New disclosures concerning drilling and completion technologies and techniques.

Annotation

In the oil and gas industry, well drilling is the most capital intensive branch. For the development of the economy in my country, Uzbekistan, alongside with Kazakhstan and Russia, members in the oil industry have set a goal to improve and develop the quality of drilling. This task includes quantitative growth such as the increase in drilling speed and an increase in the quality of drilling operations.

In recent years, the need for technical improvement, development, and introduction of new technology has grown to be more critical. Technical progress provides improved technology and performance, which in the intensive drilling conditions of the modern oil industry, prove to be a necessity. Improving upon these aspects can be achieved by introducing modern equipment, advancing drilling methods, expanding the range of materials and tools used when drilling, creating and developing the quality of bits, automating work, and increasing the level of drilling operations as a result of the inclusion of automated control systems.

"In a world where early is on-time and on-time is late, automation is crucial for any enterprise to succeed no matter the market or industry."

—Gene Chao, Global Vice President, IBM Automation [1]

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INTRODUCTION

Automation is an indispensable component of modern production. The automation process includes the creation and use of special tools that work in automatic mode, as well as the formation of technological processes that increase productivity on a permanent basis.

In order to move to the automation of technological processes and production, the company should observe a number of conditions such as staff training, the rule explanation and features of the management of new equipment to obtain an initiative response and new proposals;

consistency and specialization of production; at the same time, automation should not cover individual elements, but the entire production, that is, an integrated approach is needed;

rational use of resources. Fulfillment of this requirements will ensure effective operation of the enterprise for a long period.

Due to the industrial automation process, the number of personnel employed in production is reduced, because with the use of modern technology, one worker is able to serve several units of equipment. Another advantage of automation is the possibility of improving not only the process, but also the equipment used. In addition, production costs are reduced because of automating technological processes and standardizing the elements and mechanisms.

The main problem of automation is the necessity to develop new solutions and approaches for each process. It is important to take into consideration the exact size, shape, characteristics and properties of the component parts because the quality must meet all the requirements for better organization of the workflow. [2]

The oil and gas industry in Uzbekistan, as in many other countries play a major role in the state economy. And since the times of the Soviet Union, oil and gas have been pumped in various regions of our country, as well as by the national and foreign companies. In drilling rigs, all the main processes are carried out by people. Therefore, ensuring the safety of workers and the intensification of production is an integral part of the drilling process. [3]

The oil and gas industry has seen many drilling rig accidents (e.g. kick, blowout, sticking, hydraulic fracture treatment, etc.). These accidents lead to deplorable environmental problems and financial loss. [4] Certain accidents are usually caused by the worker's negligence and other unexpected situations. However, advances in technologies and latest scientific studies play a critical role in minimizing dangerous situations during the drilling process. The use of automated technological systems is one of the solutions for a safety and effectiveness. [5]

It is important to note that in addition to ensuring safety, automation of the management process has significantly improved the efficiency of exploration in the oil industry. [6] The use of innovative technologies in this area has eliminated many problems when measuring parameters at the bottom, and what is worth noting as a huge success is the opportunity to screen a well in real time. [7]

Today, oil and gas production puts the tasks in front of the drillers more and more difficult, which requires intensification, an increase in penetration rates. Considering that workforce and drillers are responsible for making important decisions, it causes a physical and psychological pressure on them. Because of this pressure, the wrong technological decisions can be made and it can lead to unfortunate repercussions such as increasing the drilling time.

This industry sector is difficult because you have to work with the black box and with the deepening of the well unpredictability occurs, and this model is developed as a result of studying geological and geophysical features. Consecutively, a driller, based on his experience, is able to perform drilling out of plan in order to prevent unforeseen situations on time. But such skills come with years of work, as more than 60% of the knowledge for making important decisions in this industry is earned by experience. Accordingly, it is quicker and cheaper to train a driller to use an automatic drilling method system which will choose and maintain the best drilling conditions in accordance with such as optimality criteria and among established limits. [8] The assistance of machine-controlled management systems will make it possible to standardize the drilling process more strictly and widely introduce advanced drilling technologies.

The device for gathering and preliminary processing information regarding the drilling condition is an integral part of the automated control system for this process. The target of this final project is the analysis of the development of such a tool. The selection of this problem is determined by my interest on experimental combination of automatic controllers and petroleum industry, as my final of bachelor degree was also related to the application of neural controllers in the transportation of crude oil.

CHAPTER 1. DESCRIPTION OF TECHNOLOGICAL DRILLING PROCESS

1.1. DRILLING WELL AND ITS ELEMENTS

Drilling wells is the process of constructing directional mine workings of great length and small (compared to length) diameter. The beginning of the well on the surface of the Earth is called the wellhead, and the bottom - the bottom-hole. The main elements of the borehole (*Figure 1.1*) [9]. Oil and gas are produced using wells. The main processes of their construction are drilling and strengthening. It is necessary to carry out high-quality well construction in increasing volumes, with multiple reductions in terms of project duration for the purpose of providing the consumers with oil and gas in ever-increasing quantities while reducing labor and energy intensity and capital expenditures.

Well drilling is the only source of efficient exploration and increment of oil and gas reserves.

The whole cycle of construction of wells before putting them into operation includes the following main successive procedures:

- construction of surface facilities;
- deepening of the wellbore, the implementation of which is possible only when performing two types of work in parallel - the deepening itself and washing of the well;
- segregation of layers, consisting of two consecutive types of work: strengthening the wellbore with running tubes connected to the column, and plugging (cementing) the annular space;
- development of wells. Often the development of wells in conjunction with some other types of work (opening the reservoir and attaching the bottom-hole zone, perforation and intensification of fluid flow, etc.) is called well completion. [10]

There is also the concept of "well design." The well design implies its characteristic, which determines the change in diameter (D1, D2, D3) with depth, as well as diameters (Di, Do[1]) and length (L1, L2) of casing strings 3 (*Figure 1.1*). It is possible to make another distinction, that is between a wellbore not cased with tubes (5) and a cased wellbore (2). The following diameter of the well decreases after each fixation. Each casing extends above the wellhead but can be lowered and countersunk. If it is necessary, the space between the walls of the well and the casing is filled with cement.

[1] * Di, Do – internal diameter, outer diameter.

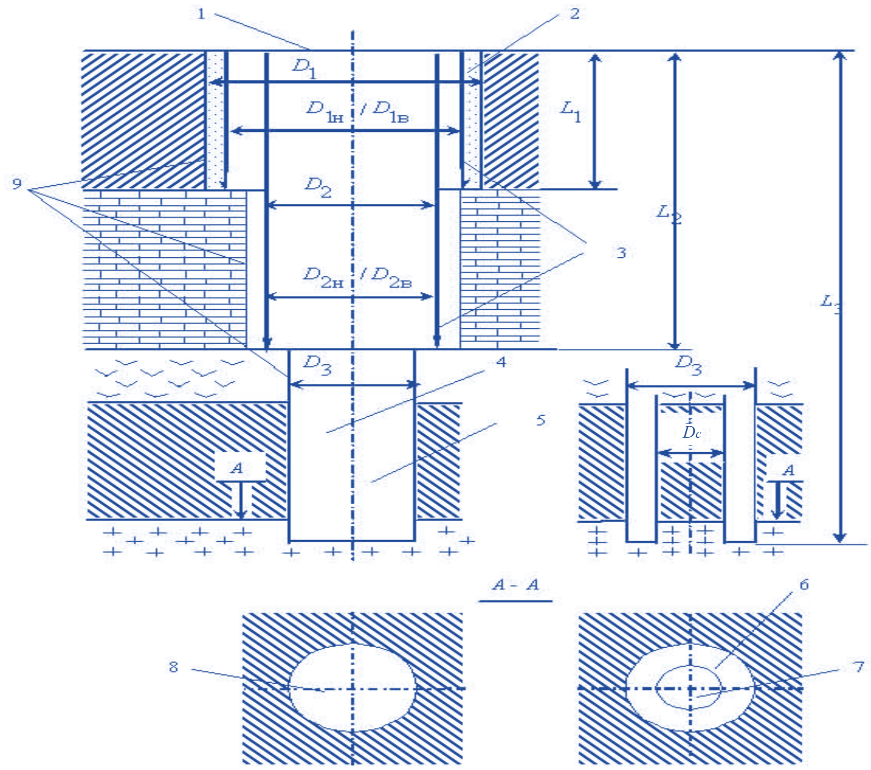

Figure 1.1 Elements of the borehole: 1 - wellhead; 2 - wellbore, cased tubes; 3 - casing strings; 4 - well axis; 5 - wellbore, not cased; 6 - the circular face; 7 - core; 8 – full hole; 9 - well walls; D1, D2, D3 - borehole diameters in different intervals; D1i, D1o, D2i, D2o are the casing diameters, respectively, external, internal; D_C - core diameter; L1, L2 - the depth of the intervals of the well, cased; L3 - well depth. [9]

1.2. CLASSIFICATION OF DRILLING WELLS

In the oil and gas industry wells drilled for the purpose of regional exploration, prospecting, exploration, and development of fields can be systematized by the following way:

Figure 1.0.2 Onshore [10] and [11] offshore exploration well.

- *Stratigraphic,* the purpose of which is the establishment (refinement) of tectonics, stratigraphy, lithology, assessment of horizon productivity (without additional well construction);

- *exploration*, serving to identify productive objects, as well as to delineate the already developed oil and gas reservoirs;
- *production (operational),* intended for the extraction of oil and gas from the earth's interior. Injection, appraisal, observation and piezo metric wells also belong to this category;
- *injection,* intended for injection into the reservoir of water, gas or steam in order to maintain reservoir pressure or to treat the bottom hole zone. These measures are aimed at lengthening the period of the flow of oil production method or improving the efficiency of production;
- *development,* serving for oil and gas production with simultaneous refinement of the structure of the productive formation;
- *appraisal,* the purpose of which is to determine the initial water and oil saturation and residual oil saturation of the reservoir (and the research);
- *control and observational,* designed to monitor the object of development, the study of the nature of the movement of reservoir fluids and changes in the gas and oil saturation of the reservoir;
- *offset wells* are drilled to study the geological structure of large regions in order to establish the general patterns of occurrence of rocks and to identify the possibility of the formation of oil and gas deposits in these rocks. [10]

1.3.FUNDAMENTALS OF THE WELL DRILLING PROCESS

The modern process of drilling a well is a complex technical and technological process consisting of a chain of links, the failure of one of which can lead to complications, accidents or death of the well. (*Figure 1*.0.3).

Figure 1.0.3 Well drilling. [13]

The drilling process is a complex of consecutive difficult tasks. First of all, the drill pipes (columns) are descended with a rock cutting tool into the well. Then the bottom-hole rock is destroyed taking into account the set parameters. This is followed by the lifting of the drill pipe from the well to change the worked-out drilling tool and the operation is repeated. One of the important processes in drilling a well is strengthening of the walls of the well when a certain depth is reached by the casing with the subsequent cementing of the space between the wall of the well and the lowered pipes (separation of the layers). [10]

Rock can be destroyed by mechanical, electrical, thermal, explosive, chemical and other methods. Rocks are usually drilled mechanically with various rock cutting tools. In our and foreign practice, scientific research and experimental and constructive works are being carried out in the field of creating new drilling methods, technologies and techniques. These include the deepening of rocks using explosions, the destruction of rocks using ultrasound, erosion, using laser, vibration, etc. Analysis of various methods indicates the need to increase the power supplied to the bottom-hole.

Some of these above-mentioned methods have been developed and used, even if in small amounts, but often at the experimental stage. For example, a *hydro-mechanical method* in comparison with mechanical methods provides an opportunity to improve technical and economic indicators through the use of water jets. *Erosion drilling* provides deepening speeds of 4-20 times more than with rotary drilling (under similar conditions). *Lasers* - quantum generators of the optical range - one of the remarkable achievements of science and technology. The high power of lasers under conditions of obtaining extremely high radiation projections is sufficient to melt and evaporate any materials, including rocks, which also crack and peel. Moreover, during laser drilling, the cross-sectional shape can be programmed, and the borehole wall will be formed from the rock melt and will be a glassy mass, which allows to increase the cement displacement ratio of the drilling mud. In some cases, we can obviously manage without strengthening walls of the wells. [10]

Therefore, the technical and technological development makes oil and gas industry easier, softer, cost and time effective, environmentally friendly and most importantly these developments ensure safety for people.

1.4.CLASSIFICATION OF DRILLING METHODS

The destruction of rocks can occur with the implementation of various processes such as mechanical, physical and physic-chemical. The process of mechanical destruction consists in the separation of a certain volume of a solid (rock) under the action of a force field on the elements - particles of small size, due to the rupture of the connection between them. This type of process occurs during creating concentrated stresses that exceed the resistance of the internal bond forces in a certain volume of a solid body. Rock destruction can also occur with a fundamental change in its quality or composition and state as a result of chemical or physic-chemical processes, such as melting, burning or dissolving the rock itself at the level of breaking molecular bonds, which we can refer to physic-chemical destructions. [14] Mostly, mechanical drilling is used and depending on the method of impact on the rock being destroyed it is subdivided into rotatory, percussion and percussion-rotary (*Table 1.1*).

