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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

İMPROVİNG THE EFFİCİENCY OF UNDERGROUND GAS STORAGE FACİLİTİES BASED ON OPTİMİZATİON OF THEİR OPERATİON MODES

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GENERAL DESCRİPTİON OF WORK

The actuality and study degree of the topic. The operation of gas storages, one of the most important strategic areas in the national economy of the country, requires the solution of many complex problems. The most important of them is the seasonal gas-injection and gas-extraction of natural gas from hydrocarbon deposits into gas storages, the effective development of wells after drilling and capital repair, and the expansion of the gas storage. In this regard, there is a need to pay more attention to the application of technological regimes and methods during the injection and extraction of natural gas in underground gas storages (UGS) created in the depleted gas condensate and salt fields, to reduce gas losses during well development.

The modern features of the UGS operation not only predetermine the performance of seasonal functions, but also gas demand and market conditions, which in turn are associated with increased productivity of its facilities and technological maneuverability of the underground storage system. From this point of view, the creation and operation of UGS for the search and development of new technological solutions to increase productivity is considered a actual research issues.

The purpose and objectives of the study.The purpose of the study consists in the development of new methods and technological solutions aimed at increasing the efficiency and reliability of the process of creating and operating UGS in the depleted gas condensate and salt deposit.

The objectives of the study:

- Development of methods for increasing of gas capacities, the efficiency of the work of gas-injection and gas-extraction wells of the UGS;
- Development of the method of forecasting geological-technological indicators on deposits in the gas-injection and gas-extraction season in UGS;
- Expansion of UGS and development of methods for assessing their active gas volume;

-Development of the method of increasing the efficiency of the work of gas-injection and gas-extraction wells and reducing the gas loss of wells of the UGS;

- Determination of the number of drilling wells and cameras to assess the possibilities of creating a gasstorage in the stone salt deposit, development of a method of safe salt removal.

Methods of research. The issues were resolved through the analysis of research conducted in the field, using modern mathematical and statistical methods and the application of creatively proposed methods.

The main provisions brought to the defense.

- Solution of problems of modeling of gas-injection and gas-extraction process of the UGS;

- Solution of geological-technological indicators forecasting of VII horizon of Garadagh structure and I and III horizons of Galmaz structure according to correction of isobar map;

-Method of expanding of the UGS and assessing their active gas volume;

- Method of increasing efficiency of drilling and gas intake wells and reducing gas loss of wells;

- Method of increasing the efficiency of the work of gas-injection and gas-extraction wells and reducing the gas loss of wells of the UGS;

- Determination of the number of drilling wells and cameras to assess the possibilities of creating a gasstorage in the stone salt deposit, method of safe salt removal.

Scientific novelty of the study. The analysis of complex geological, technological and thermodynamic researches and generalization of their results allowed to obtain the following scientific novelty:

1. The method of determining the technological modes for Garadagh and Galmaz UGS during the gas-injection and gas-extraction season and efficient selection of the operating modes of the wells has been developed.

2. The method of determining the number of wells in gas-injection and gas-extraction, completionwells for a closed circuit and

determining the volume of lost gas has been developed.

3. The technological method for extracting the fluid column collected in the well has been developed and a mathematical algorithm has been proposed to calculate its technological indicators and a calculation scheme has been created on its base for estimating the gas-producing capacity of the well according to the parameters of the technological method.

4. Well data on Garadagh (II and III tectonic block) and Galmaz (IV tectonic block) USG have been systematized, calculation method allowing expansion of gas horizons of tectonic blocks as a gas storage and estimation of their active gas volume has been developed.

5.The method of salt washing and removal was developed by creating gas storage cameras in the Tumbul stone salt deposit and determining the number of wells to be drilled in it, and a calculation scheme was created that allows estimating the active, buffer gas volume of the cameras.

Theoretical and practical significance of the study. The research carried out is of theoretical and practical importance aimed at increasing the efficiency and reliability of the process of creation and operation of UGS.

Approbation of the work. The main provisions and results of the dissertation were discussed:

- X International Scientific and Practical Conference“Fundamental and applied research in the modern world” (USA, Boston, 2021);
- X International Scientific and Practical Conference “Actual trends of modern scientific research” (Germany,Munich, 2021);
-Online Scientific Conference of young researchers and doctoral students dedicated to the 98th anniversary of national leader HeydarAliyev (Baku, ASOIU, 2021);
- Department of operation of gas storages of Azneft PU (June 16, 2016, may 16, 2017, may 29, 2018);
-Azneft PU OGPD named after N.Narimanov (June 08, 2016).

The results of the study were applied in the following field work:

1. The effective method of selecting the mode of operation of wells during the season of gas-injection and gas-extraction was applied to Garadagh and GalmazUGS wells, and as a result, the economic efficiency was 8905 thousand manats.

2. The technological method of pumping gas into the wells by stages has been applied in the wells of the UGS and as a result, additional pumping of 131,586 million m^3 of natural gas to the UGS with the wells has been provided.

3. The technological method of gas-extraction from wellsby stages has been used in the wells of GalmazUGS and as a result, an additional 144,005 thousand m^3 of natural gas has been produced. This is an economic efficiencyof 48,962 thousand manats.

