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Geological and industrial features of operation at the Oparske UGS

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SUMMARY

The article presents the results of geological and industrial analysis of the operation at the Oparske UGS. The influence of geological features reservoir rocks on the efficiency of work underground gas storage has been studied. The heterogeneity of reservoir properties in the section and in the area of the structure, as well as the presence of poorly drained areas in the peripheral areas has been revealed. It is established that the achieved UGS performance indicators are lower than the design ones. The decrease in productivity is primarily caused by the process of spreading active gas in the deposit and its accumulation in low-drained peripheral areas, as well as technological capabilities. Failure to take into account the geological features of pore-reservoirs and the associated deterioration of technological performance at underground storage causes unjustified overspending and sharply reduces the economic efficiency of its operation. It is recommended when drafting or adjusting the operation of underground storage facilities to take into account the possibility of formation "stagnant" poorly drained areas and their impact on the operation of underground gas storage.

Introduction

Underground gas storage (UGS) is one of the most important components of the natural gas market. Along with other forms of storage, UGS provides a number of functions necessary for the proper functioning of the gas market. Ukraine has the most powerful network of underground gas storage facilities in Europe. UGS is an important integral technological component of the gas transmission system of Ukraine, as it performs such functions as ensuring a reliable and uninterrupted supply of gas to domestic consumers and for transit.
Improving the efficiency of operation underground gas storage, studying the factors influencing their work, primarily geological, are important tasks of the industry.
The UGS network of Ukraine includes 4 complexes - Western Ukrainian (Prykarpatskyi), Northern Ukrainian (Kyivskyi), Eastern Ukrainian (Donetskyi) and Southern Ukrainian. Connected into a single system by a network of main gas pipelines, underground gas storage in Ukraine provide high reliability of gas supply to both domestic consumers and transit gas supply to European countries. There are 13 underground gas storage facilities in Ukraine, but currently only 11 underground storage facilities are in operation. One of them is the Oparske UGS (Gimer, 2001).

The purpose and objectives of research

The purpose is to study the geological and industrial features of exploitation Oparske underground gas storage facility.
Research objectives:
- to analyze the features of geological structure at Oparske UGS;
- to analyze the development of the Oparske gas field;
- to perform an analysis for current state of exploration at Oparske underground gas storage;
- to assess the impact of geological features of reservoirs on the operation at gas storage.

Research method - a comprehensive analysis of the impact of a set geological, technological, technical factor on the efficiency of underground gas storage in the Opariske underground gas storage.

Presentation of the main research material

Oparske underground gas storage, the second largest in Prykarpattia, is located in Drohobych district Lviv region. In tectonic terms, the Oparska structure is located in the north-western part of Kosivsko-Ugerska subzone Outer (Bilche-Volytska) zone of Precarpathian Foredeep.
UGS was created on the basis of deposits horizons ND-5, ND-7 and ND-8 of Lower Sarmatian gas field with the same name discovered in 1946-1947, which were depleted in the process of long-term development.
Oparska anticlinal fold is elongated in the north-western direction. In the vault part of the horizons there is a slight deflection, which coincides with the direction of axis folds and forms in the vault part two small uplifts. Within the UGS, the folds are complicated by shallow syncline deflections.The geological structure of storage layer is dominated by Mesozoic (Upper Jurassic) and Cenozoic (Helvet, Torton, Lower Sarmatian) sediments. The Lower Sarmatian, with which the UGS facilities are connected, is represented by the Dashavska layer, divided into two sub-lights: the lower and the upper.
Below the ND-9 horizon, the structural plan is controlled by the relief of blurred surface Helvetic-Mesozoic formations and numerous tectonic faults. The Letnianske gas condensate field is connected with this part of the section. Gas collectors of productive horizons are layers and interlayers of sandstones and siltstones, which occur among homogeneous clay layers that serve as tires for underground storage. Horizon ND-5 - lies at depths of 590 - 695 m. Among all operational facilities of underground gas storage it is the most sustained and powerful on all area of gas capacity. Its total thickness varies within 50-90 m. The ND-7 horizon lies at depths of 700 ÷ 810 m and is separated from the ND-5 horizon by a clay pack 20 - 40 m thick and is the least sustained in area and section. The share of low-permeability reservoirs in the well section is quite large and can reach 50 - 70%. The ND-8 horizon lies at depths of 790 - 890 m and is separated from the ND-7 horizon by a clay-siltstone pack, 22 - 60 m thick. It is not widespread in area. Its greatest development in the sandy facies takes

place in the northern and north-eastern parts of the structure. In the southern direction there is a gradual decrease in the thickness of the horizon to the complete lithological replacement of sandstones and siltstones by clays.