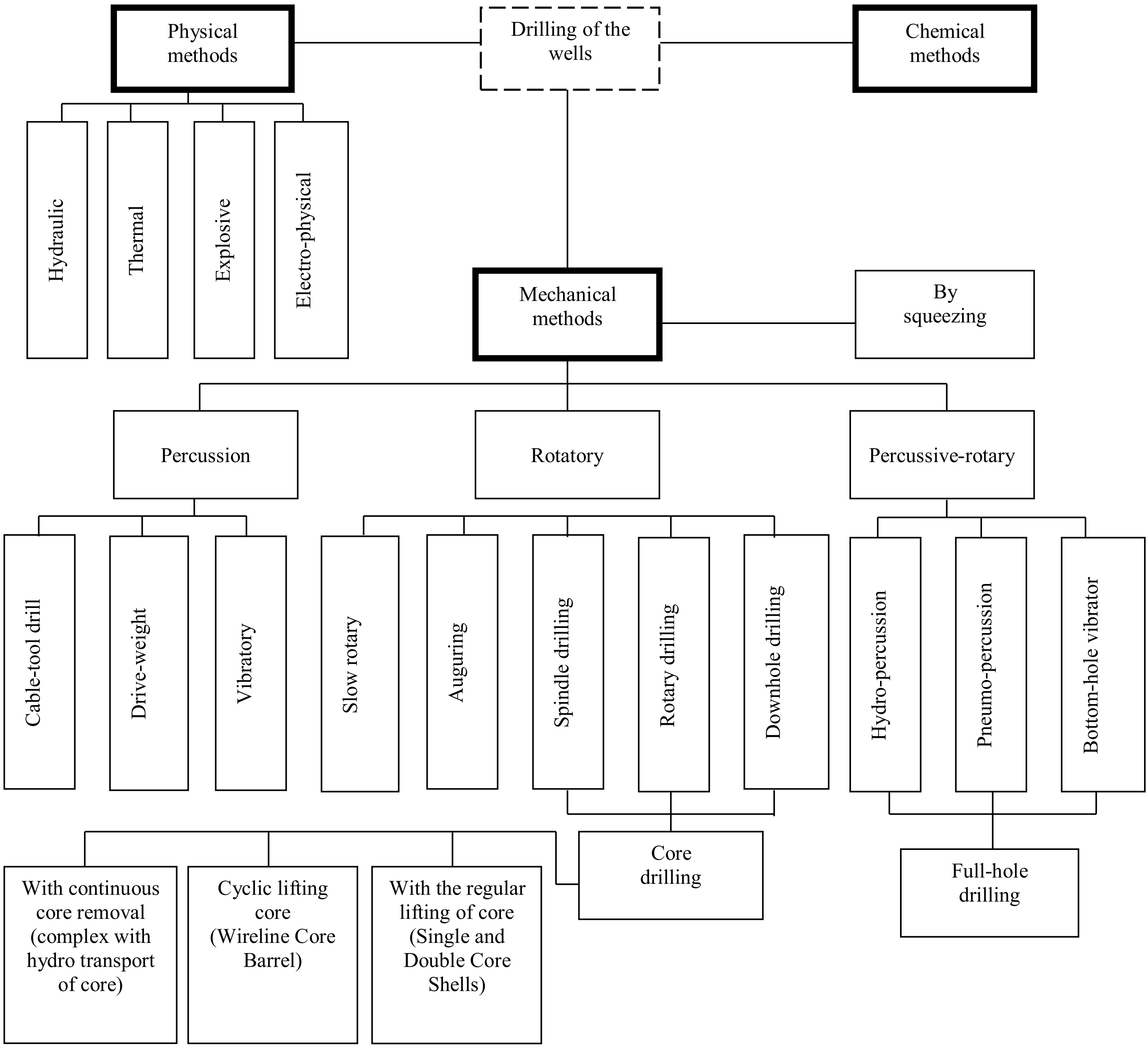

Table 1.1 Classification of mechanical methods of drilling wells

There are several combined methods of rock destruction were identified: percussion, rotatory, rotatory-percussive and percussive-rotary, vibratory, vibratory-rotational. (*Table 1.1*).

In the percussion, the destruction of the rock occurs by striking with a rock-breaking tool (chisel or balls) with a certain force and speed. After each hitting, the chisel turns at a certain angle without a load. That is the process of crushing, chipping and shearing of the rock. As a result, this type rock cutting tool belongs to the crushing-shearing tool.

The rotatory method of rock destruction is carried out with the rotation of the tool embedded in the rock under the action of a constant (static) axial load and cutting force. In this case, the processes of cutting, chipping, crushing, and abrasion of the rock are realized, and the tool, by the nature of the action, falls into the category of cutting-cleaving action or cutting-abrading.

The rotatory-percussive method of rock destruction is carried out using a roller-type tool, during the rotation of which the cones, armed with teeth, roll over the face, as a result of which the axis of their rotation rises, then descends. In the latter case, the teeth of the roller cutter collide with the rock of the face, namely, they strike with a sufficiently large force, as a result of which the rock in contact with the teeth is destroyed by shattering, chipping and squeezing. Consequently, this type of tool has a shattering-chipping-squeezing action.

The percussive-rotary method of rock destruction is also carried out when the rock-cutting tool rotates under the action of a force that penetrates into the face under the action of a force, and periodically acts of strike inflicted with the help of special percussion mechanisms with a certain frequency. At the same time, the processes of cutting, chipping, crushing, shattering and abrasion of the rock are realized, as a result of which the rock-breaking tool belongs to the category of cutting-chipping -shearing action.

The vibratory method of drilling consists in deepening a special downhole tool, usually of a cylindrical shape (pipe) with a pointed end, into loose rock under the action of forced superimposed high-frequency reciprocating vibrations (dynamic load) and axial load. At the same time, the processes of loosening, moving and rock compaction in the walls of the well.

The vibration-rotational method consists in the destruction of hard rocks during the rotation of a special tool with force, the action of axial force and dynamic high-frequency impulse alternating loads (vibrations). In this case, the destruction of the rock occurs due to the processes of chipping, cutting, crushing, shattering and abrasion (according to the scheme of percussive-rotatory drilling).

The method of drilling by squeezing with drilling tool, consists in deepening a rock cutting tool, having the shape of a cone or a hollow cylinder, into a soft rock only under the action of axial force. In this case, the rock is destroyed by the processes of crushing, movement of the rock being destroyed and its compaction in the borehole wall is similar to the process of deepening the drill tool during vibratory method, only without the action of the vibratory load. [14]

1.5.BASIC TECHNICAL AND TECHNOLOGICAL CONCEPTS OF DRILLING PROCESS

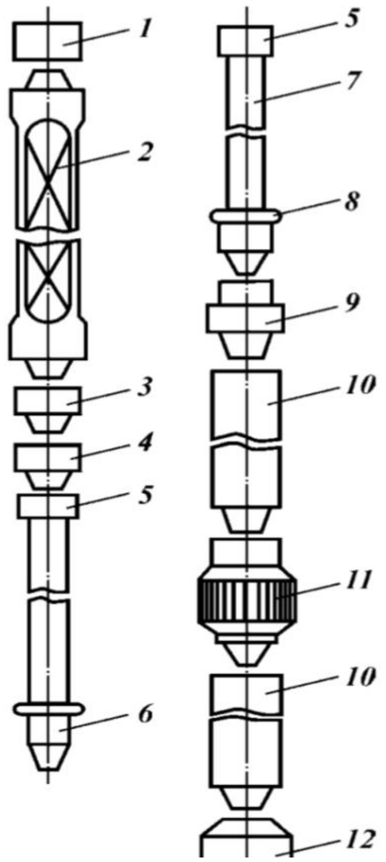

Figure 1.4 The design of the drill string:

1 – top kelly sub; 2 - kelly; 3 – bottom kelly sub; 4 – kelly saver sub; 5 - box connector; 6 – tool joint pin; 7 - drill pipes; 8 - protector; 9 - sub to DC; 10 - DC; 11 - centralizer; 12 – cushion sub

The drill string is a drill pipe assembly, designed to deliver hydraulic and mechanical energy to the drill bit, to create an axial load on the drill bit, and also to control the trajectory of the drilled well (*Figure 1.4*)[2]. The drill string connected with the bit and the downhole motor and drilling tool and it performs the following functions: transmits rotation from the rotor to the bit; receives from the downhole motors reactive moments; delivers a washing agent to the bottom-hole; delivers hydraulic power to the bit and bottom-hole hydraulic motor; presses a drill bit into rocks at the bottom, acts with its own force of gravity; provides replacement of the bit and the down-hole engine by transporting them to the bottom or to the surface; allows to conduct emergency and other special works in the wellbore. [10]

Another main tool of drill string is drill bit, which is chosen depending on the physical and mechanical properties of rocks, their depth and the method of drilling. Rolling, bladed milling, crushing, diamond and other bits can be applied depending on the situation. Tricone bits of various types and sizes have the largest application in the domestic and foreign practice of drilling.

In order to increase the drilling speed, deepening and expanding theoretical and experimental studies of rock fracture mechanics and well drilling mode play a critical role, since partial modernization of roller bits and drilling technology does not provide a significant increase in basic technical and economic indicators of drilling operations. [10]

The concept of drilling mode is understood as a certain combination of factors affecting drilling performance. These factors are called drilling mode parameters. The most important parameters are: axial load on the bit; bit rotation frequency (or rotor); the amount (consumption) of circulating drilling

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[2] **DC – Drill Collars.*

mud; quality of circulating drilling mud supplied to the bottom hole (filtration, static shear stress, viscosity and density).

The ratio between the parameters of the regime must be chosen in a way so it can obtain the highest quantitative indicators with the required quality and the lowest possible cost per 1 meter of penetration.

In the practice of drilling, there are cases when it is necessary to select the parameters of the drilling mode for solving special tasks to ensure quality indicators. Quantitative indicators of drilling, in this case, are minor. This type of drilling modes are called special. These include drilling modes used in non-favorable geological conditions, as well as drilling modes used when changing the direction of the axis of the wellbore and when selecting cores. However, the qualitative formation of the well should always be determinative.

The combination of the parameters of the drilling mode, at which the penetration rate per run and the required quality drilling indicators are obtained, with this technical equipment of the drilling rig, is called the optimal drilling mode. [15]

The effectiveness of drilling is usually judged by the rate of penetration and the cost of a meter of penetration. For the assessment of certain types of work associated with the drilling of wells, the concepts of mechanical, per run, technical, commercial and overall drilling speeds introduced.

The average mechanical drilling speed is the depth of the well per unit of net drilling time and is determined (in [m/h]) using the formula:

$$v_M = \frac{l}{t_d},$$

where l - is the value of well deepening during drilling, [m]; t_d - the duration of the well drilling, including expansion and development of t_n, [h].

Drilling speed per run - the value of the well depth per unit of time of the duration of the run and can be determined (in [m/h]) by the formulas:

$$v_r = \frac{v_M}{t_d + t_t} \quad \text{or} \quad v_r = \frac{v_M}{1 + t_t / t_d},$$

where t_t - time to perform tripping that includes RIH/POOH (Run in the hole/ Pull out of the hole) of a drill tool and auxiliary operations as replacement of rock cutting tools, etc., [h].

The technical drilling rate is determined by the volume of drilling drilled by one team (drilling rig) per month, taking into account the time spent on drilling, RIH/POOH (Run in the hole/ Pull out of the hole) and auxiliary operations, mounting and cementing, all researches, scheduled preventive repairs, etc. (in [m/machine-month] or [m/h]):

$$v_t = \frac{v_r}{c * [1 + t_{net} / (t_d + t_t)]} \quad \text{or} \quad v_t = \frac{v_M}{1 + (t_t + t_{net}) / t_d},$$

where c – time conversion factor, (hours to months).

Commercial drilling rate is determined by the volume of drilling per month, taking into account also non-productive costs (downtime, complications, accidents) (in [m/machine-month]):

$$v_c = \frac{v_t}{c*[1+t_n/(t_t+t_{net}+t_d)]} \quad \text{or} \quad v_c = \frac{v_M}{c*[1+(t_t+t_{net}+t_n)/t_d]},$$

where t_n is the duration of all non-productive work, [h].

The overall drilling speed is the ratio of the depth of the well to the time spent per month from the transportation of drilling equipment to the abandonment of the well ([m/machine-month]):

$$v_{net} = \frac{v_c}{c*[1+t_m/(t_n+t_t+t_{net}+t_d)]} \quad \text{or} \quad v_{net} = \frac{v_M}{c*[1+(t_m+t_t+t_{net}+t_n)/t_d]},$$

where t_{net} - the duration of all productive work, except for the specified t_d and t_t , [h],

t_m - the duration of the construction of the rig and installation works, [h].

