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MONITORING SYSTEM FOR THE SENSING OF VARIABLES IN A WELL SAFETY WORK OVER TEAM

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ABSTRACT

This work proposes the design of a monitoring system for the sensing of variables in a well control system (accumulator), for which reengineering is applied to measure pressure and system level, with activation of sound and visual alarms. An accumulator is a unit used to operate hydraulically BOP (Blowout Preventer) components. The monitoring system in the proposed accumulator is based on the sensing of three variables: system pressure, manifold pressure, and annular pressure. In this project, to develop the design, an in-depth study, and analysis of the BOP system is carried out to avoid errors that affect the accumulator's physical integrity. API (American Petroleum Institute) standards are also considered. As a result, the proposed design serves as the basis for the company to take an interest in deploying electronics to the other workover equipment to make them safer and more reliable.

Keywords: accumulator, workover, blowout preventer, monitoring, sensor.

1. INTRODUCTION

The industry highlights the oil sector as an important area that generates an impact on society. This industrial field is the generator of great economic and productive riches, which benefit users. The good price of the barrel of oil has led to high investment for the design, construction and purchase, and sale of workover equipment. The rapid investment recovery in this sector has led to intense competition between these companies.

Workover equipment is used in the well-completing process, preparing a newly drilled oil, water, or natural gas well to put it into production. Some of them are portable power plants, mud pumps, basic unit, accumulators, battering ram preventer and annular preventer.

In recent years and as an immediate consequence of technological development globally, new equipment has arrived in the oil sector (Pérez and Pinzón, 2012). This equipment brings a new component within their structure and incorporates electronics because from a while ago, the workover equipment was purely mechanical and manual. Electronics in the equipment implement automation and control systems that include numerous types of sensors, PLCs, electronic control boards, remote communication systems, solenoid valves, and safer and more reliable equipment by minimizing the interaction between the equipment and the operator. Numerous workover teams have been discontinued; an example of this is accumulators. It is not only because of their working time but also because of their old technology and international standards (APIs) in oil that require rigorous compliance with three essential objectives: staff safety, continuous operation, and minimal impact on the environment.

Significant works have been carried out on these workover units, such as the improvement of allocating workover equipment belonging to spending in failing production wells of Campo Casabe. Through a technical-economic evaluation procedure of wells that have stopped producing crude oil, it is possible to generate alternatives that increase the level of efficiency of the resources used throughout the process (Orozco, 2013). Likewise, the preventive maintenance plan is carried out for STS workover equipment of the Andes S.A., to which additional items were attached, such as the maintenance required by its physical plant and the transport vehicles of personnel and specialized transport (Vergara and García, 2010). It is also presented the optimization of maintenance methods for the electronic system hardware of a basic workover unit (Pardo, 2010).

This work proposes the design of a monitoring system for the sensing of variables given in a well control system, which consists of applying reengineering to measure pressure and system level, with activation of sound and visual alarms.

2. MATERIALS AND METHODS

An accumulator (also called Koomey) is a unit used to operate BOP components hydraulically: battering rams, annular preventer, HCR (Hydraulic Control Valve), and some hydraulic equipment. There are several high-pressure cylinders that store gas and hydraulic fluids or pressurized water for hydraulically activated systems (Wellcontrol, 2019).

The monitoring system implemented in the accumulator is based on sensing three variables: system pressure, manifold pressure, and annular pressure. For this project's design, an in-depth study and analysis of the BOP system are carried out to avoid errors that affect the accumulator's physical integrity. International standards (APIs) are also considered. API standards are working recommendations and not laws to comply strictly, but if not complied with, companies create undesirable legal problems.

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2.1 Pressure Accumulator Units

Figure-1 shows the 11983 accumulator, which is used in this work.

Figure-1. 11983 V-16 accumulator.

2.1.1 Background

BOP for rotary drilling rigs has been known since the beginning of the century. However, acceptable methods of closing preventers appeared in the entry of the 1950s (Xoy, 2006). Older BOP units used a manual system of the screw closure type. Today, manual closure systems are still used on some small computers. When an emergency occurs, it is essential to close the well as quickly as possible to avoid further urgency. In general, manual systems are slower than hydraulic units and can allow for higher volumes of fluid input. Injection pumps, equipment air, and hydraulic pumps have been tested as closing units, and all have given unsatisfactory results. Hydraulic accumulator systems are the first closing units to give good results.

