Experience, problems and perspectives for gaseous helium storage in salt caverns on the territory of Russia

S. A. Khan (Gazprom JSC, Russia),
P.G. Tsybulskiy, V.A. Kazarian, A.I. Igoshin,
V.B. Sokhranskiy (Podzemgazprom Ltd., Russia)

Key words: storage, helium, natural gas, rock salt, deposit, underground reservoir, East Siberia

Abstract

Together with deployment of gas resources in East Siberia planned for the coming decade, a serious concern is helium utilization, its deposits in hydrocarbon accumulations exceeding 5 bln. m³, and its content varying from 0.25 to 0.58%. According to estimates available, demand for Russian resources in order to cover a significant part of the world need for helium will come in 2020–2030s. Helium recovered prior to the period mentioned should be effectually stored in caverns formed in rock salt deposits.

The possibility in principle to store helium in salt caverns is based on the experience in operation of underground helium storage in Orenburg region.

Geologic possibility of forming large helium storages is based on the universal development of rock salt deposits in East Siberia. In order to estimate a possibility of forming rock salt storages at this territory, the basin has been zoned according to distribution and bedding conditions for salts of various ages, as well as reservoir beds suitable for injection of brine formed during underground reservoirs construction.

Following the data available on mining-and-geological conditions of the areas planned for helium storages location, the most rational variants for their construction and operations has been proposed.

1. Introduction

The perspective of development of natural gas deposits containing high amount of helium with the steady growth in consumption of the latter in various spheres of human activities leads to the necessity of storage of a considerable amount of gaseous helium. In Russia, Gazprom JSC possesses the experience of storage of gaseous helium in underground caverns formed in rock salt especially for this purpose.

In 1979 the first underground reservoir for gaseous helium storage in rock salt was put into operation. Underground reservoirs were built following the method of dissolution through bore wells. Industrial effluents from a helium treatment plant were used as a dissolvent, the fresh water content being over 90%. Compressed air was used as a “blanket”, a fluid regulating cavern shaping.

In total 6 underground caverns have been built and put into operation, the total geometric capacity being 235 thou. m³, at the depth of 1350–1450 m. The spatial planning scheme for helium storage is given in Fig. 1.

Fig. 2 shows a typical underground reservoir for compressed helium.

Helium is injected into underground reservoirs by diaphragm-type compressors; extraction is possible due to gas super-pressure in underground reservoirs.

The helium concentrate of the following composition is stored in underground reservoirs for a long period of time: 80–93% He, not more than 20% of N₂, not more than 4% of H₂, not more than 1% of CH₄, and not more than 0.5% of O₂+Ar. The maximum helium operating pressure is 18 MPa, the buffer pressure is 5 MPa.

Recently, continuous helium surface survey has demonstrated significant reduction in helium discharge in vicinity of operating and observation wells. This fact may be explained by rock salt self-healing, reduction in the pressure of the gas stores due to periodic recovery, current use of more advanced locking accessories. The actual annual process losses make not more than 0.012% (volume) evidencing in favour of practically complete impermeability of operating underground reservoirs.

Currently there is no experience in storage of helium in salt caverns abroad.
Fig. 1 — Spatial planning scheme for underground helium storage in rock salt deposits

Fig. 2 — Underground gaseous helium reservoir
In the USA gaseous helium is stored at Cliffside storage facilities (Texas) that was formed on the basis of an abandoned gas deposit and is capable of keeping nearly 1 bln. m³ of helium concentrate (70% of helium).

2. Estimates for helium production and consumption

Currently, approximately 150 mln. m³ of helium per year is consumed all over the world; by the year 2030 this figure is estimated to double. In the recent years annual increase in helium consumption equals to 5%. Fig. 3 shows estimates for consumption of helium all over the world for the period up to 2030 according to two helium consumption growth scenarios: the pessimistic scenario: 3%, and the optimistic one: 5%.

The leading helium producers (both at the moment and, as estimated, in future) are 4 countries: USA, Russia, Algeria and Qatar.

By the year 2030 the production of helium in the USA will reduce drastically due to depletion of gas resources.