From the above formulas, it can be seen that v_r, v_t and v_c depend on v_M, in addition, from the listed speeds each subsequent depends on the previous one.

Large amount of studies has shown that v_M, v_r, v_t, and v_c decrease with increasing depth l of the well, and the cost per meter of penetration for all drilling methods is an increasing function of the depth of the well.

With growth of v_c, as a rule, the specific consumption of electricity and the consumption of materials used in drilling significantly decreases. The identification of factors affecting the speed of drilling and establishing the influence of each of them separately and in total, establishing the nature of the drilling speed drop due to the deepening of the well and finding ways to reduce the rate of decrease in drilling speed due to the increasing depth of the well are in the list of high priority interests.

Three groups of factors have a decisive influence on the rate of penetration:

a) natural factors (mechanical properties of rocks, the conditions of their occurrence, the nature of the substance filling the pore space, etc.);

b) technical and technological factors (method of rock destruction, design features and durability of cutting tools, method of removing cuttings from the bottom of a well, perfection and power of drilling equipment, etc.);

c) business qualification of workers of the drilling crew. Significantly affect the speed of drilling by the organization of work in the shift, the harmonization of workers in the shift and of course their knowledge, experience and working skills. [10]

1.6.FUNDAMENTALS AND VARIETY OF DEEP ROTATORY DRILLING

As we mentioned in previous chapters, when a well is deepened, the rock can be destroyed by crushing, shattering, and / (or) abrasion. Each type of these destruction correspond to the main methods of drilling: percussion, rotatory, percussive-rotatory and vibratory drilling.

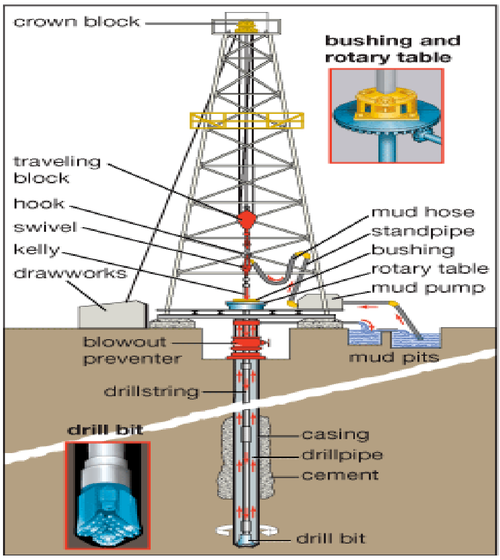

Figure 1.5 Rotary drilling rig [22]

The most widely use among all mechanical methods is rotatory drilling. In this method, a cylindrical barrel is formed by a continuously rotating chisel. Drilled particles during drilling are also continuously brought to the surface by circulating drilling mud (gas, carbonated liquid). In rotatory drilling, the chisel is embedded in the rock as a result of the simultaneous action of axial force (load), directed perpendicular to the bottom plane, and the circumferential force from torque. [15] (*Figure 1.5*).

Rotatory drilling can be divided into: rotary drilling, - when the engine, which causes the bit to rotate at the bottom, using the drill pipe string, is on the surface; turbine drilling and drilling with using an electric drill - when the engine is located at the bottom of a well, above the bit. The flow of drilling mud, besides the known functions, also performs the functions of an energy source. [10]

Rotary and turbine drilling are the main methods of drilling wells and they are used everywhere, including Uzbekistan where the turbine method of drilling is also widely used by both local and foreign companies since it is possible to apply this method regardless of the rock hardness variability and even to reach relatively high drilling rates. And practice shows that the resistance of pipes is about 10 times higher than the resistance of pipes in rotary drilling. Moreover, in the turbine drilling, the power transfer coefficient from the energy source to the bit is significantly higher than in the rotary. [10]

The success of modern turbine drilling mainly depends on the possibility of implementing the optimal modes of testing new designs of high-performance bits, created in recent years. Evidently, a turbo-drill is a high-speed machine, and therefore, creating low-speed turbo-drills that can effectively work roller cone bits with sealed oil-filled bearings has a great importance in development of these exact field. Subsequently, a number of new directions are being created in the design of turbo-drills, such as: with a system of hydrodynamic braking, multi-sectional, with a floating stator system, with a gearbox inserted, etc. But among designers of turbo-drills, there is still no consensus about the most effective and promising direction of turbine drilling method development technology. [10]

CHAPTER 2. TECHNICAL AND ECONOMIC JUSTIFICATION OF THE DEVELOPMENT OF THE AUTOMATED MANAGEMENT SYSTEM OF WELL DRILLING

2.1. TECHNICAL AND ECONOMIC PREMISES FOR DRILLING PROCESS OPTIMIZATION

The optimization process is the basis for creative engineering, including inventive activity, and allows improving the quality of functioning of already existing technical systems, improving the production technology, creating and designing new, more functional and effective technical systems. But the optimization process covers not only technological processes and technical objects, but optimization can also be subjected to organizational processes, decisions in economics, etc. Thus, the optimization process is characterized by signs of a systematic approach and is a process of continuous and comprehensive improvement of any production system.

The system approach as a method proceeds from the fact that any organization, the process is considered as a complex whole, as a set of interrelated parts - functioning elements that make up a certain system. The main properties of any system are measurability and efficiency. At the same time, measurability is the ability of the system to measure its characteristics, and efficiency is the ability to solve a problem with the help of this system. [16]

Optimization parameters can be economic, technical-economic, technical-technological, statistical, etc. Out of the many parameters characterizing the object of research, only one, often generalized, can serve as an optimization parameter, which is distinguished as optimal solution criteria. And in turn, the optimality criteria can be divided into global and local, technical and technical-economic.

Global criteria for the well drilling process characterize the completed drilling process and its main results. These include the cost and time of penetration of the wellbore and derivatives of them: the average cost and time of drilling 1 m of the well, the technical and commercial drilling speed, etc. Global criteria is not only final, but also integral and should be used at the design and production stage drilling operations, i.e., at the first stage of optimization, since the task of the first stage is to select type alternatives that affect the whole process.

However, local criteria include the instantaneous mechanical drilling speed, wear rate of a rock-cutting tool, speed per run, tool life, core output, diamond consumption per 1 meter of penetration, drilling time, etc. And thus, local criteria should be used directly during the work process, for example, when choosing a tool for drilling and determining the optimal parameters of the drilling mode. It is important to note that the optimal performance and maintenance of local criteria allows us to obtain optimal values of global criteria, since these criteria are formed as the sum of local indicators. [16]

An example of a global criteria for a geological exploration system is the interaction of three main factors, such as reliability, time and cost, each of which can also be taken as global criteria that determines the main result of any production and commercial activity, i.e. profit.

Along with the economic optimization criteria, to which the profit obtained during the performance of geological exploration works can be attributed, more detailed technical, economic and technological criteria are possible.

A modern drilling rig can be equipped with instrumentation, recorders and automatic control devices. The main, especially for high-frequency diamond drilling, remains the process of controlling the deepening of the well, the development of optimal parameters of the drilling mode. Thus, the choice of drilling method and mode is a multifactor analysis, the result of which can be the level of profit, expressed through cost savings while maintaining the high quality and reliability of the obtained geological. [16]

2.2. OPTIMIZATION OF DRILLING PROCESS AS AN AUTOMATED CONTROL OBJECT

Optimization of drilling, like any other production process, is impossible without the use of means of control, analysis and automation of technological cycle operations. In this case, the optimization tools at the first stage can be monitoring instruments, such as measuring device of axial force, drilling speeds; recorder of energy consumption, torque, flushing fluid flow meters, instrument complexes for recording parameters and monitoring the drilling process, which record various parameters of the drilling process and allow to accurately control and set the specified technological regimes.

At the second stage of improving the control system, drilling units equipped with a set of instrumentation should include a system for automatically controlling the drilling process, which solves the problem of finding optimal drilling conditions and maintaining selected parameters within specified limits.

The third stage of creating automated control systems in drilling is associated with drilling rigs that are able to work autonomously in an automatic mode: at the first stage, when deepening a well, and at the second stage, and when carrying out descent operations. At the same time, the drilling control system, controlled by the processor, is guided by the program and criteria focused on the search for optimal conditions and parameters of the drilling mode.

The basis of production automation is an automatic control, which we can describe as a set of actions aimed at maintaining or improving the operation of a controlled object without direct human participation in accordance with a given control goal. The process control algorithm must necessarily include the function of searching for optimal conditions. [16]

The goal of management is in one way or another associated with the change in time of the controlled variable — the output value of the controlled object. To accomplish the goal of control, it is important to take into account the characteristics of controlled objects of various nature and specific features of individual classes of systems, the control disturbance of the control bodies of the object is organized. It is intended to compensate for the effect of external disturbing influences that tend to violate the desired behavior of the controlled variable. The control action is generated by the control device.

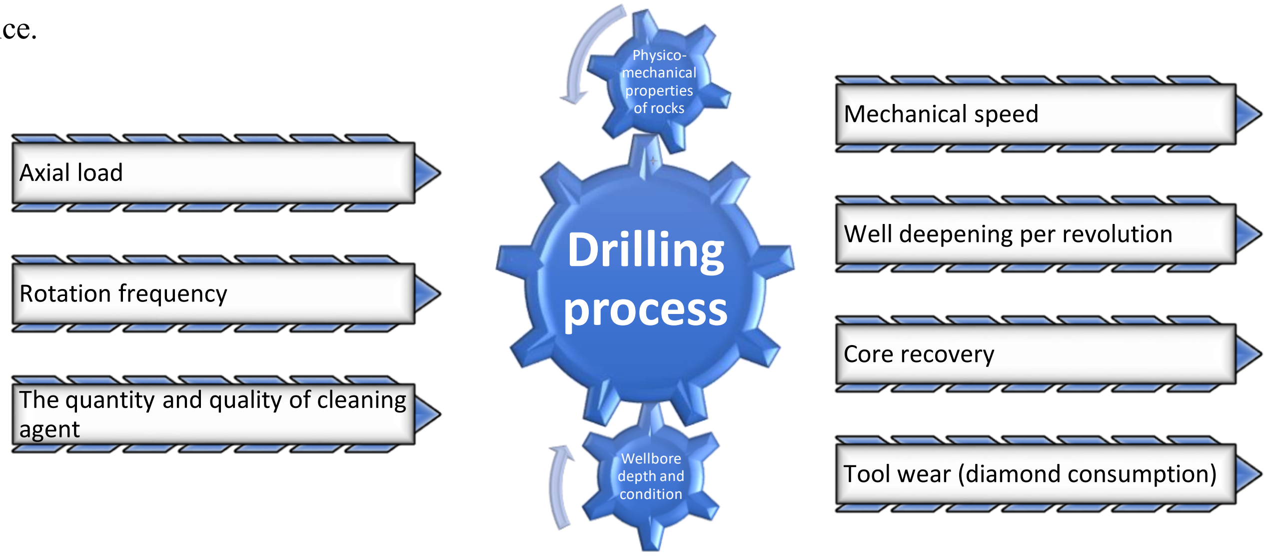

Figure 2.1 The structure of the drilling process model

While drilling, the parameters of the drilling mode are used as factors of controlling disturbance: axial load, rotation frequency, quantity and quality of the cleaning agent supplied to the well, etc. (*Figure 2.1*). The parameters of the drilling mode, their variation have a controlling effect on the object - the well deepening process taking into account external disturbing influences - rocks that vary in their physical and mechanical properties, varying depth, profile and condition of the wellbore, exhibiting of the effects of geological complications of drilling, etc.

The output values of the drilling process - mechanical drilling speed, deepening per revolution, core recovery, wear of cutting tools are parameters that evaluate the qualitative and quantitative aspects of the drilling process and can act as criteria for controlling the drilling process through weighted adjustment of control actions.

The basis of automatic process control is the generated control action on an object or a system of objects and this system is developed according to the principle of regulation and the principle of search. Thus, divided into respective classes:

In an automatic regulation system, control actions are generated by comparing the actual value of the controlled variable with its specified value. Control systems are used to control simple objects, the characteristics of which are studied in advance and for which you know in advance which direction and how much you need to change the control action with a certain deviation of the controlled variable from the specified value. For example, these are systems for heating water, indoor air or aggregates, systems for automatically shutting off water to a container, etc.

In the automatic search system, the main control actions are formed using test control actions and by analyzing the results of test actions. This type of procedure for finding the correct control actions has to be applied in cases when the characteristics of the object change or are not fully known. For example, the type of dependence of the controlled variable on the control action is known, but the numerical values of the parameters of this dependence are unknown. Therefore, search systems are also called systems with incomplete information.

Most often, the principle of automatic search is used to control objects whose characteristics have extreme parameter values. The goal of management is to find and maintain control actions corresponding to the extreme value of the controlled variable. Such search systems are called extremal systems. And drilling process control system is a bright example of extreme control system.

