MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL UNIVERSITY «YURI KONDRATYUK POLTAVA POLYTECHNIC»
Educational and Scientific Institute of Oil and Gas
Department of Drilling and Geology

DRILLING OF OIL AND GAS WELLS

Lecture notes
for students majoring in 185 Oil and Gas Engineering and Technology.
Degree of higher education - bachelor

Poltava
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Author: Yu. Vynnykov, DSc, Professor, Professor of Department of Drilling and Geology

Responsible for the issue: M. Kharchenko, DPh, associate professor, acting head of Department of Drilling and Geology

Reviewer: I. Zezekalo, DSc, Professor, Professor of Department of Oil and Gas Engineering and Technology

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Introduction

The purpose of students studying the specialty 185 "Oil and Gas Engineering and Technology", higher education - bachelor's degree, discipline "Drilling of oil and gas wells" is: providing students with knowledge and skills about drilling wells; formation of students' experience in applying the principles of drilling wells, basic concepts of drilling equipment, wells and methods of their use and operation; composition and capabilities of drilling crews, formation of professional competencies and technical and technological thinking mainly for the oil and gas industry.

The task of studying this discipline is: to develop students' ability to use and make plans, outfits and tasks for drilling wells, to apply data from well research, methods of control and monitoring of their work during drilling; to teach students to receive data of well research, to carry out technological processes of drilling, to use techniques and technologies of drilling of wells, to carry out designing and planning of actions on drilling of wells.

As a result of studying the discipline "Drilling of oil and gas wells" the student must

know:

- requirements for the preparation and preparation of technical and technological documents;
- principles, types and methods of drilling wells, their sequence;
- equipment, tools, systems and tools for drilling wells;
- opportunities and characteristics of equipment for drilling wells;
- theoretical bases of drilling of wells, technologies of carrying out such works;
- composition, responsibilities and capabilities of well drilling crews.

be able:

- use geological-industrial, technical-technological and engineering-economic information, normative documents for estimating the volume and result of drilling wells;
- use equipment for drilling wells and methods of their implementation;
- perform drilling of wells, systematize data, perform simple calculations using software in accordance with sound methods;
- use the data of hydrodynamic studies during drilling;
- solve technological problems in the field of well drilling;
- design and apply modern technologies for drilling wells;
- perform calculations of drilling design to assess their effectiveness;
- apply standard methods of performing technological operations of drilling wells;
- choose the necessary equipment, tools for drilling wells.

Lecture 1. Basic concepts of drilling wells

Drilling is the process of forming a round section in a rock by destroying the rock mechanically. In this case, the rock is destroyed by actions from the surface without the presence of people in the production.

The beginning of the well is called the *mouth*, and its bottom – the *bottom*. The well may have one *shaft (trunk)* or also its branches, ie several additional shafts.

The well is characterized by a significant length with a small diameter. In the case of a well diameter of several tens of millimeters, it is called a *hole*.

At its diameter of hundreds of millimeters – this is actually a *well*.

If its diameter reaches meters, it is already a *mine*.

Well drilling is most often used for the following **processes**:

- oil and gas production;
- extraction of drinking water;
- extraction of mineral water and saline solutions;
- injection and extraction of gas and oil into underground storage facilities;
- ventilation shafts, laying of air wires and cables at mine extraction of solid minerals;
- degassing of coal seams in mines, extinguishing fires in them, rescuing miners;
- freezing of aquifers (including floodplains) layers of soils and rocks when arranging subways and mines;
- engineering-geological and hydrogeological surveys for different types of construction;
- air supply to the reservoir and removal of combustible gases during underground gasification of coal, air supply and sulfur melting in geotechnological processes in mining;
- steam extraction at geothermal power plants;
- injection of steam during mine oil production;
- elimination of gas and oil fountains;
- study of the geological structure of the Earth and geophysical seismic survey;
- injection of production waste into deep layers;
- tests of atomic charges, etc.

In mining in general, and in the oil and gas industry in particular, ***wells by purpose*** are usually divided into:

- *structural exploration* - to study tectonics, stratigraphy, lithology and to assess the possible productivity of individual horizons; Most often they are drilled to relatively shallow depths (up to 3000 m) with the removal of a large number of cores;

- *parametric or reference* - exploration wells, which are usually drilled to great depths in a little-studied area to assess its geological structure or a new (deeper) part of the section. At the same time, many cores are selected, which are further investigated in detail;

- *exploration and prospecting* - to search for certain productive horizons, which have already been studied by parametric and reference wells, and to identify gas and oil fields in them;

- *operational* - for extraction of gas, oil and condensate;

- *injection* - for injection into productive horizons of water, air and gas in order to increase oil and condensate production;

- *piezometric* - to control the movement of the oil and gas circuit and the pressure in the reservoir (so they are arranged on the contour of the field);

- *control* - to monitor the condition of the upper layers (layers) for the absence of gas flow.

Methods of drilling wells are usually divided into:

- *impact* - the rock is destroyed by the blows of the bit at the bottom (the bit is periodically rotated to create a round cross section of the well, and the destroyed rock is washed out or in the form of a suspension exhausted from the well. ;

- *rotating* - the most popular method of drilling which has two varieties, such as:

  - *rotary* (the bit rotates with the help of drill pipes, and the drive (rotor) is placed on the ground);
  - using *downhole engines* (the bit rotates by the engine located at the end of the drill string; due to the fact that the engine is used turbodrills (which are driven by drilling fluid fed to the bottom of the turbine through drill pipes), this type is also called *turbine boring*).

As a downhole engine can be used and *screw engines*, which are also driven by drilling fluid, which passes through the engine in portions. An *electric drill* is also used as a downhole motor, the current to which is supplied through a cable laid inside the drill pipes.

Varieties of drilling also have certain prospects: *hydromonitoring* - the rock is destroyed by a jet of washing liquid; *explosive* - the rock is destroyed by explosive charges, which are fed to the bottom of the well through drill pipes; *thermal* - the rock is melted by the flames of fuel and oxidizer, which are fed to the bottom of the well.

Also, wells are classified according to ***the profile of the barrel (trunk)*** on:

- *vertical* - deviation of the face from the projection of the mouth on the horizontal plane does not exceed 5% of the depth of the well;

- *inclined* - the bottom of the well is shifted from the projection of the mouth on a horizontal plane for a considerable distance (for example, 300 - 2000 m);

- *horizontal* - part of its length of the well passes in the productive formation. The angle of inclination of this section of the well reaches 80 - 90 °, and the deviation of the face from the projection of the mouth on the horizontal plane - from tens of meters to ten kilometers;

- *multi-hole (branched)* - when the productive layer is opened by one well, but at different points due to the branching of the shaft. These wells can open several productive strata and operate them separately, without connecting them;

- *multi-row* - when several parallel columns are lowered into one well for operation of different layers.

According to the location of the wellhead on the earth's surface, drilling is divided into:

- the so-called *spray* - several wells are drilled from one site (for example, when drilling from bulk islands or sea platforms in hard-to-reach places, in swamps and the sea, etc.);

- *double-bore* - two wells are drilled simultaneously with one machine (from one - pipes are raised, and in the other - lowered).

Usually distinguish the following ***stages of drilling wells***:

- *design* - according to the task issued by the customer, which contains the basic parameters of the well, such as: stratigraphic section; its depth; construction; drilling conditions; type of drilling rig, etc. In the geological part of the project the structure of the field, stratigraphic and lithological section of the well, depths of gas, oil, aquifers, horizons, formation pressures in them, fracture pressures, intervals of various complications, etc. are given. The technical part of the project substantiates drilling technology, drilling fluids, measures to prevent accidents and complications, a list of equipment, control and measuring devices, etc. They are also developing a project to protect the environment, in particular, measures to prevent its pollution, methods of disposal of drilled rock and waste water. If the water supply of the facility is planned from a special well, the project is also drawn up and approved for it. By the way, the project can be developed for a group of identical wells;

- *tower construction works*;

- *preparatory work for drilling* - includes, in particular, the following components: equipment of the hoist system with hoist rope; mounting of drilling tools and devices; drilling under the pit to accommodate the guide pipe; establishment of the mine direction; checking the operation of this equipment;

- *well drilling* - contains the following operations with:

    - *drilling*: actual drilling of the well (going to the bottom of the weighted drill pipes, calibration and centering elements); building a drill string with the next drill pipe; raising and lowering of drill pipes;

    - *ancillary works*: geophysical research of the well; prevention (for example, washing and drilling of a well, treatment of drilling mud, checking the condition of drill pipes, their replacement, replacement of drilling equipment, etc.);

- *separate works* - repair of drilling equipment;
- *well fastening* - preparation of the well for casing descent, column descent, its cementing, equipping its mouth with anti-ejection equipment;
- *elimination of complications* (not obligatory, but, unfortunately, quite common operations) - for example, elimination of absorption of solution, oil and gas manifestations, collapse of walls;
- *elimination of accidents and downtime* (also not mandatory, but quite typical operations);
- possible *testing of open horizons*.

Drilling is completed by throwing drilling tools on the bridges, which destroyed the cement residues in the production columns and preparing the well for opening in the casing of the productive horizon.

- *development of a well* - in prospecting wells all perspective horizons are tested, and in operational - only design, and in case of negative results other horizons are tested. Thus operational horizons usually saturate with the corresponding underground equipment;
- *dismantling of drilling equipment* - dismantling of the drilling machine and reclamation of the land plot.

Lecture 2. Drilling and lifting operations

Drilling of a well is carried out by a drilling machine. ***The drilling machine*** is a large set of equipment for various purposes.

In particular, such a machine for drilling wells to a depth of 4000 - 5000 m has a mass of 600 - 1500 tons. Drilling rigs are classified depending on the drilling depth and load capacity into 11 classes.

The load capacity of the first class machine is 800 kN, it is designed for drilling a well to a depth of 1250 m. The machine of the eleventh class is designed for drilling to a depth of 12,500 m, its load capacity is 8000 kN. Accordingly, the power of the drive mechanisms ranges from 500 to 4000 kW.

The scheme of the installation for drilling deep wells (rotary and turbine methods, using an electric drill) is given in Fig. 2.1. *This drilling rig contains the following main components.*

The drilling rig is usually 41 - 53 m high and has a corresponding load capacity. It is mounted on a base with a height of 5 - 8 m for placement under the floor of anti-ejection equipment, which seals the well in case of emergency gushing. Scaffolds are mounted on the tower, one or two, depending on its height. Scaffolding is the workplace of a rider while lowering and raising a tool. Towers are tower and A-like.

The hoist system is a crown block located at the top of the tower, a hoist block moving on a hoist line inside the tower, and a hook. This system is equipped with a hoisting line. The greater the weight of the drill string, the greater the drilling rig.

The hook takes the weight of the column and allows the drill string to rotate without turning the hoist. When drilling and rinsing, a swivel is hung on the hook, and during lowering and lifting operations on slings - an elevator. The swivel provides turning of the drilling tool without turning of the hoisting system and pumping of drilling mud into drill pipes. The drilling mud is fed to the swivel through a drilling hose, and removed through the leading (square) rod into the drill pipe, which is connected to the swivel.

At the base of the rig (drilling floor level), a *rotor* is mounted to transmit rotation from the horizontal shaft of the drilling machine drive through the drive rod to the drill string lowered into the well. The torque is transmitted by chain or cardan transmission.

During lowering and lifting operations, *elevators* are hung on the hook, which capture the drill string by the upper end. They are hull and wedge. Hull elevators hold the drill pipe after closing it on the drill pipe.

The hoist system moves in the drilling rig by means of *a drilling winch*. The hoist line is wound on a drum at a traction force of 200 - 300 kN. The winch is equipped with a powerful brake system, which consists of two brake belts with brake pads. In addition, to facilitate braking, the winch is equipped with *a hydrodynamic (hydromat) or electromagnetic brake*. This brake is activated when lowering a heavy drill string, reduces the rate of descent and facilitates the braking of the column by the main brake.

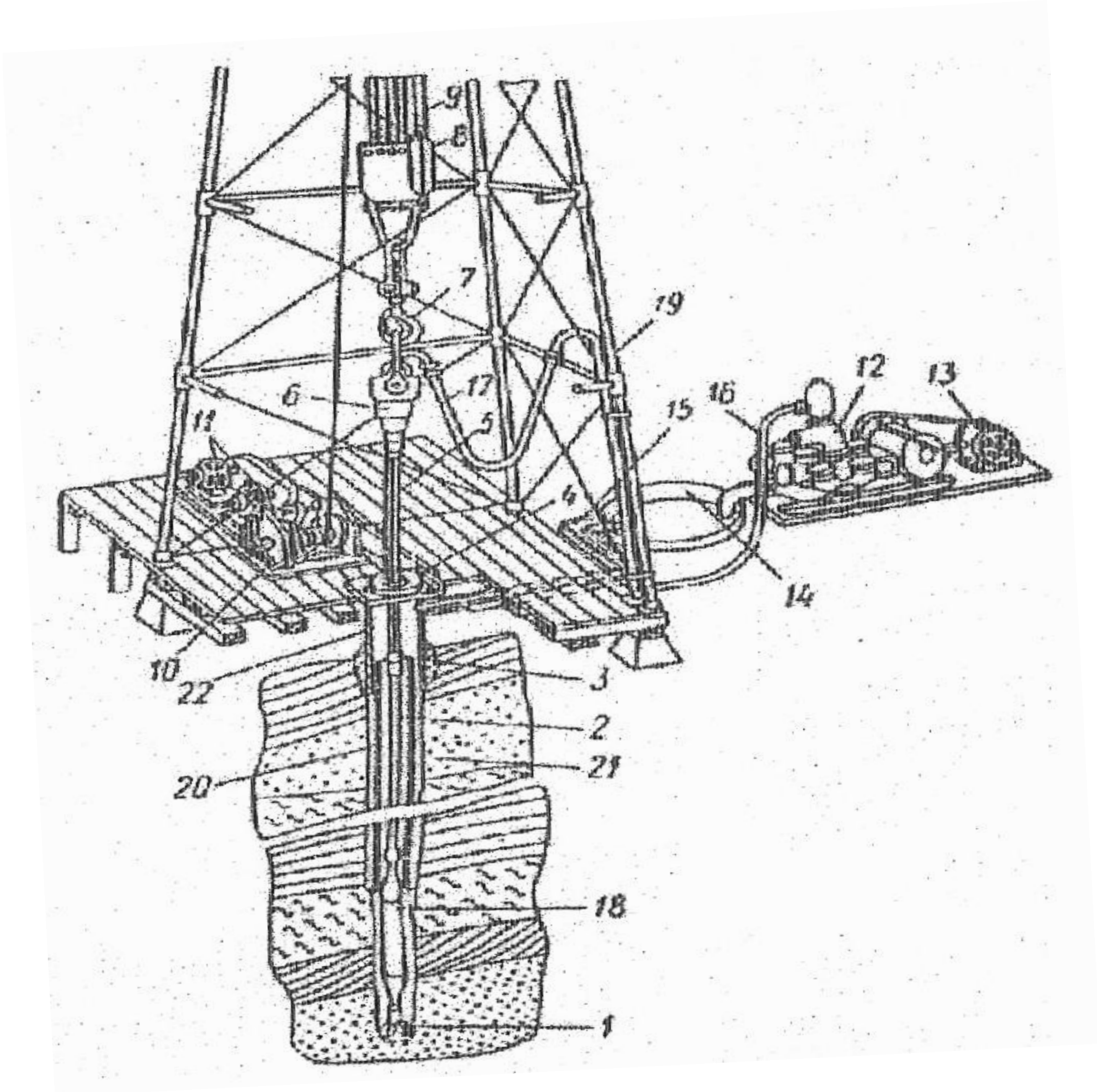


Fig. 2.1 - Scheme of installation for drilling deep wells (rotary and turbine methods when using an electric drill):

1 - chisel; 2 - drill pipes; 3 - special translator; 4 - rotor; 5 - the leading pipe; 6 - swivel; 7 - hook; 8 - hoist block; 9 - hoist rope; 10 - winch; 11 - winch and rotor motors; 12 - drilling pump; 13 - pump motor; 14 - receiving capacity; 15 - gutters; 16 - pipeline manifold; 17 - drilling hose; 18 - downhole engine (rotary drilling is not installed); 19 - tower; 20 - casings; 21 - cement shell around the casing; 22 - mine direction

To prevent accidental tightening of the hoist block in the crown block, *a counter-tightener* is mounted on the tower, which disconnects the winch drive and activates the pneumatic brake of the winch without the participation of a drill when moving the hoist block beyond the permissible limits. The winch has a gearbox that allows you to adjust the lifting speed depending on the weight of the drilling tool. An empty elevator is raised on a separate, higher gear.

Drilling mud is fed into drill pipes by *drilling pumps through pipelines - drill manifold and drill hose*. Working pressure of drilling pumps - 25 - 30 MPa. Power of drilling pumps is 500 and more kW.

After leaving the well, the drilling fluid moves in the *gutter system* to the receiving tanks of drilling pumps. With the help of *settling tanks, vibrating screens, hydrocyclones, sludge separators and centrifuges*, it is cleaned of drilled rock, degassed in degassers, ie remove air and gas.

A clay mixer for preparation of *drilling mud* and chemical reagents, *a milling mill or a water jet stirrer* for adding dry materials (weights or reagents) to the solution are also mounted near the gutters. There are also containers for *liquid reagents,* which are added to the solution.

The main mechanisms of the machine (winch, rotor, drilling pumps) are driven by *internal combustion engines* (diesels), which are paired with V-belts, chain gears, or *electric motors*. Most mechanisms are controlled by a pneumatic system.

The drilling rig is additionally equipped with an auxiliary power plant, pumps for pumping water, reagents, fuel and domestic premises.

The drilling machine is equipped with an auxiliary winch for moving loads in the drilling rig. *Machine keys* and mechanical keys with pneumatic or electric drive are used for fastening, unscrewing and unscrewing the threads of the drill string. The winch is also equipped with a *chisel feeder*.

Bridges and racks for drill and casing are placed in front of the drilling rig.

Work on moving goods on bridges is mechanized by means of a crane. For drilling in difficult conditions, especially inclined and horizontal wells use *the upper drive of the drilling tool*. It allows you to constantly rotate the drill string during the descent and ascent, to reduce the time to build the tool. It is suspended on the hook of the hoist system instead of the swivel, it moves along the guides in the drilling rig, has a hydraulic drive.

In modern drilling rigs, all mechanisms are driven by hydraulic motors.

Different types of drilling rigs are used for *offshore drilling*.

- *submerged* - the platform of which rests on the bottom;
- *drilling barges* - drilling equipment is placed on the barge;
- *semi-submerged* - part of the base is submerged, and part - above the water;
- *tender* - only a part of the machine with a tower rests on the bottom, and the rest of the equipment - on a barge;
- *self-lifting* - rest on sliding supports on the seabed;

- *drilling vessels* - the equipment is placed on the ship, but there is no rigid connection with the seabed (the ship is held above the drilling point by the appropriate system of propellers).

To control the drilling process, the drilling machine is equipped with control and measuring devices:

- weights of the drill string, showing the weight of the drill string and the tension of the string of the line attached to the base of the drill;
- manometers which control pressure on pumps;
- geological and technical stations, which record: load on the hook; torque on the rotor; pump pressure; torque on the machine key; the level of solution in the receiving vats; the cost of the solution at the entrance to the well; the cost of the solution at the exit of the well; axial load on the bit; drilling speed; rotor speed; the temperature of the drilling fluid at the outlet of the well; the composition of the drilled rock coming out of the well; the composition of the gas carried to the surface by the solution.

The process of drilling a well. Rocks are destroyed by chisels. The drilling process begins with screwing the bit on the guide pipe. As the rock is destroyed, the bit is fed down. When drilling the first meters, maintain that the square is strictly vertical, not lying on its side (so that the well does not deviate). For vertical drilling of a well it is necessary to establish a guide pipe (direction) vertically, to mount a rotor strictly horizontally and behind the center.

As you deepen, collect the design layout of the bottom of the drill string. Over the bit set weighted drill pipes (with a wall thickness of 30 - 70 mm of increased diameter). During drilling, the weight of the column (respectively the constant load on the bit), the pressure on the pumps (its decrease may indicate deterioration of the pumps or lack of column density), the torque (characterizes the operation of the bit and the behavior of the well).

When drilling, the drilling mud is constantly cleaned of rock, the solution is degassed, and its parameters are monitored. When the parameters of the solution deviate from the norm, appropriate chemical additives are added to the solution, which regulate these parameters accordingly.

After deepening the well to the length of the square, increase the length of the drill string - this is the so-called *build-up*. To do this, remove the square from the well, unload the drill string on the rotor, unscrew the square. The square is placed in a pit (a small auxiliary well drilled to the length of the square, into which the corresponding casings are lowered and into which this square with a swivel is lowered for the period of raising or lowering the drill pipes). Then from the bridges or from the finger of the tower take a drill pipe (so-called "single"), put it in the elevator, lift, pulling it into the drill, screw on the pipes already lowered into the well, remove the column from the rotor and lower down, unload on the rotor and screw the square again. If drilled quickly, the build-up is carried out by several singles or "candles" (standing in the drilling rig). It should have a square of appropriate length (so-called, double).

At the end of the work with a bit, the well is washed during the cycle. The cycle is the time required for the drilling fluid to reach the face from the surface and rise to the surface again.

Lowering and lifting operations. The drill string has to be raised and lowered periodically, mainly due to the operation of the bit (which should be replaced). This is done not by single pipes, but by candles, which are installed by the finger, vertically, in the tower. The candle contains several single pipes, and the length of the candle depends on the height of the tower. At a tower height of 41 m, the length of the candle is 25 - 27 m, it consists of three pipes of 9 m or two pipes of 12 m. At a tower height of 53 m, the length of the candle is 35 - 37 m.

The candle is lifted from the well, the column is unloaded on the rotor. At the same time unload not completely, and leave on a hook weight of a drill candle. The hook has a spring, the load capacity of which is slightly higher than the weight of one candle. The thread is unfastened, if necessary, with machine keys, and unscrewed with mechanical keys. In this case, as soon as the thread is unscrewed, the spark plug spring rises, the thread comes out of gear and is less triggered. The exception is when the candles are raised with a solution that does not have time to go down the pipes in the well. Then the solution is poured out of the candle. This is called *a siphon lift*. In this case, the candle is unloaded completely. Before lifting the candle from the thread, put a special skirt on the candle, which does not allow the drilling fluid to spill. During the descent, the elevator is raised to the top of the candle, put the candle in the elevator, close it, raise the candle, clean and lubricate the thread and insert it into the thread of the lowered column. At the same time, it is desirable not to unload all weight of a candle, for easier screwing of a carving.

When raising and lowering the column, control the weight of the column on the hook (according to the weight indicator) to prevent seizures, movement of tools, equipment, workers, etc. When lifting there are puffs (increase in weight of a column), and at descent of landing (decrease in weight of a column). When lifting the pipe is cleaned of drilling mud, and the well is filled with drilling mud, preventing its emptying.

Usually *the drill watch* consists of a drill working behind the winch brake, two drill assistants working at the bottom near the rotor. With a candle length of 35 m, there are two, and with a candle length of 25 m - one driller's assistant - the riders, who work on the upper and lower platforms of the tower. The motorist and his assistant service the engines, and one electrician works on the electric drilling rigs instead. That is, the watch consists of 7 - 8 workers. Sampling samples are taken and the parameters of the drilling mud are recorded by a laboratory collector. In addition, the equipment is serviced by one or two mechanics and a senior motorist.

The drilling rig is usually managed by two drilling foremen who are on the drilling rig and solve all issues promptly, and the drilling rig supervisor, who works in one shift and performs responsible operations.

Lecture 3. Types of drill bits. Drill string and its elements

Drill bits *according to the method of rock destruction when drilling a well* are usually classified into the following types:

- *cutting* - continuously interact with the face, cutting the rock layer when rotating on the face with a load. Examples: blade chisels; chisels with diamond plates;
- *chipping* - in which rock-destroying elements act on the rock periodically, penetrating it and chipping due to a certain slippage of the face. Examples: cone bits (teeth slide down the bottom due to the displacement of the cone axes relative to the center of the bit and change the taper of the cone along its length); single-cone bits;
- *crushing* - in which the teeth affect the rock with rhythmic blows, deepening into it, or destroy the rock without noticeable deepening due to repeated blows. Examples: cone bits (in which the cones roll along the face without slipping, and their axis passes through the center of the well);
- *abrasive (micro-cutting)* - which destroy the rock by friction. Examples: so-called diamond chisels (made of small diamonds evenly distributed in the alloy).

According to the area of action on the face of ***the bit*** is classified into:

- *for drilling with a continuous face*;
- *for core extraction* - they do not destroy the face over the entire area, creating an annular excavation and leaving an intact core in the center of the well.

The most widely used bits for drilling a solid face. Column bits or crowns are used to select rock samples from productive horizons to confirm their productivity, determine the parameters of the formation (in particular, porosity and permeability), which calculate the reserves of the deposit and make a development project.

Types of drill bits. *Drill blades* are two and three blades, blades are bent with a cutting angle of 70 - 85°. With the horizontal blades form an angle of 5 - 10° to the center of the well. Sand chisels with straight blades are used to drill cement in casings. Chisel cutting strips are reinforced by surfacing them with a hard alloy. Now blade bits for drilling are rarely used, sometimes for drilling viscous clay layers in the absence of cone bits. Preferably they are effectively used for drilling cement in production columns.

Cone bits for solid face drilling are made of one, two, three and four cone (according to the number of cones). Of these, the most popular now - three-cone bits.

In fig. 3.1 shows diagrams of *the flow of flushing fluid through the three-core bits* during conventional and hydromonitoric flushing of the well.

For equipment cone bits are classified into bits:

- with a milled tooth;
- armed with carbide inserts;
- with combined weapons.

The design of the chisel body is divided into:

- case in which paws are welded to one case;

- caseless, in which the paws are welded together and form a body.

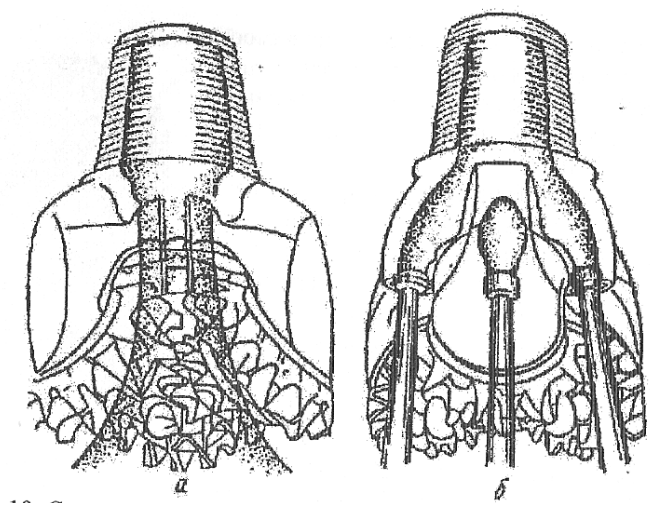


Fig. 3.1 - Schemes of the flow of flushing fluid through three-bit bits during normal (a) and hydromonitor (b) flushing of the well

There are ***details of a three-cone bit***:
- *the main cone* - the conical surface of the cone, which is adjacent to the top;
- *reverse (rear) cone* - a cone in contact with the wall of the well.
- *additional cone* - the surface adjacent to the reverse cone of the cone;
- *the base (end) of the cone* - the surface adjacent to the reverse cone;
- *a pin* - a part of a paw on which elements of a support of a bit are mounted;
- *paw* - part of the bit, which consists of the actual paw and pin;
- *chisel section* - chisel paw assembled with a cone;
- *paws of the paw* - the part of the paw of the bit that protrudes beyond the pin of the bit;
- *back (rib) of the paw* - protrusion on the lateral outer surface of the paw;
- *finger* - a rod that keeps the ball of the cone support from falling out.

Sequence numbers of cones:
I - cone with the longest cone;
II - next, if you look at the cones, clockwise.
III - next, clockwise, looking at the cones.

Долота виготовляють стандартизованих діаметрів від 46 мм до 508 мм, 40 розмірів. За стандартом Американського нафтового інституту долота виготовляють діаметром від 85.7 мм до 711.2 мм, 55 розмірів.

Chisels are made of standardized diameters from 46 mm to 508 mm, 40 sizes. According to the standard of the American Petroleum Institute, the bits are made with a diameter of 85.7 mm to 711.2 mm, 55 sizes.

***The main structural elements** on which the efficiency of the bit depends*:
- chisel armament;
- stability of support;
- prevention of diameter loss;

- flushing system (flushing).

By type of weapon cone bits are:

- chisels with milled tooth;
- chisels are armed with carbide inserts;
- chisels with combined weapons.

Depending on the type of rock for which the chisel is intended, teeth are made of different shapes:

- *for soft breeds* teeth - high, with a small angle of sharpening. Accordingly, they are rarely placed on the cone. The cones are made with an offset of their axis relative to the axis of the bit, which causes them to slip down the bottom*;*
- *for hard rocks,* the teeth of the bit are smaller, more densely placed on the cone. The chisels are made without offsetting the axes.

The milled tooth of the bit should be hard, not work when rubbed on the rock and not be fragile, well absorb shock loads. The tooth should not be blunted during operation. To increase the strength of the teeth, the inner part of the tooth is made of a viscous material, and a hard alloy is welded to the outer surface. The type of alloy and the thickness of the surfacing are different in different parts of the tooth.

Chisels with carbide teeth, depending on the strength of the rock, are reinforced with carbide teeth of different shapes (see Fig. 3.2).

Fig. 3.2 - Shapes of chisel teeth

The teeth are clamped on both sides at an angle of 40° for soft rocks and at an angle of 90° for harder ones. The teeth may have a pointed conical shape to destroy soft deposits. For strong and very strong breeds they have a spherical head, the Form of the teeth intended for reinforcement from loss by a bit of diameter, - cylindrical. Their diameter is 3.08 - 16.14 mm. Their tooth size depends on the size of the bit and the type of rock.

The height of the tooth and its flight over the body of the cone are different. For soft rocks, teeth of greater height and more protrude above the body of the cone, and for hard rocks of smaller height and less protrude (to increase the resistance of teeth to chipping and more effective destruction of the rock). The total height of the tooth is 4.8 - 23.6 mm.

Increasing the stability of the support is achieved through the following measures:

- sealing the support and filling the support with oil;
- replacement of radial rolling bearings on sliding bearings;
- installation of additional axial sliding supports;
- replacement of the ball lock of cones on elastic rings;

- improvement of a design of consolidations of a bit and selection of materials (metal, plastic, their combination);

- reduction of friction in supports (reduces their temperature at work).

Approximate stability of chisels with uncompacted support - 12 - 18 hours, with compacted roller support - 14 - 26 hours, and with compacted sliding support - 70 - 300 hours.

Prevention of loss of diameter of a bit is reached by application of such measures:

- in the chisel with a milled tooth reinforced with a hard alloy of peripheral teeth;
- T-shaped peripheral teeth;
- reinforcement carbide inserts placed between the milled teeth on the peripheral row:
- reinforcement of the peripheral crown with carbide inserts;
- reinforcement of the back side of the cone with cylindrical carbide inserts;
- reinforcement of the back side of the cone with cylindrical carbide inserts covered with diamonds;
- reinforcement of the lower part of the paw by hard alloy surfacing;
- reinforcement of the lower part of the paw with carbide inserts and inserts covered with diamonds;
- production of paws with thickening and reinforcement of this thickening with carbide inserts or inserts covered with diamonds.

The task of *the chisel flushing system* is to extract rock particles from the face immediately after chipping, but the cones interfere with the drilling fluid bed. There are two schemes of washing in the bit:

- *central* - the solution is fed through the central holes or slits and nozzles on the cones and washes them (imperfect washing, rock can accumulate on the bottom, so the bit does not work on the rock, but in the viscous mass of rock and mortar;
- *hydromonitor (side)* - the solution on the nozzles placed between the cones, a powerful jet is fed to the face (washing according to this scheme better cleans the face, but still does not completely clean the face).

The hydromonitoring system of washing is improved due to:

- placement of nozzles on the appropriate extensions to bring the hydromonitor nozzles closer to the face;
- use of elongated nozzles with effective hydraulic shape;
- placement of nozzles at a certain angle to the face to direct the flow of solution under the cones;
- eccentric placement of nozzles, the use of nozzles of different diameters to shift the flow and direct it under the cones.

The classification of cone bits is given in table. 3.1.

Table 3.1 - Classification of cone bits (according to GOST 20692-75)

Type of drill bit	**Scope**	Series for IADC	Type for IADC
М	Drilling of soft rocks	1	1 – 2
МС	Drilling of soft rocks with layers of rocks of average hardness	1	3 – 4
С	Drilling of rocks of average hardness	2	1 – 2
СТ	Drilling of rocks of average hardness with layers of hard rocks	2	3 – 4
Т	Drilling of hard rocks	3	1 – 4
ОМЗ	Drilling of very soft abrasive rocks	4	1 – 4
МЗ	Drilling of soft abrasive rocks	5	1 – 2
МСЗ	Drilling of soft abrasive rocks with layers of rocks of average hardness	5	3
СЗ	Drilling of abrasive rocks of average hardness	5	4
ТЗ	Drilling of abrasive hard rocks	6	1 – 2
ТКЗ	Drilling of hard abrasive rocks with layers of strong	6	3 – 4
К	Drilling of strong breeds	7	1 – 4
ОК	Drilling of very strong breeds	8	1 – 4

In the designation of the type of drill bits, the remaining letters have the following meaning

Ц	Drill bits with central flushing
Г	Drill bits with hydromonitor washing
П	Drill bits with central air purge
ПГ	Drill bits for drilling with purge of the face with air through the side hydromonitor nozzles
В	The support of the cones is made on rolling bearings
Н	The support has one radial plain bearing and the rest rolling
А	The support has two or more plain bearings
У	Hermetic support, oil filled

Operation of drill bits. The drill bit is lowered carefully, and through the narrowed places also slowly so as not to damage the calibration surface of the bit. Especially carefully pass the bit through the following places: drilling the second barrel; finding deflectors; with ledges; preventers; mouth equipment; casing shoe. If it is necessary to drill the shaft, the bit is raised above the face in the free zone and the well is washed. Elaboration is carried out with a speed of approximately 1 rpm and a load of not more than 20 kN.

