NEW TECHNOLOGIES AND UGS DEVELOPMENT IN RUSSIA

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Background

In 2015 we will celebrate 60-th anniversary of starting of underground gas storage (UGS) creation activities in Russia and Centennial of UGS creation beginning in Canada and in the world.

In 1 955 Council of Ministers of USSR approved Decree № 1673 dated 12 September "Concerning beginning of underground gas storage creation activities in USSR". According to this decree Ministry of Oil Industry was obliged to fulfill in II quarter of 1957 exploration in Moscow region of two geological structures suitable for underground gas storage creation. Geological and Technical Departments of Glavneftegasexploration were obliged to summarize exploration data and provide Council of Ministers of USSR with proposals regarding UGS creation.

First UGS in Russia was started-up in 1958.

UGS Performance Indicators in Russia

Located in key gas consumption areas, underground gas storage (UGS) facilities are an integral part of the Unified Gas Supply System (UGSS) of Russia.

It won't be an overstatement to say that Gazprom is not only the largest global company in terms of gas production, transmission and export, but also a leader in the UGS sector.

UGS utilization allows managing seasonal fluctuations in gas consumption, shaving peak loads in the UGSS and securing flexibility and reliability of gas supplies. UGS facilities ensure up to 22% of gas supplies to Russian consumers during the heating season. In periods of cold snaps this figure amounts to 30%.

There are 25 acting UGS facilities in Russia, of which 8 are built in aquifers and 17 – in depleted fields. 4 UGS facilities are at the design stage and 3 – at the construction stage, including 2 in salt caverns. The UGS infrastructure is comprised of 4,401 wells including 2,564 production and 1,837 monitoring ones; 3,375 km of gas pipelines with 2,912 km of flowlines; 22 gas treatment units; around 2,000 pressure units; 233 gas compressor units with 782.6 MW in overall capacity.

Fig. 1 Kasimov UGS

In 2010 Gazprom Group withdrew 40.8 billion m^3 of gas from its Russian UGS facilities. The demanded maximum daily deliverability made up 579.5 million m^3 and 47.7 billion m^3 was injected into storage.

The period between 2007 and 2011 was marked by the unique UGS operating conditions in Russia and Europe. For instance, the period of maximum total gas withdrawals from all Russian UGS facilities between 2007 and 2008 was associated with the abnormally cold winter in Central Asian countries. In early 2009 there emerged the need to bring Russian UGS facilities to the maximum daily deliverability due to the extremely low temperature in Central Russia. During the withdrawal period 2009-2010 around 30% of the planned or average amount was collected throughout Russia and there even emerged the need to inject gas into some UGS facilities. The withdrawal period 2010-2011 was featured by extra gas demand in late February – early March due to a cold snap in the entire European Russia, and the domestic UGS facilities were operated at maximum possible capacity during 17 days.

Therefore last decade characterized with high variable UGS operational modes from pick to minimal extractions and even injections at winter seasons.

By the autumn/winter period 2011-2012 the backup gas reserves in UGS facilities stood at 65.2 billion m^3 and the potential daily deliverability – 647.7 million m^3. Expanding UGS capacities is among Gazprom's strategic objectives. It costs much less to create extra UGS capacities for manag ing seasonal swings in gas consumption than to create the relevant backup capacities in gas production and transmission.

The draft General Scheme for the Gas Industry Development until 2030 stipulates the maximum daily deliverability of 1.0 billion m^3.

The analysis of this operational environment in the UGS sector proves that we have reached a new era requiring modern approaches both to operation and to sci-tech support in creating and operating UGS facilities. Further development of the UGS sector is impossible without the R&D progress, high standards of analytical and experimental studies as well as the synergy of R&D and the industry.

Major Goals and Trends in Russian UGS Sector

Being fully aware of the UGS importance for the Unified Gas Supply System of Russia and for export supplies, Gazprom took crucial measures to drastically retrofit and create highly efficient, reliable and safe UGS facilities.

The short-term goals to develop the UGS system are outlined in the relevant Activities for 2011-2015 and approved by Gazprom's Management Committee.

