WGCPARIS2015
WORLD GAS CONFERENCE
"GROWING TOGETHER TOWARDS A FRIENDLY PLANET"

26th World Gas Conference | 1-5 June 2015 | Paris, France

An Experience of Surface Active Substance Barriers Placed for Screening Out Stratum Water Advents to UGS Deposits

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Background

The underground gas storages are greatly affected by intrinsic factors, i.e. the geology and hydrogeology of a reservoir, on the one hand, and the external factors, i.e. fluctuations of gas consumption, on the other hand.

Today, the storages have to function not only seasonally, but they must also respond to the fluctuations of gas demand with reference to the market behavior, which, in its turn, needs larger flexibility of UGS and thus imposes additional tension on the operation of storage facilities. An important task is to assure variable operability modes with higher peaks, potential gas injecting in thaw periods and regular under-consumption of working gas in warmer winters. Such operation modes are characteristic of UGS in depleted fields with gas extension drive and storages in salts caverns. However, absence of good geology for building UGS in rocksalt or depleted gas fields within the gas consumption areas causes the need to build new UGS in the aquifer.

The key foundation principle of the technical design of USG in the aquifer is the cyclic operation assumption which means the equality of the amount of gas being injected in withdrawn in one cycle. Yet, in the event of variation of such cyclic operation, e.g., with permanent under-consumption of the design working storage capacity of gas against the unchanged amount of stored gas, the void gas saturated volume increases by the end of injecting, which may create conditions for the evasion of gas off the trap, decrease of the maximum reservoir pressure, and under-consumption of a significant volume of gas from UGS.

Aim

There are known facts of uncontrolled gas expansion towards another structural trap in the russian practice of the underground gas storage operation. The good example of that is UGS designed in the depleted gas-condensate field with an active aquifer system at the south of the Russian Federation. On the ground of multi-year exploitation and monitoring it was diagnosed that there is a migration of some gas volume from one structure into another one nondrained by the flowing well. (Figure 1).

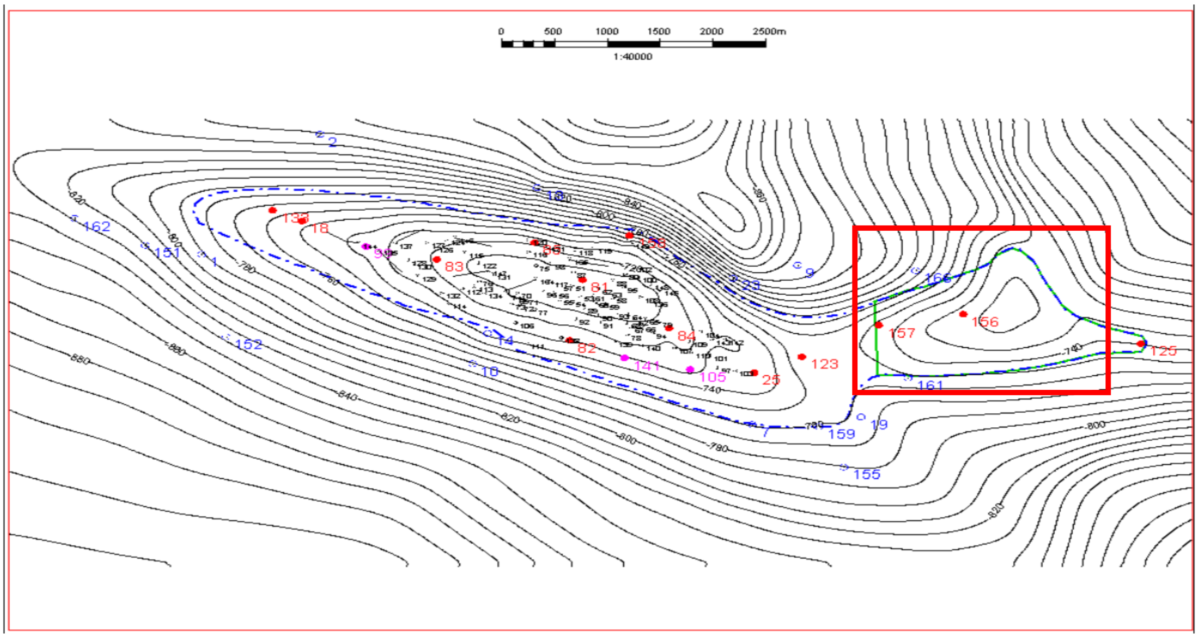


Figure 1 – An example of a structure with gas expantion towards another structural trap.

