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GAZPROM

50th ANNIVERSARY OF UNDERGROUND GAS STORAGE IN RUSSIA

CONTENTS

Underground gas storage (UGS) facilities play a particularly crucial role in our country with its climatic features and resource remoteness from end users.
Russia has the unique and unparalleled in the world Unified Gas Supply System, an integral part of which is a network of UGS facilities. UGSs enable to effectuate guaranteed deliveries of natural gas to consumers irrespective of a season, temperature swings and force majeure.
The market economy conditions considerably bolster the UGS network significance – there is the need to keep in line with the tightening requirements for gas supply flexibility, promptness and mobility.

Chairman of the Management Committee, OAO Gazprom
A.B. Miller

Underground gas storage facilities have become an integral part of the Unified Gas Supply System (UGSS) of Russia. In order to gain a deeper insight into the potential of UGS facilities and their contribution to the resource base in the autumn–winter period one should take into account that:

- *UGSs account for around 22-25 % of UGSS daily throughput, which is commensurate with daily gas export volumes bound for European countries*
- *daily gas withdrawals from UGSs are equivalent to the cumulative daily gas production from the Yamburgskoye, Medvezhye and Yubileynoye fields*
- *the price of the key UGS assets is estimated at no more than 3 % of the Company's overall assets*

This is quite illustrative and convincing.

Deputy Chairman of the Management Committee, OAO Gazprom
A.G. Ananenkov

The analysis of UGS operations over the last years makes it clear that in terms of the performance indicators the UGS system fully copes with its functions. The total potential send-out capacity and marketable gas volume of Russia's UGS system accounts for 620 mln m^3/d and 65.0 bln m^3 accordingly, with the maximum injection and withdrawal volume amounting to 51.6 bln m^3 and 50.05 bln m^3 accordingly.
The build-up of the existing daily send-out capacity during the withdrawal period will be secured by the Program-700 (with the daily send-out growth envisaged in this Program to be partially assured through UGSs located abroad).

Member of the Management Committee, Head of the Gas Transportation, Underground Storage and Utilization Department, OAO Gazprom
O.E. Aksyutin

WHY UNDERGROUND STORAGE?

The main gas pipelines carrying gas from fields to consumption areas are in relatively continuous operation. Gas consumption is however characterized by considerable fluctuations driven by seasonal, periodic (monthly, weekly and daily) and market swings of demand. In order to smooth out the fluctuations there is the need for special compensators – gas storage facilities capable of accumulating gas surpluses, storing those and in case of demand growth supplying those to consumers. Stockpiling a substantial volume of gas in surface storage facilities is practically impossible. The most efficient and safe option is storing gas under high pressure in underground tanks.

Russia has a ramified underground gas storage system that discharges the following functions:

- covering seasonal swings in gas demand
- storing gas reserves in case of anomalously cold winters
- smoothing out fluctuations in gas exports
- feeding gas in case of contingency situations within UGSS
- stockpiling long-term gas reserves in case of force majeure in gas production or transmission

Underground gas storage facilities (UGSs) are an integral part of the Unified Gas Supply System (UGSS) of Russia and are situated in the major gas consumption regions.

UGSs help cover seasonal swings in gas demand, reduce peak loads throughout UGSS and provide for better flexibility and reliability of gas supply. During heating seasons UGSs supply up to 20 % of gas to Russian consumers and during cold snaps this figure reaches 30 %.

There are currently 25 UGSs on the territory of the Russian Federation, of which 8 are built in aquifers and the remaining 17 sit in depleted gas fields. 3 UGSs are at the design stage and 2 facilities – at the construction stage.

By autumn-winter 2009/2010 commercial gas reserves accounted for 64.0 bln m^3 and daily potential send-out – 620 mln m^3. Expansion of UGS capacities is a strategic goal of Gazprom. Creation of extra underground gas storage capacity for smoothing out seasonal fluctuations is several times less expensive than construction of corresponding backup extraction and transmission facilities.

According to the draft General Scheme for the Gas Industry Development to 2030, the peak daily send-out of UGSs is projected at around 1.0 bln m^3.

Two new UGSs are currently under construction in Russia in salt caverns: the Kaliningradskoye and Volgogradskoye UGSs.

A feasibility study has been performed for a natural gas liquefaction, storage and regasification terminal to be potentially built in the vicinity of St. Petersburg. Projected regasified gas volume and peak send-out – 140 mln m^3 and 28 mln m^3/d accordingly.

Gazprom enters new markets and diversifies gas export routes, which requires creating new UGSs. A typical trend in the UGS network development is the intensified cooperation with the countries importing and transiting Russian gas.

Gazprom's underground gas storage sector undergoes development within the corporate structure streamlining process. In 2007 the subsidiary company Gazprom UGS was set up to integrate all existing UGSs and UGS well overhaul units.

The purpose of Gazprom UGS activity is the organization of natural gas storage.

Gazprom UGS operates in 13 constituents of the Russian Federation. The company's facilities are located in 18 municipal entities. The company comprises 22 branches including 16 underground gas storage centers, 4 emergency response and well overhaul centers as well as a number of ancillary subdivisions.

The company's top priority businesses are operation of a potent gas storage complex and taking of actions within Gazprom's UGS Development Strategy to 2030.