The top-priority UGS development goals in Russia are as follows:

- expanding and retrofitting the existing UGS facilities so as to boost their potential;
- technically upgrading UGS facilities in order to replace obsolete and worn out equipment and process plants by new ones that will be more efficient in terms of both economics and environment; simultaneously, they will guarantee a strong high-tech potential;
- creating new UGS facilities as the existing facilities do not permit further expansion; besides, new UGS facilities will make it possible to expand the geographic reach of the UGS network that will raise the reliability of the entire UGSS;
- creating new peak-shaving UGS facilities or facilities with a multi-cycle operating regime in salt caverns so as to secure prompt responses to all types of consumption irregularities.

It is planned to replace more than 40 compressor units and drill over 200 wells at existing UGS facilities in less than five years under new projects and with the use of new technologies.

At present, two new UGS facilities are being built in Russia: Kaliningradskoye and Volgogradskoye facilities in salt caverns.

Pre-investment developments have been completed for a number of new UGS facilities.

The Detailed Engineering Plan has been elaborated for the Bednodemyanovskoye UGS facility (Mordovia, Penza Oblast), where the working gas capacity in a deposit is determined at 5.0 billion m^3. Well drilling is in progress.

The working gas capacity will total 1.0 billion m^3 at the Shatrovskoye UGS facility (Kurgan Oblast), 0.34 billion m^3 at the Novomoskovskoye UGS facility (Tula Oblast) and 0.5-0.6 billion m^3 at the Arbuzovskoye UGS facility (Republic of Tatarstan).

The Bednodemyanovskoye UGS facility will suffice to meet the requirements for daily deliverability during anomalously cold spells in Central Russia. Moreover, it will be used to flatten out seasonal fluctuations and for export gas supplies.

The Shatrovskoye UGS facility is expanding the UGS network in Russia. Production well drilling is scheduled for 2012.

The Novomoskovskoye UGS facility will be built in salt caverns and will serve the same purposes as the Kaliningradskoye and Volgogradskoye UGS facilities.

The Arbuzovskoye UGS facility will deal with the objective to raise the gas supply reliability in the Republic of Tatarstan.

Eastern Siberia is a new gas center of Russia. More importance will be given to Eastern Siberia and the Far East between 2012 and 2020.

Based on fields in the Irkutsk Oblast, Republic of Sakha, Krasnoyarsk Krai and Sakhalin offshore areas, a large gas production center will be established in this region. In favorable conditions the annual gas production in Eastern Siberia and the Far East may amount to 110 billion m^3 by 2020.

Gazprom was appointed by the Russian Federation Government as the coordinator of the Development Program for an integrated gas production, transportation and supply system in Eastern Siberia and the Far East, taking into account potential gas exports to China and other Asia-Pacific countries (Eastern Gas Program).

The Eastern Gas Program stipulates the search for geological structures for creating underground gas storage facilities in the mentioned regions.

At the moment, geological exploration is underway in salt deposits of the Irkutsk Oblast for the purpose of creating the Angarskoye UGS facility. It is planned to drill five exploratory wells soon.

In the Tomsk Oblast exploration drilling is coming to an end so as to create the Tatyanovskoye UGS facility. In addition to other purposes, the facility will also improve the reliability of gas supplies via the Altai gas pipeline.

Geological exploration is progressing in the Malositenskoye UGS facility in the Khabarovsk Krai. The first exploratory well is being built and everything is ready for seismic survey.

A large scope of seismic survey is planned for 2011-2015 to search for potential UGS sites in the vast areas of Eastern Siberia and the Far East.

Oil, gas and condensate fields of Eastern Siberia are unique due to their multi-component structure with high content of helium from 0,25 till 0,58%. During further decade four big gas-condensate fields in Eastern Siberia will be developed. Total proved gas reserves of those fields are more than 4 trillion cubic meters with helium concentration. Total proved reserves of helium at those fields are equal 5 billion cubic meters.

Helium reserves in these fields considerably exceed the global demand for this rare product for many decades to come. That's why our researchers and experts are facing the challenge to work out a multi-level system for storing helium concentrate and helium for as long as the efficient utilization strategy requires.

