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Method of Normalization of Temperature Regimes of the Boreholes with Application of Air Purging

Djuraev Rustam Umarkhanovich, Khatamova Dilshoda Narmuratovna, Polvonov Nurbek Omonboyevich, Mustafayev Oybek Bobomurodovich.

Assistant Professor, Department of Mining and Electromechanical Engineering, Navoi State Mining Institute, Uzbekistan.
Assistant, Department of Mining, Navoi State Mining Institute, Uzbekistan.
Assistant, Department of Mining and Electromechanical Engineering, Navoi State Mining Institute, Uzbekistan.
Assistant, Department of Mining and Electromechanical Engineering, Navoi State Mining Institute, Uzbekistan.

ABSTRACT: Drilling with a purge air is effective in the most adverse conditions for liquid washing, when drilling in zones of considerable loses of circulation, in case of difficulties with water supply, a mountain or difficult terrain or in areas with severe climate. In this article methods of regulation and normalization of temperature condition of wells in case of well-drilling with a purge are considered by air.

KEYWORDS: Drilling, freezing, temperature, pressure, bottom, borehole, effect of Rank, vortex tube, purge air, crown.

I.INTRODUCTION

In the field of exploratory wells drilling, which is very important for ensuring the mineral resource base of the national economy, one of the promising directions of scientific and technical progress is the rational use of gaseous cleaning agents instead of washing liquid. The practice of drilling has proven that the use of compressed air as a cleaning agent provides a significant increase in the mechanical drilling speeds and reduces the time required to eliminate geological complications, thereby dramatically increasing the productivity and profitability of drilling operations [1].
Thus, in order to prevent these problems, it is necessary to develop technical means and technology to effectively ensure the temperature regime of the well.
One of the effective means of maintaining the temperature regime of the well when drilling with air blowing is the use of air cooled to negative temperatures as a cleaning agent.
The use of the vortex tube, in which the Rankue effect occurs, as a refrigeration unit when drilling wells with air blowing, is perhaps more effective, at the same time, an economically advantageous installation for cooling purge air [2].
Under the temperature regime of a drilled well, the distribution of the temperature of the circulating washing medium in the internal channel of the drill string and in the annular channel is defined, depending on a large number of factors that are dissimilar in their effect. One of the simplest solutions to the case of well drilling with air blowing is described in detail in [3, 4] and earlier.

II. METHODOLOGY

The final analytical expressions for the temperature at any depth *h* at the final depth of the well *H* at the given moment have the form [4]:

For outgoing flow in the drilling column

$$t_1 = m_1 e^{r_1 h} + n_1 e^{r_2 h} + {}^{9}{}_{0} - \delta(\frac{Gc}{k\pi} - h) \qquad (1)$$

$$where m_1 = \frac{Ar_2 \varepsilon^{r2H} + B}{E}; \quad n_1 = \frac{Ar_1 \varepsilon^{r1H} + B}{E}$$

For the upflow in the annular channel

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$$t_2 = m_2 e^{r_1 h} + n_{21} e^{r_2 h} + T_0 + \delta h \qquad (2)$$

$$where m_2 = \frac{A r_1 \varepsilon^{r_2 H} + B\frac{r_1}{r_2}}{E}; \quad n_2 = \frac{A r_2 \varepsilon^{r_1 H} + B\frac{r_2}{r_1}}{E}$$

In these expressions, A, B, E are abbreviations:

$$A = t_{1H} - T_0 + \frac{Gc}{k\pi}\left(\sigma - \frac{g}{c} i_1\right) - \frac{gG}{k_\tau \pi D}(i_1 + i_2);$$

$$B = \delta - \frac{g}{c} i_1 - \frac{k\pi}{Gc}\Delta t_3; \qquad E = r_1 e^{r_1 H} - r_2 e^{r_2 H}$$

$where r_1, r_2$ –the roots of the characteristic equation:

$$r_1, r_2 = \frac{\pi}{Gc}\left(\frac{k_\tau D}{2} \mp \sqrt{\frac{k_\tau^2 D^2}{4} + k_\tau k D}\right);$$

t_{1H} - temperature of the washing medium pumped into the drill pipes (°C), T_0 - conditional constant surface temperature (°C) (temperature of the neutral layer); σ - is the geometric gradient; h, H, D - depth (current coordinate), final depth and borehole diameter (m), k - coefficient of heat transfer through the wall of the drill string per unit of pipe length, W/(m^2·°C); G, and c_p - weight flow and specific heat capacity of the washing medium in kg/h and kcal/kg·°C; k_τ- coefficient of non-stationary heat exchange in kcal / m^2·h·°C;

The results of calculating the temperature regime of the well with the help of formulas (1) and (2) depends critically on the correctness of the determination of the quantities included in them.