In soft or plastic rocks, *the moment* may indicate that the bit is already on the bottom. In such rocks, drilling can be conducted on the indicators of the momentometer. The speed of rotation in soft rocks can be high, and the load can be changed to maintain a constant torque. The constant value of the moment is maintained when drilling in shales and other homogeneous rocks. The presence of layers leads to a change in moment.

In sands the moment can increase. Then reduce the axial load.

In the presence of vibration, you can continue to work at an acceptable mechanical speed and small amplitude of oscillations. Vibration can be reduced by reducing the load and increasing the number of revolutions.

High *speed of rotation of the drill bit* can lead to premature failure of the bit support and tooth breakage. The number of revolutions is limited by the condition of the drill string and the rotor drive. The optimum speed is the one that provides the maximum mechanical speed without complications. If in soft rocks an increase in the number of revolutions causes a corresponding increase in mechanical speed, then in harder rocks it can cause the opposite effect. Increasing the number of revolutions increases the temperature of the bit due to friction in the bearings, especially in the sliding bearings, which negatively affects the performance of the bit.

There are the *main reasons for lifting the bit*:

- clogging of nozzles;
- the appearance of the seal on the bit;
- drilling of harder layers;
- loss of nozzle;
- damage to the chisel armament;
- damage of a support and consolidation;
- operation of cone bits.

The choice of bit type *depends on a number of factors*:

- type of drilled rock;
- libini wells;
- method of drilling;
- the presence of certain complications;
- type of drilling (vertical or inclined);
- capabilities of the drilling machine by choosing the appropriate drilling modes;
- qualifications of the drilling crew.

It is necessary to consider high cost of bits, approximately, - from one thousand to 50 thousand dollars. The share of bit costs in the cost of wells in the US is 1.6 - 2.6%, and in Ukraine - up to 10%.

The efficiency of one type of bit compared to another is evaluated by the value of the so-called cruising speed and the cost of one meter of drilling. Flight speed is calculated by expression

$$Vp = \frac{h}{Tб + Tспо}, \qquad (3.1)$$

and the cost of 1 m of penetration will be estimated by the formula

$$C = \frac{Cд + Cв(Tб + Tспо)}{h}, \qquad (3.2)$$

where h is the passage per flight in m; T_b - time of mechanical drilling with a chisel, hours; T_{SO} - time of lowering and lifting operations, hours; S_D - the cost of the bit, UAH; S_t - the cost of the machine for one hour, UAH.

At shallow depths, drill bits are usually used, which provide the maximum mechanical speed, and at great depths - bits with high stability of support and armament.

Diamond drill bits. Diamonds are carbon crystals. The specific weight of diamonds 3170 is 3550 kg/m^3. The weight of diamonds is measured in carats. *The carat is equal to 0.2 g.* The content of diamonds in 1 m^3 of diamond-bearing ore is only 1 - 2 carats.

Діаметр алмазних доліт приймають на 1,5 – 2.5 мм менше від діаметра шарошкового долота, інакше алмазне долото важко пропустити в стовбур, пройдений шарошковим долотом. Допуски за діаметром для алмазних доліт менші, ніж для шарошкових.

Diamond drill bits provide high penetration for flight and mechanical speed, but much more expensive than cone bits.

Diamond bits are well tested for inclined drilling with downhole engines.

Diamond bits are made by inserting diamonds into *the matrix of the bit*. The die is the part of the bit body into which the diamonds are inserted by sintering the material. Large diamonds are placed on the surface of the matrix according to a certain scheme. In hard chisels, so-called impregnated chisels, diamonds are placed evenly over the entire volume of the diamond layer covering the surface of the chisel.

The matrix is made of tungsten, titanium, vanadium, chromium and boron, but most often - of tungsten with the addition of 5 - 20% cobalt, which serves as a binder. The hardness of the Rockwell matrix is: normal 25 - 35; solid 35 - 45; very solid - 50 - 60.

The stronger, more abrasive, coarse-grained rock, the greater the hardness required matrix. The stronger the rock, the lower the height of the diamonds should protrude from the matrix. If the matrix wears out faster than diamonds, then the diamonds should protrude from the matrix no more than 1/3 of the height. At the big exit of diamonds, or their sintering due to heating during work, loss of diamonds and loss of diameter, work with a chisel stop. The use of diamonds should be no more than 40%.

The hardness of diamonds depends on their orientation in the bit (different faces have different hardness). Diamonds of the same performance must be in the bit. For harder rocks, usually take smaller diamonds.

The consumption of diamonds is measured in carats. Depending on its size, from 100 to 500 carats of diamonds are used to make one bit.

The size of diamonds is divided into:

- large 10 - 20 pcs. per carat;
- medium - 20 - 40 pcs. per carat;
- small - 40 - 60 pieces. per carat;
- very small - 60 - 200 pieces. per carat.

Diamond drill bits come in different configurations (see Fig. 3.3):

1 is a stepped shape of the matrix,
2 - conical shape of the matrix,
3 - weakly conical matrix,
4 - flat matrix,
5 - for drilling downhole engines,
6 - to cut a new trunk,
7 - for drilling on oil-based flushing fluid.

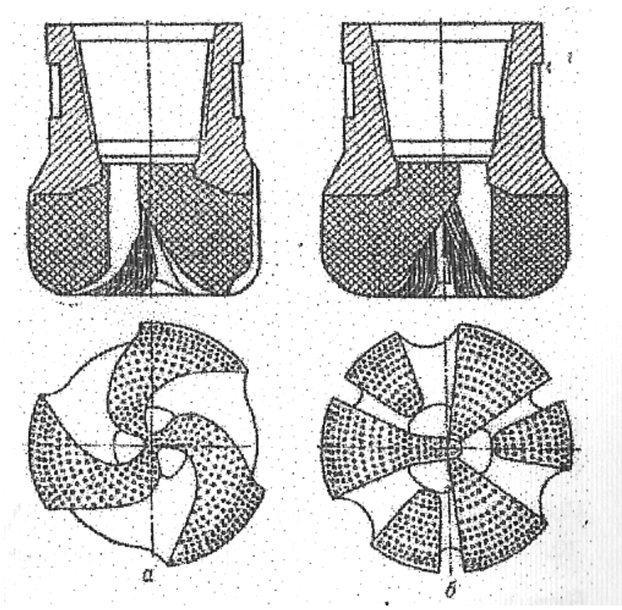


Fig. 3.3 - Diamond bits of spiral (a) and radial (b) types for continuous drilling

Diamond drill bits are marked with one or two letters and three numbers. For example, D323. The letters indicate the type of bit. The letter D is most often used. The first two digits of the code indicate the type of rocks and the size of the diamonds.

For synthetic diamonds use the number 0 in the second position. For example, D105. The third digit of the code indicates the design features of the bit or the nature of their use.

Drill bits made of diamond carbide inserts are called stratipax bits - PDC. Cutters of imported PDC chips have diameter values: 9.5 mm; 13 mm; 19 mm; 26 mm. Produce bits with conventional PDC cutters and heat-stabilized TSP for hardwoods. For hard rocks, the cutters can have a triangular shape. In PDC diamond bits, natural diamonds are used to reinforce the outer surface to prevent loss of diameter.

The cutter of a polycrystalline diamond bit (see Fig. 3.4) contains a stand (4) and a plate (2) covered with a layer of polycrystalline diamonds. The lower end of the stand has a chamfer (5) to facilitate pressing the cutter into the housing or die. The stand in most cases has a cylindrical shape and beveled front (3) and two side (1) faces. Produce conventional PDC cutters and heat-stabilized TSP for hard rocks. For hard rocks, the cutters can have a triangular shape. The matrix of chisels with polycrystalline diamonds can be steel or carbide.

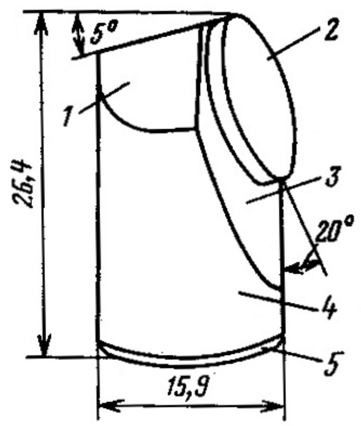


Fig. 3.4 - Polycrystalline cutter:
1 - beveled side face; 2 - plate; 3 - beveled front face; 4 - stand; 5 - chamfer

Diamond bits are very picky about the conditions of drilling, well washing. Therefore, diamond bits are produced on occasion for specific drilling conditions.

The letters in the symbols of diamond chisels mean the following:

A - for drilling with turbo drills;
B - for drilling with three-dimensional engines;
C - for geothermal wells;
E - for inclined-directional drilling;
H - with the central channel;
I - with unloading holes at the end;
L - with a low density of incisors;
M - with an average density of incisors;
N - with a high density of incisors;
O - chisel with steel body;
P - bit with a matrix body;
O - with the transverse direction of flow of the solution;
R - with the radial direction of flow of the solution;

S - jet hydraulic system.

ISM drill bits (see Fig. 3.5) are similar to diamond, but reinforced with Slavutych alloy (carbide inserts, the cutting surface of which is reinforced with natural or synthetic diamonds). The thickness of the diamond layer on the inserts is 3 - 6 mm. The chisels are reinforced with inserts with a diameter of 5 - 14 mm. Rounding (2) connects the outer cone (1), the inner (3). The outer surface has external channels (5) and wide passages (6), between which there are blades (4).

Diamond bits are fired in diameter. As a result of the operation of diamonds on the rock or on the metal on the bit formed annular recesses. The bit with a notch is unsuitable for work. The bit can be destroyed due to the erosion of the drilling fluid. Under the action of the jet of drilling mud, diamonds and inserts are exposed, which fall out of the matrix. In this case, the performance of the pumps should be reduced.

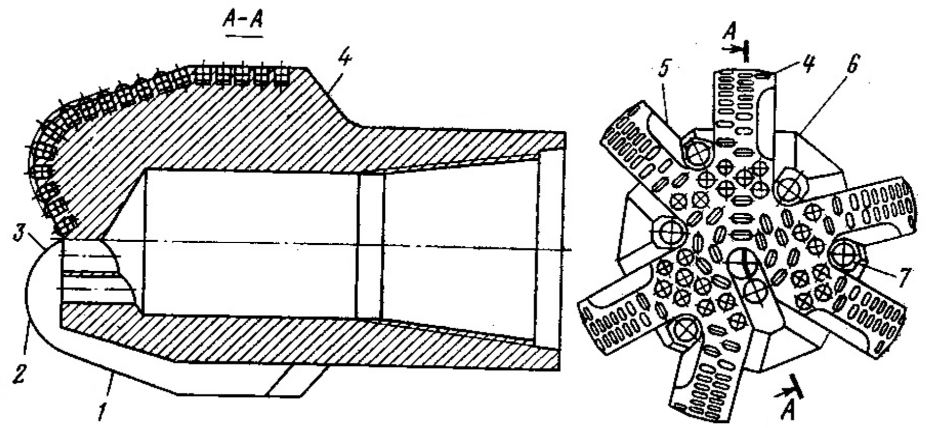


Fig. 3.5 - Drill bits ISM: 1 - outer cone; 2 - rounding; 3 - inner cone; 4 - blades; 5 - external channels; 6 - passages

Diamond bits should be handled more carefully than cone bits, because diamond is a fragile material and the bits are afraid of being hit by metal. They cannot even be placed on metal objects. When screwing, they are placed on a rubber or wooden substrate.

Column bits (see Fig. 3.6) *are designed for sampling of rock - core*. Column bits are cone and diamond. A core sampling projectile is installed above the drill bit to hold the core and separate it from the face. The projectile contains a housing in which a core pipe is suspended on a suspension with bearings. In the lower part of this pipe mount the core breakers. Kernorvachi are collet, petal, combined, which are used depending on the nature of the sediments. Shells are one- and two-section, with a stationary or replaceable core tube, which can be raised with the core and lowered again without lifting the chisel. Kern is sometimes taken with turbodolots.

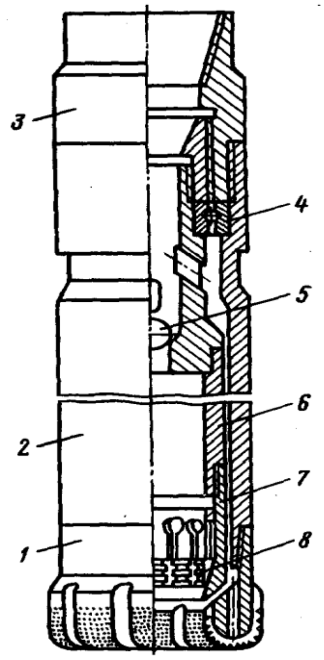


Fig. 3.6 - Columns drill bits: 1 - drilling head; 2 - housing; 3 - connector; 4 - bearing; 5 - valve; 6 - soil carrier; 7 - core receiving device; 8 - core

Core drill heads have the following designations:

K187.3 / 80TKZ; ISM-214.3 / 80 T,

where K - cones chisel; ISM - a chisel from Slavutych alloy; 187.3 and 214.3 - diameter of chisels; 80 - the diameter of the core; TKZ and T - the type of rock for which the bit is intended.

Expanders are designed to increase the diameter of the well. Sometimes wells are drilled first with a chisel of smaller diameter, and then expanded to a larger one. It is possible to expand both separately, with a new flight, and as soon as the expander is installed above the pilot bit.

The wellbore is not perfectly round. The bit does not rotate around its axis, but slightly offset. This configuration of the barrel reduces the patency of the casings and causes the need to smooth the protrusions. Alignment of a surface of a trunk is carried out by ***calibrators*** (fig. 3.7 see).

Centrators are used to center the bit and arrange the bottom of the drill string in the wellbore, to adjust the curvature of ***the wellbore*** (see Fig. 3.8).

Drill string and its elements. *The drill string is designed to transfer torque and drilling fluid to the bit.*

The layout of the drill string *consists of the layout of the bottom, the actual drill pipes and the leading pipe (square), conductors that connect the individual parts of the column.*

The drill pipe (see Fig. 3.9) contains, in fact, *a pipe and devices for connecting pipes to the drill string - locks. The lock contains the upper half - the coupling and the lower - a cone or nipple.*

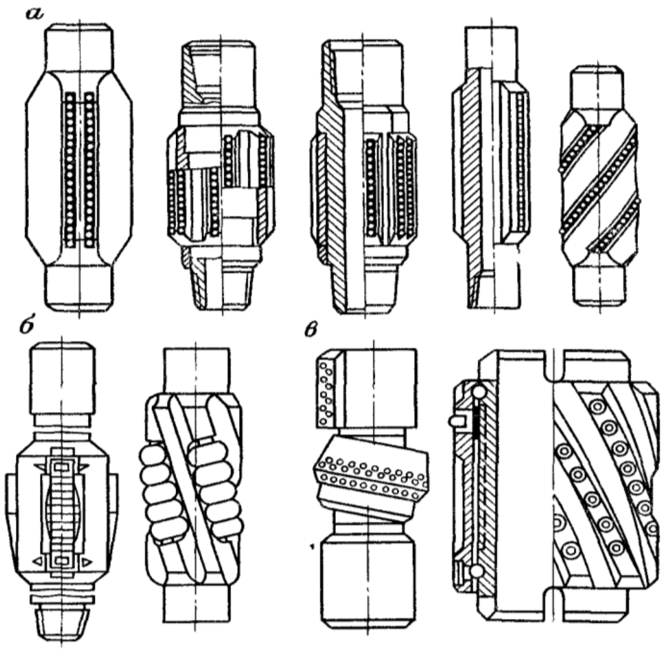


Fig. 3.7 - Calibrators: a - blade; b - cone; in - on the ball bearing (ROP and CRP)

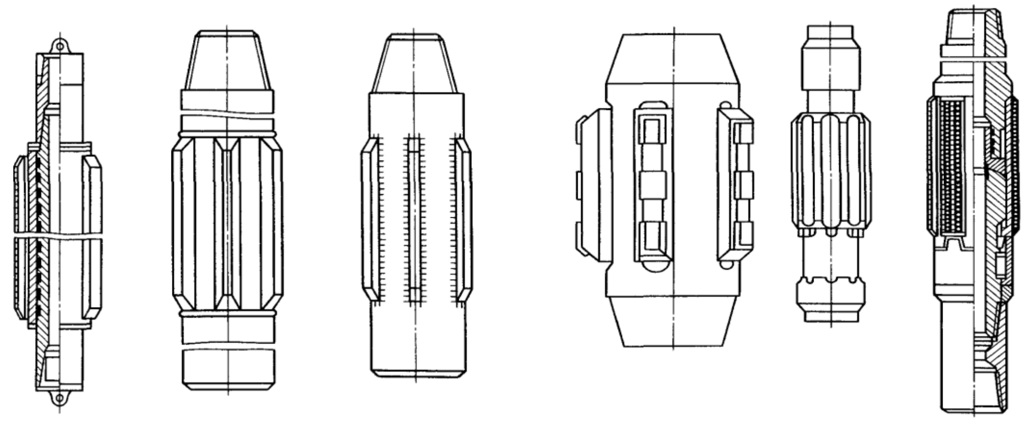


Fig. 3.8 – Centrators

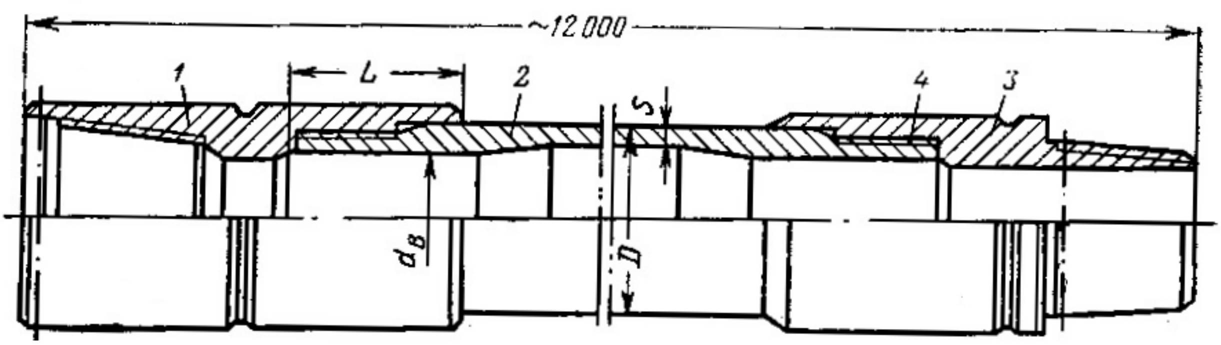


Fig. 3.9 - Drill pipe: 1 - lock coupling; 2 - pipe; 3 - cone (nipple) of the lock; 4 - pipe thread

According to the method of connecting parts of the lock to the pipe drill pipes are:

- without locks;
- with the screwed locks of a combined design;
- with welded locks.

Lockless pipes are made only of small diameters: 33.5; 42; 50 mm. These pipes are connected by nipples. The nipple has a nipple thread on both ends, and the pipes (rods) of the coupling also on both ends.

The lock has a lock thread with large turns, which allows many times to screw and unscrew the drill pipes. The lock has a diameter much larger than the diameter of the pipes and serves not only to connect the pipes to the column, but also to capture the column with special elevators for the lock during the descent and ascent of the drill string.

The length of drill pipes is made of three groups*:*
- 5.5 - 6.7 m;
- 8.2 - 9.1 m;
- 11.5 - 13.7 m.

Drill pipes are made of five strength groups of steel D, which meets the standard ANI D, with a yield strength of 372 MPa:
- E (E) - 539 MPa;
- L (X-95) - 637 MPa;
- M (G-105) - 735 MPa;
- P (S-135) - 882 MPa;
- T - 1078 MPa.

The strength group does not mean a certain brand of steel pipes in chemical composition. It regulates only the strength of steel.

Both parts of the drill lock of pipes of a prefabricated design have two types of a cut. One, a pipe, to connect the lock to the pipe, and a lock, to connect the pipes together. On a profile pipe cuts happen: triangular (round), 8-thread and trapezoidal. *Triangular threads* have low resistance to fatigue, low tightness and often break behind the first loaded thread of the thread, ie in the main plane. The main plane is called the plane passing through the first thread of the turn of the thread with a full profile. The profile of this cut has an angle of 60^{o} C at the top, a step of 3.175 mm, a taper of 1:16, the tops are rounded. This type of pipe cut is almost no longer used. It is used in fishing tools and other devices.

Pipes with *trapezoidal* cuts TT (TBVK or TBNK) are much more reliable. The thread has a persistent ledge, a cylindrical sealing belt at the end and a conical stabilizing belt behind the thread, which perceives variable, according to the sign, the load on the body of the pipe. The profile of the TT thread has the shape of a trapezoid, the side faces of which are inclined to the horizontal by 15^{o}. The angle at the top is 30°. Cut pitch 5.08 mm, profile height 1.7 mm. Taper of a cut 1:32. Screwing of a pipe and the lock is conducted in a hot condition, after heating of the lock to temperature 450 - 500° C.

Taking into account the type of landing ends and the type of pipe cuts, there are *four types of pipes with screwed locks*:

- pipes with triangular pipe cut:
  - type 1 - pipes B with the ends planted inside;
  - type 2 - pipes H with the ends landed outside;
- pipes with pipe cutting TT:
  - type 3 - TBVK pipes with the ends planted inside and stabilizing belts;
  - type 4 - TBNK pipes with the ends landed outside and stabilizing belts.

Drill locks are made according to the type of drill pipe and landing. Locks for drill pipes of prefabricated construction are made of the following types: ZSh and ZN for pipes with the ends planted inside. Locks of the ZN type (with a normal through section) are used only for pipes with a small diameter (60 - 89 mm), and ZS (with a wide through section) - for pipes with a diameter of 73 - 168 mm. These locks have lower drilling fluid pressure losses, larger diameter instruments can be passed through pipes and they are the most widely used. For pipes with outward ends, locks of the ZUK and ZSHK type are used, depending on the diameter of the pipe at the landing site.

Locks are marked with the type of lock and its outer diameter. For example, a lock with a diameter of 178 mm with a wide passage for pipes with a diameter of 140 mm is designated ZSh-178 - the most popular type of lock.

The geometric dimensions of locks for welded pipes depend on the diameter of the pipes, wall thickness and strength group. They are marked as follows: ZP-155-54, where 155 is the outer diameter of the lock, and 54 is its inner diameter. Drill pipes with welded locks are of two types:

- with a rectangular (execution A) ledge under the elevator;
- with a conical (execution B under 180o) ledge under the elevator.

The latter are denoted by the letter K. Locks of drill pipes made according to the ANI standard are reinforced with carbide surfacing, and the lock cut is covered with copper coating.

Locks to drill pipes are welded by friction. Drill pipes with welded locks have practically supplanted prefabricated drill pipes.

In the pipes made according to the ANI standard, put the following marking:

- factory - knock out or apply paint;
- nomogram ANI - knocked out or applied with paint;
- diameter of pipes - put with paint;
- weight of one foot in pounds - beaten out and applied with paint;
- steel grade - beaten out and applied with paint;
- type of steel - applied, and in the manufacture of converter steel VO - knocked out and applied with paint;
- length of a pipe - put a paint;
- weight of the pipe - applied with paint;
- type of cut - applied with paint.

Weighted drill pipes are designed to create a load on the bit by unloading the pipes on the bit. These are thick-walled pipes, mostly round in cross section with locking cuts at the ends. The grooves are made with grooves on the thread to reduce the concentration of stresses in the groove. Weighted drill pipes use balanced, hot-rolled and according to the ANI standard.

In balanced pipes, the hole is obtained by drilling and external processing to achieve a balanced mass. The length of the pipes is 6 - 6.5 m. They are made of alloy steels. At a distance of 0.8 - 1.2 m from the ends of the pipe is subjected to heat treatment.

Hot-rolled weighted drill pipes, which are made by rolling from group D steels, have low strength and are used in simple conditions. Weighted drill pipes according to the ANI standard are of the following types (see Fig. 3.10):

- smooth without indentations of type A;
- with grooves under the elevator and wedge grip type B;
- square section type D;
- with spiral grooves of type E;
- with a spiral groove with grooves under the elevator and a wedge capture like EN.

Spiral grooves on weighted drill pipes are designed to reduce the area of contact of these pipes with the walls of the well and reduce the likelihood of entrapment. Weighted drill pipes are made of alloy steels with heat treatment along the entire length. The length of weighted drill pipes is 8.3 - 9.45 m.

To prevent the operation of weighted drill pipes on the outer diameter, they are made with carbide surfacing. Weighted drill pipes can run up to 3500 hours before repair (cutting new threads). Weights of weighted drill pipes can be cut six times. Threads must withstand up to 700 screws.

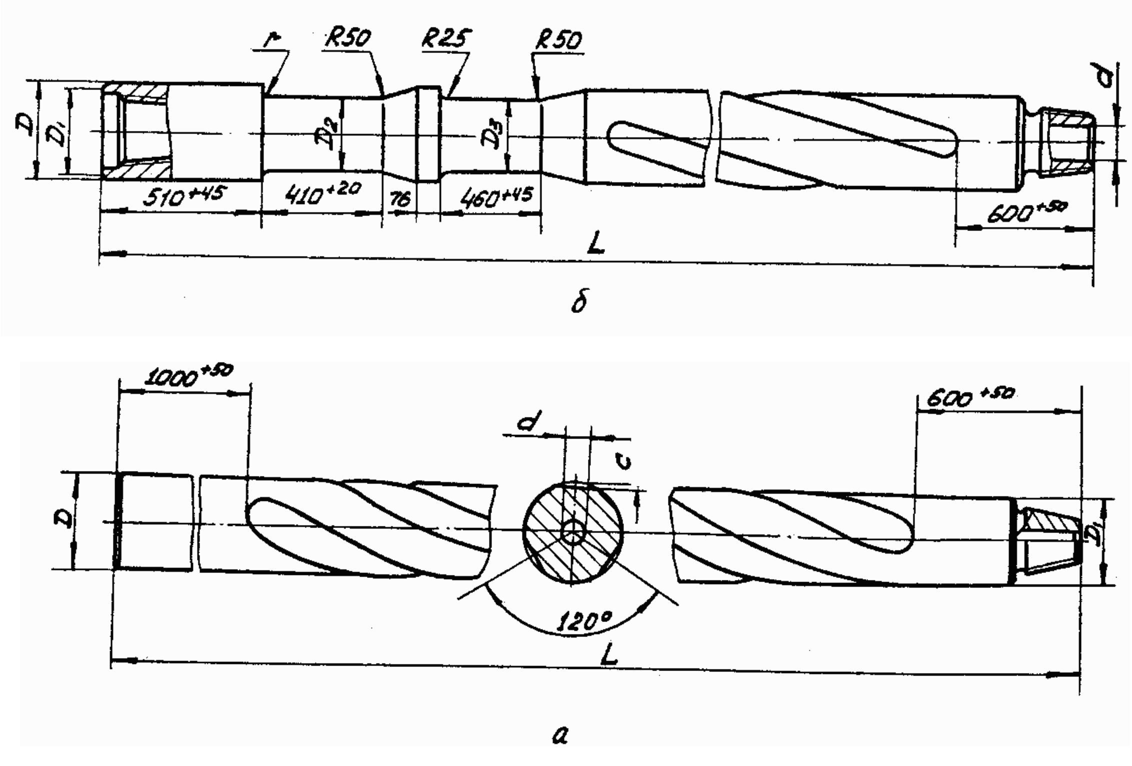


Fig. 3.10 - Weighted drill pipes: a - with spiral grooves of type E; b - with spiral grooves and groove type EN

Square weighted drill pipes are used to prevent unauthorized curvature of the well and have a gap between the faces and the wall of the well 2 - 3 mm.

The ratio of the diameter of a conventional weighted drill pipe to the diameter of the well should be 0.75 - 0.85 for bits up to 295.3 mm in diameter and 0.65 - 0.75 for bits of larger diameter.

The diameter of the weighted drill pipes should not be larger than the diameter of the downhole engine.

In difficult drilling conditions, the maximum diameter of the weighted drill pipes must provide the necessary clearance to the well wall for fishing and drilling of the weighted drill pipes with pipe milling machines.

The ratio of the diameter of the drill pipes and the weighted drill pipes placed under them must be at least 0.75. Otherwise, it is advisable to use a stepped column of weighted drill pipes.

The difference in diameters of weighted drill pipes should not exceed 50 mm. The lower weighted drill pipes must have the maximum thread diameter. It is recommended to install 150 - 250 m of drill pipes of larger diameter and with a larger wall thickness above the weighted drill pipes. It is advisable that these drill pipes be made of steel D, which has the highest rates of metal fatigue.

The length of the weighted drill pipes is chosen according to the value of the load on the bit. In the case of a load on the bit due to the weight of the drill pipes, they will work in a compressed form, bend and may break. Therefore, the load on the bit should be maintained only by the weight of the weighted drill pipes. The length of the weighted drill pipe is chosen so that its weight in the solution was 17.5% higher than the load on the bit during rotary drilling

$$L_у = 1{,}175\ P_д / q(1 - \gamma_р/\gamma_м) \cos\alpha\ , \tag{3.3}$$

where γ_p is the density of the solution; γm - metal density; P_d - load on the bit, kN; q is the weight of 1 m running weighted drill pipe, kN; A is the angle of inclination of the wellbore.

In drilling fluids of normal density, the weighted drill pipe loses 15 - 17% of its weight. That is, taking into account the weight loss in the solution in this case, the excess weight of the weighted drill pipe on top of the load on the bit in the drilling fluid will be about 10%.

With turbine drilling, weighted drill pipes and drill pipes work in better conditions than with rotary drilling. When drilling with downhole motors in uncomplicated conditions, drill pipes (tools) may not be rotated at all, or rotated periodically or continuously at low speeds. The length of the weighted drill pipe can be reduced by the weight of the turbodrill

$$G_{убт} = G_д - G_т\ , \tag{3.4}$$

where G_t is the weight of the turbodrill during turbine drilling.

Working conditions of the drill string. *When drilling by rotary method, the drill string is subjected to tensile, compressive, torsional, bending loads*.

Under the action of the own weight of the column, the pressure of the drilling mud in the drill pipes due to the pressure drop in the downhole engine and hydromonitor nozzles of the bits, the friction of the column against the well walls there are *tensile loads*.

Due to the load on the bit there are *compressive stresses*.

When turning the column there are *torsional stresse*s.

Due to the centrifugal forces acting on the locks, turning of the compressed and respectively bent part of the column, work in a curved well, drilling from floating platforms, *bending loads occur*.

During the operation of the bit there are *vibrations* that are transmitted to the column.

Additional *inertial loads* are also available during column braking.

In the wedge grip, the pipes carry a *crushing load*. Crushing loads occur during the testing of formations on drill pipes.

Most of these loads are difficult to account for reliably.

The following types of hydraulic motors are mainly used for downhole motors: turbo drill and screw motor.

The parameters of the drilling mode usually include:

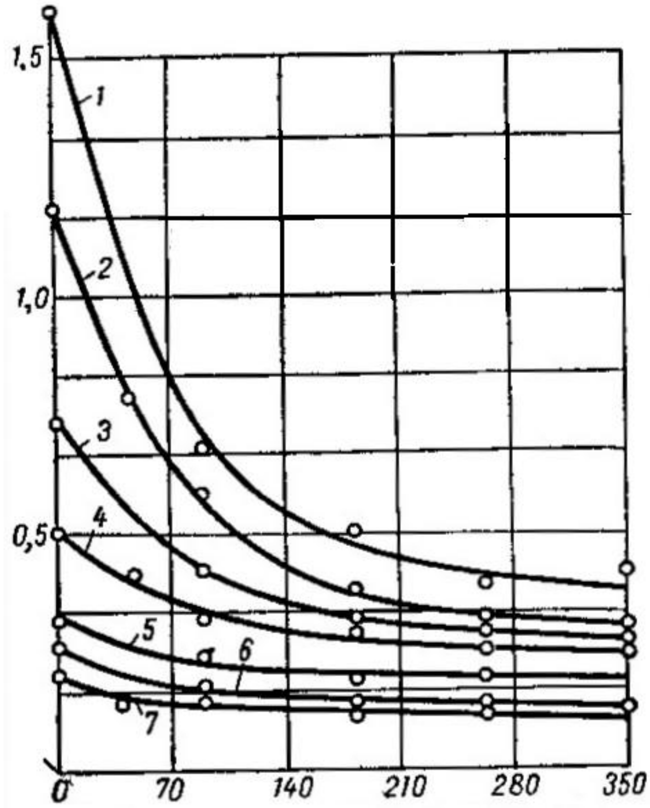
- axial load on the bit, kN or t;
- number of revolutions of the bit or rotor per minute or sec;
- pump capacity in m3 per second or l per minute;
- qualitative parameters of drilling mud (density, filtration, etc.).

The effectiveness of the destruction of the rock is determined by:

- deepening of the well by one revolution;
- mechanical drilling speed, ie the amount of mechanical drilling, m / h;
- cruising speed, ie drilling speed, taking into account the drilling on the bit and the time of lowering and lifting operations;
- the cost of 1 m of penetration.

