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DEVELOPMENT OF AN EFFECTIVE TECHNOLOGY FOR THE CONSTRUCTION OF LARGE-DIAMETER WATER WELLS

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Abstract

Subject of study. Technology of drilling large-diameter water wells with reverse circulation in the conditions of the Samskoye groundwater field.

Methodology. The tasks were solved by a complex research method, which includes a review and generalization of literary and patent sources, analytical studies of existing methods for optimizing the technological parameters of drilling with reverse circulation using an airlift.

Purpose. A sharp increase in the use of groundwater resources of the Samskoye field through the introduction of advanced technologies for drilling water wells, ensuring their maximum flow rate at high quality and at the lowest cost.

Findings. It has been established that in the study of the airlift circulation method during rotary drilling with reverse circulation, an important role is played by the analysis of the pressure balance arising in the course of drilling in the annulus and in the drill string. It takes into account both hydrostatic pressures and pressure losses for pumping water and water-air mixture. A technique has been developed for assessing the effect of rate of penetration on circulation parameters.

1.1. Introduction

Water resources play a crucial role in the economy of any country. An important resource is groundwater extracted from boreholes. The problem of the development and protection of groundwater is in the focus of attention of special UN organizations [1]. In the Republic of Kazakhstan, there is a noticeable shortage of water resources, which is a consequence of the natural features of its territory and climate. A significant part of its vast territory, including the center, south and west, belong to the zones of deserts and semi-deserts, characterized by rare precipitation and underdeveloped river networks. The earth's surface is often covered with salt marshes, and the permeable horizons close to the surface contain waters with high mineralization and cannot be used for drinking purposes.

Since 2002, the country has been consistently implementing the programs «Drinking Water» for 2003-2010, «Ak-Bulak» for 2011-2020 and the State Program for the Development of Regions for 2020-2025.

The «Drinking Water» Program started in 2002. The goal this program was the complete provision of drinking water to more than 7,000 settlements, including the installation of water supply systems in 174 villages and 86 towns. It lasted 8 years for its implementation, 195 billion tenge was allocated from the budget [2].

The second program, which was supposed to help provide Kazakhstan with clean drinking water, was launched in 2011 for a period of 9 years. The program was supposed to provide by 2020 with high-quality drinking water from centralized water supply systems the rural population of Kazakhstan by 85% and the urban population by 100%. For these purposes, it was planned to allocate a total of 1,3 trillion tenge. In 2011-2018, within the framework of the state program for the development of regions, 2015 projects were implemented from the republican budget for the development of water supply and sanitation systems [2].

Unfortunately, for a number of reasons, the implementation of these programs did not allow solving the problems of water supply in certain regions.

According to the Concept of the State Program for Water Resources Management of Kazakhstan for 2020-2030, by 2040 water consumption will increase by 56% and water deficit will be about 12 billion m^3.

Mangystau is an industrial region. The basis of the economy is the oil and gas sector. In the structure of industry, the main share is occupied by the mining industry and quarrying, the share of which at the end of 2020 amounted to 85%. The industry employs about 25% of the population of the region; the share of the industry in the gross regional product is about 50%. Regional enterprises annually produce more than 10% of the industrial output of the country [3].

Based on the current demographic situation and the development of the region as a whole, the need for water supply in the region is growing every year. The water supply of the region is carried out from the Astrakhan-Mangystau water conduit and desalinated sea water, since there are few sources of natural groundwater. To date, drinking water consumption is 149 thousand m^3/day. There is a deficit in the region's water supply in the amount of 51 thousand m^3, and given the development of the region by 2025, the need will be 250-260 thousand m^3, and the deficit will be 100-110 thousand m^3 [4].

The implementation of the 2nd stage of bringing the capacity of the desalination plant «Kaspiy» to 40 thousand m^3/day has begun. JSC NC KazMunayGas is building a plant with a capacity of 17 thousand m^3/day at the Karazhanbas field.

To supply the city of Zhanaozen in the area of Kenderli and the village of Kuryk, it is planned to build desalination plants with a capacity of 50 thousand m^3/day, and on the territory of MAEC-

Kazatomprom LLP with a capacity of 24 thousand m^3/day. It is planned to build a desalination plant with a capacity of 5 thousand m^3/day in the city of Fort Shevchenko [3].

Drinking water supply is provided by three sources and their share in the total volume of water consumption has the ratio:

- sea water - 52.4%;
- Volga water - 12.5%;
- groundwater - 35.1% [5].

1.2 Literature review

The Samskoye field is the main source of groundwater for the city of Zhanaozen. The field has been in operation since 1970. In 1979, the established total water withdrawal was only 0,02 thousand m^3/day, mainly due to private wells dug by the local population. Currently, the withdrawal of groundwater in the city of Zhanaozen has increased to 6,4 thousand m^3/day, which is 18% of the resources of the Samskoye field, although the problem of high-quality water supply to the city is still acute [6].

This problem can only be solved by significantly increasing the number of water wells and obtaining the maximum flow rate of groundwater of standard quality at the lowest cost.

Established according to the report [7] and approved for category B, the operational groundwater reserves are 21,2 thousand m^3/day for fresh water and 14,3 thousand m^3/day for slightly brackish water. The same values appear in modern documents [6].

For successful drilling of a well in the conditions of the Samskoye field, it is necessary to justify the drilling method, select drilling equipment, composition and parameters of the drilling fluid, rock cutting tools and drilling mode parameters.

As a rule, the main directions of scientific research are carried out in two main directions: solving issues related to the technology of cleaning a well from cuttings [8] and developing optimal parameters for the operation of a rock cutting tool [9,10].

Most often, drilling with direct circulation of drilling fluid is used for water wells. This technology is simple to organize, does not require additional equipment, and allows efficient use of the energy of the drilling fluid for the destruction of rocks [11].

The drilling rig is equipped with a rotator that rotates a drill string with a bit at its lower end. Destruction products are brought to the surface by drilling fluid, which is fed into the well by a drilling pump. Through the injection hose and swivel, it enters the drill pipe string, along which it moves down to the working bit. Cleaning the bit and the bottomhole, the fluid returns to the surface together with the drill cuttings, where, after being freed from the cuttings in the cleaning system, it is again sucked in by the drilling pump, thus circulating [12].

However, with this circulation method, low drilling fluid flow rate, poor particle retention, low drilling efficiency, and severe wear of the drill bit are observed [13].

Another huge problem with this method is the high time and cost involved in combating fluid losses [14].

Usually, to eliminate this complication, the installation of casing strings or plugging of the absorbing horizon in various ways is used [15]. However, when drilling wells for water, the use of these methods will only lead to unjustified expenditures of time and money.

The use of reverse circulation effectively solves the problem of drilling fluid losses in the well [16].

Reverse circulation drilling has proven to be highly effective in drilling wells for various purposes.

Thus, this method was successfully applied for the extraction of uranium ore by underground borehole leaching at operating technological wells of Volkovgeologiya, with an average total depth of 300-500 m [17].