We experimentally investigated the temperature conditions of the vortex tube, during which the dependence of the temperature of the cooled air on the magnitude of the compressor pressure was revealed. Thus, a relationship has been established to determine the temperature regime of the drilled well, depending on the compressor pressure and other process parameters when using the vortex tube. The dependence is shown in Figure1.

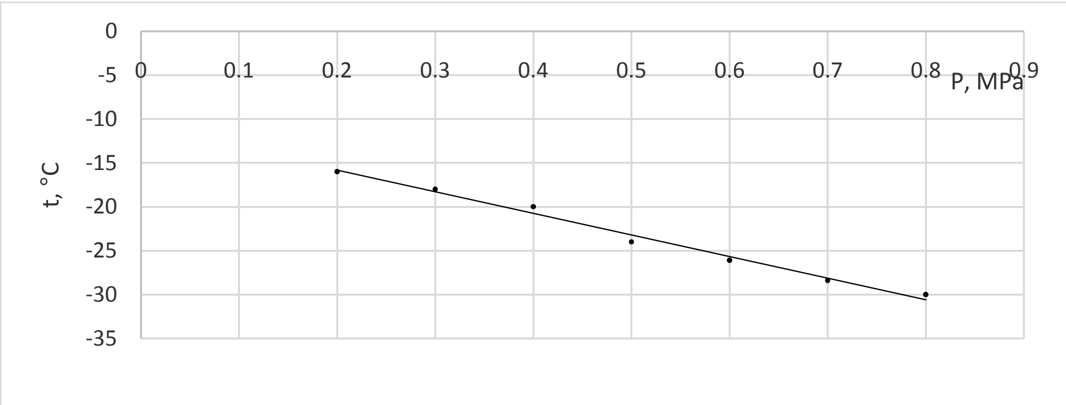

Fig. 1. Dependence of the temperature change of cold air on the pressure value.

When drilling with air blowing using a vortex tube as a refrigeration unit, the air temperature at the cold end of the vortex tube injected into the drill pipes is determined from the following dependence of the vortex tube obtained from the tests (Fig. 1).

$$t_{1н} = -2{,}46 \cdot P - 10{,}9,\ ℃; \qquad (3)$$

where P is the pressure of the compressed air leaving the compressor MPa.

Based on the obtained dependence, it is possible to calculate the temperature regime of the well with the following parameters.

We calculated the temperature regime of the borehole when drilling with the air cleaning in the Mathcad program using its graphical interface based on formulas 1 and 2.

The temperature regime of the borehole has been considered for two cases, in the first case the vortex tube is installed at the wellhead, cooled air is fed into the well along the thermally insulated drill pipes (Fig. 2).

In the second case, the vortex tube is built into the drilling tool over the core pipe (Fig. 5).

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The temperature regime with non-thermally insulated drill pipes is not considered, since air has a low heat capacity and when it is fed through non-thermally insulated drill pipes in which the thermal conductivity is high, the air at the initial depths of 30-40 m acquires a temperature close to the rock temperature. Therefore, the use of non-thermally insulated drill pipes in this case is not rational.
When the vortex tube is located at the wellhead (Figure 2), compressed air from the compressor 1 compressor is fed into the vortex tube 3, after temperature separation, the cold air flow through the swivel 4 enters the heat-insulated drill pipes 5, cooling the crown 7 and cleaning the slaughter face, Along the annular gap and enters the slurry catcher 8.