The underground storage segment employs true professionals. Sustainable supply of fuel to millions of people and uninterrupted operation of utility, industrial and agricultural companies depend on their responsibility and commitment.

HOW IT ALL BEGAN

The problem of gas reserve creation first arose in Russia during the Saratov–Moscow pipeline construction. The pipeline was projected to supply the capital with more than 1 mln m^3/d of natural gas. There emerged the question: "How will daily swings in Moscow's gas demand be covered"?

In 1946–1955 Moscow saw the construction of 7 gasholder stations with cylindrical tanks having a diameter of 3 m, a length of around 17 m and a working pressure of up to 6 atm. Their combined active capacity averaged 1.1 mln m^3. The stations played a certain role in smoothing out daily fluctuations in the city's gas supply up to the late 1960s when Moscow was consuming less than 10 bln m^3 of gas per year.

In the mid-1950s natural gas production started intensively developing in the country. In order to cover gas demand swings there emerged the need for gas storage facilities with a bigger capacity. The only way of meeting that challenge was building gas storage depots in depleted oil or gas fields, water bearing traps meeting leak tightness requirements or salt caverns.

Prospecting activities for aquifers fit for gas storage sites began in 1956, with the focus placed on the country's central regions: Moscow, Ryazan and Kaluga Oblasts.

In May 1958 Kuibyshevneftegaz Trust was the first national company to perform experimental injection of gas in the Bashkatovskaya depleted gas deposit of the Ufimskaya suite. The deposit was located at a depth of around 400 m. Initial reservoir pressure was 45.2 bar. Initial gas reserves were estimated at 30 mln m^3. During water injection the storage facility was fed with 9.275 mln m^3 of gas, and the deposit pressure increased from 16.5 to 32.7 bar.

In 1958 gas was experimentally injected under a 35 bar pressure in four wells of a Tulsky horizon in the Yelshano-Kurdyumskoye field, Saratov Oblast.

Exploration, design and construction of aquifer located UGSs required performing special theoretical research and meeting a number of gas hydrodynamic challenges.

In 1957 the first UGS well was drilled near the town of Kaluga, with the second one drilled in 1958 near the town of Shchyolkovo, Moscow Oblast. These areas, especially Kaluga, were not chosen occasionally. The Kaluzhskoye reclamation was well studied through previous geological surveys and was located near the Dashava – Kiev – Bryansk – Moscow gas pipeline route.

Exploration and construction of first UGSs was successfully completed, and Kaluzhskaya and Shchyolkovskaya structures were prepared for gas injection by the early 1960s. In 1959 the first pilot gas injection was carried out in the Kaluzhskoye UGS facility and in the autumn of 1960 – in Shchyolkovskoye. Kaluzhskoye's complex structure predetermined a big scope of prospecting work including drilling of 40 exploratory wells that were subsequently used for gas injection, off-loading and monitoring purposes. Gas was injected with the use of two compressors, 735 kW each, providing for two-step 25–55 and 55–125 bar compression and 500,000 m^3/d output.
In 1959 a 3-month period saw the injection of 23 mln m^3 of gas, which was fed via 2–4 wells under a peak buffer pressure of 103 bar with an intake capacity of up to 500,000 m^3/d. Pressure reassignments were monitored during the winter period.
In the autumn of 1960 the first pilot gas injection was performed in the Shchyolkovskoye UGS facility (Shchigrovsky reservoir). During a 6-year period that UGS facility was brought to a cyclic operation and active capacity was increased to 1.2–1.3 bln m^3.
Peak daily withdrawals reached 18–20 mln m^3 in December during exceptional cold spells.
Construction of the first UGSs – Kaluzhskoye and Shchyolkovskoye – was of principle significance for further development of the national underground gas storage sector. That was a successful large-scale industrial experiment carried out within a short time period. In 1963/1964 (autumn-winter) Moscow started receiving gas from those facilities.
Kaluzhskoye was operated as a peak shaving facility. Based on the experiment results, the search and exploration principles for reservoirs fit for gas injection were elaborated, UGS separator quality assessment criteria were identified and important methodological aspects were addressed.
In the early 1960s unique efforts were stepped up to construct an UGS facility in a flat dipping aquifer in the vicinity of Leningrad. Later on, those efforts resulted in the creation of the Gatchinskoye UGS facility, which is currently in successful operation and is playing a key role in reliable gas supply to the Leningrad Oblast.
Later on, prospecting activities to build UGS facilities in aquifers were carried out in many areas of the European part of the USSR, Baltic States, Belarus, Ukraine, Transcaucasus and Central Asia. Based on the collected geological data, a whole set of UGSs were designed and constructed including the Kasimovskoye (Russia), Poltoratskoye (Kazakhstan), Incukalns (Latvia), Osipovichskoye (Belarus), Olishevskoye, Chervonopartizanskoye (Ukraine), salt cavern Abovyanskoye (Armenia) and many other underground gas storage facilities.