There are examples of its use even in mine exploration instead of traditional core drilling, where reverse circulation drilling has high drilling efficiency and low cost [18].

According to [19], compared with traditional core drilling, drilling with reverse air circulation increased drilling efficiency by 70-90% while reducing costs by 30-50%, the number of accidents during drilling decreased by 60-70%. In addition, reverse circulation drilling is more environmentally friendly [20].

The reduction of accidents is the most important factor in improving the efficiency of drilling wells, since the cost of repairs significantly increases the cost of well construction [21].

Airlift reverse circulation drilling showed high efficiency when drilling geothermal wells [22].

The application of airlift reverse circulation drilling technology is possible even in the construction of wells with a depth of 4200 m, which is the deepest geothermal well in China [16].

Note that another possible application of reverse circulation with the help of an airlift is not drilling a well, but expanding it with the help of jet jets [23].

The experience of using this technology in drilling wells for gas hydrates is also known [24].

Thus, in recent years there has been a steady trend towards expanding the scope of drilling wells with reverse circulation of drilling fluid. This is due to the fact that this method has a number of significant advantages.

Thus, the use of reverse circulation drilling allows drilling wells with a diameter of up to 1500 mm [25].

Reverse circulation drilling technology is much more efficient, has better technical support and will play an increasingly important role in water well drilling in the future [26].

There are many difficulties in well drilling with groundwater and large diameter wells with direct circulation of drilling fluid. The main reason for this is that due to the large drilling diameter, there are problems with cuttings to the surface, which can lead to well failure, long drilling period and high cost. The use of the reverse circulation process can effectively increase the rate of penetration (ROP), reduce the cost of the project, and reduce the labor intensity of the process. Due to the high rate of the upward flow of the drilling fluid (usually above 2 m/s), large diameter cuttings can be brought to the surface, and therefore, the ROP can be increased. Using this method, the ROP increases by about 30% compared to direct circulation drilling [27].

Analyzing the cost of drilling wells, researchers identify three characteristic trends:

1. Well costs increase exponentially with depth due to more difficult drilling conditions.

2. Well cost uncertainty increases with depth due to increased likelihood of problems and less predictable drilling conditions.

3. Deep wells have a positive cost probability distribution [28].

Thus, it is very important to maximize the speed of well construction through efficient drilling technology.

The key parameters of the drilling technology with reverse circulation and airlift gas injection are the volume of gas injection and displacement of the drilling fluid, the change of which regulates the bottomhole pressure [29].

It should be noted that reasonable recommendations do not include a choice of parameters for reverse circulation mechanisms and a large number of design flaws hinder the wide practical application of this drilling method [30].

1.3. Geological, geophysical and hydrogeological knowledge of the work area

1.3.1. Physical and geographical characteristics

The described territory is characterized by a very low water supply and an extremely tense water balance. Water supply of national economic objects is carried out at the expense of surface and underground waters. In the 1960s and early 1970s, water conduits Guryev-Sagiz, Guryev-Astrakhan, Guryev-Karaton were built to supply water to the population of workers' settlements associated with oil production and maintenance of the railway with water intake from the river Ural. The share of groundwater in the balance of water consumption of the rural population of Atyrau region is 45-48%.

The layout of explored groundwater deposits is shown in Fig. 1.1.

For the Mangystau region, the main sources of drinking water supply are groundwater and an energy plant for seawater desalination. A significant amount of surface water is supplied to water consumers through many kilometers of water conduits. The prospective need of settlements for drinking water can be partially covered by the predicted resources of fresh groundwater in sandy massifs, as well as by desalination of brackish waters of Cretaceous deposits.

Groundwater is contained in deposits of the Quaternary, Neogene, Cretaceous, Jurassic and Paleozoic ages. The groundwater horizon in the described territory is underlain everywhere by a thick layer of clays of the Quaternary age, which is a regional aquiclude. It is believed that there is no significant overflow through the aquiclude. Therefore, the description of the aquifers and complexes lying below it is not given her [31].

Ground waters are confined to fine- and fine-grained, sometimes clayey sands of Quaternary deposits with interbeds of clays that are not consistent along strike. The total thickness of water-bearing deposits ranges from 2-10 to 15 m (Fig. 1.2).

Filtration properties of water-bearing rocks are low. Filtration coefficients are mainly in the range from 0,1-0,2 to 3-5 m/day. The depth of groundwater in a significant part of the coastal zone ranges from 1-3 m, increasing to 5-7 m in elevated areas of the described territory. Groundwater mineralization is high (from 10 to 300 g/l); the chemical composition is often sodium chloride.

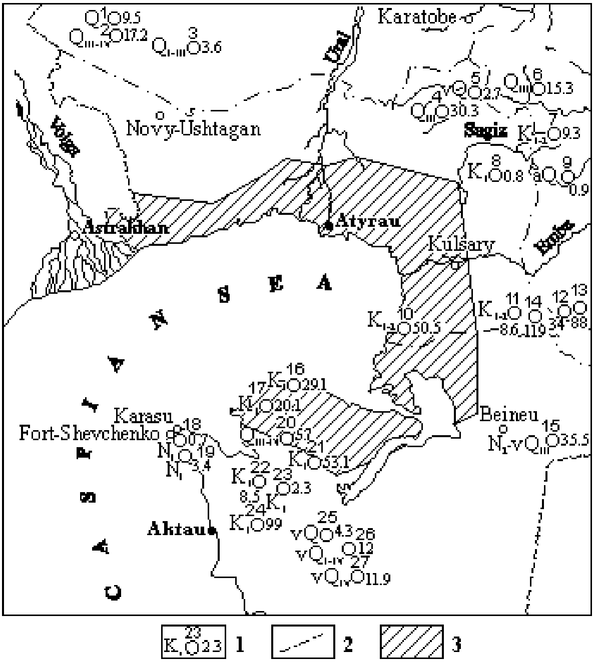

Fig. 1.1. Scheme of location of groundwater deposits: *1* - deposits with approved groundwater reserves in the sum of categories A+B+C_1+C_2 (thousand m^3/day); geological age index of water-bearing rocks and field number (*1* - Urda; *2* - Aimekenskoe; *3* - Iskrovskoe; *4* - Taisoiganskoe; *5* - Miyalinskoe; *6* - Uilskoe; *7* - Keregen-Sagizskoe, *8* - Eibetinsky, *9* - Oryskazgan, *10* - Tengiz, *11* - Balinsky; *12* - Myngyr; *13* - Mataykum; *14* - Zhanasusnoe; *15* - Samskoye; 16 - Aksyn-Kalamkassky site; 17 - Aktumsyk-Karazhanbasky section; 18 - Ketykskoye; 19 - Saubet; 20 - Kyzylkum; *21* - North Aktau; 22 - Ulanak; *23* - Akmysh; 24 - Kuyulus; *25* - Baskuduk; *26* - Sauskan; 27 - Tyuesu); *2* - conditional external border of the coastal zone of the Caspian Sea in the Caspian lowland; 3 - study area