Another illustrative example is a storage designed in the aquifer in the Central Region of Russia. The exploitation of that storage is complicated by a constant growth of a gas-saturated pore volume, thus, a gradual decreasing withdrawing potential. This certain object was chosen as a priority one for a trial of the gas deposit shielding method.

This report is dedicated to a successful experience of solving the problem of uncontrolled gas evasion with the help of a foam barrier using the technology of Surface Active Substance injecting developed in Russian State Oil and Gas University named after academician Ivan Gubkin (RGU) and VNIIGAZ.

Tectonically, the structure within which UGS was built refers to Oka-and-Tsna dislocation area. The latter complexifies the uniclinal of the southern wing of Moscow Upper Paleozoic tectonic depression.

Gas is injected into sandstone of the upper part of Upper Devonian Shchigry level. The terrigene formation has complex lithology due to specific sedimentation.

Over the roof of Shchigry collector layer, the structure is an asymmetric anticlinal fold projected towards north-west. The arch of the roof has three minor domes with the closure of up to 5 m. The structure has the size of 17 x 7 km. The closure constitutes 23 m. The depth of the collector layer constitutes 755-775 m. The terrigene formation of Shchigry sediments is built by facially irregular areas and cross-sections of interspersed sandy-aleuritic and clay minerals which are a uniform aquifer system divided by the irregular clay veins.

The special trait of the operation of this UGS is the impossibility to draw the design capacity of the working gas during the 150 day drawing period. The withdrawing process is concurred with water breakthrough into the wells since the very first days of operation. Due to water breakthrough, about 50% of the operating stock is decommissioned by mid-January (Figure 2).

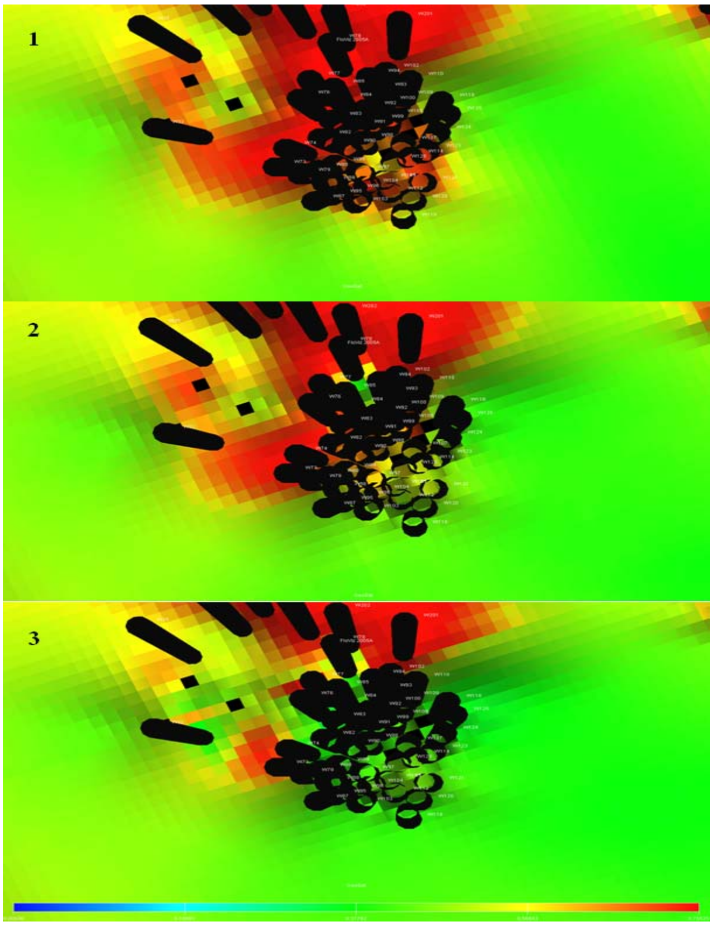


Figure 2 – Distribution of Gas Saturation in Reservoir at Different Periods: 1 – withdraw starts, 2 – middle time, 3 – withdraw ends (after 292 days).