4. The technological method of gas-extraction from wells by stages has been applied in GaradaghUGS wells and as a result, additional natural gas-production of 416,276 million m^3 has been provided from the storage.

5. Completionof wells in Garadagh and Galmaz UGS was carried out by the method of closed-circuit development, and as a result of the application of the method, 1,998,092 million m^3 of natural gas was saved during development. As a result, 679,351 thousand manat economic efficiency was obtained.

Approved acts on the application are attached to the dissertation.

15 scientific papers were published on the materials of the dissertation, including 12 articles in scientific journals (4 - at abroad country), 3 articles or theses in conference materials (2 - at abroad country).

The name of the organization where the work was performed. Azerbaijan State Oil and Industry University.

The total volume of the thesis with a separate indication of the individual structural parts of the thesis. The dissertation consists of an introduction, 6 chapters, 23 paragraphs, conclusions, a list of 139 used literature and 5 appendices. The work consists of 160 pages of computer writing, including 45 numbers of pictures and 25 numbers of tables. The total volume of the dissertation with a sign is 231966.

BRİEF CONTENT OF THE WORK

In the introduction, the relevance of the dissertation is substantiated, the purpose of the work, its general provisions, ways to solve the issues posed, scientific novelty and the practical significance of the work are reflected.

Water layers, spent gas, gas condensate, oil and salt deposits are used as operational objects in the creation of UGS. Around the world, about 74% of UGS is formed in depleted oil, gas and gas condensate fields, 12,6% in the base of water horizon structures, 13,4% in non-porous structures (13,2% in the base of salt deposits and 0,2% in worked mines). Gas storage can be characterized by two main parameters: volume and power. The first parameter - characterizes the storage volume, that is, active and buffer gas volumes. The second parameter - characterizes the daily productivity in gas injection and degassing processes and the period when the reservoir works with maximum productivity.

The processes of creation and operation of UGS using traditional technology are characterized by a number of negative aspects, including a sufficient amount of active gas, gas leakage and watering of wells. In the direction of searching for and creating new technological solutions that provide some elimination of these negative aspectsresearches were conducted by Aslanov V.D., Ismayilov F.S., Agayev F.T., Zakirov S.N., Kurbanov M.N., Buzinov S.N., Koratayev Y.P., Levikin E.V., Lure M.V., Hein A.L., Grichenko A.I., Khan S.A., Lopatin A.Y., Parfenov V.I., Petrenko V. .I., Simirnov V.I., Shirkovsky A.I., Mikhailovsky A.A. and other authorsand depending on the geological conditions of the creation of UGScertain regularities of the regulation of its work have been defined.

Despite the large number of researches on the creation and operation of the gas reservoir, the management of regulatory processes in the UGS and use of gas resources, as well as ensuring optimality in the organization of its work, require the investigation of numerous physical and technological issues.

The first chapter presents a review and analysis of studies on

certain regularities of regulation of the work of underground gas storage (UGS) created in porous and porous deposits with the aim of regulating the inequality of gas supply and ensuring long - term storage of gas resources.

The second chapter examines the possibilities of implementing methods for solving problems on the assessment of geological and technological parameters, which are necessary and important in the development of the UGS formed in porous structures.

The problem of determination of reservoir permeability, porosity and other technological parameters in cycle processing of UGS was considered. The determination of parameters was approbated on the basis of well data interpretation according to the decided and unresolved gas filtration modes.

In the first case, the study is conducted from the lowest debit to the highest debit level (flat fare). The well is left to work until the pressure and debit with a small debit are completely fixed. The first point of the indicator line is fixed on the basis that the well pressure and flow rate do not change according to the time. The stabilization process of pressure and debit is continuously recorded, and the received debit and pressure curves are used to set the lay parameters. After performing appropriate pressure measurements in the bottom of the well, at the mouth of the well (lifting pipes), in the circular and annular spaces, as well as temperature and gas and liquid debit measurements at the required points, the well is closed. Well pressure begins to recover. The wellhead is continuously recorded until the pressure recovery process is approximately equal to the static pressure layer pressure.

The test results of the well are interpreted by the following two-step equation characterizing the dependence of reservoir energy losses on the flow rate in the process of drilling or gas extraction:

$$p_l^2 - p_w^2 = A \cdot Q + B \cdot Q^2 \quad . \tag{1}$$

Here, p_l and p_w –the formation and wellbore pressures, respectively; A and B –filtration resistance coefficients; Q –gas consumption; $A \cdot Q$ – pressure loss due to viscous forces;

$B \cdot Q^2$ –pressure loss due to inertial forces.

Graphical and numerical methods are used to estimate the filtration resistance coefficients, and based on their results, the filter-capacity parameters are identified.

In the second case, the method of research is based on the processes of redistribution of pressure in the reservoir after launching and closing the well. The nature and speed of distribution of pressure in the collector depends on the properties of the gas, porous medium. There is a functional relationship between the filter-capacity parameters of the layer-collector and the nature of the pressure distribution.