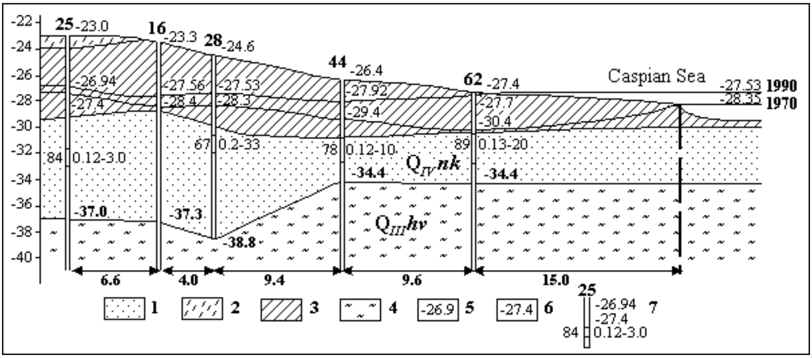

Fig. 1.2. Hydrogeological section along the line I-I: *1* - sands; *2* - sandy loam; *3* - loams; *4* - clays; *5* – groundwater level for 1970; *6* - groundwater level for 1990; *7* - well. Numbers: at the top - her number; on the left - mineralization, g/l; on the right - well flow rate, l/s and water level decrease, m; the numbers near the arrow are the absolute marks of the groundwater level

Groundwater has a single hydraulic surface with a slope mainly towards the Caspian Sea and numerous sor depressions into which groundwater is discharged. In low water, it is also carried out in the riverbeds. Groundwater is fed as a result of precipitation infiltration, water inflow from the Caspian Sea in certain sections of its coastline, as well as the loss of river flow in the flood.

1.3.2. Hydrogeological conditions of the Samskoye field

Conditions for the formation of groundwater, water abundance, degree of mineralization are determined by the features of the geological structure of the area, relief and climate.

The following aquifers are distinguished in the described area:

1. Aquifer of modern deposits (Q_{IV}).
2. Aquifer of Upper Pliocene-Upper Quaternary deposits ($N_2^3 + Q_{III}$).
3. Aquifer of the Upper Miocene deposits of the Sarmatian stage ($N_1^3 + S$).

Separately, the distribution contours of permeable, but practically waterless Upper Pliocene-Upper Quaternary deposits are distinguished. The distribution of groundwater, their mineralization, and chemical composition are shown on a schematic hydrogeological map at a scale of 1:100,000.

Recent sediment aquifer (Q_{IV})

The described aquifer is confined to the deposits of sors, which have spread along the outskirts of the Sam sandy massif. The largest of them are Sam, Samoldyn, and others. Water-bearing rocks are sands, sandy loams, and silts. The thickness of the described deposits reaches 10 m (sor Sam). In the northern direction, due to the uplift of the bed of underlying rocks, the thickness of the sor deposits decreases and, consequently, the thickness of the flooded stratum also decreases. The depth of the water level on the sors usually does not exceed 0,5 m, sometimes reaches 3 m. The aquifer is fed mainly due to precipitation and water influx from other aquifers, in particular, Upper Pliocene-Upper Quaternary deposits.

According to the chemical composition, the waters in the sor deposits are chloride-sodium and sulfate-chloride-sodium.

Upper Pliocene-Upper Quaternary aquifer ($N_2^3 + Q_{III}$)

The described aquifer is confined to the sand massif Sam. Water-bearing rocks are fine-grained sands, less often fine-grained, quartz-feldspar.

Groundwater, depending on the hypsometric position, occurs at various depths. The minimum depth of groundwater penetration corresponds to the zone from the unloading, the maximum depth - in the bed of dune sand development. The groundwater level varies between 1,35-29,0 m. The thickness of the aquifer varies from 2,2 to 26,5 m.

The aquifer of the Upper Pliocene-Upper Quaternary deposits is underlain by sandy loams, loams of the same age, as well as clays of the Lower Sarmatian stage. In some places, sands lie directly on the calcareous strata of the Lower Sarmatian.

The flow rates of wells, according to the data of numerous pumpings, vary within 0,35-6 l/s, with depressions of 2,3-4,5 m, respectively. The aquifer contains very variegated waters in terms of mineralization and chemical composition. Over the entire area of the massif, except for the central part of the sands, a change in the hydrochemical composition of groundwater is observed vertically from top to bottom. This pattern is especially pronounced in the marginal parts. The type of water in the fresh zone of the sandy massif is predominantly sulfate-chloride, sulfate-hydrocarbonate and hydrocarbonate-sulfate-chloride, less often hydrocarbonate. In the area of distribution of slightly brackish and saline waters, chloride-sulphate waters predominate; in the discharge zone, where the water level is closer to the surface, the mineralization reaches 34,7 g/l. The discharged waters create a backwater for the waters moving from the central parts of the massif to its outskirts, which creates a stagnant regime and an increase in the mineralization of groundwater. The aquifer is discharged into sors, which are located in the peripheral parts of the Upper Pliocene-Upper Quaternary deposits. For all lenses of the Sam sandy massif, the total slope of groundwater varies within 0,0007-0,0050.

The feeding area of the aquifer coincides with the area of distribution of the sandy massif. The main source of nutrition is atmospheric precipitation.

The described aquifer is currently used by the local population, both for drinking and for watering livestock. In the area of the village of Sam-2 for water supply to the compressor station, the Central Asia-Center gas pipeline and the Beyneu station.

Upper Miocene aquifer of the Sarmatian stage ($N_1^3 + S$)

In the study area, the aquifer of the Sarmatian stage is distributed along the outskirts of the Sam sandy massif. Water-bearing rocks are various limestones with a general slope to the axis of the North Ustyurt trough. The conditions of their occurrence, associated with structural features, determine both the thickness of the deposits themselves and the thickness of the flooded part, as well as the depth of the level. In areas of uplifts, the thickness of the deposits decreases, respectively, the thickness of the watered part of the section decreases and the depth of the groundwater level increases. In the zone of troughs, the thickness of precipitation and their water-containing part increase, and the groundwater table approaches the day surface. This is especially clearly observed in the region of the axial part of the North Ustyurt trough. In general, the thickness of the flooded part of the aquifer varies within 8-47,4 m.

The waters of the aquifer as a whole are free-flowing, however, in the area of the Samskoye depression, pressure and even weakly self-flowing waters have been discovered by wells. The creation of pressure is facilitated by the sharpness of absolute marks between the side parts of the depression, which are the feeding area, and its lowest part, as well as the presence of poorly permeable rocks in the roof of the complex.

The productivity of workings that reveal groundwater varies quite widely. In general, the flow rate fluctuates within the range of 0,55-8 l/sec with water level drops of 60-10 m, respectively. The mineralization of groundwater is very diverse, and the Sarmatian aquifer is also distinguished by a distinct vertical zonality. Slightly brackish waters with a salinity of 1-3 g/l are distributed in the crests of uplifts, which are partial feeding areas, from which groundwater moves along the slope of the layers towards depressions, to areas of discharge. In general, the total mineralization of groundwater ranges from 2-10 g/l. According to the ionic composition, the waters are predominantly sulfate and sulfate-chloride-sodium.