LAYOUT OF UGS FACILITIES IN RUSSIA

- **1950–1960**
  Amanakskoye
  Kaluzhskoye
- **1960–1970**
  Mikhailovskoye
  Shchyolkovskoye
  Gatchinskoye
  Yelshano-Kurdyumskoye (2 reservoirs)
  Peschano-Umetskoye
- **1970–1980**
  Dmitriyevskoye
  Kiryushkinskoye
  Kasimovskoye
  Nevskoye
  Severo-Stavropolskoye (green suite)
  Kanchurinsko-Musinsky Complex (Kanchurinskoye)
  Sovkhoznoye
  Stepnovskoye (2 reservoirs)
- **1980–1990**
  Severo-Stavropolskoye (Khadum)
  Krasnodarskoye
  Punginskoye
  Kanchurinsko-Musinsky Complex (Musinskoye)
- **1990–2007**
  Uvyazovskoye
  Kushchevskoye
  Karashurskoye (2 reservoirs)
- **At the construction stage**
  Volgogradskoye (salt cavern)
  Kaliningradskoye (salt cavern)
- **At the design stage**
  Bednodemyanovskoye
  Shatrovskoye
  Udmurtsky Reserving Complex (5 reservoirs)

- Operating UGS facilities with a working volume below 5 bln m^3
- Operating UGS facilities with a working volume in excess of 5 bln m^3
- UGS facilities under construction and design
- Geological exploration areas
- Primary gas pipelines

UNDERGROUND GAS STORAGE DEVELOPMENT STAGES IN RUSSIA

1955–1958

- A period of first prospecting activities for geological structures suitable for gas storage

1958–1970

- Creation of the first UGSs in aquifers: Kaluzhskoye (1959), Shchyolkovskoye near Moscow, Gatchinskoye and Kolpinskoye near Saint Petersburg and utilization of small worked-out gas fields in the Samara Oblast (early 1958)

1970–1985

- Wide use of depleted gas and gas condensate fields in the Saratov Oblast (Peschano-Umetskoye, Yelshano-Kurdyumskoye, Stepnovskoye UGSs), Orenburg Oblast (Sovkhoznoye UGS facility) and Bashkiria (Kanchurinskoye UGS facility)
- Construction of the Kasimovskoye UGS facility in an aquifer

1985–1995

- Introduction of a concept stipulating the construction of basic UGSs both in depleted fields (Severo-Stavropolskoye, Kushchevskoye, Punginskoye, Krasnodarskoye) and aquifers (Nevskoye)
- Geological exploration in the Oksko-Tsninsky Swell with a view to detecting aquifers
- Commencement of exploration activities in Western Siberia near Novosibirsk, Omsk, Tomsk and other cities

1995–2000

- Exploration activities in Russia's Northwest region
- Introduction of a regional gas supply concept based on existing basic storage facilities
- Enlargement, reconstruction and technical re-equipment of existing UGSs
- Introduction of automated UGS process control systems

2000–2010

- Increasing daily send-out capacity of UGSs
- Technical re-equipment of existing UGSs
- Improving the technology of enhancing oil recovery from depleted fields through the construction of UGSs

UNIQUE PROJECTS

The experience gained during the construction of a number of Gazprom's UGS facilities has a worldwide value. These are the world's largest Kasimovskoye UGS facility in an aquifer and Severo-Stavropolskoye in a depleted gas field; Gatchinskoye (unique in terms of its hydrodynamic characteristics) in a horizontal bed; Udmurtsky Reserving Complex (unique in terms of engineering solutions).

Kasimovskoye UGS facility

Construction work on the Kasimovskoye UGS facility began in 1977 in an explored aquifer of the Oksko-Tsninsky Swell. Considerable dimensions of the structure (6 by19 km) and geological characteristics of the reservoir made it possible to gradually design and implement this facility with the biggest volumetric parameters in the world.

Working volume, bln m³	12
Peak daily withdrawal, mln m³	130
Daily injection, mln m³	68
Reservoir pressure, MPa	
maximum	11.5
minimum	6

Initial reservoir pressure during the current artificial deposit filling is exceeded by 45 %.

Severo-Stavropolskoye

UGS facility **in the Khadumsky horizon** was built in a depleted gas deposit at a depth of 650–750 m with a large volume of the high-permeability reservoir and anomalously low reservoir pressure. Gas injection is carried out through excess pressure in the gas main and gas withdrawal – via a compressor station. At the same time, the large volume of the reservoir caused certain difficulties for creating a working gas-saturated volume in the storage facility. That's why the decision was made to locate the boreholes centrally-grouped in the reservoir area. This enabled to prevent gas spills on the bed outskirts and concentrate the bulk of the gas in the central zone of the reservoir.

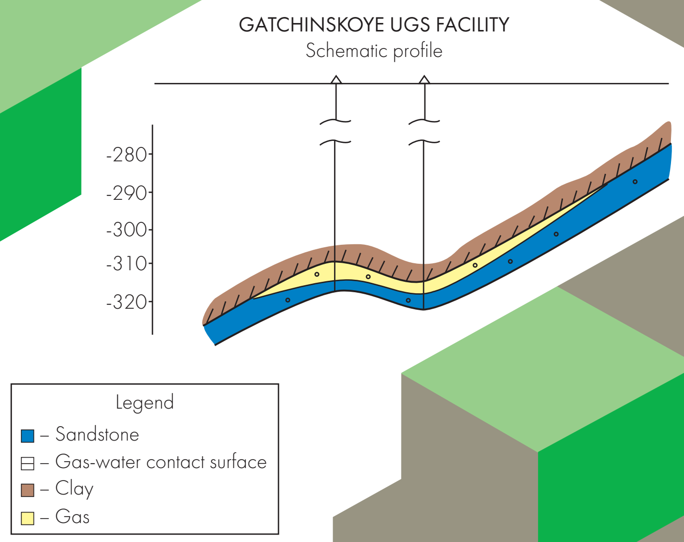
	Green suite	Khadumsky horizon
Working volume, bln m^3	5.5	37.8
Peak daily withdrawal, mln m^3/d	37	150
Peak daily injection, mln m^3/d	33	115
Reservoir pressure, MPa		
maximum	8.7	2.9
minimum	5.6	2

