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MODELING OF DRILLING WATER SUPPLY WELLS WITH AIRLIFT REVERSE FLUSH AGENT CIRCULATION

Purpose. Determination of the influence of mining and geological conditions of drilling hydrogeological wells with backwash on the technological parameters of the airlift method of cleaning it from drilled rock and the properties of the ascending flow of aerated washing liquids.

Methodology. The tasks were solved by a complex research method, including analysis and generalization of literary and patent sources, analytical, experimental studies, using computer and mathematical modeling methods.

Findings. An algorithm for the functioning of the airlift circulation method during rotary drilling with backwash has been developed. The algorithm takes into account: hydrostatic and hydrodynamic pressures, and the effect on them of the rate of drilling of the well; the effect of the sludge content in the upstream. The effective values of the airflow rate, the density of the water-air mixture and the velocity of its upward flow are established. A method for estimating the effective values of technological parameters and their changes in the upward flow of the mixture is proposed. A model has been developed that allows analyzing the dependences of the air flow rate, the density of the mixture and the rate of its ascent on the parameters of the well being drilled. The model is applied to typical drilling conditions of a large-diameter water intake well at the Samskoye groundwater deposit on the Mangystau peninsula.

Originality. A mathematical algorithm has been developed for the functioning of the airlift backwash method when drilling large-diameter water intake wells. The method is based on the analysis of the pressure balance in the descending and ascending flows of the washing agent. For the case of backwash, a formula for estimating the content of sludge in it was obtained. A method has been developed for determining the average effective density of the mixture in terms of the height of the well, as well as the air content in it. Based on the average effective values, a method is proposed for estimating changes in the density of the mixture, its flow rate and velocity along the upward flow.

Practical value. The proposed algorithm is the basis of a computer model that allows you to determine the dependences of the values of the density of the mixture, the content of air and sludge in it and the rate of ascent, from the depth of the well, the depth of the mixer descent, the speed of deepening, the specified velocity of the upward fluid flow, as well as the diameters of the well and drill pipes. Specific modeling results have been obtained in relation to the Samskoye groundwater deposit of the Mangystau peninsula.

Keywords: *peninsula, Mangystau, hydrogeological well, reverse flushing, airlift method*

Introduction. Water resources play a crucial role in the economy of any country. An essential resource is groundwater extracted from drilling wells. In the end, their source is most often climatic precipitation, which moves through the pores of underground permeable horizons. Due to filtration, groundwater is usually characterized by higher consumer properties.

Literature review. The problem of the development and protection of the underground waters of the planet Earth is in the focus of attention of special UN organizations and many countries [1, 2].

There is a shortage of water resources in the Republic of Kazakhstan. A significant part of the territory of the Republic of Kazakhstan contains vast areas of deserts and semi-deserts, characterized by rare precipitation and underdeveloped river networks. The surface is sometimes covered with salt deposits, and the groundwater close to it is highly mineralized. These problems are typical for the Mangystau peninsula, where large hydrocarbon deposits are concentrated.

Since the sixties, exploration work has been carried out here, which made it possible to discover a number of underground water deposits suitable for development. A typical deposit is the Kama deposit. It has a total area of 1500 km^2 and is composed of quaternary sediments of the North Ustyurt trough. Water-containing formations have the form of lenses of various shapes and sizes. Fine-grained sands with small admixtures of medium and fine-grained sands represent them. The field has been in operation since 1970. A number of wells have been drilled, both manually and with UGB-50 drilling rigs. These wells are characterized by a low flow rate; their depth rarely exceeds 50 m, and their diameter is 150 mm.

According to the recent materials [3], the total water withdrawal of the Samskoye deposit did not exceed 18 % of the explored groundwater reserves. However, the problem of water supply to the local oil production center – the city of Zhanaozen is still acute. There is a pipeline supplied with fresh water from the Volga delta, but its performance is inconvenient, and does not fully meet the needs. For drinking, the population uses water located close to the surface with a mineralization of more than 1 g/liter.

The reason for the low use of open groundwater reserves is the low productivity of drilled wells. The water is located in sandy strata with an average filtration coefficient of only 6.5 m/day, and the flow rate of existing wells with a diameter of 150 and even 190 mm does not solve the local problems.

According to the available literature data [4], in these conditions, an increase in the volume of groundwater extraction can be achieved by drilling water intake wells with a diameter of 500–1500 mm by flushing with industrial water carried out in the reverse way – with an upward flow moving along the drill string.

The sharply increased diameter of the well gives not only a large filtration area and a corresponding increase in flow rate, but also contributes to the installation of a powerful gravel filter that provides high-quality water purification, and a significant increase in the inter-repair life of the well [5, 6].

During the backwash, the speed of the ascending water flow is in the range from 1 to 3 m/s. These are several achievable speeds when drilling with direct circulation [7]. High upstream speeds guarantee complete cleaning of the face from sludge particles, which significantly increases the speed of deepening [8].