The principle of operation of the system is based on the extreme nature of the dependence of the drilling speed on the drilling thrust into the well. Each value of the rock hardness corresponds to a certain value of the force at which the mechanical drilling speed will be maximum. Therefore, the task of the system is to find the optimum value of the force at different, previously unknown hardness of the rocks. As a response, another parameter can be used, for example, a deepening per one revolution of the tool at the bottom hole, or the magnitude of the torque.

The drilling speed is measured in the system using a tachometer generator, kinematically connected with the drill rod and acting as a drilling speed sensor. The feed force is created by the hydraulic cylinder, into which the working fluid flows through the choke. The feed force depends on the throttle position. The throttle is affected by the servomotor. The direction of rotation of the motor depends on the position of the contact of the electromagnetic relay. The relay is an actuator and at the same time performs certain logical functions together with a storage device. The storage device consists of a diode and a capacitor and supplied with a voltage proportional to the speed of drilling.

The search for the optimal values of the tool feed force is as follows. If the feed force is less than the value then it will be able to provide the maximum drilling speed which will allow the engine to move the throttle upwards. As the speed increases - the diode is conducting, the voltage on the relay coil is zero, the contact is in a position that corresponds to an increase in feed force. As soon as the force exceeds the optimal value, the speed will begin to decrease. In this case, the voltage will also begin to decrease, and a voltage equal to the difference of two values will appear on the relay coil: the previous one, which is now in the memory of the capacitor, and the current, proportional to the speed of drilling at the moment. The relay turns on and changes the direction of rotation of the motor. At the same time, a capacitor will be discharged through the contact (the old value is reset). Now the feed force will begin to decrease, and the drilling rate will approach the maximum value along the opposite path of the extremal characteristic. In the future, this process of reversing the engine is repeated many times, so that drilling occurs mainly at an optimal feed force. [16]

IBM believes that now is the time to accelerate digital transformation at both the strategic and operational level, and drive significant improvement in business value realization. Improving the output of facilities and wells, streamlining maintenance and turnarounds, and optimizing downstream commodity trading are areas where information technologies create improvements in cost reduction and avoidance, operational uptime and revenue generation. [17]

2.3. EFFICIENCY OF DEVELOPMENT AND IMPLEMENTATION OF SYSTEMS OF AUTOMATED DRILLING PROCESS MANAGEMENT

The automatic process control system for drilling wells provides:

- ✓ optimization of the technological process by the criterion - cost of 1 m of drilling or implementation of management by private criteria - maximum performance with limited consumption of diamonds or minimum consumption of diamonds with limited performance;
- ✓ high quality of drilling operations on the core recovery;
- ✓ prevention (warning) of technological complications and accidents;
- ✓ improving the organization of labor of drilling crew;
- ✓ decrease in psychological loadings on the driller in the conditions of the forced technological process;
- ✓ independence of technical and economic indicators of drilling from qualifications of the drilling crew personnel;
- ✓ the possibility of rapid adjustment of the process by software;
- ✓ the ability to create an extensive automated system for the production of drilling operations throughout the geological survey object.

While working on automatic control mode, the following operations can be performed:

- flushing wells;
- the setting of the cutting tool to the bottom-hole at the beginning of the tripping;
- running in rock cutting tool;
- the search for the optimal values of axial load, flow rate of drilling fluid and the speed of rotation of the drill;
- adjustment of drilling parameters in accordance with changing geological and technical conditions;
- control and prevention of emergency situations;
- illustration of the main drilling parameters on the display in the form of histograms;
- the output of operational messages and the sound signal when an abnormal situation occurs in the process;
- the termination of the run in the implementation of the measurement or the occurrence of a non-eliminated emergency situation.

Therefore, when working in an automatic mode, the functions of the driller consist in performing launching operations, round-trip operations, starting the system, maintaining the equipment, and preparing the technological tool for operation. [16]

An example of creating a fully automated drilling unit is the RBC-4 system - a robotic drilling rig for drilling exploration wells for solid minerals. This drilling rig contains a drilling unit, which incorporates a numerical control system and a flush pump with a continuously adjustable hydraulic drive and with a water intake pump for liquid additives and flushing fluid, as well as a closed circulation system consisting of a tank with flushing fluid and a flushing fluid cleaning unit; a toolkit with two on-board storage device for drill pipes, devices for maintaining core pipes and cores, devices for measuring and sharpening diamond crowns, tank and industrial water heater, as well as standard geophysical probes for well logging and operator's cabin. [16]

The greatest effect from the use of robotic drilling rigs can be obtained during operation as part of an automated production system (APS). The main purpose of the APS is to create a closed information system, the elements of which are sources of information and its consumers. The APS system should ensure obtaining of high-quality geological, technological and production information, the rapid transfer of information and its automated processing for the purpose of making decisions, the transfer of information and decisions to production units for execution.

As part of an automated production system, drilling machines equipped with local control. Also, data acquisition systems can be operated. And APS consists of three production units:

1) the drilling subsystem, which includes the automated workplaces of the process engineer and dispatcher in the unit (the unit is equipped with radio communication and an

information transmission system); robotic drilling complexes; electronic service and hydro-service facilities; pipe base and tool storage; mud room;

2) geological substation, including: automated workplaces of the geologist, automated core storage; conducting an express analysis, sample preparation unit and analytical unit;
3) economic subsystem, including: automated workplace supervisor; services: transport, energy, maintenance, engineering, etc.

Automated drilling systems of the company Atlas Copco (Epiroc[3]) are the most well-known drilling units. These are the Diamec® U6 APC and the Diamec® U8 APC drilling units (*Figure 2*.0.2).

Figure 2.0.2 Drilling units Diamec® U6 APC and the Diamec® U8

The core drilling rig with automatic control of drilling parameters and a direct core receiver Diamec® U6 APC is equipped with a direct acting hydraulic cylinder (without a chain), a rod holder

[3] **Epiroc AB is a Swedish industrial company that was created in 2018 when it was split off from Atlas Copco and dividended out to Atlas Copco's shareholders. Epiroc was listed on the Nasdaq Stockholm stock exchange on June 18, 2018. Epiroc makes mining and infrastructure equipment.* [32]

with a gas cartridge with a long service life and a rotator with isolated reducer valve. The rotation frequency of the rotator is adjusted from the control panel, the actions of the hydraulic expansion tool holder and rod holder are synchronized. The electric power of the plant reaches 55 kW, diesel 85 kW. The machine is operated by one operator due to the new positioning design, which speeds up the preparation of the machine when changing the direction of drilling and also due to the full automation of drilling processes.

The automatic drilling control system with which the machine is equipped allows to drill in automatic mode. The APC system records the drilling data in the computer's memory: well depth, amount and water inlet pressure, rotational speed, drilling speed, weight on bit, pressure in the hydraulic system, etc. The APC system optimizes drilling speed, adjusts the feed force, rotational speed and torque in accordance with changes in drilling conditions. This allows the operator to perform other work while drilling - empty core receiver, prepare crowns and rods.

The use of modern machine tools with an automated control system show very high drilling performance results. In the United States (Idaho), on a Diamec U8 machine with a columnar diamond drilling in automatic mode, a penetration reached 185.6 m in 10 hours. The result shows the capabilities of automated systems that can optimally control the drilling process. [16]

2.4. DEVELOPMENT OF THE TECHNOLOGICAL CONTROL SYSTEM OF DRILLING PROCESS

The features of the process control system are: large volume and complexity, which is associated with the transfer of a significant amount of information and the need to use additional equipment for intermediate information processing; and also the presence of the equipment, allowing to carry out the control process both from the dispatcher and automatically; the possibility of transferring the information from the controlled objects to the computer and from the computer to the objects; and, of course, the availability of hardware for interfacing a remote control device with a computer, which makes it possible to work with and without a computer.

The use of microprocessors and micro-computers has led to a significant change in the process of the control system. Modern systems are better protected from interference due to more advanced codes, and data compression allows you to increase the amount of information transmitted over the same communication channels. In addition, automated system has a self-monitoring device capable of detecting errors both in the system itself and in the signals of synchronicity and transmitted information.

One of the most striking discoveries of Russian scientists (Moscow Special Design Bureau for Geophysical Instrument Engineering and Computer Science) in this industry is the development of a system for the technological monitoring of the drilling parameters “SGT-micro”. The system is recommended by the State Mining and Safety Organization of the Russian Federation for implementation in all drilling enterprises, primarily as equipment to ensure the safety of drilling operations and prevent accidents.

The system "SGT-micro" is designed to monitor the technological parameters of drilling with the aim of operational control and optimization of oil and gas well deepening.

The system functionally provides:

- ❖ automatic collection, processing with the calculation of derived parameters and the presentation of current information in visual form on the means of display and registration of the driller and drilling master;
- ❖ documenting the results of drilling in digital-analog and graphic form, including a report for the shift;
- ❖ control of the output of technological parameters beyond the limits set by the user with a light or sound alarm of these events;
- ❖ alarm signaling when the "Weight on Hook", "Inlet Pressure", and "Position of Travelling Block" parameters go beyond the limit values, with blocking signals issued to the corresponding drilling equipment;
- ❖ speech warning of the master about changes in the situation while drilling;
- ❖ saving the input settings and constants in case of disconnection of the primary supply voltage;
- ❖ autonomous operation of the driller's console when the computer is turned off;
- ❖ performance of any computer calculations and solutions of tasks for well installation without disrupting the operation of the system;
- ❖ high operational functionality and durability with minimal maintenance and metrological services;
- ❖ safety of the system due to the implementation of intrinsically safe electrical circuits, filling blocks with high-pressure air and the use of sensors with flameproof enclosures;
- ❖ the ability to install external surveillance devices with video output to the working monitor and / or additional video monitoring devices;
- ❖ connection of additional instruments and sensors (inclinometer, chromatograph, calcimeter, IR analyzer, etc.) to any of the available 22 backup channels. [19]

The main components of the technological monitoring system of the “SGT - micro” (*Figure 2.3*) drilling parameters are: a set of sensors; unit of amplification, switching and power supply for receiving analog and pulse signals of sensors, converting them into a digital code and data exchange with a computer and driller's console; driller's remote control panel for displaying information provided by the driller and remote control system; IBM PC type computers for configuring and setting the initial settings of the system, for displaying information provided to the drilling foreman and technologist, and maintaining a database of recording all parameters and events in the drilling process, as well as transmitting information, including a video image of drilling sites, over the available communication lines in management of drilling operations and the Internet.

[4]

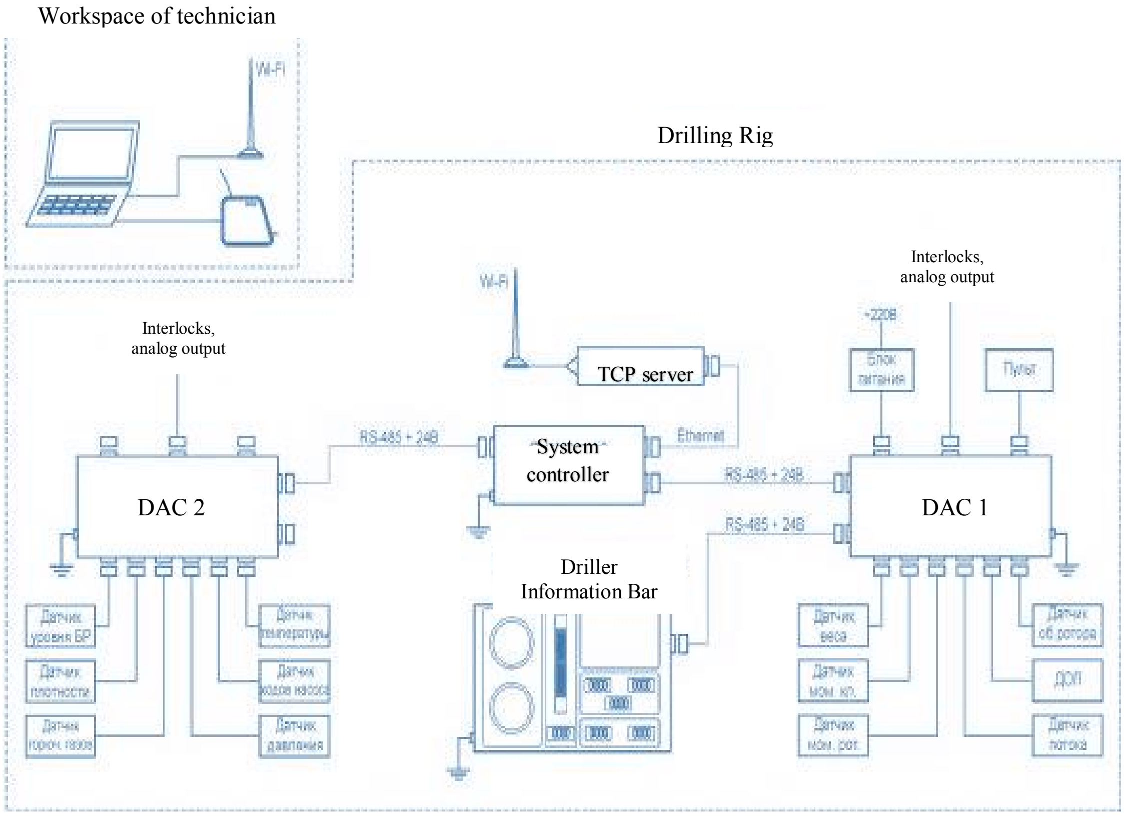

Figure 2.3 Block diagram of the system of technological control of drilling parameters [19]

Thus, progressiveness is the sequence of development of the technological process in the direction of improving its optimality, when each period of development of engineering and technology corresponds to its highest level of optimality, which invariably increases with the improvement and transformation of the technical system.

