STUDY OF OIL WELLS WITH THE USE OF ACCELERATOR TUBES, TIME AND ENERGY SPECTROMETERS OF NEUTRONS AND GAMMA RAYS IN A SINGLE GEOPHYSICAL COMPLEX

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Abstract

The report discusses the finding of the coefficient of oil saturation of the reservoir by of nuclear methods. For this purpose, the data about pulse and the activation neutron logging and spectral logging of natural gamma activity are used in a single geophysical complex. As sources of neutron radiation can been applied accelerating tube (AT) based on different ion sources, such as plasma discharge with oscillating electrons (gas AT), vacuum arc and laser-plasma (vacuum AT). For investigation of the oil reservoir, in particular with heavy oil, we discuss the prospects of using vacuum accelerating tube based on a laser-plasma source of deuterons with coaxial acceleration geometry and pulsed magnetic isolation of electrons.

INTRODUCTION

The coefficient of oil saturation $k_н$ (i.e. the relative volume of the pores in oil collector occupied with a productive fluid) is the most important criterion that shows a technical condition of a working oil well. It is determined by the properties of the reservoir, which can also contain water and clay. Between k_n, volumetric content of the solid phase (skeleton) – k_{sk}, relative water content in the pores (water saturation coefficient) – k_w and the relative content of clay in the pores (coefficient of clay content) – k_c installed connection [1]: $k_{sk} + k_c + k_w + k_n \approx 1$.The sum of k_w and k_n is the porosity coefficient: $k_p = k_w + k_n$. The information for the evaluation of k_n can be obtained by using combinations of different nuclear-geophysical methods, such as pulsed neutron lodding (PNL), activation logging, wells logging of natural γ-activity (JCC), laboratory nuclear techniques, well as the classical methods of petrophysics [1].

Method PNL gives information about the state of the forwation developed in the presence of the casing of the well, creating inconvenience for other "opaque" geophysical methods [2 – 3]. In the process of implementing a temporary field, analysis PNL thermal neutrons or γ-quanta of radiation capture (RC) generated in the borehole accelerator (AT). Their temporary structure is determined by the sum of the exponentials:

$$n(t,z) = A_п(z)\exp(-\lambda_п t) + A_c(z)\exp(-\lambda_c t),$$

$n(t,z)$ – spatial density of neutrons or γ-quanta; z – coordinate, set along the wellbore; λ_n и λ_c – decrements recession of density radiation field in the reservoir and wellbore respectively as a result of the RC.

The mathematical apparatus of separation exhibitor at wireline signal received as a result of the interim analysis [4] makes it possible to determine the parameter λ_n, as well as amplitude $A_n(z)$. In Fig. 1 is shown a typical example of computer processing logging signal.

Using the additivity rule, you can set up a relationship between the λ_n and radiation capture sections based on its individual components using the ratio:

$$\lambda = (\Sigma_{ск}k_{ск} + \Sigma_{н}k_{н} + \Sigma_{в}k_{в} + \Sigma_{гл}k_{гл})(1+\varepsilon),$$

$\Sigma_{с,н,в,гл}$ – macroscopic cross-section of RC in the skeleton, in reproductive fluid, in water and clay, respectively; $\varepsilon \approx 0.1$ – dimensionless correction option, resulting in model experiments.

This formula allows to judge quality of reservoir fluid saturation and determine the position of the boundary water-productive fluid because of the cross-section of RC in water significantly more than the hydrocarbons due to the presence of salt, and, hence, chlorine whose nuclei are abnormally high micro-cross RC.

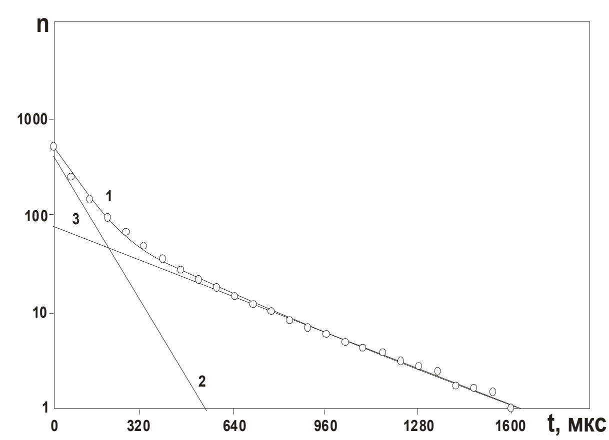

Figure 1: An example of splitting the Exhibitor in a logging signal. Slopes define by the direct signal λ_n (3) and λ_c (2).

