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The technology of spatial radio wave researches for monitoring the thawing of permafrost. The case study of investigation on oil and gas field in Western Siberia

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Abstract

Currently the priority is the control of the permafrost rock mass condition on the different objects of oil and gas sector, located in the Far North regions. We present the technology of spatial radio wave researches (RWGI) and new experience of monitoring at a multiple-well platform of an oil field in Western Siberia.

Keywords: permafrost, geophysical monitoring, radio wave researches, oil and gas fields.

Introduction

Currently the priority is the control of the permafrost rock mass condition on the different objects of oil and gas sector, located in the Far North regions. The oil development is carried out by multiple drilling method. The heads of the production and the injection wells are tightly grouped on the small territory in a close proximity to each other which are named multiple well platform. . Injection wells participate in the production cycle. Heated solution with the temperature of 120 ^{0}C is pumped through their wellheads. Thermal interaction between permafrost rocks and injection well occurs during exploitation of the object. This results in formation of a thawing zone that can transform into a thermokarst pit. Merging of such zones around production wells is a special hazard, as this is an extremely adverse factor for stability and long service life of the multiple well platform facilities. The development dynamics of thawing area of permafrost rock mass depends on lots of factors, such as the climatic and geocryological conditions at a specific site, the construction of thermal protection, and the temperature of the fluid at the wellhead. The changes of permafrost rock mass on the multiple well platform are estimated according to regime thermometric observations. A significant disadvantage of the borehole thermometry is the locality of the study, only the limited area of the borehole environment is studied. The linear interpolation of borehole thermometry does not characterize the array of permafrost rock mass in general, because of the complex structure of the upper part of the section. Electrical parameters of rocks - electrical resistivity (ϱ) and permittivity (ε) are more sensitive to changes in physical and mechanical properties of permafrost rock massif comparing with temperature data.

Methods

The technology of spatial geoelectric monitoring has been developed and experimentally tested for the early diagnosis of frozen-thawed state variations of the in-site rocks. (Cherepanov, 2013, 2014) The technology is based on modern radio wave methods of borehole geophysics: Radio wave geo-introscopy (RWGI) and Multi-frequency one-well radio wave profiling (ORWP) (Istratov &. Frolov, 2003).

Radio wave methods are based on the study of the intensity of radio wave energy absorption by rocks, located on the path of wave propagation from the emitter to the field's receiver. Rocks with low values effective electrical resistivity (ϱ_{eff}) and effective permittivity (ε_{eff}) are characterized by high absorption of radio waves.

Radio wave geo-introscopy of inter-well space (RWGI) - way of «visualization» of an internal structure of geological media in space between wells. RWGI researches are conducted on a special network of observation wells and characterized by high density of research. Algorithms and data processing programs permit to obtain volume distribution of ϱ_{eff} and ε_{eff} of rocks in the inter-wellbore space. Method ORWP-MF is high-frequency electromagnetic method of resistivity logging, which permit to determine the ϱ_{eff} and ε_{eff} of rocks near the well.

Results

The report describes the experience of using new technologies at the stages of engineering design, construction and production time of the multiple well platforms of oil and gas fields in Western Siberia. The variety and complexity of the geocryological situation are illustrated. The development of the thawing area around the injection well has been demonstrated for the current multiple-well platform of one of the fields for several years.

The technology of spatial geoelectric monitoring makes it possible to determine the geoelectric structure of the research site, to classify the state of the rocks into three main categories: 1 – frozen rocks, which are in an unchanged state, 2 - rocks in the thawing state, when the process of phase transition of ice into water began; 3 - completely thawed rocks, in which the phase transition has been completed.

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