The feeding area of the aquifer coincides with the area of its distribution. Nutrition occurs due to atmospheric precipitation, partly due to infiltration of groundwater from the Upper Pliocene-Upper Quaternary deposits. Groundwater of the described aquifer is used for drinking and cattle watering.

1.3.3 Justification of drilling parameters of a typical well in the conditions of the Samskoye field

In [32] based on the study of the geological and technical conditions of the Samskoye field, it was substantiated that the use of a rotary drilling method with reverse circulation makes it possible to multiply the well flow rate; reduce their required number; improve the quality of produced water; drastically reduce the well completion time; significantly lengthen the time of operation of wells; provide high rate of penetration (ROP); reduce the cost per cubic meter of produced water. Below, in support of this proposal, mathematical algorithms are given that allow obtaining the necessary numerical characteristics.

In order for the mathematical apparatus to be focused on the specific geological and hydrogeological conditions of the considered groundwater deposit, a basic model of a water well was built, which must meet the requirements of economic, geological and technological factors. Taking into account the above requirements, the following typical model for drilling a water well was adopted (Table 1.1).

Table 1.1

Basic drilling parameters of a typical well

No	Parameter	Meaning
1	Drilling depth, N, m	200
2	Depth of the roof of the productive formation, N_R, m	170
3	Reservoir thickness, m	14
4	Filtration coefficient, K_F, m/day	6.3
5	Static formation head, H_S, m	100
6	Drilling diameter, D, mm	800
7	Drill string diameters: out./in., d_O/d_i, mm	146/136
8	The height of the mixture above the surface, h, m	10
9	Upward water flow rate, U_W, m/s	2.5
10	Rate of penetration, ROP, m/h	15
11	Mixer immersion depth, L, m	H 2

In a comparative assessment of drilling methods, the main role is played by the maximum possible drill bit diameters.

For rotary drilling with reverse circulation we accept the diameter value equal to 800 mm (Table 1.1).

For rotary drilling with direct circulation in the case of using the widespread installation 1BA-15V, the final diameter can be a diameter of 190 mm [33].

When percussive drilling with the UKS-22 rig, a well with a depth of 200 m requires a casing telescope consisting of six columns. With an initial diameter of 22 inches (600 mm), the final diameter is 12 inches (324 mm) [34].

The initial data given in lines 1-5 of Table 1.1 were taken as the basis for comparative calculations.

The general parameters used in the comparative analysis of the three drilling methods are given in Table. 1.2.

Table 1.2

General parameters used in the comparative analysis

No.	Parameter	Meaning
1	Maximum possible theoretical flow rate, Q_S, m^3/h	245
2	Depression required to achieve it, H_S, m	100
3	Permissible filtration rate, U_F, m/h	5,01

The results of comparative calculations are given in Table 1.3.

Table 1.3

Main indicators of drilling water wells

Parameter name	Rotary drilling	Percussion drilling	Reverse circulation drilling
Diameter of the receiving part *D*, m	0,190	0,324	0,800
Filter pipe diameter D_F, m	0,146	0,146	0,146
Sprinkling layer thickness δ, m	0,022	0,089	0,327
Required filter length at a flow rate of 245 m^3/h (Table 1.2), *L*, m	82	48	20
The highest production rate (at reservoir thickness *m* = 14 m), Q_{max}, m^3/h	41	71	176

According to the results of the work, rotary drilling with reverse circulation in the conditions of the Samskoye field has such advantages.

The maximum possible, taking into account the limited thickness of the aquifer, the flow rate of drilling with reverse circulation is 4,3 times higher than with rotary drilling with direct circulation and 2,5 times higher than with percussion-rope drilling.

If the reservoir thickness is not a limiting factor, then with the same flow rate, the indicated ratio will be valid for the required lengths of the receiving part. The larger the diameter, the smaller the required length, with a decrease in which the costs of both the equipment of the receiving part and its repair are reduced.

With the same diameter of the filter pipe, the maximum possible thickness of the gravel pack layer during reverse circulation drilling is 15 times greater than for conventional rotary drilling and 3,7 times greater than for cable percussion drilling.

Powerful gravel sprinkling provides the best quality of mechanical cleaning of the sampled water. The consequence of this is also the minimum time required for experimental pumping and the minimum length of the well sump. Such sprinkling also provides the maximum duration of overhaul operation.

It should be borne in mind that with rotary drilling of large diameter wells with reverse circulation, labor costs for the manufacture of a gravel pack are minimized. As a rule, gravel is filled manually through the wellhead, since the large area of the annular space eliminates the possibility of plugging and failure of the filled material to reach the receiving part.

1.4 Optimization of technological parameters of airlift operation when water wells drilling

Currently, a number of reverse circulation mechanisms have been developed during well drilling: airlift pumps, submersible piston pumps, devices that convert the direct flow of drilling fluid in the bottomhole zone into counterflow, etc. However, reasonable recommendations lack the choice of parameters for reverse circulation mechanisms and a large number of design drawbacks hinder the wide practical application of this drilling method [30].

A significant factor that reduces the efficiency of well drilling with reverse circulation is the uncertainty of airlift operating conditions. This is due to the fact that the depth of the well is constantly changing, the pressure in the annular space and in the drill string, the depth of the mixer immersion are changing, which means that the optimal parameters of the airlift are changing. Currently, there is no method for determining the parameters of airlift operation in changing drilling conditions.

On Fig. 1.3 shown how, in the process of drilling at a level close to the bottom of the well 1, equilibrium is established between the pressures outside and inside the drill string 3.

As a first approximation, the pressure outside the drill string can be taken as the hydrostatic pressure of the water column 13 of the corresponding height.

Inside the drill string there is a mixture 15 of water with air 14, which is supplied there through the mixer 4 from the compressor 6 through the air channel 7.

Let us consider the balance of external (with respect to the drill string) and internal pressures in more detail. This balance is expressed by the equation

$$P_0 = P_I, \tag{1.1}$$

where P_0 is the pressure outside the drill string; P_I is the pressure inside it.

The pressure outside the drill pipes consists of two components

$$P_0 = P_S + P_D, \tag{1.2}$$

where P_S is the hydrostatic pressure; P_D is the hydrodynamic pressure (pressure loss) of the downstream.