One of possible ways to reduce investments for the establishment of cushion gas volume in the reservoir is partial replacement of injected cushion natural methane gas for less expensive non-hydrocarbon gases, in particular CO_2. Now investigation of such opportunities are under the process at the Russian UGS created in exhausted gas field.

Gazprom UGS system abroad

As a part of Gazprom's strategy to ensure reliability and flexibility of gas export deliveries to European consumers during periods of high demand in winter, and implementation of repairs on gas transmission system (GTS), the Company is successfully and consistently working to develop underground gas storage system in Europe.

Realization of independent UGS projects allows to minimize risks of insufficient capacities while pick gas demand.

Gazprom already has underground gas storage facilities (UGS) in Latvia, Germany, Serbia, UK and Austria.

From 2006 till 2011 Gazprom's UGS capacities in Europe has increased from 1,4 to 2,5 billion cubic meters of working gas and from 18,2 to 30 million cubic meters of daily withdrawal rate.

Special researches and calculations fulfilled by VNIIGAS has confirmed that to secure Russian gas export to European consumers quantity of gas reserve in UGS in Europe should be equal to 5% from annual volume of total export. Therefore Gazprom decided to further increase its storage capacities abroad. New UGS facilities are being planned in Netherland, Germany, Czech Republic, Grate Britain and etc.

By 2015, the Company plans to increase the storage capacities in European UGS to almost 5 billion cubic meters and 70 million cubic meters of daily withdrawal rate, or almost double the current figures.

The East-oriented vector of Russian gas exports evolves successfully as well. Depending from gas transportation routes Russian annual gas export for China in 2030 could be 30 ("Altay route") or 38 ("East Program") billion cubic meters.

Therefore development of UGS system in China for securing import deliveries is also very important question. It is necessary to mention successful experience of cooperation Gazprom with Chinese specialists in framework of UGS project at the oil field "Jen-11".

On November 2011 Gazprom and State Assets Committee of Belorussia signed Agreement on the purchasing of 50% of JSC "Beltransgaz" shares. Taking into account purchasing of 50% shares of JSC "Beltransgaz" in 2007-2010 Gazprom now is an 100% owner of 7490 km of main pipelines and 3 UGS (Pribugskoe and Ocipovicheskoe in aquifer and Mozirskoe under construction in rock salts) with total capacity near 1 billion cubic meters of working gas and 13 million cubic meters of daily withdrawal rate. This will increase safety of Russian export to Europe. In 2011 Russia exported through Belorussia to Europe more than 30 billion cubic meters of gas.

New Technologies and UGS

Russian UGS facilities owned by Gazprom Group host investment projects involving advanced engineering solutions. These projects cover the following sectors:

- Gas compression

Energy saving technologies are becoming increasingly important within the UGSS. In this context, the use of ejectors during gas injection into and withdrawal from UGS facilities as well as during gas withdrawal from ancillary facilities and equipment of UGS stations is one of engineering and scientific priorities for our experts.

The operation of gas compressor units at existing UGS facilities is characterized by a wide range of operating regimes and compression degrees of injected gas as well as by the irregularity of daily injection rates.

In order to streamline the operation of GCUs a technology has been introduced featuring simultaneous gas compression and ejection during injection into storage.

The compressor shop is isolated from the varying pressure system at an underground gas storage facility, while excessive pressure at the compressor outlet is

switched to the mode of continuous ejection of extra gas from a collecting intake line of the compressor shop.

So, the control function is transferred to ejectors. The control is exerted by means of changing the quantity of connected gas ejectors as well as equipping an ejector unit with several technological groups of ejectors fitted with different air-gas channels.

Overall, the technology enables to:

– boost the efficiency of gas compressor injection beyond the cumulative capacity of GCUs installed;
– reduce energy consumption (fuel gas, electric power, engine oil, etc.);
– control the rate and pressure of gas injection into storage;
– increase the mean time between GCU failures;
– mitigate an adverse environmental impact on population centers located near UGS facilities.