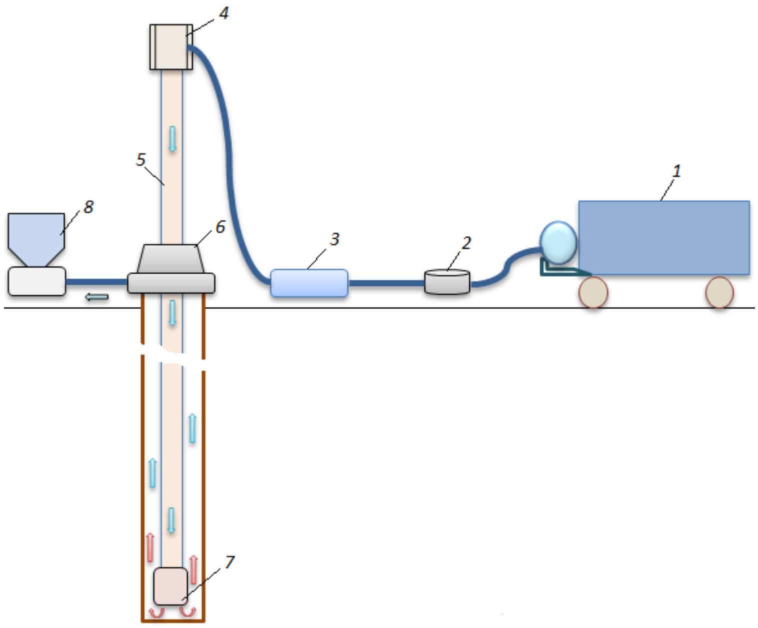

Fig. 2. Flow pattern of air flow during drilling with air blowing using a vortex tube.
1-compressor, 2-moisture separator, 3-vortex tube, 4-swivel, 5-heat-insulated drill pipe, 6-seal, 7-crown, 8-slurry catcher.

III. EXPERIMENTAL RESULTS

In the first case of calculation, heat-insulated drill pipes were used to determine the temperature conditions of the well. The borehole with a diameter of 76 mm with an air flow rate of 400 and 600 kg/h; the borehole depth L = 100 m; outside diameter of drill pipes D=0.063 m; Inner diameter d = 0.04 m; A rock of the sandstone type at $\delta = 2600$ kg/m^3; Cn = $1.05 \cdot 10^3$; $\lambda_п = 1.86$ W/(m·°C) with a temperature $T_п = 10$ ° C; Power on the face 2.5 kW.

The results of the calculations in the Mathcad program are presented in Figures 3 and 4.

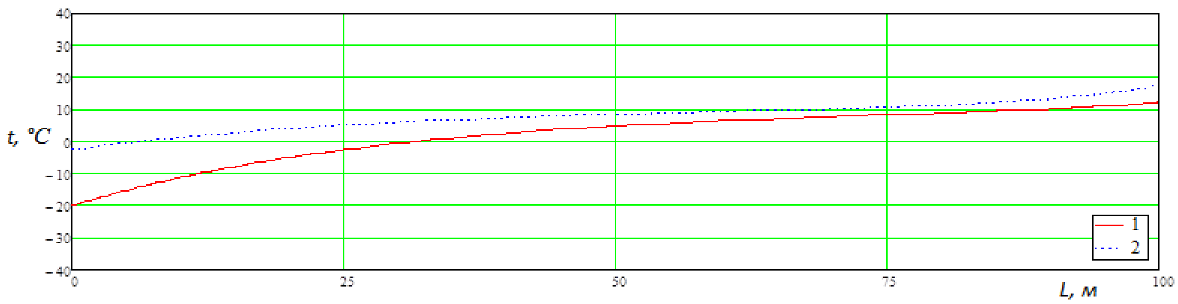

Fig. 3. Graph of temperature distribution in heat-insulated drill pipes (1) and annular channel (2), G = 400 kg/h, $H_к = 100$ m, $\tau = 2$ h.

The results of calculation with thermally insulated drill pipes with the location of a vortex tube at the wellhead with an air flow of 400 kg/h at a depth of 100 meters and a purge air temperature of -20°C (Fig. 3) show that from the upper

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sections of the trunk to a depth of 75÷80 meters there is an increase in the temperature of the purge air and the temperature becomes close to the temperature of the rock. In the bottomhole zone at a depth of 90 meters, a gradual increase in air temperature is observed under the influence of heat extracted from the rock cutting tool. The air temperature at the final depth of 100 meters reaches 11°C in the drill pipe and 18°C in the annular channel.