Green suite

The **green suite** UGS facility was built in a depleted gas deposit at a depth of 950–1,000 m with water drive. By the moment the facility construction was over, the original gas-saturated volume of the deposit had been entirely drowned. One of the main tasks was to set permanent control over the water level and form a persistent gas-saturated volume during gas injection. It was also important to set control over the gas-water contact displacement during gas retrieval. This task was solved through the method of gas injection and withdrawal volume distribution over the facility area, subcontact gas injection and the zonal gas injection and withdrawal method.

This enabled to achieve the controlled displacement of gas-water contact beyond the operating injection borehole area and secure the stable borehole operation under the water drive conditions.

Given the current deposit formation status, the initial reservoir pressure is exceeded by 18.5 %. Gas injection is carried out by gas pumping units and gas withdrawal – through excess reservoir pressure.



Gatchinskoye UGS facility

As a result of the core drilling activities performed in the 1960s in Gatchina, St. Petersburg suburbs, it was found out that the crystalline basement surface and the superincumbent Lower Cambrian sedimentary rocks form a slide dumped reclamation stretching from south-west to north-east and complicated by several dome folds. For gas storage purposes the first sand layer of the Gdovsky horizon with a 7.6–10.2 m capacity was recommended. A small size and insignificant amplitude of the found structures didn't make it possible, as known in that period, to qualify that area as suitable for the UGS facility construction.

The theoretical and practical research on underground hydrodynamics pointed however to the possibility of UGS facility construction in horizontal and slightly pitching formations.

Working volume, mln m^3	200
Peak daily withdrawal, mln m^3	2.0
Daily injection, mln m^3	1.8
Reservoir pressure, MPa	
maximum	4.6
minimum	2.7

Udmurtsky Reserving Complex (at the design stage) is a streamlined interlinked system of geological sites and surface technological facilities located within an economically effective space. The Complex will comprise four independent anticline structures situated within a 10 km radius from the central Karashurskaya structure that includes the main technological units securing its operation.

Aggregate indicators projected for Udmurtsky Reserving Complex

Working volume, bln m^3	2.6
Peak daily withdrawal, mln m^3	43
Daily injection, mln m^3	17

UGS SYSTEM NOWADAYS

Gazprom performs all types of work related to the UGS facility construction, design and operation in:

- aquifers
- depleted gas and gas condensate fields
- salt caverns

	Total number of UGSs (data as at 01.01.2010)
In operation	25
Working gas volume, bln m^3	64.0
Potential daily send-out by the startup of the withdrawal period 2009/2010, mln m^3/d	620
Number of operational wells	2,600
Compressor stations capacity, MW	778

In addition, the 360 MW booster stations 1 and 2 of the North Stavropol line pipe operation center are used for gas withdrawals from the Khadumsky horizon in the Severo-Stavropolskoye UGS facility.

The UGS Development Strategy to 2030 hinges on the following basic principles:

- maintaining the achieved level of Russian UGS capacities by upgrading and replacing aged and obsolete capacities
- promptly building up Russia's UGS daily withdrawal capacity by expanding the existing and building new UGSs
- providing UGS capacities for "deficit" regions of the Russian Federation, including constructing an UGS network in Eastern Siberia and the Far East
- developing at best the UGS system along with UGSS, synchronizing the UGS and gas trunkline operation profiles
- expanding the UGS network abroad to store Gazprom's gas for higher reliability and flexibility of gas exports and bigger presence in the spot market

TECHNOLOGICAL PROCESS

The technological operating profile of an UGS facility is divided into three processes – **injection, storage** and **withdrawal** of gas.

The **gas injection** process includes injecting gas into an artificial gas bed in accordance with parameters set in a technological chart.

Out of the trunkline gas is pumped to the gas cleaning area where it is cleaned from mechanical impurities. Then gas goes to the metering unit and then to the compressor shop where it is compressed and is fed through collectors to distribution points. There, gas flows into technological lines that are connected with borehole loops. The line piping makes it possible to measure output of each well and gas temperature and pressure during injection.

The **gas storage** process includes systematized technological, geological and environmental control over a gas storage site and related capital assets.

Gas withdrawal out of an UGS facility is quite the same technological process as gas production from fields but with one considerable distinction: the entire working (commercial) gas volume is withdrawn during 60÷ 180 days.

Proceeding through the loops, gas flows into gas collecting points where it is concentrated in the gas gathering line. Out of there, gas enters the gas separation area for reservoir water and mechanical impurities removal. Afterwards, it goes to the purification and dehydration area where the dropping liquid catchment in extractors and the absorption drying process or low pressure separation takes place. Purified and dry gas flows then into main gas pipelines.