Cumulative helium recovery by Algeria and Qatar will make only approximately 45 mln. m³. Meeting of the world’s demand in helium by 2030 will be possible only on the account of helium recovered in East Siberia at oil-gas condensate fields that contain a large amount of helium (0.25-0.58%).

The estimates of annual world’s helium production with consideration to East Siberian deposits are demonstrated in Fig. 4 (according to the Institute for Oil and Gas of the Academy of Sciences of the Russian Federation). The dashed line represents the volume of helium production in Russia without taking into account deposits in East Siberia.

At least four oil-gas condensate fields containing large amount of helium are planned to be developed in East Siberia: Kovyktinskoye, Chayandinskoye, Yurubcheno-Tokhomskoye and Sobinsko-Paiginskoye oil-gas condensate and gas-condensate fields. Helium content in the natural gas recovered from the mentioned deposits is shown in Table 1.

3. Focal aspects of helium storage in East Siberia

In the process of development of deposits in East Siberia, the issue of accumulation of large amount of helium will rise as early as in the near future; the issue will remain acute until the helium market becomes developed enough.

Geological and engineering possibility for formation of underground helium deposits is based on omnipresent location of rock salt deposits at the territories developed, such deposits forming one of the world’s largest East Siberian salt basin.

In order to determine facilities location and exploration works performance the salt basin was zoned in accordance with the construction conditions for underground storages of various designations, including helium ones.

The zoning of East Siberian salt basin according to conditions of formation of underground storages by means of salt dissolution through bore wells is based on three principal conditions predetermining perspectives for formation of underground reservoirs in rock salt:

- availability of sufficient salt rock masses of appropriate lithological composition, with the optimal salt bedding depth (700–1500 m);
- availability of sufficient amount of natural solvent (water);
- possibility of removal of resulting construction brine by means of surface and underground disposal or industrial utilization.

As far as a possibility of provision of the reservoir formation process with process water for salt dissolution, the territory in general is characterized by a developed ricer network (primarily, Angara river basin), and presence of alluvial and intrapermafrost water, etc.

Rock salt at the territory in question can be found in Sordian and Cambrian systems deposits that are characterized by significant changes in the coeval rock facies composition both in terms of the area and vertical section.

The advantages consists primarily in developed Cambrian saliferous units represented by various rocks, unevenly distributed in section and grouping into well-distinguished and traceable lithologic-and-facies complexes and zones.

The scheme of East Siberian salt basin zoning has been compiled by mans of overlapping formation development zones with various Cambrian salt complex bedrocks perspective for underground storage (Fig. 5). The scheme demonstrates that the majority of the salt basin may be used as underground helium storages formed in rock salt.
Fig. 3 — Consumption of helium in the world for the period up to 2030

<table>
<thead>
<tr>
<th>FIELD</th>
<th>% (VOLUME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOVYKTINSKOYE GAS-CONDENSATE FIELD</td>
<td>0,25</td>
</tr>
<tr>
<td>CHAYANDINSKOYE OIL-GAS CONDENSATE FIELD</td>
<td>0,53</td>
</tr>
<tr>
<td>YURUBCHENO-TOKHOMSKOYE OIL-GAS CONDENSATE FIELD</td>
<td>0,31</td>
</tr>
<tr>
<td>SOBINSKO-PAIGINSKOYE</td>
<td>0,58</td>
</tr>
</tbody>
</table>

Table 1 — Helium content at East Siberian deposits
Fig. 4 — Annual helium production estimates
Fig. 5 — Zoning scheme of East Siberian salt basin in terms of the conditions of underground helium storage formation in rock salt

Due to the fact that there are practically no brine processing facilities on the territory of the basin, the key means of construction brine removal will be its discharging to the depths. A sedimentary cover section of East Siberian salt basin demonstrates a significant amount of deep permeable bedrocks containing water, oil, gas and condensate. However, not all of them meet the requirements for facilities meant for construction brine discharge.

There are a number of bedrocks notable for relatively good filtration-and-capacitance properties, characterized by more or less regional distribution and lying at the depth down to 3000 m. Using reservoir rocks properties estimates schemes forming such bedrocks, as well as lithologic and facies maps of salty terrigenous deposits a regional zoning scheme for East Siberian basin in terms of construction brine removal (Fig. 6) has been compiled.