The ratio $A_п(z_1)/A_п(z_2)$ carries information about slowing down and diffusive properties of formation, which are determined by the content of hydrogen there [2]. The relative content of hydrogen in water and hydrocarbons are close enough, so one could argue that this attitude will clearly depend on porosity ratio and will serve as a device for its definition.

ISBN 978-3-95450-181-6

One of the problems of interpreting data of INL is related to ambiguity of presence of clay in the pores, the amount of which may vary. One of the possible version of its solution is associated with additional information by method of JCC.

Another problem occurs when low mineralization, reduces contrast PNC to the level when the method ceases to be effective. In this case, you must use direct methods for determination of hydrocarbons.

Currently, the direct method is widespread enough γ-spectrometric method for the determination of carbon and oxygen (C/O logging) [5]. However, the equipment for its implementation is difficult to operate, has great size and commercial value.

As an alternative is suggested methods for determination of oxygen isotope activation ^{16}O and carbon isotope ^{12}C in the forwation using nuclear reactions $^{16}O(n,p)^{16}N$ and $^{12}C(n, p)^{12}B$ (oxygen and carbon logging) [6].

Consider two modes of implementation of the activation methods on the example of oxygen logging. In the first mode, the generation frequency of the neutron flares accelerating tube (AT) $f \leq 100$ Hz, in the second – $f = (300 - 1000)$ Hz.

Low frequency mode lets you start registration system after γ-quanta RC density will drop to a level more than 10 times lower level of external γ-radiation. Interfering background noise other radionuclides clipped the establishment of appropriate energy threshold, beyond which is carried out by γ-quanta emitted by excited nuclei of oxygen ($E_\gamma = 6.13$ MeV), formed in β-decay nuclei ^{16}N.

The second mode involves the generation of neutron flares with actuation frequency $f = 300 - 1000$ Hz. Use for the gas-filled AT have high pulse stability, allows you to simplify the system of registration, excluding monitor the neutron flux.

The difficulty of implementing the method of activation of oxygen in specified frequency mode is a small (~1 ms) time interval between the neutron flares, which does not allow to allocate to measure induced γ-activity time interval at which there is no radiation. While a constant stream of γ-quanta emitted by excited nuclei ^{16}O inevitably superimposed pulse-periodic flow of γ-quanta RC, against which you want to select continuous signal. To highlight it sponsored was a method of processing, in which the separation of alternating and direct signal similar methodology [4] and simultaneously obtained information, as activation effect and as decrement decline γ-quanta fields RC. Example of this separation is shown in Fig. 2.

In order to effectively determine the oxygen reaction $^{16}O(n,p)^{16}N$ accelerating tube should generate $\geq 10^8$ n/c with the energy of 14-MeV. Such AT successfully developed in VNIIA [7]. The first mode can be used with AT vacuum-arc sources of deuterons and for a second mode can be used gas-filed AT based on Penning discharge source.

When determining carbon AT should generate neutrons also the reaction $T(d, n)^4He$ when accelerating deuterons to energy $T_d \geq 0.3$ MeV, predominantly in the direction perpendicular to the wellbore. Neutron flux should exceed 10^{10}n/c. Modern AT with vacuum-arc sources deuterons do not allow to achieve such parameters of radiation.

In addition, to the effective implementation of the activation methods of logging high stability play neutron flares from impulse to impulse at the level < 5%.

Operating experience with ARC-AT sources revealed substantial instability of deuterons, output associated with the characteristics of the source of deuterons. It can reach 50%. This requires, as noted above, involving of pulsed neutron flux monitor, which greatly complicates the logging facility.