Backwash is created in one of two ways [4]: by suction of the washing liquid from the annular space of the well using a centrifugal pump (back-suction method); by reducing the density of the updraft in the drill string due to its aeration (airlift method).

In the first method, the vacuum created during suction cannot exceed atmospheric pressure in magnitude. The vacuum that a centrifugal pump can create is much less than atmospheric pressure. Therefore, in order to restore circulation after its technologically necessary interruptions, a special vacuum pump is also used. It raises the liquid to the upper position of the swivel, from where it merges. It fills the working centrifugal pump, which allows it to resume circulation. The use of atmospheric pressure as a circulation drive limits the maximum depth and the maximum speed of deepening.

The second method is associated with the complexity of the drill string design due to the need to include a compressed air supply channel in its composition, as well as one or more mixers. However, unlike the first method, this method does not have limitations caused by such independent physical factors as atmospheric pressure. The drilling depth and its speed here depend on the power of the compressor used.

Taking into account the above, it is advisable to drill large-diameter water intake wells at the Samskoye field using the airlift method of reverse circulation of the washing liquid, which requires studying the technological features of this method in relation to local conditions.

The purpose of the study is: determination of the influence of mining and geological conditions of drilling hydrogeological wells with backwash on the technological parameters of the airlift method for cleaning it from drilled rock and the properties of the ascending flow of aerated washing liquids.

Problem statement. Based on the analysis of the presented information, the obtained dependence of the above values on the following factors: drilling depth; mixer descent depth; the speed of the recess; the speed of the upward fluid flow; the diameter of the well; the diameter of the drill string; air flow, the density of the mixture and its velocity along the upward flow.

At the same time, the following were created: mathematical description of the process of reverse circulation of the washing agent; computer models of the reverse circulation process; recommendations for determining the values of technological parameters for drilling large-diameter water intake wells at the Samskoye field. In addition, the research tasks have been solved in relation to the conditions of the Siam deposit.

Methods. Development of a computer model of the reverse circulation process. Based on the theoretical provisions outlined above, a computer model of the airlift method of reverse circulation of the washing liquid has been created (Fig. 1).

The parameters of the drilling process are fed to the model input, and in addition, the technological parameters of the model itself.

In the calculation block, the entered parameters are transformed into the desired output values. Initially, the values are calculated, which do not change in the future (outside the cyclical value). This is followed by two nested program cycles.

The task of the external cycle is to establish the dependence of the output values on this investigated parameter A of the drilling well. This parameter is changed according to the formula

$$A(i) = A(0) + dA \cdot i, \qquad (1)$$

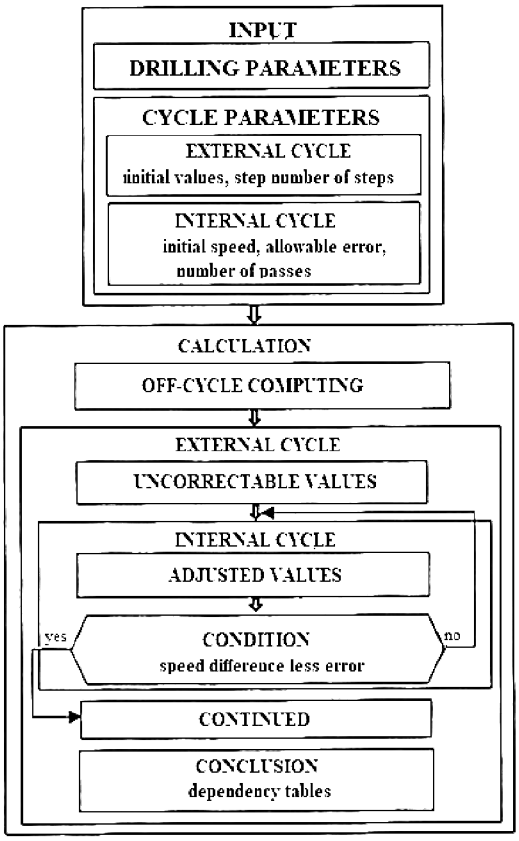

Fig. 1. Block diagram of a computer model

where i is the cycle number (step number); $A(0)$ is initial ($i = 0$) parameter value A; dA is a step of its change. The required values of these magnitudes are fed to the model input along with the number of steps n. When the value of the mixture velocity UM is required during the external cycle, the transition to the internal cycle occurs.

In the internal cycle, the flow rate of the water-air mixture U_M, as well as the associated output parameters ρ_M, Q_A,Q_M, is determined by iterations. An arbitrary value is supplied to the input $U_M(0)$, its acceptable mistake δ, and the largest number of m passes. The block of the inner loop contains a condition under which the loop is terminated and its results are transmitted to the outer loop, which continues. Thus, the external cycle, with each of its passage, begins with the calculation of uncorrectable (unrelated to U_M) quantities, and then it is interrupted by an internal loop and, after its completion, continues printing the results, including U_M-based output parameters.