There are difficulties in UGS facility operation during gas withdrawal, which are driven by internal and external factors. These factors include the heterogeneous lithologic structure and physical properties of the reservoir, influencing to a larger extent the nature of water-gas substitution, non-uniformity of gas withdrawal over the area, inflow of reservoir water and rock elements in the wellhead stream, appearance of hydrates in gas pipelines and resistance points (reduction point, stop valves), etc.

GEOENVIRONMENTAL ENGINEERING TO PRESERVE NATURE

Maintaining safe and secure operation of the UGS system is a top priority challenge

Beginning from the UGS facility study and design phase, Gazprom tackles a whole range of geoenvironmental matters related to impacts on the geological ambience (rock formations and underground water) and environment (atmosphere, soil, water).

Gazprom applies state-of-the-art technologies, equipment and techniques to mitigate negative impacts on rock formations, hydrogeological ambience and environment.

The operational activity of UGSs meets the environmental, technical, social and gas industry standards.

Gazprom creates and introduces at UGSs environmentally oriented technologies and solutions along with measures for eliminating industrial impacts. The adherence to the developed technical specifications and environmental standards throughout the entire operational lifetime of UGSs enables to maintain a high technical reliability and environmental sustainability level of UGSs.

Technical and managerial actions stepped for ensuring environmental safety of UGS facilities

- UGS organization and management
- Air emissions reduction
- Introduction of new natural gas flaring technologies and methods
- Creation of low-noise gas pumping units as a compromise between technical capabilities and economic feasibility
- Water use scheme upgrading
- Liquid and solid waste impact reduction

UGS FACILITIES CONSTRUCTION AND OPERATION RELATED CHALLENGES

Challenges faced during UGS facility creation in aquifers:

- determination of the difference between maximum injection pressure and initial reservoir pressure
- gas driven water expulsion determination
- trap filling optimization and well spacing area dehydration
- optimal well spacing determination
- buffer & working gas volume optimization
- UGS containment control

Challenges faced during UGS facility creation and operation in depleted gas, gas condensate and oil fields:

- lack of information about the reservoir properties
- inaccurate data on remaining reserves
- inadequate information on the reservoir behavior
- full flooding of several fields
- sharp areal and vertical inhomogeneity
- inspection and disposal of old wells
- recording of the injection and withdrawal rate excess over recovery rates
- secondary production of oil and condensate

Gazprom's research centers and organizations have practical experience in meeting all of the above sci-tech challenges.

From formation testing to a geotechnical model

The methods applied for subsurface resource monitoring during the UGS facility operation can be divided into **hydrochemical, geophysical, upstream (analytical and hydrogasdynamic).**

The **hydrochemical methods** consist of identifying quantitative and qualitative changes in a gas saturation time for formation waters in incumbent control layers and water bearing reservoirs.

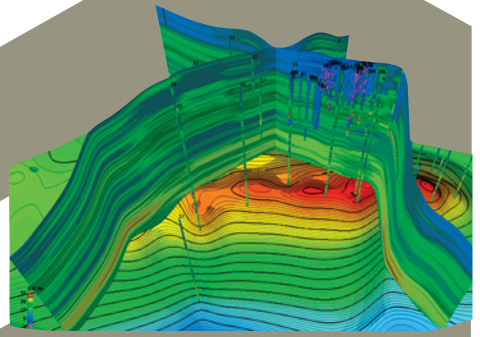
These investigations are carried out in all UGS observation and benchmark wells. The investigations result in an estimation of the general content of dissolved gas, presence of methane and its homologous compounds, saturation pressure of dissolved gas, mineralization and chemical composition of formation waters.

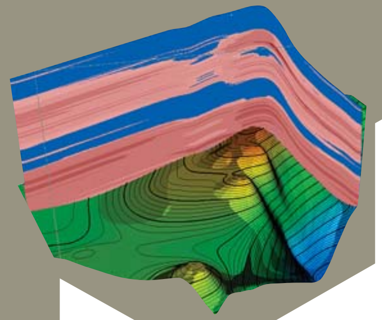
The **geophysical methods** include field seismic survey, electric exploration, gravity exploration, radon/thoron exposure, subsoil gas survey, logging operations, etc.

UGS well geophysical research methods help achieve the following:

- detailed lithologic column differentiation and volumetrics evaluation
- control over the gas-saturation area location and evaluation of volumetric parameters
- control over the structural integrity of the casing annulus
- determination and evaluation of the scope and impact types in the environment – UGS system
- development of a corporate geo information system base

The **upstream methods** are those directly associated with control over the main operational parameters of a storage facility. The **analytical methods** are implemented under the author's supervision and are monitored by the institute – technological scheme developer.



