Experience in using the Russian LWD complex for well drilling

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Abstract. The experience of using the LWD production complex of Research and Production Company VNIIGIS-ZTK LLC, which allows you to track the lithology and thickness of the layers in the direction of drilling, to predict the point of entry into the reservoir, to conduct the well on the most productive part of the reservoir, is considered.

1. Introduction

Despite the sufficient knowledge of the fields of the Volga-Ural oil and gas province as a whole, the reservoirs of many of them can be classified as complex, characterized by a high proportion of heterogeneity of the structure and reservoir properties. Currently, for the effective development of such fields at a late stage of operation, it is necessary to use modern means and methods of designing, researching and operating to achieve the maximum result on the way to increase the flow rate of wells. Collective work in the field of using modern field development tools combines a wide range of specialists with key skills in the field of knowledge of geology, geophysics, petrophysics, mechanics, etc. [1].

2. LWD complex of Russian production

Since 2012, Research and Production Company VNIIGIS-ZTK LLC has been actively developing in the field of creating logging equipment for the drilling process - LWD (logging while drilling). LWD technologies allow real-time adjustment of the position of the wellbore in the formation with optimal filtration and capacitive properties. In Russia, this market began to develop relatively recently. The complexes implemented on the basis of telemetry with a hydraulic communication channel LWD, represented by a wide range of geophysical modules, are successfully used by foreign companies (Schlumberger, Halliburton, Baker Hughes, Weatherford, etc.). A significant amount of LWD work at the moment relates primarily to the drilling of horizontal sections of wells, which are a means of access to the development of hard-to-recover reserves and are widely used in offshore field development. Horizontal technologies contribute to an increase in oil recovery, and, consequently, well production due to an increase in drainage area and play a decisive role in well construction. However, the services provided with the LWD complex of foreign companies have one significant drawback - the very high cost of the work. This leads to a significant increase in the cost of well construction. And such additional costs, even in spite of all their efficiency, are not economically justified for deposits that are at a late stage of development [2, 3].
To solve the problem of determining the formation resistance and its reservoir properties during drilling, the Research and Production Company VNIIGIS-ZTK specialists developed a complex of geophysical methods of electromagnetic and radioactive logging: GRL gamma logging methods, IL induction logging, NNL neutron neutron logging, neutron logging gamma ray logging NGL. The NNL, NGL radioactive logging complex is used only as part of the extracted ZTK-42KK downhole telemetry system. Figure 1 shows the layout option of the bottom of the drill string (BHA) with LWD modules and provides indicative non-measurement data (distance from the bit to the measurement sensors of each module).

![Figure 1. Drill string bottom layout with LWD modules](image)

The neutron logging module (NLM) manufactured by VNIIGIS-ZTK NPF LLC has two thermal neutron neutron neutron logging (NNL) probes and one gamma-ray neutron (NGL) probe (Figure 2, Table 1). It has end-to-end design, that is, it is installed inside a non-magnetic pipe and has overall dimensions corresponding to the dimensions of other nodal modules of the tele-system. It is used to determine the porosity (hydrogen content) of rocks during drilling. The module also has an internal flash memory for reading data after drilling [4, 5].

![Figure 2. Location of sensors in the neutron logging module: NGL, NNL2, NNL1, III](image)

| Table 1. NLM Specifications |
|-----------------------------|
| Options                      | Values |
| The range of measurement of porosity (volumetric hydrogen content),% | 1-40 |
| Pressure, MPa                | 0-60 |
| Maximum working temperature, °C | 100 |
| Overall dimensions, mm:      |      |
| diameter                     | 42   |
| length                       | 1120 |

Ampoules containing Pu-Be powder are used as a source of ionizing radiation. The ampoule source is installed by specially trained personnel at the rig just before the telesystem is launched to the face.

The induction logging module is designed to differentiate rocks by resistance (conductivity) during drilling, and is used on any type of drilling fluid, including saline and invert emulsion. The induction logging module provides measurement and calculation of electrical resistivity by phase shift and amplitude attenuation using two current generation frequencies - 2 MHz and 400 kHz. 4 resistance curves are transmitted to the surface in real time (table 2). The module consists of the most measuring multi-coil device located inside a non-magnetic pipe (casing), which has radio-transparent windows. To work with the induction logging module, a plug-in autonomous power supply and a transceiver for docking with a telemetry system are used [6].
Table 2. Induction Log Module Specifications

| Options                                                   | Values          |
|-----------------------------------------------------------|-----------------|
| Nomenclature of transmitted curves, Ohm · m:              |                 |
| - P06h                                                    | 0.1-2800        |
| - P06L                                                    | 0.1-2800        |
| - P10H                                                    | 0.1-900         |
| - A06H                                                    | 0.1-120         |
| Maximum working temperature, ° C                          | 120             |
| Maximum hydrostatic pressure, MPa                         | 80              |
| Continuous work hours                                     | 150             |
| Overall dimensions, mm:                                   |                 |
| - diameter of the measuring module                        | 48              |
| - diameters of casings                                    |                 |
| - the total length of the module assembly with power and a |                 |
|   transmitter-receiver unit                               | 108; 120; 178;  |
|                                                           | 5500            |