All calculations on the model were carried out with magnitudes whose values were set in the SI system of units. However, when demonstrated in tables and graphs, extra-system values were used for the convenience of placing and perceiving numerical values.

Research results and their analysis. *Establishment of typical values of parameters for drilling large-diameter water intake wells at the Samskoye field.* The considered technique was used to study the drilling of water intake wells at the Samskoye field located on the Mangystau peninsula, where the water is located in sands with low water content. Drilling large-diameter water intake wells with backwash will be very effective here. For calculations on the model, typical drilling conditions at the field are accepted, presented in Table 1. Below, using the developed model, the dependences of the output parameters on the drilling parameters are constructed.

Some blocks of the model contain data common to all dependencies. These are the parameters of a typical well according to Table 1.

Table 1

Drilling parameters of a typical well

Name of the parameter	Unit	Value
Drilling depth, H	m	200
Mixer loading depth, L [8]	m	H-2
Drilling diameter, D	mm	800
Drilling column diameters: external/internal, d_0/d_i	mm	146/136
The height of lifting the mixture above the surface, h	m	10
The speed of the rising water flow, U_W	m/s	2.5
Drilling speed, U_D	m/h	15
Water density, ρ_W	kg/m^3	1000
Dynamic viscosity of water [4]	Pa·s	0.0001
Rock density, ρ_F	kg/m^3	2600

The results of off-cycle calculations are also common.

In further calculations, the values indicated in Tables 1 and 2 are used only if they are necessary to establish this considered dependence. The remaining values, being entered (Table1), or calculated (Table 2), may in this particular case remain unused.

The values on which the dependence is established are not taken from Tables 1 and 2, but are specified separately, in accordance with the (1).

When all dependencies are established, the internal cycle is built based on the parameters given in Table 3.

Solving research problems in relation to the conditions of the Samskoye field. *Dependence of output values on the depth of the well.* In Table 1, a well with a depth of 200 m is proposed as a typical well. However, when determining the dependence of the output parameters on the depth, in order to conduct an analysis for the extreme case, the considered depth of the well is extended to 300 m.

In Table 4 and in Fig. 2 it can be seen how with increasing depth and hydrostatic pressure, the volumetric airflow rate Q_A drops sharply. The flow rates of the air-water mixture Q_M exceed Q_A by 2.178 m^3/min.

Table 2

Off-cycle computing

Name of the parameter	Unit	Value
Through section of the drill pipe, F_i	m^2	0.0145
Flushing water consumption, Q_W	m^3/s	0.0363
The Reynolds Criterion, R_E		$3.4 \cdot 10^6$
Coefficient of hydraulic resistances, λ_W		0.019
Hydrostatic downhole pressure, P_{SO}	atm	19.620
Density increase due to sludge, Δ_F	kg/m^3	92
Hydrostatic component of sludge pressure, P_{Si2}	atm	1.901
Its hydrodynamic component, P_{Di2}	atm	0.085

Table 3

Internal Cycle Parameters

Name of the parameter	Unit	Value
The initial value of the mixture velocity, $U_M(0)$	m/s	2.5
Its maximum allowable error, δ	m/s	0.005
Maximum number of cycle passes, m		10

Table 4

Dependence of output parameters on the depth of wells

H, m	P_{SO}, atm	$P_\Delta, = P_{Si2} + P_{Di2}$, atm	ρ_M, kg/m^3	Q_A, m^3/min	Q_M, m^3/min	U_M, m/s
30	2.94	0.38	577	1.595	3.773	4.333
60	5.89	0.66	697	0.945	3.123	3.585
90	8.83	0.94	744	0.749	2.927	3.360
120	11.77	1.22	769	0.654	2.832	3.250
150	14.72	1.50	784	0.597	2.775	3.189
180	17.66	1.79	795	0.560	2.738	3.143
210	20.60	2.08	803	0.534	2.712	3.113
240	23.54	2.36	808	0.514	2.692	3.091
270	26.49	2.64	813	0.499	2.677	3.073
300	29.43	2.92	817	0.487	2.665	3.059

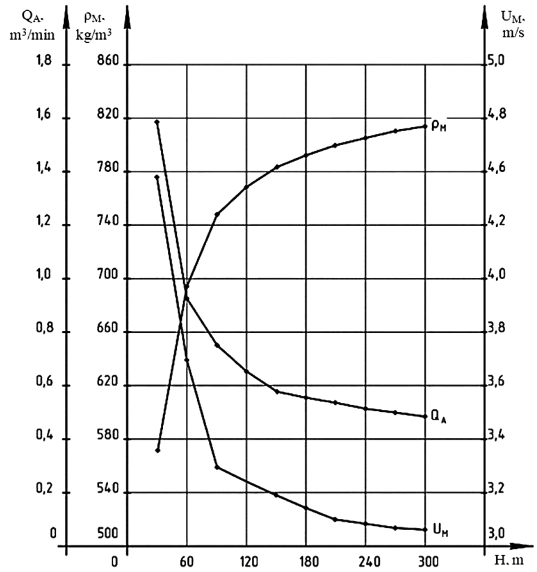

Fig. 2. The dependence of the average effective values of the mixture density ρ_M, its rate of rise U_M and air flow Q_A on the depth H

This is a given (Table 2) water flow, which, unlike airflow, is constant and does not depend on depth. The rate of increase in density ρ_M is the same as the rate of decrease in its consumption Q_M.