This functional relationship is determined by the solution of the system equations of plane-radial filtration of the process of gas injection into the reservoir and its extraction from the reservoir:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{khp\beta}{\mu Z p_{at}}\frac{\partial p}{\partial r}\right) = \frac{\partial}{\partial t}\left[\frac{mhp}{Zp_{at}}\right],\ D=(R_w \le r \le R_k),\ t \in (0,T), \quad (2)$$

$$p(r,t)\big|_{t=0} = p_l(r), \quad (3)$$

$$2\pi r \frac{khp\beta}{\mu Z p_{at}}\frac{\partial p}{\partial r}\Big|_{r=R_w} = \pm Q_0(t), \quad (4)$$

$$p(r,t)\big|_{r=R_k} = p_l(t)\ . \quad (5)$$

İf linearization is carried out in the equation (2) and we solve it taking into account the initial, boundary conditions, it will be taken:

$$p_l^2 - p_w^2(t) = \frac{1{,}28 Q_0 \mu p_{at}\beta}{\pi kh}\left[e^{-5{,}78\frac{\chi t}{R_k^2}}\right],\ \chi = \frac{kp_l}{\mu m}\ . \quad (6)$$

The pressure recovery curve is made according to the equation:

$$\lg(p_l^2 - p_w^2(t)) = \alpha_1 - \beta_1 t\ . \quad (7)$$

Here, $\alpha_1 = \lg 1{,}28\cdot\alpha$, $\alpha = \frac{Q_0\mu p_{at} Z\beta}{\pi kh}$, $\beta_1 = 5{,}78\frac{\chi}{R_k^2}$.

For the determination of α_1 and β_1 the pressure recovery curve is built in the coordinate system $(\lg(p_l^2 - p_w^2); t)$. Then the reservoir

parameters, including reservoir permeability and piezopermeability, and the volume of gas saturation of the drainage zone of the well is determined.

The problem of calculation of indicators of technological modes for UGS in the seasons of gas injection and gas production was considered, the algorithm for determining the pressure in the surface and drainage zone of wells in the process of cycle development, technological indicators based on changes in the component composition of the gas phase was introduced.

Advantages of certain technological modes of operation in accordance with the regulation of certain complexities of wells, lanes, monifold lines, separators, heat exchanger, absorbers, desorbers, compressor and other mine equipment in the process of gas production in UGS are substantiated and, ultimately, the possibilities of choosing the right measures for increasing the efficiency of the operation of wells are evaluated.

Also, the problem of the optimal distribution of the gas produced and the volume of gas injected into the wells of the UGS was considered, and its solution was determined based on the time-dependent change dynamics of the value of debit and depression at the stage of gas extraction from the storage, and the value of acceptanceof wells and repression at the stage of gas injection into the storage.At the same time, restrictions on debit and depression values of üells ensuring minimum watering of wells in total gas production, acceptance and repression values of wells ensuring maximum removal of total gas from wells of the gas-water boundary were taken into account.

On the issue of optimization of gas produced on wells, it is investigated to find effective well balances for selection of rational mode of operation of wells at the stage of gas production from UGS and optimal distribution of production between wells. In conditions of technological limitation and fulfillment of given demand in rational mode (presence of certain restriction and demand for well production and depression value) the values of technological parameters (debit and depression) characterizing the mode of exploitation wells corresponding to the provision of minimum

watering of well product are selected according to the value of total gas produced from UGS. Implementation of technological limitations is considered equally powerful in fulfilling conditions of non-destruction of the wellhead zone, and it is not allowed to reduce the wellhead pressure below the minimum permissible value by ensuring the removal of liquid and solid particles from the wellhead zone. At this time, it is assumed that the number of wells allocated for gas production from UGS is known in advance, and in solving the problem of optimal distribution of gas production among the wells (the issue of choosing rational operating modes of wells at the stage of gas production from UGS), technological restrictions for the total volume of gas supplied to the main gas pipeline are applied and the values of the time-dependent variation of the downhole depression and flow are sought, which allow to ensure that the amount of liquid in the gas taken from the reservoir is minimal by meeting the requirements.At this time, the minimization of depression averaged over time in the wells is chosen as the optimality criterion of the gas produced by the wells of the UGS, taking into account the averaged value of the parameters of the degree of dilution of the wells for a certain period of time.

On the issue of optimizing the volume of gas injected into the wells, the reception of the wells and the optimal distribution of the total volume of gas into the wells at the stage of gas injection into the wells of UGS are investigated. The number of wells allocated for gas injection is considered known, and wells located in the central zone of the reservoir are usually used for this purpose. The values of wellbore pressure and gas injection volume, which allow to ensure the maximum removal of the gas-water boundary from the bottom of the well, are sought in the fulfillment of the technological limitations of the operating mode of the wells and the requirement for the total volume of injected gas. As an optimality criterion, the maximization of the repression depending on the time for the wells is selected, taking into account the average value of the parameters of the watering rate of the wells in a certain period of time.

In the third chapter, the analysis of geological structure and geological-technological researches of UGScreated in the structure of

depleted Garadagh and Galmaz gas-condensate fields was carried out.

The issue of clarifying the tectonic structure of the geological trap of the UGS created in the VII+VII^{a} horizon in the southern wing of the Garadag structure was considered. In this regard, the clarification of the existing structural map according to the ceiling of the VII horizon, the clarification of the locations and amplitudes of tectonic disturbances in the existing structural maps, the clarification of the lithological wedge boundaries of the VII and VII^{a} layer reservoirs, based on the well logging data, the investigation of the conditions of the gas-oil border of the VII+VIIa horizon in the western area of the field and specification has been realized.