Inhomogeneity of the collector parameters of the collector layer lead to results in selective penetration of gas into the most penetrable veins, due to which gas distributes over a vast area. Over the high penetration areas, the gas apparently runs off the design layout of USG. In the 2013-2014 period, the drawing volume constituted just 36% of the design active storage capacity in 292 days. The maximum daily production only constitute 42% of the designed capacity in the beginning of the drawing season, with the maximum reservoir pressure, and can only be maintained for 24 hours.

The various ways of managing the operation of the storage (based on the main principle of changing the operation modes in order to control the mobile gas and water contact (GWC)) have not brought any significant outcome. A radical solution was a proposal to drill new wells in order to drain the additional amount of gas and, consequently, to increase the maximum daily production. The multi-option calculations on a 3D model with different layouts of the wells demonstrated visible effectiveness in terms of daily productivity. Depending on the option, it was as large as max. 2.5 million m^3/day, due to which drilling was rejected.

Through studying a successful experience of using physico-chemical effects on the collector layer via applying different compounds to the collector and the bottom-hole area and upon weighing up the opportunity of introduction of such methods into the underground storage domain, an industrial foam use program for UGS has been drafted in order to raise the daily productivity and draw volumes.

The purpose of using the foam systems with this storage is to compact the deposit, i.e. minimize the flow and technology losses. First of all, the use of foam systems was suggested in order to intensify fluid displacement by gas for better involvement of low penetrable layers of the formation, thus improving the process of drying the stratified inhomogeneous collectors. Second, we supposed making a wall-shaped barrier to restrict the water influx from the south (

Figure 3), since the wells here are also decommissioned within the first month of the drawing period due to lateral water breakthrough. In order to take the planned measures, the actual operation properties of the wells were analyzed, as well as the results of 3D numerical modeling, which resulted in the determination of the well numbers to place the barrier.

