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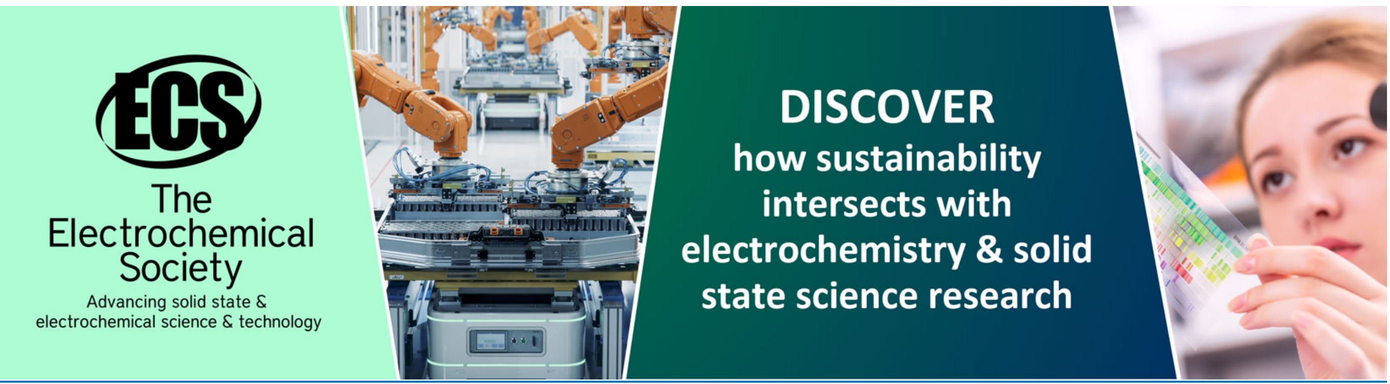

Development of Drilling and Casing Technologies for Permafrost Areas

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Abstract. During the well drilling operations in permafrost there are a number of specific complications that often lead to serious accidents: soil bulging, destruction of wellheads, collapses of wells walls, breakage and crushing of casing columns due to inefficient cementing in the frozen soil, griffins, etc.

The above-mentioned complications are predetermined by incorrect drilling and fastening of wells. 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.

1. Introduction

During the well drilling operations in permafrost there are a number of specific complications that often lead to serious accidents: soil bulging, destruction of wellheads, collapses of well walls, breakage and crushing of casing columns due to inefficient cementing in the frozen soil, griffins, etc. The main factors determining the degree of permafrost influence on well drilling are the physicochemical and mechanical properties of frozen rocks, the drilling fluid temperature. The frozen rocks differ in their physicomechanical properties from those of the same mineralogical composition that have not been frozen [1-3].

During the well drilling the ice that fills the pores transforms into a liquid phase that takes up a smaller volume. The formed void fills the positive temperature drilling fluid. The forces of cohesion between particles of friable rocks sharply decrease, which leads to the caving-in of well [4].

Violation of the thermal regime of permafrost soils during the well construction leads to the emergency situations with serious economic, material and technical, environmental and social consequences. Thermal interaction has a significant influence on the soil state, which negatively affects the quality of work [5-7].

The drilling technology in permafrost with hard and strong rocks of low permeability is almost identical to drilling in the same rocks with a positive temperature. However, the well construction in permafrost with ice, weakly cemented, friable rocks differs sharply from the well construction in similar rocks with a positive temperature.

In this case the main role is played by factors that have a decisive influence on the wellbore walls thawing such as the temperature regime of the well cleanout and the drilling time of the permafrost layer [8].

If drilling fluid with a positive temperature is used, then the rocks in the near-bottom zone are gradually heated and thawed. The thawing radius is greater, the higher the drilling fluid temperature and the longer its effect. Often the thawing radius reaches several meters.

The cause of drill pipes sticking is often the collapse of rocks in the thawing process. There are cases of subsidence of rocks around the wellhead at a depth of several meters. As a result, there is a danger of accidents with drilling equipment. The subsidence of rocks after completing the drilling works may cause damage to the casing columns and operational equipment, explosions and fires [9].

With long downtime, negative temperatures in the near-well zone are restored. When the water in this zone freezes, the casing may be damaged if it is run into the well.

The main way to prevent these complications is to maintain the negative temperature of the well walls. This can be achieved by cooling the drilling fluid to minus 2-5 ° C. Compressed air drilling or aerated fluid drilling can minimize the thawing of rocks. A useful practice is the use of a reduced diameter bit: by the time the well is drilled to the depth at which the casing is to be lowered, the diameter of the well will increase to the size required for this purpose. After drilling the wellbore must be strengthened by a casing string and thereby eliminates the possibility of further rock sloughing. The casing shoe should be installed in strong rocks that do not become incinerated during the process. The annular space between the column and the well walls of impermeable rocks at a positive temperature, is useful to be sealed by a packer, especially in gas and gas condensate wells. This will prevent the breakthrough of gas into the casing string annulus and the formation of griffins around the well head [10-12].

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 $H = \frac{150}{0,2} = 750$ 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 ℃. 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 ℃ 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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