The issue of forecasting the geological-technological indicators of the VII horizon of the Garadagh structure was also considered. The technological indicators of the VII^{a}-VII horizons of the Garadag UGS and their wells according to the total gas volume according to the necessary demand, the gas injected and withdrawn to the UGS according to the calculation results of the joint modeling of the gas injection and gas extraction process and the optimal distribution of the gas produced on the wells and the gas volume injected into it dynamics of its volume, the amount of water coming when the gas is taken was determined and the isobar map of the reservoir was corrected based on them.

Based on the isobar map, the technological indicators of the cycle operation process have been predicted for the current period, based on the optimization of the volume of gas produced and the volume of gas injected from the wells of the VII^{a}-VII horizons of UGS. At this time, the distribution dynamics of the optimal volumes of injected and withdrawn gas between the wells according to the total volume of gas according to the seasonal demand was determined and the amount of water entering during the withdrawal of gas was determined. Thus, during the gas extraction season, approximately 1245685 thousand m^3 of gas will be produced from 42 wells included in the VII^{a}-VII horizons, and during the gas injection period, this indicator is predicted to be approximately 114679 thousand m^3. More precisely, during the gas injection period, an

average of 151,6927 thousand m^3 of gas was injected with one well in UGS, and during the gas extraction period, this value was approximately 164,7732 thousand m^3. When the gas is taken from the wells, the water production is predicted to be approximately 8651 m^3. During the extraction of gas, the pressure in each well changed according to the pulsation mode, and its gradual decrease trend was manifested. The fact that the average amount of water volume in the product produced from each well is quite small confirmed that the nature of the complexes is poorly simulated.

The solution of similar issues (corresponding to the VII horizon of the Garadagh structure) on blocks I and III of the structure of Galmaz UGS has been implemented. Technological indicators of the cycle operation process have been predicted for the current period on the basis of optimization of the volume of gas produced and gas injected into the wells of blocks I and III of the Galmaz UGS. The possibility of extracting 837,447 thousand m^3 of gas from 102 wells included in the blocks and injecting 840,508 thousand m^3 of gas into those horizons during the gas injection season was determined. More precisely, it was determined that in the period of gas injection, approximately 54,935 thousand m^3 of gas was injected into UGS with one well, and during the period of gas withdrawal, this value was approximately 39,2394 thousand m^3. When gas is taken from the wells, water production is predicted to be approximately 5365,4 m^3. During the extraction of gas, the dynamics of wellhead temperature change in each well showed periodicity.

The fourth chapter is devoted to the solution of the issues of assessing the possibilities of increasing the volume of active gas in the Garadag and Galmaz UGS.

The issue of evaluating the possibilities of increasing the active gas capacity due to the III and II tectonic blocks of the Garadag UGS field was considered. Based on the calculation model for the differential depletion regime due to the composition of gas taken from the III and II tectonic blocks, the dependence of the gas volume coefficient on the reservoir pressure was corrected and the available active gas volume of the Garadag UGS is 1.5 billion m^3, and the buffer gas volume is 0.75 billion m^3. has been done. The total gas

volume of UGS is 2.25 billion m³, the number of working wells is 42 units, the volume of gas injected into one well is 150-300 thousand m^3 / day, the final injection pressure is 16,0 MPa, the volume of gas taken from one well is 160-300 thousand m^3 / day, the pressure $p \in (8;16)$ MPa and gas injection during the year based on the fact that the number of days is 180, and the number of gas extraction days is 160 days, and by selecting the wells that are higher in terms of the volume of total gas that can be pumped by the months of the season and with the optimal receiving capacity, identifying the increase of the active gas capacity of the reservoir due to the drilling of new wells in the area where those wells are located. justified. It was determined that the volume of gas injected into the operational wells around the newly drilled wells for the expansion of the Garadag UGS is 298,1 thousand m^3 / day on average. Considering that it is appropriate to use the new areas of tectonic blocks III and II as UGS, and in this case, by drilling 15 wells with a design depth of 3100 m, the volume of gas to be injected into one well is 300 thousand m^3 / day, and the volume of active gas that can be injected can be increased by about 0,5 billion per season has been identified.

The issue of evaluating the possibilities of increasing the active gas capacity at the expense of the IV tectonic block of the field in Galmaz UGS was considered. Based on the analyzed data of the interpretation results of the research of some wells of the IV (former V-VII) tectonic block, the possibility of increasing the active gas volume due to the determined gas reserves was determined. For this purpose, not only the drilling of new wells, but also the possibility of using exploration and exploitation wells numbered 401-409, which were previously drilled and operated, was established. The possibility of using its capacity by expanding the existing compressor station for the new gas storage to be created in the IV tectonic block and the newly built Gas Distribution Station (GDS) in the territory of the III tectonic block has been shown.