The destruction of the rock occurs in the mode of surface abrasion, when the contact pressure of the tooth on the rock is small compared to the strength of the rock, destruction due to fatigue, when repeated contact of the tooth with the rock reduces the strength of the rock, there is volumetric fracture when the tooth due to contact pressure sticks to the rock and destroys it. *The time of contact of the tooth with the rock, necessary for its destruction, should be at least 2 - 6 milliseconds. If the duration of contact is shorter, the breed is not destroyed.* This is especially important when drilling in plastic deposits.

Influence of well flushing. Effective deepening of the well is possible only with effective cleaning of the face from the drilled rock. First of all, the performance of the bit depends on how much the hydrostatic pressure of the drilling fluid exceeds the formation (see Fig. 3.11). Increasing the density of the solution leads to a decrease in mechanical speed.



Hydrostatic pressure at the bottom, kg / cm^2

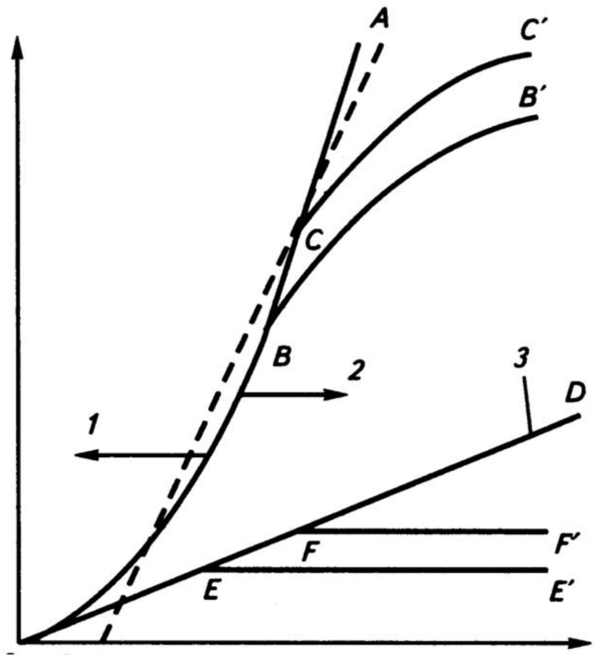
Fig. 3.11 - Dependence of mechanical speed on hydrostatic pressure on the face: 1, 2, 3 – clay; 4 – limestone; 5 – sandstone; 6 – basalt; 7 - dolomite

The most effective destruction of the rock during drilling with blowing the face with air. In this case, the pressure on the bottom is minimal. However, this method has limited use.

When rinsing with water, the mechanical speed increases by 1.5 - 2 times, but this method is possible only in resistant rocks.

In practice, in particular, it is established that an increase in the content of solid particles by volume in the drilling fluid by 1% leads to a decrease in mechanical speed by 7%. Therefore, the correct choice and quality of drilling mud is essential for the effective destruction of rock. Reducing the density of the drilling fluid and its solids content is an effective way to increase the drilling speed.

Another factor that significantly affects the effectiveness of rock destruction is the cleaning of the face from the drilled rock. If we plot the dependence of mechanical speed on the load on the bit (see Fig. 3.12 - author - M. Bingham), then insufficient cleaning of the face from the rock increase in the load on the bit may not lead to an increase in mechanical speed. According to M. Bingham: "The area below the direct dependence is the area of insufficient face clearance."



Specific load

Fig. 3.12 - Diagram of drilling rocks (by M. Bingham): 1 - area of perfect cleaning of the face; 2 - area of imperfect face clearance; 3 - the line of the minimum deepening

Also according to M. Bingham: “When the density of the solution decreases, it is possible to move from a direct OD to a direct OA or to any intermediate between them. In the case of improved face clearance from the drilled rock, it is possible to move from the OBB 'dependence to the OCC' dependence and, ideally, to the OA dependence, or from the OEE 'dependence to the OD or OFF dependence'.

In practice, it is not uncommon for pits to accumulate large volumes of drilled rock, especially in the process of drilling soft sediments. At the same time, *the so-called seals* are formed - mixed rock in the drilling mud. The stuffing box can have a height of up to 100 m. This rock is no longer carried to the surface, but is mixed with a chisel for a long time and can be partially dissolved in drilling mud. As a result, the teeth of the bit may not come into contact with natural, undamaged rock.

Increasing the performance of the pumps simultaneously leads to an increase in pressure losses in the annular space. This increases the pressure of the mortar on the face, and reduces the drilling speed.

Therefore, to improve the cleaning of the face, it is necessary not so much to increase the performance of the pumps, but to improve the process of cleaning the face. The performance of the pumps must be such that the lifting of the drilled rock solution to the earth's surface is ensured. This performance is calculated. The specific consumption of drilling mud per 1 cm^2 of the face area according to the rules for rotary drilling and drilling with electric drills should be in the range of 0.035 - 0.05 $l/s.cm^2$, and in the case of drilling with hydraulic downhole engines should not exceed 0.07 l/s.cm2 face. The diameter of the nozzles of the hydromonitor bits is chosen from the calculation of the flow rate of the drilling fluid jet not less than 80 l/s.

According to various data, *to effectively ensure the rise of rock particles*, the rate of upward flow of drilling mud in the annular space should be 0.61 - 1.2 m / s.

The performance of the pumps must prevent excessive enrichment of the drilling fluid with drilled rock. This amount of rock must be handled by the drilling treatment system, and the increase in the density of the solution due to the drilled rock should not lead to the absorption of the solution.

The approach to the choice of drilling mode parameters for rotary and turbine methods is different. In the rotary method, the parameters of the drilling process do not depend on each other and can be changed from the surface. In turbine mode, the number of revolutions is related to the load on the bit. If you change the load, the number of revolutions also changes.

The optimal parameters of the washing process in the case of the rotary drilling method are selected according to the following criteria:

- with the achievement of the maximum hydraulic power on the bit - this is the power consumed in the hydromonitor nozzles of the bit, it is calculated by the formula

$$N = к\, Q\, V^2 . \qquad (3.5)$$

The process optimization is carried out according to the following algorithm:

- determine the minimum capacity of the pump, which provides the minimum allowable flow rate in the annular space, equal to 0.61 m / s;
- at this speed choose the minimum size of the cylinder liners;
- drilling is carried out at the ultimate pressure on the selected bushings by selecting the appropriate nozzles;
- the performance of the pumps decreases with deepening until the ratio of the power on the bit and the hydraulic power of the pumps reaches the value of 0.65. Continue drilling at this ratio.
- with the achievement of the maximum, so-called, "shock" force of the jet

$$N = к\, Q\, V . \qquad (3.6)$$

This is better than in the first version. For this:

- using the maximum power of the pumps, choose the flow rate of the solution, which allows you to realize on the bit 75% of the hydraulic power of the pump;
- at constant productivity of the pump allow reduction of power on a bit to 48% of hydraulic power of the pump (with deepening of a well) and further support such ratio.

For good face cleaning, power consumption per 1 mm of face area should be k = 3.74 - 6.94 W / mm^2 (or 3 - 7 hp per inch^2 of face area).

The optimal mode is also considered when 2/3 of the pressure developing the pump is spent in nozzles of a bit. According to the recommendations of ANI, the pressure loss in the bit nozzles should be maintained at 48 - 65% of the pressure on the pump (excluding pressure losses in the downhole motor and downhole system MWD).

Діаметр насадки долота з досягненням максимальної сили удару струменя оцінюють за виразом

$$d_o = 1{,}13\sqrt[4]{\frac{\rho_p Q}{\mu^2 n^2 P_н}}, \tag{3.7}$$

where ρ_p is the density of the liquid, kg / m^3; μ = 0.9 - 0.95 - nozzle flow rate; n is the number of nozzles; Q - pump capacity, P_n - pump pressure, Pa; d_o - diameter of the nozzle, m.

The drilling mode parameters affect the mechanical speed and stability of the bit in different ways (see Fig. 3.13).

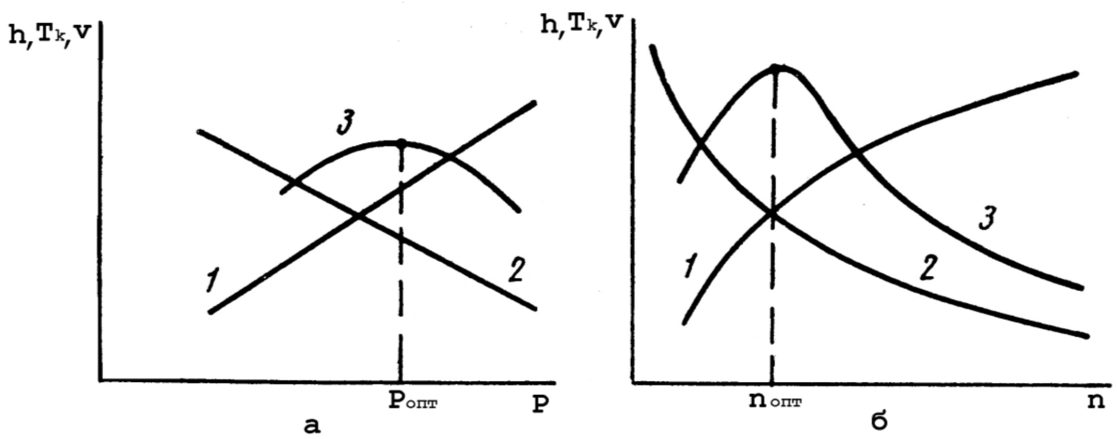


Fig. 3.13 - Influence: a - load on the bit on: 1 - mechanical speed v = ∫ (P); 2 - duration of the bit Tk = ∫ (P); 3 - drilling on the bit h = ∫ (P); b - the number of revolutions on: 1 - mechanical speed v = ∫ (n); 2 - duration of the bit Tk = ∫ (g); 3 - drilling on the bit h = ∫ (n)

So *with increase in loading on a bit at perfect clearing of a face the mechanical speed also increases*. There is *a critical load on the bit*, which does not increase the mechanical speed. This value depends on the strength of the rock and the degree of purification of the face from the drilled rock. If the rock is soft and the tooth penetrates it to full height, then further increase in load is impractical.

The penetration of the tooth into the rock is also hindered by sludge at the bottom. The height of the sludge depends on the quality of the face. Further increase of loading, after penetration of a tooth on full height into slime and breed also is not expedient. Depending on the design of the bit and the hardness of the rock, there is a critical load on the bits, which leads to the destruction of teeth and especially carbide teeth, the destruction of the support, and so on.

The bits can withstand significant static loads. For example, a bit with a diameter of 190 mm is approximately destroyed at a load of 200 tons. *Under conditions of vibration, the stability of the bit is much lower*. Of course, it is impossible to work under critical loads and close to them. *As the load increases, the duration of the bit always decreases*. It works faster.

Therefore, the maximum drilling on the bit can be obtained at a certain *average optimal load*. It may be different depending on the criteria by which it is evaluated:

- mechanical speed;
- flight speed;
- the cost of 1 m of penetration.

The load on the bit can be determined by the hardness of the rock by stamp tests $p_{ш}$

$$P = a\, p_{ш}\, S\ , \tag{3.8}$$

where $p_{ш}$ - rock hardness according to stamp tests, kg/mm^2; S is the sum of the areas of contact of the teeth of the bit with the rock, mm^2.

However, this approach is not very popular due to the lack of reliable initial data on the strength of rocks.

As the number of revolutions increases, the mechanical speed increases, but the duration of the chisel operation decreases. Until the moment of operation at a certain load, the bit can make a certain number of revolutions, ie has a certain *endurance resource*. As the number of revolutions increases, the efficiency of rock destruction decreases. At very high speeds, and especially in hard rocks, the teeth of the bit may not have time to destroy the rock, and the face is cleaned of drilled rock. That is, in each case there is an optimal number of revolutions. At each number of revolutions there is a certain optimum loading, and among various options of optimum revolutions it is possible to choose the most optimum.

The optimal ratio of the number of revolutions and the load on the bit also depends on the type of bit and strength, abrasiveness, ductility of the deposits that are drilled.

In plastic, viscous clay, weakly cemented, low-abrasive sand-clay and sandstone rocks, it is advisable to drill at high, close to the maximum speed recommended by the manufacturer, and low axial loads on the bit. In similar rocks, increasing the rotational speed contributes to a more significant increase in the mechanical speed of drilling than increasing the axial load, which leads to contact of the cone body with the surface of the wellbore. Increasing the number of revolutions reduces the risk of formation of seals on the bit.

In carbonate rocks of even low hardness, it makes sense to drill at increased axial loads on the bit and reduced speeds because in such rocks, increasing the axial load has a greater effect on increasing the drilling speed than increasing the number of revolutions.

In sandstones, similar to abrasive rocks, fractured and debris, it makes sense to reduce the number of rotations of the rotor to prevent rapid operation of the bits in diameter, the destruction of weapons, sealing elements of the supports of cones, boards and paws, and so on.

In the event of significant vibrations of the drilling tool during drilling, the driller is obliged to change in one direction or another the value of the axial load on the bit or the speed of rotation of the rotor to the values at which the vibrations stop. Each drill tool layout has its own oscillation frequency. When this frequency coincides with the oscillations of the bit, the vibration of the drill string is manifested. Appropriate shock absorbers are installed above the bit to prevent vibrations.

Significant restrictions on the parameters of the drilling regime are imposed by drilling equipment and drilling tools. The load on the bit can be limited by the number and quality of weighted drill pipes, the performance of the pumps - their condition and the condition of the manifold, and the number of revolutions - the condition of the drill string, and so on.

During turbine drilling during the flight, the parameters of the drilling mode can be adjusted mainly due to the load on the bit and the performance of the pumps. In this way, all drilling parameters are interconnected. Increasing the load leads to a decrease in speed and vice versa. Also regulate the drilling mode by selecting the appropriate characteristics of the downhole engine. When using screw motors, it is possible to adjust the number of revolutions of the bit due to the performance of the pumps.

Lecture 4. Drilling solutions. Types of solutions. Materials and chemicals. Equipment for working with drilling solutions

Drilling solutions (fluids, muds) play an important role in increasing the volume of drilling and hydrocarbon production. The quality of drilling mud depends on the speed of drilling the well and the result of drilling the well as a whole. It is well known that with poor quality drilling solution, you can drill a well, but not get products from it.

Drilling solution (fluid, mud) is a complex multicomponent dispersed system of suspension, emulsion and aerated fluids, which are used to wash the well during drilling.

The technology of well construction is directly related to the destruction of rocks at the bottom and the transportation of drilled rock to the surface. That is why an important technological component in the process of arranging a well is the process of washing.

The process of well washing is a set of technological processes and operations for cleaning the bottom and wellbore from sludge, removal of sludge to the surface and removal of solids from the circulating agent. Flushing the wellbore is a continuous process of mechanical drilling.

When passing wells, ***drilling mud performs a number of different functions***, in particular:

- *due to the movement of drilling mud in the well is*:
    - removal of drilled rock from the well;
    - power transfer from the drilling pump to the downhole engine;
    - cooling of the bit while working on the face;
    - erosion of rocks at the bottom;
- *due to the weight of the solution*:
    - prevents the ingress of gas, oil and water into the wellbore;
    - particles of the drilled breed and the weight are kept afloat;
    - the destruction of well walls decreases;
    - the load on the equipment is reduced by reducing the weight of the pipes in the drilling fluid;
- *due to the appearance of crusts on the walls of the well*:
    - the friction force of drill and casing pipes against the well walls decreases.
    - chisel supports are lubricated.
    - reduces the permeability at the bottomhole zone and prevents the absorption of drilling mud.
    - prevention of destruction of walls of a well which are made of not cemented breeds is prevented.
- *due to the chemical properties of the solution*:

- the walls of the well are protected from destruction due to the chemical action of the filtrate on the rock.
- reduces corrosion and abrasive operation of drilling equipment.
- the natural permeability of productive deposits at their opening remains.
- the properties of the drilling mud are preserved for a long time despite the action of the drilled rock, formation waters and temperature.
- improves the drillability of the rock.
- the thermal regime is preserved in the permafrost during its drilling.

The main requirement for drilling fluids *is to prevent complications that may occur when drilling a well*.

Requirements for flushing fluids depend on the specific geological and technological conditions of well drilling and are as follows:

- washing fluids must be chemically neutral in relation to the drilled rocks, not to cause their dissolution, dispersion and swelling, which will reduce the likelihood of complications when drilling a well;

- the properties of the washing liquids must be stable for a significant period of time, the dispersed phase should not be dispersed when the thermobaric drilling conditions change, which will reduce the cost of drilling reagents;

- parameters of washing liquids should be changed in a wide range by means of chemical reagents, weights and other impurity which provide change of each technological indicator at constant other indicators;

- the liquid phase of the liquid should have a low viscosity, low surface tension at the boundary with the rocks, which will improve the working conditions of the bit at the bottom of the well;

- thixotropic properties of washing liquids should increase over time, especially after the cessation of circulation, which will keep the drilled rock in a suspended state;

- the concentration of clay particles in the solid phase should be minimal, and the weighted average density of the solid phase - the maximum, which will reduce the likelihood of thickening of the washing liquids;

- the filtration rate of the flushing fluid should be intensively reduced over time, providing the minimum filtration required to prevent complications in the wellbore;

- flushing fluid must protect corrosion of drill and casing pipes, downhole motors, ground equipment, etc .;

- the rheological parameters of the fluid must be changed so as to ensure perfect cleaning of the bottom of the well, satisfactory hydraulic transport of the drilled rock and optimal bit hydraulics;

- flushing fluids should limit the inflow of mineralized water, acid and hydrogen sulfide gases ($CO_2;H_2S$), reducing the likelihood of various complications when drilling a well;

- the electrical conductivity of flushing fluids must be sufficient to conduct the necessary geophysical surveys in the well to identify oil, gas or aquifers;

- washing liquids must not contaminate the upper aquifers and be safe when stored in barns or disposed of.

Any chemical reagent added to the liquid must be environmentally friendly, and so on.

The main functions of washing liquids, factors and limitations that affect them are as follows:

- *the main function of washing liquids is to transport sludge from the face to the surface*. There is almost no other way to take the drilled rock out of the well. Hydrotransport in vertical wells is more efficient at high flow velocities and high viscosity and fluid densities. However, at high fluid velocities in the annulus, there is erosion of the well walls, an increase in hydraulic losses, which can lead to hydraulic fracturing;
- *cleaning of the face from the destroyed rock*. This function of the flushing fluid is important because the faster the drilled rock is washed away from the face, the more efficiently the bit works. Even a small amount of rock particles left in the face reduces the drilling speed, because the already drilled rock is re-ground, which passes into the washing liquid as an active phase, increasing its viscosity and density.
- *reservoir pressure balancing in the well*. Reservoir pressure in the well can be balanced in two ways: the weight of the column of flushing fluid; creating back pressure at the wellhead.
- *keeping in the ground state of the solid phase particles that are in it*, especially after the cessation of circulation during the lowering and lifting operations, repair and other work in the well;
- *maintaining the stability of the well walls*. In the process of drilling wells, the hydrostatic pressure of the flushing column exceeds the formation. Under the action of the pressure drop, the solid phase together with the filtrate penetrates into the porous rock, forming a filtration crust on the walls of the well. The filtration crust has mechanical strength, binds weakly cemented rock particles, slows down the inflow of filtrate into the well walls, reduces the area of further spread of the wetting zone around the wellbore. However, it is not always possible to maintain the stability of the well walls in this way, especially when drilling tectonically disturbed rocks with large angles of incidence. The stability of the well walls is maintained in different ways: reduce filtrate recovery and increase the rheological properties of the flushing fluid. In this case, clays, shales and other geological formations swell less, disperse and fall into the well. This fluid better clays cracks and pores of rocks, increasing the stability of the well walls; use washing liquids with high fixing properties (low-silicate, polymer-potassium, etc.); increase the pressure of the flushing fluid on the walls of the well. But with increasing hydrostatic pressure, the intensity of filtrate penetration into rocks increases, and the mechanical drilling speed decreases. Under such conditions, the insulating and fixing role of the filtration crust significantly increases.

For the initial opening of productive horizons (both carbonate and terrigenous reservoirs), drilling fluids with different dispersion media were tested, the most common of which are aqueous, water-alcohol, hydrocarbon and synthetic solutions.

The greatest difficulties in choosing a liquid for the initial opening of productive horizons arise for terrigenous reservoirs due to their complex geological structure.

Despite the existing disadvantages of water-based drilling fluids in terms of contamination of reservoirs, they are more in demand than hydrocarbons.

According to the technological properties, the following groups of parameters of drilling fluids are distinguished:

- *main primary parameters*:
  - imaginary density;
  - true density;
  - conditional viscosity;
- *filtration properties*:
  - filtration rate under normal conditions;
  - filtration rate at temperature and under pressure (HTHP);
  - thickness of the filtration crust;
  - coefficient of friction of the filtration crust;
- *rheological properties*:
  - gel strength;
  - plastic viscosity;
  - maximum dynamic shear stress;
  - apparent viscosity;
- *solid phase content*:
  - total solids and lubricants;
  - sand content;
  - cation exchange capacity;
- *chemical analysis of drilling mud filtrate*:
  - the content of the ion Cl -;
  - the content of K^+ ions; Na^+; Ca^{2+}; Mg^{2+}, OH^-, CO_3^{2-}, HCO_3^-;
  - determination of alkaline properties;
- *hydrogen index (pH)*.

Sampling to determine the gas content and temperature of the solutions is carried out at the beginning of the gutter system before the cleaning unit. Measurements are performed using a field laboratory immediately after sampling.

To determine the parameters of the solution entering the well, samples are taken at the outlet of the treatment system.

In particular, *the rheological properties of drilling fluids significantly affect the performance of the following functions*:

- providing high-quality cleaning of the wellbore from sludge during flushing;

- ensuring the separation of particles of drilled rock and gas carried to the surface, on cleaning agents;

- providing optimal conditions for working chisels due to effective cleaning of the face;

- reduction of erosion of the wellbore walls, etc.

Fann rotary viscometers are used to measure the rheological properties under drilling conditions.

According to the measurement results, the strength of the gel ($Gel_{10/10}$, dPa), plastic viscosity (PV, SP), ultimate dynamic shear stress (YP, dPa) and apparent viscosity (AV, SP) are calculated.

It is advisable *to consider the definition of each of the rheological parameters of the drilling fluid*.

Gel strength (static shear stress) ($Gel_{10/10}$, dPa). Static shear stress is the minimum stress required to destroy the structure of the drilling fluid.

Because the strength of the structure of thixotropic drilling fluids depends on the time the system is at rest, the static shear stress, which determines the strength of the structure, is a variable that gradually increases in each case to a certain value over time. The strength of the gel is measured after 10 sec. and 10 minutes rest of the drilling fluid.

Plastic viscosity (PV, sP) - a component of the viscosity of drilling mud, which is in a dynamic state. The amount of plastic viscosity directly depends on the size, shape and number of particles present in the moving solution.

Plastic viscosity is defined as the difference between the readings of a rotary viscometer at 600 rpm. and 300 rpm

Maximum dynamic shear stress (YP, dPa). The magnitude of the force required for the initial flow of fluid. Indirectly characterizes the resistance of the drilling fluid flow.

The shear stress in lb/100 inches^2 is defined as the difference between the readings at 300 rpm. and plastic viscosity in centipoise.

Imaginary viscosity (AV, sP). The value that characterizes the total viscosity of the drilling fluid in the state of dynamics. Indirectly may be associated with a conditional viscosity index at low gel strength.

The property of dispersed systems to restore the original structure, previously destroyed by pumping or mixing, is called *thixotropy*.

Numerous studies have shown that *the thixotropy of dispersed systems is provided by the following factors*:

- a sufficient amount of dispersed phase, which facilitates the construction of a spatial grid;

- the presence of a colloidal fraction in the dispersed phase, which plays the role of an adhesive (adhesive) substance for coarse particles;

- low strength of the structure and its property to residual deformations.

Thixotropy is an important characteristic of drilling fluids, which assesses the ability of the fluid to keep the drilled rock in the milled state after the cessation of circulation. It significantly affects the efficiency of cleaning the bottomhole zone of the well from clogging and maintaining the natural permeability of the rocks of the productive reservoir.

If necessary, also determine a number of *additional parameters,* in particular: the sand content in the drilling mud; oil content; the content of the solid phase, including the content of the colloidal phase, clay phase, weighting agent, salts of potassium, calcium, magnesium, sodium, chlorine, sulfate; total mineralization of drilling mud filtrate; concentration of hydrogen ions (pH); stickiness of clay crust, etc.

The main principle of ***classification of drilling fluids*** (see Table 4.1) is *the characteristics of the composition of the dispersion medium - the main component in which other components are dissolved (chemical reagents, materials), to ensure the specified parameters and technological properties of the solution*.

In particular, a distinction is made between drilling fluids based on water and hydrocarbons (WHB) and based on gaseous agents.

Розчини на водній основі *складаються з двох основних екомпонентів*:

– дисперсійне середовище (вода) рідка фаза, у якій розчинені або завислі всі мінеральні або хімічні компоненти розчину (тверда фаза);

– тверда фаза – наповнювачі (глиниста фаза, карбонат кальцію, обважнювачі), мінеральні солі (хлоридів Na^{+}; Ka^{+}; Ca^{2+}; Mg^{2+} і т. ін.), органічні полімерні чи синтетичні компоненти, розчинені або завислі у воді.

Water-based solutions *consist of two main components*:

- dispersion medium (water) liquid phase, in which dissolved or suspended all the mineral or chemical components of the solution (solid phase);

- solid phase - fillers (clay phase, calcium carbonate, weights), mineral salts (chlorides Na^{+}; Ka^{+}; Ca^{2+}; Mg^{2+}, etc.), organic polymeric or synthetic components, dissolved or suspended in water.

Water-based drilling fluids are divided into two main types of systems:

- dispersing - when there is a chemical dissolution followed by mechanical destruction of the drilled rock in the dispersion medium - water;

- non-dispersible - when the drilled rock is protected from mechanical destruction due to the maximum suppression of the process of chemical dissolution of rocks.

Table 4.1 - Classification of drilling fluids by primary and secondary characteristics

1. Main features	Name of the system
The composition of the dispersion medium	Water based Emulsion Hydrocarbon based On a synthetic basis
2. Minor features	Characteristics of the system
The composition of the dispersed solid phase	Clay-free Little clay (<28 kg \ m3) Clay (> 28 kg \ m3) Clay - organophilic
According to the composition of mineralization	Fresh Slightly mineralized (<3%) Medium mineralized (<15%) Highly mineralized (> 15%)
The composition of mineralizers	Sodium chlorine (salt) Potassium chlorine Chlorine-calcium Magnesium chlorine Gypsum Limestone
By composition of fillers	Aerated Emulsion (oil + water) Weighted (barite) Carbonate (chalk, Baracarb)
By composition of the environment, indicator (pH)	Highly alkaline (> 11.0) Medium alkaline (8.5-11.0) Slightly alkaline (7.0-8.5) Neutral (7.0) Sour (<7.0)

It is known that in the process of drilling wells, the stability of the parameters of the solutions depends on the degree of contamination of the drilled rock and, in particular, on the increase in the content of active (clay) solid phase.

The use of dispersing systems has a number of disadvantages:

- high cavernousness of the wellbore walls;
- the formation of seals on the elements of the drill string;
- significant operating volumes of washing liquid;
- negative impact on productive reservoirs.

The relative advantage of such systems is low cost, which allows them to be used during the drilling of terrigenous deposits in the upper drilling intervals, while ensuring high-quality purification of the solution from the drilled rock.

The parameters of water-based solutions are regulated by chemical reagents. Their interaction with the rock in the walls of the trunk in the bottomhole zone is due to the penetration of solid and liquid phases of the solution. In aqueous solutions, the dispersion medium is water, and the dispersed phase is both solid (clay powders, microspheres, weights, drilled sludge) and liquid (hydrocarbons and other water-insoluble organic liquids).

When arranging a well there is a decrease in the natural permeability of the reservoirs of the reservoir, which negatively affects its productivity. There are *the main reasons for the decrease in permeability*:

- blocking of pores by a solid phase;
- pressing the hydrocarbon phase with the filtrate of the washing liquid.

Untreated clay solutions are washing liquids used for drilling sediments in the upper part of the section, where there are freshwater aquifers in order to prevent their contamination with chemical reagents. Clay drilling mud is prepared on the basis of fresh water, which is pre-softened with baking soda, in the amount of 5-10 kg/m^3 of water. Bentonite clay powder is added to water in an amount sufficient to form a clay suspension with the required parameters.

The addition of chemical reagents to the water, which improve its structural-rheological and filtration properties, can also reduce the natural permeability of the reservoir.

In particular, *the reduction of swelling and dispersion of clay sludge is achieved by:*

- introduction into the suspension of an electrolyte containing a polyvalent cation (gypsum, calcium chloride);
- treatment of the clay solution with coagulant salts $(NaCl, KCl)$;
- adding salts of polyvalent metals that turn into hydroxides;
- treatment with highly alkaline compounds that increase the clay capacity of solutions;
- using modified lignosulfonates;
- treatment of the solution with polymeric compounds;
- addition of aluminum, iron higher fatty or naphthenic acids, which give the solution diphilic properties;
- combined treatments with the already listed compounds.

Only inhibitory solutions can increase the restoration of permeability by reducing the swelling of clays.

Highly alkaline solutions are of limited heat resistance, and the higher the colloidal nature of the rocks to be drilled, the lower the heat resistance of the solution. Chemical reagents - stabilizers in a highly alkaline environment work worse.

Clay solutions treated with carbon alkali reagent (CAR). According to the geological and technical conditions of drilling, clay solutions require adjustment of the basic parameters (density, conditional viscosity, structural-mechanical and filtration properties), traditionally humic reagents are used for this purpose. Carbon alkaline reagent (CAR) is the main source of humic and is widely used to regulate the parameters of clay solutions based on fresh or slightly mineralized water when drilling wells, the section of which is represented by stable rocks. The heat resistance of solutions treated with CAR is 80 - 100° C.

Clay solutions treated with polymers have a simple composition. Artesian water is treated with soda ash 2 - 3 kg/m^3 to remove Ca^{2+} ions and add bentonite to 40 kg/m^3. The clay suspension hydrates for 8 to 10 hours and is stabilized by the polymer up to 3 kg/m^3.

Clay solutions treated with lignosulfonate reagents are more advanced systems, they are used for washing wells in difficult geological and technical conditions of drilling. Practical use of lignosulfonates allows to solve the problems connected with stability of walls of a trunk of a well, in sections of unstable shales to depth of 6000 m. Such systems are characterized by high thermal resistance to 160° C and stability of filtration properties, both in usual and downhole conditions, at due to the creation of a dense impermeable filtration crust. The use of lignosulfonate thinners of the type (FHLS) increases the clay capacity of the systems up to 140 kg/m^3 and allows to control the relatively low rheological and structural-mechanical properties.

Clay solutions treated with lignosulfonate reagents such as KSSB; KLSM and KLST increase the stability of the system under conditions of polyvalent aggression to 3% by the content of Ca^{2+} and Mg^{2+} ions against the background of increasing mineralization to full saturation with sodium chloride.

However, on the positive factors, solutions treated with lignosulfonate chemical reagents have *disadvantages*:

- the presence of harmful (chromium and iron), dangerous (formaldehyde and phenols) substances that are part of them, limits the use in protected areas, especially in offshore drilling;

- high material consumption when using liquid lignosulfonate reagents and problems with the disposal or disposal of drilling waste;

- high content of solid and clay phases reduces the quality of the initial opening of productive horizons.

Service companies (HALLIBURTON, SCHLUMBERGER) have a sufficient range of lignosulfonate deflocculants and high-performance diluents, which are recommended for the treatment of solutions in cases where the operational reduction of structural and mechanical properties is required. The concentration of the added lignosulfonate diluent may vary from 0.5 to 1.0 kg/m^3 during a single treatment of the solutions.

Modern imported lignosulfonate chemical reagents do not contain harmful and dangerous substances and their use is permissible when drilling deep wells in Ukraine, and their high cost cannot compete with new non-dispersible inhibited polymer solutions.

Non-dispersible drilling fluids are designed to solve problems associated with complications and accidents that occur as a result of landslides and debris of clay rocks (clays, argillites, shales). Such complications lead to the greatest loss of productive time in the process of drilling a well, and sometimes ends with the elimination of the well.

These solutions are characterized by high stability of the main parameters. *The main advantages of non-dispersible systems*:

- ensuring the stability of the walls of the wellbore;
- stability of parameters and technological properties;
- the possibility of long-term storage and reuse;
- improving the quality of the initial disclosure of productive horizons;
- reduction of drilling wastewater volumes;
- solving environmental problems.

For work in the conditions of AVPD clay drilling muds are burdened, using as additives barite, ferrous and other weights. These systems are characterized by relatively low cost, a wide range of processing reagents and extensive application experience. However, the use of such solutions leads to irreversible clogging of the reservoirs, and the restoration of the permeability of the reservoirs does not exceed.

Inhibiting drilling fluids. The formation of inhibitory systems is based on the acquisition of protective properties that inhibit the hydration of clay minerals that are part of the drilled rock, wellbore walls, as well as part of the sandstone productive strata.

Polymer clay and clay-free solutions. Drilling fluids with a low concentration of solid phase - polymer clay and clay-free. A significant difference between these solutions from ordinary clay solutions is the insignificant content of the solid (clay) phase (3 - 5%) or its complete absence. The basis of these solutions are polymeric reagents. They relate to various modifications of cellulose, derivatives of acrylic polymers, biopolymers and copolymers. Polymers used for the preparation and treatment of drilling fluids are polyelectrolytes in the molecular chain of which there are different functional groups. One of the most important properties of polymers is the ability to flocculate dispersed particles of other mineralogical composition.

As flocculants of drilled rock particles use polymers released in the form of gel, liquid, powder. Mechanical and hydraulic stirrers are used to dissolve liquid and powdered polymers.

