Innovative approaches to the formation of environmental safety at the objects of oil and gas production

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Abstract. The innovative approach to environmental safety upgrade of pumping-circulatory equipment of drilling rigs based on the analysis of life history and continuous perfection principles. Examples of implementation of innovative approach in environmental safety investigation of oil and gas wells in order to define environmentally hazardous units of equipment and technological processes are given. In order to solve the problem of environmental safety improvement and the effectiveness of flushing out of well that are being drilled a modernized scheme of drilling rig pumping-circulatory system has been designed. System approach of modernizing separate elements of pumping-circulatory system has been used. The maximum air-tight pumping-circulatory drilling rig system has been designed. The proposed model takes into account the necessity of hazardous evaporations outlet with the aim of their further utilization. Such an approach will avoid the entry harmful substances into the environment and prevent harmful effects of aggressive substances on health personnel of drilling rig, environment and on state of the technological equipment.

1. Introduction

Oil and gas industry complex is one of the objects of high ecological hazard. It uses ignitable, highly flammable, dangerously explosive and toxic substances. The process of drilling oil and gas wells is the source of air pollution. The pollution takes place during scheduled technological processes at the cost of evaporations and emitting hazardous substances.

An important of the strategic direction, according to 2008/50/EC Directive of the European parliament and council [1], is preventing hazardous substances emission from particular sources. At the same time the most effective measures of defining and implementation of air pollution reduction are taken at the local level.

Pumping-circulatory system (PCS) of drilling rigs is mainly open. The mud circulates there together with different hazardous substances; some of them are used in order to improve technological processes: 55% - gel powder, chalk, barytes; 16% - acids; 11% - surface-active substances; 7% -
water-soluble salts, polymers - 5%, dissolvent - 4%, caustic and different chemical reagents 1% each. Hazardous substances may create in the process of mud circulation and it contact with drilling layers, saturated for example with hydrogen disulphide and other dangerous substances [2].

The open equipment containing drilling fluid cause evaporations and distribution of hazardous substances saturated with toxic components. This may have following negative consequences:
- Health effect for staff and population of adjacent territories covered by hazardous evaporations distribution;
- Negative effect for flora and fauna;
- Negative effect for operating conditions and useful time of all main equipment that comes into contact with evaporations.

That is why the investigations aimed at upgrade the environmental safety of oil and gas extraction process, namely pumping-circulatory equipment of drilling rigs (DR), for the time being remain up-to-date and require complex approach based on evaluation of the present state and finding faults of main equipment and processes with their further elimination.

2. Analysis of present designs and defining ways of improvement

The evaporation of liquid substances used during well construction creates the risk of some ailments origination with drilling rig staff, aggressive evaporations may damage the equipment and at favorable climate conditions there happens intensive dispersal of pollutants onto adjacent territories. The origination of evaporations during drilling fluid circulation has been described bin works by Steinsvag, K., Galea, K.S., Krüger, K., & Peikli, V. 2011, 7. [3].

At the time being all the regions of the world possess a great number of oil wells. These objects are quite dangerous for the environment as in the course of regular operating processes and also at states of emergency. A great amount of scientific papers in the sphere of ecological safety are about oil and gas industry complex problems. However, the analysis of the whole state found the problem of defining separate problematic fields. Famous investigations of the state of atmospheric air of DR and approved methodologies do not take into account the evaporations of chemical substances that originate during DF circulation. In order to evaluate and forecast the state of atmospheric air the important role is played by the analysis of evaporations from evaporation surfaces of PCS taking into account real conditions and operating functions of DR equipment.

During technological drilling operations especially after used drilling fluid lifting, its passing the chutes and its purification, as well as keeping bore mud in sludge pits the pollution of surface layer by hazardous substances that constitute DF takes place. These substances come to atmosphere in the process of evaporation that takes place quite intensively due to comparatively high temperature of the flushing fluid [4]. The results of investigation of evaporation processes at different units of PCS DR are given in work [5]. Gaseous substances that penetrate ground layers of atmosphere as the result of eddy diffusion and by the action of wind expands over drilling rig territory and beyond its borders which poses risk of toxic effect for staff and population of adjacent territories. The forecast of prevalence of pollution of ground layers of atmosphere caused by evaporations is given in work [6].