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[4] *DAC - data acquisition controllers.

CHAPTER 3. IMPORTANCE OF THE COLLECTION AND PRIMARY PROCESSING OF INFORMATION ON THE STATE OF DRILLING PROCESS

Mathematical model is very useful in the process of automation of the system. This innovative step we can call machine learning. This is a new developing term in the evaluation of technology of the XXI century. Last centuries we used to improve technologies by dictating them what to do, but now when we reached highest levels of technological development, we are able to teach the machines not only to do processes instead of us, but also how to act in different situations according to the experience or by analyzing the previous outcomes. And we can reach this by using neural controllers, which is made by engineers on the basis of human brain, that is an example of the best application of neural networks. The application of this system can significantly change the process and the whole industry.

Effective management of a complex process of well drilling by using above mentioned innovations becomes much more real when its basic laws are presented in the form of mathematical expressions and the use of an empirical approach to obtain a working mathematical description of the process. In order to define these inter-connected expressions, information can be obtained through experiments or observations. But the results obtained in this way may not be particularly satisfying. Therefore, greater preference is given to the use of stochastic models, which are based on probabilities. From this method, we can get more effective results, since the constructed model will be as close to real as possible. But despite this, the results may vary due to the imperfection of the experimental method, as well as due to various random effects, which, regardless of the control of the monitor, are included in the measurement process.

The technological process of drilling a well is characterized by such basic features as a large number of random factors that change over time, space and affect the quality and technical and economic indicators of the work; a variety of geological and technical drilling conditions, due to random nature of which it is impossible to control most of the parameters; distortion of the useful signals (about the weight on the hook, torque, input power, mechanical speed, etc.) used to determine the parameters of the drilling mode. [19]

It is known that a physical process, during which a certain set of conditions is carried out, repeating as many times as necessary, is called experience. And any outcome or result of experience is an event that can have a quantitative or qualitative characteristic. And the pattern of these random phenomena is studied by the theory of probability. In order to identify experimentally the patterns of random phenomena occurring in natural conditions, it is necessary to repeat the experiment many times under the same conditions.

In the past, we studied various areas of the industry and enriched our knowledge, and then collected information and made decisions based on our knowledge. Although we could not always get the desired results. But with the development and complication of techniques and technologies in exploration drilling, it became necessary to study random events in order to learn how to forecast the actions of random factors and take them into account in practical problem solving, which is quite possible using process automation. For effective analysis of technological processes of drilling wells, it is necessary to establish to which theoretical law the distribution of experimental data is subjected. Knowledge of the distribution law has a great benefit in the development of drilling technology and in planning the processing of empirical data.

There are two types of random variables: discontinuous and continuous. The discrete (discontinuous) can take isolated values from one another, which can be enumerated in advance (for example, the number of defective diamond crowns in a batch, the number of failures of the drill string elements for a certain period of time, etc.). But continuous can take any values from some finite or infinite interval (for example, the diameter of the well or the mechanical drilling rate, etc.). If the value of a random variable is formed under the simultaneous influence of a large number of independent factors, each of which causes its random fluctuations, which are approximately the same in size and equiprobable in sign, then the random variable obeys the normal law of Gauss distribution. The probability density of a normal distribution is determined by the following equation:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-a)^2/2\sigma^2}, \quad (3.1)$$

where a and σ are the distribution parameters, the expectation and the standard deviation of the stochastic quantity x; e - the basis of natural logarithms.

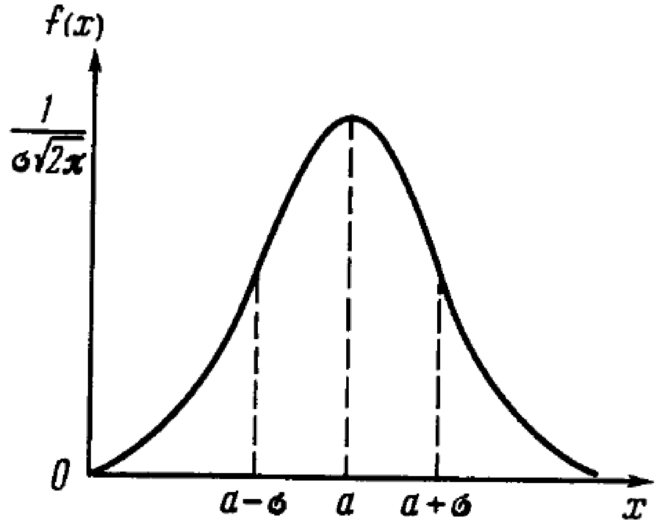


Figure 3.0.1 Normal distribution plot

The graph of the density of the normal distribution, constructed from the results of the calculation by formula (3.1), is called the Gauss curve (*Figure 3*.0.1). The graph has the maximum ordinate at $x = a$, through which the axis of symmetry of the curve passes. The change in the parameter at a fixed value of σ describes the shape of the Gaussian curve. The points $x = a - \sigma$ and $x = a + \sigma$ are points of inflection. Consequently, the larger the value of σ, the greater the spread of the stochastic value x around its average value a. Taking into account that the area under the Gaussian curve is always equal to unity, then when we increase the value of σ, the curve becomes flat-topped, and when it decreases, the curve stretches upwards. But the shift of the value a along the axis Ox for a fixed value of the σ, changes the position of the curve with a constant shape. [19]

The normal distribution is well studied and is widely used in the development of empirical data and is confirmed in many drilling tasks. It is considered that measurement errors, measurement results, results of rock-cutting tools development, rock drillability indicators, mechanical speed of penetration under constant conditions, indicators of the properties of washing liquids obey the normal distribution law.

In the practice of drilling operations, when observing or experimenting, the researcher has only a limited number of values of a random variable, which is a certain sample from the total population. The total population is a complete set of all values, in which the number of experiments N can be finite or even infinite. It is assumed that the experiments were carried out under the same conditions and the probability of the outcome of each experiment does not depend on what outcomes other experiments had. The part of the total population of n elements that is significantly smaller than

N, selected for observation is called a random sample. And the accuracy of the obtained parameters depends on the number of samples n, which we decided to take from the total population N.

Let us make an example illustrating the possibility of applying the normal distribution in measurements of the magnitude of the mechanical drilling speed. The scatter of values is the result of a large number of random factors such as random deviations of the properties of rocks, changes in the parameters of the drilling mode, vibration of the drill, wear of rock cutting tools, etc., each of which produces a small error. They all act almost similar and independently of each other. And by using the equation of Standard deviation we can calculate the reduction of errors by increasing the number of random samples n.

$$S_n = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}, \qquad (3.2)$$

where n - number of data points, x_i – each of the values of the data, $\bar{x}$ - mean value of the x_i.

Let's consider that we have the list of the values of the mechanical speed v_M:

n	1	2	3	4	5	6	7	8
v_M, [m/h]	0,55	0,56	0,57	0,58	0,59	0,60	0,61	0,62

Table 3.1 Measured values of mechanical speed

So, at first, we can find mean value of mechanical speed by using the following equation:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i, \qquad (3.3)$$

If we substitute our values of mechanical speed into the equation (3.3), we obtain that $\bar{x} = 0{,}585$. Now by using the equation (3.2) we are able to calculate the values of standard deviation for the cases when our random number of samples are equal to 2, 4 and 8 respectively:

$$S_2 = \sqrt{\frac{(0{,}55-0{,}585)^2+(0{,}56-0{,}585)^2}{2-1}} = 0{,}043$$

$$S_4 = \sqrt{\frac{(0{,}55-0{,}585)^2+(0{,}56-0{,}585)^2+(0{,}57-0{,}585)^2+(0{,}58-0{,}585)^2}{4-1}} = 0{,}0265$$

$$S_8 = \sqrt{\frac{(0{,}55-0{,}585)^2+(0{,}56-0{,}585)^2+\ldots+(0{,}61-0{,}585)^2+(0{,}62-0{,}585)^2}{8-1}} = 0{,}025$$

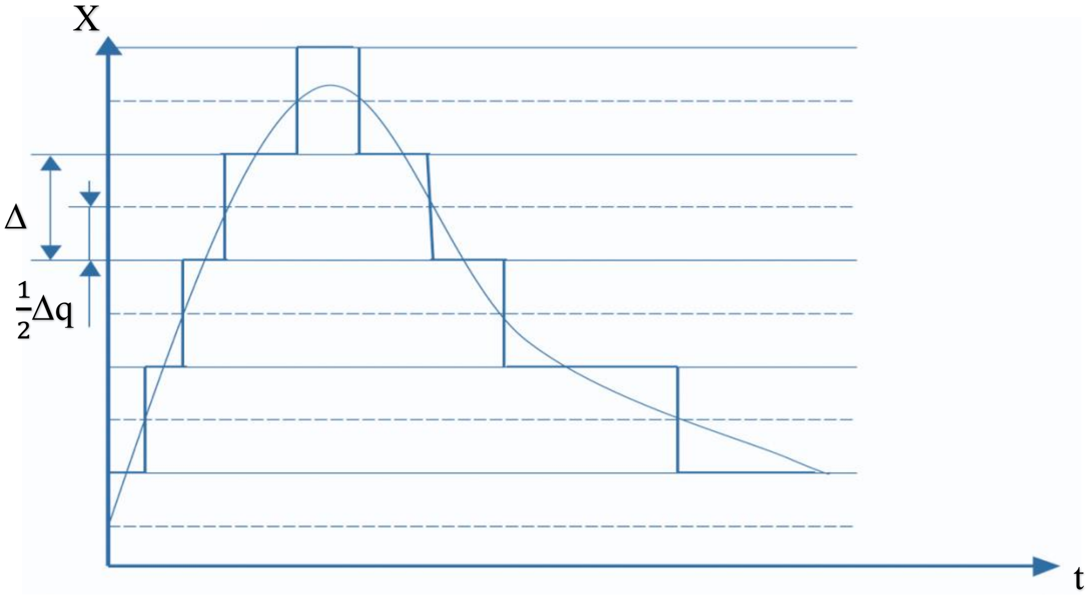
From the values obtained above we can see that when we have higher number of random samples our parameter deviates less, which will provide us more accurate results and less errors, that will increase the efficiency of the applied method.

Another necessary condition for the qualitative solution of the problem of automatic control of the drilling process is to obtain information about the state of the process with the required efficiency and accuracy. The required efficiency of obtaining information is determined by the need to control the process in real time, that is, control actions must be formed out of the acceptable delay regarding changes in the state of the controlled process. Therefore, the effectiveness of our system at the first stage depends on the performance of the sensors and the transmission capacity of the communication channels. And it is more important that the communication channels could not just pass signals, but as much as possible not distorted information in a short unit of time.

In automatic devices, messages are transmitted from one device link to another as signals. For signal transmission, physical processes with the properties of movement in space are used: sound, electric or electromagnetic oscillations, movement of air jets and so on. These are the so-called information carriers, which must have the property to change their form or parameters under the influence of a message. So, in order for the recipient (operator or machine) to know about the event or receive some new information, an information chain must be formed: an event - a message with information - a signal. The signal is transmitted to the communication line and goes to the recipient, where it is again converted into a message and information, since the recipient needs not the signal itself, but the information that it carries. [20]

In electronics, discrete signals are increasingly used, since this provides higher noise immunity and reproduction of information with greater accuracy. At the same time, the primary values, which are taken from the sensors and have to be transmitted by measurement systems, are in many cases continuous and need to be converted to discrete ones. Replacing a continuous value with a discrete one can be performed by using quantization. In quantization, the value of a function at an arbitrary time is replaced by its nearest value, called the quantization level. The interval between two discrete values of the levels is called the quantization step q.