Positive properties of polymer clay and clay-free liquids:

- no or low solids content;
- high lubricating and inhibitory abilities;
- selective flocculating action relative to the dispersed phase;
- the ability to adjust the filtration properties in a wide range depending on the drilling conditions.

Carbonate drilling mud with low solids content. Polymer systems of this type with a high content of calcium carbonate (chalk, calcium carbonate) are designed for drilling wells in fields where the density of PBR 1150 - 1250 kg/m^3, when opening productive horizons, and the composition of the drilled section is represented by terrigenous crystalline (sandstones and rocks (limestones, marls). To prepare such a solution, artesian water is used, which is treated with a polymer stabilizer DEXTRID LTE, structurant BARAZAN D and encapsulant GEM GP. Marble crumb type BARACARB 5/25/50 is used to increase the density.

Weighted clay solutions. To prevent complications associated with the violation of the integrity of the wellbore and possible gas and oil manifestations, there is a need to increase the density of the clay solution in significant limits (up to 2200 - 2400 kg/m^3). It is impossible to obtain such a density by increasing the concentration of the clay solid phase and salts in the washing liquid. To do this, materials with a high density are introduced into the solutions, which are called weights, increase the density of the solution to the required values.

Weights are divided into two groups depending on their density:

- *the first group includes materials of low density - 2600 - 3500 kg/m^3* (for example, low-colloidal clays, marls, chalk, limestone, salts NaCl, $CaCl_2$). They have a low weighting capacity and can provide weighting only up to 1450 kg/m^3, with significant material consumption, which increases the solids content in the solutions and reduces the drilling efficiency. Therefore, weights of the first group are used in the absence of more efficient weights;

- *the second main group of weights includes materials with a density of 3500 - 5300 kg/m^3* (barite, iron and siderite weights, heavy salts, etc.). The most common weight is barite (crushed barium sulfate, $BaSO_4$). Barite is used to increase the density of the solution on aqueous and hydrocarbon bases. The maximum density of a solution due to barite is 2500 kg/m^3. The main disadvantage of barite is its acid insolubility, which leads to contamination of productive horizons and reduced fluid yield of productive reservoirs, especially in low-permeability and fractured formations, and requires additional operations to restore the permeability of the formation.

For better disclosure of productive horizons as weights, up to a density of 2200 kg/m^3, use heavy salts such as calcium bromide, zinc or a mixture thereof. The use of these salts provides minimal contamination of productive horizons and the possibility of almost complete restoration of permeability (up to 70 - 90%).

To weight the solution using cooking units equipped with mechanical and hydraulic mixers.

Mineralized systems of solutions. Solutions of this type are characterized by resistance to salts that enter the drilling fluid in the process of drilling layers that are saturated with highly mineralized water, as well as intervals composed of different salts (rock salt, sylvinite, bischofite).

The simplest salt-resistant solution is a saturated salt solution or highly mineralized formation water containing at least 25% salt. Clay solutions saturated with salts are used for drilling in the event that clay-free solutions cannot be used.

Hydrocarbon-based (HCB) drilling fluids are a three-phase colloidal system in which the dispersion medium is represented by a hydrocarbon substance (oil, diesel fuel, mineral oil), and the dispersed phase by mineral or polymeric reagents (organophilic clay, polymers and weights) and emulsified water.

Their use significantly improves the restoration of permeability of productive reservoirs, because their carrier medium is a liquid, physicochemical properties related to the hydrocarbon fluid, which saturates the productive formation, and thus does not create in their interaction sedentary mixtures that block the pore space.

The main advantage of hydrocarbon-based solutions compared to water-based solutions is that it has the highest effect of inhibiting clay rock and almost 100% prevents the dispersion of drilled rock and reduces the flow of solids into the solution.

The filtrate of the solution on HCB does not contain free water and is almost identical in basic chemical composition with the fluid of the productive horizon, which allows to maximize the quality of the initial opening of the productive horizon. In addition, the high content of hydrocarbons in the system provides the maximum possible lubricating and antifriction properties. The possibility of storage and reuse provide extensive use of the solution, including when drilling in difficult conditions on the shelf of the seas.

The main disadvantage of hydrocarbon-based liquids is their high cost.

The properties of drilling fluids on HCB are influenced by water-oil factor, type and concentration of emulsifier, solids content, temperature and pressure in the well.

Recently, *when washing wells using HCB solutions, mineral oil is used, which allows to form a stable*, easily controlled system, effective for practical use, both in deep and horizontal drilling of production wells, in particular:

- solutions based on mineral oil are thermally stable up to 260° C, used in drilling deep exploration and production wells;

- the use of mineral oil improves the technological properties of the solution, which allows to form a protective zone on the wall of the wellbore, which increases its stability, prevents the penetration of filtrate and fine solid phase to the reservoir, increases antifriction and lubricating properties, which is almost ideal for drilling horizontal drills. in productive horizons;

- the density of the solution can vary in a wide range from 1000 kg/m^3 in a clean system and weighted up to 2300 kg/m^3, due to the hydrophobic barite and protective mineral fillers;

- the solution is characterized by high stability in downhole conditions by filtration index equal to 8–10 cm^3 / 30 min. at a temperature of 200° C;

- the solution has high structural and mechanical properties and low rheological properties, which provides optimal conditions for well washing;

- the use of solutions for explosives reduces the risk of catching drilling tools in particularly difficult geological and technical conditions of drilling, and provides trouble-free wiring of horizontal wells with a horizontal length of more than 1000 m;

- the solution easily removes the drilled rocks on mechanical means of cleaning, especially on the first stage (vibrating screens), and demands its maximum clearing of the drilled rock and formation fluids.

- increasing the efficiency of mechanical purification of the solution allows you to control the solids content in the optimal range and maintain the stability of structural-mechanical and rheological parameters;

- the filtrate of the solution on HCB penetrating into the rock does not contain free aqueous phase or mineralized water, which reduces to a minimum the wetting of clay minerals and prevents their swelling and destabilization.

- the results of drilling wells in shale deposits with a content of montmorillonite of more than 60%, showed that clay minerals do not change the structure of the rock and preserve its natural state.

HCB solutions are prepared in enterprises without the addition of a weighting agent. The density of the finished starting product can vary from 800 to 1000 kg/m^3. Given the transport feasibility of the drilling site, it is delivered unladen. The required density of the solution on VVO is achieved at the site by adding barite and calcium carbonate BARACARB, immediately before use in the drilling process.

However, the significant cost of materials, the duration of cooking, multicomponent is inherent in the already tested hydrocarbon solutions.

Thus, it is clear from the analysis that hydrocarbon-based solutions, for all their advantages, have a number of significant disadvantages (environmental and fire hazard, toxicity), which limits their use.

Equipment for drilling mud preparation. *The design of equipment for the preparation of drilling fluids depends on the initial materials used - clays, weights and chemical reagents.*

Thus, the preparation of solutions from dry powder materials requires only thorough mixing and creating conditions for complete wetting of solid particles. For preparation of solutions from lumpy materials or damp powders preliminary crushing of pieces or stuck lumps is necessary. The processes of crushing the initial solid materials and mixing them with water are carried out in mechanical or hydraulic stirrers.

The most progressive and economical is the equipment for preparation of solutions from dry powdery materials.

Mechanical two-shaft stirrers are used for the preparation of drilling fluids from lumpy materials, as well as liquid chemical reagents. Drilling fluids in two-shaft mixers can be prepared from any lumpy materials.

High quality solution preparation is combined with low productivity. When loading the clay mixer with lumpy clay, the yield of the suspension is 2 - 4 m^3/h, and when loading the clay powder - 6 m^3/h.

On drilling two-shaft mixers are usually mounted on high wooden or steel bases. Therefore, the prepared suspension is poured into the gutter by gravity. The solid materials in the mixers are preferably fed by trolleys that move on an inclined rail by means of ropes and a system of blocks connected to the shafts of the mixer. Trolleys are loaded manually; unloading them into the receiving funnel of the stirrer is carried out mechanically.

Two-shaft stirrers are often used to prepare liquid chemical reagents from brown coal and alkali or other solid components. Small portions of drilling mud and chemicals are prepared in two-shaft clay mixers.

Lumpy clays are not currently used. When switching to dry powders, the need for two-shaft stirrers is eliminated.

The milling and jet mill MJM-3 (see Fig. 4.1) contains the following main components: rotor (2); receiving hopper (8); safety hinge plate (12); dispersing corrugated plate (1); trap (15); tray for draining the finished suspension (4), etc.

It is a machine of continuous action of relatively high productivity. Uninterrupted work is provided by mechanized loading of initial materials by the belt conveyor. In most cases, MJM is used to introduce into the solution of wet materials, in particular weights.

However, such a suspension contains solid particles and therefore requires additional mixing or repeated circulation according to the scheme "mill - tank - mill".

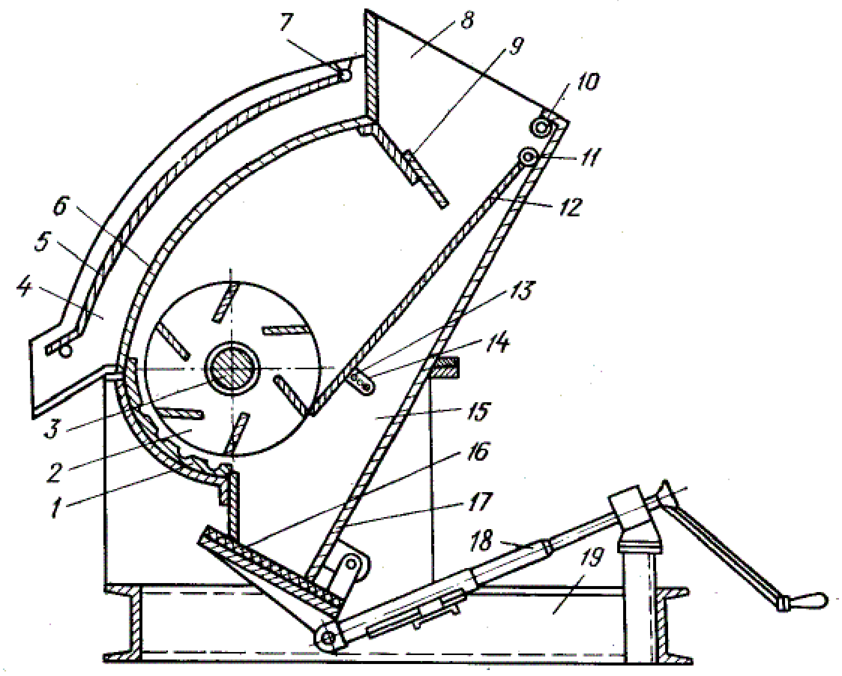
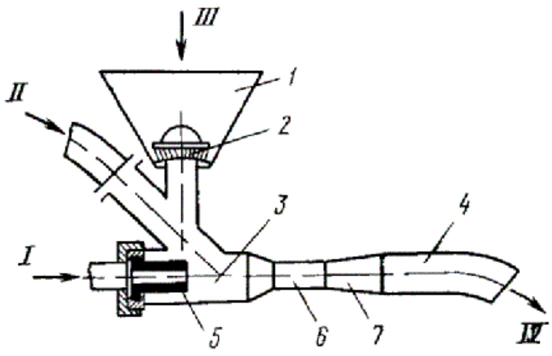


Fig. 4.1 - Milling and jet mill: 1 - corrugated plate; 2 - rotor; 3 - shaft; 4 - tray; 5 - folding shield; 6 - lattice; 7 - hinge; 8 - receiving hopper; 9 - movable rod; 10 - perforated pipe; 11 - hinge; 12 - safety plate; 13 - replaceable pins; 14 - bar; 15 - trap; 16 - rubber gasket; 17 - hinged lid; 19 – frame

Large portions of drilling mud are prepared in ***ejector hydraulic mixers*** (see Fig. 4.2) and ***special blocks for solution preparation*** (BSP). The solution is prepared from dry powders of clay, weights and chemical reagents. You can prepare the solution using cement-mixing machines. Water-based drilling mud is prepared from bentonite clay powders. Blocks for preparation of a solution, at the same time serve for its preservation. Materials in dry form are transported in appropriate containers or special transport.



Supply lines: I - liquids; II and III - powder; IV – drain

Fig. 4.2 - Hydraulic mixer: 1 - loading funnel; 2 - grid; 3 - receiving chamber; 4 - drain pipe; 5 - fitting; 6 - mixing chamber; 7 - diffuser

In a hydraulic mixer, the powder is mixed with the liquid due to its ejection by the jet of liquid coming out of the nozzle. Dry powder is loaded into the mortar preparation unit (see Fig. 4.3) (it is transported by cement trucks, which are unloaded with the help of air). To prepare the solution or to weight it, the silo powder is fed by air into a hydraulic mixer, into which the solution is fed by drilling pumps. The solution enters the tank of the circulatory system.

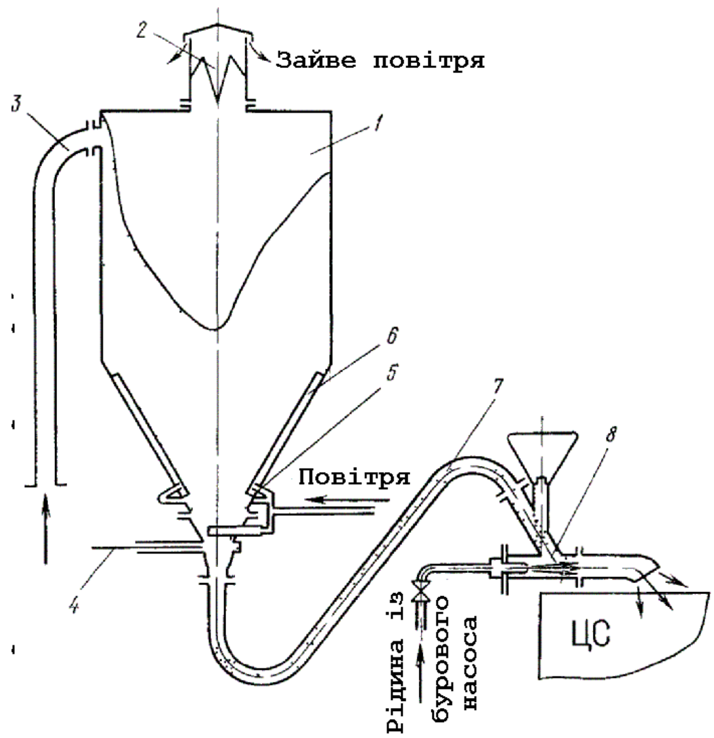


Fig. 4.3 - Block for preparation of BPR-70 solution: 1 - silo; 2 - filter; 3 - loading branch pipe; 4 - unloading regulator; 5 - air supply system; 6 - air pipes; 7 - supply hose; 8 - hydraulic mixer

The installation for preparation of drilling muds UPPZh-2 (see fig. 4.4) is intended for preparation of drilling mud from lumpy and powdery clays, weighting, chemical processing and storage of a solution on drilling rigs. Its components: car (1) with a trailer (7); paired FSM milling and jet mills (3 and 4); diesel drive (9 and 10); bucket elevator (8) with auger; tanks for diesel fuel and oil (2); piston pumps (5); centrifugal pump (6); solution storage tank. The milling and jet mill (3) is equipped with a loading hopper.

Clay, weights or chemical reagents are picked up with an auger, fed to an elevator, which delivers the starting material to the loading hopper of the milling and jet mill. Water or solution is pumped into the same hopper by pumps (5). The elevator and auger are moved to the transport position by means of two hydraulic cylinders. A bulldozer is used to load the initial materials, which periodically digs up the clay or weight to the auger. The solution prepared in the first mill is fed for better dispersion to the second mill, from where it is stored in a flexible hose in a storage tank.

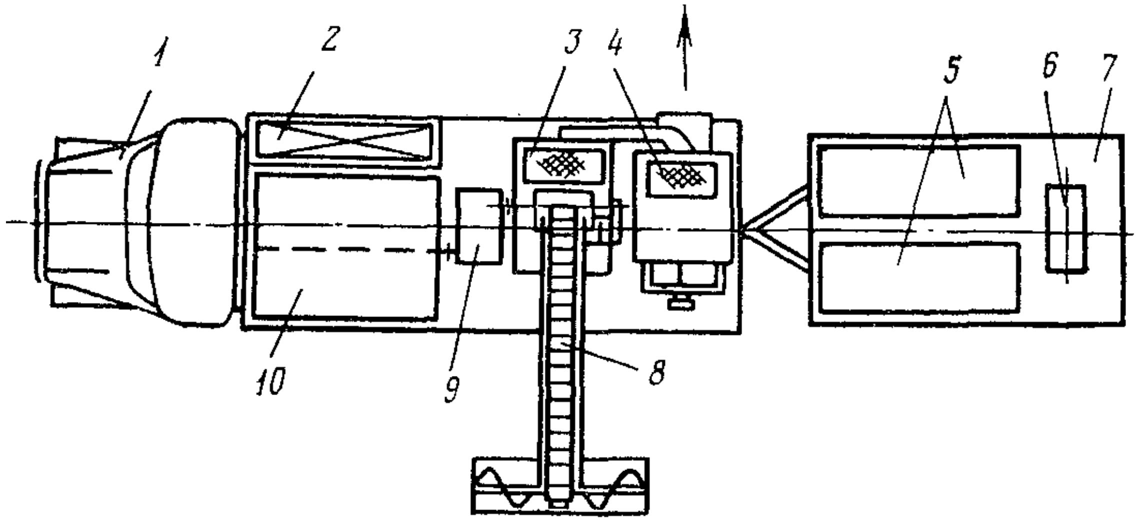


Fig. 4.4 - Installation of drilling fluids UPPZH-2: 1 - car; 2 - tanks (2) for diesel fuel and oil; 3 and 4 - paired milling and jet mills FSM; 5 - piston pumps; 6 - centrifugal pump; 7 - trailer; 8 - bucket elevator; 9 and 10 - diesel drive

Productivity of installation of 50 m^3/hour of solution, power consumption of 58 kW. In comparison with a milling and jet mill this installation has the following advantages:

- higher quality of drilling mud preparation;
- mechanized loading of initial materials.

Equipment for drilling mud cleaning. *The drilling fluid circulates in a closed system, ie the solution pumped into the well comes out of it and it should be pumped back into the well.* Therefore, the parameters of the solution coming out of the well change slightly. It already contains solid particles of drilled rock, as well as, for example, clay particles. In addition, mineralized groundwater and gas usually enter the solution. The parameters of the solution are also affected by elevated temperature and pressure. Sometimes part of the solution is absorbed in layers, and therefore in the process of drilling should be periodically added portions of fresh solution.

Therefore, the circulating system of the drilling rig is usually equipped with devices for cleaning the effluent from gas, drilled rock, sand and silt, and the purified solution is restored - brought to viscosity, density, water yield and other parameters that it had before injection into the well. Sometimes, depending on the rocks being drilled, the properties of the solution should be changed.

The equipment for cleaning the drilling mud coming out of the well must ensure not only the removal of solid particles of drilled rock, but also gas, sludge and impurities. Purification of the solution plays an important role in the drilling process. The less in the solid phase solution, the more efficient drilling.

Solid particles in the drilling fluid are divided into:

- colloidal, less than 0.02 mm in size;
- sludge with a particle size of 0.02 - 0.8 mm;
- grit with a particle size greater than 0.8 mm.

To clean the drilling mud from the drilled rock using purification systems of this solution. These systems are characterized by the number of stages of purification - up to five. The cleaning system works effectively if all stages work. If a degree does not work or does not work well, then the whole system does not work effectively.

Two types of devices are used to clean drilling fluids from drilled rock:

- devices for mechanical cleaning by means of sieves, in which the size of the particles to be removed depends on the size of the cells of the sieve;
- devices in which the separation of solid particles and liquids is carried out by centrifugal forces.

When cleaning sieves with small cell sizes, the viscous solution does not penetrate well through them, and therefore the sieves can not perform fine cleaning. In devices based on the action of centrifugal forces, particles of almost any size can be removed from the solution. Therefore, such cleaning can be called fine in contrast to the rough mechanical cleaning with sieves. Purification of the solution can also be carried out due to the natural loss of drilled rock.

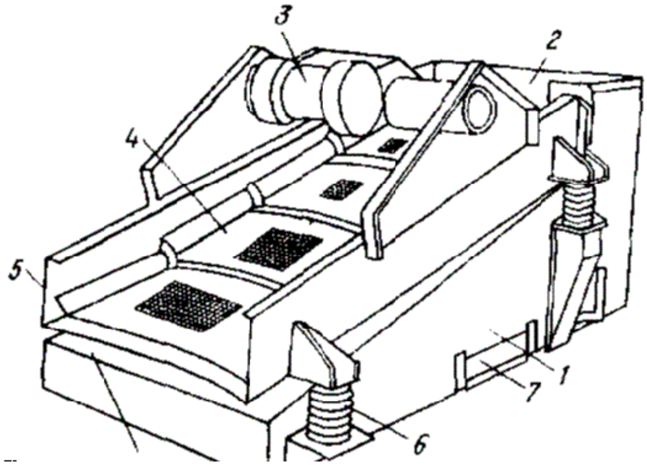
The largest particles settle in gutters or in special settling tanks. Settling tanks have a conical shape, tapering to the bottom. In the settling tanks, the speed of the drilling mud is low and the sludge particles have time to fall out. As the sludge accumulates in the lower part of the settling tank, the sludge is released. Cleaning in settling tanks can take place at a density of drilling mud up to 1400 kg/m^3. This method is especially effective when drilling in the upper intervals.

For mechanical cleaning of drilling fluids usually use ***vibrating screens****, screen conveyors, self-rotating separators.*

Vibrating screens became the most widespread (see Fig. 4.5). Vibrating screens remove particles larger than 0.25 mm.

The vibrating screen contains a frame (5) mounted on a frame (1) with a distribution chute (2) and a vibrator (3), on which the net (4) is stretched. The net is stretched on the drums with springs. The frame oscillates due to the rotation of the eccentric sinkers by the electric motor. The frame is placed with a certain inclination. The oscillations of the frame must be such that the solution passes freely through the sieve and the sludge rolls the mesh beyond it. The solution should not bounce with the net. Correct oscillations of the grid are achieved by adjusting the weight and placement of the eccentric sinkers, the number of engine revolutions. In this case, the center of the vibrating screen must move in a circle, and the extreme points behind the ellipse. The vibrating screen is completed with grids of different density with the size of cells from 0.16 mm to 4 mm. The size of the mesh cell is chosen depending on the quality of the drilling mud, the type of rock, the amount of sludge, and so on.

When drilling at shallow depths, where the mechanical speed is high and a lot of clay in the sludge, use grids with cells of at least 0.9 mm. At great depths, where there is not much sludge, use grids with cells the size of 0.25 - 0.50 mm. The capacity of the vibrating screen depends on the size of the cell. The denser the mesh, the lower the throughput of the vibrating screen.



Sludge discharge

Fig. 4.5 - Vibrating screen: 1 - bed; 2 - solution supply regulator; 3 - vibrator; 4 - grids; 5 - vibrating frame; 6 - springs; 7 - gutter

Vibrating screens are made of different designs. Vibrations of the sieve frame can be caused by an eccentric shaft or an eccentrically placed mass. To increase the throughput and the degree of purification using grids with cells of different sizes, which are placed either sequentially or one above the other (see Fig. 4.6).

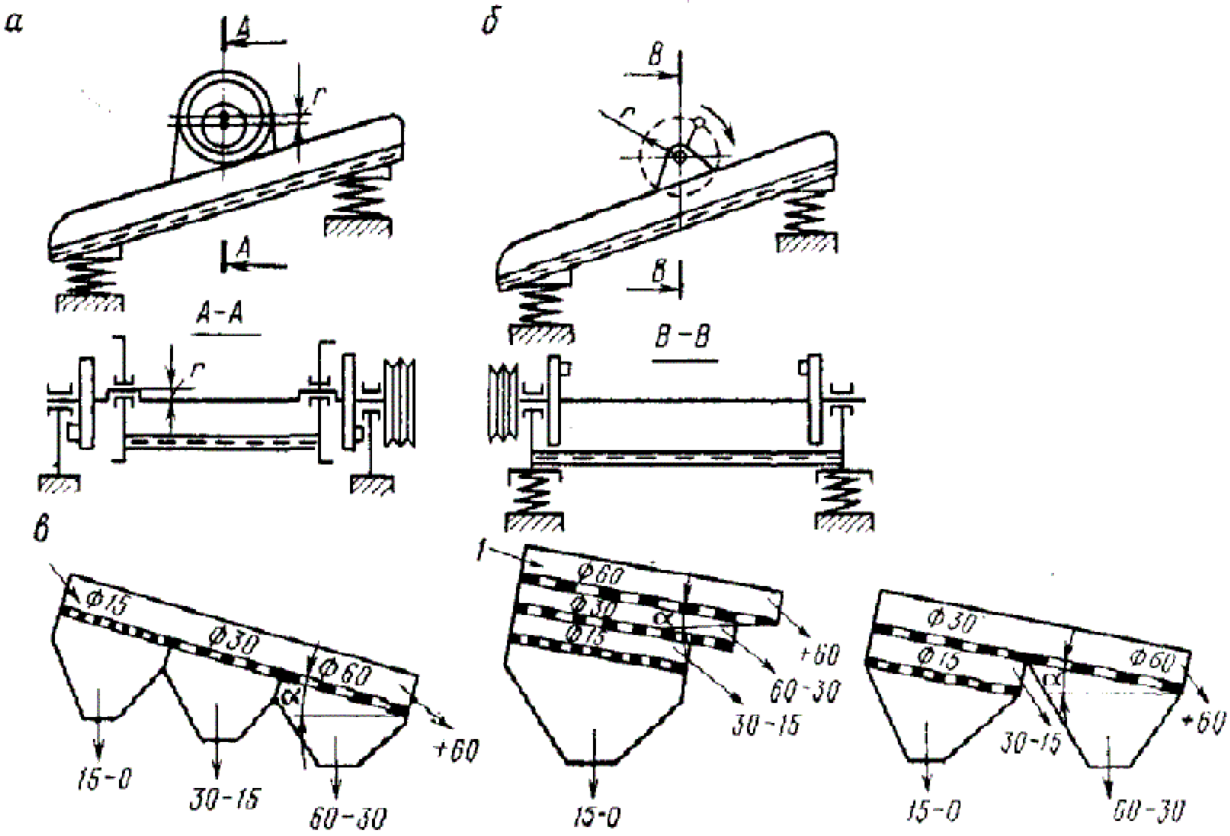


Fig. 4.6 - Vibrating screen schemes: a - vibrator with eccentric shaft; b - vibrator with eccentric mass; in - schemes of placement of grids

The fractions of the solid phase of the suspensions are separated in ***hydrocyclones and centrifuges by centrifugal forces***.

At an average density of 2.5 g/cm^3, which is usually found in rocks, in particular clays, in hydrocyclones and centrifuges, the fractions are separated by their particle size distribution. This process occurs during fine cleaning of drilling fluids from drilled rock. One fraction consists of sand and other rocks, the other - a purified solution.

Sand separators remove sludge particles ranging in size from 0.08 mm to 0.25 mm. The principle of operation of the *hydrocyclone* is that the drilling fluid is fed tangentially into the conical body, which tapers to the bottom. The solution is swirled and rotated in a hydrocyclone around the axis. Due to centrifugal forces, heavy sludge grains are concentrated on the outside of the stream, and light - in the center.

The purified solution is taken from the center. The sludge behind the conical part is lowered and it is released outside from the lower nozzle. The twisting of the solution is so powerful that air can enter the hydrocyclone through the lower nozzle.

During normal operation of the hydrocyclone from the lower nozzle sludge with the solution should come out in the form of an umbrella. The density of the pulp leaving the hydrocyclone should be 400 - 600 kg/m^3 greater than the density of the drilling fluid. The hydrocyclone works effectively at a pressure of 0.25 - 0.35 MPa. To regulate the pressure in the hydrocyclone on the outlet mount the latch, depending on the amount of sludge change the diameter of the sludge nozzle. The diameter of the hydrocyclone body for sand removal is 150 - 450 mm.

The principle of operation of the *sludge separator* is similar to the sand separator. The difference is in the diameter of the case. Sludge separators have a diameter of 50 - 100 mm. The smaller the diameter of the body, the smaller the particle size of the rock it removes. In the sludge separator, the solution rotates faster and releases smaller particles with a diameter of 44 - 74 microns from the solution. The difference in density of pulp and drilling mud should be 250 - 350 kg/m^3.

Of the above devices for cleaning drilling mud:

- vibrating screen removes 25% of sludge;

- sand separator of 20% of sludge;

- sludge separator - 35% of sludge.

Part of the drilling fluid is consumed together with the sludge. From 1 m^3 of sludge is lost:

- 1.3 m^3 of drilling mud - on a vibrating screen;

- 1.95 m^3 of drilling mud - on the sand separator;

- 3.0 m^3 of drilling mud - on the sludge separator.

The three-stage cleaning system allows to remove 90% of sludge. The performance of the equipment, ie its capacity must exceed the performance of the pumps by 20%. To do this, install two vibrating screens and two hydrocyclones and 6 - 12 sludge separators.

In weighting solutions, the fractions are separated by their density. This process occurs during the regeneration of the weight and the regulation of the composition of the solid phase.

Fine cleaning of the drilling mud is carried out mainly in hydrocyclones. They are equipped with sand separators consisting of one or more cyclones and a slurry pump.

The sand separator 1PGK (see fig. 4.7) contains: the battery of hydrocyclones (1); vertical slurry pump (4); tank (3); connecting pipe (2) between the pump and the battery. The battery contains a welded frame, four hydrocyclones, a crosspiece and four leads with rubber sleeves. The inner part of the frame is made in the form of a tray with a sloping bottom and a hatch, a gate in the front end wall. When the gate is closed, the nozzles are immersed in the sludge flowing through the upper edge of the front end wall. When the gate is open, the sludge flows freely through the hatch.

The hydrocyclone (see Fig. 4.8) contains: a metal body (1); inside it is fixed a rubber solid hollow cone (3); nozzles (5); metal drain nozzle (2); a rubber nozzle (4), which is attached to the lower end of the rubber cone by means of a flange in the nozzle and a steel ring (6). The outlet of the nozzle can have two diameters - 15 and 25 mm.

The smallest particles of rock and clay can be removed by ***centrifuges*** (see Fig. 4.9).

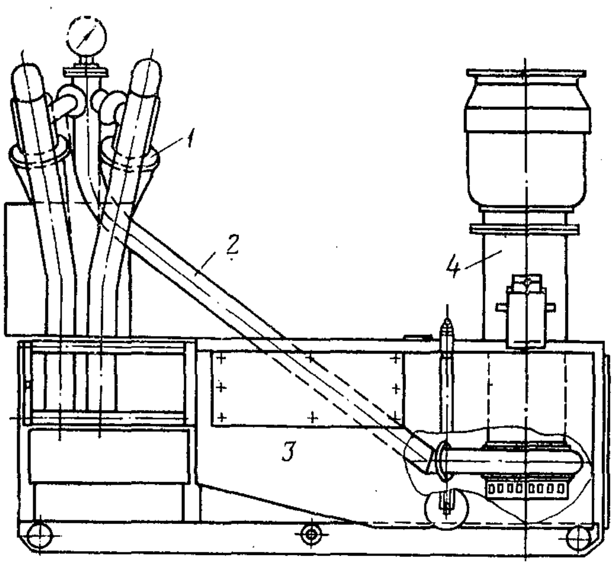


Fig. 4.7 - Sand separator 1PGK: 1 - battery of hydrocyclones; 2 - connecting pipe; 3 - tank; 4 - vertical slurry pump

The centrifuge is a horizontal drum in the form of a grid, which rotates with the number of 1500 - 4000 rpm./min. In the centrifuge, the solution acquires an acceleration that is 900 times higher than normal. Centrifuges remove particles with a size of 2 - 44 microns.

Centrifuges have low productivity. Not all drilling mud is passed through them, but only a part of it. Solid particles of the solution can be:

- low density (2500 - 3500 kg/m^3);
- high density (4200 kg/m^3).