The variability of the sandstone reservoir properties in area and thickness, which characterizes all three horizons, causes significant difficulties in maximizing the use of effective pore volume when creating underground storage facilities.

Brief analysis of development productive horizons ND-5, ND-7, ND-8, which are objects of gas storage. Oparske gas field was put into operation in 1940. Within the field, 6 gas deposits were discovered. Deposits associated with horizons ND-3, ND-4, ND-9 are in the final stages of development. Deposits of horizons ND-5, ND-7 and ND-8 were put into development in 1946. In 1979 their development was suspended. In the same year, the deposits were transferred to the underground gas storage.

Development of the ND-5 horizon gas deposit. Until 1951, the deposit was developed by 4 wells. By the end of development, the existing fund amounted to 3 wells. The initial formation pressure was 6.04 MPa. Since the beginning of development, 804.7 million m^3 have been extracted from the deposit, while the formation pressure has decreased to 2.01 MPa. The initial gas reserves, determined by the method of material balance, amounted to 932 million m^3. Residual reserves - 127 million m^3.

The most intensively deposit was developed in 1948-56 (33-48 million m^3 of extracted gas per year) and in 1963-67 (36-42 million m^3 of extracted gas per year). Working flow rates of wells were in the range of 35 - 195 thousand m^3 / day. By the end of development, due to lower formation pressure and partial flooding of wells, the working flow decreased to 10 - 40 thousand m^3 / day.

Analysis the dynamics of development indicators shows that 82.8% of all gas from the deposit was extracted by well 25. This is due to the fact that compared to other wells, it is located in the most permeable part of the reservoir, which is located in the vault of the structure, where the gas-saturated power is equal to the floor of the gas-bearing capacity. A well-defined productive horizon in the peripheral parts of the structure is represented by less permeable formation rocks. The exploitation of wells was accompanied by the removal of formation water. During the development period, the GWC area rose by an average of 12 m. The water content of gas deposit was 60%. Therefore, as shown by the geological and industrial data of the development process, the exploration of gas deposit at horizon ND-5 in the depletion mode was carried out with the active manifestation of the water pressure regime.

Development of gas deposit ND-7 horizon began in 1946 and was carried out by 6 production wells. The initial formation pressure was 7.26 MPa. During the development period, 1841.9 million m^3 of gas were extracted from the deposit. Accordingly, the pressure dropped to 2.21 MPa. Until 1954, the operation process was characterized by an increase in annual production (from 56 million m^3 in 1947 to 133 million m^3 in 1953). Beginning in 1954, gas production decreased and during 1958-1967 fluctuated around the value of 60 million m^3. The subsequent period of operation (1968-1978) is characterized by a steady decrease in the flow rate of wells. The initial gas reserves, determined by the method of material balance, amounted to 2070 million m^3. Residual - 228 million m^3. According to the drilling materials, the current position of GWC averaged minus 453 m, which is close to its initial value. To analyze the process of development ND-7 horizon deposit, a graph of dependence the reduced formation pressure on the total gas extraction is constructed.

