Reliability improvement of the automated system for measuring wells production

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Abstract. The article is devoted to improving the work of an automated system for measuring wells production. Malfunctions during the operation of automated group metering installations are analyzed. The object of the study is a multi-way well switch. The features and disadvantages of the multi-way switch of wells are considered. The article solves the urgent problem of increasing the reliability, functionality, and maintainability of the multi-way switch of wells. The ways of modernizing the design of the multi-way switch wells are presented. These modernization methods increase the turnaround time, simplified maintenance of the unit, and more accurate measurement of wells production.

1. Introduction

Wells production measurement is fundamental in the development of oil fields. It is necessary to control and regulate the development process. Also, measuring the amount of oil, gas, and water for each well is important for the oil gathering and treatment system. Automated group metering units are designed to automatically measure the flow rate of a well, control the operation of a well by the presence of fluid supply, and block wells in case of emergencies. The mass makes measurements of crude oil minus the mass of water, net mass of oil, and the volume of associated petroleum gas both by the separation method and by the non-separation method of measurements by connecting the well to a measuring unit or a multiphase flow meter [1].

For many years, an installation for automatic measurement of the flow rate of oil and gas production wells has been a leader in the oilfield equipment market. Major and regular customers are large oil companies of the Russian Federation. The measuring unit is based on the principle of measuring separated flows of gas and liquid with mass Coriolis flow meters and determining the water cut of wells production with a flow moisture meter or by an indirect method. This unit has many versions that meet the highest safety and reliability requirements and can be operated in various conditions [2, 4].

2. Materials and methods

The principle of operation of the installation is based on the separation of the gas-liquid mixture into crude oil and oil gas in a separator, measuring the mass of the liquid flow and the volume fraction of water in it, as well as the mass (or volume) of the oil gas, and then bringing the gas volume to standard conditions. The measuring units are designed for direct and indirect measurements of the mass of separated crude oil, the mass of separated anhydrous oil, and the volume of free petroleum gas, as well
as for measuring the average mass flow rate of crude oil, the average mass flow rate of dehydrated oil and the average volumetric flow rate of petroleum gas extracted from the subsoil. The installation includes a further technological unit and a hardware unit. The units also include a separate well-switching unit. The technological, instrumental, and wells switching blocks are made in the form of block-boxes, which are made on one or separate frame bases. The installation is made in the form of one unit by placing the equipment of the instrumental unit in the technological unit in explosion-proof enclosures [3].

The main elements of the technological block are the measuring line and the distribution module. The measuring line includes a measuring installation depending on the purpose and conditions of use of the installations. The distribution module provides automatic alternate connection of wells to the measuring line through a system of three-way valves or a multi-way switch of wells driven by a hydraulic drive. In this case, the production of other wells is directed to a common pipeline. The distribution module is also equipped with a bypass line for the manual connection of wells to the measuring line using valves [6].

The layout and design of a specific unit and the standard size of the separator are selected depending on the expected values of oil and oil gas flow rates, the formation water content in crude oil, and oil gas content in dehydrated oil.

The hardware unit collects, processes, registers, displays, stores the obtained measurement results in the archive, transfers them to the upper-level automation systems, and manages instrumentation, automation, life support systems, security, and fire alarms [5, 9].

3. Results and discussions
Separation and non-separation measurement methods are used in automated group metering installations.

The separation measurement method is based on a measuring installation, which includes an oil and gas separator, mass liquid flow meters, mass or volumetric gas flow meters, moisture meters, temperature, and pressure transducers.

The separator is made in the form of one cylinder or two, located one above the other, equipped with a cyclone, which is the first stage of separation and serves for the primary gas separation from the oil-gas-water mixture as for drying the oil gas using drop separators. The design of the separator also provides collection and settling of crude oil, during which dissolved gas is released from the oil [11-14].

The regulation of the cycles of accumulation and discharge of the oil and gas-water mixture and the flow rate through the flow meters-meters of crude oil and oil gas is carried out in two ways:
- using a damper installed at the connection point of the pipeline for the removal of petroleum gas (gas line) and a floating device, mechanically connected through levers and a rod. A flow regulator is installed on the crude oil return line (liquid line).
- electrically controlled cranes, or pneumatically controlled valves, are installed on liquid and gas pipelines (in this case, an air preparation system for valves is included in the life support kit).

The non-separation method of measurement is based on the use of a combination of a Venturi tube and a gamma fraction meter. As the flow passes through the venturi, a pressure drop occurs, which allows the total mass and volumetric flow rate to be measured. The gamma fraction meter provides data on the ratio of oil, gas, and water fractions. For measurements of absolute and differential pressures and flow temperature, sensors with a digital or analog output signal are used [7].

The computing device of the flow meters calculates the flow rate of the mixture fractions – oil, gas, and water. The calculations are based on a specially developed complex physical model (hydrodynamic, thermodynamic, and nuclear) that considers the features of a multiphase flow, including its inherent instability. The current measured values of the multiphase flow parameters are statistically processed. The results of measuring the flow rates of the phases of the flow and its fractions are stored in the control computer's memory. The flow meter has the function of measuring time intervals to register the values of the measured parameters accumulated over a specific time interval [8].
In order for the installation to be in working condition, the CG availability factor is calculated. Availability factor – the probability that the installation will be in an operational state at an arbitrary moment and, starting from this moment, will work without failure for a given time interval.

