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TECHNOLOGICAL PROBLEMS AND FUNDAMENTAL PRINCIPLES OF METHODS OF ENGINEERING-GEOCRYOLOGICAL EXPLORATION DURING CONSTRUCTION AND EXPLOITATION OF WELLS IN PERMAFROST ROCK MASS

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The article describes peculiarities and complicating factors when constructing wells in cryolithic zones. It also presents fundamental principles of methods of pilot parametric drilling for complex exploration of engineering-geocryological conditions of multiple-well gas production platforms. The article describes peculiarities of geophysical examinations within the complex of parametric drilling for clarification and correlation of log sheet, and identifying non-commercial gas reservoirs and interpermafrost head oil-filled water horizons in permafrost rock mass.

We defined main ecological issues of parametric drilling and presented potential environment pollutants from well drilling in cryolithic zones. It concludes a list of factors, which should be considered during gas well drilling in northern zones for meeting the «safety – sustainability – low waste» criteria.

Key words: permafrost rock mass, engineering-geocryological exploration, parametric drilling, gas production wells

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Introduction. More than 10.5 million km² of Russia territory lies within the permafrost rock mass (61.4 %), and the European part of the country has less than 1 million km². This territory is more promising for prospecting and exploration of raw hydrocarbons.

It should be noted that construction of wells in cryolithic zones is quite challenging due to the following: thawing of permafrost rock not only deforms and destroys surface facilities, but the metal well support loses its longitudinal stability because of its declination and wave-shaped curve, that leads to loss of contact between drive tubes and well cellar and walls; when the bed freezes again the drill-stem buckling happens. This leads to well drilling system pressure loss, uncontrolled fluid breakthrough from a bed to land surface and consequently to punitive damages [1-4, 8, 9, 12, 13].

The major concern in exploration of northern deposits of raw hydrocarbons is a degree of stability of production wells when contacting permafrost rock mass (PRM), selection of operation drilling techniques and well support type and design and platform location, basing on geocryological conditions of the explored territory [6, 11].

Current theoretical approaches to solving this problem. It is known that the key factor of well drilling and exploitation reliability loss is misbalance of PRM thermal state and accompanying processes. Among them are increase in caving formation as a result of thermal and erosive actions on PRM drilling fluids with positive temperature, formation of significantly large-sized cellar sink-holes during tubing of melting ice-rich rock, longitudinal curves of casing as a result of refreezing of melted rock in well zone and other complications causing activation of cryogenic processes that lead to environmental disruption of the explored territory [6, 10].

The absence of initial information about natural condition of PRM log and deposit area and current government legal framework for well design in PRM regions with consideration of quantitative characteristics of permafrost rock composition, cryogenic fabric and properties; all of these complicates the selection of optimal process technology for well stability and protection. Note that in this sphere we had efficient local legal frameworks when the main government legislation is currently being changed and updated.

The given facts conditioned the need for development of complex technology of engineering-geocryological exploration for design, construction and exploitation of sustainable gas production wells in cryolithic zone using parametric drilling before design and construction stages accompanied with detailed examination of parameters and characteristics of permafrost especially in ice-rich collapsing PRM.



Exploration method. Pilot parametric drilling has to provide complex exploration of engineering-geocryological conditions of given multiple-well platforms in places of their design location for deposit development [14, 15].

Operational complex includes the following:

1. Drilling wells to the depth exceeding thickness of ice-rich rock bed sinking during melting of permafrost. Drilling is done with rotor and spindle rigs using core barrel with minimal diameter of 108 mm, which enables to take cores with diameter of 93-95 mm meeting the requirements of laboratory tests. Drilling is performed in short runs (up to 3-4 m) and cleanout with a drilling fluid with temperature as low as practicable, that reduces possibility of permafrost thawing and core wash.

2. Complete core taking, field description of composition and cryogenic structure of permafrost rock with assessment of observable ice content, and identification of its humidity and density in natural state. The intervals for identifying natural humidity and density depend on uniformity of permafrost lithological composition and cryogenic and equal from 0.5-1 m in the top part of the log to 5 m in the bottom.

3. Taking permafrost rock monolith for laboratory tests in their natural state, in order to do this drilling platforms are equipped with coolers, waxing systems and other tools. Transportation of monoliths in thermostatic containers to a stationary lab is done with helicopters, which disables thawing of samples.