The LWD operating mode provides for the simultaneous recording of GRL, IL, NNL, NGL logs and the transfer of all data, including from the over-bit module (or engine with telemetry), to the surface in real time via a wireless communication channel at a speed of up to 5 bits/sec. Logging during drilling makes it possible to quickly correct the wellbore trajectory depending on changing geological conditions, and allows to abandon additional intermediate and georeferenced logs. A comprehensive interpretation of the GRL, IL, NNL methods allows online to determine the reservoir properties of the reservoir and to calculate the petrophysical parameters already at the stage of initial opening.

3. Experience with the use of the LWD complex

Industrial implementation of the LWD complex produced by Research and Production Company VNIIGIS-ZTK LLC began in 2015 at the facilities of PJSC Tatneft. In total, for the period 2015-2019, with the full LWD complex, 7 horizontal wells were drilled in PJSC TATNEFT. As part of the BHA, in addition to improving the quality of the wellbore wiring in the reservoir, measurement systems on the bit were used - an over-bit module or an engine with integrated sensors. The data transmitted from the LWD modules helps to conduct the drilling of wells inside the reservoir in a more efficient way. Neutron-neutron logging data allows you to select dense rocks in the section (Figure 3) [7, 8].

In 2018, the joint work of Permneftegeofizika PJSC (Perm) and Research and Production Company VNIIGIS-ZTK (Oktyabrsky) LLC on providing service support for drilling at the facilities of LUKOIL Perm LLC (Perm). The main purpose of drilling was to restore the old well stock by drilling sidetracks, which at the end have an extended horizontal section. The objects of research were terrigenous reservoirs of the Bobrikov and Tula horizons and carbonate rocks of the Tournaisian stage. At the development stage, in terms of drilling support for LUKOIL-Perm LLC, a comprehensive approach was applied, including telemetric, technological, geo-navigation support services provided by Research and Production Company VNIIGIS-ZTK. The telemetry complex with a combined communication channel (ZTK-42KK) included the full LWD complex: gamma-ray logging (GRL), neutron gamma-ray logging (NGL), neutron-neutron logging (NNL), induction logging (IL). Based on the data on resistance and porosity obtained at the stage of primary opening, the main filtration-capacitive properties of rocks were calculated [9, 10].

The specialists of Permneftegeofizika PJSC based on the data of radioactive and electromagnetic logs obtained during the drilling process made the final interpretation of the well material. Correction of the wellbore during drilling was carried out on the basis of a dynamic geological model, which is built according to the correlation of the set of logging while drilling (LWD) methods of the reference and drilling wells. Geo-navigation support for drilling was carried out by geo-navigators of Research and Production Company VNIIGIS-ZTK LLC (Figure 4).
Figure 3. Determination of the interval of dense rocks according to the NNL method of the LWD complex
Between July 2018 and December 2019, 10 horizontal lateral shafts were drilled with the LWD complex of Research and Production Company VNIIGIS-ZTK LLC in Perm at the facilities of Lukoil-Perm LLC.

In 2019, the LWD complex was successfully widely used at one of the fields owned by the small oil company in Tatarstan, Okhtin-Oil JSC, where well support services using the LWD complex were provided at 7 horizontal wells [11, 12].

4. Conclusion
With a full range of LWD (including radioactive and electromagnetic logs) for the period 2015-2019, more than 30 wells were drilled in various mining and geological conditions. The use of LWD systems significantly reduced the time for well construction, as it allowed to abandon the final logging. The availability of online data from the logging complex and geo-navigation support services allowed us to quickly respond to changes in the geological situation at the bottom, reduce risks and uncertainties during the drilling process (control of the OWC zone, trace lithology and power in the direction of drilling), and predict the position of the wellbore relative to structural boundaries, to maneuver in the interbedded stratum of thin rocks. The integrated approach used made it possible to conduct wells in the most efficient way, having the ability to control the position of the productive part of the reservoir zone. The subsequent development of the drilled wells confirmed the presence in the interval of penetration of the horizontal section of oil-saturated reservoirs identified earlier during the drilling process.

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