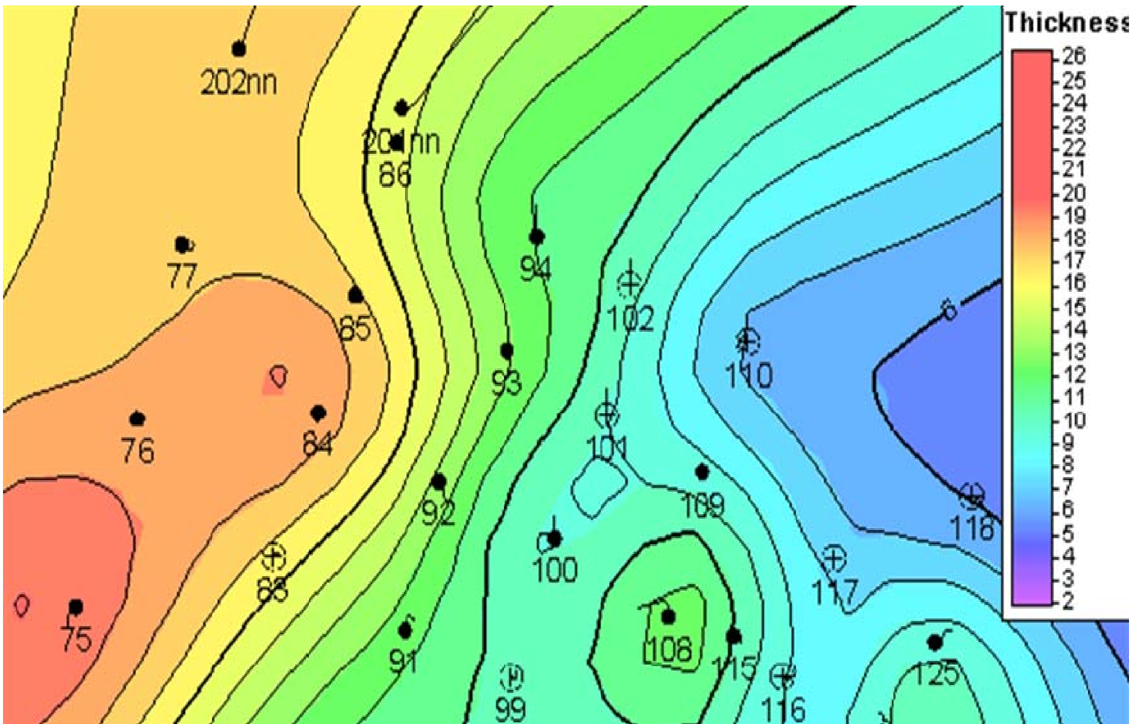


Figure 3 – Schematic layout of the planned foam barrier and the water influx direction

Methods

Processing of the chosen wells and designing of the intrastratal screen were performed on the ground of the patented technology [1, 2].

The essence of a well processing technology is the injection of the Surface Active Substance foaming solution and the gas. To achieve more efficiency of a strata desaturation (if it consists of many partings), the process of the disperse medium (foam) formation must be devided into several cycles as it helps to inject the partings with different permeability. Injecting in each cycle is performed in a volume that provides the inequilibrium foam formation in the reservoir conditions with the lowest value of the phase permeability. (Chart 1).

Chart 1 – Calculated volume of Surface Active Substance and gas for local well treatment.

Serial number	Number of wells	The number of partings accepted in calculations	The volume of the solution on reservoir water, m^3	SAS mass OP-10, kg	SAS CSSL mass, kg	Number of cycles	Quantity of solution injected at one cycle, m^3	Quantity of gas injected after each cycle, m^3 at reservoir conditions
1	81	4	40	200	120	4	10	40
2	83	1	20	100	60	1	20	80
3	89	2	11	55	33	2	5,5	22
4	98	4	20	100	60	4	5	20
5	99	4	15	75	45	4	3,8	15
6	101	4	45	225	135	4	11,3	45
7	109	4	40	200	120	4	10	40
8	110	3	15	75	45	3	5	20
9	116	2	10	50	30	2	5	20
10	118	2	16	80	48	2	8	32
11	117	2	10	50	30	2	5	20
12	123	3	12	60	36	3	4	16
13	124	2	10	50	30	2	5	20
In total			**264**	**1320**	**792**			

The solution of a foam agent was performed in the following way. A synergic composition that consisted of the main foaming non-ionic Surface Active Substance (oxyethylated alkyphenol OP-10) and the supplemental anionic Surface Active Substance (consentrated spent sulfite-alcohol liquor (CSSL) in the ratio from 0,6:1 pts.wt, to 1:1, pts.wt.) was used as a foam agent solution.

The solution was based on the reservoir water of the same horizon, the number of the necessary volumes was performed from the monitoring wells. In the figure there is a process of Surface Active Substance solution preparing at the field.

Figure 4 – The process of Surface Active Substance solution preparing

The process of carbonates crystallization was found out in the wells during the implementation of the program. Quartz and clay material adhere to a stainless steel wire of a well filter and this process reduces the Surface Active Substance solution well injectivity almost to a zero level (Figure 5).

In those cases where mudding was found out, the processings were made with the systems destroying both mudding clay and mineral deposits, and only then the subsequent injecting of the Surface Active Substance solution was carried out according to the described technology.

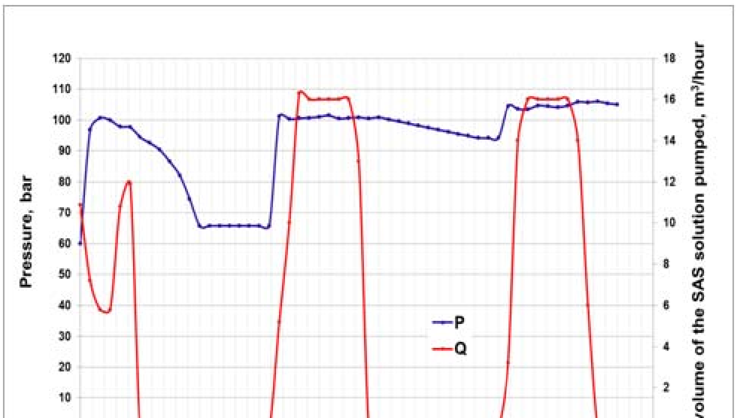


Figure 5 –The pressure dependence vs the volume of Surface Active Substance solution injected into the well: a) the bottomhole area of the well is not mudded, b) the mudded filter