Taking into account the possibility of using a compressor station during gas injection into horizons I and IV of the IV tectonic block, the volume of active gas is calculated based on the application

of the balance equation of the gas regime, taking into account preliminary data (for horizon I - Ω = 2,9 million m^3 and for horizon IV - Ω=2,0 million m^3, $T = 310$ K, $p_{max} = 15{,}0$ MPa, $p_{min} = 7{,}5$ MPa) respectively 272 and 188 million $m^3$of active gas volume for newly created UGS it is determined. More precisely, the possibility of increasing the volume of active gas by 460 million m^3in Galmaz UGS and the fact that this increase is reflected in the technological project to be drawn up for the new UGS, which is planned to be created in the productive layer of the IV tectonic block, was considered to be practically important.

Also, the issue of increasing the volume of active gas of the I and III tectonic blocks of Galmaz UGS by adjusting the output pressure of the compressor unit was considered. Based on the researches, in the process of operation of the gas reservoir, the determination of the degree of activity of individual layers, intermediate layers, collector zones and the specification of the filtration-capacity parameters of the well bottom zones were realized. By raising the output pressure of the gas compressor unit from 15,0 MPa to 21,0 MPa, the possibility of increasing the active gas volume (480-600 mln. m^3) of UGS was established.

The fifth chapter is devoted to solving the issues of increasing the efficiency of the gas injection and gas extraction regime and developing the methods of assessing gas losses during well development.

Initially, the issue of implementation of effective methods for increasing the efficiency of gas injection and gas extractionregimes of UGS was considered. In order to increase the efficiency of the regimes of gas injection and extraction with wells along the horizons of the UGS field, a new gas injection and gas extraction method was proposed according to the “Technological method of stepwise injection of gas into wells” and “Technological method of stepwise extraction of gas from wells”.

In the first case, gas is injected into wells along horizons in 3 stages per season. In the first stage, gas is injected into the central wells of the structure, in the second stage into the central wells of the structure, and in the third stage into the wells close to the contour.

By means of the volume of gas pumped through the compressor unit, the fluid compressed towards the wells close to the contour of the formation is removed from the wellbore around the contour. Due to the liquid removed from the formation, the formation pressure decreases, the useful work coefficient of the compressor unit increases, and the injection of gas into the wells becomes more efficient and effective. This results in the injection of additional gas volume into the layers, and the coefficient of gas removal from the layers increases.

In the second case, gas extraction from wells along the horizons is carried out in 3 stages per season. In stage I, gas is taken from wells in the center of the structure, in stage II near the center of the structure, and in stage III near the contour.

During the gas extraction season, the process of gas extraction along the horizons is started from wells drilled in the central parts of the productive layer of the structure. According to the demand, gas is taken from central and contour wells. During gas extraction, optimal modes are selected for each horizon according to the amount of gas taken. Modes are selected according to the minimum volume of liquid and sand that comes with the gas taken from the wells. In this regard, the pressure difference between the wellhead, the gas junction of the wells, the separator block, the measuring junction and the gas pipeline is regulated by gradually lowering it through the gas regulator choke valve.

In the application of the method, during the operation of gas wells, the occurrence of sand manifestation and the factors that cause the disintegration of the layer structure in the area of the well bottom are prevented, and there is no need to use methods of impact that are weak against sand. This also determines the provision of economic efficiency.

Also, the issue of determining the characteristics of gas losses during the operation of the UGS was considered. A certain amount, but unstable gas losses (characterized by geological, technical and technological factors) occur in the processes of seasonal operation of UGS in gas extraction and gas injection mode, as well as continuous operation of all technological equipment under pressure.

From this point of view, the form of process gas losses in the process of seasonal gas extraction and gas injection mode of Galmaz and Garadag UGS, as well as in the process of non-stop operation of all technological equipment under pressure, shown in figure 1, 2, and the possibilities of its assessment, are considered to be practically significant.

According to the processing according to the technological scheme and the statistical data taken from the UGS, during the gas injection season, depending on the volume of gas supplied from the main gas pipeline and the replacement and maintenance of the number of compressor units for technical reasons, on average, stoppages occur 5-6 times in both UGS during the day. During stoppages, the gas in the unit is released into the atmosphere, as a result, technological gas loss occurs.

Depending on the location of the well in the field during the garadagh and Galmaz UGS gas supply season, technological gas loss occurs during the purification of the hydrate, fluid and mechanical compounds formed within the schleyf lines (2000-3000 m long 114 mm 178 schleyf lines) (3-4 times during the season). On the other hand, depending on the amount of gas required, displacement and stopping operations are carried out as a result of hydrate, mechanical mixtures and other technical problems in 28 seperators used during gas transmission, as a result of which there is a need to discharge gas under high pressure within the seperator into the atmosphere and as a result, gas losses increase.

In this regard, the issue of calculating technological losses during the operation of equipment in UGS is considered. Technological gas losses during operation of equipment at UGSas a result of an error in the flowmeter, when blowing of seperators, degassing of condensate, when blowing of slag and other different diameters, when blowing the pipeline and other different diameters of gas injection and gas extraction lines, in ground-based technological equipment working under pressure, when blowing and completionwells, etc. the resulting gas losses are classified and empricised expressions are proposed for their calculation. On their basis, the construction of a gas purge facility that allows ensuring the

