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Features of Determining the Temperature Regime of the Drilling Wells in Permafrost

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Abstract. Rational regulation of the thermal regime during wells drilling operations grows into an important practical task. Its successful solution largely determines the efficiency of the well construction and the fulfillment of its objective function.

Under the influence of both high positive and negative temperatures surrounding the rock well, various kinds of complications and accidents often occur during drilling and fastening of wells. Productivity of drilling operations is sharply reduced and drilling costs are increased.

When drilling various wells in areas of the Northeast and the Arctic zone of Russia with extreme natural and climatic conditions and a thick layer of permafrost the selection of optimal drilling tools and drilling technologies requires special requirements. Deposits of the permafrost zone have significant differences from analogs located in regions with a temperate climate and a positive temperature of rocks. Their specificity is due to the complex interaction and influence of mining-geological, permafrost and climatic factors. It has been established that the temperature factor determining the efficiency of the process of destruction and transportation of frozen rocks lies at the basis of the complicated conditions for rotary drilling of wells in permafrost.

1. Introduction

At the present time about 80% of the explored minerals deposits are confined to territories with permafrost zones. The prospect of the growing demand of the Russian market for fuel and chemical raw materials contributes to intensive development of these territories and a significant increase in the volume of drilling wells.

The Russian experience of drilling wells in traditional technologies in Yakutia, the Krasnoyarsk Territory, the Komi Republic, the Arkhangelsk region, and the Tyumen region indicates that thawing and destruction of permafrost leads to a number of problems, especially in the wellhead zone. With the high ice content, the process of well construction is significantly complicated: wellhead erosion, griffins, destruction of foundations, increased cavern formation, casing breaks, subsidence of surface casings, and drilling rigs in general. There are wellhead funnels, curved wellhead equipment, crushing of columns, increased hydration and paraffin formation. All this leads to significant economic losses. Many of the accidents occurred in the wells during their construction and operation in permafrost were largely determined by the lack of detailed data on the low-temperature section structure, the deep



geocryological conditions in the wells and the absence of proven special methods for monitoring the thermal interaction of wells with frozen soils. This affected the quality of well construction, the reliability of their operation, led to wellbore problems and, accordingly, to additional costs.

The need to prevent drilling problems in permafrost, improve the quality of their construction and ensure the reliability of the production wells is an urgent task.

2. Choosing the surface casing depth

Set cement with the necessary mechanical properties, high resistance and low permeability can not yet fully guarantee the reliable sealing of the annulus. The weak point is the contact between set cement and the frozen rock. Permafrost is mainly represented by rocks with ice interlayers and streaks. In the drilling process the drilling fluid temperature rises [13].

As a result of the fluid at an elevated temperature circulation, the frozen rocks behind the surface casing melt. On the contact of cement with the rock and in the rock itself can be formed channels for gas movement to the well head. In order to reliably isolate the annular space, the casing shoe is recommended to be installed no less than 100-150 meters below the base of the permafrost. It ensures a reliable contact of the cement with the rock.

Minimum the surface casing depth is $H = \frac{150}{0,2} = 750 \text{ m}$.

3. Use drilling fluids with a negative temperature

The analysis of caver formation depending on the circulating fluid temperature in the Sredne-Vilyuiskaya area (Republic of Sakha (Yakutia), Russia) shows that wells drilled in winter with drilling fluids with a temperature close to zero have a cavernousness factor of about 1.2, i.e. completely satisfactory.

Therefore, when drilling in winter, it is necessary to use low ambient temperatures and drilling fluids with a temperature of +2 to -1.5 °C. This temperature is quite sufficient to protect against the thawing and destruction of the well walls. The production of fluids that do not freeze at a temperature of +2 to -1.5 °C is carried out by the addition of 3-5% sodium chloride or calcium chloride.

Similar wells drilled in summer at high positive drilling fluid temperatures have a cavernous factor of 1.7-2 [14].