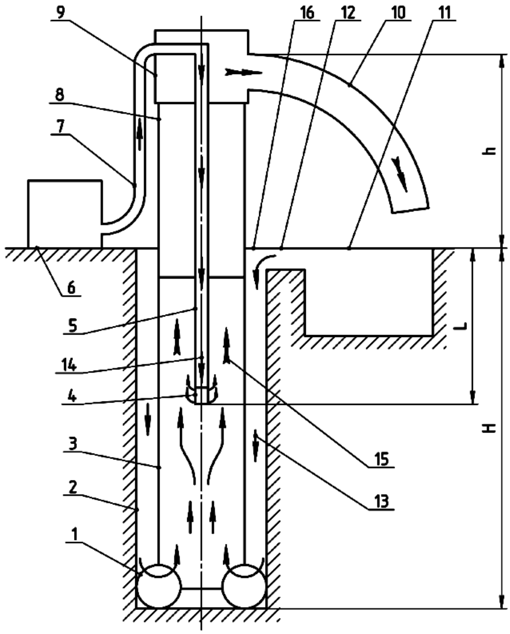

Fig. 1.3. To the algorithm of functioning of the airlift method during rotary drilling with reverse circulation: *1* - drill bit; *2* - borehole wall; *3* - drill string; *4* - mixer; *5* - air duct; 6 - compressor; *7* - hose; *8* - kelly; *9* – swivel: *10* - throwaway sleeve; *11* - sump; *12* - gutter; *13* - water; *14* - compressed air; *15* - mixture; *16* - the surface of the earth; H is the depth of the well; *L* - mixer loading; *h* - the highest height of the mixture (the highest height of the swivel)

Hydrostatic component of external pressure

$$P_S = \rho_W g L\,, \tag{1.3}$$

where ρ_W is the density of water (1000 kg/m^3); g - free fall acceleration (9,81 m/s^2), L - mixer load (distance from mixer to the surface).

Pressure losses inside the drill string also have static and dynamic components

$$P_I = P_{SI} + P_{DI}\,, \tag{1.4}$$

The hydrostatic component splits into two parts

$$P_{SI} = P_{S1} + P_{S2}\,. \tag{1.5}$$

where P_{S1} is the hydrostatic pressure of the mixture

$$P_{S1} = \rho_M g (L + h)\,, \tag{1.6}$$

where ρ_M is the average density of the mixture along the length $L+h$.

The flow moving along the internal channel of the drill string carries with it particles of destroyed rock, which increase the overall density of the upward flow, and hence the hydrostatic pressure. The second term in formula (1.4) takes into account the growth of hydrostatic pressure depending on the sludge content

$$P_{S2} = \Delta_F g(H+h), \tag{1.7}$$

where Δ_F is the increase in the density of the upward flow due to the sludge contained in it.

With regard to drilling with direct circulation, the required cuttings removal rate is determined based on the maximum allowable increase due to its content in the density of the upward flow. The required cuttings removal rate is

$$U_F = \frac{D^2(\rho_F - \rho_W)U_D}{(D^2 - d_O^2)\Delta_F}, \tag{1.8}$$

where ρ_F is rock density, U_D is ROP.

Transforming formula (1.8), we obtain the actual excess of the density of the upward flow due to the content of sludge in it at a known removal rate

$$\Delta_F = \frac{D^2(\rho_F - \rho_W)U_D}{(D^2 - d_O^2)U_W}, \tag{1.9}$$

Thus, we finally accept that for the sludge removal rate equal to the upward water flow rate U_W, the increase in the density of the upward flow is determined as

$$\Delta_F = \frac{D^2(\rho_F - \rho_W)U_D}{d_i^2 U_W}, \tag{1.10}$$

The hydrodynamic component of pressure inside the drill string includes three components

$$P_{DI} = P_{D1} + P_{D2} + P_{D3}, \tag{1.11}$$

The first component characterizes the pressure loss on the path of the upward flow of water from the bit to the mixer

$$P_{D1} = \rho_W \lambda_W (H-L)\frac{U_W^2}{2d_i}, \tag{1.12}$$

The coefficient of hydraulic resistance λ_W, as in the above case formula (1.8), is determined using the Reynolds criterion.

When water moves inside drill pipes, the Reynolds criterion is determined by the formula

$$R_{Ei} = \frac{\rho_W U_W d_i}{\nu}, \qquad (1.13)$$

For the drilling conditions of a typical well, the rate U_W of water rise along the drill string from the bottom to the mixer is assumed to be 2,5 m/s. Given that the water density ρ_W is 1000 kg/m^3, its dynamic viscosity γ=0,0001 Pa s, and the inner diameter of the selected drill pipes is d=136 mm, the Reynolds criterion determined by formula (1,13) is $3{,}4\cdot10^6$. This is higher than 10^5 and is therefore indicative of a turbulent regime [35]. In this case, in formula (1.12), the coefficient of hydraulic resistance to the movement of water along a circular channel is defined as

$$\lambda_W = \frac{0.0121}{d^{0.226}}. \qquad (1.14)$$

The second component in the formula (1.11) P_{D2} is the pressure loss due to the increase in density due to the content of sludge in the upstream

$$P_{D2} = \Delta_F \lambda_W (H + h)\frac{U_W^2}{2d_i}, \qquad (1.15)$$

Since the sludge particles are located in the water flow, formula (1.15) uses the same values of the hydraulic resistance coefficient λ_W and flow rate U_W as in formula (1.12) directly related to this flow.

The third component in the formula (1.11) P_{D3} is the pressure loss during the movement of the mixture

$$P_{D3} = \rho_M \lambda_M (L + h)\frac{U_M^2}{2d_i}, \qquad (1.16)$$

where L is the distance from the surface to the mixer (the depth of its loading); h is the maximum lifting height of the swivel above the earth's surface; U_M is the average rate of the mixture lifting at the specified interval L+h, λ_M is the average value of the coefficient of hydraulic resistance during the movement of the mixture.

With the height of the lift and the decrease in hydrostatic pressure, the air bubbles coming from the mixer into the water flow become larger and larger. For this reason, the volume of the mixture of water and air increases, which means (with a constant bore section of the drill string) its rate, also increases. From the fact that, as shown above, water that does not yet contain air moves in a turbulent regime, it follows that this regime can be adopted all the more for the movement of a mixture whose rate is higher. Therefore, $\lambda_M = \lambda_W$.

The pressure balance equation (1.7) for the drilling fluid circulation created by the airlift method, taking into account all the above components, takes the form

$$P_S + P_D = P_{S1} + P_{S2} + P_{D1} + P_{D2} + P_{D3}\,. \qquad (1.17)$$

From equation (1.17) it is possible to determine its average, effective density. We write this equation as follows

$$P_{S1} + P_{D3} = P_S + P_D - P_{S2} - P_{D1} - P_{D2}\,, \qquad (1.18)$$

Let us write out the content of the two terms on the left side of equation (1.18)

$$\rho_M g(L+h) + \rho_M \lambda_M (L+h)\frac{U_M^2}{2d_i} = P_S + P_D - P_{S2} - P_{D1} - P_{D2}\,. \qquad (1.19)$$

Or, bracketing the common terms

$$\rho_M (L+h)\left(g + \lambda_M \frac{U_M^2}{2d_i}\right) = P_S + P_D - P_{S2} - P_{D1} - P_{D2}\,. \qquad (1.20)$$

Where do we get the average density of the mixture

$$\rho_M = \left(P_S + P_D - P_{S2} - P_{D1} - P_{D2}\right) / \left((L+h)\left(g + \lambda_M \frac{U_M^2}{2d_i}\right)\right). \qquad (1.21)$$

Having determined ρ_M, we find from it the average rate of rise of the mixture. To do this, we use the mass flow equation

$$Q_W \rho_W + Q_A \rho_A = (Q_W + Q_A)\rho_M\,, \qquad (1.22)$$

where Q_W and Q_A are the volume flow of water and the average volume flow of air, ρ_W and ρ_A are the corresponding densities; ρ_M is the density of the mixture of water and air.

