Combined development of oil and salt layers in an oil field

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Abstract. The problem of complex development and simultaneous use of hydrocarbon mining raw materials in the oil field is relevant for a number of domestic and foreign fields. Combined development of oil and salt layers in an oil field allows obtain a saline solution to intensify oil recovery from productive layer and create an underground reservoir in salt layer for underground storage of hydrocarbons, including creating an underground gas storage (UGS) in rock salt. Joint development of oil and salt reservoirs in the oil field allows to obtain a salt solution of a certain concentration for subsequent injection into the oil reservoir to intensify the capacity (underground reservoir) in the salt reservoir for underground storage of hydrocarbons, including the creation of an underground gas storage (UGS) of associated petroleum gas in rock salt. In this article, the authors used the method of theoretical, practical and experimental studies of complex development of oil and salt reservoirs in the oil field. For the first time in the world practice, joint development of oil and salt reservoirs was carried out at the Talakan oil field.

Keywords: crank punching machines, durability, high-cycle fatigue, stress concentrator, structural rigidity.

1. Introduction
The integrated development of deposits and the maximum use of georesource potential in explored deposits, as well as the multifunctional use of the waste space of mineral deposits, represent one of the main tasks of mining science [1-7].

In some oil fields, the screen is located above the productive oil layer of the salt layer of various capacities. This can be used to produce saline water with subsequent injection of saline water into the productive oil layer, and the generation capacity formed in the salt bed (underground reservoir) can serve as a depository of hydrocarbons extracted from the productive layer (natural gas, associated petroleum gas, oil). The classification of underground storage facilities in rock salt [8] by purpose and types of stored products are showed in figure 1.

The construction of underground workings-tanks for hydrocarbon reserves in rock salt is carried out by supplying a solvent and dispensing brine through a borehole [9-14].

The construction of underground workings-tanks in rock salt is largely determined by mass transfer processes in the marginal zone. When the solvent is supplied through a borehole with hydrodynamic effects at the “rock salt-fluid” boundary, mass transfer processes take place, which characterize the speed of construction of the underground production capacity and its shaping.

Furthermore, studies of the hydrodynamics of gas bubbles in a liquid are of great practical importance not only for the processes of drilling and cementing boreholes, but also in the construction of underground workings-tanks in rock salt by dissolving through boreholes, as well as for use in various mining technologies oil, for example, in the operation of boreholes jet pumps and the water-gas impact on the reservoir. Experimental studies of the coalescence of gas bubbles in aqueous electrolyte solutions [15-18] showed, in particular, that there are areas of rational salt composition and concentrations in which the coalescence of gas bubbles is suppressed, which contributes to the creation of stable gas-liquid mixtures with foamy structure.
The value of the mass transfer coefficient during the dissolution of rock salt with a high gas content increases, compared with the dissolution of the traditional salt.

![Figure 1. Classification of underground storage in rock salt by purpose and types of stored products.](image)

The mass transfer coefficient of the sample with rebounding of salt plates and gas evolution is 30% more than that of rock salt samples without rebounding of salt plates and gas evolution.

The method of underground dissolution of rock salt in the Leykovskoye field, taking into account the significant value of gas, built in 10 volumes of mineral resources in the amount of 50 or 75 thousand m³). At the Leikovsky salt stock with a significant gas content in the intercrystalline space of rock salt and impurities, a factor was found to increase the mass transfer coefficient of rock salt by dissolving by about 30% and faster construction of workings-tanks (about 10%) compared with the calculated parameters.

### 2. Materials and methods

The use of water flooding to intensify the extraction of oil from the productive layer is associated with the salinity control of injected water and the compatibility of the injected water with the layer of mineralized water and features of the mineral composition of the manifold [19].

The use of saline water in development of oil fields can increase by 5-40% recoverable oil reserves.

Some principal schemes of the construction and operation of underground hydrocarbon storage can be used in the combined development of oil and salt reservoirs of an oil field together with the corresponding schemes for the development and operation of productive oil reservoirs. The principal technological scheme of operation of the underground gas storage in rock salt is presented in figure. 2.

To obtain saline water, it is advisable to drill wells in the salt layer and conduct underground dissolution of rock salt, to obtain a solution of rock salt with certain concentration (combined with the actual concentration of the reservoir saline water in the oil field) for download through injection wells into the productive layer and the extraction of oil from the productive layer through production wells.

Clay minerals play a significant role in the development of oil deposits. A change in the salinity of water layer in the process of displacing oil from the reservoir, can lead to a change in the state of clay cement in the reservoir and a change in the structure of the porous medium and a change in the main filtration characteristics of the medium. The increase in clay is due to the swelling of clays. Clay dispersion sometimes occurs [20, 21].
Figure 2. The principal technological scheme of operation of the underground gas storage in rock salt:
1 - underground tank; 2 - gas throttling knot; 3 - gas loop; 4 - gas refrigerator; 5 - compressor station;
6 - knot of measurement of a consumption of gas; 7 - filter separator; 8 - dust collector; 9 - main gas pipeline;
10 - absorbent regeneration installation; 11 - absorber; 12 - gas heating; 13 - separator; 14 - operational well.

Figure 3. Scheme of a Construction of Vertical Underground Development Capacity steps (I – III) from below up
(layer-by-layer technology): 1 – upsetting column; 2 – external suspended column; 3 – central suspended column.