4. Set of geophysical well logging for geological sectional layering, identification of gas and water saturated reservoir beds and determining their reservoir properties, and controlling well technical condition.

5. Testing of wells for identifying pressure reservoir beds, their saturation status and carrying out of gas hydrodynamic research.

Including geophysical well logging in a procedure of parametric drilling, besides updating and correcting the geological log data, is done mainly for identification in PRM non-commercial gas reservoirs and interpermafrost head oil-filed water horizons, which significantly complicate drilling and construction of production wells. The positive conclusion on these issues becomes a basis for starting gas-hydrodynamic research in wells for identification of well capacity, lithostatic pressure, and other characteristics of reservoirs including chemical composition of reservoir fluid samples.

6. Lab testing of a core for identifying their composition, water-physical, mechanic and thermal-physical properties of permafrost and thawed rock.

The important part of engineering-geocryological exploration during parametric drilling is laboratory testing identifying composition and properties of rocks based on the SNiP list 2.02.04-88 «Foundations and basements on permafrost soils» [5] of 35 parameters and characteristics used in design of drilling techniques, well support for permafrost areas and safety operational measures.

Results of research. The main principles of this method were used and implemented in parametric drilling of wells with depth from 150 to 550 m at gas and condensate fields during last 20 years in West Siberia: Bovanenkonsky, Kharasaveisky (Yamal peninsula), Yamburgsy, Pestsovy (Tazovsky peninsula), Zapolyarny (Pur-Tazovskoe interfluve).

The main task of parametric drilling was to examine geocryological conditions (identifying composition, cryogenic structure and properties of permafrost rock) at given multi-well platforms selected for construction of production wells.

We should separately mention the ecological issues of drilling permafrost rock in northern areas [3, 4, 7].

Maximal danger of environment contamination is during drilling. From ecological point of view it is necessary to consider high level of ground water, their contamination and distribution of pollutants to large distances. However, presence of PRM prevents infiltration of liquid phase. Major pollutants during permafrost rock drilling are technological fluids, chemical agents and materials



used for their preparation; fuel combustion products from internal combustion engines; lubricants and greases; waste water and solid consumer waste. Soil and natural water can be polluted due to absence of waste collecting and recycling systems and damage of collectors; leakage of drilling fluid system or grease tanks; unloading, transportation, loading and storage of chemical agents. The air is polluted with fuel combustion products from internal combustion engines of diesel power stations and heavy equipment and leakages of lubricants and fuel from containers and other storage areas.

Taking into account the abovementioned factors they used clay drilling fluid on CM cellulose, its ecological safety is maintained through reagents with known sanitary toxicological properties. Chemical reagents are stored in original packing on sledges with uniform metal coating, which prevents spills to the ground in case of loss of packaging sealing. Tarps are used for protection of storage area from atmospheric precipitations. The drilling fluid runs in a closed system: boring shore – well – boring shore. Slurry is stored in sludge collector, which is a metal box on sleighing platform.

During cementing the drilling fluid from the well goes into fluid tank, then is deslimed and used in drilling of the next well [12]. The waste drilling fluid and slurry are strong pollutants and can become a real danger and hazard to environment even after their removal. The waste drilling fluid and slurry should be sent into ecological safe storage areas.

The holes are spudded in dry mode and the drilling fluid is used after lowering into the well and cementing the direction and wellhead connections with circulation system, which prevent leakages of drilling fluid into the soil.

The implementation of the abovementioned activities enables sustainable development of production wells and other technological processes.

After completion of all construction operations wells can be used as relief (when discovering highly productive interpermafrost gas deposits), thermometric (for monitoring thermal condition of PRM), or abandoned.

Conclusions. We would note that from the ecological point of view the nature of European north need to have closer attention when performing any technological processes and operations because of high level of ground water, which promotes its contamination and transmission of pollutants to far distant places. However, the presence of permafrost rock mass prevents filtration of liquid phase at the major part of the European north. Nevertheless, the severe climate has some limitations and requirements for construction of any wells in these conditions. In particular, industrial facilities and drilling rigs need to have extra thermal and wind protection, and personnel besides wearing required clothes and boots should have special skills and training for working in northern regions. Thus, when having operations in northern regions it is necessary not only to make a detailed analysis of all production technology but to provide a high level of safety, environment protection and waste reduction of all operations.

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