Transforming formula (1.22), we obtain the average volumetric air flow

$$Q_A = \frac{Q_W (\rho_W - \rho_M)}{\rho_M - \rho_A}\,, \qquad (1.23)$$

Since the density of air (even compressed air) is negligible compared to the density of water, the air density can be neglected and then the average volumetric air flow will be

$$Q_A = \frac{Q_W(\rho_W - \rho_M)}{\rho_M}, \tag{1.24}$$

Average mixture consumption

$$Q_M = Q_W + Q_A, \tag{1.25}$$

Substituting in this formula instead of Q_A its value obtained from formula (1.24), we obtain

$$Q_M = Q_W \frac{\rho_W}{\rho_M}, \tag{1.26}$$

Where is the average rate of the mixture

$$U_M = \frac{Q_M}{F_i}, \tag{1.27}$$

where F_i is the bore area of the drill string.

Formula (1.21) already involves the average flow rate of the mixture U_M, which has not yet been determined. This problem is solved by the method of successive approximations used in computational mathematics. Specifically, in relation to this case, this method is implemented as follows.

In formula (1.21), as an unknown value of U_M, the closest possible value (based on general considerations) is substituted. For example, it is advisable to use the value of the water flow rate

$$U_M = U_W, \tag{1.28}$$

The value of ρ_M thus obtained by formula (1.21) is then substituted into formulas (1.24) and (1.26), and then a new value of U_M is obtained by formula (1.27). This new value is again substituted into formula (1.21) and the calculation procedure according to formulas (1.24), (1.26) and (1.27) will be repeated, and the error in finding the value of U_M will decrease again. With each repetition of the described procedure, the error will decrease more and more.

The described procedure is repeated until the value U_M found by formula (1.27) differs in absolute value from the previous value found by the same formula, less than by a predetermined negligible value δ. The condition is set

$$U_M(j) - U_M(j-1) < \delta, \tag{1.29}$$

where *j* is the serial number of the above repeated procedures.

In the direction of movement of the drilling fluid in the direction from the bottom up with a decrease in height, the hydrostatic pressure decreases all the time. For this reason, the size of the air bubbles released from the mixer increases accordingly, which, in turn, causes an increase in the volume of the water-air mixture and a decrease in its density. With an increase in the volume of the mixture and simultaneously with a decrease in its density, its flow rate increases.

By dividing the well according to its depth into conditional intervals of the same length, we can calculate the change in density

$$\rho_{M\Delta}(i) = \rho_M(i) \cdot i - \rho_M(i-1) \cdot (i-1), \tag{1.30}$$

In this formula, $\rho_{M\Delta}(i)$ is the average density on some interval number *i*; $\rho_M(i)$ - effective density from the mouth to the lower boundary of *i* - that interval, $\rho_M(i\text{-}1)$ - effective density from the mouth to the lower boundary of the previous interval. Index *i* is not only the number of the interval, but also the number of conditional intervals included in the distance from the wellhead to the depth of the well, i.e. to the lower limit of the considered conditional interval.

An important result of the above algorithms is the ability to set the required air supply by the compressor. Since the volume of air is inversely proportional to the pressure that acts on it, the compressor flow is usually referred to as atmospheric pressure. The compressor flow in relation to the airlift reverse circulation method can be found by the average air flow for the first (from surface) interval.

$$Q_{ABAR} = \frac{Q_{A\Delta 1}(\rho_{M\Delta 1} g (0.5 h_1) + 10^5)}{10^5}, \tag{1.31}$$

In this formula, on the left is the air flow rate, providing a given rate of rise of the drilling fluid, at atmospheric pressure. On the right in the numerator before the brackets is the air flow in the first interval, and further in brackets is the hydrostatic pressure in this interval (related to its middle) including the density of the mixture, the acceleration of gravity and the height of the interval.

1.5. Modeling of drilling water supply wells with airlift reverse circulation

Based on the theoretical provisions outlined above, a computer model of the airlift method of reverse circulation of the drilling fluid has been created [36].

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

$$A(i) = A(0) + dA \cdot i, \tag{1.32}$$

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 U_M 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.

The considered technique was used to study the drilling of water intake wells at the Samskoye field. Drilling large-diameter water intake wells with reverse circulation will be very effective here. For calculations on the model, typical drilling conditions at the field are accepted, presented in Table 1.4. 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 1.4.

Table 1.4

Drilling parameters of a typical well

Name of the parameter	Unit	Value
Drilling depth, H	m	200
Mixer loading depth, L	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	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 1.4 and 1.5 are used only if they are necessary to establish this considered dependence. The remaining values, being entered (Table 1.4), or calculated (Table 1.5), may in this particular case remain unused.

The values on which the dependence is established are not taken from Tables 1.4 and 1.5, but are specified separately, in accordance with the (1.32).

Solving research problems in conditions of the Samskoye field.

In Table 1.4, 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 Fig. 1.4 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.

This is a given (Table 1.5) 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.

Table 1.5

Off-cycle computing

Name of the parameter	Unit	Value
Through section of the drill pipe, F_i	m^2	0,0145
Drilling fluid 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, $_F$	kg/m^3	92
Hydrostatic component of sludge pressure, P_{Si2}	atm	1,901
Its hydrodynamic component, P_{Di2}	atm	0,085

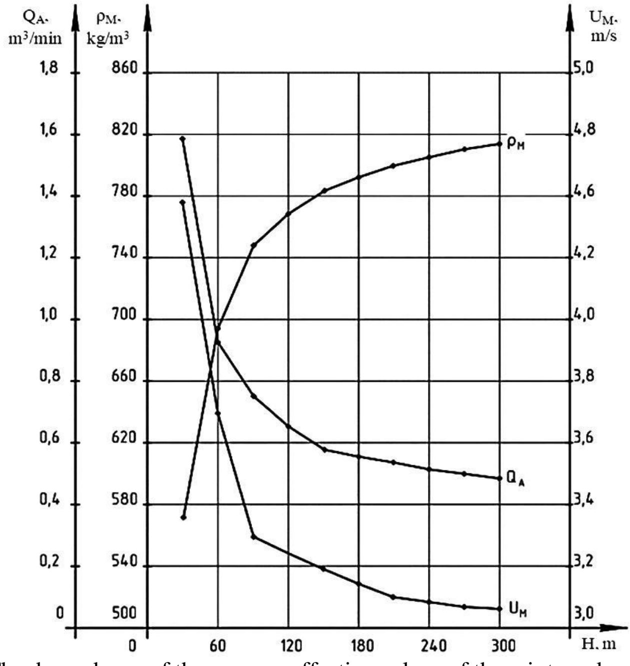

Fig. 1.4. The dependence of the average effective values of the mixture density ρ_M, its rate of rise U_M and air flow Q_A on the depth H

In addition to the U_M velocities, their differences U are given here compared to 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 δ=0,005 already at the fourth iteration.