2.1.2 Purpose of the accumulator

The accumulator's purpose is to provide a fast, reliable, and practical way to close BOPs in emergencies. Given the importance of the reliability factor, the shut-off systems have extra pumps and excess fluid volume, as well as alternative or backup systems.

2.1.3 Operation

Standard equipment uses a control fluid that can be a hydraulic oil or a unique mixture of chemicals and water stored in bottles or accumulator cylinders at 3000 psi (207 bar). A sufficient amount of fluid is stored under pressure so that all components of the BOP assembly can operate under pressure and always maintain a safety reserve. As the pressure on the accumulator bottler decreases, the air or electric pumps installed to recharge the unit start automatically. Under very cold environmental conditions, the accumulator system's temperature should not reach below zero, as the rubber elements inside, such as the chambers (bladder), can crystallize and burst.

2.1.4 Manifold components

It consists of the valves (four-way) opening and closing of preventers, the pressure regulator (choke), and pressure indicators (manometers). Figure-2 details these components.

Figure-2. Manifold components.

2.1.5 Basic control system

It consists of a set of valves that drive pneumatic jacks housed under the four-way valves. Four-way valves must be in the open (left) or closed (right) position and never OFF (center), see Figure-3.

Figure-3. The basic control system of the 11983 accumulator.

2.1.6 Volume requirements

The accumulator system must provide the volume necessary to meet or exceed the closing systems' minimum requirements. There are several standard methods for calculating the required volume. For example, API RP 16E details the mathematical calculations to calculate the minimum API volume. The MMS (Mineral Management

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Service) requires once, and a half more of the volume needed to close and keep all BOP units closed with a minimum pressure of 200 psi (13.8 bar) above the preload pressure. Because it is better to have more than the minimum volume, most operators and contractors prefer to use a factor of three times the volume required to close everything in the column. The main idea is to maintain a sufficient energy reserve for the accumulator system; to operate the column to have more energy than the remaining nitrogen preload. The number of gallons needed to fill the accumulator tank optimally depends on each unit and its cubicle. On average, 160 gallons of Rando HD 68 hydraulic oil are used, which equates to 32 barrels of crude.

2.1.7 Accumulator load fluids

The fluid used for the accumulator must be an anti-corrosive, anti-sparkling lubricant, resistant to fire and adverse weather conditions. Also, it must prevent the softening of rubber sealing elements. Hydraulic oil has these characteristics. A mixture of fresh water and "soluble oil" (with ethylene glycol for low temperatures) can also give good results.

The mixture "soluble oil" and water (ratio 1 to 5) has some advantages: it is less expensive and non-polluting; therefore, this mixture is preferred over hydraulic oil. In temperate climates, bacteria, algae, and fungi can accumulate in the system; therefore, chemicals are added to prevent these organisms' development following the manufacturer's recommendations. The use of inadequate oils or corrosive water may damage the accumulator and closing elements of the BOP assembly

2.1.8 Nitrogen preload

A vital element of the accumulator is the preload of 1000 psi nitrogen (68.9 bar) in the bottle. In case the bottlers lose the load completely, no additional fluid can be stored under pressure. It is necessary to keep the load on the bottle near the 1000 psi of operational preload pressure. Nitrogen tends to leak or disappear over time. This process varies from bottle to bottle. A load of each of them at the bank must be verified and recorded in each of the wells.

This project uses accumulators with eight 11-gallon bottlers each and six 15-gallon bottle racks each; up to 16 bottles are used in each accumulating unit. Each bottle is designed to withstand up to 5000 psi and features a life cycle where it goes through hydrostatic and performance testing.

2.1.9 Bypass

It is a derivation made from the high-pressure line that switches between 1500 psi (manifold pressure with which the lock preventers work and which is regulated by the adjustable choke) and 3000 psi (taken directly from the pressure of the system (Used in case of an emergency in the well). It is usually found in 1500 psi.

2.1.10 Adjustable manual strangler

The strangler (choke or regulator) is an element that controls the flow rate of circulation of the hydraulic fluid. By restricting the fluid passage with a hole, extra backpressure or friction is generated in the system. It provides a method of controlling flow and pressure in the accumulator.