When compiling the scheme, consideration was made only to the areas of bedrock types I, II and III (high-high, high and average quality), their permeability being 100-1000 mD and more.

Presented zones evidence for a wide range of manoeuvres for helium storage formation in various scenarios of gas processing facilities location at the territory of East Siberia.

Within the perspective areas where rock salt lies at the depth of 700–1500 m, and its mass varies from 20 to 100 m, it would be advisable to construct vertical single-well underground reservoirs, their geometric capacity being at least 200 thou. m³, two-well tunnel excavation with the individual volume capacity of 300-400 thou. m³.
For formation of underground reservoirs in rock salt a well-tested scheme is supposed to be used. Water from land-based or underground sources is injected into drilling wells; the brine resulting from rock salt dissolution rises to the surface and then is pumped into deep lost circulation horizons or transferred to brine consuming facilities. Project underground mines configuration is formed by injection to drilling wells of a non-solvent.

In order to support underground reservoirs construction a water-brine complex will be built, the complex will be disassembled as soon as construction is completed.

For formation of a vertical type underground reservoir with the capacity of 200 thou. m$^3$ 1.6 mln. m$^3$ of water will be required; 1.8 mln. m$^3$ of brine will be used or discharged to lost circulation horizons (taking into account the brine displaced from the reservoir in the process of primarily filling-in with helium concentrate).

The average water injection rate for underground storage formation makes 200 m$^3$/h. The time needed for construction of an underground reservoir with the volume of 200 thou. m$^3$ equals to approximately 1 year.
The maximum underground mine diameter, its form and the distance between process wells is determined by special rock mechanics calculations based on surveys of mechanical properties of rock samples obtained in the process of prospect and process wells drilling.

The water-brine complex comprises the following key components (Fig. 7):
- process water intake (from land basins or artesian wells);
- waterway from the intake to the ground complex area of the underground storage;
- process facilities and buildings for underground reservoirs construction including:
  - ground buffer tank for water;
  - pump station for transfer of water to underground reservoirs under construction and pumping of brines resulting from construction for further utilization;
  - blanket feed package;
  - ground brine sinker;
  - intra-site water, brine and blanket networks for the period of underground reservoirs construction;
- brine pipes for transfer of brine for utilization;
- operating wells;
- injection wells or discharge of brine into underground bedrocks.

Underground helium concentrate storage is planned to be put into operation under the so-called "non-brine" scheme, namely: helium concentrate is injected into an underground reservoir by means of compression at the compressor unit of the underground storage or gas processing plant (Fig. 8). Helium concentrate will be recovered from underground storage due to super-pressure, herewith underground storage will still contain cushion amount of gas with the pressure predetermined by mechanical characteristics of rocks and conditions of helium concentrate delivery to consumers.

Because of lack of geologic data the principal objective consists in development and implementation of a geological exploration program for rock salt fields in vicinity of gas processing facilities in East Siberia. Such operations require 2-3 years to be implemented. Pre-design and design works for construction of storages with account to the period of design coordination will take nearly 3 years. Construction of first underground helium reservoirs will last 1-2 years. Thus, the period from commencement of geological exploration program development to commissioning of first underground helium reservoirs will equal to 6 years.

Fig. 7 – Principal process scheme for underground gas storage in rock salt

1, 2 – water intake alternatives: from surface sources, from underground sources, respectively; 3 – water pump station; 4 – process water pipe; 5 – brine pipe; 6 – brine transfer preparation unit; 7 – brine pump station; 8, 9 – brine removal alternatives: discharge to injection wells, transfer to salt consuming facilities, respectively; 10 – blanket injection and recovery unit; 11 – blanket pump station; 12 – blanket pipe; 13 – underground reservoirs.
Fig. 8 — Helium production and storage

4. Conclusion

Taking into consideration the aforesaid, the following conclusions may be drawn:
– Gazprom JSC possesses a technology for gaseous helium storage in underground reservoirs formed in impermeable rock salt.
– On the territories of estimated location of gas-and-chemical facilities in East Siberia there are plenty rock salt deposits perspective for underground helium storage formation.
– Creation of underground storages in rock salt in vicinity to gas processing plants will provide the solution of the issue of helium accumulation in East Siberia until the demand for helium grows.