In Fig. 1.5, 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.

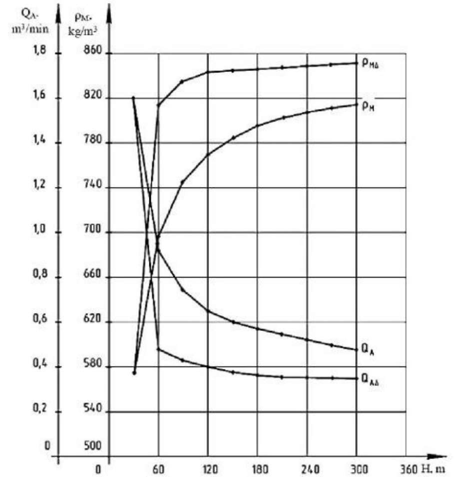

Fig. 1.5. Comparison of the average effective ρ_M and Q_A and the interval values of the density of the mixture of ρ_M and air flow Q_A

According to Table 1.4, 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. In some cases a higher location of the mixer provides an increase in the possible well depth [34].

The values of P_{SI2}, P_{DI2} and P_{DI1} are subtracted from the hydrostatic pressure P_{S0} of water in the annulus at the mixer level.

The analysis of Fig. 1.6 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 Fig. 1.7. The increase in the density of the ascending water flow F is proportional to the drilling speed U_D, according to which U_D multiplies as if by a constant coefficient.

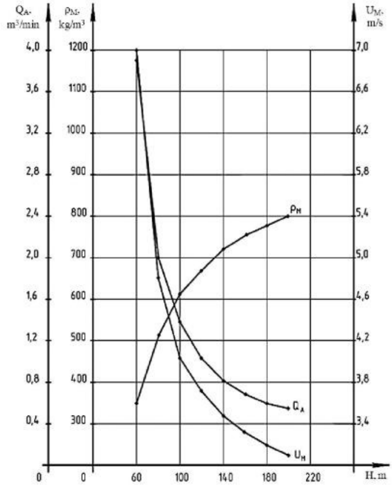

Fig. 1.6. The dependence of the average effective values of the density of the water-air mixture ρ_M, its rate of rise U_M and airflow Q_A on the depth of the mixer loading

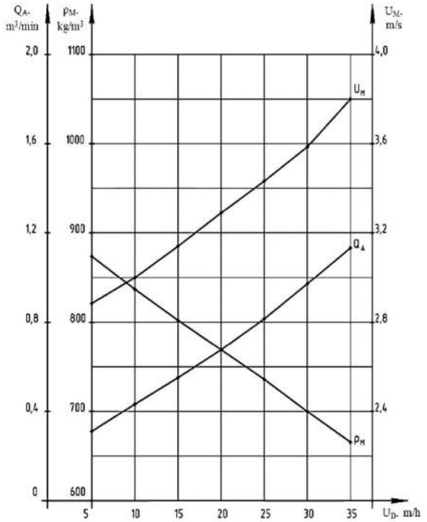

Fig. 1.7. The dependence of the average effective values of the density of the water-air mixture ρ_M, the rate of its rise U_M and airflow Q_A on the rate of deepening U_D

The increase in the density of the ascending water flow Δ_F is proportional to the drilling speed U_D, respectively, the pressures P_{SI2} and P_{dI2} caused by the presence of sludge increase. Their growth causes a drop in the density of the ρ_M mixture (Fig. 1.7) by increasing the air content in it Q_A, which has a nonlinear accelerating character.

1.6. Improvement of technology for drilling large diameter wells with reverse circulation

The disadvantages of the airlift method are reduced to the need for a significant complication of the design of the drill string, which must not only ensure the removal of drill cuttings to the surface, but also the supply of compressed air to the mixer (while the reverse suction method allows the use of a conventional commercially available drill string).

The most common type of drill string is that the drill pipes are connected by welded flanges having three through holes. The hole located in the center of the flange has a diameter equal to the inner diameter of the drill pipes. Two other, smaller holes are located symmetrically with respect to the central hole. They correspond to the inner diameter of the compressed air supply pipes located outside the drill pipes. Flanges with the help of bolts and sealing gaskets connect such triple pipes into a single column. The pins are designed for easy alignment of the connected flanges, as well as for torque transmission.

A disadvantage of flanged drill strings is that such drill strings and their connections are very different from standard commercially available drill pipes and their connections. In practice, serial pipes have to be recut, removing the threaded ends and prefabricated flanges are welded onto the ends, ensuring their strict parallelism (its absence violates the tightness of the column).

The connection of two pipes takes an average of 30 minute [37]. The connection process takes up a large part of the working time balance in well construction. However, flanged connections are the most common.

There are also a number of other ways to supply compressed air to the mixer. In particular, instead of flanges, pipes can be connected using special weld-on joints with conical threads. The diameter of the joint is sharply increased taking into account the attached air pipes, the same type as with flanged connections.

Such joints reduce the connection time by about half, but they are complex and increase the cost of the drill string significantly more than flange connections. The practice of using such connections has shown that they do not provide reliable sealing of the drill string [38]. In addition, tool joints have not of the advantages of a flange connection, in terms of the possibility of both right and left rotation of the drill string.

Some firms use concentric twin drill strings. An upward flow of pulp is created in the inner column, and air enters through the annulus between the pipes. Columns can have both flange and joint connections. The described method increases the weight and cost of the drill string and, ceteris paribus, is characterized by a reduced flow area of the pulp-lifting part.

Sometimes the method of separate descent of the drill and air strings is used. Air string runs inside the previously run drill string. During drilling, it does not rotate and has its own swivel located above the swivel of the main string. The process of building up and tripping such a combined drill string is sharply complicated and takes a lot of time. In addition, the inner column hinders the passage of large slurry particles.

Summing up, we note that both of the above methods for creating reverse circulation are characterized by the following features [39].

The most important advantages:

- For the reverse suction method - the uses of commercially available drill pipes and connections;

- For the airlift method – the absence of physical restrictions in the intensification of circulation and increasing the depth of wells.

Main disadvantages:

- For the reverse suction method -the use of a vacuum created by a centrifugal pump, which is limited by atmospheric pressure, as a drive for the circulation system.

- For the airlift method - complication of the design of the drill string due to the addition of the cuttings removal function to the function of air supply to the airlift mixer.

The main disadvantage of reverse circulation is due to fundamental physical laws, and therefore it is not possible to eliminate it.

The main disadvantage of the airlift method is associated with the design of the drill string and can in principle be eliminated. However, existing solutions to this problem are cumbersome and require a lot of time and money.