The existing constructions of pumping-circulatory systems and their separate components studied in the works of [2, 7] that state about the negative impact of evaporations that appear in the process of primary purification of the mud on the mud screen.

The above-mentioned investigations prove the necessity of design modernized circulatory system which will make it possible to perform flushing process at the rig effectively and will ensure utilization of hazardous evaporations in order to increase environmental safety of oil and gas wells drilling.

3. Innovative approaches to the increase of the level of environmental safety of pumping-circulatory system of drilling rigs

Academic specialists of Ivano-Frankivsk National University of Oil and Gas conducted investigations and estimated life history of the objects of wells construction in compliance with ISO 14000 standards
which helped identify the most powerful environmental effects. The decrease of environmental pollution at oil and gas extraction works demands thorough investigation of every stage from the ecological safety viewpoint. It will make it possible to establish faults in operation of the equipment, technological processes and management decisions that need to be disposed of. An offer has been made to use systematic investigation approach that will be based on the analysis of each life cycle stage of the well. The above-mentioned approach will make it possible to trace the connections of the combination of factors and the results of the environmental impact as the whole set of elements. The result of implementation of this approach will be the definition of real ecologically hazardous processes and their delimitation \[8\].

The sections of PCS DR that are more likely to emit hazardous substances into ground layer of the atmosphere have been defined. Guided by the principle of life history management concerning continuous improvement several stages of modernizing operating machinery and processes on order to reduce emissions of pollutants into ground layers of atmosphere have been conducted. Fig. 1 shows the chart of the stages of the increase of levels of environmental safety of pumping-circulatory system of drilling rig.

The first step in order to reduce the amount of emissions was to modernize the set of operating machinery, namely: the mud screen model with insulating screen for primary purification of drilling fluid has been improved which prevents penetration of hazardous substances to the environment that emerge intensively during mud screen vibration \[5\]; a new model of mud cone for fine drilling fluid purification has been designed which makes it possible to operate as mud cleaner and desilter which respectively reduces the amount of equipment that is necessary to install in order to obtain required result of drilling fluid purification \[9\]; there has also been designed constructive solution purification equipment block of drilling mud and device for cleaning the downhole tool \[10\].

**Figure 1.** The chart of basic stages of the increase of environmental safety level of pumping-circulatory system of drilling rig

Using the proposed equipment will avoid harmful substances into the environment, prevent harmful effects of aggressive substances on health personnel and increase fire safety rig.

At the second stage modernized pumping-circulatory system from the viewpoint of obtaining efficient operation results, meets the following requirements: quickly readjusts for the drilling mode in certain conditions; takes minimum time for transportation to the operating site, assembling and disassembling; is compact for mobility; has convenient and safe labor conditions for mans; has high resistivity to damages \[2\].
During further analysis of the chart of closed off PCS it has been defined that vapors in isolated sections can accumulate and create unfavorable conditions for pumps operation and later penetrate ground layers of the atmosphere thus endangering environment. That is why a decision has been made to improve the design of closed off PCS by means of vapor disposal from definite sections of PCS with their further utilization in order to minimize the risk of poisoning by DF vapors.

4. Recommendations for improvement of closed off PCS
In order to ensure safe, reliable operation of closed off PCS with separate modernized equipment it is necessary to conduct additional analysis and take into account the specifications of operating conditions. The work [2, 10] contains the chart and operating peculiarities of closed off PCS where it describes the operating peculiarities and design features of separate units of equipment from flexible material that make it possible ensure air tightness, mobility, compactness and a set of other positive factors that help increase the level of environmental safety of PCS. Fig. 2 shows the chart of improved closed off PCS with vapor disposal for utilization.