As can be seen from the graph, the deviation calculated points from the straight line is observed after the selection of 900 million m^3 of gas (1955). This, along with flooding, could be related to the inclusion in the work at the last stage of exploration low-permeability layers and interlayers. For the same reason, the increase in formation pressure at the end of development can be explained. Calculated by a special method, the watered volume of the formation was 16.87 million m^3, and the water content of the formation was 61.5%, which contradicts the materials of development. During the development period, the GWC rose only by 1 - 4 m. The water content of formation does not exceed 5%. Therefore, the significant deviation of design points at the final stage of development can be explained to some extent by poor drainage conditions, which is due to the presence low-permeability reservoirs and a small number of production wells. Due to the significant reduction of reservoir pressure during development and the reduction in the rate of selection, low-permeability collectors are connected to the work and the points are deflected upwards. The volume of poorly

drained areas is calculated in the work. It should be noted that when drilling production wells on underground storage facilities (1978 - 1979) formation pressure in the latter was 0.4 - 0.5 MPa higher than in wells that developed the deposit. It follows that the initial gas reserves accepted for development (2070 million m^3) were significantly underestimated. If we conditionally assume the average water content of the formation equal to 5%, then the flooded volume of gas-saturated formation will be 1.37 million m^3. The gas-saturated volume of poorly drained formation zones is 15.5 million m^3. Estimated at the last point of the graph dependence reduced formation pressure on the total gas extraction in the horizon ND-7, gas reserves are 2560 million m^3. Taking into account 5% of the flooding, we will get the initial gas reserves for the Oparske field, which will amount to 2432 million m^3 and an initial gas-saturated formation volume of 32.2 million m^3.
The ND-8 horizon deposit was put into development in October 1947 with an initial formation pressure of 7.85 MPa. The horizon was operated by 5 wells. Reservoir pressure at the end of development was equal to 0.98 MPa. During the period of development, which stopped in 1979, 1887 million m3 of gas were extracted. The initial gas reserves amounted to 1954 million m^3. Residual - 67 million m^3. A feature of ND-8 horizon deposit development is the long-term manifestation of the gas regime in it. The maximum withdrawal from the deposit was reached in 1954 (175.6 million m^3), the pressure decreased by more than 0.6 MPa. In the following years, there was a gradual decline in the rate of selection. The selection period in 1960-1967 is characterized by the stability of gas production in the amount of 42-52 million m^3 per year. Since 1968, there has been a steady decline.
To analyze the process of development ND-8 horizon deposit, a graph of dependence reduced formation pressure on the total gas extraction is constructed. The dependence has the form of a straight line, which is characteristic of the gas regime for reservoir development, the heterogeneity of which is much less pronounced [1].
It deserves special attention the analysis of negative results for well drilling (Boiko et al., 2019) and creation a computer database of processes for the development and operation UGS to monitor the ecological state of the environment (Fedechko et al., 2019).
Oparske gas storage was put into operation in 1979. It's created on the basis of depleted horizons ND-5, ND-7, ND-8 Sarmatian deposits, which are separate objects of gas storage and drilled by separate grids of production wells. Wells are evenly spaced throughout the structure. There are 3 stages in the history of creation and operation Oparske gas storage.1-Creation of gas storage facility (1979-1982).2- Operation with the maximum performance (1983-1988). 3- Gradual decline in exploitation (1989-2020). As a result of analysis geological-industrial indicators of work at the Oparske underground gas storage it is established that operation of underground storage takes place at indicators lower than design.
Already at the first stage of work Oparske UGS it was established that it is almost impossible to provide the projected active gas volume (2900 million m^3). Despite the fact that the difference between the maximum and minimum formation pressures was higher than the design (4.11 MPa) and amounted to the horizon ND-5 - 4.13 MPa, ND-7 - 5.52 MPa, ND-8 - 4.93 MPa, the active volume of gas reached only 2195 million m^3. To some extent, this is due to significant flooding of the ND-5 horizon. The main reason for the decrease in the active volume of gas - incomplete drainage of low-permeability layers and interlayers during cyclic operation. In terms of productive horizons, especially ND-7, they will be from 25 to 60% (Voitsitskyi, 2003).
Control over the operation mode of the gas storage is carried out by monitoring the current position of gas-water contact (GWC) and changes in the liquid level in piezometric wells. In addition, dependency graphs are used for the same purpose $P(t)/z$ from ΣQ_{ugs} (Figure 1).
The dependence is not a straight line, characteristic for the gas mode of formation, but a series of curves that deviate to the right along the abscissa. This phenomenon is explained by incomplete drainage of the storage tank - the formation of "stagnant zones", which are confined to low-permeability reservoirs and near-contour areas of deposits. The presence of "stagnation zones" leads to decrease the level of drainage porous gas-saturated volume at deposit and, as a result, to an increase the buffer volume of gas. The segment intersecting the resulting line on the UGS axis ΣQ_{ugs} characterizes the volume of gas that does not participate in the cyclic operation at the UGS. A quantitative assessment of the impact low-permeability reservoirs on the operation of underground storage facilities was established. The volume of "stagnant" zones is 16.2 million m^3. Then the initial