The above-mentioned shortcomings could be eliminated when using AT laser-plasma source deuterons, diode system with radial acceleration and magnetic isolation accelerating gap [7].

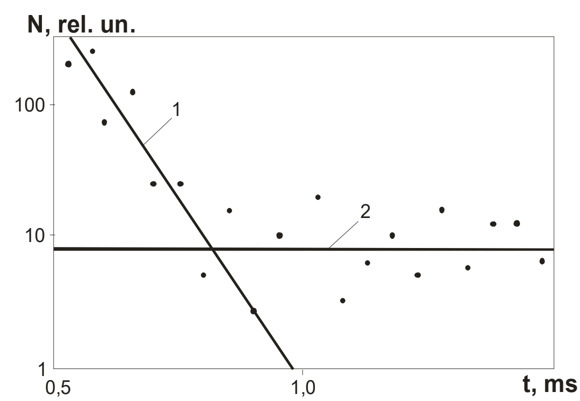

Figure 2: Logging signal decomposition. 1 − intensity radiation RC; 2 − the intensity of radiation nuclei of oxygen (points marked with the values measured in individual account temporary channels).

The accelerating voltage sources based on of generators Arkadiev-Marks allows creating on the led gap AT impulses of the acceleration (duration ≤ 100 ns) with amplitude up to 500 kV. Due to the low pulse duration combined with magnetic system suppressing electronic conductivity of diode systems, you can significantly reduce the requirements for high-voltage insulation in device in well.

In the experiment with the layout well neutron generator (SGBV) on the acceleration gap AT has been able to generate pulses of voltage with amplitude up to 350 kW and generate up to $2 \cdot 10^8$ n /impulse when using deuterons source based on Nd:YAG laser, generating pulses with energy up to 50 mJ.

Application of suppression the electrons from the cathode by magnetic elements placed in a working volume of AT [8], small lasers generated pulses of radiation with an energy of up to 1 J and frequency up to 100 Hz, as well as new high-power pulsed sources the accelerating voltage, makes a real creation of efficient and high-stability of SGBV. Such neuron generator allowing for its output parameters implement techniques for neutron activation logging with direct determination of carbon and oxygen.

ISBN 978-3-95450-181-6

This is confirmed by the results of recent experiments that was made in NRNU MEPHI [9, 10].

The work regarding the establishment of a gas-filled AT (as effective neutron source) with a frequency up to 1 kHz should be designed to increase their thermostability (heat stability). The benchmark should be considered temperature ~150 C, due to the increased depth of field wells in the process of development of new oil fields.

As noted above, to overcome difficulties associated with the presence of clay, JCC method should be involved. It gives additional information about a parameter k_c because clay have γ-activity at the expense of the nuclides ^{208}Th in the thorium series (line with $E_\gamma = 2.62$ MeV) and ^{40}K (line with $E_\gamma = 1.46$ MeV).

The intensity of these lines with the appropriate calibration allows to determine the concentration of thorium C_{Th} and potassium C_K withto study geophysical Wednesday [11].

It was found that value $G = 10^6 C_{Th} C_K$ potassium-thorium index) weakly depends on the mineral composition of clay and can serve as a yardstick for measuring the k_c. An analysis of the experimental data was obtained by the least squares method approximate empirical dependence: $k_c(G) = 1.294G - 0.965G^2$, which lets you remove marked above the ambiguity.

To implement these studies on geophysical sites with different geological structure and thermal conditions with the participation of the authors developed a simple to operate, dampen downhole γ-spectrometer [12], mastered at the pilot plant of JINR.

CONCLUSION

1. The solution to the problems of increasing the contrast of the dimensions and impact of exceptions results clay logging oil and gas wells with difficult geological conditions seen in the way of integrated management methods INL with the methods of neutron activation and MLK.

2. Attention should be drawn to the prospect of using AT with a laser source of deuterons and magnetic isolation due to the possibility of obtaining large neutron output combined with high impulse stability.

3. Work done in the framework of agreement No. 15-19-00151 between RNF, NRNU MEPHI and A.V. Nesterovich project leader of the grant for research.

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