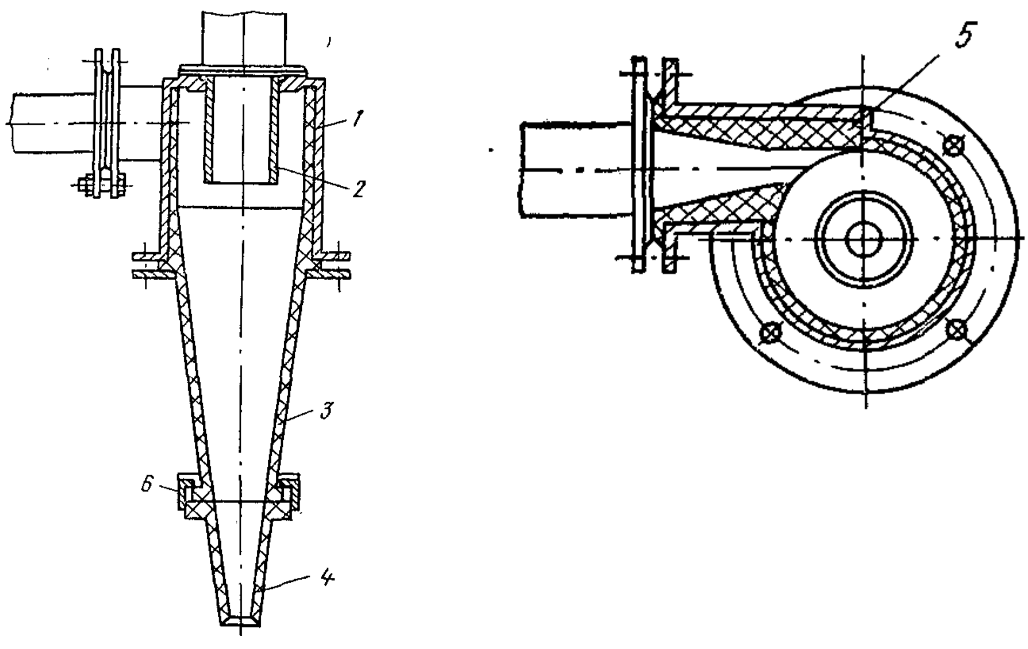


Fig. 4.8 - Hydrocyclone: 1 - metal case; 2 - metal drain nozzle; 3 - rubber solid hollow cone; 4 - rubber nozzle; 5 - nozzle; 6 - steel ring

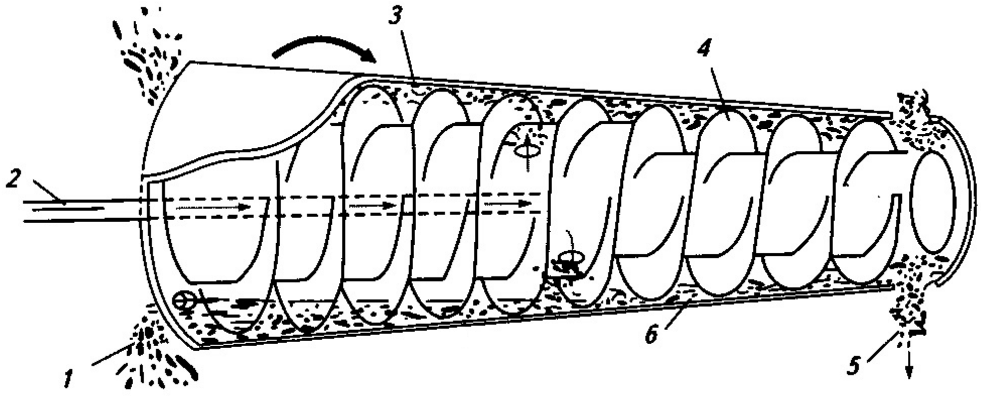


Fig. 4.9 - Centrifuge scheme: 1 - solution yield; 2 - supply of solution; 3 - rotating cylinder; 4 - auger; 5 - clay yield; 6 - solution level

Hydrocyclones remove all particles. Together with the sludge is removed and weighed. Purification of the suspended solution on hydrocyclones and centrifuges can be carried out in two stages.

First, remove all solid particles of sludge and weight. After that, the pulp containing the sludge and the weighting agent is diluted with water, passed through a mesh with small cells, through which passes the weighting agent. The weight is returned to the drilling mud, and the rock is discarded. Centrifuges are used, which remove only the weight from the solution (from 1500 rpm). Later on the next centrifuge remove the sludge, and the weighed back into solution.

Degassers are used to ***remove gases***. In degassers, the solution is passed through chambers in which a vacuum is created by a vacuum pump.

The degasser (see Fig. 4.10) contains two identical halves, which work alternately.

The drilling mud enters the degassing chamber through the gutter or from the tank through the suction valve. After creating a vacuum, the parameters of which are regulated by the regulator, and raising the level in the chamber to the spool level regulator, the discharge valve switches the vacuum pump to the second chamber. In the process of creating a vacuum in the second chamber, the degassed solution is poured into the gutter. Then the process is repeated.

To the vacuum pump

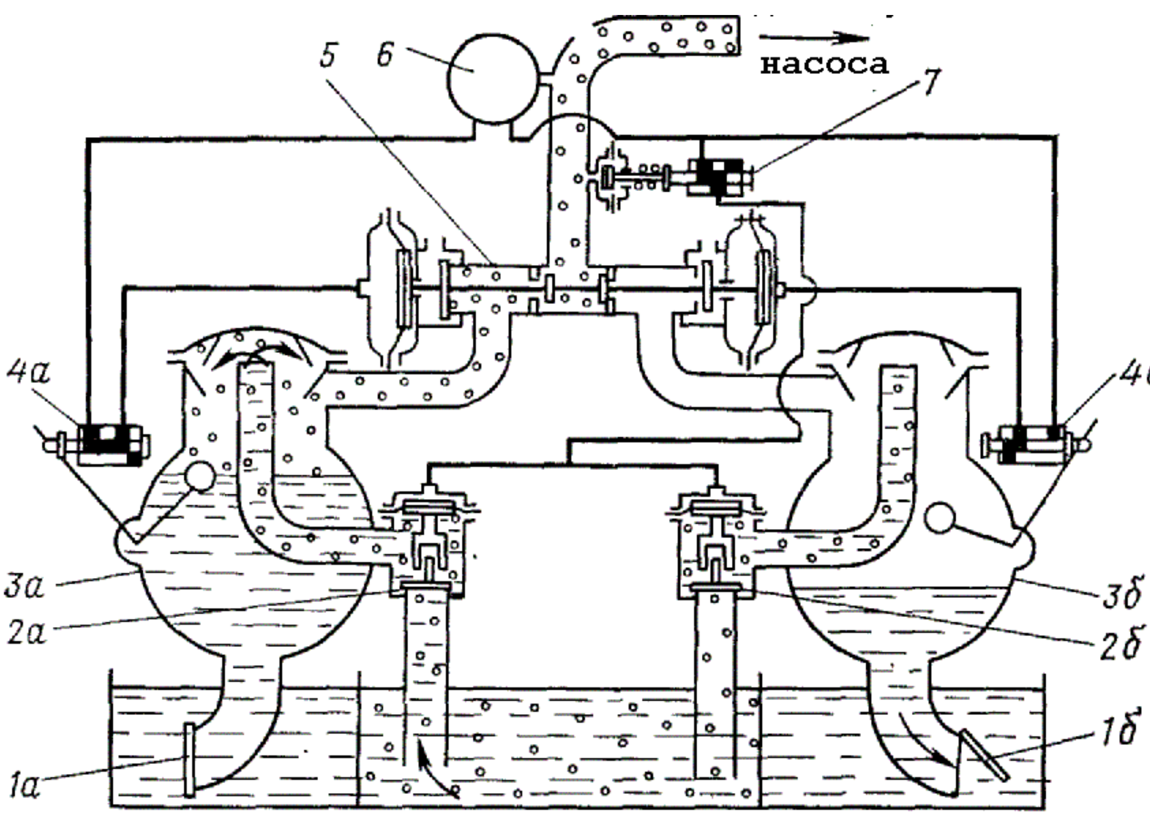


Fig. 4.10 - Vacuum degasser: 1 - drain valve; 2 - the suction valve; 3 - degassing chamber; 4 - spool of the level regulator; 5 - the valve the arrester; 6 - vacuum receiver; 7 - vacuum regulator

Lecture 5. Fastening of wells. Well constructions. Cementing of wells

The main task of the borehole is to create a reliable connection of the productive formation with the earth's surface. Usually the well reveals a number of layers. Productive formations have different properties, for example: oil, gas and aquifers with different formation pressure and permeability. Operation of all layers at the same time is impossible. Some of them are flooded faster, others later. Therefore, a reliable separation of these layers is required.

Hence, ***the purpose of well cementing***:

- to provide long-term isolation of productive objects from the neighboring horizons with formation waters and from the earth's surface to prevent the destruction of the field;
- prevent the movement of liquid and gas outside the column;
- to fix unstable breeds by fastening them with a cement stone;
- prevent the release of gas in the well under high pressure;
- isolate productive horizons for temporary conservation, which is not yet included in the development;
- isolate aquifers used for water supply;
- prevent casing destruction due to corrosion;
- fixing the casing from displacement.

Separation of layers includes two stages:

- fastening of a well by metal pipes, so-called screwing among themselves in continuous casings;
- actual cementing of the well.

During drilling, there is a need for *intermediate fixing of the wellbore until the well reaches the design depth*. Therefore, before drilling, *a program is developed, according to which the well is attached to the casing*. *This program is called **well construction***.

In the design of the well indicate:

- diameters of the bits with which the well will pass;
- length of pipes for assembly of casings;
- diameter of pipes for a complete set of casings;
- thickness of walls of pipes for a complete set of casings;
- steel grade pipes for casing assembly;
- data on column cementation.

Casing columns have different purposes:

- the first short column, descending to a depth of 5 - 15 m, is called *the direction - serves to secure the mouth from erosion by the flow of solution, it is lowered to the first stable deposits*. Drilling of a trunk under the direction is usually conducted by digging of mine under the direction of the corresponding depth, but seldom - by drilling. The biggest problem in establishing the mine direction is the prevention of its washing, ie the exit of the solution out of direction and ensuring its verticality and coaxiality with the hole of the mounted rotor. Therefore, it is carefully centered and built up. When drilling at sea, this column is lowered to the bottom of the sea. It insulates the well from the water column and is called a riser;

- the second column - *the conductor* - for overlapping of unstable top deposits, isolation from pollution of horizons with drinking water, sealing of a well at oil and gas displays, suspension on the mouth of the following columns. The conductor descends to a depth of 40 - 50 m, and sometimes - 500 m or more, depending on the section of the well. It is generally accepted to lean the conductor on the roof of chalk deposits. Consideration of the conductor is given considerable attention, given the need to preserve sources of drinking water;

- the last column - *operational* - for the extraction of oil and gas, injection of various agents into the productive layers.

When drilling, there may be mutually unacceptable conditions, for example, in some formations - the absorption of drilling mud, in others - the manifestation of formation fluid. Drilling mud of different densities is required to open these intervals. To create favorable drilling conditions, to provide reliable conditions for the opening of productive horizons, *intermediate columns* are lowered.

Some intermediate columns, and sometimes operational, do not reach the mouth. They fix only the lower, not lined, open part of the well. Such columns are called secret or *shanks*.

By the number of columns of the structure are:

- *single-column*, when the intermediate columns are not lowered;
- *two-column*, when lowering one intermediate column;
- *multi-column*, when lowering several intermediate columns.

The lower end of the column (a short, thick-walled piece of pipe, often in the form of a casing coupling) is called *a shoe*.

The diameter of the production string depends on the purpose of the well, the method of operation of the well and its flow rate.

Exploration wells are designed mainly only for testing horizons, complete with production columns with a diameter of 140 - 146 mm, and sometimes 127 mm. Exploitation of wells is also practiced.

Production columns in production wells must ensure the descent into the well of the necessary operating equipment, repair work. Pipes with a diameter of 168 and 178 mm are usually used as production columns, and in the case of high flow - 194 mm. Pipes with a diameter of 140 and 146 mm are also used, in particular, for oil wells.

The number and depth of intermediate columns is determined from the drilling conditions. A combined graph of the formation (pore) pressure gradient and the fracturing pressure gradient (absorption) is constructed.

The formation pressure gradient (fracturing) is the ratio of the corresponding pressure to the depth of its occurrence, determines the maximum and minimum density of drilling mud for a certain interval. It is determined by formulas

$$k_n = \frac{P_{пл}}{\rho_в g H} \qquad (5.1)$$

or

$$k_{гр} = \frac{P_{гр}}{\rho_в g H}, \qquad (5.2)$$

where P_{pl}, P_{gr} - pressure, respectively, formation and fracturing, Pa; H is the depth corresponding to the specified pressure, m; g - acceleration of free fall, m/c^2; $\rho_в$ - density of fresh water, kg/m^3.

Fracture pressure and formation pressure (MPa) are determined according to industrial data or calculated, in particular, based on empirical dependence

$$P_{гр} = 0{,}0083H + 0{,}66P_{пл}\ . \qquad (5.3)$$

The graph of changes in depth gradients (for an example of such a graph, see Fig. 5.1) *identify areas of possible joint opening of horizons* by drawing parallel lines between the minimum value of the fracture pressure gradient and the maximum value of the formation pressure gradient.

Intermediate casings are also lowered to differentiate different compositions: salts from fresh sediments; sediments prone to edema or with floating properties; zones of very unstable rocks, etc. It is taken into account that increasing the length of an unfixed wellbore causes a complication of the wellbore.

The length of the unfixed wellbore is called the exit from under the column. In the general case, with increasing magnitude of the output from the column increases the percentage of accidents, complications, drilling fluid consumption, and so on. In the case of long-term drilling in the unfixed wellbore there are *cavities - the expansion of the wellbore in unstable deposits.* Over time, the sludge and clots of the solution fill the cavities. This complicates the drilling process.

Analysis of the frequency of accidents and the cost of drilling mud shows the presence of their degree dependence on the magnitude of the output from under the column. Securing the shaft with a column dramatically reduces such negative phenomena and creates more favorable conditions for successful drilling.

Take into account that the complexity of the wellbore depends on the duration of drilling in it. *The introduction of highly efficient drilling technology, high-quality chisels and drilling fluids, high organization of work, can reduce the need to lower the intermediate casing.*

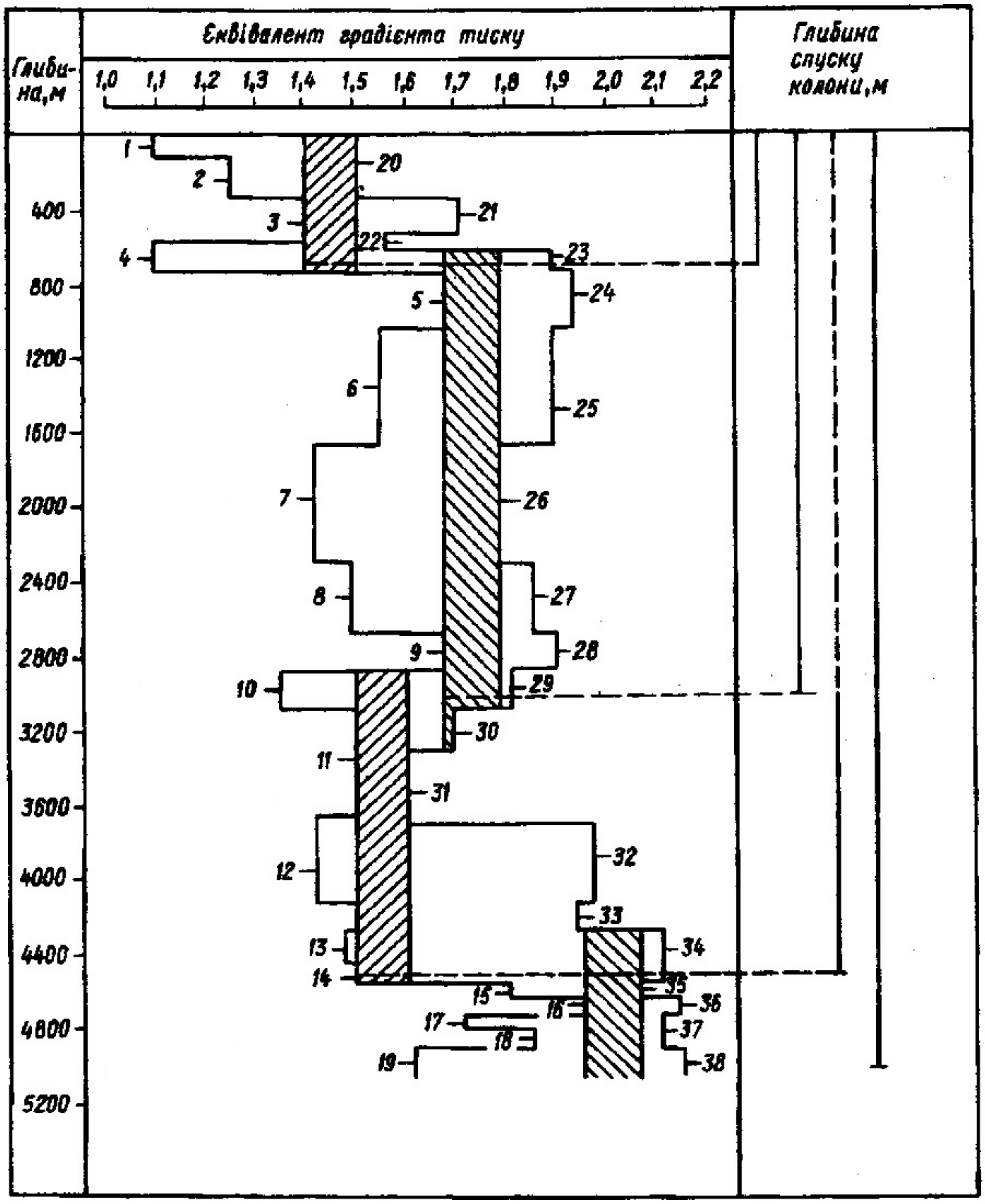


Fig. 5.1 - Example of a combined pressure graph:
1 - 19 and 20 - a38 - sections of the well with the same
reservoir gradient and fracturing pressure, respectively
Note: Areas with compatible drilling conditions are shaded

The intermediate column, which is lowered before the opening of productive horizons, is used to seal the well in case of oil and gas development and emergency gushing. The depth of the shoe of the column is assigned so that the fracturing pressure of the sediments below the shoe was greater than the pressure of the fluids during oil and gas manifestations and gushing.

$$L = \frac{P_y}{\rho_p - \rho_\phi} \quad , \tag{5.4}$$

where R_v is the expected pressure at the mouth, MPa; ρ_p - hydraulic fracturing pressure gradient, MPa/m; ρ_ϕ is the gradient of the hydrostatic pressure of the column of degassed drilling mud or formation fluid in the well, which is taken for:

- water - 1.08 10^{-2} MPa/m;
- oil - 0.745 10^{-2} MPa/m;
- gas - 0.11 - 0.35 10^{-2} MPa/m.

Also take into account the operation of the column during drilling. During long-term operation, it sometimes works in such a way that it no longer provides sealing of the well. This is either taken into account when choosing the wall thickness of the pipes, or lower the additional column before opening the productive layers.

After that *substantiate diameters of columns and chisels at drilling. The minimum required radial clearance between the casing coupling and the well wall depends on the stiffness of the column, the depth of its descent, the curvature of the well.* Its value is usually taken in the range of 10 - 15 mm for columns with a diameter of 140 - 168 mm and 45 - 50 mm for columns with a diameter of 377 - 426 mm. This gap can be reduced by using more rigid bottom configurations, which include weighted large diameter drill pipes and calibrators.

The wellbore, drilled with one bit without calibrators, has not a perfect round shape, but a polygon shape, because the bit rotates in the well not strictly around its axis, but with a certain eccentricity. In addition, the wellbore often changes direction when moving from one rock to another. Centering the bottom of the drill string brings the shape of the barrel closer to the circle and reduces changes in its direction. The gaps can also be increased through the use of casing with a reduced diameter of the couplings, couplingless casing, the use of expanders. This allows you to lower the columns of larger diameter. The diameter of the bit is determined from the expression

$$D_д = D_м + 2\delta \, , \tag{5.5}$$

where D_d is the diameter of the bit, mm; D_m - diameter of the coupling, mm; δ is the recommended clearance, mm

Then choose the diameter of the next column. The gap between the bit and the inner diameter of the casing is usually 2 - 4 mm.

Casing designs. *Casing pipes are coupling and coupling-free*. In coupling casings, couplings are screwed to the body of the pipe to connect these pipes to the column. *Couplings are of normal diameter and reduced*.

Couplingless pipes are made without thickening the ends for threading (for example, type OG-1m), or with the landing of the upper end in the form of a socket, where the coupling part of the thread is cut, or with partial landing of one end. There are structures with partial landing and inside.

According to the profile of the thread, the casing is made with *a round (triangular) thread*. The thread is short and elongated. Round threads are leaky. The strength of the thread is less than the strength of the body of the pipe, so now it is practically not used. *Threaded trapezoidal threads* have become popular. The profile of these threads is different. The most common profile (OTTM, Batres), in which the upper side of the coil is inclined at an angle of 3o to the transverse plane, and the lower 10o. The pitch of the thread is 5.08 mm (5 threads per inch).

During the fastening of the well, it is necessary to ensure the tightness of the threaded connections. The threads are sealed by applying a lubricant after screwing. The most common sealing of threads due to the contact of a special form of sealing surfaces "metal - metal", which are made on pipes and couplings in the manufacture of OTTG, VAM, BDS (see Fig. 5.2).

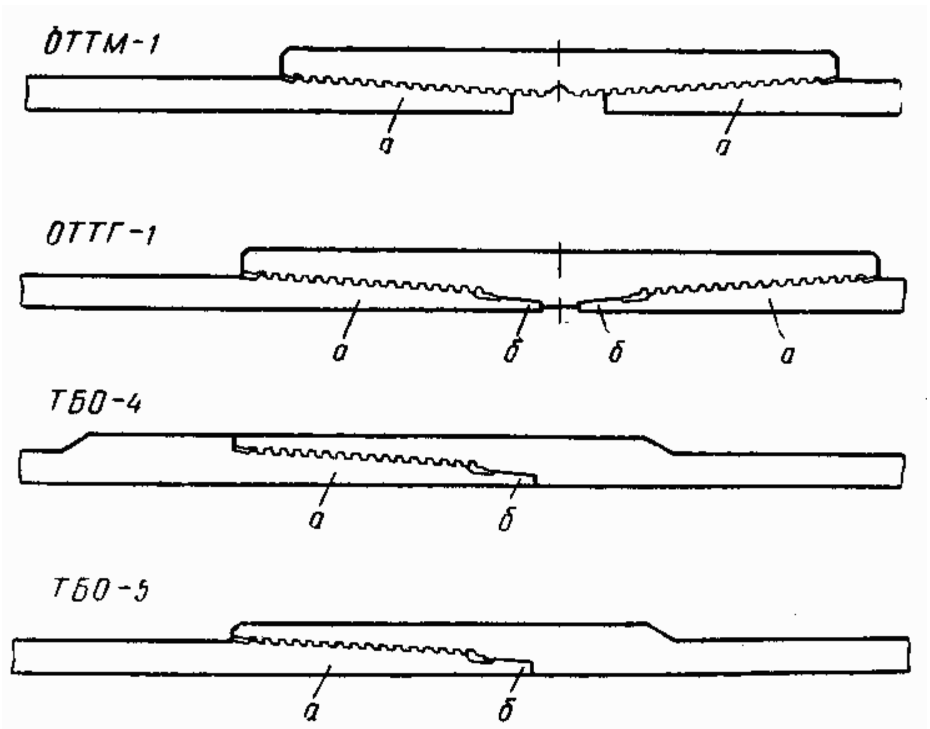


Fig. 5.2 - Designs of casings: a - thread; b - seal

At the end of the pipe (where the thread ends) is equipped with a conical or barrel-shaped recess, which enters the corresponding recess in the coupling. Seals are achieved by resting the end of the pipe in the recess of the coupling. The surfaces have a certain tension, which ensures the density of the cut. The taper of the casing threads is mainly 1:16, but there are others.

Expanding pipes. When choosing the design of the well, it is advisable to reduce to a minimum the number of columns, because for each additional column should increase the diameter of the bits and previous casings. In difficult geological conditions (in particular, drilling at sea), the well has up to 9 casings. Expandable pipes are often used to preserve the previous diameter of the bit after the descent of the next casing. After the descent of the next drilling string is drilled with a bit with an expander, which forms a wellbore larger than the diameter in the previous column. When the depth of descent of the next column is reached, the casing is lowered from the expandable pipes. Immediately after the cement is pumped, they are expanded. The expanding cone mechanically deforms the pipe forever. The cone is moved along the pipe under the action of pressure transmitted to the cone through the drill pipes from the surface, or by mechanical force up or down. As a result of the passage of the cone there is a plastic deformation of the walls of the pipe at stresses higher than the yield strength, but less than the strength of the pipe material. The degree of expansion with a change in inner diameter should reach 25%, and usually casing should be expanded by less than 20%.

At the bottom of the shank of the expandable pipes fix the launcher, which has thinner walls. The wall thickness of the device is less than the nominal deviation of the inner diameter of the previous column, which allows you to lower the device through this column. In the upper part there is a suspension device with an elastomeric coating, which is sealed in the previous casing. After the expanded pipe has an outer diameter larger than the outer diameter of the trigger, and the inner is equal to the inner diameter of the trigger. This technology uses expandable systems for shanks in the open trunk, expandable systems for casing trunks and expandable devices for shank suspension.

The use of expandable pipes allows to preserve the diameter of the wellbore, eliminates the need for a special shank suspension and packers, provides a better seal of the annular space, it is possible to strengthen the casing during its repair, and so on.

There are the following expansion systems:

- system of axial expansion "from top to bottom". The expansion tool includes a fixed tip for initiating the expansion and movable axial rollers to complete the expansion. The pistons push the rollers when changing the profile of the barrel;
- expansion system at low axial load with rotation at low rolling friction force. Suitable in the presence of narrowings of inner diameter, because it can pass through the narrowing. You can extend individual intervals;
- hydraulic expansion system.

Preparing the well for the descent of the column. The casing is larger in diameter than the drilling tool, when lowering the column is limited opportunities to eliminate obstacles. The well cannot be drilled. It is rare for a casing to be lifted out of a well without complications. Therefore, the well is carefully prepared for descent.

Before lowering the casing in the well perform a set of electrometric and other research work to ensure the mounting process.

The strength of the intermediate columns and the preventers installed on them when drilling a well in areas with hydrogen sulfide and on the continental shelf should ensure the closure of the mouth with open gushing.

Analyze the condition of the well. Determine the places of complications, existing narrowing of the trunk, areas of shedding, gutters. These zones are determined according to geophysical studies and the behavior of the well during drilling. If the bottom layout, which was used when drilling insufficient rigidity, the well is calibrated with more rigid layouts. The rigidity of the bottom layout must match the rigidity of the casing. Drilling of a trunk is carried out in intervals of narrowings, and calibration - on depth of descent of a column at uniform giving of a bit and washing with the same productivity, as well as at drilling.

Particular attention is paid to the elimination of seals in the trunk. Before lowering the column, check the absence of seals with a cavernometer. Before the descent of the column, it is desirable to remove the sludge from the well. Before lowering the column, it is advisable to check the absence of plugs in the barrel control descent of the bit. The descent of the column must take place without delay.

Before the descent of the column check: the foundation; the base of the tower; tower and its centering; condition of fastening of elements of a tower; efficiency of suspension of machine keys; free access to the mouth; winch; her reason; engines; brake system; fastening of a crown block; condition of the hoisting rope; drilling pumps; clean receiving vats, etc.

Casing columns are lowered into the well in one step (usually) or in sections, ie in parts. It is allowed to lower the columns in two sections when using docking devices compressed before lowering into the well at a pressure that ensures the test of the column for tightness.

The lower section of the column is lowered on the drill pipes. They are connected to the casing on the left thread. After cementing, the cement residues are washed through special holes, and after the cement hardens, the drill pipes are unscrewed from the casing. The following sections are joined to the lower section.

Lowering the column sections is used to reduce the load on the drilling machine when lowering heavy casing, reducing the duration of the column descent and thus preventing well complications, reducing the height of cement rise behind the casing to prevent absorption of cement mortar and occurrence of overflow flows. Reducing the height of the cement is achieved by cementing the column in parts, in two steps with a cementing coupling, which is installed at the design height. Cementing the column in parts is called *stepwise*.

The depth of joining of sections is chosen in the previous casing. The depth of installation of the coupling for step cementing or the joining device is determined on the condition that when the cement mortar hardens, it absorbs water and reduces the pressure on the layers. Reducing the pressure leads to the flow of gas into the well and the manifestations of gas in the dental space. The installation depth of the coupling is determined by the expression

$$H = \frac{102P_{пл} - L\rho_в}{\rho_p - \rho_в}, \tag{5.6}$$

where R_{pl} - formation pressure, MPa; L - depth of the roof of the formation, m; ρ_p, $\rho_в$ - density of drilling mud and water, g/cm^3.

Reducing the pressure on the layer during the hardening of the cement is achieved by creating and maintaining excess pressure in the annular space.

Casing equipment (see Fig. 5.3). The bottom of the column is equipped with a ***guide plug***, which serves to guide the bottom of the column behind the wellbore, prevents stops at the end of the column on the ledges. The guide plug is cast iron (the most reliable, so it is used for inclined wells) and concrete.

The cast-iron guide plug is screwed, and the concrete one is made together with ***the shoe of the column*** (thick-walled elongated coupling with a chamfer under 45o to direct the bit and other tool into the column when lifting; prevents the destruction of the end of the column when lifting the drill string). The concrete plug is easily destroyed. Holes closed with diaphragms are made in the concrete shoe above the guide plug. These holes make it possible to resume rinsing in the event that the central hole is clogged. For this purpose the filling branch pipe established above a shoe also serves.

A non-return valve is placed above the shoe in the next threaded connection (to prevent backflow of cement after cementing). If the column is kept under pressure (in an inflated state), a gap may form between the pipes and the cement after the pressure is reduced. For better contact of cement with the column, it makes sense to reduce the pressure in the column as much as possible after cementing, so that the cement hardens in this position. Check valves are used only in the direct method of cementation. They prevent sludge from entering the column. Behind the column there is an upward flow of solution, which prevents the accumulation of sludge at the end of the column and its stop. The gap between the wall of the well and the casing is small. The non-return valve prevents the overflow of drilling mud through the pipes during their descent into the well because the resistance to the movement of the solution into the column is less than outside the column. Check valves use plate, in which the saddle and plate are made of cast iron.

TsKOD type check valves (see Fig. 5.4), in which the overflow of the solution during descent is prevented by throttling through a rubber diaphragm, and before cementing a plastic ball is thrown into the column, which is pushed through the diaphragm and split washers, after which the ball prevents backflow of drilling fluid.

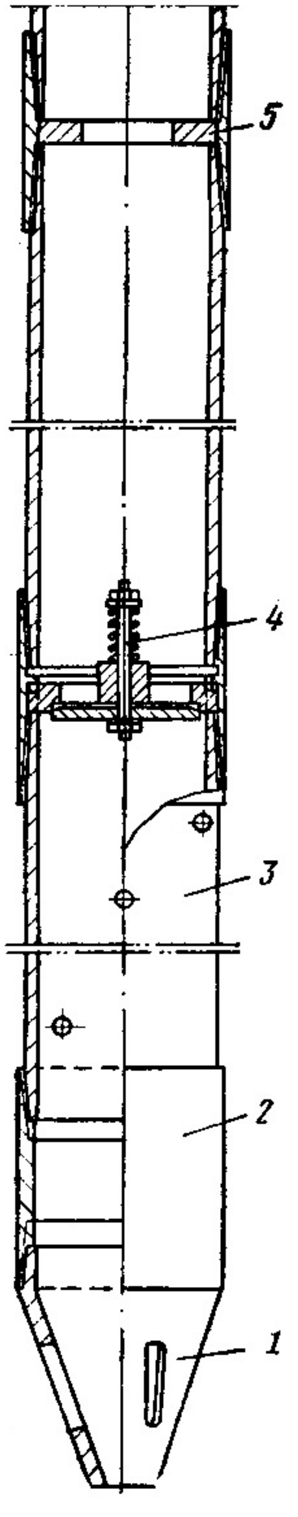


Fig. 5.3 - Laying of the bottom of the casing: 1 - a directing stopper, 2 - a shoe; 3 - filling branch pipe; 4 - check valve; 5 - thrust ring

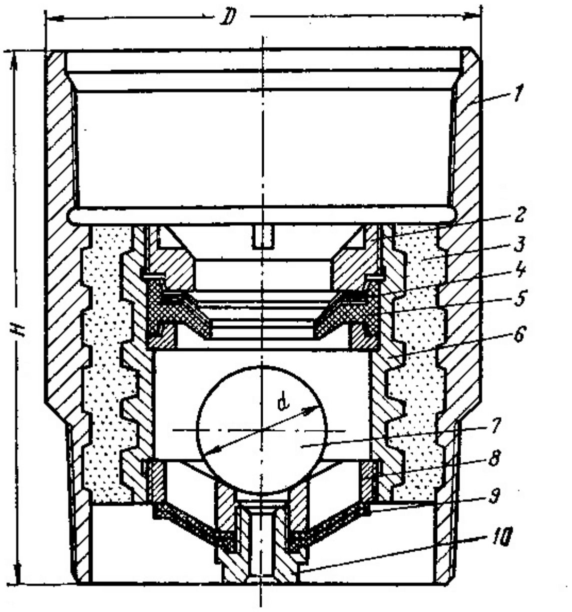


Fig. 5.4 - CCOD check valve: 1 - housing; 2 - push nut; 3 - suspension (concrete or plastic); 4 - split washers; 5 - rubber diaphragm; 6 - cast iron bushing; 7 - plastic ball; 8 - limiting ring; 9 - rubber-fabric membrane; 10 - throttle

Calculation of casings. A number of loads act on the casing. Their combination depends on the operation carried out in the well, the state of development of the field, and so on. The column is subjected to tensile or compressive load, compressive and internal pressure, bending moment, etc. Tensile load arises from the own weight of the column, the internal pressure created in the column, the reduction of the column from lowering the temperature in the well, due to the heavier solution in the pipes compared to the annulus, the friction of the solution during movement through the column. Compressive loads occur when unloading the column on the face, on the cement stone, on the "head" in the well, the compressive load due to the presence of a heavier solution in the pipes compared to the solution in the pipes.

The compressive pressure is caused by formation (pore) pressure in the deposits covered by the column, the action of rock pressure from rocks that tend to leak or swell, the presence of a column of drilling and cement mortar, water, gas and oil behind the column, creating pressure behind the column from the surface, heating and the expansion of the fluid behind the column.

The internal pressure is created by the action of fluids coming from the formation, the pressure created from the surface in a closed well, the pressure of the cement mortar column when cementing the next column, the drilling mud column, which drills the well under the next column, heating and expanding fluid in the column.

Bending stresses occur when the column passes through the places of change of the direction of the wellbore, bending from unloading the column and compressing it due to thermal expansion.

The action of these forces is assessed in certain specific periods of construction and operation of the well, when performing certain operations, and so on. The resulting action of tensile or compressive axial load, internal or compressive pressure from the simultaneous action of compressive and internal pressure at the same time, as their difference

$$P_р = P_в - P_з , \tag{5.7}$$

where P_r is the resulting pressure; $P_в$ - internal pressure; P_z - external pressure.