uniformity of seperated gas during gas extraction, reducing the num-

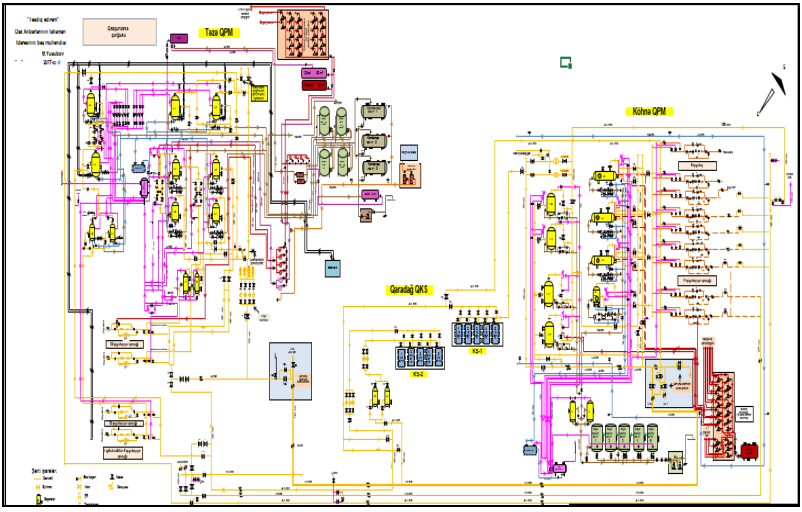

Figure 1. Technological scheme of Garadagh UGS

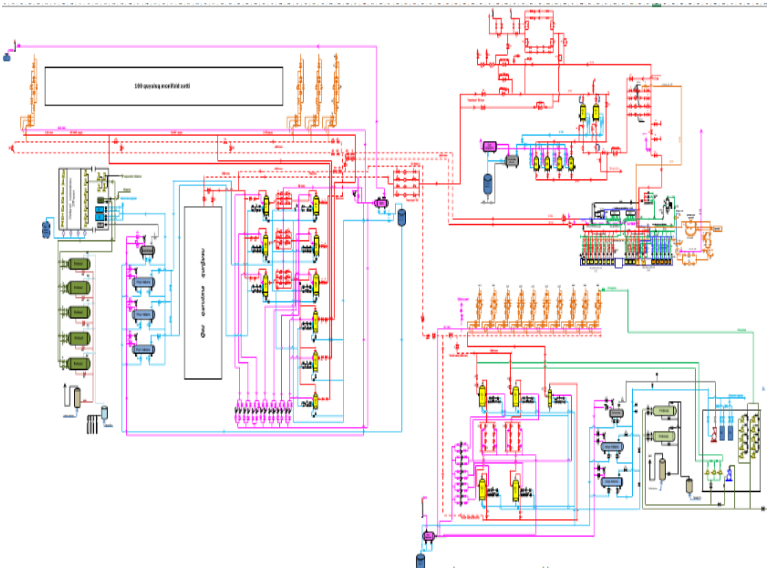

Figure 2. Technological scheme of GalmazUGS

ber of blowing operations carried out in seperator and compressor units by ensuring the correct choice of gas extraction and gas injection mode, reducing the number of blowing by preventing the accumulation of fluid in the well lug and manhole lines, also, the possibility of minimizing technological gas losses due to ensuring the hermeticity of technological equipment is confirmed.

In the process of the cycle operation of the UGS with different geological conditions, intra-layer and inter-layer irreversible geological gas losses are formed during the injection and extraction of gas into the wells. Based on the dynamics of the technological indicators of the process of operation of the UGS, in the calculation of intra- and inter-layer gas losses (leakage), some parameters, including the gas leakage coefficient, the thickness of the arch, the measurement of formation pressure, etc. being problematic creates certain difficulties. The volume of gas leakage and its intensity mainly depend directly on the amount of formation pressure in the reservoir. The gas injection process is carried out in UGS until the value of formation pressure is permissible and does not exceed the maximum possible design value. The gas extraction process is carried out until the formation pressure is not lower than the minimum possible design value. During each period of operation, the actual value of the current formation pressure in the reservoir and the flow rate of the produced (injected) gas are measured. The current formation pressure is measured from the dome part of the formation, and this allows to determine a fairly accurate value of other measured parameters and ensures an increase in the calculation accuracy of gas losses.From this point of view, during the process of gas injection and withdrawal of gas into the wells in the process of operation of the UGS, a method was proposed that allows calculating the gas losses of the reservoir based on the determination of the gas loss coefficient according to the minimum of the difference between the actual value of the current formation pressure and the calculated value of the geological gas losses within and between the formations, and based on it in the process of operation of Galmaz UGS, the result of gas loss determined based on the dynamics of technological indicators exceeds the results of intra-reservoir and inter-reservoir

gas losses determined according to the difference between the actual (balance) and calculated volumes of gas in the formation (imbalance) by about 70-85%. The quantitatively found value of the gas loss coefficient allows to assess the risk of loss in the operation of the UGS and ensures the project indicators and reliability of the UGS.

A modeling method has been introduced that allows UGS to estimate the limits of possible changes in reservoir gas losses. In this case, the gas-saturated volume in accordance with the selected layers is divided into two parts (top and bottom), and each of the parts in turn is divided into internal and external zones. Gas can enter the external zone only due to the flow from the central zone. Gas balance equations were compiled for each layer (first for internal zone and second for external zone) and it was accepted that in four separated zones gas-saturated volumes change under the influence of reservoir water motion.