The ejection technology has been successfully introduced at various underground gas storage facilities such as:

– Peschano-Umetskoye UGS facility (Russia) built in a depleted gas deposit. GCU type – centrifugal supercharger and electric drive;
– Bernburg UGS facility (Germany) built in salt caverns. GCU type – reciprocating compressor and electric drive.

Fig. 2. Ejector at the Bernburg UGS

Besides, GCUs are employed with centrifugal superchargers under a parallel/series circuit scheme (Yelshano-Kurdyumskoye, Sovkhoznoye UGS facilities, Kanchurinsko-Musinsky UGS complex); dry gas-dynamic seals and magnetic bearings are also in use. Special attention is paid to the reverse flow operation of compressor stations during gas injection and withdrawal. This enables, on the one hand, to enhance the utilization rate of costly equipment and, on the other hand, to increase, if necessary, the daily deliverability at the final withdrawal stage when storage pressures significantly decrease.

- Gas treatment system

Gas treatment equipment at UGS facilities should meet more stringent requirements than those in place during gas production due to low (down to subzero) gas temperatures at the initial withdrawal stage, dramatic fluctuations of daily flow rates, oil and condensate contaminants in the fluid, high salinity of formation water.

The decline in reservoir pressure during the withdrawal season is accompanied by an aggravating adverse effect on the gas dehydration quality.

The solutions are:

– application of high-efficiency primary separators (carryover of moisture up to 5–6 mg/m^3 of gas, mechanical impurities – 3 mg/m^3, hydrocarbons – 15 mg/m^3); salts wash-over;

– application of high-pressure gas dehydration technologies;

– application of equipment with wide-range efficiency and low-response time;

– gas throttling up to the main pipeline pressure level after a dehydration unit;

– glycol recovery in soft heating units (using thermosyphons, applying an offset combustor).

Low-temperature separation is planned to be in place at the Sovkhoznoye, Kanchurinskoye and Shchyolkovskoye UGS facilities. At the Yelshano-Kurdyumskoye, Kaluzhskoye, Stepnovskoye and some other UGS facilities it is intended to apply absorption dehydration at pressure, which is close to gas inlet pressure at a gas distribution point. It helps reducing methanol consumption at an UGS facility, and excluding methanol utilization at sections from gas distribution points to the separation area.

Separation, mass-transfer and heat-exchange units for gas treatment facilities are supplied as pre-fabricated modular blocks with valve kits. Pipe and connecting joints and forges are manufactured at contractors' dedicated assembling shops.

- Well drilling and operation

Large-diameter wells are constructed with 245 mm production casing and/or horizontal well completion (Kasimovskoye, Shatrovskoye, Stepnovskoye, Kushchevskoye UGS facilities), as well as simultaneous multiple entry in the pay zone.

During well overhaul:

– clayless biopolymer drilling mud is introduced for killing wells and entering the pay zone. The Saraksan Russia-produced rhodopol gum is used as a biopolymer basis. The application of biopolymer drilling mud permits to save the natural formation permeability, decrease the absorption intensity, reduce the well development time;

– the technology of reservoir chemical bonding is improved by means of polyorganosiloxane based substances (organic-silicon siloxane). The application of new chemical substances for reservoir bonding has enabled to decrease or completely prevent sand production without well killing and bottom hole equipment replacement;

– activities are stepped up for stimulating enhanced recovery and wells. Organic and non-organic acids, surfactants and peroxidates based substances are applied. The stimulation result is an average two-three fold boost of production rates with a considerable reduction of depression.

– hydraulic packers are applied so as to shut off the production zone while replacing the Christmas tree and avoiding the cement bridge plug installation help drastically save time and material for well overhaul;

– new gravel pack technologies are applied. Particularly, a natural circulation method, which uses selected equipment and entirely stainless steel filter-frames;

– milling or hydro-mechanical slot perforation of casing pipes is done in the reservoir interval.