2.1.11 Electric motor

The electric motor used in this project is shown in Figure-4. It is a three-phase engine, with 15 HP delivered at 1750 RPM, explosion-proof certified (Class 1 Division 2) and 220V operation with configuration and 440V in the configuration. It has twelve connecting terminals (six coils) with which it is configured as desired.

Figure-4. Electric motor connected to triplex pump.

2.1.12 Pneumatic pump

With air connection (150 psi and 1-inch diameter pipe) and direct connection to the accumulator tank, it is responsible for maintaining working pressure (3000 psi) in the unit when the triplex pump is not operational or faulty. Although the pneumatic pump is not main but is an emergency alternative, it is still important that the compressor pressure is at its working pressure (150 psi). This situation is because in the well, it is not possible to waste time waiting for it to load the compressor, and it leads to saving human lives.

Air bypass: The pneumatic pump has an air supply, with passage restricted by a mechanical pressure switch. This thermostat through system pressure opens the way to supply air to the pneumatic pump and has a shunt that takes air directly to the pump (Bypass).

2.1.13 Triplex pump

Composed of three pistons and driven through the electric motor, it is responsible for carrying the accumulator system's pressure from 0 to 3000 psi in a maximum of 15 minutes. After that, it sucks the hydraulic fluid and pumps it to the unit lines. Their work is counted from 1000 psi to 3000 psi, because from 0 to 1000 psi is carried out with Nitrogen's preload. The on/off (powered by the engine) is controlled by a pressure switch.

2.1.14 Air compressor

It has a screw motor that compresses air to 150 psi to store it and provide it to the pneumatic pump.

2.1.15 Add-ons

Like other essential components within the accumulator is the check that restricts in one direction the fluid, the strainer that filters in one direction fluid, the four-way valves that allow two directions of circulation with a return, and the thermostat or automatic responsible for the on and off of the electric motor.

2.2 Accumulator Unit 11983

The 11983 accumulator unit was shown in Figure-1. This unit brings a monitoring system that alerts well personnel to an abnormal event in one of three sensing variables (air pressure, system pressure, and oil level). The unit is equipped with the company's voltage-driven; some components are relocated and installed on a trailer where they are coupled with their loads (preventers, hydraulic wrenches).

2.2.1 Components of the accumulator electrical system

The sensors used by this system are housed inside the explosion-proof chest, as shown in Figure-5. Sensors are located at the top of the accumulator, except for the level mechanical sensor attached to the tank. In addition to the sensors, the chest contains other components such as those detailed below.

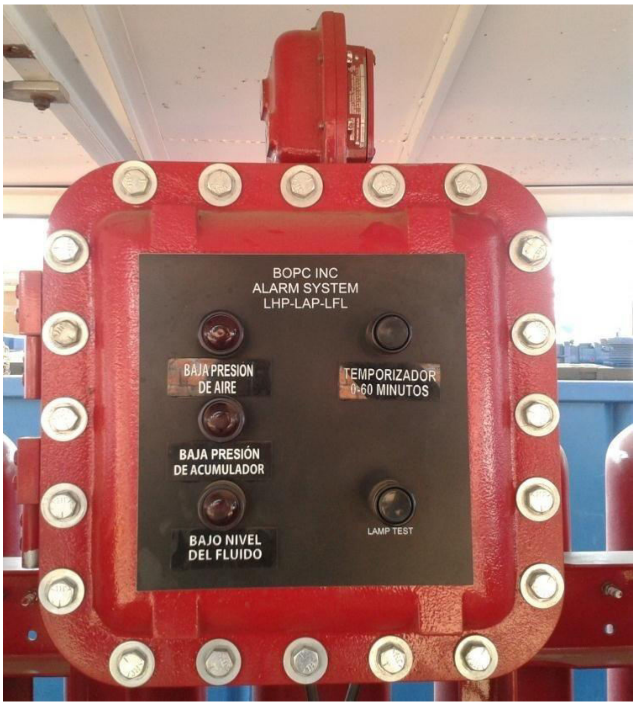

Figure-5. Explosion-proof chest front panel.

Relay: Three relays are responsible for switching electrical signals (110V) and timer responsible for operating the siren and pilots. Each relay consists of the induction coil and four switchable sections.

Timer: The timer is responsible for keeping the alarm activated for an instant of the scheduled time to check the correct operation. The model 310 programmable timer is shown in Figure-6.

Figure-6. Timer.