To simplify the calculations, graphs of the dependence of external, internal and resulting pressures on depth are constructed. The combined effect of pressure and axial load on the column should also be taken into account. The presence of internal or external pressure affects the value of the allowable tensile load and vice versa.

Cementing of wells. *Cementing of casings is carried out for*:

- ensuring long-term isolation of productive objects from neighboring formations with formation waters and with the earth's surface to prevent the destruction of the field.
- prevention of liquid and gas movement outside the column;
- consolidation of unstable rocks by strengthening them with cement stone;
- prevention of gas emissions from formations in which it is under high pressure;
- isolation for temporary conservation of productive horizons, which are not yet included in the development;
- isolation of aquifers used in water supply;
- preservation of the casing from the effects of corrosion;
- fixing the casing from moving.

The intervals of lifting the grout on the casing are determined by the technical design for the construction of the well and are usually:

- behind the conductor - to the wellhead;
- for intermediate columns of oil wells with a design depth of up to 3000 m, taking into account geological conditions, but not less than 500 m from the shoe of the column;
- for intermediate columns of exploration, prospecting, parametric, reference and gas wells (regardless of their depth) and oil wells with a design depth of more than 3000 m - to the wellhead;
- for production columns of oil wells, taking into account the overlap of the shoe of the previous column not less than 100 m. The same condition applies to gas and exploration wells when performing measures that ensure the tightness of casing. In all other cases, the grout must rise to the wellhead.

If there are zones of intensive absorption in the section of wells for raising the cement mortar to the planned height, the use of step cementing with the use of special couplings, solutions of reduced density, etc. is envisaged.

Among *the methods of cementing* should be noted:

- *direct method*, when the cement mortar is pumped into the column and pushed behind the column;
- *the reverse method*, when the cement mortar is pumped directly behind the column.

Direct cementation of the column is performed by:

- in one event;
- several measures, ie steps with a gap in time;
- two or more sections.

When *cementing the column, a buffer liquid is pumped in one step* before the cement mortar, the *lower plug* is lowered into the column, followed by the cement mortar, the second plug, the buffer liquid and the pushing liquid. The lower plug prevents the displacement of the cement mortar with the drilling fluid, which is important when cementing columns of large diameter. When cementing columns of large diameter, the heavy cement mortar overtakes the light drilling mud due to the difference in their density and mixes with it, which reduces the quality of cementation. The lower plug has a central hole closed by a diaphragm. Upon reaching the stop ring, the diaphragm collapses at low pressure, and the cement mortar passes freely through the lower plug into the annular space.

For cementing columns of large diameter is used for a similar task, cementing columns through pipes, which are specially lowered into the casing. These pipes are used to pump the cement mortar and push it through the pipes, which reduces the mixing of the cement and reduces the amount of pushing.

When *cementing steps*, the column at the calculated height from the face is equipped with couplings for cementing steps. The installation depth of the coupling is assigned similarly to the joining of sections when lowering the column in parts. After the buffer fluid, the cement mortar intended for lower stage cementation is pumped into the pipes, the first pressure plug is introduced, the volume of liquid equal to the volume of the casing from the shoe to the coupling is injected, the second plug is passed and the cement mortar is forced. The first plug must pass freely through the coupling, and the second sits in the coupling on the saddle, cuts the pins of the sleeve that closes the flushing holes, moves the sleeve down and opens the flushing holes in the coupling. Through these holes, the drilling fluid washes the well. The return movement of the cement pumped back into the column is prevented by check valves or by fixing the first plug in the stop ring. After hardening of cement of the first stage cement the following stage. In this case, the plug, which is started by the cement mortar, closes the flushing holes in the coupling, which ensures the tightness of the column. After cementing, the plugs and sockets of the coupling are destroyed.

Cementation of columns, which are lowered by sections, is carried out as follows. The section of the column on the drill pipes is lowered to a certain depth and the well is washed. Before the cement mortar, pump buffer liquid, cement mortar, inject a parachute plug into the drill pipes, inject the drilling mud into the volume of the casing, insert the next plug and push. The first punch plug sits in a suspended plug mounted in the device for joining sections and moves with it behind the column. After injecting a volume of mortar equal to the volume of the drill pipes, the second plug reaches the docking device, cuts the pins, opens the flushing holes in it, which allows you to wash away the remnants of excess cement that has risen behind the drill pipes. After the column is suspended with the help of a special device in the previous casing or on the cement stone after the cement hardens, the drill pipes are unscrewed and lifted. Lower the next section of the column. The upper section of the column is cemented in one step. The sections are joined before cementing or after cementing, depending on the design of the docking device.

The reverse method of cementing has a number of advantages. In the direct method of cementing, the first portion of the cement mortar passes through the entire well from top to bottom, and then from bottom to top. The properties of the cement mortar must meet the conditions at the face and mouth. In reverse cementing, the cement mortar passes only downwards and it is possible to select the cement mortar formulation separately for the face, and separately for the conditions at the mouth. With reverse cementation, it is possible to fill the annular space to a greater height by reducing the pressure on the layers due to the lack of hydraulic losses and thereby reducing the risk of absorption of cement mortar. In the process of cementing, less pressure is created on pumps and cementing units. The time of cementing operation is reduced. There is no stage of pushing the solution. Mixing of cement and drilling mud takes place in one zone.

The disadvantage of this method is the lack of an exact way to determine the end of the cementing process. The first portion of cement that covers the productive horizons must be of the highest quality. To prevent intensive overflow of drilling mud from the pipes, the column is equipped with a cast iron throttle diaphragm with a central hole with a diameter of 50 - 80 mm, which is installed 8 - 10 m from the shoe of the column. After the descent of the column, the well is first washed by direct washing, and then switch to reverse. First, 4 - 5 m3 of signal buffer fluid is pumped into the column, it is forced with drilling mud in the volume of the casing, minus 1.5 volumes of buffer liquid, which is pumped before the cement mortar and the volume of cement glass in the column. The end of the cementation process is determined by the output to the mouth of the entire volume of the signal buffer fluid.

To control the position of the cement in the well, the first portion of cement marked with radioactive material is used, and a device that registers the appearance of this portion of cement near the shoe of the column is lowered into the casing.

Standard cement is produced according to GOST 1581-96 unified with the American standard 10A. In Ukraine, it was put into operation under the code DSTU BV.2.7.-88-99. The standard, in particular, provides for the following cement:

- I - without impurities;
- I-G - without impurities with normalized V / C = 0.44;
- I-H - without impurities with normalized V / C = 0.38;
- II - with mineral impurities;
- III - with impurities that regulate the density of cement mortar (light, density 1360 - 1640 kg/m^3, heavy - density 1960 - 2340 kg/m^3).

At the temperature of wells in which cement is used, it is made for:

- low temperatures from -5^o C to + 15^o C;
- normal temperatures - from 15^o C to 50^o C;
- moderate temperatures from 50^o C to 100^o C;
- high temperatures from 100^o C to 150^o C.

Tamponade cement is obtained by firing clinker (a mixture of limestone and marl before sintering the components at a temperature of 1450o C) and its subsequent grinding. Chalk and limestone form calcium oxides, and clay and marl form alumina and iron oxides. Gypsum is added to the cement to create the structure and initial strength of the cement stone. Also add slag, tripe, crucibles, sand, ash. Standard grouting cement contains calcium oxide CaO - 60 - 67%, silica SiO2 - 17 - 25%, alumina - Al2O3 3 - 8%.

In addition to the standard types of cement mortar are produced: light OCG, OSHC, heavy UCG-1, UCG-2; slag and sand for high temperatures SHPTSS-120, SHPTSS-200; weighted slag cement USHTs-120, USHTs-200; low hygroscopic cement for long-term storage in conditions of high humidity, heat-resistant cement, gypsum-alumina cement for elevated temperatures, etc.

Cement is used in aggressive environments. *According to the degree of aggressiveness of the substance is placed in order to reduce the aggressiveness*:

1. gaseous hydrogen sulfide at high (above 10 MPa pressure);
2. magnesium salts (chlorides are more aggressive than sulfates);
3. dissolved hydrogen sulfide;
4. dissolved carbonic acid;
5. sulfides of basic metals;
6. sulfates (at low temperatures);
7. carbon dioxide;
8. calcium chloride at a concentration above 20 g/dm^3;
9. formation waters with pH <6
10. sodium chloride at a concentration above 100 g/dm^3.

Cement mortars are characterized by the following parameters:

- *water-cement ratio* - the ratio of the mass of water to the mass of cement, for ordinary cement - 0.38 - 0.60;

- spreading (determined on the AzNDI device by the diameter on which the sample of cement mortar spreads on the plane) for standard grouting solutions - 18 - 25 cm;

- the beginning and end of hardening of cement (determined using a needle Vika) - for the beginning of hardening take the time from the beginning of dissolution of cement to the moment when the needle reaches the bottom by 1 - 2 mm, and for the end of hardening take time for which the needle stops loading cement more than 1 mm (tests are carried out at a temperature of 22 + -2oC or 75 + - 3oC);

- sedimentation resistance (water release) - release of free water from the cement mortar;

- the strength limit of cement stone (testing of cement beams measuring 40x40x160 mm for compression and bending);

- rheological properties.

The properties of cement are regulated by various additives.

Buffer fluids *are used to prevent mixing of drilling mud and cement mortar and more complete displacement of drilling mud.* Water, on which cement is dissolved, is most often used as a buffer liquid. Water dissolves the clay crust on the walls and reduces the viscosity of the drilling fluid. Chemical solutions are often used, which reduce the filtration of drilling mud, reduce its viscosity. High-viscosity, elastic mortars are also used to completely displace the drilling fluid. If necessary, the buffer fluid is weighed to prevent pressure drop on the productive layers. It is advisable to use both low-viscosity and high-viscosity buffer fluids. The volume of buffer fluid is calculated depending on the volume of cement and drilling fluid, specific geological and technical conditions in the well, etc. The volume of the buffer fluid is usually 3 to 10 m^3.

Equipment for cementing columns. Preparation of cement mortar is carried out with the use of cement mixing machines and cementing units.

Cement mixing machines are equipped with a hopper for transportation and storage of cement. Cement is prepared in an ejector mixing funnel. The liquid in which the cement is dissolved is fed into the funnel by a cementing unit. Cement units CA-320, which are designed for the preparation of cement have a special water pump that takes water from its meter and feeds it into the funnel. With another pump, the unit selects the prepared solution and feeds it into the well. The capacity of measuring tanks of these units is 6 m^3. The capacity of the measuring tanks of the two units is enough to dissolve 20 tons of cement. High pressure pumps for cementing units can create a pressure of 32 to 100 MPa depending on the type of unit.

The BM-700 *manifold block* is used to bind the cementing units together and with the wellhead. The unit is used to receive the finished cement mortar from the units and direct them to the cementing head. The block of manifolds also serves for providing units with water and pushing liquid. A cementing head is used to connect the manifold block to the casing. Plugs and balls are pushed into the cementing head. They are held in the head on pins. When you need to release the plug, the pins are unscrewed, and the plug with a special line from the units, pushed into the column. This line is connected only to push the plug. Prior to that, she is free not to sell the cork in advance. Two lines lead to the head from the manifold block, which ensures work in the presence of gaps in one of them.

To improve the homogeneity of the cement mortar is also used *averaging containers*. The tank is equipped with blades that mix the cement mortar and increase its homogeneity. In the case of using averaging tanks, the cement mortar is fed into the well after cooking, and already from it is fed through a block of manifolds into the well.

Lecture 6. Oil and gas development, absorption and other complications

Oil and gas development is the most severe and dangerous complication in the drilling process. They lead to *open fountains*, which cause great damage to the environment and damage to the state.

Most often, oil and gas manifestations occur due to a decrease in pressure on the formation, but can be formed without this factor.

Among the reasons are the following:

- *penetration of gas into the well together with the drilled rock;*
- *penetration of gas into the well by osmosis through the filtration crust of the drilling fluid;*
- *gas penetration due to capillary flows;*
- *gas penetration due to gravitational substitution*.

Such reasons create danger at long action of these factors, ie leaving of a well without washing for a long time.

The reasons for the decrease in pressure on the formation are usually divided into *geological and technological*.

Geological causes of oil and gas development are most often caused by:

- opening of the zone of abnormally high formation pressure, which is not provided by the project;
- opening cavities filled with gas, for example when drilling limestone;
- gas supply through tectonic cracks from greater depths and under higher pressure.

The technological causes of oil and gas manifestations usually include:

- low density of drilling mud compared to the design;
- drop in the level of drilling mud in the well;
- reduction of pressure in the well due to the hydrodynamic effect;
- formation of artificial zones of abnormally high formation pressure due to gas flow from the lower layers to the upper ones;
- reduction of pressure in the well due to contracting of cement.

The decrease in the density of the drilling fluid is mainly due to the following reasons:

- insufficient study of the conditions of well drilling and formation pressure distribution;
- installation of baths (oil, water, acid) to eliminate seizures of the drill string from low-density fluid;
- deviation from the requirements of the project in terms of the density of drilling mud;
- topping up the well when lifting the drilling tool or in case of absorption, with a solution of lower than required density;
- treatment of drilling mud with liquid chemicals of low density;

- the use of large volumes of water to wash the drill pipes and cable when lifting them from the well.

The reasons for the decrease in the level of drilling mud in the well are often:

- underfilling of the well during the lifting of the drilling tool (the volume of the raised drill pipes should be compensated by topping up the drilling mud);
- underfilling of the well during long downtime of the well (the volume of the solution that is filtered into the rock must be compensated by topping up);
- clogging of flushing holes in the bits of downhole engines when lowering the drill string, and then their release;
- destruction of the non-return valve of the drill string during its lowering and leveling of the solution levels in the pipes and annular space;
- absorption of drilling mud due to incorrectly selected well design;
- too high density of drilling mud due to its excessive weighting or due to insufficient cleaning of the mud from sludge;
- fracturing due to high speeds of lowering pipes into the well;
- hydraulic fracturing due to the occurrence of the seal;
- fracturing due to high viscosity of drilling mud;
- incorrect elimination of entrapment by reducing the level of solution in the well.

Due to the hydrodynamic effect, the pressure on the formation is reduced in the following cases:

- lifting of pipes with an epiploon;
- lifting pipes with a siphon;
- high pipe lifting speed with high drilling fluid viscosity and small gaps between drill pipes and well walls;
- lifting pipes with a packer;
- lifting pipes in an untreated well.

The vast majority of oil and gas development is characteristic of lowering and lifting operations or the start of drilling due to underfilling of the well. The success of the *elimination of oil and gas significantly* depends on its timely detection.

There are *characteristic signs of oil and gas*:

- increase the productivity of the solution at the exit of the well;
- increase in the volume of the solution in the receiving vats;
- reducing the density of drilling mud due to degassing;
- the volume of solution required to top up the well during lifting is less than the volume of raised drill pipes;
- the volume of solution displaced from the well during the lowering is greater than the volume of the lowered pipes;
- the movement of drilling mud along the gutter in the absence of flushing was recorded.

There are also *indirect signs of oil and gas development and approach to the zone with abnormally high pressure*:

- *increase in mechanical speed of drilling* (the breeds which are under the big pressure, break more easily; internal pressure helps a bit to destroy breed);

- *increase in torque on the rotor during drilling* (torque increases due to greater penetration of the teeth of the bit into the rock);

- *reducing the pressure on the pumps and increasing the weight of the drill string by reducing the density of the drilling fluid in the annular space* (when light fluid enters the drilling fluid from the formation, the density of the drilling pipe decreases ;

- *the appearance of gas in the drilling fluid according to gas logging stations* (such stations are specially installed to control the content and composition of gas entering the drilling fluid, which helps to identify productive horizons and prevent manifestations);

- *increase in the amount of sludge* (layers with high pressure are destroyed faster, which causes landslides and increase in the amount of sludge on vibrating screens);

- *change of parameters other than density, drilling mud* (viscosity may increase due to the ingress of gas into the solution; filtration - due to the ingress of salt water from the reservoir; oil content - due to its inflow from the reservoir);

- reduction of the d-exponent is a dimensionless coefficient, which with normal rock compaction gradually increases with depth (the zone with abnormally high formation pressure is characterized by less rock compaction and lower d-exponent). the d-exponent is calculated for the entire depth of the well during drilling by expression

$$d = \frac{1{,}26 - \log \dfrac{V}{N}}{1{,}58 - \log \dfrac{P}{D}}\ , \qquad (6.1)$$

where V is the mechanical speed; N is the number of revolutions of the rotor; P - load on the bit; D is the diameter of the bit.

Plot a graph of the change of the d-exponent with depth and predict *the value of reservoir pressure by decreasing* it;

- an increase in the temperature of the drilling mud may also *indicate the approach to the zone with abnormally high formation pressure*;

- when approaching the zone with abnormally high formation pressure, *the electrical resistance of clays decreases* (they are more saturated with salt water).

To seal the well in case of oil and gas occurrence and prevent open gushing, a column head is mounted on the casing, and on the column head - ***anti-ejection equipment***, which consists of *preventers and their strapping*.

Preventors are die, which have dies for drill pipes and deaf dies, which close the well in the absence of drill pipes and universal, sealing the well in any configuration of pipes in the well. At the same time control of preventers is usually hydraulic with manual duplication.

The plate preventer (see Fig. 6.1) contains a housing (1), dies (2), side covers (4) with hydraulic cylinders (7). Covers are attached to the body on cast hinges. The rod is made together with the piston (8) and has a T-shaped protrusion under the die at the end. The screw (10) is screwed into the piston (8), passes through the cover of the hydraulic cylinder, and the other end with a square cross section, connected to the manual drive. In the case of offshore drilling and hydrogen sulfide deposits, cutting dies are used, which cut the drill pipes and seal the well.

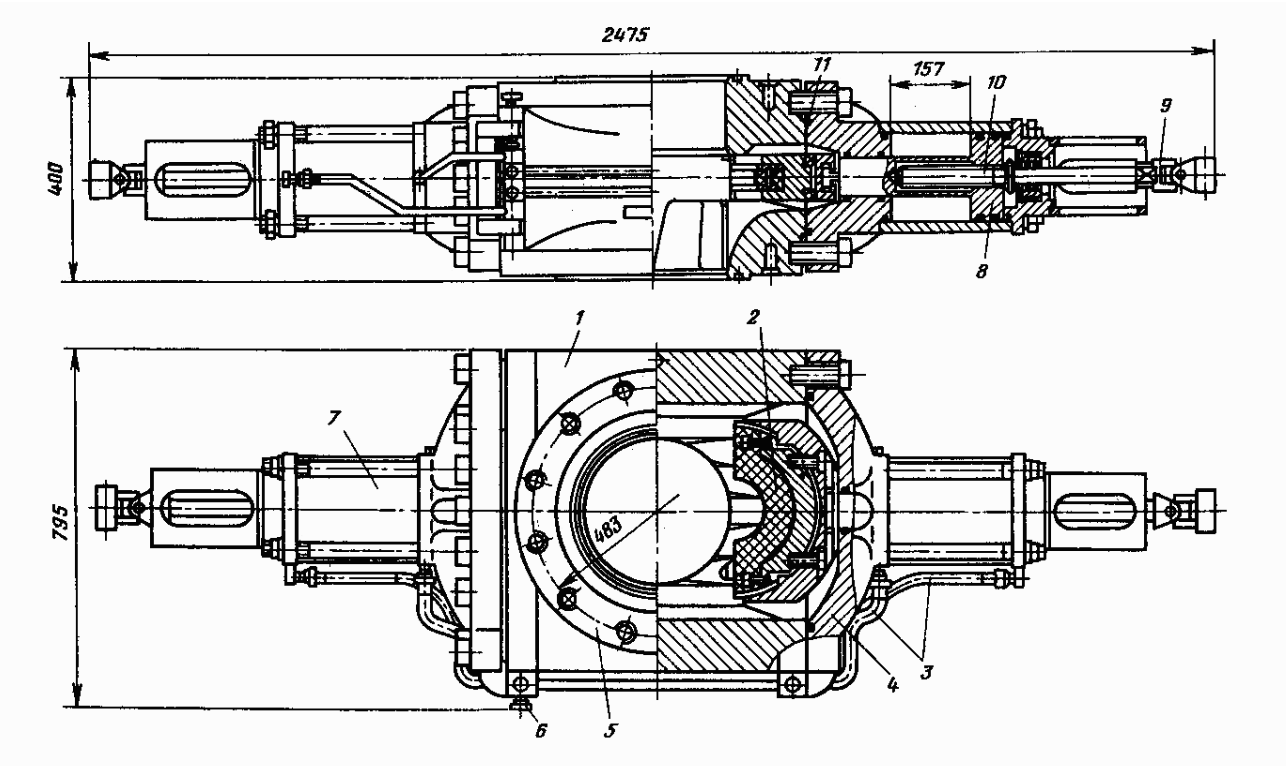


Fig. 6.1 - Spot preventer: 1 - housing; 2 - die; 3 - oil pipeline; 4 - side cover; 5 - flange; 6 - plug; 7 - hydraulic cylinder; 8 - the piston; 9 - fork; 10 - screw; 11 - seals

The universal preventer (see fig. 6.2) contains the case (7). the cover (9), which is screwed into the housing, the plunger (5), which when supplying oil through the lower supply compresses the annular seal (6). When oil is supplied through the upper supply, the preventer opens. The preventer allows to move pipes at the closed condition with regulation of pressure of oil.

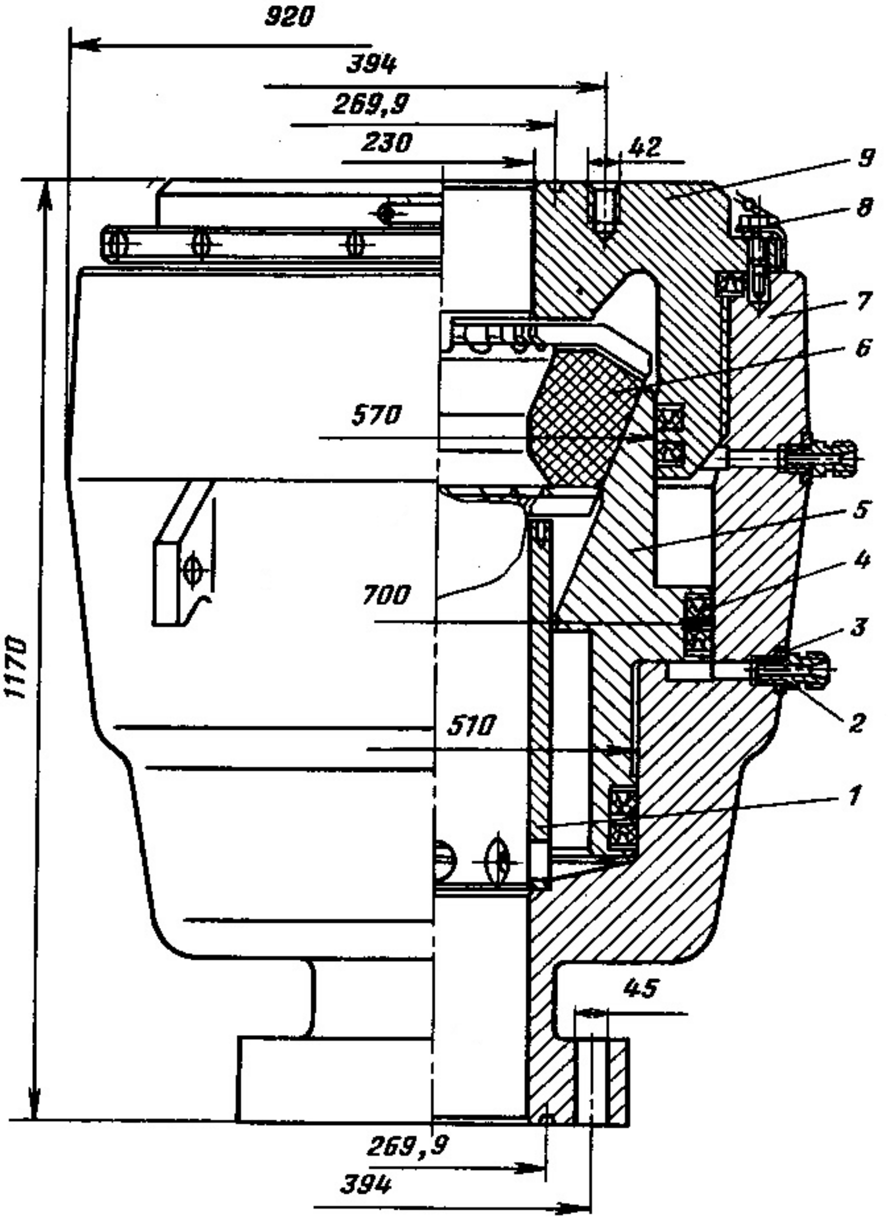


Fig. 6.2 - Universal preventer: 1 - bushing; 2 - fitting; 3 - sealing ring; 4 - cuff; 5 - plunger; 6 - annular seal; 7 - housing; 8 - limiter; 9 - cover

Measures to prevent oil and gas development:

- in the process of drilling should be maintained in accordance with the design density of drilling mud and other parameters;

- when calculating the density should take into account the vertical depth of the roof horizons in inclined wells, constantly monitor the condition of the well, no overflow during downtime, increase productivity and volume of solution in receiving tanks during drilling and the volume of solution that goes to refill or displaced during lowering and lifting operations;

- for enhanced control, the drilling rig is equipped with level gauges on the vats, flow meters on the manifold and at the well outlet, gas logging stations or drilling control stations, which continuously record the parameters and signal their deviation;

- geophysical surveys should be carried out regularly, the structure of the reservoir and formation pressures should be specified, the density of drilling mud should be specified, the possible opening of the zone with abnormally high formation pressure should be controlled by calculating the d-exponent according to geophysical researches and other measures;

- the drilling crew must have the skills to quickly and correctly seal the well in case of oil and gas;

- In order to successfully combat oil and gas leaks, it is necessary to have serviceable anti-ejection equipment and a reliable casing on which it is mounted.

The list of specific measures is specified depending on drilling conditions and danger of manifestations.

There are *measures to be taken depending on the type of work in the well*:

- in case of development, plans are developed for sealing the well, which outlines the responsibilities of each member of the watch;

- work on sealing the well during the process of direct drilling is carried out in the following sequence:

  - stop flushing the well;
  - install a ball valve under the square (in its absence in the process of raising the drilling tool at 0.5 - 0.8 m above the rotor) and securely fasten the winch brakes;
  - install an elevator under the drill lock coupling
  - check the position of the latches on the harness of the preventers;
  - all valves that pass the drilling fluid to the degasser must be open;
  - open the hydraulic valve near the cross of the preventer on the throttle unit and close the universal preventer or the top with dies for drill pipes;
  - the latch on the degasser is closed and within 5 - 10 min. monitor the pressures at the mouth and drill pipes;
  - at certain pressures further determine the course of silencing the well;
  - these pressures determine the pressure in the formation, the required density of drilling mud, which fluid (oil, gas or water) came from the formation, for example, if the value of the density of the fluid is less than 360 kg/m^3, the gas flow is obtained at a density of 1080 - 1200 kg/m^3 - water, and at 700 - 800 kg/m^3 - oil.

Fluid behavior in the well. Oil and water entering the well and rising upwards expand little. When they appear on the surface, they are removed from the drilling fluid. The gas that enters the well expands when it rises and the pressure drops. The expansion saw further reduces the pressure on the formation. After that, the layer works with even greater intensity. If you do not seal the well in time, it leads to its gushing. If you close the well, the gas spontaneously rises up the drilling fluid. Failure to allow it to expand will increase the pressure in the well. Upon reaching the mouth, the gas will increase the pressure at the mouth to the reservoir. The gas rises up the drilling fluid at a speed of 300 m / h. If the well is not closed, the gas expands and increases in volume in proportion to the pressure in the well. At the mouth of an open well, it expands so many times, so much formation pressure exceeds atmospheric. Gas cannot be left in the well for a long time. It must be washed out of the well as soon as possible.

Depending on the conditions, different *methods of well silencing* are used. So with *the two-stage method of silencing* the operation of silencing consists of two stages: 1) wash the fluid from the well; 2) pump the weighed drilling mud of the required density. The fluid is washed out, maintaining a constant pressure on the drilling pumps (the sum of hydraulic pressure losses, the pressure recorded after closing the well and another 0.5 - 1 MPa). After washing the fluid, the pressure in the pipes during the injection of drill pipes with drilling mud is gradually reduced to the tic of hydraulic losses during washing with a weighted drilling mud.

In the continuous method of silencing the well is carried out in one cycle, by injecting into the well a weighted solution of the desired density.

In the method of waiting and weighting, first prepare a solution of the desired density, and then wash the fluid with the weighed drilling mud.

The stepwise method of well silencing is used when it is not possible to achieve complete removal of fluid at one time due to unacceptably high pressure at the mouth, which is unacceptable for the casing. In the first stage, only the volume of fluid flow decreases.

Each method calculates the expected nozzle pressures during gas leaching, plots the pressure versus volume of the injected solution, and develops appropriate maps.

The reasons for the transition of gas manifestations into an open fountain. The oil and gas manifestation turns into an open fountain when the well cannot be closed. This is due to inconsistencies in the design of the well or the scheme of strapping the mouth to the geological conditions of drilling, deviations of the actual design of the well in the depth of descent columns and their strength from the design, violation of installation technology and rules of explosion-proof equipment etc. Improper drilling of wells to close the well and violation of well control technology in the process of liquidation of oil and gas oil can also cause open gushing.

Mortar absorption is the output of drilling mud from the wellbore to the reservoir in an amount that exceeds the cost of the well to fill the well, fill the cracks formed near the wellbore and filter the solution into the reservoir.

To filter the drilling mud into the formation, it should be permeable to at least 325 D, because less permeable layers clog. The main reason for such acquisitions is the opening of cracks by the well and fracturing. In permeable rocks, the solution that got into the crack is filtered into the formation. In the case of hydraulic fracturing of dense rocks, the solution may return when the pressure is reduced.

There are the following signs of absorption:

- reduction of injection pressure;
- reducing the output of drilling mud from the well;
- reducing the volume of solution in the circulatory system;
- increase the mechanical speed of drilling;
- failures and jamming of drilling tools.

Also identify the most common causes of takeovers:

- absorption in cavernous, hollow, fractured, loose rocks;
- incorrect installation of the casing shoe, when the fracture pressure of the formation is less than the value of the pressure in the well;
- too fast lowering of pipes and creation of hydrodynamic fluctuations of pressure;
- vibration of pipes;
- narrowing of the trunk;
- excessive productivity of pumps in the process of washing;
- a sharp challenge to the circulation with a high structure of the solution and without prior destruction of the structure;
- shedding of the trunk and increase in the density of the solution due to the significant volume of sludge;
- accumulation of sludge in the well during drilling due to insufficient cleaning of the solution and insufficient performance of the pumps;
- formation of plugs and seals in the well;
- insufficiently qualified elimination of oil and gas manifestations;
- high viscosity of the solution;
- thick clay crust;
- high density of drilling mud.

To prevent takeovers at the design stage it is necessary:
- to determine in the section of the well the zone of weakened rocks prone to fracturing;
- calculate fracturing pressure gradients and formation pressures;
- to determine the allowable limits of changes in the density of drilling mud during drilling and cementing, which provide prevention of absorption and manifestations, taking into account pressure losses during the movement of the solution in the annular space;
- to develop measures to increase the pressure gradients of fractured weakened formations;
- develop measures to reduce the hydrodynamic pressure in the annular space of the well above the absorption zone;
- calculate the boundaries of incompatible drilling intervals and choose a rational well design;
- select the appropriate values of the gaps between the outer diameter of the casing and drill string and the well wall;
- choose the formulation of drilling fluids that fix the walls of the well;
- choose rational layouts of the bottom of drilling columns and drilling methods;
- calculate the regime-technological parameters that ensure drilling of the well without complications;
- calculate the required capacity of pumps, etc.

The following measures to prevent takeovers during drilling are well tested:
- to start drilling only after bringing all the parameters of the drilling fluid to regulatory requirements;

- constantly monitor the quality of drilling mud, the values of its rheological parameters, compliance with their regulatory requirements;

- timely treat the solution with chemicals that reduce hydrodynamic losses;

- systematically measure the parameters of the drilling fluid, in particular, the following:

- density after 15 minutes;

- temperature at the outlet of the well and the content of free air (gas) after 30 minutes;

- drainage, crust thickness, static shear stress (shift) after 1 hour;

- measure in the laboratory the presence of oil in the drilling fluid, alkalinity and stickiness of the crust at least twice a week;

- not to allow excessive weighting of the drilling mud, to maintain its density at the level of the lower permissible limit;

- in the process of processing the drilling mud to prevent sharp fluctuations in its parameters;

- to ensure complete degassing of the drilling mud and its purification from sludge;

- to recalculate the value of the density of gassing drilling mud, which is measured at the outlet of the well to its actual value;

- not to allow deviation of the actual density of drilling mud from the norms provided by more than 20 kg / m3;

- before starting the drilling pumps to diverge the tool with its rotation; to restore circulation by one pump with simultaneous raising of the tool on length of a working pipe and gradual overlapping of the latch on emission, and to connect the second pump after restoration of circulation and decrease in pressure;

- in the process of drilling periodically tear the bit from the bottom of the well and make a bottomhole zone;

- before building the wellbore to work on the length of the working pipe and to achieve free movement of the tool from the face;

- before lifting the tool, flush the well for at least one cycle;

- 50 m to the absorption zone to switch to the rotary drilling method, reduce the diameter and length of the weighted drill pipe if possible;

- to determine the beginning of the absorption, constantly monitor the state of circulation of the drilling fluid, its cock in the receiving tanks, changes in the mechanical speed of drilling, etc .;

- after opening of an absorption zone to lower the tool with intermediate washings in a shoe of a column and further according to the plan;

- limit the performance of pumps to their lower design limits;

- limit the mechanical speed of drilling;

- use chisels with central flushing;

- do not allow sharp movements of the tool in the well;

- to prevent the formation of seals on the drilling tool;

- constantly have the necessary stock of drilling mud (at least one volume of well) and inert fillers on the drilling rig;

- at opening of partial absorptions to lift a bit in a shoe of earlier lowered column and to leave the tool alone for 6 - 8 hours;

- use drilling fluids that fix the walls of the well;

- use mechanical means that increase the clogging of the near-wall zone of the wellbore;

- add appropriate inert fillers to drilling and cement mortars;

- in case of acquisitions to carry out insulation works.