- Automated process control system (APCS)

The effective and up-to-date monitoring of the gas storage facility construction and operation, prompt monitoring of UGS facilities is performed through an automated process control system, which incorporates a number of hardware and software devices and tools aimed at:

– streamlining the control over technological facilities;

– enhancing the withdrawal of working gas from gas storage facilities (by 10 to 30% according to various estimates);

– increasing the process reliability of equipment;

– streamlining joint operation of an UGS facility and neighboring sections of the gas transmission system;

– preventing emergency situations;

– improving the working conditions of personnel, etc.

APCS is implemented as a multi-level system. The first level comprises sensors, control valves and fittings.

The second level – automatic control and logical management stations where controllers are used. The controllers are also utilized for gathering and processing information on process parameters, on the status of control valves and fittings.

The third level – a work station of the shift engineer to provide visual interpretation of the technology process and the effect of control.

All modern underground gas storage facilities are equipped with APCS systems.

New technological solutions have already enabled to reduce the scope of on-site construction and assembly operations by transferring a part of the work to plants. This has provided for a considerable increase in the quality of the work performance along with a reduction in its duration.

Maintaining Safe Operation of the UGS System is the Highest Priority Task

The operation of UGS facilities is defined by permanently high working pressures during the whole life-cycle of a UGS facility, and in some cases, when injection pressure is increased – by their shift to higher values. With that, cyclic oscillating thermo-baric loads on the wells, basic process equipment and pipelines require increased attention in assessing their technical status and maintaining it at the design level.

A complete cycle of diagnostic activities is carried out at UGS facilities with the help of advanced methods.

A list of technological devices, equipment and facilities undergoing such diagnostics follows:

– pressure vessels (dust arrestors, filter-separators, filters, absorbers, etc.), drums and tanks;

– surface and underground process pipelines (well pipeline, intra- and inter-field gathering pipelines, Christmas trees, gas distribution and gas collecting stations pipelines, gas processing units pipelines);

– wells used for different purposes, wellhead equipment, casing heads of UGS wells (diagnostics is carried out without killing a well);

– potentially dangerous linear sections of pipelines (motor and rail road crossings, pipeline crossings, aerial crossings, etc.);

– control valves and fittings, quick-release locks;

– compressor equipment;

– connection pipeworks for wells and compressor stations;

– weight-lifting devices.

For securing of industrial safety Gazprom has developed and successfully apply unique complex of in-well logging equipment and technologies. This complex allows to evaluate well integrity including casing and cement bonding without well killing.

Developed complex includes scanning magneto-impulse flaw detection, gas - hydrodynamic investigations and nuclear logging have no analogs in the world.

Developed technology provide with high resolution and minimal expenditures information about well's technical conditions which is comparable with results of logging in killed well.

Stress strain behavior of pipelines and engineering structures is examined by computational methods. Their results are used to perform technical maintenance of piping elements and insulation coatings of process pipelines.

Starting from exploration and design phase of an UGS facility Gazprom solves a number of geological and ecological tasks connected with the impact on geological structures (rocks, subsurface waters) and on the environment (atmosphere, soil, water bodies).

Most advanced technologies, equipment and methods are used to reduce adverse effects on subsurface rocks, hydrogeological conditions and the environment.

Operational activities of UGS facilities are in compliance with environmental protection, technical and social rules and standards of the gas industry.

Gazprom creates and implements for UGS facilities ecologically oriented technologies and approaches, tactical measures to minimize industrial impacts on the environment.

Adhering to developed technical and ecological regulations during the whole life cycle of UGS facilities enables to maintain the status of their high technical reliability and environmental stability.

Technical and managerial measures to support ecological safety of UGS facilities follow:

- UGS organization and management;
- cutting down atmospheric emissions;
- implementing advanced technologies and methods of natural gas combustion;
- development of low-noise GCUs as a compromise between technical characteristics and economical considerations;
- improvement of water management;
- reduction of solid and liquid wastes impact.

Major research developments in the area of UGS

Possessing several research centers Gazprom carries out the following major research developments in the area of underground gas storage:

1) Development of optimum control methods of aquiferous UGS facilities operation.