The elimination of the main disadvantage of the airlift method is the purpose of the proposed device [40].

The essence of the device is that instead of special drill pipes with special connections, commercially available drill pipes with commercially available connections are used.

Air is supplied from the compressor to the mixer through a hose wound on a drawworks included in the drilling rig. Through a swivel, a hose with a mixer at the end is wound into the drill string to the required depth.

The scheme of the device is shown in Fig. 1.8 [41].

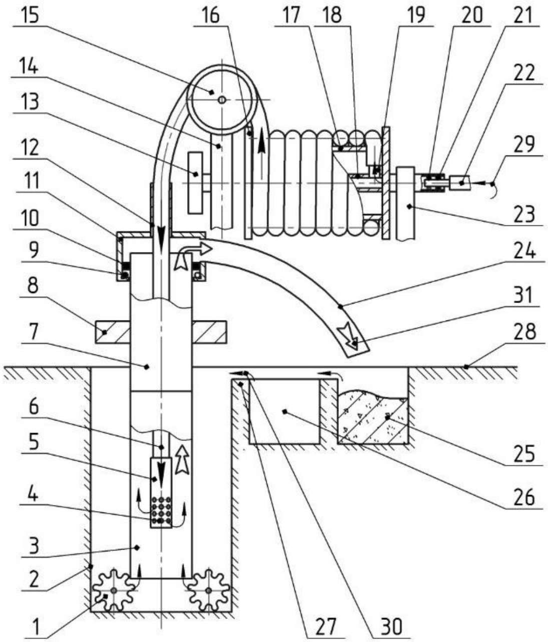

Fig. 1.8. An improved version of the device of the circulation system for drilling wells with reverse circulation using an airlift: *1* – drill bit; *2* – borehole wall; *3* – drill string; *4* – mixer; *5* – weighting pipe; *6,22* – hose; *7* – kelly; *8* – rotor; *9, 20* – bearing; *10, 21* – seal; *11* – swivel body; *12* – guide pipe; *13* – drive gear; *14, 23* – drawworks shaft support; *15* – pulley; *16* – drawworks; *17* – drum; *18* – shaft; *19* – fitting; *24* – throwaway sleeve; *25* – sump; *26* – capacity of the purified fluid; *27* – gutter; *28* – day surface; *29* – compressed air from the compressor; *30* – downward flow of fluid; *31* – ascending flow of water-air pulp

The device works as follows. In the process of drilling, compressed air *29* from the compressor through a hose *22* with a fitting through the stuffing box *21*, and bearing *20*, enters the hollow shaft *18* of the drawworks *16.* From the shaft through the fitting 19, the air enters the initial coil of the hose *6* wound on the drum *17.* C of the drum through the pulley 15, the hose enters the guide pipe *12* and through it through the central hole in the cover of the swivel *11* – into the kelly *7* and further – along the central axis of the well – into the drill string *3.* At the end of the hose, a weight pipe *5* is fixed, with a mixer *4*.

Since the hydrostatic pressure of the slurry column *31* (a mixture of drilling fluid, air and drill cuttings) is less than the hydrostatic pressure of the drilling fluid column in the space between the drill pipes and the well, the drilling fluid, together with the destroyed rock, rushes up to the mixer and then, together with air, to the upper end leading pipe. Here in the body of the swivel there is a hole connecting the swivel with the hose 24, through which the pulp merges into the sump (sludge collector *25*), where the sludge settles, and the purified fluid flows through the chute 27, and, overflowing the container *26*, enters the annular space of the well and then returns downhole to the bit working there. This completes the circulation cycle.

As the well deepens, the brake of the drawworks 16 is periodically released (the brake is not shown in the figure) and the weight pipe *5* causes the hose to be reeled to the appropriate length (or the drum starts to rotate in the direction of the descent using the drive).

Before connecting the drill string or before tripping operations, the hose is removed from the drill string with the help of a drawworks *16* until the weight pipe *5* with the mixer *4* is hidden inside the kelly *7.* When performing operations for connecting drill pipes, the hose is held by the brake of the drawworks in the leading pipe taken away from the mouth. After completion of the operation of making up the drill pipes and connecting the kelly to the drill string, the brake is released, and the pipe 5 with the mixer and the hose are lowered into the well to the required position.

1.7. Conclusions

1. An analysis of the geological and hydrogeological conditions of the Samskoye groundwater deposit was carried out. Aquifers are

composed mainly of sands with a filtration coefficient of 5-7 m/day, and the thickness of the layers varies widely, averaging 10-20 m, and the depth reaches 200 m.

2. Based on the literature data, the effectiveness of the main methods of drilling water wells was analyzed in relation to the conditions of the Samskoye field. The drilling of water wells carried out, as a rule, by a rotary method with direct circulation or by a percussion method.

The total water withdrawal from all wells at the Samskoye field does not exceed 18% of the proven reserves. It is obvious that the methods of construction of water wells used in this field do not allow for the water withdrawal necessary to meet the needs of the region in drinking and household water supply.

3. As a result of a comparative analysis of existing advanced technologies for drilling wells with reverse circulation of drilling fluid, it was found that for the conditions of the Samskoye field, the most effective method is rotary drilling of water wells using reverse circulation created by the airlift method. Its application will ensure a sharp increase in the flow rate and quality of produced water, while reducing the time and cost of well construction. It has been established that a significant drawback of the chosen drilling method is the need to use special drill string connections, which leads to high time spent on round trips and drill string extensions.

4. As a result of the analysis of scientific, technical and patent sources, it was found that a significant factor that reduces the efficiency of well drilling with reverse circulation is the uncertainty of the airlift operating conditions. This is due to the fact that the depth of the well is constantly changing; the pressures in the annular space and in the drill string are changing too, which means that the optimal parameters of the airlift are changing.

5. Based on the analysis of the geological and geographical conditions for the construction of water wells in the Mangystau region, a typical model for drilling water well in the conditions of the Samskoye field was developed.

6. A mathematical algorithm has been developed for studying the airlift circulation method during rotary drilling with reverse circulation, based on the analysis of the pressure balance in the annulus and in the drill string that occurs during drilling. The pressure balance

takes into account both hydrostatic pressures and pressure losses for pumping water and water-air mixture.

On the basis of mathematical algorithms, computer models were created that made it possible to investigate the main dependences of the required values of the output parameters on the given conditions. Calculations were made in relation to a typical well, the individual parameters of which were varied to obtain the corresponding dependencies.

7. The main disadvantage of the airlift method is the need to abandon mass-produced drill pipes in favor of special multi-channel drill pipes and their connections. As a result, there is a significant increase in the time spent on connections in the processes of building up the drill string and tripping. There is also an increase in the cost of the drill strings themselves.

The disadvantages of the airlift method can be eliminated if the proposed new technology is introduced, for which a patent of the Republic of Kazakhstan has been received.

The essence of the invention consists in the refusal to use the drill string as a channel for supplying compressed air to the mixer. It retains only its traditional functions, and thus it becomes possible to use commercially available drill pipes with conventional connections.

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