The iteration procedure is given in Table 5. In addition to the U_M velocities, their differences ΔU are given here compared to

Table 5

Example of setting the speed of the U_M mixture in m/s

Depth, m	Iteration number (passing the internal cycle)									
	1		2		3		4		5	
	U_M	Δ_U	U_M	Δ_U	U_M	Δ_U	U_M	Δ_U	U_M	Δ_U
30	3.993	1.493	4.257	0.264	4.316	0.059	4.330	0.014	4.333	0.003
120	3.158	0.658	3.238	0.080	3.248	0.012	3.250	0.002	3.250	0.000
210	3.042	0.542	3.104	0.062	3.112	0.008	3.113	0.001	3.113	0.000
300	2.996	0.496	3.051	0.055	3.058	0.007	3.059	0.001	3.059	0.000

the previous passage. It can be seen how with each passage these differences fall and for all depths except 30 m, they become less than $\delta = 0.005$ (Table 3) already at the fourth iteration.

Changing the output data in the course of the upstream. In Table 6, the depths of wells from Table 5 are considered as the lower bounds of ten intervals of one 300-meter well. To calculate the interval values of the output parameters of this well using the formula, the average effective values for ten wells were used.

In Table 6 and Fig. 3, both ρ_M and $\rho_{M\Delta}$ (mean-effective and interval density values) increase with depth, but interval values increase more intensively. The fact is that, unlike the average effective values, the low densities of the upper intervals do not affect them.

According to Table 1, the most effective position of the mixer corresponds to the full depth of the well minus 2 m – in order to avoid turning the compressed air into the annular space. This requirement was observed above when considering the dependence on the depth of the well and below for all other dependencies except for the one considered in this. It is known [8] that in some cases a higher location of the mixer provides an increase in the possible depth of the well.

Table 6

Comparison of average effective and interval values of output parameters of airlift circulation

H, m	ρ_M, kg/m^3	$\rho_{M\Delta}$, kg/m^3	Q_A, m^3/min	$Q_{A\Delta}$, m^3/min	Q_M, m^3/min	$Q_{M\Delta}$, m^3/min	U_M, m/s	$U_{M\Delta}$, m/s
30	577	577	1.597	1.597	3.773	3.773	4.333	4.333
60	697	818	0.945	0.486	3.123	2.664	3.585	3.058
90	744	838	0.749	0.421	2.927	2.599	3.360	2.984
120	769	844	0.654	0.402	2.832	2.580	3.250	2.961
150	784	847	0.597	0.393	2.775	2.571	3.186	2.952
180	795	848	0.560	0.389	2.738	2.567	3.143	2.946
210	803	849	0.534	0.386	2.712	2.564	3.113	2.943
240	808	850	0.514	0.385	2.692	2.563	3.091	2.942
270	813	850	0.499	0.383	2.677	2.561	3.073	2.940
300	817	851	0.487	0.383	2.665	2.561	3.059	2.939

Dependence of the output parameters on the depth of the mixer.

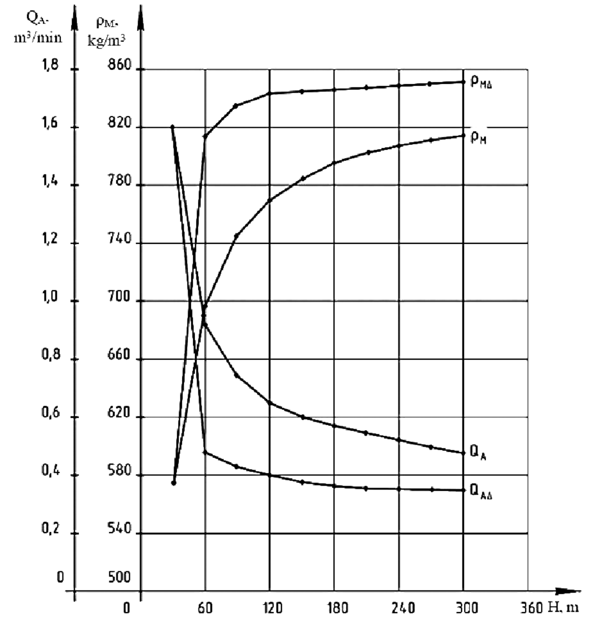

Fig. 3. Comparison of the average effective ρ_M and Q_A (as in Fig. 3) and the interval values of the density of the mixture of $\rho_{M\Delta}$ and air flow $Q_{A\Delta}$

It follows from Table 7 that the descent of the mixer to depths of 20 and 40 m is practically impossible. The values of $P_{S\Pi 2}$, $P_{D\Pi 2}$ and $P_{D\Pi 1}$ are subtracted from the hydrostatic pressure P_{SO} of water in the annulus at the mixer level. In the top row of the table, we have negative values of the difference, which is physically impossible. In the second line, the difference mentioned is very small and an unrealistically high air content in the mixture is required to create an upward flow.