gas-saturated volume Ω_0, taking into account the flooding of 5% will be 31.4 million m^3. The adjusted value of the initial gas records Q_0 is 2368.8 million m^3.

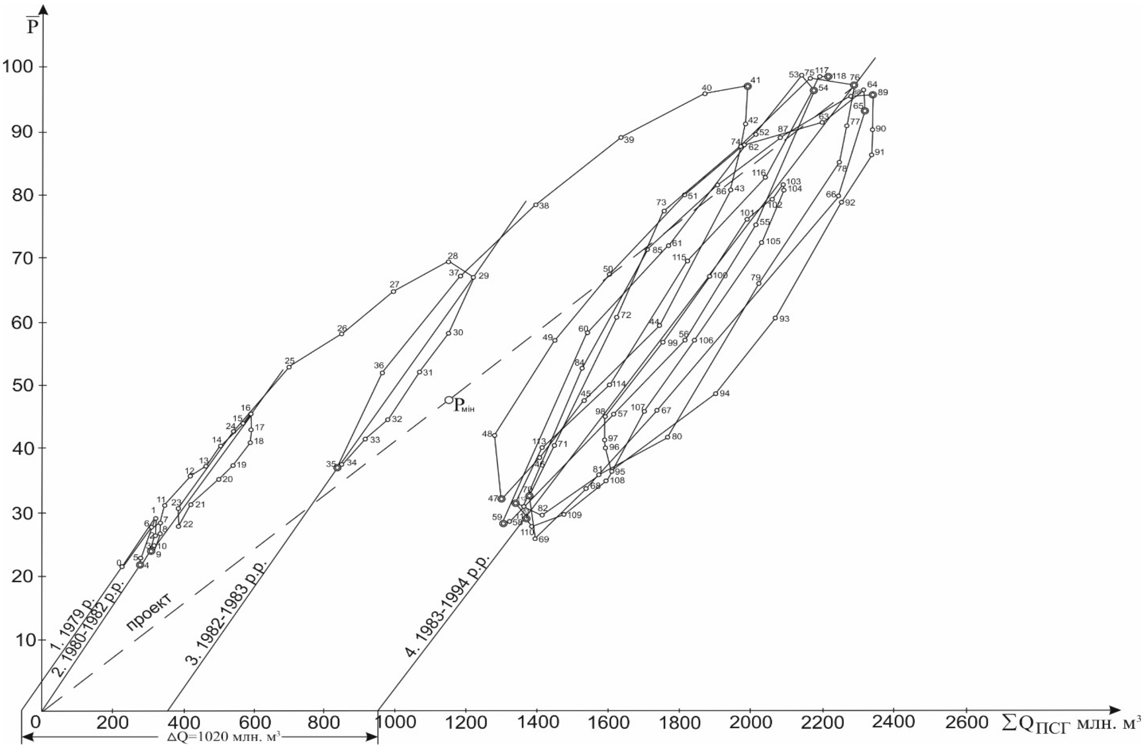

Figure 1 *Hodograph for the ND-7 horizon of Oparske UGS*

Conclusions

Having performed a geological and industrial analysis of work Oparske underground storage, we can conclude that its output on the design indicators is limited, on the one hand, the conditions of formation drainage, on the other hand, technological capabilities.

Failure to take into account the geological features of the reservoir and the associated deterioration of technological performance underground storage causes unjustified overspending (overestimation the number of wells, compressor station capacity, etc.) and sharply reduces the economic efficiency of its operation. It is recommended when drafting or adjusting the operation of underground storage facilities to take into account the possibility of formation "stagnant" poorly drained areas and their impact on the operation of underground gas storage.

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