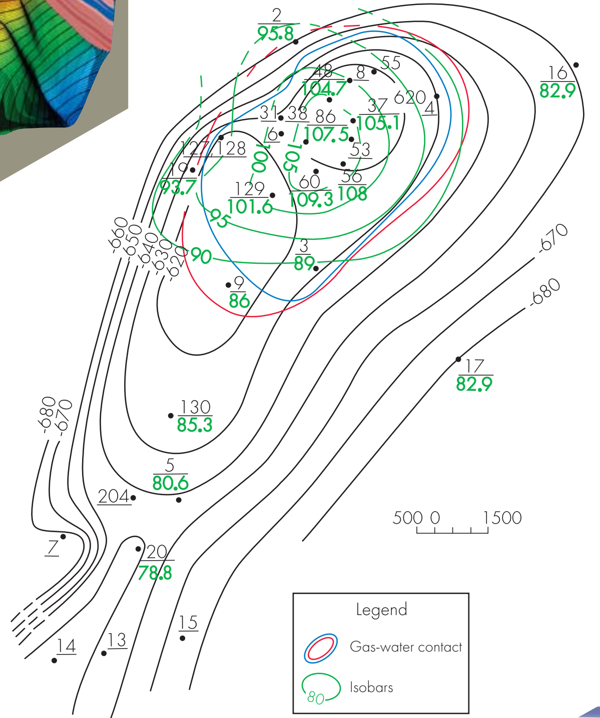


Geotechnical simulation of UGS facilities in porous beds

A numerical geotechnical simulator of an UGS facility is based on the integration of investigation data, colligation of all available information on the facility and background knowledge in geology, geophysics and development.

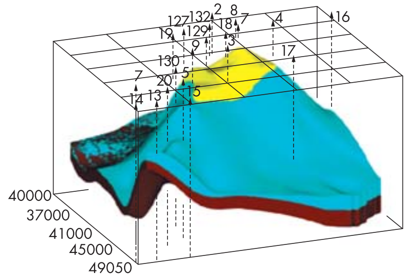
Geological simulation ensures fulfillment of the following tasks:

- development of a numerical geological simulator
- differentiated calculation of a trap volume (through the volumetric method) or a storage facility volume
- field and geophysical analysis of current reservoirs
- development of a numerical geological simulator for handover to a filtration simulation complex, etc.



Filter and gas-dynamic simulation software systems help carry out the work in the following directions:

- development and examination of numerical filtration and gas field simulators
- adaptation of existing numerical filtration and gas field simulators relating to the gas storage history and well operation and survey data as well as their feedback as regards the numerical geological simulator adjustment
- differentiated calculation of accumulated and drained gas volumes in a layer (through the gas and hydrodynamic method)
- on-line computation of UGS operating modes and visualization of output data



Automated control system

Effective and up-to-date control over the gas storage facility construction and operation
Operational control over underground gas storage facilities is executed through the automated flow process control system, which represents a complex of technical and software tools aimed at:

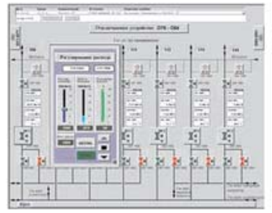
- streamlining the control over technological facilities
- increasing the operational reliability of equipment
- preventing emergency situations
- improving the working conditions of personnel, etc.

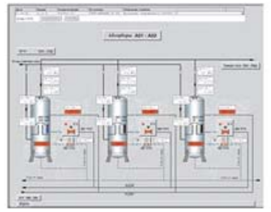
The automated flow process control system is implemented as a multilevel system. It provides for the centralization and presentation of the data obtained from sensors and actuating devices on screens in a compact and demonstrable form as mnemonic diagrams, trends (diagrams) and table records.

Level one – sensors, control and check valves.
Level two – controllers used for automatic regulation and logical control stations. Controllers are also aimed at collecting and processing information related to the technological characteristics and position of stop and check valves.
Level three – shift engineer workstation used for the control over the flow process and visual indication of its progress.

The automated flow process control system at up-to-date UGS facilities has the following features:

- real-time collection and processing of information concerning the flow process
- analog and digital regulation
- flow process data presentation in a compact and demonstrable form
- processing of messages on flow process changes and exercising control over processes in emergency situations
- database creation and handling
- data archiving and report making





All up-to-date underground gas storage facilities are equipped with automated flow process control systems

The automatically controlled workplace of an UGS facility geologist makes it possible to calculate:

- wellbore reservoir pressure using wellhead pressure
- well flow rate
- UGS facility operation profiles
- tank characteristics (gas volume, reserves) using a network model at any point of time
- reservoir pressure fields on a two-dimensional network model covering the entire area of the underground gas storage facility for separation and injection at a prescribed time
- rates of volumetrically weighted average reservoir pressure as well as those measured in the separation/injection area
- forecasting the UGS facility operation profiles considering the reservoir heterogeneity
- reserves calculation

State-of-the-art well repair methods – longer UGS facility lifespan

UGS well overhaul permits to:

- ensure reliable facility operation
- improve the structure of wells in line with up-to-date technical solutions
- increase productivity

Technologies applied at Gazprom's UGSs

- Introduction of clayless biopolymer drilling mud to kill wells and expose formations. The Saraksan Russia-produced rhodopol gum is used as a biopolymer basis. Application of biopolymer drilling mud permits to save natural in-place permeability, decrease absorption intensity, reduce well development time