The analysis of Table 8 and Fig. 4 shows that with a decrease in the depth of the mixer descent, the density of the mixture decreases in the form of a curve gaining steepness, and the air consumption increases in a similar way.

The results of processing input data on a computer model are presented in Table 8 and Fig. 5. It can be seen from the data in Table 10 that the increase in the density of the ascending water flow ΔF is proportional to the drilling speed U_D, according to which U_D multiplies as if by a constant coefficient (all other terms of the formula remain unchanged). According to column 2, the calculated U_D values increased stepwise from 5 to 35 m/h, i. e. 7 times. In the 3rd column of the table, the corresponding ratio is given of the maximum and minimum values of Δ_F: 215/31 = 6.94 (the deviation from 7 is caused by rounding).

Table 8 and Fig. 6 show the dependence of the output parameters on the specified speed of the upward flow of oxen.

It can be seen from Table 9 that the increase in the density of the ascending water flow ΔF is proportional to the drilling

Table 7

Dependence of the average effective values of the airlift circulation parameters on the depth of the mixer

L, m	P_{SO}, atm	$P_{D\Pi 1}$, atm	ρ_M, kg/m^3	Q_A, m^3/min	Q_M, m^3/min	U_M, m/s
20	1.96	0.79	–17.08	–124	–122	–140
40	3.92	0.70	5.66	382	384	441
60	5.89	0.61	358	3.90	6.08	6.98
80	7.85	0.52	519	2.02	4.19	4.81
100	9.81	0.44	612	1.38	3.96	4.08
120	11.77	0.35	674	1.05	3.23	3.71
140	13.93	0.26	719	0.85	3.03	3.48
160	15.70	0.17	753	0.72	2.89	3.32
180	17.66	0.09	779	0.62	2.80	3.21
200	19.62	0.00	800	0.54	2.72	3.12

Table 8

Dependence of the average effective values of the airlift circulation parameters on the speed of deepening

U_D,, m/h	Δ_F, kg/m^3	P_{S2}, atm	P_{d2}, atm	ρ_M, kg/m^3	Q_A, m^3/min	Q_M, m^3/min	U_M, m/s
5	31	0.63	0.03	869	0.33	2.51	2.88
10	62	1.27	0.06	835	0.43	2.61	2.99
15	92	1.90	0.08	800	0.54	2.72	3.12
20	123	2.53	0.11	766	0.67	2.84	3.26
25	154.	3.17	0.14	731	0.80	2.98	3.42
30	185	3.80	0.17	695	0.95	3.13	3.59
35	215	4.44	0.20	660	1.12	3.30	3.79

Dependence of output parameters on the speed of deepening.

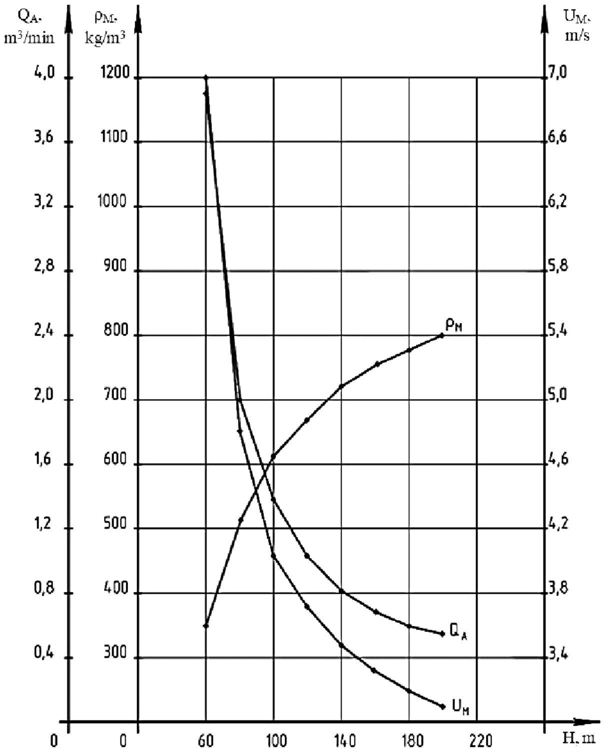

Fig. 4. The dependence of the average effective values of the density of the water-air mixture ρ_M, its rate of rise U_M and airflow Q_A on the depth of the mixer loading