Designing and Implementation of the screen was performed for the first time in the world's underground gas storage operation experience and will have wide prespectives. Formation of the screen was realized through the chain of wells (Chart 2 -

Figure 6), using the technology that suppose injecting of the estimated volume of the foaming solution with individual markers into the injection wells, so they appear in the relief wells indicating the formation of the screen and its continuity between those wells.

Chart 2 – Calculated volumes of Surface Active Substance and gas the screen designing

№s.N	**Wells numbers**	**The volume of the injected solution, m^3**	**The volume of the injected gas in the reservoir conditions, m^3**	**SAS mass, kg**	
				OP-10	**CSSL**
1	87	156	624	780	468
2	95	1208	4832	6040	3624
3	103	332	1328	1660	996
4	111	1525	2952	3690	2214
6	**In total**	3221	9736	12170	7302

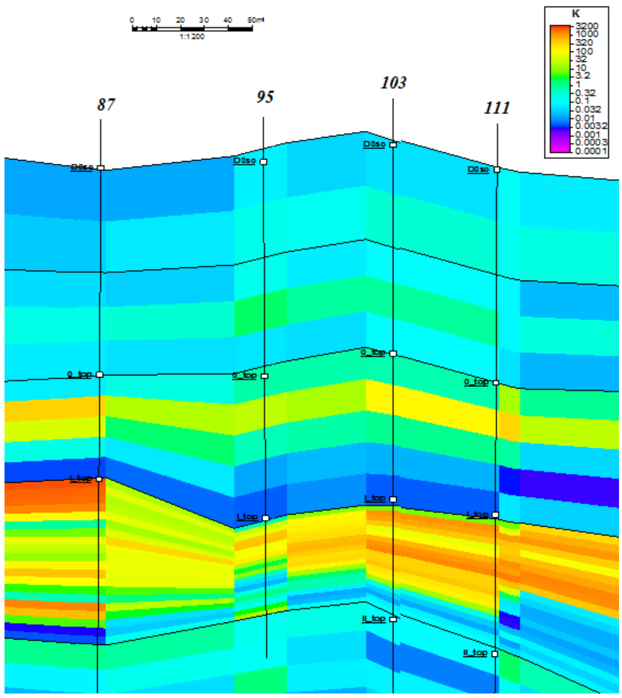
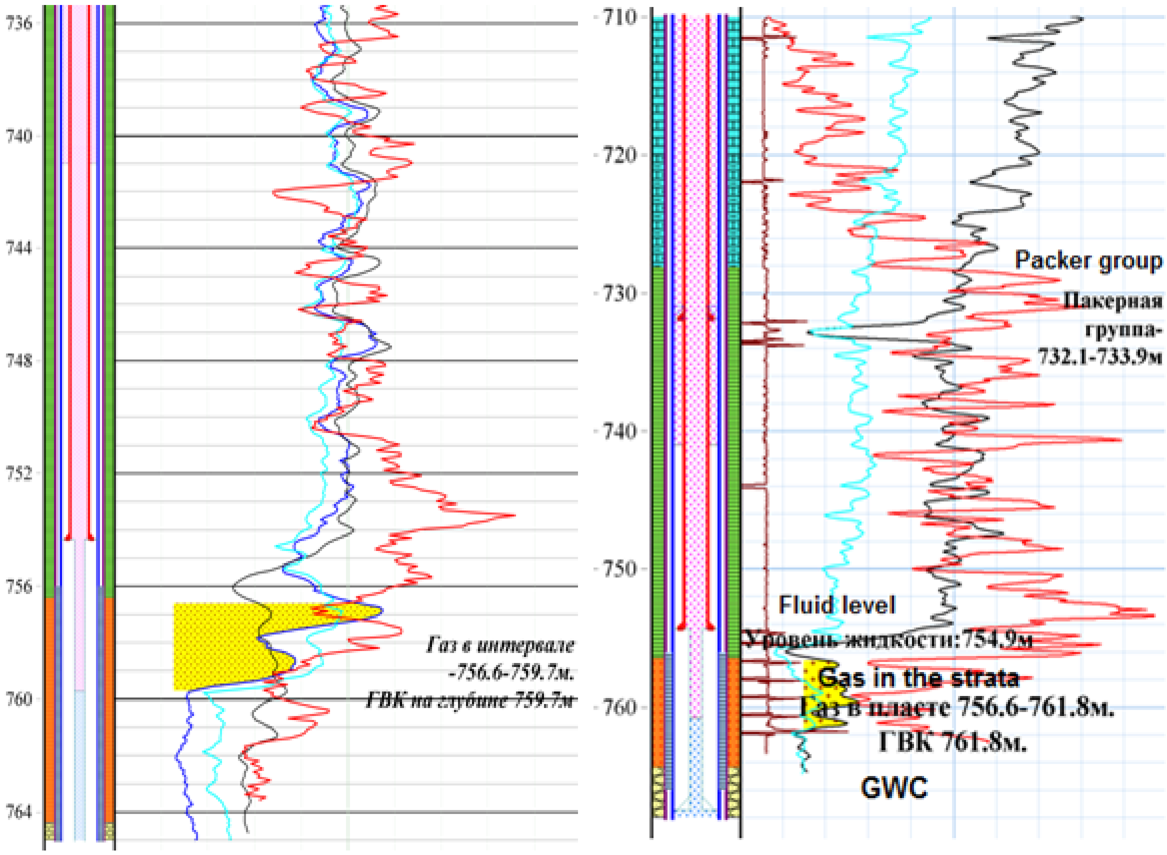