Modernized pumping-circulatory system consists of: 1 air-tight accept tanks are made of elastic material; 2, 3, 4, 24 - intake line; 5, 8, 11 - drilling mud pumps; 6 - drilling pumps; 7 - tanks with chemical reagents; 9, 23 - section of channel-circulatory line; 10 - purification unit; 12 - back valves; 13, 25, 27 - lock valves; 14 - the drilling mud preparation unit; 15, 16, 17, 18 - the sections of discharge line; 19 - standpipe; 20 - equipment of the mouth of the well; 21 - rotary swivel; 22 - safety switch units; 26 - fill-up line.

The offered PCS in chart 2 contains separated units where vapors accumulate. Though PCS is closed off separate units accumulate vapors. The most favorable conditions for evaporation rate are created by high temperatures of the fluid coming out of the well and in summer when the temperature of the environment is high. These sections are marked in the chart as: A1, A2, A3, A4.

Figure 2. Improved closed off PCS with vapor disposals for utilization
A1 - the unit of drilling fluid purification that comes out of the well. The given unit contains mud screen for primary drilling fluid purification designed with insulating screen [8], under which saturated vapor microclimate is created; for fine purification - hydroclone batteries, desanders and desilters, skimming machines and also degasser. All these technical means are sources of intensive evaporation. And it is recommended to install at every above-mentioned objects vapor disposals at B1, B1, B1, B1 to common manifold C.

A2 - the section of elastic, airtight reservoirs that contain and store spare drilling fluid. It is recommended to install vapor collectors in the upper part. If the vapors are not disposed of their volume increases and they may penetrate pumps 5, 6, 8, 11, and they as a rule at the presence of gas in the fluid stop acting as they should. This may cause the failure of closed off PCS DF. That is why there has been offered to install disposals B5, B6, B7 to common manifold C.

A3 - the section of elastic, airtight reservoirs for containing chemical substances meant for drilling fluid processing. It is also recommended to install disposals analogic to A2. This section is equipped with disposals B8, B9, B10 and connected to common manifold C.

A4 - the section of drilling mud mixing unit. It contains operating machinery for drilling mud mixing, the mining itself takes place, dispergation of fluid that is being mixed. These processes facilitate intensive evaporation. At the above mentioned objects, it is recommended to install vapor collectors and with the aid of disposal B11 move vapors to common manifold C.

If the drilling rig equipped by diesel engines the reservoirs and tanks for fuel storage can also be the sources of pollution. That is why this machinery should be equipped by analogic vapor disposals to fuse carriers that prevent vapors from penetrating the atmosphere (utilization section).

From common manifold C vapors enter line D and flow to safety area. This area can be discharge to atmosphere at the absence of hazardous substances. If hazardous substances are present it is necessary to utilize them. There exist designs for vapor recovery of volatile matters at big and small breathings of reservoirs [11]. The principle of the given design is based on two processes: sorbate for adsorptive light carbohydrates entrapping, thermoelectric cooling for denuding and condensation of recuperated vapors and sorbents regeneration. The design [12] is also to our knowledge, where the vapors are scavenged out of the reservoir by the pump, pressed to 0.2 - 0.4 MPa and components similar to amyl hydride and hexane become liquid and collect at holding tank and propane and iso-butane come to cold storage room where they condense at appropriate temperature.

5. Conclusions
The innovative approach to the increase of environmental safety of the equipment of pumping-circulatory system of the drilling rig, which is based on the analysis of life history and constant perfection principles. The given methodological approach can be used to reduce pollution of atmosphere and for other objects where liquid hazardous substances are kept.

The existing charts of PCS have been analyzed and the necessity to dispose vapors for utilization has been defined. The directions of equipment improvement have been outlined and the modernized scheme of pumping-circulatory system has been offered. The given chart takes into account all evaporation sources. This design of pumping-circulatory system makes it possible to ensure high environmental safety level when high-toxic substances are used in the system.

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