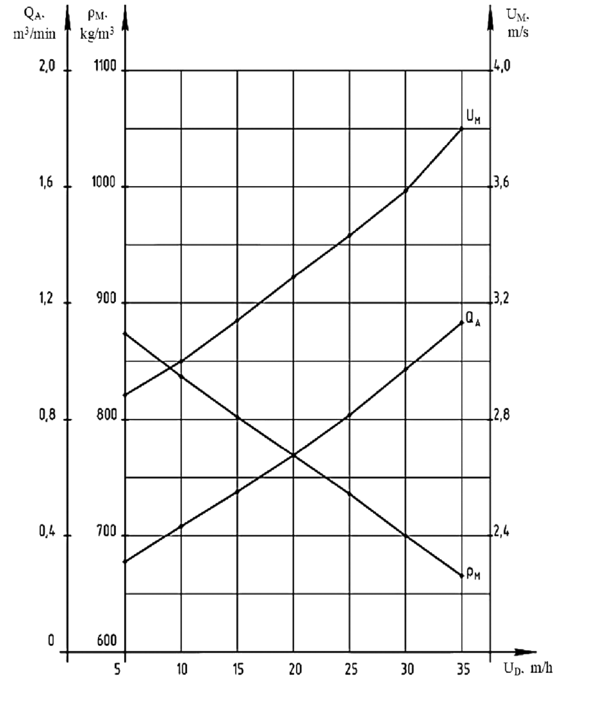

Fig. 5. The dependence of the average effective values of the density of the water-air mixture ρ_M, the rate of its rise U_M and airflow Q_A on the rate of deepening U_D

speed U_D, respectively, the pressures P_{Sl2} and P_{dl2} caused by the presence of sludge increase. Their growth causes a drop in the density of the ρ_M mixture (Fig. 7) by increasing the air content in it Q_A, which has a nonlinear accelerating character.

Dependence of the output parameters on the set rate of ascent of the water flow from the bottom to the mixer. The minimum value of U_W = 1 m/s [8]. As shown above, this value and all

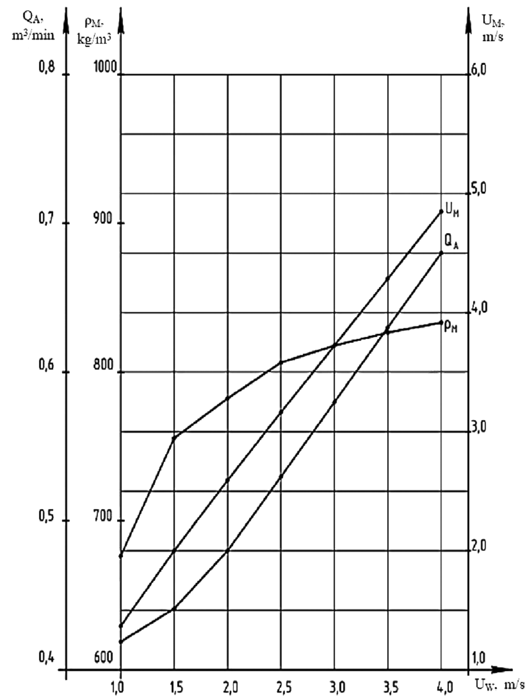

Fig. 6. The dependence of the average effective values of the density of the water-air mixture ρ_M, the rate of its rise U_M and airflow Q_A on a given velocity of the upward flow of water U_W

Table 9

Dependence of the average effective values of the airlift circulation parameters on the water flow rate

U_W, m/s	Δ_F, kg/m³	P_{S2}, atm	P_{d2}, atm	ρ_M, kg/m³	Q_A, m³/min	Q_W, m³/min	Q_M, m³/min	U_M, m/s
1.0	230	4.75	0.03	677	0.42	0.87	1.29	1.48
1.5	153	3.17	0.05	748	0.44	1,31	1.75	2.00
2.0	115	2.38	0.07	784	0.48	1.74	2.22	2.55
2.5	92	1.90	0.08	805	0.53	2.18	2.71	3.11
3.0	76	1.58	0.10	818	0.58	2.61	3.19	3.67
3.5	65	1.36	0.12	827	0.63	3.05	3.68	4.23
4.0	57	1.19	0.14	834	0.69	3.48	4.17	4.79

values exceeding it correspond to a turbulent regime in which the coefficient of hydraulic resistance λ_W = 0.019.

Table 10 and Fig. 8 show that to create a growing water flow Q_W, an accelerated growing air content Q_A is required in the mixture. At the same time, there is a drop in ΔF and P_{Sl2} (the sludge is diluted in a growing stream of water). As a result, the increase in the density of the ρ_M mixture with an increase in the water content is not proportional, but it is flattening out.