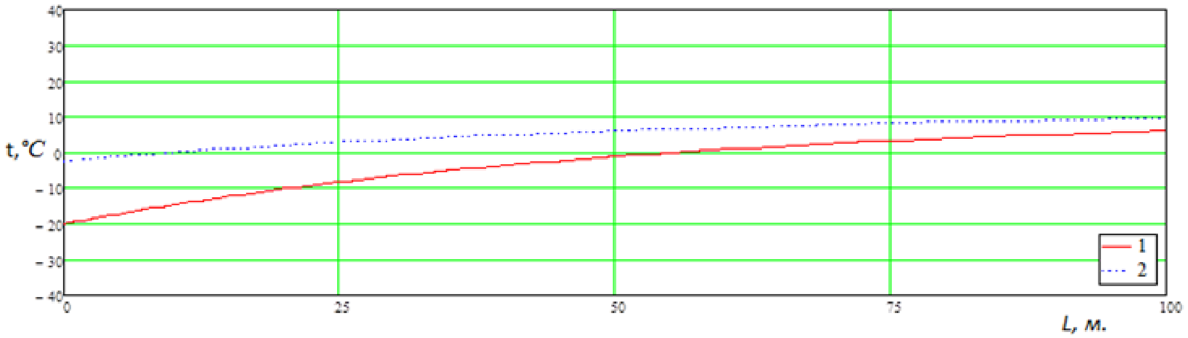

Fig.4. Graph of temperature distribution in heat-insulated drill pipes (1) and annular channel (2), G = 600 kg / h, $H_к$ = 100 m, τ = 2 h.

When the airflow is increased to 600 kg/h (Figure 4), in the upper sections of the well, the air temperature also gradually increases, at a final depth of 100 meters, the air temperature in the drill pipes is 7°C, which is lower by 4°C when compared with graph 3 and in the annular channel is 10 °C, too, which is lower by 8°C.

Thus, it can be concluded that with an increase in the amount of scavenging air, in the bottomhole zone of the well, the temperature decreases, and the temperature in the bottomhole zone of the well is related to the air flow rate.

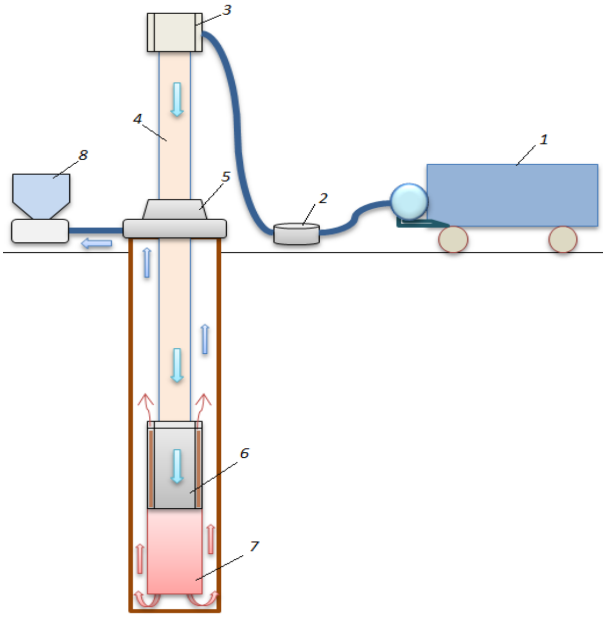

Fig.5. Scheme of air flow when the vortex tube is positioned above the core pipe.
1-compressor, 2-dehumidifier, 3-swivel, 4-drill pipe, 5-seal, 6-vortex tube, 7-column tube, 8-slurry catcher.

In the second case, the vortex tube is built into the drilling tool over the core pipe (Figure 5). Compressed air from compressor 1 through drill pipes 4 is fed into the vortex tube 6, where it is divided into cold and gorjachiy flow. The cold flow is directed into the core tube 7, falls on the face and along a narrow annular gap between the walls of the borehole and the core pipe is directed upwards, transporting the slurry from the face. Hot air is released directly into a wide gap between the walls of the well and drill pipes, where it mixes with the cold flow.