Hydraulic oil pressure sensor: It is an adjustable mechanical sensor that works by deformation and delivers dry contact. It comes to the line of 3000 psi.

Air pressure sensor: It is a different sensor than the previous one because it does not use elastic deformation, and its diaphragm is not a sensing element. This sensor seals two media outlets and transfers pressure to the disc spring, which responds instantly when system pressure reaches its set points. Figure-7 shows the CCS Sensor (Custom Control Sensor, Inc.) model 611G8005.

Figure-7. CCS sensor.

Pressure switch: This pressure switch gets the 3000 psi line and sends a signal through a contact to activate or deactivate the electric motor depending on the accumulated pressure.

Oil level sensor: More than a sensor is a float located on the tank's side and by contact allows the

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passage of an electrical signal. Figure-8 shows the Wellmark, Cencomajor level sensor, model 790SF-1AS.

Figure-8. Wellmark level sensor.

Thermal relay: It is used to protect the engine against mild and constant overload. It is not a fundamental part of the alarm system, but it is related and housed next to the sensors.

Contactor: This electromechanical element allows or interrupts the passage of the current that puts the motor into operation. It is not a fundamental part of the alarm system, but it is related and housed next to the sensors.

Industrial control transformer: It is responsible for regulating the voltage of 220V to the appropriate voltage required. On the front of the explosion-proof chest are three pilots indicating low oil pressure, low air pressure, and low fluid (oil). Also, it has two switches, one of them in charge of performing a test run of the pilots and the other in charge of performing a siren operation test. The siren is activated with a 110V signal and is located at the top of the chest.

3. RESULTS AND DISCUSSIONS

3.1 Design of the Monitoring System

The monitoring system of the 11983 accumulator uses the sensors' signal to be switched by a series of relays that allow the operation of the pilots and a siren. Three variables are monitored: the solvent fluid level variable, the air pressure variable, and the accumulator pressure variable, all with low alerts. Besides, it has a button to do a test of light bulbs or pilots and one for the siren, controlled by the timer. The explosion-proof chest located near the electric motor houses circuit protection, a voltage transformer, and a switch that controls compressor ignition, either automatic or manual. Figure-9 shows the electrical circuit schematic of the proposed 11983 monitoring system.

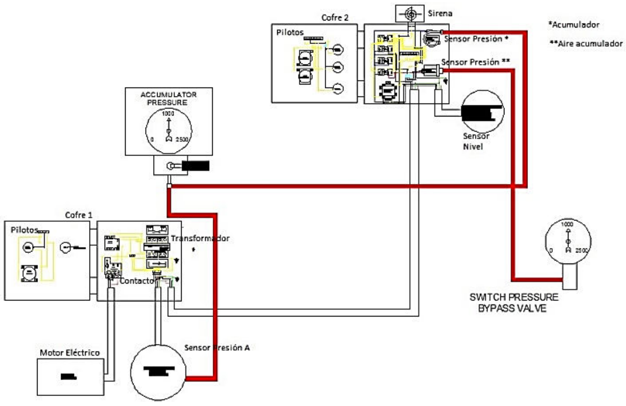

Figure-9. The electrical circuit of the monitoring system.

The design is proposed based on the optimization of resources, economy, and quality of the components. Three design alternatives mentioned below are proposed.

Design 1: The signal provided by the sensors is stored in a PLC that subsequently takes already programmed actions, such as generating alarms at a specific state of the sensing variable.

Design 2: The signals provided by the sensors are switched in a series of relays that allow the activation of visual and sound alarms.

Design 3: The sensors' signal is directed to a process alarm indicator responsible for analyzing the electrical signal to convert it into a numerical amount of the variable in-process and generates an alarm under which it has already been programmed.

The choice of one of the three designs is conditioned by the criteria of availability, profitability, and components' characteristics. It is also noted that the pressure accumulator is designed to work in the open field, exposed to sun, water, moisture, and other environmental factors. Finally, the number three design is chosen by the economy and updated technology. However, design ideas number two are taken to switch the three signals and bring them to the siren and indicator light. Figure-10 presents the number three design chosen.