Proposed effect:

- increase in UGS daily operating efficiency;
- formation of persistent artificial gas deposits which provide for favorable conditions of a long-term cyclic operation;
- reduction or complete elimination in aquiferous UGS of such negative developments as disintegration of a gas bubble, its transition beyond a trap zone, reduction of a gas saturated volume, bearing out of large volumes of formation water while gas is being off-taken;
- optimal site positioning of wells, rate and sequence of their commissioning.

2) Research in durability of bottom-hole zone under elastoplastic strain of the formation.

Proposed effect:

- prevention of bottom-hole zone destruction by analyzing limitations of strength condition;
- reduction of opex caused by break down of bottom hole filters, production string, well-head;
- reduction of probability of failures in mechanical strength of the whole formation under prolonged cyclic oscillating load during its exploitation;
- upgrade of filtration models by more detailed modeling of geo-mechanical processes accompanying UGS operation and identifying filtration parameters of the formation, i.e.

allowable pressure drawdown, gas flow rates and maximum allowable formation water content in wells production.

3) Development of gas storages operation control algorithms and respective computer software.

Proposed effect:

- increase in the daily operating efficiency of wells and UGS facility as a whole by not less than 5 to 7%;
- utilization as practical applications of the theoretical research results of gas dynamic processes taking place in the formation and the bottom hole zone;
- implementation of automated control systems along the whole chain of underground gas storage: formation, well, connection pipeline, field facilities, gathering pipeline, gas treatment facility, compressor station, measuring point, gas mains.

The UGS sector is characterized by some specific peculiarities. For example, gas field exploitation causes a constant and gradual decrease in working pressure and a relatively constant withdrawal rate, which is not the case in UGS surface facilities or in their reservoirs. Besides the alternation of maximum and minimum allowable reservoir pressures throughout the year, the mobility and the direction of gas-water contact movement requires the coordination of well construction and overhaul activities with UGS exploitation regimes, and monitoring activity. Modern UGS installations are expensive and complicated industrial facilities. They are equipped with integrated systems, incorporating subsurface and surface technological and geological processes simulation systems in order to allow for fast system analysis and improved performance prognosis. High levels of UGS automation also imply the need for minimal level of staffing. This means that UGS staff needs specialized knowledge and skills in addition to having standard geological and engineering capabilities.

No high school trains licensed specialists who might satisfy the broad professional, technical and managerial requirements of a UGS staff member. As a rule UGS companies have to employ specialists with a standard industry educational background: geological, geophysical, drilling, development of oil and gas fields, engineering and process systems, etc. The knowledge of any of these specialists is very specific. At best, they have experience in gas field development and operation.

In Russia the issue has been addressed with an initiative to build specific curricula dedicated to underground gas storage (UGS) competencies. The curricula are jointly designed by JSC Gazprom and organisations which have scientific, intellectual and teaching potential, and which also have appropriate experience and staff to take on the work.

Conclusions

The long-term scientific and operational expertise acquired by OAO Gazprom enables not only to support the execution of proposed plans, but to intensively develop new trends as well:

A. Maintaining state-of-the-art capacities:

1) Instruments for monitoring the UGS facilities engineering status so as to secure the required level of process safety are being developed;

2) Well-workover operation technologies are being developed for the purpose to increase the operating reliability thereof and recovery of production efficiency.

B. Increasing production efficiency of the UGS system by expanding the existing UGS facilities and constructing peak-shaving UGS facilities:

1) Development of technologies for constructing high-rate gas wells;

2) Increase of gas pretreatment efficiency.

C. Building UGS facilities in areas of gas deficiency:

1) Development of methods for efficient geological prospecting and exploration;

2) Construction of local UGS facilities not integrated within the UGSS.

D. New trends and technologies:

1) Creation of smart UGS facilities;

2) Utilization of UGS facilities to store carbon dioxide and other sour gases, as well as helium;

3) Technologies for storage of compressed gas (CNG) and gas in the form of hydrates (HNG);

4) Building temporary storage facilities for associated gas;

5) UGS operation management under the condition of minimum impact on the environment.

So, the ever increasing technological level of JSC Gazprom provides for maintaining a technology leader position in the underground gas storage sector.