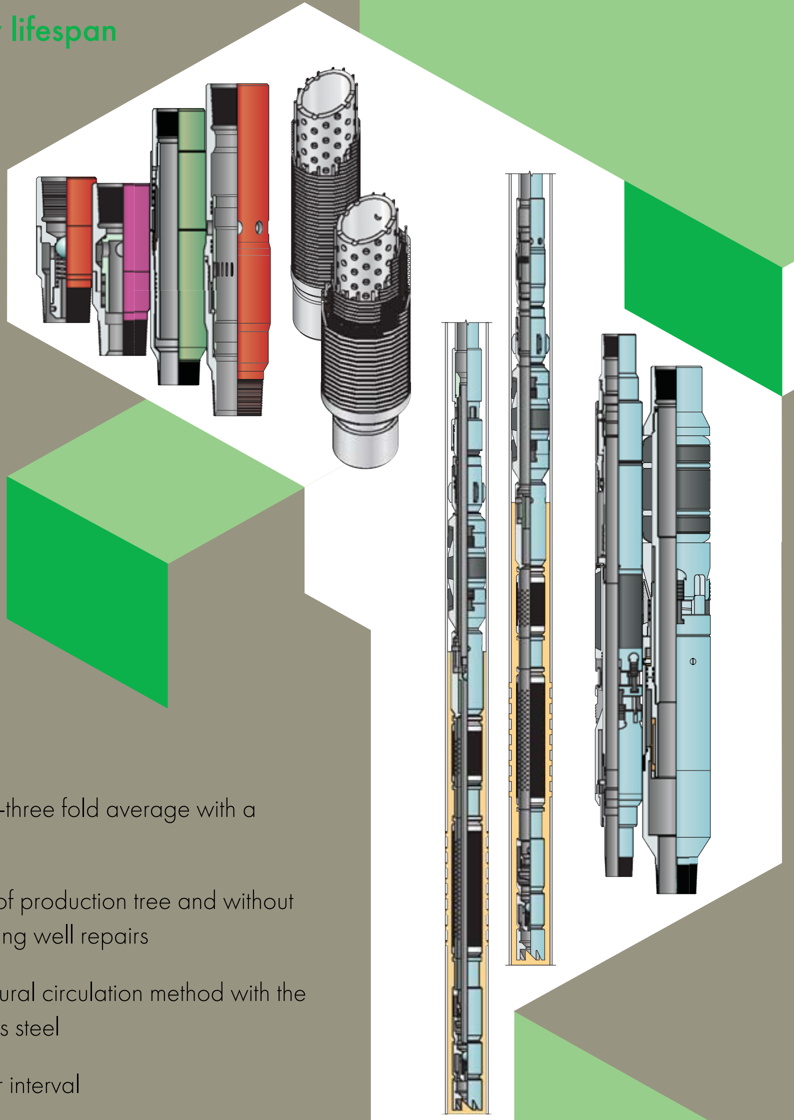
- Improvement of reservoir chemical fastening technology by means of systems based on polyorganosiloxane (organic-silicon siloxane). Application of new reservoir chemical fastening systems has enabled to decrease or completely stop sand production without well killing and face equipment replacement

- Stepping up activities to stimulate wells, with systems applied based on organic and non-organic acids, surfactants and peroxidates. As a result of stimulation measures, the deliverability of wells increases by a two-three fold average with a considerable reduction of depression

- Application of hydraulic packers for bed severance with the replacement of production tree and without cement bridging permits to essentially cut down the time and materials used during well repairs

- Utilization of a new technology to construct gravel filters, particularly a natural circulation method with the use of special technological equipment and filter-frames totally made of stainless steel

- Milling or slot hydromechanical perforation of casing pipes in the reservoir interval



Diagnostic study is a prerequisite for reliable operation of a gas storage facility

The full cycle of up-to-date inspection operations are being undertaken at UGS facilities.

Inspection is performed on the following technical devices, equipment and installations:

- vessels working under pressure (dust collection chambers, filter separators, separators, absorbers, etc.), containers and reservoirs
- aboveground and underground process pipelines (gathering lines, in-field and inter-field collectors, well-head connections, pipelines for gas distributing and collecting stations, gas treatment facilities)
- various-purpose wells, well-control equipment and surface wellheads of underground gas storage facilities
- potentially hazardous sections of linear pipeline portions (motor and railway crossovers, pipe crossings, aerial crossings, etc.)
- shut-off and control valves, quick-release gates
- compressor equipment
- hookups, connection and compressor station pipelines
- lifting installations

The research on the stress-deformed state of pipelines and constructions with the use of computational tools is being performed to support the maintenance of equipment hookup elements and protective coatings for process pipelines.

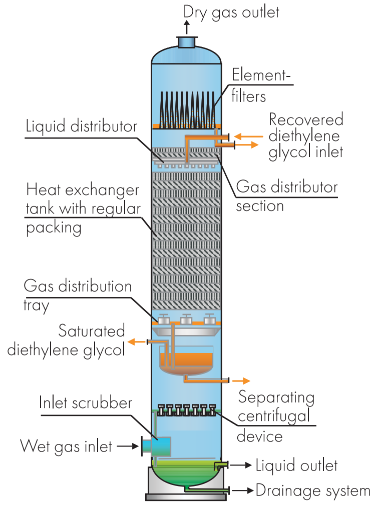
NEW TECHNOLOGICAL SOLUTIONS

Qualitative gas treatment as a crucial element of underground gas storage operation

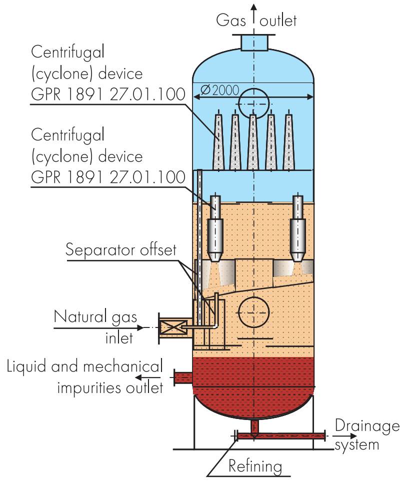
Gas treatment equipment at UGS facilities should meet more stringent requirements than those during gas production: low (down to subzero) temperatures at the initial phase of gas withdrawal, dramatic fluctuation of daily production rates, oil and condensate contaminants in the fluid, high salinity of stratal water.
The decline in reservoir pressure during withdrawal season is accompanied by aggravating negative effect on the gas dehydration quality.

