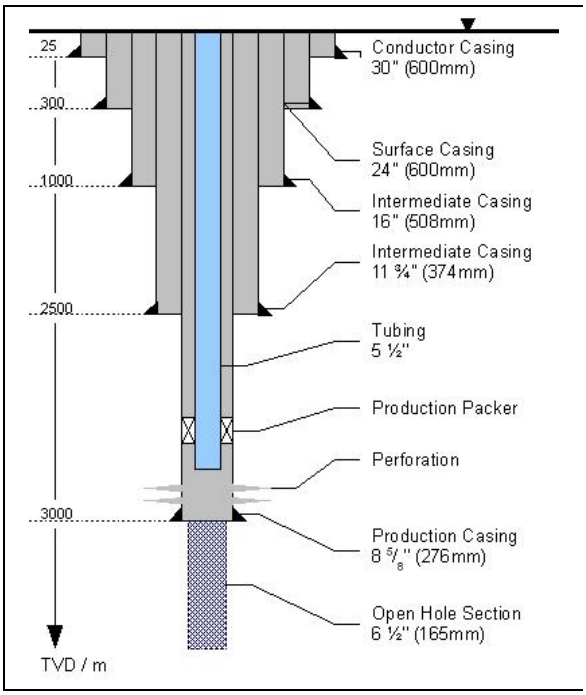

Fig. 10 - Completion scheme of a high productive gas production well

4.5 Safety analysis

The area of expertise of DBI includes the analysis of aged and worn UGS facilities. At that point safety as well as operation and capacity of aged storage facilities are analysed.

Especially analysed are thereby:

- well integrity, particularly of old wells
- mixing of different gas qualities
- identification of gas losses
- control and adjustment of storage operation

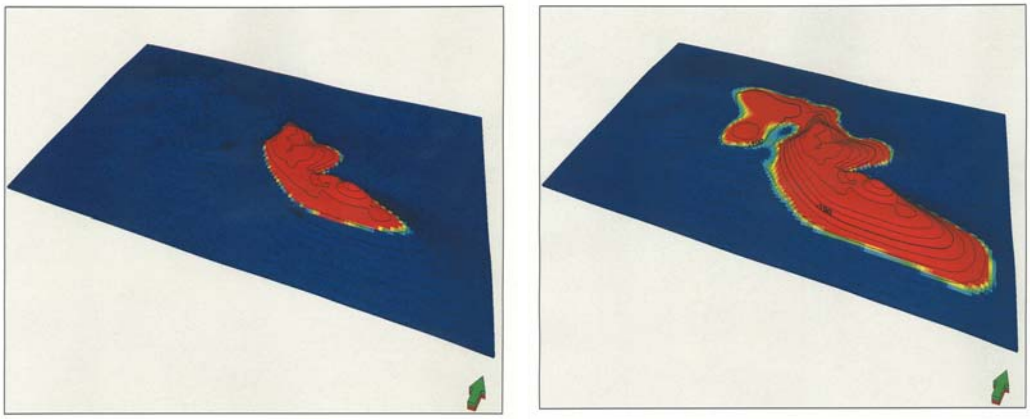

Fig. 11 - Identification of gas losses – gas saturation after simulating the correct storage operation in comparison with gas saturation after simulating the historic, real and incorrect storage operation (red = gas, blue = water)