Pumping mineralized water in a clay-containing collector, with excellent mineralization from sheeted, can reduce permeability of the collector and does it by a low-permeability collector. Control of mineralization of the pumped water and properties of clays in productive layers can significantly increase oil recovery coefficient [22].

Use of mineralization waters allows reduce hydration of clay layers, but it is desirable to use such composition of water, which is most compatible to bedded components of productive layer. Use of the mineralized water received at dissolution of salt layer of the oil field allows solve substantially a
problem of compatibility of the pumped mineralized water with reservoir water and the mineral list of the collector.

With development of salt layer, power in several tens of meters with supply of solvent through a borehole on production schedules creates underground development capacity in rock salt (vertical or horizontal) for storage of hydrocarbons. In figure. 3 scheme of a construction is submitted to vertical underground development capacity by steps.

3. Results

On the Talakan oil-gas, condensate field (Sakha Republic) realization of the combined development of oil and salt layers of oil-gas condensate field with creation of an underground gas storage in rock salt and use of the mineralized solution for an intensification of oil recovery was begun [23].

According to the intensity of gas evolution when the salt of the Talakan deposit is dissolved, the mass transfer process is characterized mainly by gas evolution: from rock inclusions and from the intercrystalline space. During the dissolution of core samples from the Talakan site, gas bubbles with a diameter of 2 to 15 mm were noted.

A non-solvent (diesel fuel, gas) is used to control the underground dissolution process. Diesel fuel was used as a non-solvent in the Talakan field.

In the process of dissolving rock salt from the Tuz Galu deposit, when the rocky partition is thinning in a salt crystal, in which gas is under pressure, plates of rock salt rebound and gas is released (microdischarge).

The micro-discharge of gas from the salt crystal with the rebounding of salt plates in the process of dissolution is a continuous process of the separation of salt particles (destruction of the contact zone of the rock).

In the process of mass transfer, gas, particles of insoluble inclusions and particles of salt are released from rock salt (when gas is included in salt crystals). Depending on the stratification of the solution, insoluble heavy particles sink to the bottom of the mine, and light particles together with gas microbubbles rise up, resulting in a significant amount of particles entering the non-solvent (diesel), significantly changing its properties.

It has been found that at the roof of the production capacity, which is constructed in rock salt with a significant gas content and with the use of diesel fuel as a non-solvent, a foam layer is formed [24, 25]. The foam layer at the roof of the mine at the Talakan field is represented by a cluster of gas bubbles evenly distributed between thin layers of solid mineral particles and rocks of small size with diesel fuel and mortar. Suspended particles of rocks of different densities and sizes, like gas bubbles, are in the entire volume of the solution. On the right side of the diagram, processes of gas evolution from the intercrystalline space and particles of insoluble rocks are shown when salt is dissolved with a high gas content (typical of salt dissolution at the Leukovo field). On the left side of the diagram, the process of gas extraction from salt crystals (typical for the dissolution of salt in the Tuz-Galu field) and particles of insoluble rocks during the dissolution of salt with a high gas content is presented. Gas bubbles stand out from the rock, and gas bubbles stand out from the water supplied to the production capacity [26, 27].

4. Discussion

By results of large-scale modeling, dependences are received and the technique of a construction of horizontal developments capacities in rock salt is developed (one horizontal well constructed with use or with use of horizontal and vertical wells). The technology of construction to horizontal development capacity in rock salt is realized in the Volgograd UGS.

In the process of dissolving rock salt from the Tuz-Galu deposit, when the rocky partition is thinning in a salt crystal, in which gas is under pressure, plates of rock salt rebound and gas is released (micro-discharge).
A similar significant gas emission with the release of drilling equipment to the surface occurred during the drilling of a borehole in the Tuz-Galu field.

The definitions on the core material of the Talakan stock from the intervals of underground workings-capacities of the mass transfer coefficient of the vertical surface of the rock salt in water under conditions of natural convection revealed gassing containing mainly methane (~ 99%).

When foaming and changing the properties of the non-solvent, there is a problem with determining the location of the non-solvent in the underground working-capacity. To determine the location of the non-solvent, repeated gamma-gamma logging was performed after injection of an additional amount of non-solvent.

Conclusions

The heads of a number of wells on the Talakan salt stock, to reduce the external negative impact, were placed with a depth of 3 m into the ground in a protective hemispherical concrete dome with an earthen top on the surface. In the upper part of the dome there was a hatch through which the necessary operations were performed on the wellhead. Because of the leakage of threaded connections on the tip of the well, methane was released from the brine. Fire situations have arisen in a confined unventilated space at the top of a well located in a protective dome. It should be noted:

1. During the construction of workings-tanks at rock salt deposits with a significant gas content, drilling conditions are complicated. Perhaps the effect of gas released from brine and rock salt on the quality of cementing works and the tightness of the well.
2. As a result of research, the influence of gas shows during the construction of underground workings-tanks in rock salt with a significant gas content with the formation of three-phase foam in diesel fuel (non solvent) at the roof of the mine has been established.
3. The process of building workings-tanks is accelerated by increasing the mass transfer coefficient when salt is dissolved with a significant gas content.
4. Fire hazard increases when methane is released from rock salt in the process of dissolution on closed ends of wells.
5. When dissolving rock salt with a significant gas content, the gas goes into brine. In the production capacity, when operating an underground reservoir in rock salt with a significant gas content, in addition to the hydrocarbon product, there is a brine with a significant gas content. Gas can transfer to the stored product and affect its properties.

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