Figure 6 – The profil between the wells participated at the foam screen formation

After completion of the SAS solution injecting into the wells the program of special studies allowing to control the continuity of the designed screen and evaluating the effectiveness of the measures was developed. The program included a range of geophysical and hydrodynamic studies to determine the coefficients of gas saturation of the strata, especially in GWC expansion in the wells as well as the inflow profile determination.

Results

According to the results of the geophysical studies it was found that the performed works helped to increase gas saturation capacity of the wells of that area (Figure 7)



a) b)

Figure 7 – The results of the geophysical study on the well 83 in the selection process: a) February 2014, b) February 2013

That was also confirmed with the operation data, the results of which helped to extend the work of a number of wells 5 times in comparison with previous years and by the mid-season of drawing to increase the total accumulated volume of the topping gas at wells on the average 10 times, and the water factor decreased on the average 4 times.

Processed wells and wells situated near the designed screen showed a significant increase in the production rate when the daily production was increased in a period of lowing the pressure below hydrostatic one in the processing area.

Sudden flooding of the stock and as a consequence decommissioning did not happen and in a number of wells the value of the water factor was within an acceptable range a significant amount of time. It is not typical for this storage as an increase of daily production causes drastical watering of the wells of this group and they do not participate in the further work.

Such measures allowed us to raise the daily production by 30% and assure water-free operation of a series of wells which had been scarcely involved in drawing due to high water factor within the previous seasons.