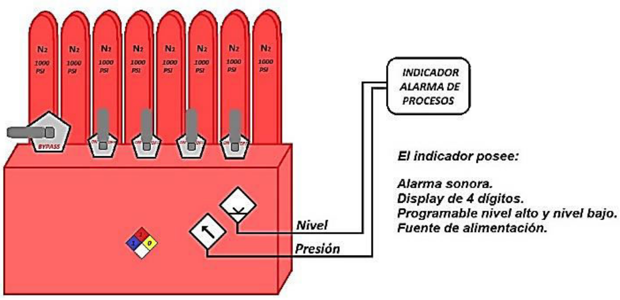

Figure-10. Design number three of the monitoring system.

3.2 Description of the Devices Chosen

3.2.1 System pressure sensor

The heart of the pressure transmitter is the measuring cell, which transforms the applied pressure into a measurable electrical signal. That pressure-based signal

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is analyzed by the integrated electronics and converted into a standardized output signal. Different sensors are used for pressure detection. Ceramic cells provide the advantage of excellent long-term stability and high overload resistance. The metal cells also cover high measuring ranges, using stainless steel as the membrane material. Figure-11 shows the chosen Vegabar 17 pressure sensor (Vega, 2019). This metallic process pressure sensor is ideal for measuring pressure in gases, vapors, and liquids.

Figure-11. Vegabar pressure sensor.

The Vegabar 17 can withstand the preload of the accumulator system, which goes from 0 to 1000 psi in a couple of seconds. The Shimaden digital indicator process visualizer receives the signal generated by the sensor (4 to 20mA). The sensor's location inside the anti-explosion box is on the left side of the sensor with a 1/2 inch NPT (National Pipe Thread).

3.2.2 Fluid level sensor

The Vegaswing 61 level sensor shown in Figure-12 (Vega, 2019) is chosen. With a fork only 40 mm in length, the Vegaswing works reliably in all types of liquids regardless of their mounting position. Pressure, temperature, foam, viscosity, and bubbles do not influence their detection accuracy. Typical applications are overfill and dry-running protection. The piezoelectric drive is the heart of the equipment, vibrating the fork to its resonance frequency. The frequency is reduced when immersed in the liquid. This change in frequency is evaluated by integrated electronics and converted into a switching signal. A threaded connection is used to ensure that the piezo connection is robust and reliable.

Figure-12. Vegaswing level sensor.

Vegaswing 61 is used as a universal level switch in liquids. Reliably and accurately detects millimeters when a certain level is reached. It can operate in tanks and pipes in any installation position. The equipment can also be used as a full or vacuum detectors, such as certified overfill protection, dry running protection, or pump protection. Among its advantages are non-adjustment commissioning, high level of reproducibility, independent switching point of the product, without wear or maintenance.

3.2.3 Four-digit display

The chosen process visualizer, Shimaden digital indicators, is shown in Figure-13 (Shimaden, 2019). Four-digit multi-input and multi-range process visualizer, user selectable thermocouple, RTD, with voltage and current inputs. It requires a resistance of 250o through the input terminal of 4-20mA DC. Reverse scaling possible, and the front panel is splash and dust proof.

Figure-13. Shimaden process visualizer.

Two units are chosen to visualize the air pressure and pressure of the system. They receive the signal (4-20mA) from the pressure sensors and display it in four digits each. It is possible to program a set point high or low. Also, it generates a contact accompanied by a slight timbre when the reading reaches in set point. Setpoint for air pressure signal 100 (psi) and setpoint for system signal (fluid) 2700 (psi). They are located on the front panel of the explosion-proof box side by side.

3.2.4 Namur amplifier

The Namur (Galvanic Separator) amplifier is a signal conditioner for equipment with a Namur interface. Typical applications are overfill protection. Among its advantages are: Control Current Circuit IIC, reversible sense of action, detachable bornes, and NAMUR interface, according to IEC 60947-5-6.

The Namur galvanic separator energizes the Vegaswing 61 level detector and works as a fault protection barrier. Besides, it receives the signal provided by the Vegaswing 61 and processes it to generate a contact (relay) on its terminals. Its location is inside the explosion-proof box where the Vegaswing 61 signal arrives. Thanks to its structure, it is easy to locate, vertically.

3.2.5 Explosion-proof selector

The switch provides safety by connecting and disconnecting lighting and light energy loads in hazardous classified locations. The chosen switch is the Appleton® SWE016C101AG shown in Figure-14 (Emerson Electric, 2019).

Figure-14. Switch to Appleton®.