In general, malfunctions in the operation of the installation are divided into three groups: assembly (damage during the assembly of metal structures), operational (malfunction caused by natural wear of parts and assemblies of the car during its operation or that occurred for reasons not related to poor manufacturing quality or scheduled repair), technical (the state of a technical object, characterized by its inability to perform the required function). Figure 1 shows the information on the types of faults.

Installation faults account for 8.4%. These installation faults include jamming of external wall panels, damage to paintwork, breakage of pipelines, the unilateral opening of equipment, changes in equipment's design, and purchased components.

Operational faults account for 63%. These operational faults include failure of products (operator panels, notifications, sensors, valves), lack of purchased components, lack of necessary documentation.

Technical malfunctions account for 28.6%. These technical malfunctions include the following faults: deviation from design documentation, peeling of the exterior paint and varnish coating, defective welded joints, mismatch of fasteners, ingress of solid particles into flow controllers PP, multi-way wells switch, TOP liquid meters, flow meters; premature wear of pipelines due to violation of the operating conditions of equipment and assemblies.

The main problem of the measuring unit for automatic measurement of the flow rate of an oil and gas production well is the wear of the multi-way switch of wells (Multi-way switch of wells) (metal corrosion, shells, channels).

The sequential connection of wells for measurement in automated group metering units is carried out using a multi-way switch of wells of a switch of multi-way wells.

In the hollow casing of the multi-way well switch, a rotary shut-off-switching element is made in the shape of a square. A spring-loaded carriage is installed on the side branch pipe of the square, which has two rollers and a rubber seal between the carriage and the housing of the multi-way well switch for directing the production of the measured well into the square. The upper branch pipe of the elbow is connected to a hollow shaft, through which the production of one well is directed to the measuring device. A cylindrical protrusion-axis is made coaxially with the upper branch pipe in the lower part of the square, inserted into the recess in the lower part of the housing of the multi-way switch wells. The task is to switch flow rate measurements from one well to another. The shaft with a square is rotated at a certain angle, while the carriage rollers roll along grooves of variable depth made on the inner cylindrical surface of the multi-way switch housing. When the rollers move along the grooves, a gap is formed between the rubber seal of the carriage and the housing of the multi-way well switch. However, when the angle is opposite the nozzle of the measured well, the rollers sit in the recess, and the carriage seal is pressed against the housing of the multi-way well switch.
The solution implemented in the multi-way switch has many significant disadvantages, the main of which are:

a) low reliability of the rubber seal between the carriage and the inner cylindrical surface of the housing of the multi-way well switch, due to the shape of the sealed surfaces, which leads to accelerated corrosion-erosive wear of the section of the housing of the multi-way switch under the seal and the guide grooves;

b) when the rollers, pressed by the spring, move along the bottom of the guide grooves, wear and an increase in the depth of the grooves occur, which leads to insufficient lift of the carriage when the square moves between the well's pipes and, as a result, to damage to the seal and the surface of the multi-way switch housing;

c) there is a significant gap between the square axis and the recess in the housing of the multi-way well switch, which increases with wear and is not compensated by anything [3]. By the size of this gap, under the action of the carriage spring, the square is skewed, which leads to the uneven pressing of the seal against the housing of the multi-way well switch, accelerated wear of the sections of the housing of the multi-way well switch under the lower part of the seal and the lower guide groove;

d) fragility of the housing of the multi-way switch of wells;

e) high labor intensity and cost of repairing the body of the multi-way switch wells, low maintainability.

These shortcomings negatively affect the accuracy and regularity of measuring the production rates of production wells prescribed by federal regulations [10].

If the indicator is important, then, in general, the work of the oil field is based on this indicator. We based on the obtained measurements of wells flow rates, the state of the downhole pumping equipment. So, the productivity of the pump and the productive formation is assessed, measures are developed to optimize the pump parameters, and their drives, the resuscitation of downhole pumping equipment, the technological regime is drawn up.

There are versions of the housing of the multi-way switch of wells made of high-alloy steels (for example, 12X18H10T) [4]. These designs, as practice shows, did not give significant improvements to the disadvantages listed for the multi-way switch of wells since the erosive wear of the housing of the multi-way switch made of high-alloy steels did not decrease, the same for the wear of the guide grooves.

4. Conclusion

Therefore, to extend the service life of the multi-way switch, the following solutions have been proposed:

1) Application of a new design of the manifold tee after the multi-way switch of wells, excluding welding of fillet welds.

2) Introduction of powder coating technology for internal surfaces.

3) Reassessment of suppliers of purchased components.

It is also proposed to replace the powerful hydraulic drive with a torque electric drive [5]. Installation is carried out on top of a multi-way switch of wells. The shaft of the torque motor is connected to the shaft of the multi-way well switch using a sealed coupling. Due to this, the rack-and-pinion transmission and the hydraulic drive are eliminated, leading to an increase in the overhaul period and simplification of maintenance. Since there is no rack wear, higher and more accurate switching, less wear of the seal, less leakage, more accurate measurement.

In recent years, the industry has shifted to the production of "complex" oil. Field development costs have increased, production conditions and well designs have become more diverse, and, accordingly, the requirements for measurement systems of the produced product in terms of accuracy and reliability have increased. Therefore, more reliable technologies are required, such as an upgraded flow controller for liquid and gas.

The ways of modernizing the design of the multi-way well switch are proposed to increase the reliability, functionality, and maintainability of the equipment.
The above proposals for the modernization of the multi-way switch of wells make it possible to increase the reliability of the automated group metering unit and the accuracy of wells flow rate measurements.

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