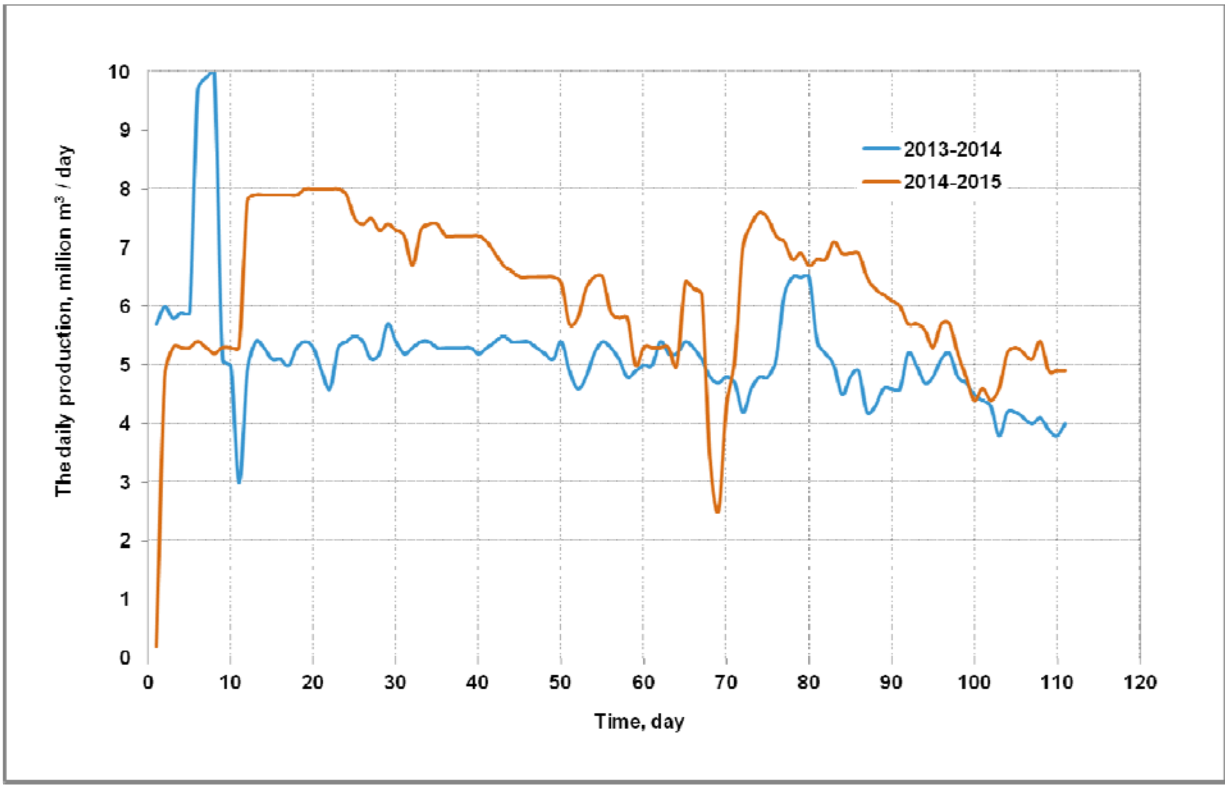


Figure 8 – Comparison of the daily productions for the drawing of the seasons 2013-2014 years и 2014-2015 years

Chart 3 – Comparison of the well works in the seasons before and after works

Well	After Drawing – For the season 2014 - 2015		Before Drawing – For the season 2013 - 2014	
GGP-1	Gas Q	At work	Gas Q	At work
N of the well	t. m³	hour	t. m³	hour
90	6735,9	1986,4	623	87,75
88	2538,3	2092,9	218	71,89
96	1956,8	2045,3	149	305,2
97	4531,2	1174,5	354	74,18
100	2113,7	1671,1	383	198,3
107	8345,8	2161,5	342	68,8
105	2656,4	2009,6	966	310,1
114	13933	2128,3	1703	310,1

The economic efficiency was calculated to evaluate the success of the activities in monetary terms. It confirmed the commercial benefit of more that 500 mln.rubles with small enough material costs for the preparation and execution of works.

Conclusions

Obvious results attained by the use of SAS solutions for the intensification of fluid repression with gas allowed to develop complex recommendations and measures for their further use at this storage.

In conclusion, it is worth mentioning that the said technology, being very cost effective, proved fairly efficient and we believe it must be further improved to develop any new agent compounds and expand the sphere of usage, as the world practice of UGS knows quite a few storage facilities where foam barrier could isolate the gas deposits and prevent the evasion of gas off the trap.

References

1. The patent of the Russian Federation № 2471970,
2. The patent of the Russian Federation № 2375281