Its purpose is to manually open and close the anti-explosion box's output circuit to the visual and sound alarms. When the system is turned on, the alarms are deactivated while reaching their operating pressure (3000 psi), then activated. It will be located on top of the anti-explosion box along with the siren and emergency light.

3.2.6 Emergency light

Emergency light with certifications to operate in classified areas is suitable for visually alerting well personnel in emergencies. The indicator light lights up when an abnormal event occurs, such as low fluid (oil), low air pressure, and/or system. It is located at the top of the anti-explosion box, next to the selector (switch) and siren.

3.2.7 Emergency siren

The Neset Nutsteel electronic siren has a microprocessor to allow the user to choose from 32 pitch variations, including local switching, selected internally by a switch connected to the circuit. It allows 32 combinations and has an internal volume control through an integrated potentiometer. It is used in areas where there is a risk of explosion. The appearance taken into account for the choice of the siren was the melody of the tone because, in the field, they handle the typical sound of the siren to evacuate the area. It is located at the top of the anti-explosion box, along with the selector and indicator light.

3.2.8 Explosion-proof box

A box scheme is made with the required dimensions and perforations, considering the chosen devices mentioned above, as shown in Figure-15. Connections to the inside of the anti-explosion box are shown in Figure-16.

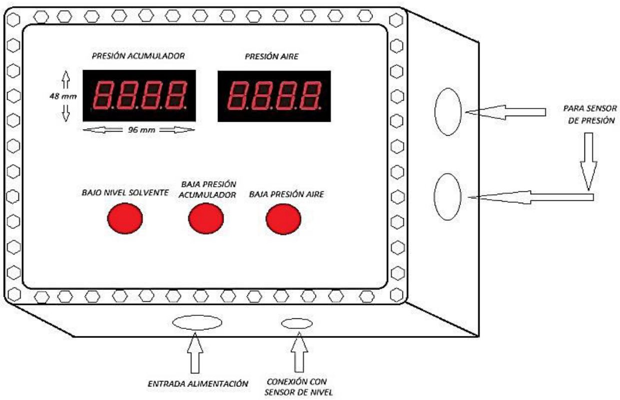

Figure-15. Scheme of the box needed to accommodate the sensors.

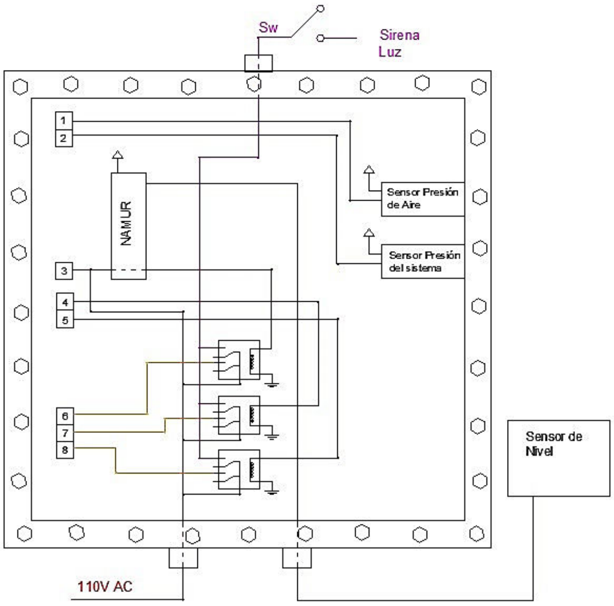

Figure-16. Connections inside the anti-explosion box.

4. CONCLUSIONS

The technology update provides tools to make accumulators safer and more reliable equipment when monitored, minimizing the risks faced in the well. Similarly, the monitoring system helps reduce the likelihood of a disaster caused by BOP closure system failures.

The proposed design is based on the operating characteristics of a company that currently has ten teams operating. As this is an initial proposal, the quoted elements have an established unit value with a minimum discount. A higher discount is achieved with the vendor by carrying out the project to the other accumulating units. The mentioned before causes the total cost of the project per accumulator to be significantly reduced.

The chosen sensors needed to carry out the monitoring system, unlike the 11983 accumulator sensors, do not require calibration or adjustment. It means greater autonomy with saving time and money spent on their maintenance.

The project serves as the basis for the company to invest electronics on the other workover equipment to make them safer and more reliable. Also, for other companies that do not have this system to carry it out, in this way generate extra revenue from the commercialization of the project.

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