The area of the face is proportional to the square of its diameter. The mass of the drilling mud is proportional to the area of the face and the speed of deepening The effect of the sludge on the properties of the washing liquid is characterized by the parameter ΔF – an increase in the density of the liquid as a result of the presence of sludge in it. The data in Tables 11 and 12 demonstrate how the static P_{Sl2} and dynamic P_{dl2} components of the pressure in the drill string increase with an increasing well diameter, and the increase is directly proportional to ΔF. According to the formula, the growth of these components causes an accelerated increase in air flow Q_A and velocity U_M, water-air mixture with a sharp drop in its density ρ_M.

Dependence of output parameters on the diameter of the well.

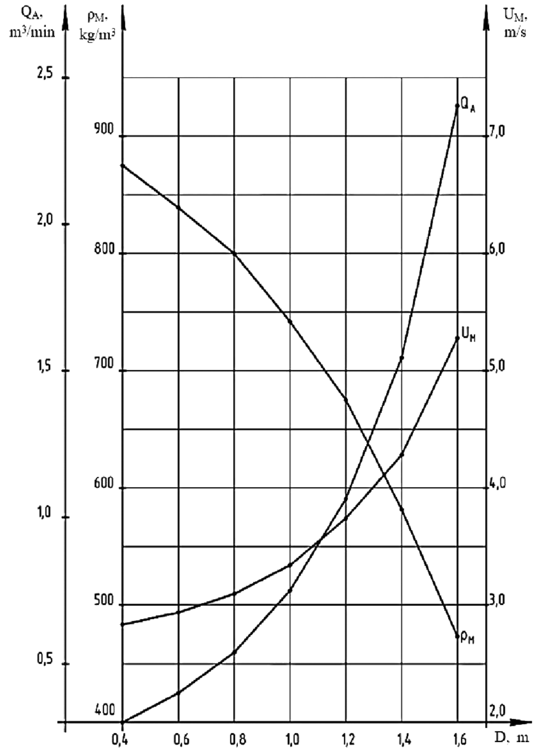

Fig. 7. The dependence of the average effective values of the density of the air-water mixture ρ_M, its rate of rise U_M and air flow Q_A on the diameter of the well

Table 10

Dependence of the average effective values of the airlift circulation parameters on the diameter of the well

D, m	Δ_F, kg/m^3	P_{S12}, atm	P_{d12}, atm	P_M, kg/m^3	Q_A, m^3/min	Q_M, m^3/min	U_M, m/s
0.4	23	0.48	0.02	878	0.30	2.48	2.85
0.6	52	1.07	0.05	846	0.40	2.58	2.96
0.8	92	1.90	0.08	800	0.54	2.72	3.12
1.0	144	2.97	0.13	742	0.76	2.94	3.37
1.2	207	4.28	0.19	669	1.08	3.06	3.74
1.4	282	5.82	0.26	581	1.57	3.75	4.30
1.6	369	7.60	0.34	473	2.42	4.60	5.28

If, according to Table 1, the typical water lifting speed U_W = = 2.5 m/s is observed, the water flow rate Q_W increases proportionally to the pipe cross-sectional area. Accordingly, the table shows an equally sharp decrease in ΔF and P_{S2} and P_{d12}. At the same time, according to the formula, the density of the ρ_M mixture increases. As well as Q_W in the flow of the mixture with the diameter of drill pipes, Q_A also increases, but more moderately.

Conclusions.

1. Based on the analysis of the pressure balance in the descending and ascending flows, an algorithm for the functioning of the airlift circulation method during rotational drilling with backwash has been developed.

2. The balance takes into account hydrostatic and hydrodynamic pressures, and the influence of the deepening speed on them.

Dependence of output parameters on the diameter of the drill string.

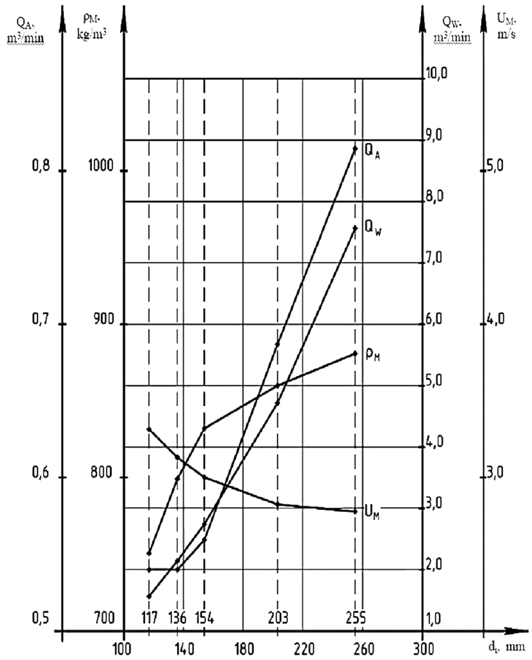

Fig. 8. The dependence of the density of the mixture ρ_M, the rate of its rise U_M, air flow Q_A and water Q_W on the diameter of the drill string (above the abscissa are the internal diameters of drill pipes)