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Calculation parameters: a borehole with a diameter of 76 mm with an air flow rate of 400 and 600 kg / h; Length of the core pipe L = 5 m; A rock of the sandstone type at δ = 2600 kg/m^3; Cn = 1.05·103; $\lambda_п$ = 1.86 W/(m·°C); Temperature of rock $T_п$ = 10 ° C; Power on the face 2.5 kW.
The results of the calculations in the Mathcad program are presented in Figures 6 and 7.

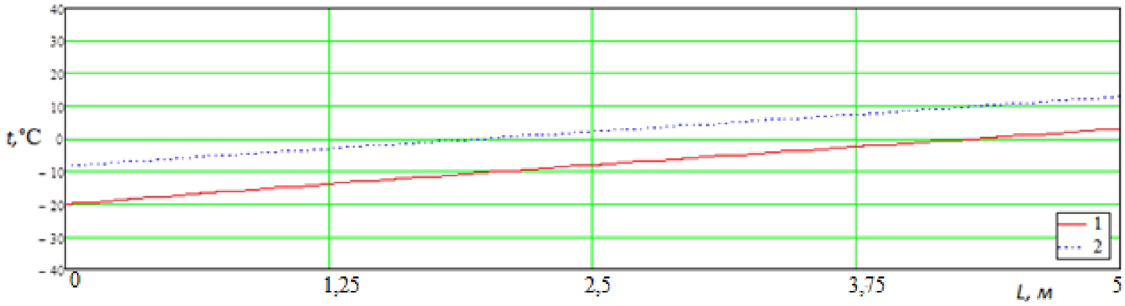

Fig.6. The temperature distribution graph for the installation of the vortex tube in the composition of the drilling tool over the core pipe, 1- in the core pipe, and 2- in the annular channel, G=400 kg/h,$H_к$= 5 m, τ=2 h.

An intensive increase in temperature is observed in the graph (Fig. 6), at an initial temperature of tn1 = -20°C and an air flow rate of G = 400 kg/h at a final depth, the temperature is 1 ° C in the core pipe and 11°C in the annular channel.
If the blowing air flow rate is increased to 600 kg / h (Fig. 7), the temperature increase is lower by a factor of two than in the graph (Fig. 6), and the final temperature in the core pipe is -8°C, and in the annular channel - 1°C. Here, too, the dependence of the temperature change on the air flow is observed.

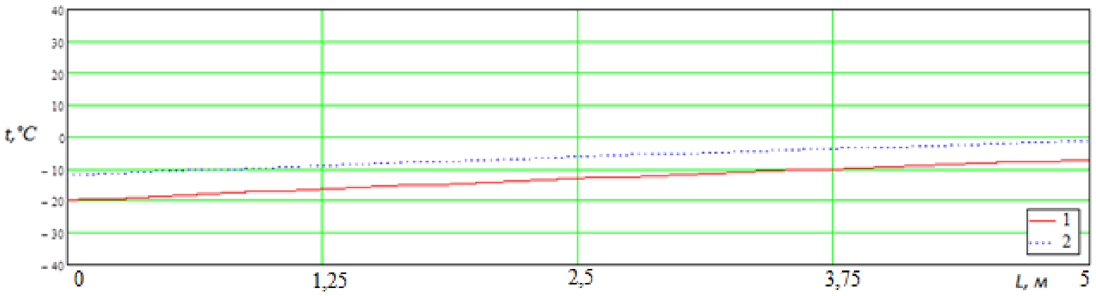

Fig. 7. The temperature distribution graph for the installation of the vortex tube in the composition of the drilling tool over the core pipe, 1- in the core pipe, and 2- in the annular channel, G=600 kg / h,$H_к$= 5 m, τ=2 h.

IV.CONCLUSION

Based on the results of the calculation of the temperature regime of the wells shown in the graphs (Figures 3, 4, 6 and 7), it can be concluded that the use of cooled purge air significantly reduces the temperature in the well, which creates favorable temperature conditions for the rock-cutting tool, Preventing the negative influence of high temperatures at the bottom of the borehole.
The best cooling on the face can be achieved by installing a vortex tube in the composition of the drilling tool over the core pipe. But in this case, there is a need to develop a reliable design of downhole drilling equipment, which ensures uninterrupted operation.

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