The constant coefficients included in the balance equations mean the corresponding phase conductivity, viscosity, and field average values of the generalized conductivity coefficients between the selected zones by gas or water - in general, the layers in which flows occur. The modeling process for the practical determination of the values of the conductivity coefficients of flow areas is divided into two stages. At the first stage, the inverse problem is solved, i.e. all proportionality coefficients and gas-saturated volumes are considered unknown, and the pressure and well debits are considered to be known at certain time intervals during the operation of UGS. The system of equations for pressures at certain values of unknown coefficients is solved in the time period under study, the mean quadratic deviation between the calculated and actual values of pressure is determined. The set of values of unknown parameters corresponding to the minimum of this deviation is considered as actual data. At the second stage, the values (actual values) of flow - characterizing coefficients and the final prices of gas-saturated volumes are used for the calculation of reservoir pressure changes for the next period by the system of equilibrium equations at current reservoir pressures and gas-saturated volumes for certain modes of operation of the UGS.

Based on the calculation method, the calculation result of gas losses in the reservoir when the gas flows to upper horizons and is compressed in the low-permeability, edge and transition zones, based on the dynamics of the technological indicators in the process of the recent current operation of the Galmaz UGS, was estimated to be 0,91% of the calculated balance value of the total gas reserves. The calculated amount of reservoir gas losses was approximately 1,83% of the active storage volume.

Positive dynamics in the reduction of gas losses can be ensured by developing an effective method for well development and conducting efficiency evaluations based on it. From this point of view, in order to reduce gas losses, a technological solution method has been developed to initially inject water under a certain pressure into the well and then to repeat the process with air under a certain pressure during the exploitation period, and to continue this process until the liquid column collected in the well pipe is completely removed from the operational pipeline and a mathematical algorithm was proposed that allows to calculate its technological indicators.Based on the determined parameters of the technological method, an assessment of the volume of gas injection losses during the exploitation of a well with a liquid column in Galmaz UGS was realized. During the exploitation of one well in Galmaz UGS, saving of gas losses in the range of approximately 4000 - 5000 m^3 was determined.

At the same time, has been proposed method, wich it is reflective possiblity to increase the permeability of the layer in the filter zone by using sulfamic acid and surfactant, which are environmentally friendly, safe to transport and use, with high detergent properties, as well as recycling the natural gas back into the process using natural gas as a working agent, when the completion of gas wells from drilling and major repair.In the application of the method, sulfamic acid is injected under pressure into the filter zone of the productive layer through the pump-compressor pipes lowered into the central part of the well and a pause is made for a certain period of time. Compressed gas in the compressor unit is injected into the space behind the pipe, and at the same time, a surfactant -

sulfanol solution is injected with a washing unit (in order to lower the specific gravity of the liquid behind the pipe),aeration (aeration) is carried out by injecting gas-liquid in parts into the back-of-pipe space, the liquid-gas coming out of the well enters the separator, the gas separated in the separator is collected in the compressor unit, and the liquid is collected in the liquid tank and directed to the absorption process again, the cycle continues until the absorption process is completed does.In Garadag and Galmaz UGS, as a result of the application of the cycle utilization method of wells during the gas extraction season for the previous current years, a total of 1,998,092 thousand m^3, and 111,921,000 m^3 and 1,818,023 thousand m^3 of natural gas were saved in seasonal current years, respectively.

The sixth chapter is devoted to solving the issues of geological and technical justification of the possibility of using the Tumbul salt field of Nakhchivan AP as a UGS.

Tumbul stone-salt field is located 750 m from Tumbul village, 9 km west of Nehram salt field and 5.4 km south of Nakhchivan city. The site is located in a hilly-plain area with an absolute height of 800 - 850 m. The situation in the Nehrem salt field - based on the data of the exploratory wells (wells No. 51, 58, 59), the lithological-stratigraphic comparison of the well sections planned to be drilled in the Tumbul field shows that the total thickness of the salt layers (40-57 m) from the central zone to the west (Tumbul area) allows to confirm the increase. This shows that the geological conditions for the creation of gas chambers in the Tumbul rock-salt field are promising.

In this regard, the issue of developing a technological method of safe washing and extraction of salt from the rock salt layer of the Tumbul deposit was considered, and the creation of horizontal chambers through two or more vertical wells at a distance of 30-40 m at the same time as the method of horizontal washing through vertical wells in the rock salt layers was considered. considered appropriate. In the creation of horizontal chambers by the washing method, the realization of the process of gas injection and gas removal from vertical wells drilled by using two (first and last) wells for every ten drilled wells is considered to be practically important in

ensuring economic efficiency.

The issue of forecasting technological parameters for the creation of underground gas storage chambers in the Tumbul salt field was considered and the forecast indicators of the process of creating underground gas storage chambers were realized according to three different variants of the thickness of the salt layer and the radius of the chamber. The forecast of suitable active and buffer gas volumes and other technological parameters determined by calculation is presented in the table.