Table 11

External Loop Parameters

Column diameters – external/internal, d_O/d_i	Unit	Value
The first diameter	m	0.127/0.117
Second diameter	m	0.146/0.136
Third diameter	m	0.168/0.154
Fourth diameter	m	0.219/0.203
Fifth diameter	m	0.273/0.255

Table 12

Dependence of the average effective values of the airlift circulation parameters on the diameter of drill pipes

d_O/d_i, m	Q_W, m^3/min	Δ_F, kg/m^3	P_{S12}, atm	P_{d12}, atm	ρ_M, kg/m^3	Q_A, m^3/min	Q_M, m^3/min	U_M, m/s
0.127/0.117	1.61	125	2.57	0.14	750	0.54	2.45	3.34
0.146/0.136	2.18	92	1.90	0.08	800	0.54	2.72	3.12
0.168/0.154	2.79	72	1.48	0.06	832	0.56	3.36	3.01
0.219/0.203	4.85	41	0.85	0.02	879	0.67	5.52	2.84
0.273/0.255	7.66	26	0.54	0.01	903	0.82	8.48	2.77

3. The pressure balance also takes into account the influence of the content of sludge in the upstream.

4. By the method of successive approximations with a given accuracy, the average-effective values of the airflow rate, the density of the water-air mixture and the velocity of its upward flow are determined.

5. Based on the average effective values of the output parameters, a method is proposed for estimating their changes during the upward flow of the mixture.

6. Based on the created mathematical algorithm, a computer model has been developed that allows analyzing the dependences of the airflow, the density of the mixture and the rate of its ascent on the parameters of the well being drilled.

7. Drilling parameters and parameters of two nested program cycles are fed to the input of the model; the calculation unit includes off-cycle calculations, calculations on nested cycles, and printing of the results obtained.

8. The model is applied to typical drilling conditions of a large-diameter water intake well at the Samskoye groundwater deposit on the Mangystau peninsula.

9. For typical conditions, the dependences of the air flow rate, the density of the water-air mixture and the rate of its ascent on the depth of the wells, the depth of the mixer descent, the speed of deepening, the set speed of the ascending water flow, the diameter of the well and the diameter of standard drill pipes are established.

10 The estimation of changes in the output parameters along the upward flow of the mixture is given.

11. The required compressor capacity has been determined.

12. An example of using the method of successive approximations in estimating the values of the output parameters of the model with a given accuracy is given.

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Моделювання буріння водозабірних свердловин зі зворотним промиванням ерліфтним способом

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Мета. Визначення впливу гірничо-геологічних умов буріння гідрогеологічних свердловин зі зворотним промиванням на технологічні параметри ерліфтного способу їх очищення від вибуреної породи та властивостей висхідного потоку промивальної аерованої рідини.

Методика. Поставлені завдання вирішувалися комплексним методом дослідження, що включає аналіз й узагальнення літературних і патентних джерел, проведення аналітичних, експериментальних досліджень із використанням методів комп'ютерного й математичного моделювання.

Результати. Розроблено алгоритм функціонування ерліфтного способу циркуляції при обертальному бурінні зі зворотним промиванням. Алгоритм ураховує: гідростатичний та гідродинамічний тиск, і вплив на них швидкості поглиблення свердловини; вплив вмісту шламу у висхідному потоці. Встановлені ефективні значення витрати повітря, щільності водо-повітряної суміші та швидкості її висхідного потоку. Запропоновано метод оцінки ефективних значень технологічних параметрів та їх зміни у висхідному потоці суміші. Розроблена модель, що дозволяє аналізувати залежності витрати повітря, щільності суміші та швидкості її сходження від параметрів свердловини, що буриться. Модель застосована до типових умов буріння свердловини великого діаметру на Самському родовищі підземних вод півострові Мангістау.

Наукова новизна. Розроблено математичний алгоритм функціонування ерліфтного способу зворотного промивання при бурінні водозабірних свердловин великого діаметра. Метод заснований на аналізі балансу тисків у низхідному та у висхідному потоках промивного агента. Для випадку зворотного промивання отримано вираз оцінки вмісту в ньому шламу. Розроблено метод визначення середньо-ефективної за висотою свердловини густини суміші, а також вмісту в ній повітря. На основі середньо-ефективних значень запропоновано метод оцінки змін щільності суміші, її витрати та швидкості по ходу висхідного потоку.

Практична значимість. Запропонований алгоритм покладено в основу комп'ютерної моделі, що дозволяє встановлювати залежності значень щільності суміші, вмісту в ній повітря та шламу й швидкості підйому від глибини свердловини, глибини спуску змішувача, швидкості поглиблення, заданої швидкості висхідного потоку рідини, а також діаметрів свердловини й бурильних труб. Отримані конкретні результати моделювання стосовно Самського родовища підземних вод півострова Мангістау.

Ключові слова: *півострів Мангістау, гідрогеологічна свердловина, зворотне промивання, ерліфтний спосіб*

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