4. Spontaneous well deviation

Spontaneous deviation can have a number of negative consequences: the development grid of the deposit is disrupted; increase the length of the wellbore, the cost of its construction, the frictional forces between the pipes and the well walls; the execution of downhole operations is complicated; increase the cost of drilling; key-seating is increased at the points of the wellbore bend; accidents with pipes often increase; deterioration of the quality of cementing wells.

There are several reasons for contributing to spontaneous well deviation [15-17]:

a) geological reasons: anisotropy of rocks; frequent alternation of rocks with different mechanical properties, especially when they are inclined; the presence of cracks and other cavities in rocks, etc. The drill bit in such rocks meets at different points substantially different resistances. The resultant bottomhole reaction is displaced relative to its center. The bending moment acts on the lower section of the drill stem, the drill bit turns to some angle to the axis original direction [18].

b) technical reasons: the presence of bent pipes in the lower section of the drill stem or skewed threaded connections when drilling with mud motors; misalignment of the block and tackle system and the rotary table, misalignment of the rotary table and the well direction.

c) technological reasons: excessively high axial loads on the drill bit, causing longitudinal bending of the lower section of the drill stem.

To prevent spontaneous well deviation, or at least to minimize it, it is possible to properly select the bottom hole assembly for a given axial load on the drill bit; systematic monitoring of the well

direction; excluding from bottom hole assembly bent and distorted threaded connections of pipes; careful alignment of the block and tackle system relative to the rotary table.

5. Drilling with smaller diameter drill bits with subsequent reaming

Drilling of wells № 8, 3, 10 of the Mastakhskaya area (Republic of Sakha (Yakutia), Russia) in the permafrost zone was carried out with drill bit № 12, followed by reaming with drill bit № 16. The average well diameters after reaming in the caliper logs are respectively equal to: 400 mm, 405 mm, 410 mm. At wells № 9 and № 2 of the Mastakhskaya area, drilling of permafrost rocks under identical conditions was carried out with drill bit № 16. The average diameters of the caliper logs are 620 mm and 600 mm, respectively.

Table 1. Commercial speeds.

№ of well	Commercial speed (m/ rig month)
1	4140
3	2770
8	2850
9	5610
10	2780

According to this drilling data, it can be concluded that drilling with subsequent well reaming eliminates caving process, but leads to a decrease in drilling speed. Therefore, this drilling method should be used during the summer period when drilling fluids have a high positive temperature. The complications caused by the wellbore thawing require more time to eliminate them than time for the well reaming. Significant reduction of the time for the well reaming can be obtained by using planetary bits or special reamers.

6. Achieving the maximum commercial speeds

When drilling in permafrost with drilling fluids with a positive temperature, it is necessary to achieve the maximum reduction in time. The longer the contact of fluids with positive temperature with frozen rocks persists, the more intensive thermal erosion destruction affects to the well walls. It can lead to serious complications in the wellbore [19].

The most acceptable commercial speed is in the range of 6-7 thousand m/rig month.

To achieve these speeds, preparation for drilling operations is necessary, in particular: advance drilling under a kelly hole, preparing and laying on the bridges of all pipes intended for the surface casing, drawing water for drilling fluids preparation in the summer from the deepest places, where the water has a lower temperature. The fluid must be prepared before drilling, minimizing the time for its preparation in order to keep the solution in a low temperature. Electrical measurements for reconnaissance must be carried out selectively on individual wells drilled in the winter. Drilling is carried out in forced mode, using the most optimal types of drilling bits. In the summer it is necessary to use drill bits of smaller diameter with subsequent reaming [20].

7. Conclusion

The article gives the main recommendations that contribute to the successful wells completion in permafrost:

1. Construction of wells without descending shaft and elongated directions;
2. Drilling on low-temperature drilling fluids;
3. Drilling in the summer period by drilling bit of smaller size with the subsequent reaming to the required diameter;
4. Achieving the maximum commercial speeds.

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