There are *the following measures to prevent takeovers in the process of fixing the well*:

- before lowering the casing to prepare the wellbore: drill, calibrate, flush, etc .;

- lower the casing into the well in sections or use step cementing; the distance from the absorption zone to the top of the section or filling coupling should be determined taking into account the pressure gradient of fracturing;

- in case of need to reduce density of a cement solution due to additions to it of various facilitating impurity;

- in the process of preparation of the grouting solution to prevent deviation of its density from the specified more than + 30 kg / m3;

- to prevent premature thickening of the grout to ensure its uniform injection and pressing without stopping;

- to reduce hydraulic resistance, cement mortar should be treated with plasticizers, special chemicals to reduce water yield;

- to prevent mixing of drilling and cement solutions to use buffer liquids and separating stoppers;

- not to allow increase in productivity of cementing units over settlement; in case of partial absorption to reduce the productivity of cementing units;

- to use as buffer liquids having high clogging properties.

The choice of ***method of liquidation of absorption depends*** on its intensity. First, determine what *interval the well absorbs*, as well as *the intensity of absorption* (ie, how much solution the well absorbs over a period of time - and the volume of solution spent on filling the well over a period of time). It is determined by a flow meter, which is lowered into the well on the cable. The flow meter is placed at a number of depths, and the solution is added to the well. The lower limit of absorption is observed in the absence of absorption.

The absorption zone is determined using an electrothermometer lowered into the well. First, measure the temperature at the wellbore after a long stop, ie without topping up and rinsing. Then fill the well or try to cause flushing. The temperature in the well will change to the upper limit of the absorption interval. A sharp change in temperature is recorded in the absorption zone.

The absorption zone can also be determined using a resistivimeter, which measures the electrical resistance of the solution in the well. If the well is filled with a solution with a resistance different from that which was previously in the well, you can set the limit where the solution changes.

The absorption zone can also be determined by recording the background radioactivity in the barrel and after injecting the radioactive liquid. The absorbing layers are characterized by a low value of natural gamma activity and the potential of the spontaneously arising electric field, which is determined using standard and radioactive logging.

Acoustic logging can detect fractured and karstic rocks.

Borehole cameras and TVs are sometimes used. These methods can also be used in combination.

Hydrodynamic studies are performed to determine the intensity of absorption. In particular, the well is investigated by injecting fluid with different productivity and measurements of the static level of the solution in the well. Static level is the depth at which the fluid level in the well is maintained in the case of injection of fluid with a certain capacity or in the case when the injection is not carried out at all.

Similarly, it is possible to record the pressure at the mouth in the case of injection of fluid into the well with different performance.

The volume of the solution poured into the well is also recorded at regular intervals.

The absorption zone can be detected by changing the mechanical drilling speed. Comparing the velocity in the absorption zone, above and below the zone, you can set the size of the open cracks.

Absorption zones are divided into:

a) filtration zones with an absorption rate of 0.15 - 1.5 m^3 / h;

b) partial absorption with an intensity of 1.5 - 10 m^3 / h;

c) complete absorption, when the level is kept at a depth of 50 - 150 m;

d) partial or complete absorption due to fracturing;

e) complete loss of circulation with a decrease in level by 150 - 300 m.

By the nature of the absorption it is possible to assess the type of absorption. If the level in the vats decreases constantly, but slightly - this is the process of filtration into permeable rocks.

In the case when this level decreases constantly and by a significant amount, the well revealed fractured deposits.

In firing, when cracks have arisen due to hydraulic fracturing of the rock due to hydraulic loading on the formation, the absorption is sudden and complete.

And if a cavity is encountered, the failure of the bit, the increase in torque on the bit and complete absorption, etc. are recorded.

Технологію боротьби з поглинанням призначають залежно від виду поглинання та його інтенсивності.

The technology of anti-absorption is prescribed depending on the type of absorption and its intensity.

For example, in the case of absorption by filtering the solution into porous or fractured layers, the bit should be raised to a safe area, hold the well without rinsing to gain structure with the solution that got into the pores and cracks. If the absorption does not stop, then you should add small (small) fillers (fibrous up to 3 mm, granular - straw, rubber 0.5 mm, mica, cellophane up to 3 mm, etc.). It is most effective to use mixtures of different fillers, so that one clogs cracks of smaller size and the other larger.

At full absorption it is necessary to lift a bit in a safe zone, to hold a well without washing within 4 - 8 hours and then to inject a portion of a solution with a filler.

At very intensive absorption the cement solution with filler or without it, solar-bentonite mixes, fast-hardening mixes with various additives is pumped up.

In the table 6.1 presents a classification of fillers that have been tested to combat different types of absorption.

Table 6.1 - Classification of fillers

Class	Filler type	Types of fillers
1	Dispersed	Straw, fine plastic, aqueous dispersion of rubber, aqueous dispersion of latex
2	Fibrous	Cord fiber, wolf, asbestos fiber, sawdust
3	Granulated	Walnut husk, expanded clay, expanded perlite, silica gel, crushed plastic
4	Granular elastic	Shredded rubber, vulcanization waste and latexy
5	Plastic scales	Cellophane shavings, mica
6	Capable of swelling	Clay powder, bentonite
7	Plastic	Clay, bitumen, paraffin

The most common causes of ***well wall destruction*** include:

- mechanical destruction of the rock under the action of static load from the weight of the upper rock;
- mechanical destruction of rock under the action of the drill string and its elements, fluctuations in drilling fluid pressure during lowering and raising of drill pipes, fluctuations in temperature in the well and erosion of well walls by drilling mud;
- destruction of well walls due to the interaction of drilling mud filtrate with rock (swelling of clays and stratification of shales) and the action of osmotic pressure;
- dissolution of rock (salt) in drilling mud;

- thawing of frozen rocks.

In the natural massif, the rock is compressed on all sides. Drilling a well changes the stress state of the rock and causes its destruction. Proven way to reduce the effect of stress changes is drilling at high density drilling mud. The lateral force is compensated by the hydrostatic pressure of the drilling fluid. In a heavy solution, the particles of the rock have less gravitational force, they hold the walls of the well better, and when chipped from the wall, such particles are easier to carry out of the well. Given the fact that increasing the density significantly reduces the drilling speed, this method is used only in extreme cases.

To reduce the mechanical destruction of the well walls by the drill string, simple bottom layouts are used, the drilling mode is selected, which ensures the absence of vibrations and minimal loads on the well walls. The strength of the action of the elements of the bottom arrangement on the walls of the well is evidenced by the significant operation of the elements of the layout of the bottom of the drill strings and frequent breakdowns of these elements. The curvature of the well and the bends of the shaft increase the forces acting on the walls of the well. Particles of rock, which are located on the upper wall of the trunk, are more quickly separated from the array. The curvature of the well contributes to the more rapid destruction of its walls.

At the speed of drilling mud movement (more than 300 m / min.), Turbulent mode of drilling mud movement, there are conditions of erosive destruction of well walls. Uncemented deposits are most often destroyed in the absence of a strong clay crust. Therefore, it is advisable to reduce the speed of the solution in the annular space to 150 m / min, use elements of a small diameter drill string, limit the speed of the column in the well, use low-viscosity drilling fluids, etc.

Reducing the effect of drilling mud filtrate on the destruction of the walls is achieved by using high-quality inhibited drilling fluids with low filtration, drilling fluids based on petroleum.

To reduce the dissolution of the walls of the well choose a drilling fluid that does not dissolve the rock. When drilling salts, the drilling fluid is saturated with salts.

Melting of frozen deposits is prevented by their thermal insulation.

To date, the problem of preventing the destruction of walls has not been completely solved, in particular with regard to shale. To some extent, the walls of wells collapse.

Signs and elimination of landslides. There are the following signs of landslides:

- during landslides the volume of rock on vibrating screens increases;
- there are puffs of the drilling tool;
- the pressure on the drilling pumps increases due to the increase in the density of the solution due to the saturation of its sludge and the formation of plugs, which leads to loss of circulation and capture of the drilling tool;
- the tool stops during the lowering period.

There is a need to drill a wellbore. Geophysical studies of the well indicate the presence of caverns.

In the cavernous trunk, the process of sludge removal is complicated. It accumulates in the caverns, which further complicates the situation. After the accumulation of a critical volume of sludge in the caverns, changing the mode of washing, the sludge from the caverns is shifted into the wellbore. This leads to prolonged drilling of the well because the sludge moves from one cavity to another, while being carried to the earth's surface.

In case of landslides, the circulation of drilling mud should be constantly maintained. When the circulation is switched off, the sludge settles and catches the drill string. In case of divergence of a column the sludge stopper is condensed, as a result circulation is lost and possibility of elimination of capture is reduced. Therefore, in case of landslides, the well should be washed first, keeping the sludge in a suspended state, diverge the drill string only within the limits where it moves freely and divergence does not increase the pressure on the pumps.

Landslides are eliminated by drilling a wellbore. The sludge in the well is crushed and raised to the earth's surface. The sludge does not immediately rise to the surface. It can move from one cavity to another, kept afloat in the drilling fluid. During processing the mode of washing of a trunk opposite to caverns with slime changes. All new portions of sludge from other caverns move out of place. This process is called "peeling". But in reality, this is not peeling, but washing the sludge from the caverns. Clots saturated with sludge are removed from the well. The density of this mass is 100-200 kg / m3 heavier than the density of drilling mud. Especially a lot of such sludge accumulates in the case of the transition to drilling with bits of smaller diameter.

In the process of drilling a wellbore, you should periodically raise the bit to the length of a square or simply lift the bit from the blockage area so that the sludge is removed from the drilling mud, and it could be crushed again with a bit. To improve the removal of sludge, the viscosity of the drilling mud is increased, a bundle of viscous drilling mud of increased density with a volume of 10 - 15 m^3 is pumped through the well. The build-up is performed only when there is a guarantee that during the build-up the sludge will not settle and will not catch the drill pipes, ie when the drilling tool moves freely when the circulation is switched off.

Prevention of well curvature. The presence of curvature of the trunk leads to a number of complications. In particular, *the working conditions of the drill string are deteriorating*:

- drill pipes are subjected to additional alternating load;
- the number of breakdowns due to metal fatigue increases;
- the physical operation of drill pipes increases;
- the load on drill pipes increases;
- grooved workings and capture of the drilling tool due to its jamming in these grooved workings are formed;
- in unstable rocks the intensity of landslides increases;

- drilling tool pressed against one wall of the well, which forms stagnant zones during the movement of drilling mud, which impairs the removal of sludge from the well and increases the intensity of adhesion of the drill string under the action of pressure drop;

- deteriorating replacement of drilling mud with cement, which leads to intercolumn flows;

- deteriorating tightness of casing threads;

- ledges are formed in the wellbore;

- there are problems in the period of geophysical research of wells. For example, geophysical devices stop in caverns, the cable breaks because it hits the gutters and caverns. Therefore, to bring geophysical instruments to the face, they should be equipped with special devices (weights, centers, bullets, etc.) to improve their permeability to the barrel, there is a need for geophysical work through the drill string, which reduces its capabilities;

- complicates the elimination of accidents. In particular, the fishing tool is difficult to allow to the desired depth. Appropriate centering devices must be used to connect to the remaining tool, the upper end of which deflects and may be hidden in the cavity. When the angle of curvature increases for every 7°, the number of accidents doubles, and the time to eliminate them - four times. Therefore, in the absence of a special need to deflect the wellbore, it is necessary to drill vertical wells

Most wells are subject to greater or lesser curvature. Wells in which the zenith angle does not exceed 3 - 5^{o} are considered vertical.

Quite often in wells the zenith angle by itself increases to 15 - 20^{o}, that is wells become inclined. The deviation of the face from the position of the mouth can be 150 - 250 m.

It has already been noted that the curvature of wells can occur due to the influence of various factors, such as: geological; technological; technical.

Geological factors include:

- the angle of inclination of the layers to the horizon;
- frequency of rock hardness change;
- anisotropy;
- stratification;
- cracking;
- insight;
- stability of walls, etc.

Rocks with different properties are destroyed at different speeds at different points of the face, which leads to a change in the direction of the well.

The technological factors include:

- method of drilling;
- drilling mode.

These include the load on the bit and the number of revolutions. As a rule, with increasing load on the bit, the forces that contribute to the deflection of the barrel increase. Increasing the speed can stabilize the deviation of the trunk. The intensity of its curvature is also influenced by the type and configuration of the chisels used in drilling. The most intensively deflected wells are drilled with short diamond bits. The curvature is significantly affected by the stability of the well walls. In the shaft, which expands rapidly as a result of shedding of the well walls, the intensity of its curvature is higher.

The technical factors include:

- the composition of the layout of the bottom of the drill string;
- the presence of deviations in the alignment of the threads;
- the presence of eccentricity;
- no curvature of the pipes;
- balance of the elements of the layout of the bottom relative to the axis by their mass.

Of course, we cannot influence geological factors. They should simply be considered, in particular:

- to lay wells taking into account their future deviation;
- know the intervals of curvature;
- take measures to reduce or increase (if necessary), the impact of geological factors, etc.

Of *the technological and technical factors*, the curvature is most affected by:

- load on the bit;
- layout of the bottom of the drill string.

Under the action of axial load, ie its own weight and torque, the weighted drill pipes are bent.

The critical load at which the weighted drill pipes lose stability is determined by the following expression

$$P_{кр} = (1{,}94 - 3{,}35)\sqrt[3]{EIq_{т}{}^{2}}\ , \qquad (6.1)$$

where P_{kr} - critical load, H; EI - stiffness of weighted pipes, Nm^2; qt is the mass of 1 m of the running column in solution, N / m

When the load is increased by 1.94 times, the column bends again. The first deflection occurs at a load of 3 - 5 tons and a length of 35 m.

To prevent warping, the column is centered in the trunk. This effect is achieved by using a weighted drill pipe of larger diameter, installing hubs on the column and limiting the load on the bit.

During drilling, it is impossible to allow significant operation of the hubs in diameter, usually within 2 mm.

The efficiency of the layout depends on maintaining the diameter of the well. This means that the walls should not crumble. The most intense crumbling of the walls is characteristic of the zones of tectonic faults, where the rocks are crumpled, fragmented. In these areas there are large cavities and an intense increase in the zenith angle.

The curvature of the well is influenced by the design of the lower 25 - 30 m of the bottom of the drill string. The hubs set above do not affect the deviation. The most significant effect on the curvature of the centering elements, which are located near the bit. They can increase the zenith angle.

There are *rigid arrangements* of the bottom and pendulum. In rigid bottom configurations, the gaps between the column elements and the well walls should not exceed 2 mm. These configurations use calibrators above the bit and one, two or three hubs. Weighed drill pipes of square cross-section with a small gap between the faces and walls of the well are also used in such configurations. Hubs are installed at a distance of 6 - 12 m from each other. The distance between the hubs increases with distance from the bit.

In *pendulum configurations*, the concentrator is placed on the weighted drill pipes in such a way that the weighted drill pipes do not touch the walls of the well to the center. Then a force consisting of the weight of a weighted drill pipe in an inclined shaft will act on the bit, which corrects the well to the vertical. The lower part of the weighed drill pipe to the point where it touches the wall of the well, it is advisable to take a larger diameter than the rest of the weighed drill pipe.

The location of the hubs is chosen by calculation. However, it is necessary to analyze the actual data and adjust the composition of the lower part of the drill string in accordance with the actual data.

Formation of gutters. *Gutters are formed in places of change of curvature (zenith angle and azimuth) of the well.*

Behind the gutter is usually taken a place where the smaller axis of the trunk has a diameter less than 1.3 of the diameter of the lock.

They occur due to:

- long lowering and lifting operations;
- long-term drilling of the well by rotary method;
- drilling locks during operation gradually cut through the wall of the well with the formation of a gutter.

To reduce grooves it is necessary:

- use drilling with downhole engines;
- use highly efficient bits, -

to reduce the number of lowering and lifting operations.

The most dangerous gutters are in the transition from hard to soft rock and vice versa. The diameter of the chute is equal to the diameter of the drill pipe lock. Jams in the gutters most often occur in the case of pulling through the gutter element of a drill string of larger diameter. The most dangerous is when the diameter of this element is larger than the diameter of the lock in 1.01 - 1.35 times.

To prevent seizures in the gutters you need:

- avoid changing the configuration of drilling tool layouts;
- when lifting do not allow puffs and wedges;
- the layout includes (above the weighted drill pipe) output hubs and percussion mechanisms (jaws) for knocking out the jammed tool.

The gutter is eliminated:

- working out and their expansion by expanders which are established above a bit on 300 - 400 m;

- operation of eccentric expanders;

- blasting torpedo torpedoes.

There is a risk of losing the barrel when blasting torpedoes.

Drill pipes are raised at intervals of gutters with their turning.

Drilling in salts. From the usual deposits which meet in a section of wells, *salts differ in that they easily dissolve in fresh water and acquire plasticity under the influence of temperature and pressure*.

That is, salts from a depth of 1500 m, and especially from 3000 m "float". To prevent erosion of salts, they are destroyed on a salt-saturated drilling mud. Drilling in saline clays is especially dangerous. They tend to flow in the same way as salts, but are less soluble. Clay accumulates near the trunk, which is pushed into the trunk by the bulk of the saline rock. If pure salt can be washed away by washing, the clay does not erode and can catch drill pipes faster than salt.

During the drilling of salts, the solution is saturated with salt, and the solubility of the salt is reduced. After the exit of the salt-saturated solution from the well, the solubility of the salt decreases with decreasing temperature, and the salt crystallizes in solution.

To prevent narrowing of the shaft are forced to increase the density of drilling mud. On the basis of experimental researches empirical dependences between density of drilling mud and temperature of salt in a formation are established:

for t = 75°C $Yp = 2{,}35 - 2802/H$;

for t = 100°C $Yp = 2{,}35 - 2590/H$;

for t = 125°C $Yp = 2{,}35 - 2493/H$;

for t = 150°C $Yp = 2{,}35 - 2156/H$,

where γ_p is the density of the solution, g / cm^3; H - depth of salt, m

When drilling salts on drilling mud of lower density, there is a need for long-term expansion of the well on each voyage and increases the likelihood of catching the drilling tool.

In salts casing of casings is possible. Therefore, casings are calculated taking into account their fluidity from the effects of rock pressure.

Drilling has certain features, where *layers of potassium-magnesium salts - bischofite* - are revealed. They consist of clays, carnallite, which has the formula $KCl.MgCl_2.6H_2O$, and actually bischofite - $MgCl_2.6H_2O$.

The solubility of these salts is much higher than ordinary table salt. If 1 liter of water can contain 350 - 400 g of table salt, then bischofite 800 - 900 g. Bischofite actively absorbs water from the air and turns into a solution.

In the process of opening the salts of bischofite, it is possible to capture a drilling tool. Later, the bischofite layer dissolves and forms a large cavity. As salinization occurs, the solubility of bischofite decreases, and it itself is replaced by less soluble rocks (carnallite, clay, etc.), which leads to a narrowing of the trunk. Narrowing is greater the longer the layer is in the open state.

In the presence of a bischofite formation, the wellbore is periodically patterned after 48 - 72 hours, ie the bit is raised above the formation to control the presence of narrowing and to study the narrowing location. The casing is designed for full rock pressure. To prevent casing crushing, the bischofite interval must be securely cemented. An interval should be created in the bischofite interval so that the rock pressure on the column is transmitted through the destroyed cement or drilling mud evenly in height. Casing pipes must not come into contact with the rock. The rock flows unevenly, and contact of the rock with the casing leads to bending of the column and loss of patency. The casing of any strength is bent. There were cases of bending of a weighted drill pipe with a diameter of 203 mm, trapped in the bischofite formation.

Lecture 7. Drilling accidents

A drilling accident is an interruption of the technological process of construction (drilling and testing) of a well, which requires special works for its elimination, which are not provided for in the project. Accidents are most often the result of breakage, leaving or falling into the well elements of drill and casing, seizure, open gushing, falling into the well of some foreign objects.

Interruption of the technological process of well construction in compliance with the requirements of the technological process and the rules of drilling, which are caused by geological phenomena, such as: absorption; oil and gas manifestations; emissions; landslides; shedding; gutter workings; curvature of the wellbore; open gushing, etc., as well as processes caused by natural phenomena, are complications.

The following *classification of accidents* is quite popular:

- accidents with drill string elements;
- capture of drill and casing;
- accidents with chisels.
- accidents with casings and its elements;
- accidents due to unsuccessful cementing;
- accidents with downhole engines;
- falling into the well of foreign objects;
- other types of accidents.

Accidents with drill string elements include the leaving in the well of a drill pipe string or bottom layout elements (in particular, conductors, tori centers, shock absorbers, weighted drill pipes, expanders, etc.) due to:

- breakage and failure of the thread;
- weld breakage;
- breakage behind the body of the pipe;
- breakdowns of a leading pipe and elements of arrangement of a bottom;
- unscrewing and dropping part of the drill string.

Acquisitions of the drilling tool and casings carry loss of mobility at the maximum admissible loadings applied to them because of:

- pressure difference between the well and the reservoir;
- jamming of the column during its movement in the well;
- jamming of the column with foreign objects;
- lack of proper washing.

Accidents with bits include leaving bits, drill heads or their elements and parts in the well.

Accidents with casings include accidents with columns that are lowered or already lowered, elements of casings or their parts, in particular:

- separation of columns by threaded connection;
- break behind the weld;

- wrinkling or rupture behind the body of the pipe;
- falling of the column or its part;
- damage to the column during the drilling of the cement plug, stop ring, check valve and guide plug.

Accidents due to poor cementing include:

- capture by the hardened cement of a column of drill pipes on which the casing or "shank" descended;
- failure and damage to the suspension units of the casing sections, which disrupt the normal process of fastening and further deepening of the well;
- bare shoes or insufficient lifting of cement, if it is not necessary to carry out work to eliminate violations.

Accidents with downhole engines include leaving such an engine or its components in the well due to breakage or disconnection from the drill string.

The fall of foreign objects into the well includes the fall into the well of the rotor inserts, the rotary wedges of the guide pipe and the wedge gripper, the elements of the wellhead strapping, keys, sledgehammers and other tools used to work on the wellhead.

Other accidents include, in particular, accidents during industrial and geophysical works (capture and leaving in the well of logging cable, devices, weights, templates, torpedoes and other devices used to study wells and ancillary works in it.

This group of accidents also includes the so-called accidents of the first and second categories, which are investigated by special commissions with the participation of Dertechnadzor.

Accidents must be investigated within 72 hours of occurrence. The commission draws up an act of investigation, which indicates the causes, perpetrators of the accident and measures for their further warnings. Accidents are registered in a special journal. The costs of time and money for the elimination of accidents are calculated separately and indicated in the statistical reporting. For each accident, measures are taken to eliminate it.

Accidents of the first category are open oil and gas fountains; explosions and fires of tank farms, compressor and pumping stations of underground gas storage facilities, which led to the destruction or destruction of the facility; explosions and fires at oil and gas refineries, which caused the shutdown of the enterprise, shop and the need for restoration work.

Accidents of the second category are falling or destruction of towers, sea bases in the course of operation, construction and movement; falling elements of the hoist system (crown block, hoist block, hook, etc.); explosions and fires at drilling facilities, group oil and gas collection points, compressor and pumping stations, which led to equipment failure, the need for its overhaul and shutdown of the facility; explosions, fires and fires at oil and gas refineries, which caused the shutdown of the installation (site) and require replacement or overhaul of individual buildings, machines, units, devices, tanks, pipelines and commodity tanks, etc.

Accident elimination takes 3 - 10%, and sometimes more time than the total duration of drilling. Sometimes they lead to human casualties, the piston of ecology, and so on. Accidents occur both through the fault of the contractors and for reasons beyond the control of the contractors. Some accidents are the result of imperfect technology and equipment.

The state of emergency is assessed by the following indicators:

- the total number of accidents;
- the number of accidents per 1000 m of drilling wells;
- the total cost of time to eliminate accidents;
- specific time spent on the elimination of accidents in the total time spent on drilling wells (units - percent);
- severity of the accident (units of measurement - the cost of time to eliminate the accident, hours).

Thus, the main way to combat accidents is to improve technology and use modern reliable equipment.

It is necessary to establish the real cause of the accident, the depth of its occurrence, the affiliation of this interval to the relevant stratigraphic unit, the time of the accident, the progress of work before the accident, contractors and their qualifications, equipment and tools used in the work, the quality of drilling mud. On the basis of the investigation, measures are being developed to prevent similar accidents. Measures should not complicate the work of contractors.

Important means of accident prevention are staff training, as well as control over the work of subordinates. The cost of time to eliminate accidents depends on the correct choice of method of elimination and the condition of the well. A rational way to eliminate the accident can be chosen only by determining the true cause of the accident and knowing the condition of the well. This allows you to choose the right fishing tool. It is important to know the depth of the individual elements of the emergency drill string and the condition of the well. Complications in the elimination of the accident occur mainly in complicated wells. Elimination of the accident is complicated, in particular, by the collapse of the walls of the well, the loss of flushing, the capture of the fishing tool, the failure of the fishing tool to a given depth, absorption and oil and gas development. Drilling tools must have passports. There are ways to catch this element from the well.

There are *the most common causes of seizures*:

- adhesion of the drill string due to the large pressure difference between the well and the formation;
- jamming of the bit with rock;
- drilling without flushing or with insufficient pump performance;
- Insufficient cleaning of the shaft and accumulation of sludge in the well;
- leakage of the drill string;
- flushing of threaded connections;
- solution passes through the nipple of the downhole motor;
- drilling with high mechanical speed without sufficient sludge removal;

- planting a bit in the sludge plugs in the trunk or bottom;
- collapse of the rock with loss of circulation and emissions;
- formation of seals;
- jamming of pipes in gutters;
- fluidity of salts;
- jamming of the bit in the narrowed part of the barrel;
- jamming of the bit in the narrowing due to the operation of the diameter of the bit;
- inadmissible plus tolerance of a bit on diameter;
- lowering the rigid or full layout of the bottom of the drill string;
- use of full drill pipes, weighted drill pipes or tools;
- jamming of the bit or arrangement by a foreign object;
- capture by cement which has not yet seized;
- unsatisfactory quality of the washing liquid due to its thickening and loss of solid particles, etc.

The following measures are known to prevent seizures:

- reducing the density of drilling mud;
- use of centralizers;
- use of weighted drill pipes of square section and weighted drill pipes with a spiral groove;
- creation on the tool of strong lubricating films;
- use of oil-based emulsion solutions;
- prevention of a sharp change in the curvature of the trunk; in the presence of delays to use output calibrators;
- do not allow landings; the amount of tension to release the capture is three times greater than the allowable landing;
- adhere to the hydraulic program for cleaning the barrel;
- limit the mechanical speed of penetration;
- when drilling with loss of circulation, fill the well with viscous drilling mud;
- increase the viscosity of the solution to improve the removal of sludge;
- cone bit should be lowered carefully at intervals drilled with a diamond bit and vice versa;
- when drilling turbo drills with diamond chisels, above the bit to install expanders to smooth the steps;
- use clearings in the layout of the drill string, etc.

There are also *the following ways to eliminate seizures*:

- divergence of the tool with its rotation;
- installation of oil baths;
- installation of liquid baths;
- hydropulse method;
- hydro-vibration method;
- lowering the level in the annular space;
- shaking the tool with hull and cord torpedoes;

- unscrewing of a free part and work by clearings;
- reduction of pressure by the tester of wells;
- perturbation of the seized tool;
- firing of weighted drill pipes below the capture and restoration of circulation;
- explosion of a torpedo on a bit to restore circulation;
- drilling a new barrel, etc.

There are the most common *types of tool failures:*
- breakage or failure of the threaded part;
- breakage behind the weld;
- breakage behind the body of the pipe;
- breakage of the leading pipe and layout elements;
- falling or unscrewing part of the drill string;
- falling of drill string elements due to breakage of lowering and lifting equipment or tools, breakage of the hoisting rope or lifting on one sling;
- sudden closing of the preventer in the winter in the process of lifting the tool when the preventer is closed earlier;
- spiral fracture of pipes behind the body due to fatigue in wells whose diameter is not more than 100 mm larger than the diameter of the pipe (the direction of the spiral coincides with the direction of rotation; the angle of rise of the spiral 45 °); arises from the presence of a transverse crack; in the transverse direction, the pipes break due to manufacturing defects (shells) and violation of the heat treatment regime, which leads to internal stresses and fatigue of the metal;
- in the thickened ends of the pipes due to uneven cooling during hardening there are small cracks, which lead to destruction due to fatigue of the pipes in the main plane of the threads;
- light-alloy drill pipes are destroyed also due to erosion operation of the pipe body under the couplings and operation according to the wall thickness;
- drill locks and couplings (especially with a diameter of 118 mm and less) are destroyed due to the creation of significant loads; the ends of the destroyed parts have increased diameters and barrel-shaped shape;
- Insufficient fastening of the locking connection contributes to the intensive movement of the plane of the threads relative to each other and the operation of the threads.

The following signs of accidents are typical:
- a sharp decrease in the mass of the drill string on the weight indicator;
- sudden movement of the column;
- pressure drop of the washing liquid in the discharge line;
- lowering the temperature of the flushing fluid coming out of the well.
- drop in mechanical speed;
- failure of the drill string, etc.

The following factors should be assessed before the accident is eliminated:

- the condition of the raised part of the drill string and the nature of the destruction of its elements;

- the condition of the wellbore in the place of the most probable location of the broken part and the presence of complications throughout the wellbore;

- lithological composition of rocks, which corresponds to the interval of destruction and in the adjacent area;

- the nature of the work to eliminate accidents that have occurred before;

- permissible (limit) loads on the fishing tool and expected loads on it.

The causes of accidents include:

- *metal fatigue*, which is accelerated by the following factors:

- defects of pipe material - stratification and structural inhomogeneity of metal, foreign inclusions in metal and structural defects;

- small radii of rounding of pipe threads;

- use of pipe connections without end stop or pipe connections with couplings;

- unfavorable geological and technological conditions and violations of the designed drilling regimes:

- frequent stratification of rocks, steep angles of incidence of layers (layers), which leads to curvature of wells;

- the work of the column in large caverns;

- operation of the tool in chemically aggressive environments;

- creation of unacceptable loads on pipes;

- mismatch of the diameter of drill pipes the size of the bit;

- mismatch of the type of bit strength of the rocks that destroy;

- occurrence of resonant oscillations from pressure pulsation or bit operation;

- creating a load on the bit due to the weight of drill pipes;

- installation over weighted drill pipes of fragile pipes of strength groups E, L or, so-called, alloy drill pipes;

- use of pipes of inappropriate strength;

- dents in the pipes;

- violation of the integrity of the pipes by foreign objects;

- eccentricity of the tower and rotor relative to the wellhead;

- stress concentration in the threads of weighted drill pipes;

- excessive operation (wear) of the elements of the drill string;

- blows that fall on the drill pipes during unloading, and blows of drill and guide pipes on the rotor when tightening them in the drill or feed to the center of the well;

- non-alignment of threaded joints and welded parts;

- use of wedges of inappropriate size.

- low-quality threading;

- insufficient or excessive tightening torque of threads;

- unscrewing of threads from blows;

- *fall of the drill string*, for possible reasons:

- lifting on one sling;

- loss of the swivel sling from the hook;

- mismatch of the size of the elevator or its malfunction;
- discrepancy between the load capacity of the elevator and the slings of the mass of the drill string;
- malfunction of the automatic elevator;
- opening of the elevator after a sudden stop of the tool through stops on ledges or in elements of a binding of a mouth;
- rupture of slings;
- breaks of brake belts;
- excessive operation of the brake pads and their loss;
- breaking the brake pulleys of the drilling winch;
- breakage or failure of the thread of the brake bolt;
- jamming of the brake lever;
- leaving the heated brake system with the brake fixed;
- pressure drop in the pneumatic system with the brake cylinder on;
- imperfection of the design of the lifting hook latch;
- destruction of side earrings and hook barrel;
- abrupt landing of the column on the elevator wedges;
- excessive operation of slings;
- untimely closing of the elevator, etc.

Pipe traps, slips, taps, and bells are used to *eliminate accidents*. Thus, *tubes (slips)* are used in the case when the weight of the lost pipes does not exceed the load capacity of the fishing tool and when the tool is not caught. First of all, use external tubing.

Taps are used in case of destruction of pipes in locks or the thickened part of a body. Taps use universal and special, designed to capture the lock thread of a certain size.

Bells are used to grab the pipe by its body. Bells are ordinary, which capture the upper end of the destroyed pipe, and through, in which the torn end of the pipe passes freely through them, and they capture the next lock or coupling.

It is forbidden to lower the fishing tool without centering devices if the sum of the outer diameter of the fishing tool and the diameter of the remaining pipes is less than the diameter of the well. At an uneven break at first unscrew the broken pipe. In case of danger of catching the catching tool is lowered with a clearing and a safe conductor.

Alloy drill pipes are drilled with a chisel or a special milling machine. Pipes are drilled with a T or TK bit, preferably by a turbine method with a load of 20 - 40 kN, and when drilling cemented ABT up to 60 - 110 kN. During drilling, the column is raised by 10 - 15 m through 1.5 - 2 m of penetration.