The quantization process according to the level of the function $\lambda(t)$ is illustrated in *Figure 3.2*. On the ordinate axis, the magnitude of the pre-selected quantization step q is laid and lines parallel to the time axis are drawn, indicating the quantization levels. The transition from one level to another occurs when the value of the function is in the middle of the quantization interval, since at this moment the absolute quantization error is the greatest. Indeed, if the value of the function is in the middle between two levels, then uncertainty arises, since the function is equidistant from both levels. Therefore, the quantization process is carried out in this way: quantization intervals are divided in half and dashed horizontal lines are drawn until they intersect with the quantized function. The intersection points that indicate the value of the function which is transmitted the least accurately. At other points, a quantization error occurs which is equal to the difference between the values of the function $\lambda(t)$ and the nearest level. Since the function is transmitted least accurately at the point located between the two quantization levels and from the quantization interval $q/2$ standing on them for half the quantization interval, the maximum quantization error in the level is $\pm q/2$. [20]



Thus, as a result of quantization of function $\lambda(t)$, produced by a certain rule, it is possible to select a series of its discrete values. Actually, with the selection of the points the quantization process ends.

Figure 3.2 Quantization of the continuous signal by level. [20]

Let's consider that we received signals on our sensors, that are in the form of digital signals. So, the next procedure has to be to covert our digital data to analog one by using ADC. And only after that by applying some empirical formulas we can transform them into physical units, where we will use conversion factors for each of the parameter. And depending on the complexity, we can also apply some mathematical tools to obtain values with high precision. These processes are done taking into account the specific parameters of the field, and the characteristics of using tools or the importance of the accuracy of the obtaining parameters. However, now, with the application of innovative technologies these actions can be done automatically, and the operator will receive only the final results on the display, only for monitoring and the procedures like data acquisition, conversion, preprocessing and saving are all part of the automatic processing system.

In most cases, the future value of the indicator or the development of any drilling process can be estimated based on accumulated experience, and is usually very approximate. This is explained by the fact that the complexity, uncertainty and the multiplicity of causes involved in the process being analyzed do not make it possible to calculate their total effect. But static prediction methods provide an opportunity to estimate the future values of the parameters of the drilling process from the results of observations of past and current values using their probable characteristics. The main advantages of the statistical prediction methods used are the objectivity of the information obtained, high accuracy, and the ability to automate the prediction process while using computers. And taking into account the fact that we will deal with a huge amount of complex information the task of the system for the collection and primary processing of information is the formation of a trend, which, from the point of view of the software implementation, should be an array of memory cells, in which the values of parameters ordered in time are stored.

In this system, our data can be stored as in the form of stack organization and it means thatreceived data will find its position in the array, which will continue till the point, when all the positions will be filled. After that depending on chosen rule it can have different kinds of positioning, as FIFO[5] or FILO. The first rule is more reliable to use in our system, which is based on the principal of queue (e.g. the data leave the queue in the arrival order) (*Figure 3.3*).

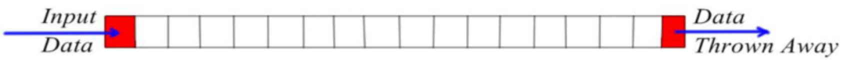


Figure 3.3 FIFO.

Taking into account how many parameters we are analyzing the part of the Random Access Memory in which the operational information base can be divided into the same amount of blocks comprising 64 memory cells for each block. Each of these blocks is an array of data of the corresponding parameter, where we use the rule of FIFO. For example, initially at the time equal to t_0 in array of mechanical speed (v_M), there were 64 previous values of v_m, (v_{M1}, v_{M2}, ..., v_{M65}). Later at time equal to $t_0 + \Delta t$, the next measurement v_{M65} was formed, which must be pushed onto the array, v_{M64} will be moved to the 63rd element, v_{M63} to the 62nd element and thus to the "top" of the array, i.e. to the 1st element, in which the value of v_{M2}, will be placed, and the value of v_{M1} will be removed from the array. Therefore, each new dimension of this parameter will be pushed onto the array by this logic.

Recording to all array is done synchronously with the period Δt_i, i.e., at time $t_0 + C\Delta t_i$ (where C is the number of the measurement cycle). After the process of measurement of all parameters, obtained values are recorded in the corresponding array. At any moment of time $t_0 + C\Delta t_i$ any of the arrays contain 64 measured values of each of the parameters of the drilling process, ordered in time and allowing to estimate the change of parameters in the time interval from $t_0 + (C - 63)\Delta t_i$ to $t_0 + C\Delta t_i$. For example, for Δt_i = 5 s, the measurement evaluation interval parameters will be $(t_0 + C\Delta t_i) - (t_0 + (C - 63)\Delta t_i) = 63\Delta t_i = 315\ s$.

Subsequently, we can analyze the state of the drilling by storing the measured parameters and theirs change during relatively long period, that will provide us with enough information in order to

[5] FIFO* - First In First Out; FILO – First In Last Out.

understand the technological process and its behavior. And by using above mentioned mathematical methods, preprocessing and storing information about the parameters and indicators of the drilling process implemented by the ACS[6] software module by the technological process, which receives control cyclically, with a period Δt_i, we can forecast and develop the drilling process with lowest percentage of errors.

The period of measurement parameters Δt_i
The number of measured parameters C
The number of polls in the measurement of the 1st parameter
The number of polls in the measurement of the 15th parameter
The ADC channel address of the 1st parameter
The ADC channel address of the 15th parameter
The address of the 1st parameter processing subroutine
The address of the 15th parameter processing subroutine
The accumulator of polls of the 1st parameter Q (1)
The accumulator of polls of the 15th parameter Q (15)

Table 3.2 Table of Polling parameters (TOP)

This table demonstrates the procedure of polling the analyzing parameters. As we can see at the beginning, we solve the time of measurement and receiving data, and also the number of parameters under the investigation. The system will dictate the mode and measurement characteristics and arrange received information in the polling arrays. So, the process repeats while have all the required data for the development, that is shown in the figure below (*Figure 3.)*.

[6] *ACS – Automatic Control System

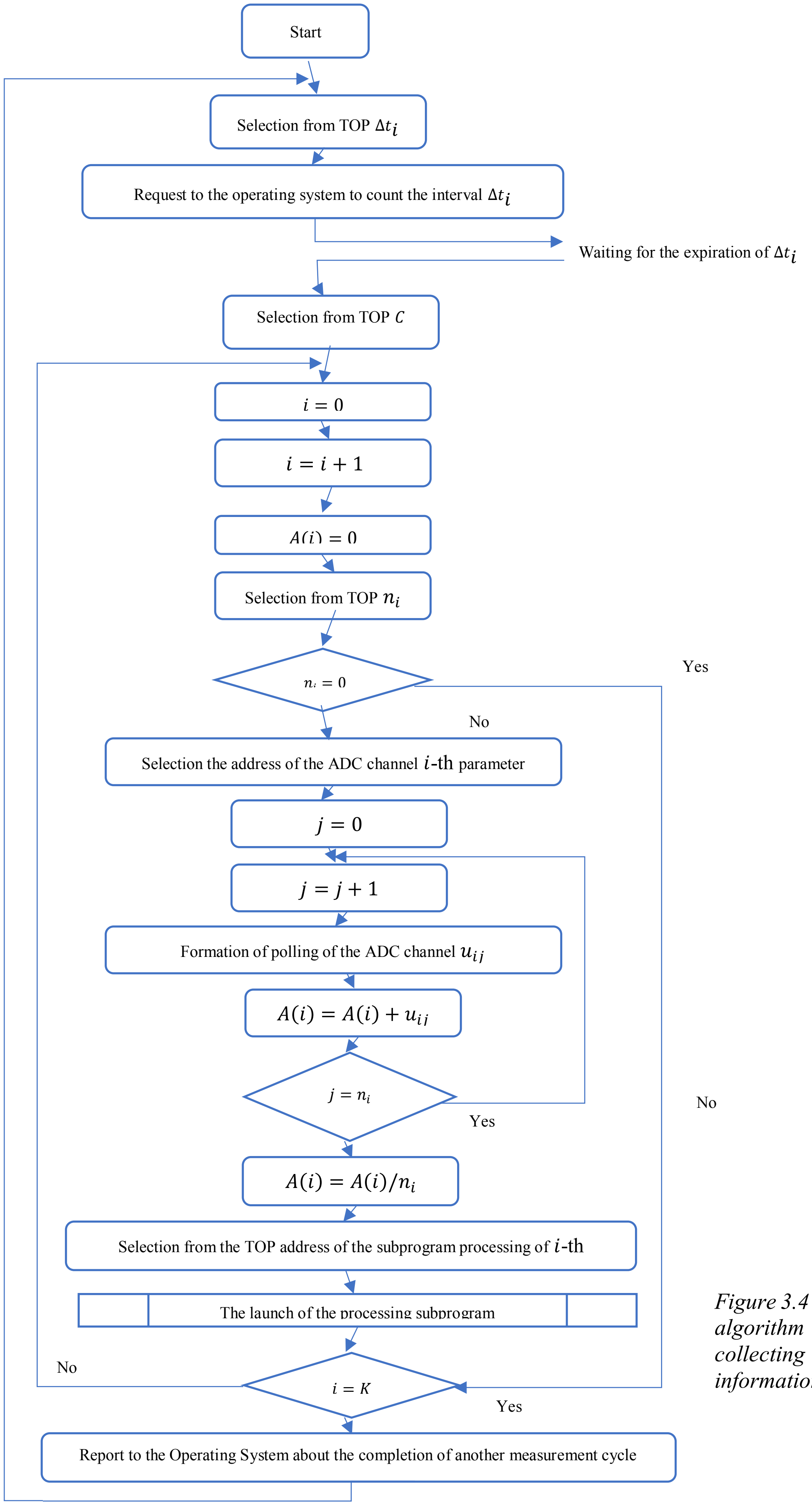


Figure 3.4 The block diagram of the algorithm of the system for collecting and preprocessing information

The block diagram of the algorithm of the module is shown in *Figure 3.*, where we can see how the loop of collecting and preprocessing of the data will work.

As in any other automated systems, having the well-constructed algorithm of block diagrams, will increase the efficiency of the work and will provide good and secured communication of the computer with sensors and other tools of technological processes.

CHAPTER 4. DEVELOPMENT OF A PRINCIPAL SCHEME OF A COMMUNICATION DEVICE FOR A PERSONAL COMPUTER WITH AN AUTOMATION OBJECT.

4.1 DESCRIPTION OF THE AUTOMATED DRILLING PROCESS MANAGEMENT SYSTEM SGT-Micro.

In this chapter, we will analyze the working process of the automated drilling process control system SGT-Micro (*Figure 2.3),* by means of sensors and instruments of automated system.

Any system or automatic device is performed from a number of nodes, blocks and subunits assembled from elements. The element transforms the impact it received from the previous element or node and transmits it to the next element or node. In our system, the sensors are installed on the ground equipment of the drilling rig and are connected with individual cables directly to the data acquisition controllers (DAC) units. The analog output signal of the sensor is converted to digital form in DAC. Analog sensors according to the type of output signal are divided into two groups: sensors with a current signal output in the range from 4 to 20 mA and sensors with a voltage output signal in the range from 0 to 4 V. Each DAC can process output signals from 6 sensors.

The hook load sensor (weight sensor) is mounted on the fixed end of the cable of the strings system of the drilling rig, and measures the load on the hook using the tension force of the cable. The transverse component of the cable tension force, which is formed due to its bending on the middle sensor support, acts directly on the sensitive element. The measuring range of the sensor is controlled by changing the bend angle of the cable due to the change in length of the pressure bolt.

The torque control sensor (strain gauge) is mounted on the rotor drive gearbox instead of the fixing tie-rod or fixing support. So, it is possible to control the increasing tension or compression that acts on the sensor.

The sensor monitoring the pump strokes (inductive proximity sensor) is installed on the pump drive pulley.

The depth sensor provides basic information for calculating the bottom-hole depth, feed, position of the traveling block. Sensor chain transmission is connected to the shaft of the winch.

Mud pressure sensor at the inlet (pressure sensor) - strain gauge pressure sensor with internal medium separation membrane - is connected to the discharge line through a welded coupling (adapter).

The torque sensor on the rig tong works in tension and measures the torque on the tong by the tension of the drive cable.

The sensor of the flow rate of the drilling fluid at the outlet (flow sensor) converts the deflection angle of the sensor blade by the flow of drilling fluid in the trough into a proportional DC voltage. The range of deviation angles from 0 ° to 60 °, the output voltage varies from 0.25 to 3.5 V.

The mud level density sensor consists of a pneumatic system and differential pressure sensors connected to sparge tubes of different lengths, immersed in the drilling fluid. The pneumatic system provides continuous and constant air flow in the sparge tubes. Under the action of compressed air supplied to the bubbling tubes, the drilling mud is completely expelled from the tubes. As a result, they establish excess pressure equal to the hydrostatic pressure at the ends of the tubes vertically lowered into the drilling fluid. The measurement of the density of the drilling fluid sensor based on the measurement of the difference in hydrostatic pressure at two points of the drilling fluid on a fixed vertical base, equal to 200 or 400 mm. The pressure difference in the tubes, proportional to the density of the drilling fluid, is measured by differential pressure sensors. The signal from the output of the differential pressure sensors is transmitted for further processing in the DAC. The density of the drilling fluid is determined by the pressure difference in the tubes.