The solutions are:

- application of high-efficiency primary separators (carryover of moisture dropping up to 5–6 mg/m³, mechanical impurities up to 3 mg/m³, hydrocarbons up to 15 mg/m³); salts wash-over
- gas dehydration technologies at high pressure
- application of equipment with wide range efficiency and low reaction time
- gas throttling up to the main pipeline pressure level after mounting a dehydration unit
- glycol recovery in soft heating units (using thermosyphon, applying offset combustor)



Gas drier absorber
with regular packing



Gas fine purification
separator

Next generation gas pumping facilities for UGSs

Gas pumping system GPA-10 Ural for UGSs

Indicated cubic capacity under the temperature of 20 °C and the pressure of 760 mm of mercury column, m³/d	4.966 ·10⁶
Compressor pressure rate increase	2.4
Ultimate final pressure of pumping gas, kgf/cm²	156
Maximum drive power, MW	9.6
Free turbine rotor frequency and compressor rotor in nominal conditions, rev/min	8,900
Range of power turbine rotation frequency, %	70–105
Drive efficiency on the output shaft sleeve of a gas-turbine facility in an indicated mode, %	31.4

Gas pumping system GPA-4RM

The gas pumping system GPA-4RM was designed by NPO Saturn especially for gas transmission companies of Gazprom. The gas turbine engine GTD-4RM was designed for operation in this system.

The engine efficiency in an indicated mode on the output shaft sleeve is at least 32 %. This is proven by the operation tests.
The centrifugal supercharger operated in this system was designed and produced by Nevsky Zavod. Centrifugal supercharger TsBN 47-71-1 is installed on the prototype of the system.
It makes it possible to reach the compression rate of 2.4 in an indicated mode and in 7 cascades with 3.44 mln m³/d (39.8 m³/s) and with polytropic efficiency of 80 %.

Maximum pressure of compressed gas in the pressure line is 11.5 MPa. The MSKU 5000-01 multiprocessor system of complex control produced by NPF Sistema-Service (in the prototype system MSKU-SS-4510) is used as an automated control system in GPA-4RM.

INTERNATIONAL COOPERATION

Gazprom pursues the gas supply efficiency, reliability and flexibility via the construction and operation of UGS facilites abroad, which is an important part of the UGS development strategy.

Since 1991 Gazprom has been storing gas in Latvia and nowadays the Company is active in contributing to the Incukalns UGS facility upgrading and development.

Rehden, the biggest UGS facility in Western Europe, has been operated in Germany by WINGAS joint venture since 1993.

Gazprom export stores gas on a contract basis in UGSs in Austria, Germany and the UK.

Gazprom is involved in the operation and expansion of the Haidach UGS facility in eastern Austria. The Rehden UGS facility (Germany) is the largest in Europe in terms of storage and withdrawal capacity, with Haidach to be the second-largest in future.

In addition, Gazprom holds shares in the companies owning and operating UGS facilities, namely, ZAO ArmRosGazprom (Armenia), AO Latvijas Gaze (Latvia), and VNG AG (Germany).

Agreements have been reached regarding the construction of the Banatski Dvor UGS facility in Serbia and the Pusztafoldvar UGS facility in Hungary. The work has begun to construct the Katharina UGS facility in Germany.

Gazprom is an active member of the IGU and UNECE, and promotes sci-tech cooperation with its partners in France, Germany, the Netherlands and China.

GAZPROM'S EXPERIENCE IN CONSTRUCTING UGS FACILITIES

Gazprom executes all operations connected with UGS facility construction

- Feasibility studies for UGS facility construction
- Site selection
- Geological and geophysical research
- Project preparation
- Well drilling
- Surface facility construction
- Control over the entire UGS facility construction process
- Designer control over UGS facility construction and operation
- Geological and technical audit of UGS facilities
- UGS facility operation, parameter optimization
- Reconstruction, development and technical re-equipment
- Staff training and qualification upgrading

Gazprom's UGS facilities: from design to operation observing a whole set of geological and technical parameters at a single facility

	Minimum	Maximum
Working volume, mln m^3	50	25,000
Peak daily withdrawal, mln m^3	0.4	150
Withdrawal time at peak output rates, d	50	180
Number of wells	1	649
Initial reservoir pressure, MPa	3.5	20.0
Reservoir depth, m	350	3,500
Trap amplitude, m	6	600
Reservoir thickness, m	5	450

Reservoir operating regime	Gas, Water drive
Collector type	Porous, Fractured-porous

In addition, Gazprom employs a storage technology for helium. In Russia there are 6 helium storage facilities with a total geometrical volume of 235,000 m^3 and peak pressure of 18.5 MPa.