Part of the drill string up to 100 m long is captured by external pipes, slips or smooth bells.

When lowering the fishing tool, it is stopped in the casing shoe and the well is washed. Allow the tool and 5 - 10 m above the head, with minimal washing and feeding of 20 - 30 cm bring the tool to the calculated depth. Make a mark on the guide tube in front of the fixed part of the rotor table. If the top of the column cannot be found, it is raised by 3 - 5 m, the column is rotated by 3 - 5 turns, stopping at 90 ° from the first mark, and the search is continued. At a meeting with the left column, turning a rotor on 30 - 40 °, get the catching tool on a head.

Lecture 8. Drilling of inclined and horizontal wells

Inclined wells *are used to solve the following problems* (see Fig. 8.1):

- drilling of several wells from one sea basis;
- opening of productive strata from the shore, which lie under the seabed;
- opening of the formation in the productive part, if the vertical well opens the formation in the unproductive part;
- opening of the formation at a point that is not available for placement of the drilling rig (mountain, settlement, ravine, swamp, etc.);
- opening of layers that lie at large angles and the probability of opening which, a vertical well is small;
- silencing of open oil and gas fountains;
- bypassing the drilling tool left in the well due to the accident;
- opening of layers covered with salt domes;
- restoration of operational wells;
- formation of the formation at an angle to increase the area of opening of the formation and increase the productivity of the well;
- preservation of agricultural lands.

Inclined wells are divided into: single-barrel; multi-hole and bush. In a multi-hole (another name - branched) well (see Fig. 8.2) from one main shaft opened several layers or one layer, but at different points. The main trunk is branched into several additional ones.

Boreholes (see Fig. 8.3) are drilled from one site. They are arranged to reduce the cost of arranging sites for drilling and construction of wells for production. Bush drilling is most commonly used in wetlands, where significant funds are required to prepare the site for drilling. 2 - 30 wells are drilled in the bush (usually - 16 - 20).

Inclined also include *horizontal wells*, the angles of which are close to horizontal and which are drilled both to open the reservoir at different points, and to increase the productivity of wells, for example, with insufficiently permeable reservoirs. The operation of such fields by vertical wells is often unprofitable, namely horizontal wells make it possible to operate them profitably.

Deviation of wells from the vertical is carried out due to:

- the use of natural patterns of deviation of wells, when the deviations are regulated only by the drilling regime using natural patterns;
- the use of appropriate drilling tool layouts, when changes in the direction of the well are achieved by selecting the appropriate elements of the drill string and installing them in the column at a certain distance;
- the use of appropriate devices to regulate the direction of the well.

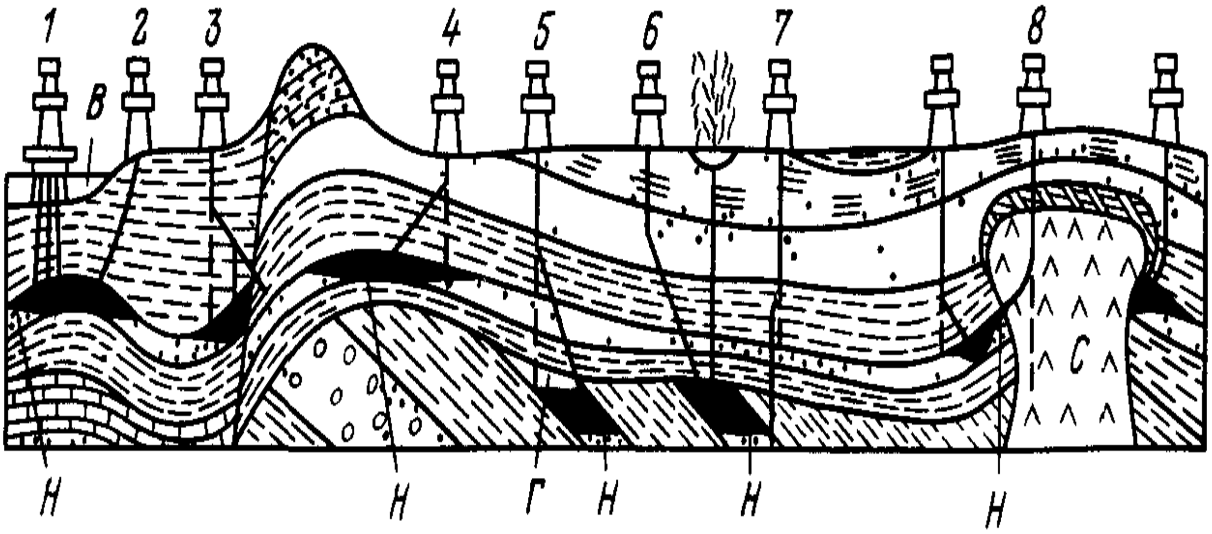


Fig. 8.1 - The use of inclined wells for:
1 - drilling of several wells from one sea base; 2 - opening of productive strata from the shore, which lie under the seabed; 3 - opening of the formation in the productive part, if the vertical well opens the formation in the unproductive part; 4 - opening of the formation at a point that is not available for placement of the drilling rig (mountain, settlement, ravine, swamp, etc.); 5 - opening of layers that lie at large angles and the probability of opening which, a vertical well is small; 6 - silencing of open oil and gas fountains; 7 - bypassing the drilling tool left in the well due to the accident; 8 - opening of the layers covered with salt domes

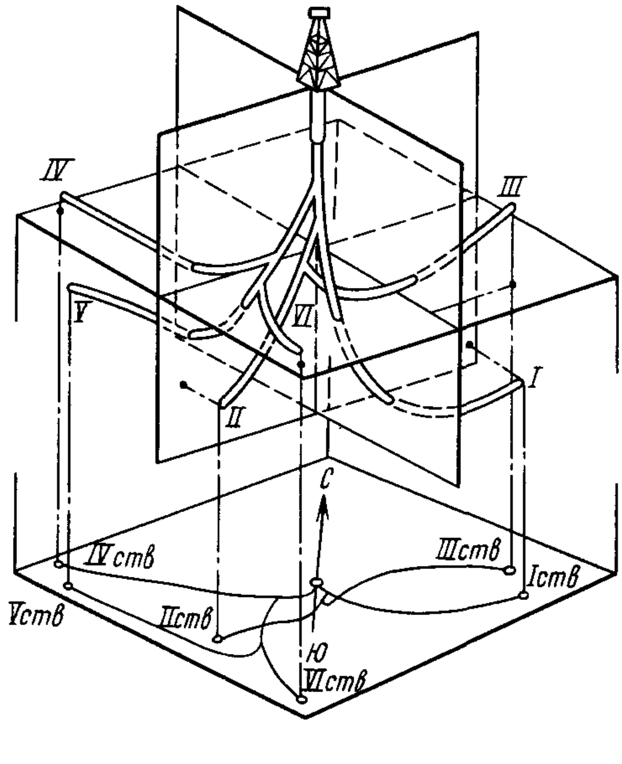


Fig. 8.2 - Scheme of a downhole well

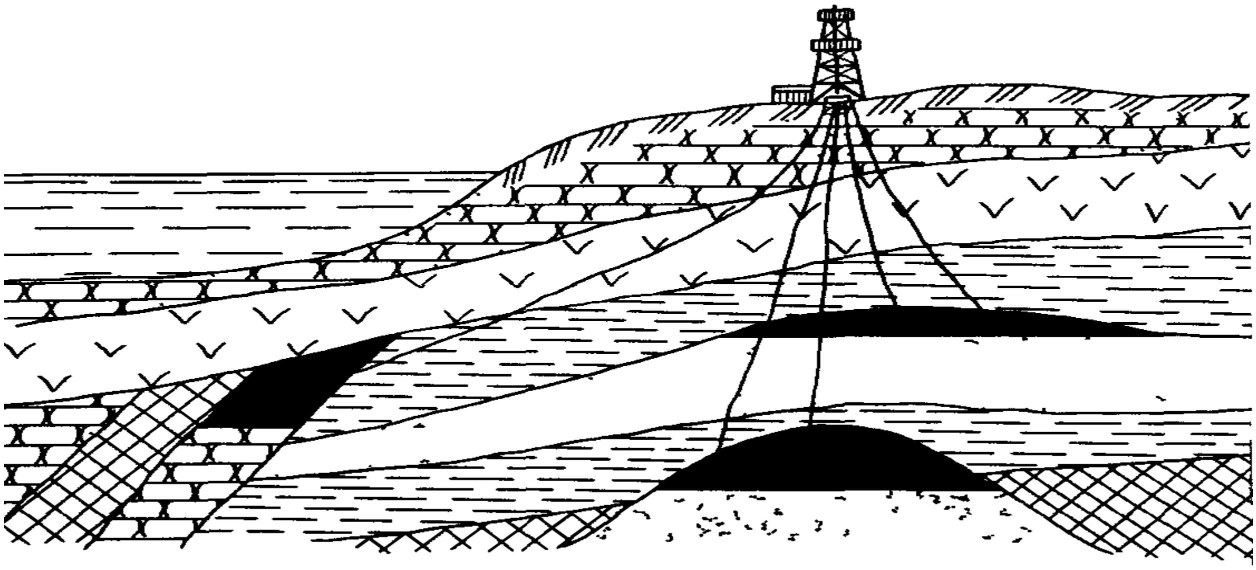


Fig. 8.3 - Scheme of a borehole

The curvature of the well (see Fig. 8.4) describes the following parameters.

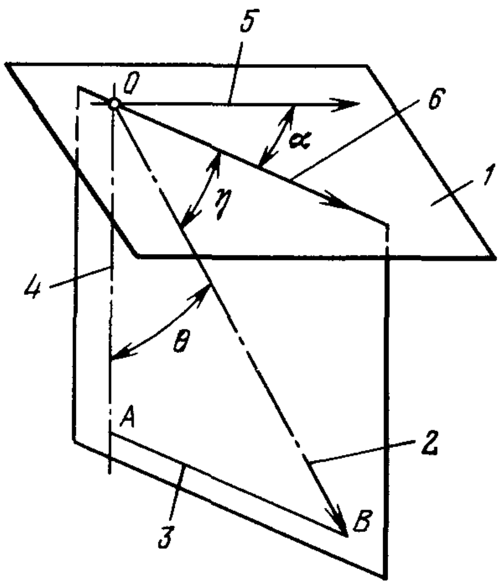


Fig. 8.4 - Parameters that determine the position of the well in space:
1 - horizontal plane; 2 - axis of the well; 3 - the plane of the axis of the well (the so-called apse plane); 4 - vertical; 5 - direction of the origin (direction to the north); 6 - direction of drilling (well azimuth)

There are two corners at each point of the trunk. *The angle of curvature or zenith angle* (θ) is the angle between the vertical at this point and tangent to the profile of the trunk axis at the same point (ie, the angle between the tangent to the trunk axis and the projection of this tangent on the vertical plane). The angle that complements the zenith angle to the horizontal direction, in other words $\eta = 90^o - \theta$, is called *the angle of the trunk*. The second angle indicates the direction in which the curvature occurs. This angle is called *the azimuth or azimuthal angle* (this is the angle between the projection of the tangent to the axis of the barrel on the horizontal plane and the accepted direction from which the reference is made). The direction to the north is taken as the starting point. In this case, this direction can be geographical or real, magnetic or conditional. The devices measure the magnetic azimuth. To obtain the geographical azimuth, you need to add a correction to the magnetic one, which for our area is + 5^o.

The vertical plane passing through the tangent at the point of measurement on the axis of the trunk is called *the apse plane*. *The curvature of a well is a change in the zenith or azimuthal angle between two points on the axis of the wellbore*. There are zenith and azimuthal curvature, respectively.

Almost in the well changes both zenith and azimuthal angles. *The general curvature occurs at an angle* that determines the following relationship

$$\cos\beta = \cos\theta_2 \cos\theta_1 + \sin\theta_2 \sin\theta_2 \cos\Delta\alpha , \tag{8.1}$$

where θ_1, θ_2 - zenith angle at the beginning and end of the trunk segment;

$\Delta\alpha$ is the difference between the azimuthal angles at the beginning and end of the trunk segment.

The intensity of curvature is the ratio of the total angle of curvature to the distance between the measuring points on the axis of the well.

The curvature of the well is influenced by the following factors:

- geological;
- technological;
- technical.

Geological factors include the angle of the strata to the horizon, the frequency of rock hardness, anisotropy, stratification, cracking, permeability, wall stability, ie rocks with different properties are destroyed at different speeds, causing a change in the direction of the well at different points of the face.

Technological factors include the method and mode of drilling (load on the bit, the number of revolutions). As the load on the bit increases, the forces that contribute to the deflection of the barrel increase. Increasing the speed can stabilize its deviation. The intensity of curvature is also influenced by the type and configuration of the chisels (the most intensively deflected wells that drill short diamond chisels). The curvature is also affected by the stability of the well walls (in particular, in the wellbore, which expands rapidly due to shedding of the walls, the intensity of the curvature is higher).

The technical factors include the composition of the bottom of the drill string, the presence of deviations from the alignment of the threads, the presence of eccentricity, curvature of the pipes, the balance of the elements of the bottom relative to the axis by their mass. The presence of eccentricity in the threaded joints or skew in the axes leads to an increase in the angle of the well, especially during turbine drilling. The angle changes during eccentric drilling with a chisel of smaller diameter in the trunk of larger diameter. The use of short bottom layouts increases the angle of their inclination in the wellbore. A similar result can be achieved by drilling with large gaps between the elements of the layout and the wellbore. The misalignment or non-horizontality of the rotor table leads to the acquisition of the zenith angle at the beginning of drilling. This also leads to the deviation of the direction from the vertical.

The bit tries to become perpendicular to the layers of rock. The reaction of the well and the influence of technical factors depends on the angle of contact of the bit with the rock and the magnitude of the zenith angle. At angles of curvature up to 15°, geological factors significantly affect the direction of the well, ie the azimuth of the well can change due to geological factors. At large angles, geological factors have little or no effect on changing the direction of the well.

Regarding the azimuth of the formation drop, the azimuth of the well curvature goes up with a deviation to the right or left by 15-30°. In the turbine method, this deviation is greater than in the rotor.

Consider ***the means to change the zenith angle and azimuth in inclined drilling, in particular*** (see Fig. 8.5):

- *curved transducer* is a short section (length 0.4 - 0.7 m) of a weighted drill pipe, in which one of the cuttings is made at an angle to the axis of the transducer. The angle at which the cut is cut - 1 - 4°. At an angle, usually cut the conical part of the translator. The transducer is screwed directly on the turbodrill, and 8 - 24 m of the weighed drill pipe is installed above. The transducer has significant rigidity and creates a significant deflection load on the bit.

The curved gear is used with single-section short turbodrills or screw engines. The magnitude of the skew of the axis is chosen depending on the length of the turbodrill, the gaps between the wall of the well and the turbodrill in such a way that the layout can be lowered into the well without its significant deformation. As the load on the bit increases, the deflection force on the bit increases and the efficiency of the translator increases. The curved converter in a complex with the one-section turbodrill allows to increase an angle with intensity of 1 - 2° on 10 m and to bring an angle to 40 - 45°, and in combination with a short turbodrill - with intensity of 4 - 5 ° and to bring an angle to 50 - 55°, and in complete with special short motors - 5 - 6o on 10 m and to bring an angle to 90°.

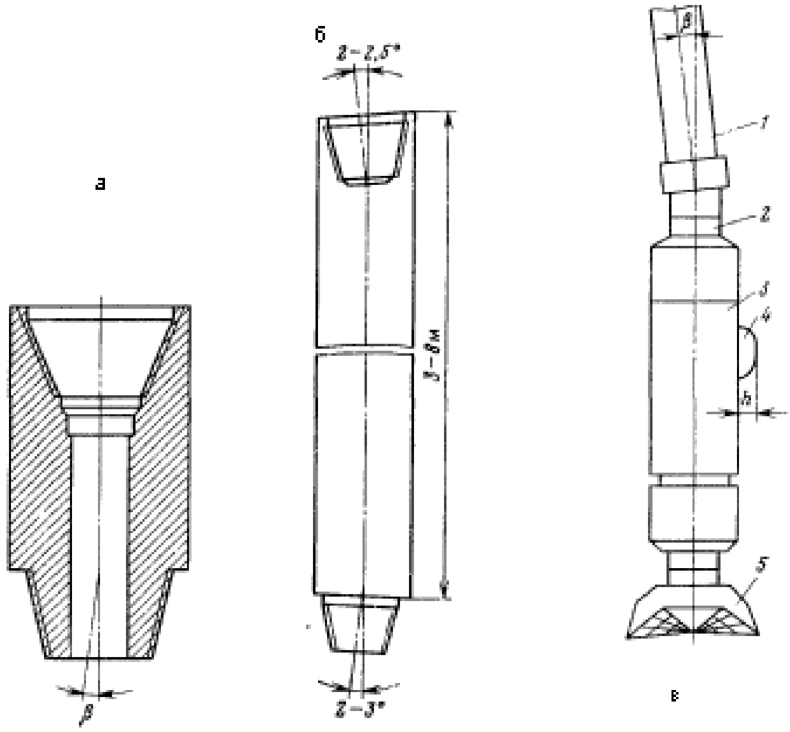


Fig. 8.5 - Means for change of an zenith angle and azimuth at inclined-directional drilling: a - the curved translator; b - deflector P-1; in - a deflector with an overlay

- *deflector P-1* is a section of a weighted drill pipe, in which both incisions, top and bottom are cut at an angle in one plane. The upper cut is cut at an angle of 2 - 2.5°, and the lower - 2 - 3°. For elastic configurations, its length is 6 - 8 m, and for rigid - 3 - 4 m. The intensity of the angle change depends on the geometric dimensions of the layout, the magnitude of the skew of the axes, the drilling mode, the diameter of the well. Used for a set of zenith angles of 90° and more, cutting new barrels in the cavernous areas of the trunk;

- *the deflector with an overlay contains* a curved transducer located above a single-section turbodrill and an overlay, which is welded to the turbodrill body in the plane of action of the curved transducer. Ordinary or light-alloy pipes are installed above it, in which the curvature of the well can be measured. These deflectors are used to lower a low stiffness arrangement into a well;

- *TO2 turbine deflectors* contain one or two sections of the turbodrill and the spindle, connected by a curved conductor, and the connection of the shafts of the turbodrill and the spindle is hinged. The curved transducer is made with a skew of axes 1 - 2^{o};

- *SHO1 deflector spindles* contain a sectional turbodrill and a spindle consisting of two parts. The lower part receives the load on the bit, and the upper - the hydraulic load from the pressure drop on the turbodrill. The housings of the lower and upper halves of the spindle are connected by a curved conductor, and the shafts are hinged. Used for drilling new barrels and increasing the angle at considerable depths. The disadvantage is the low stability of the shaft joint.

In addition to these deflectors use turbo drill spindles with a nipple cover, bent drill pipes. Electric drills are equipped with distortion mechanisms. In rotary drilling, wedge deflectors or whipstocks are used to deflect the shaft (see Fig. 8.6). *Wipstock* is a thick-walled pipe, the diameter of which is close to the diameter of the well, the end of which is beveled at an angle of 4 - 10^o. The inclined surface of the wedge should have a gutter, the diameter of which is larger than the diameter of the bit, which will drill a new barrel. Wipstocks are removable and non-removable. Removable are attached to the drilling tool above the bit, and when lifting the bit is also lifted from the well. Immovable is lowered and left in the well. Fixed whipstocks are fixed to the left tool or cemented.

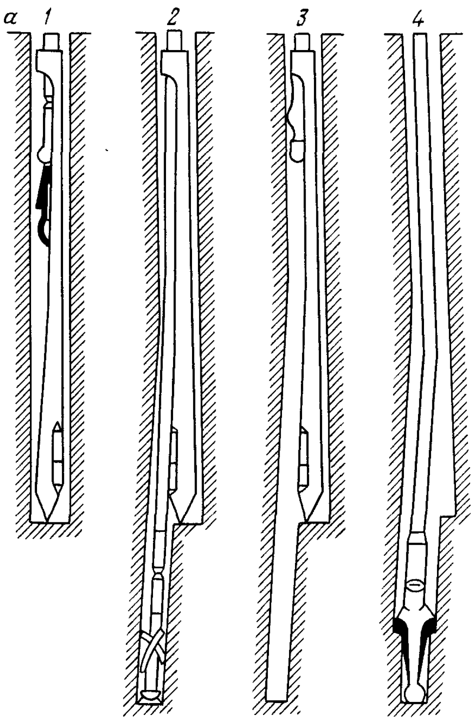


Fig. 8.6 - Stages of deflection of the wellbore during rotary drilling with wipstock: 1 - installation of wipstock; 2 - drilling of the second shaft; 3 - rise of a stockstock; 3 - well expansion

The zenith angle can be changed without the use of means to force a change of angle. Different bottom configurations are used to increase the zenith angle, stabilize it or decrease the angle with a given intensity. The condition for adjusting the angle by these configurations is the presence of a certain zenith angle of curvature. Analyze the operation of layouts depending on the stability of sediments, drilling mode parameters, etc. Oriental configurations change the zenith angle, but the azimuth cannot be changed in a wide range. The azimuth is changed within small limits (up to 15^o) by changing the drilling method, drilling mode parameters, etc. In unorientated layout, the azimuth varies widely, but only due to geological factors that are affected by man. Their influence can be through the use of rigid configurations with multiple hubs. Orientationless drilling is more profitable than with orientation. Check the direction of the well periodically.

Orienteering tools:

- *lowering the drilling tool according to the marks*. After screwing the curve of the transducer, it is directed in the right direction with a compass, and the mark on it is worn on the rotor table. On each drill pipe, on the top and bottom end put marks, strictly on one generating. When lowering, after fixing the connections, the displacement of the marks on the upper pipe is measured and recorded in the log in comparison with the lower one with a + sign clockwise and with a sign - counterclockwise. Summing the offset of the labels on all pipes determine the position of the transducer in the well. The disadvantage of this method is low accuracy. Used at shallow depths;

- *orientation using the Shangin-Kuligin device*. Knives are mounted in the transducer in the plane of curvature, which on the lead seal give an imprint in the form of arrows-triangles, the top of which is directed towards the action of the curved translator. After lowering the bit to the bottom, the device is lowered into the drill pipes. The method is used in the presence of the zenith angle of curvature and relatively shallow depths (up to 1500 m);

- *orientation with the use of a translator with a magnetic label*. A transducer with a built-in magnet and an inclinometer seat is installed above the deflector. An aluminum drill pipe or a diamagnetic steel pipe is used above the conductor. The magnet is mounted so that it points to the plane of action of the deflector. After lowering the inclinometer into the socket, the angle between the plane of action of the transducer and the azimuth of the well curvature is measured, and by raising the inclinometer into the diamagnetic tubes, the azimuth of the well is measured. Comparing this on a pie chart, determine the position of the deflector relative to the azimuth of the curvature of the well;

- *orientation in the absence of curvature of the well* (see Fig. 8.7). At the zenith angle of curvature less than 3° inclinometers give significant errors, and to apply the previous means is not correct. Therefore, a diamagnetic tube with a landing socket is installed above the deflector, where the inclinometer is not vertical, but inclined at the greatest possible angle;

- *orientation with the use of telesystems*. Allows you to control the position of the deflector directly in the process of deepening the well. In the telesystem for turbine drilling above the deflector, a deep block with an inclinometer is installed in the diamagnetic housing, which measures the zenith angle and azimuth at the location and direction of the deflector. After the deflector is lowered into the well, a connecting coupling is lowered into the drill pipes on the geophysical cable, by means of which (under its own weight) the unit is connected to the geophysical station on the surface. The cable outlet from the drill pipes is sealed in a conductor. The telesystem constantly monitors the position of the deflector, adjusting its position by the load on the bit;

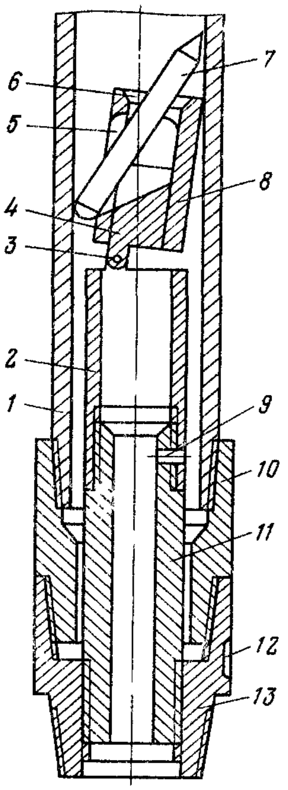


Fig. 8.7 - Device for orientation in a vertical well:
1 - diamagnetic tube; 2 - diamagnetic branch pipe; 3 - hinge; 4 - conical cutout; 5 - cutout in the clamp; 6- clamp; 7 - inclinometer; 8 - clamp; 9 - pin; 10 - translator; 11 - sleeve; 12 - label on the deflector; 13 - deflector transducer

- *measurement of parameters in the well (MWD)* - an effective means of orienting the deflector. The downhole unit measures not only the angles of curvature of the well and the position of the deflector, but also the downhole parameters of the drilling mode. Geophysical research of sediments is constantly carried out, which allows to estimate the place of the bit in the sediments, to quickly change the direction of drilling. Signals from the face are transmitted by pressure pulses on the column of drilling mud, and on the surface they are decoded. Used when drilling horizontal wells.

The well profile is the configuration of the wellbore in space. There are conventional profiles, in which the wellbore passes in one vertical plane, and spatial, in which the wellbore has the form of a spatial curve. In the projection on the horizontal plane, ordinary profiles have the form of a straight line, and spatial - the form of a curve.

The profile is chosen by the following factors:

- opening of the formation at a given point, taking into account the allowable deviation, with a minimum amount of work on the orientation of the deflectors;

- bringing the well to a given depth in the current state of the art and drilling technology;

- high-quality drilling at a minimum cost;

- drilling of a well with the minimum number of bends of a trunk;

- the possibility of free passage behind the trunk of the casing, the necessary bottom layouts during drilling and underground equipment, which is lowered during operation of the well;

- long and trouble-free operation of the well with submersible pumps and the possibility of separate operation of several horizons in the development of a multilayer field.

Conventional profiles are widely used. *Ordinary profiles are classified according to the form into six types* (see Fig. 8.8):

a b c d e f

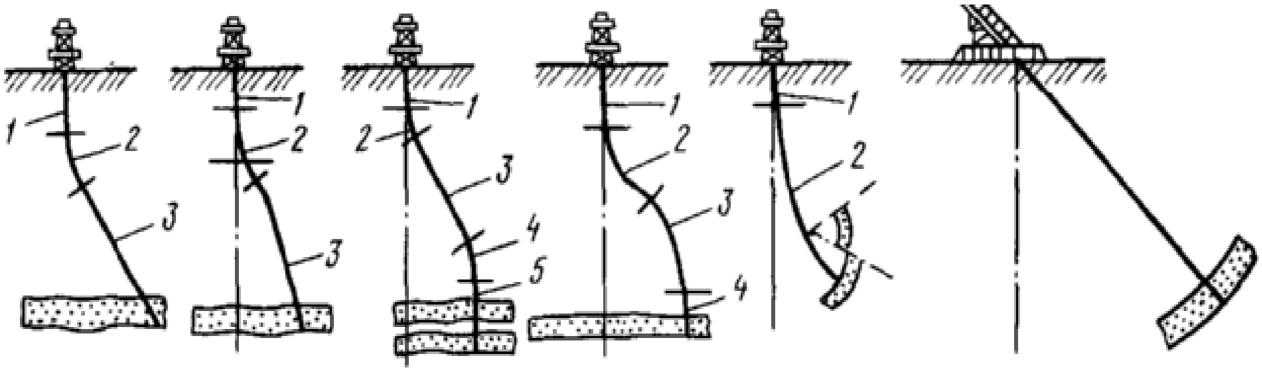


Fig. 8.8 - Types of profiles of inclined wells:
a, b, c, d, e, f - answered from the first to the sixth types;
1 - vertical section; 2 - area of increase of the zenith angle; 3 - inclined rectilinear section; 4 - area of natural angle decrease; 5 - vertical section

- *the first* (Fig. 8.8, a) - contains a vertical section (1), the area of increase of the zenith angle (2) and an inclined rectilinear section (3). This profile has only one bend, which reduces the load on the drill string and column of rods during operation, the minimum number of flights with the orientation of the deflectors. It is close to optimal. Minimal equipment loads occur if the profile is close to the shape of a "chain" connecting two points. When drilling, the zenith angle should be maintained to the design depth, which is difficult at considerable depths;

- *the second* (Fig. 8.8, b) - also has three sections, but instead of rectilinear there is a section of gradual natural decrease in curvature. Used if it is difficult to maintain an angle to the design depth;

- *the third* (Fig. 8.8, c) - has five sections: vertical (1); increasing the angle (2); inclined rectilinear (3); natural decrease in angle (4); vertical (5). This profile allows you to cross several productive layers and continue to operate them simultaneously, but each separately. It has two bends, which increases the load on the equipment. Therefore, the possibility of the formation of gutters and accidents increases;

- *the fourth* (Fig. 8.8, d) - in contrast to the previous one, the inclined rectilinear section (3) and the section of angle reduction (4) are combined into one section of natural angle reduction;

- *fifth* (Fig. 8.8, e) - contains areas of vertical (1) and increasing the angle (2). Used to reveal productive horizons of complex structure;

- *sixth* (Fig. 8.8, e) - has only one inclined rectilinear section. Requires special equipment. It takes place in oil production.

Of course, the profile of a particular well may differ from the above. It is chosen with maximum regard to specific conditions, the use of natural curvature, and so on. The deeper the beginning of the deviation, the less load on the equipment. The maximum zenith angle should exceed the angle at which geological factors have little effect, which makes it possible to use aimless drilling. That is, the angle should be more than 15 - 16°. But the increase in angle complicates drilling. Increasing the angle every 7° increases the accident rate under the same conditions twice, and the time spent on their elimination - four times. Therefore, the angle should be minimal.

Spatial profiles (see Fig. 8.9) are used under the significant influence of geological factors (using the natural tendency to curvature).

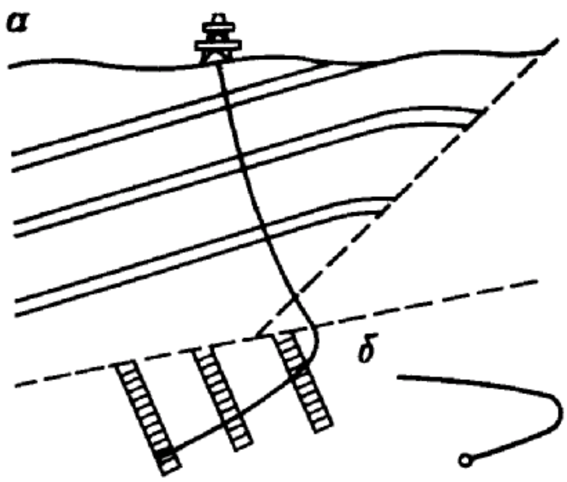


Fig. 8.9 - Spatial profile of the well: a - profile; b - plan

Profiles of inclined wells are calculated depending on the type of profile. Individual profile elements are described by trunk length l, deviation in horizontal direction A, vertical depth h, zenith angles at beginning and end of section θ_1, θ_2, azimuth at beginning and end α_1, α_2, curvature radius R, curvature intensity (deg. at 10 or 100 m.

The actual profile and deviation of the face horizontally is determined by measuring the zenith angle and azimuth in the well. The angles in the well are measured with an inclinometer every 10 - 25 m. For each segment (between the measuring points) at the average zenith angle determine the deviation ($a = l \times \sin\theta$) and postpone it in the actual azimuth on the plan. Delaying the total deviation depending on the depth of the well profile is built.

Horizontal wells differ from inclined ones in that part of the shaft passes in the productive formation (to increase the flow rate of wells). *They are classified by the radius of curvature and the intensity of the set of angles for wells with*:

- *small radius of curvature* (radius 9 - 14 m at a rate of angle of 4.1 - 6.3° per meter; the length of this section of the trunk - 23 - 28 m; their drilling is articulated; wells are drilled with small (150 - 160 mm) diameters of bits; drilling flexible pipes with hinges, fastenings of the drilled section do not lead, these profiles are used for drilling short (up to 200 - 250 m) new shafts from production wells with little waste);

- *the average radius of curvature* (radius 91 - 152 m at a rate of set angle of 26-66° per 100 m; the length of the site - 150 - 800 m; their drilling is the usual short layouts at low intensity set angle (up to 45° per 100 m) and special at a more intense increase in angle, drill pipes are used with nipples up, geophysical surveys are conducted through them, these profiles are used for drilling horizontal shafts up to 900 m);

- *large radius of curvature* (radius 366 - 914 m at a rate of angle of 6-20° per 100 m; section length - 300 - 1200 m; drilling is carried out by conventional short layouts and pipes; geophysical surveys are conducted through pipes; these profiles are used for drilling horizontal shafts from 1500 m and more, for horizontal drilling use the upper drive of drill pipes, powerful pumps, high-quality drilling fluids, etc.).

The design of horizontal wells is based on:

- forces of friction of a column at its lowering, raising and turning;
- development of the washing mode which provides clearing of a well of the drilled breed;
- method of geophysical research;
- ensuring the stability of the well walls;
- ways to attach the well.

The drilling machine must have a significant stock of carrying capacity, two or three drilling pumps, top drive, a significant capacity of the candlestick. When designing a profile, the set of angles in soft, unstable, weakly cemented rocks should be avoided. Increasing the angle above 40° should be designed in stable rocks. The smaller the radius of curvature, the smaller the length of the horizontal section. The trajectory is changed smoothly. Drilling fluids (oil-based or pseudo-oil) must ensure the stability of the shaft, cleaning the well.

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