The ultrasonic level sensor measures the level of drilling mud in the tank with respect to the propagation time of an elastic deformation pulse in a steel wire. The time interval is measured from the moment of formation of an excitation current pulse to the moment of reception at the upper end of the rod of an electric pulse excited by an elastic deformation pulse arising in a steel rod at the level of the location of magnets in the float floating on the surface of the drilling mud.

The gas contamination sensor (combustible gas sensor) is designed to determine the total content of combustible gases in the air of a controlled area in order to assess the explosion hazard of a gas-air mixture. The principle of the sensor is thermochemical, measurement is carried out in percent (%LFL). The sensor is installed in the space of the controlled area and converts the level of gas into an electrical signal in the range from 4 to 20 mA.

Information from the sensors is transmitted via cables to the DAC unit, where signal conversion and processing takes place, and then to the driller’s console and computer.

Information and metrological characteristics are fully listed in the attached *Table 4.1*.

Controlled parameter			Display form			
№	Parameter name, unit	Control range	Driller's console		Drilling Tools	
			Digital	Analog	Display	Printer
1	Hook load, [kN]	0 - 5000; 0 - 4000; 0 - 3000; 0 - 2500; 0 - 2000; 0-1500; 0-1000	+	+	+	+
2	Weight on bit (WOB), [kN]	0-500	+	+	+	+
3	Torque on the rotor, [kNm]	0-30 0-60	-	+	+	+
4	Torque on the tool, [kNm]	0-30	-	+	+	+

		0-60				
5	Inlet pressure, [Kg/cm^2]	0-40	+	-	+	+
6	Input flow rate, [L/s]	0-100	+	-	+	+
7	Rotor speed, [rpm]	0-300	+	-	+	+
8	Change of the flow rate of the drilling fluid at the outlet, [%]	0-99	+	-	+	+
9	Feed, [m]	0-99,9	+	-	+	+
10	The position of the traveling block, [m]	0-45 0-60	-	+	-	+
11	Bottomhole depth, [m]	0 - 9999	-	-	+	+
12	The position of the bit over the bottom hole, [m]	0 - 9999	-	-	+	-
13	Drilling time per 1 m of penetration, [min/m]	0-1000	-	-	+	+
14	Mechanical speed, [m/h]	0-200	-	-	+	+
15	Speed per run, [m/s]	0-50	-	-	+	+
16	Boring time, [min]	0-999999	-	-	+	-
17	Deepening per drill bit, [m]	0-999	-	-	+	-
28	Drilling mud density, [g/cm3]	0,8-2,6	+	-	+	+
19	The level of drilling mud, [m]	0,8-2,4; 1,2-2,8	+	-	+	+
20	A total volume of drilling mud, [m3]	0 - 500	-	-	+	+
21	Change in total volume of mud, [m3]	± 100	-	-	+	+
22	Speed of the change of the total drilling mud volume, [m3/min]	0-100	-	-	+	+
23	The volume of drilling mud in each tank, [m3]	0-150	-	-	+	+
24	Change in total volume of mud in each tank, [m3]	± 99,9	+	-	+	+
25	Speed of the change of the total drilling mud volume in each tank, [m3/min]	0-100	-	-	+	+
26	The total content of flammable gases, %LFL (Lower Flammability Level)	0-50	-	-	+	+
27	Inlet and outlet temperature, [° C]	0-100	-	-	+	+
28	Air temperature, [° C]	0-100	-	-	+	+
29	Current time, [h-min]		+	-	+	+
30	Date		-	-	+	+

Table 4.1 Transmitted information

4.2 IMPORTANCE OF THE DEVICE COMMUNICATION WITH AN OBJECT IN AN AUTOMATIC DRILLING PROCESS CONTROL SYSTEM

An automatic process control system must have the ability and means of communication with the control object. However, one of the main differences between data processing systems and the automated process control system is that the latter should be able to obtain real-time information about the state of the control object, respond to this information and automatically control the process flow. To solve these issues of the computer, on the basis of which the automated process control system is built, must belong to the class of process control computers, i.e. it must be a computer controlled information complex. A computer controlled information complex can be defined as a computer, focused on automatic reception and processing information received in the management process, and issuing control actions directly to the executive bodies of the process equipment. This type of orientation is provided by a process interface unit (*Figure 4.1*) - a set of specialized blocks for information exchange between the control computer and the control object. There are passive and active process interface units.

Passive devices execute commands for polling sensors and commands for issuing control actions. They contain sets of input and output units and a control unit. The input and output blocks that receive analog and discrete information include form converters of information such as analog-code and code-analog, switches, amplifiers, etc. The control unit provides the necessary information exchange with the control computer and controls all units of the device decrypts commands from the computer, and provides the necessary exchange of information through the I / O units.

Active process interface units are capable of operating offline monitoring of the state of a controlled object (process), and also perform certain algorithms for converting information, for example, algorithms for registering parameters and signaling their deviation from the norm, regulation according to one of the relatively simple laws and others. Building the process interface units by the active principle allows increasing the reliability of the process control system as a whole and the efficiency of using the control computer as a result of reducing the flow of information from the control object to the control computer.

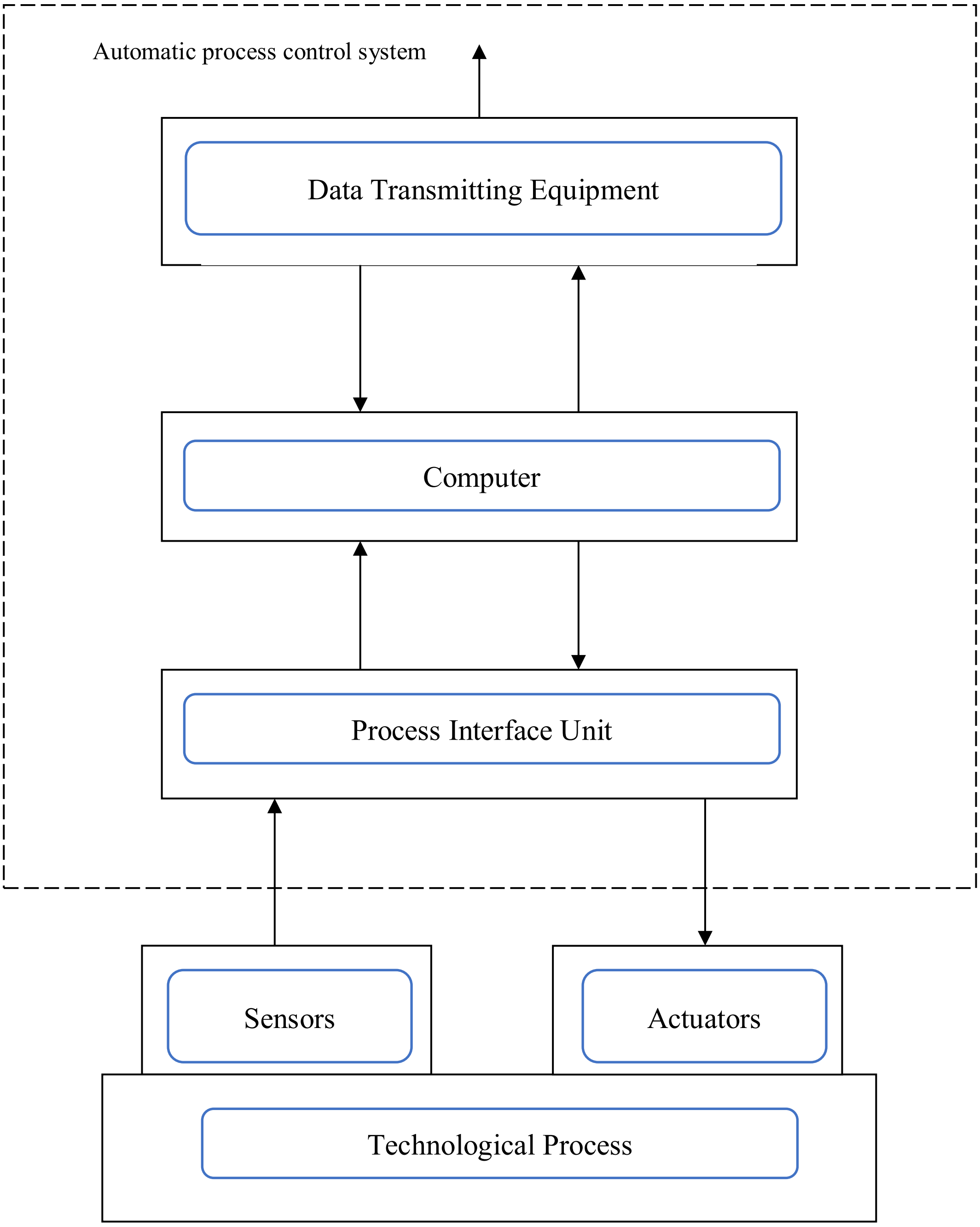


Figure 4.1 The typical structure of the automated process control system based on the control computer.

In this thesis, I am analyzing the development of the design of a functionally complete communication device with an object in a system for collecting and preprocessing information about the state of the drilling process. The system of collecting and processing information about the state of the drilling process is the most important functional subsystem of the automated process control system.

The principles of the IBM PC system bus and the basic hardware interface with which the above design is connected, as well as the operation of the interrupt system, counters and timers are discussed in detail.

4.3 DESCRIPTION OF THE WORK OF THE SCHEME

In the developed scheme, it is possible to use up to 64 ports – 32 for input and 32 for output. *Table 4.2* gives the port allocation for the board.

Port Selection Line	Port number (16-ary)	Name	Function	Chip
E0	300	PORTA	Parallel BB port A	Intel 8255
E1	301	PORTB	Parallel BB port B	Intel 8255
E2	302	PORTC	Parallel BB port C	Intel 8255
E3	303	PCNTRL	Parallel BB Control	Intel 8255
E4	304	CNT0	Counter 0	Intel 8253
E5	305	CNT1	Counter 1	Intel 8253
E6	306	CNT2	Counter 2	Intel 8253
E7	307	TCNTRL	Timer / Counter Control	Intel 8253
E8	308	ADC	ADC Address, data	
E9	309	STAT	ADC Condition	
E10	30A	START	ADC launch	
E11	30B	DACO	DAC address	
E12	30C	GATE	Timer / Counter strobe	
E13	30D		Handle port Management	
E14	30E		Not involved	
E15	30F		Not involved	
E16	310		Not involved	
E17	311		Not involved	
E18	312		Not involved	
E19	313		Not involved	
E20	314		Not involved	
E21	315		Not involved	

E22	316		Not involved	
E23	317		Not involved	
E24	318		Not involved	
E25	319		Not involved	
E26	31A		Not involved	
E27	31B		Not involved	
E28	31C		Not involved	
E29	31D		Not involved	
E30	31E		Not involved	
E31	31F		Not involved	

Table 4.2

The parallel input-output port

The IBM PC has very powerful data processing tools, however, it is not enough. It also needs a means of interaction with the outside world. For exchanging data between a computer and peripheral hardware Input-Output devices and appropriate software are necessary.

Timing charts

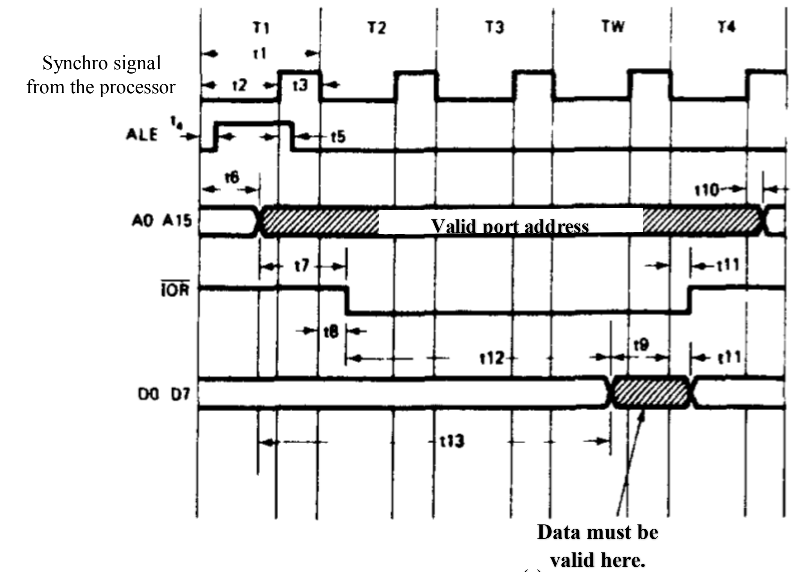
The key to the successful creation of any interface with the system is to ensure the compatibility of the time distribution of its work with similar parameters of the system bus. The time diagrams and tables, shown in *Figure 4.2*. [20], provide detailed information on the temporal distribution of write and read of bus cycles for BB.