Table

Prediction of technological parameters suitable for the creation of underground gas storage chambers in rock salt layer of Tumbul field

No	Technological indicators	The thickness of the salt layer, m		
		40 (I option)	50 (II option)	60 (III option)
1	Radius of underground chambers, m	27	33	40
2	Geometrical volume of 1 underground chamber, thousand m^3	30	58	100
3	Total geometric volume of underground chambers, thousand m^3	812	812	812
4	Number of geotechnological wells, number	27	14	8
5	Maximum pressure in	12,5	12,5	12,5

	underground chambers, MPa			
6	Minimum pressure in underground chambers, MPa	2.5	2.5	2,5
7	Active gas volume of UGS, mln. m^3	150	150	150
8	Active gas volume of 1 underground chamber, mln. m^3	5,5	10,7	18,7
9	UGS's buffer gas volume, thousand m^3	28	28	28
10	Buffer gas volume of 1 underground chamber, thousand m^3	1,1	2,1	3,7
11	The amount of salt that can be extracted from 1 underground chamber, thousand tons	65,7	127	219
12	Total amount of salt that can be extracted from underground chambers, mln. tons	1,773	1,778	1,752

Taking into account the density of natural gas ($\rho_g = 0{,}717\, kg/m^3$), 139 m^3 of active gas can be stored in 1 m^3 underground chamber based on the expression of the balance equation of active gas volume. If the presence of minimal pressure in the salt chamber is accepted $p_{\min} = 2{,}5\, MPa$, according to the expression of the balance equation of buffer gas volume in 1 m^3, 34,7 m^3 of gas storage is identified. If the thickness of the rock salt layer is 50 m, and the radius of the chamber is 27 m, the active gas volume of the reservoir for 14 underground chambers is predicted to be 150 mln. $m^3$and buffer gas volumeto be28 mln. m^3(active gas volume in 1 chamber is 10,7 mln. m^3; buffer gas volume is 2,1 mln. m^3).When the thickness of the rock salt layer is 40 m, the radius of the chamber is 27 m, and the geometric volume of one chamber is 28 thousand m^3, it is necessary to drill 27 geotechnological wells to increase the active gas volume of the reservoir to 150 mln. m3.In order to dispose of the salt solution according to these conditions, there is a need to prepare 8 evaporation ponds with an area of 12 ha and a useful height of 2,0 m, the bottom of which is covered with insulating polyethylene and a butyl curtain.

Thus, in order to continuously meet the gas demand of Nakhchivan Autonomous Republic in the autumn and winter season, the creation of underground gas storage chambers in salt fields is considered appropriate and has great economic efficiency.

CONCLUSİON

The analysis and analysis of the complex geological, technological, thermodynamic and hydrodynamic studies carried out on the regulation of the work of the UGS, the summarization of their results allowed the following main results to be obtained:

1. The theoretical basis for modeling the injection and extraction gas process to the UGS according to the changes in the values of gas volume coefficient and viscosity due to the change in the component composition of the gas phase and pressure was developed, and on its basis, the regulation of the efficient operation

of the wells during gas-injection and gas-extraction season was identified.

2. A method that allows calculating the gas losses of the storage based on the determination of the number of wells in gas-injection and gas-extraction, of the gas loss coefficient according based of the minimum between actual value of the current reservoir pressure and the determination value at the completion of wells for a closed circuit and the at periodic impact to the layer has been developed and realized on tectonic blocks of Garadagh and Galmaz UGS

3. The technological method for extracting the accumulated fluid column in the well has been developed and a mathematical algorithm has been proposed to calculate its technological indicators, and on its basis according to the set parameters of the technological method the possibility of gas recovery estimation has been realized during the completion of a well with a fluid column in the Galmaz UGS.

4. Well information on Garadagh (II and III tectonic block) and Galmaz (IV tectonic block) UGS was systematized, possibility of expansion of gas horizons of tectonic blocks as a gas storage and of increasing their active gas volume was assessed.

5. In order to increase the active gas volume of Garadagh (on II and III tectonic block) and Galmaz (on IV tectonic block) UGS, the necessity of modification of the existing compressor station or construction of a new compressor station allowing to increase the pressure at the outlet is substantiated.

6. By creating gas storage chambers in the Tumbul stone salt field and determining the number of wells to be drilled, the technological method of salt washing and extraction was developed and the evaluation of the active, buffer gas volume of the chambers was predicted for different values of the thickness of the salt layer and the radius of the chamber.

The main content of the dissertation is reflected in the following published scientific works:

1.Shiraliyev, A. Increasing the efficiency of gas volumes and the useful working coefficient of compressor aggregates in non-permanent underground gas storage / A.A. Shiraliev, H.F.Miralamov, A.N.Qurbanov[et al.] // Scientific works of the Scientific-Research Institute “Geotechnological problems of oil, gas and chemistry”, − Baku: − 2017. XVIII v., − p. 355-362.

2. ShiraliyevA. Calculation of gas losses generated in the process of operation of gas wells / A.A. Shiraliev, Z.S.Gadirov, A.Y.Jomardov[et al.]// Journal of Baku Engineering University - Mechanical and Industrial engineering, − Baku: − 2017. vol. 1.No 2, − p. 132-139.

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The claimant's personal contribution in published scientific works related to the conducted research:

[9, 12, 13, 14, 15] – performed freely;

[1, 2, 5, 6, 10] – participation in setting the issue, conducting research and summarizing the results;

[3, 4, 7, 9, 11] – participation in conducting reports, analyzing results, conducting laboratory tests and summarizing results.

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