The bus cycle usually consists of four working periods with a duration T (machine cycle), however, the computer automatically enters an additional waiting period (TW) into this cycle. Thus, in the computer, the entire bus cycle of explosives contains at least five periods T, i.e. its duration is approximately 1.05 μs. The bus cycle can be further increased by adjusting the duration of the ready signal on the system bus. It is possible to see that pins A16-A19 of the address bus of the computer are not transferred to the active state during BB bus cycles.

A BB bus read cycle is initiated each time the microprocessor executes an IN command. During the period T1, the ALE signal line is switched to the active state, the slice of which indicates that the AO-A15 bits of the address bus contain the actual address of the port BB. During the T2 period, the IOR control signal is switched to the active state, which indicates that the response of the addressed input port should consist in outputting its content to the data bus. At the beginning of the period T4, the processor reads information from the data bus, and then the IOR signal line is placed in an inactive state.

The BB bus write cycle is initiated each time the 8088 processor executes an OUT command. During the period T1, the ALE control signal is transferred to the active state, the slice of which indicates that the address bus AO-A15 bits contain a valid port address. Then, during the T2 period, the IOW signal switches to the active state, which indicates to the selected output port that it should read the contents of the data bus. Further, during the same period, the processor outputs to the bus the data that must flow to the output port. At the beginning of period T4, the IOW signal goes to an inactive state and the processor deletes the data from the bus.

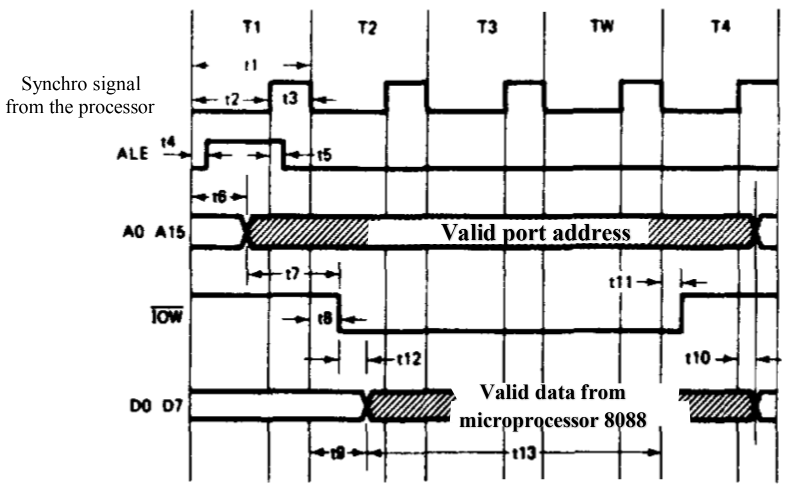
The tables presented in *Figure 4.2* [20] provide information on the temporal ratios in the form of data for the worst case on the maximum and minimum. Therefore, this data is valid for all bus load conditions and all levels of supply voltages within specified tolerances.



Symbol	Max	Min
t1		209 5
t2		124 5
t3		71 8
t4	15	
t5	15	
t6	128	16
t7		91,5
t8	35	10
t9		42
t10	35	10
t11		10
t12		551,5
t13		668

All times are in nanoseconds

(a)



Symbol	Max	Min
t1		209 5
t2		124 5
t3		71 8
t4	15	
t5	15	
t6	128	16
t7		91 5
t8	35	10
t9	122	14
t10		10
t11	35	10
t12	112	
t13	-	506,5

All times are in nanoseconds

(b)

Figure 4.2 Timing diagrams of the input-output port. Time distribution of the bus read cycle for the input port (a) Time distribution of the bus write cycle for the output port (b). [20]

Programmable Timer / Counter

The programmable timer contains three independent, 16-bit counters that perform counting in the opposite direction. Pre-installation allows to set a binary or binary-decimal counting algorithm, and each of the counters can operate in one of six modes:

1. Interruption of the terminal account;
2. Single-shot multi-vibrator;
3. Pulse generator;
4. Square wave generator;
5. Single software-configured strobe signal;
6. A single hardware strobe signal.

The clock frequency can be up to 2.5 MHz

In the device being developed on the basis of the timer counter, a counting circuit is implemented. A voltage source of 5 V is connected between the V_{CC} and GND points. Lines D0-D7 are routed to the buffered data bus.

D / A converter

Internal circuit organization of the 8-bit DAC of the company Analog Devices. When both chip select control lines are active, the data byte from the data bus enters the 8-bit latch. This 8-bit binary number is kept in a latch until the next crystal is selected. Each bit of the latch controls the state of the transistor switch acting on the R = 2R resistor matrix with laser-fit, consisting of 16 resistors. A resistor circuit is connected to the final operational amplifier with which the user can set the range of variation of the output signal.

Connection diagram of the DAC outputs when used on the interface board. The port of choice of port E11 (port OOB) initializes the selection of the DAC as an output port. When switching the control line, the output voltage changes in the range of 0 - 2.56 V.

The presence of two common pins on the AD558 chip is typical for devices that implement both analog and digital functions. These pins are designed to minimize resistive coupling and noise in analog signal circuits.

To reduce noise (interference) in a system containing both analog and digital components, good practical results are obtained using separate wires for analog and digital circuits throughout the system and connecting these common wires to each other at one point only.

Analog-to-digital converter

Performance calculation

System performance is calculated by estimating the total time spent per transformation. A list of all time delays (*Table 4.3*), called a time budget, facilitates the calculation of performance.

Time budget	
S/H [7]circuit capture time	6 microseconds
S/H circuit output acquisition time	1 microsecond
ADC conversion time	110 microseconds
The delay associated with the execution of the command output (OUT) and input (IN)	40 microseconds
Total conversion time	157 microseconds
Maximum performance	6369 count/sec

Table 4.3 Time delays.

Accuracy calculation

To calculate the accuracy of the system, a list of the main sources of errors in the system is used (*Table 4.4*), starting from its analog input and ending with a digital output. Other errors that are not listed in the error budget table (the error resulting from the voltage drop at the output of the S / H circuit in storage mode, etc.) are negligibly small (do not exceed 0.01%).

Error budget	
S / H circuit voltage uncertainty	0,2%
S / H circuit gain error	0,01%
Quantization Uncertainty in ADC	0,2%
Offset error, gain, and non-linearity of the ADC	0,3%
ADC error associated with the drift of the reference signal	0,1%
Maximum total error (algebraic sum)	0,81%
Total static error (rms)	0,42

Table 4.4 Errors occurred in the system.

Thus, accuracy is guaranteed not worse than 1%.

CHAPTER 5. DEVELOPMENT OF SOFTWARE

[7] *S/H circuit – sample-and-hold circuit.

The software of the station for geological and technical research is intended to perform the tasks of collecting, recording, visualizing, processing, interpreting and transmitting geological and technical information. And all the tasks listed above, apart from the interpretation, should be solved in real time while deepening the well. In real time, continuous polling of process parameter sensors with a periodicity of no more than 1 second should be provided for rapidly changing parameters (travelling block position, hook load, rotor torque, rotor speed) and no more than 5 seconds for the other parameters.

Software for solving geological problems should provide input, calculation, analysis, formation, display and storage of the following data:

- ✓ planned or forecasted stratigraphic and lithological section of the well, indicating the expected productive reservoirs;
- ✓ sludge diagram (percentage of different rocks (mineral groups) in the sludge sample);
- ✓ fractional composition of the sludge;
- ✓ physical and chemical characteristics of rocks (hardness, density, porosity, gas content, carbonate content, pH, liquid hydrocarbon content, bitumen content, etc.);
- ✓ data on the actual lithological composition of the rock section for the analysis of samples of sludge and core;
- ✓ macro and micro descriptions of rocks;
- ✓ description of reservoirs in the section of the well, indicating the actual nature of saturation;
- ✓ clarification of the boundaries of lithological differences according to the rate of penetration;
- ✓ calculation of fluid coefficients;
- ✓ determination of the character of saturation of reservoirs.

At the same time, the software for solving technological problems should provide the following:

- ✓ calculation of the speed per run and cost per meter;
- ✓ calculation of generalized drillability indicators;
- ✓ optimization of drilling parameters;
- ✓ optimization of the bit operation time for its change;
- ✓ analysis of drill bits, the choice of the most rational type of bits;
- ✓ calculation of hydrostatic pressure in the well;
- ✓ calculation of hydrodynamic losses in the circulation system (pipes, downhole motor, chisel, annular space);

- ✓ calculation of reservoir pressures, correction for actual measurements and comparison with expected ones;
- ✓ control of the borehole trajectory (calculation of the coordinates of the bottom-hole according to the inclinometric measurements).

And general-purpose software should provide:

- ✓ Illustration in graphical form of all registered and calculated data (geological, geochemical, technological), including well log data presented in LAS-format;
- ✓ possibility to edit data (shift, interpolation, smoothing, filtering);
- ✓ performing arbitrary calculations on data;
- ✓ conversion of data obtained at the scale of depth, in LAS-format. [22]

Then by taking into account mentioned tasks above, we can choose algorithms of steps and operating hardware, programming language, that are main stage of software development. Only after that it is possible to start coding, making tests and debugging.

The software is divided into general and special. The general software of the automated process control system is the part of the software that is usually supplied with computer equipment. The most important part of the general software is the operating system, which is a set of programs that manage the computational process and implement the most common information processing algorithms and control the standard input-output device for a specific computer. The need for an operating system when using control computers is caused by two main factors: the efficient use of computing resources, in particular, time and computer memory, and the speed of reaction to events occurring in the process. An operating system consists of some main program, called a supervisor or monitor, and a set of special system routines that are running under the control of the main program. The operating system in the software of the industrial control system is the "computing environment" in which there are special programs that implement the actual automated process control. The operating system provides the implementation of system-wide procedures, as well as all standard operations used when working with software modules of special software.

<u>Development of a program for displaying information about process parameters on a computer screen.</u>

Using the board developed by the analyzed work and the video card of a personal computer, it is possible to convert a computer into a digital oscilloscope to collect and process analog data on the state of the drilling process.

A digital oscilloscope program is written in C language. This product is intended for visualization of parameters taken from sensors, which greatly facilitates their subsequent analysis. The program allows to receive from one channel and play the analog signal with the selected sampling rate. The functions implemented here make it possible to manipulate data in a variety of ways, in particular, to perform low-pass filtering, differentiation, and integration. During the development, compiler C of the company Microsoft was used.

Development of program Basic for managing the operation of the ADC

The cycle of OUT and IN commands are executed in BASIC for approximately 5 ms, so the sampling rate is limited to a value slightly less than 200 counts/ s.

Development of a program for sampling data from ADC

The program is written in C language for sampling from the ADC of channel 1 with an interval of 5 ms and sending each selected value to the DAC.

CONCLUSION

For the successful functioning and competitiveness of industrial enterprises in modern conditions, advanced modern technologies are absolutely necessary. They allow solving a wide range of tasks in the field of automation of basic technological and industrial business processes.

Automation of technological processes on the basis of modern technology should ensure the intensification of production, improving quality and reducing production costs.

Process automation is part of automated systems. Many enterprises and organizations seek to automate the production of their activities: oil and gas production, engineering, energy, etc. Currently, automation of technological processes and automation, in general, is carried out using modern automation and mechanization tools, as well as software and hardware systems for collecting data from managed objects and managing them with the implementation of the top level using IBM PC compatible computers. Now the use of IBM PC compatible computers is a thing of the past, and touchscreen operator panels are used, but they have one major drawback: they are focused on the use of specialized equipment and are designed to use specialized software.

For several years, the industry has been conducting research on the creation of microprocessor-based automated control systems for exploration drilling, implementing methods and means of universal, multifunctional control, which, unlike hard analog solutions, is capable of implementing flexible drilling technology.

One of the most important, economic effect of automation comes immediately after the introduction of the system. Savings can be achieved through rational resource management. Automation also reduces the number of personnel. For example, in the automated fields, the need for daily visual monitoring of equipment parameters will decrease significantly. Data is read by sensors and transmitted over the network to the monitor of the dispatcher. Thus, due to the automation of the labor process, one employee is able to manage the work of several engineers. In addition to savings on the salary fund for the company, it also leads to the reduction of tax deductions to pension, insurance funds, as well as the cost of the internal social life of the enterprise. Improving site safety is no less important than increasing productivity and reducing costs. Automation allows, due to the exclusion of a person from performing potentially dangerous operations, to significantly reduce industrial injuries.

Moreover, the archival storage system opens up interesting prospects for optimizing the operation of equipment. Using the accumulated statistics makes it possible to set up equipment for their most economical modes of operation, depending on the technological tasks being solved. With the help of automated systems, it becomes possible to better effectively manage the economic security of the enterprise. Key data of the production process that are automatically accumulated are accounting of materials, the scope of work, and consumption of energy resources. These allow for a comprehensive analysis of the appropriateness of certain expenses.

Automatization by means of computer-integrated control systems is a new step in optimizing production processes in the industry that will contribute to solving the main problems associated with drilling as well as the oil and gas industries as a whole.

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