LOGGING WHILE DRILLING; AN APPLICATION OF NUCLEAR LOGGING FOR REAL TIME DATA OBSERVATION AND RECORDED MODE DATA PRESENTATION AS A DEMAND OF HIGHER TECHNOLOGY IMPLEMENTATION IN OILFIELD INDUSTRY

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Abstract

Most oil and gas companies are now in their high activities to perform drilling for exploration and production to meet the world's demand of oil and gas. More effective and efficient process of drilling exploration is becoming a priority. Formation evaluation of the wellbore to support the success of a drilling operation takes a great deal of attention. Technologies providing Logging While Drilling (LWD) services are expected to minimize time delay and change of formation due to time difference it takes if only conventional wireline logging tools are to be run. Neutron porosity and gamma-ray density as main core of LWD with nuclear sources using AmBe and Cs-137 is generally employed for formation evaluation to get the petrophysics properties for making up key decision regarding to the drilling process. Real time data provided by LWD with radioactive sources give a greater advantages as fresh data during the drilling process is occurring can be obtained. Although real time data does not necessarily have high quality, the sampled data sent uphole to the surface can be quite representative. The memory within the LWD tools offers both real-time and recorded mode data reading, the latter version presents a much higher quality of data, based of the number of sample saved within the memory itself, will usually be attached to the report sent to the client as a final result. The risks associating the radioactive materials applications in LWD must be anticipated by employing complete procedures based on health, safety and environmental concerns as regulated by the nuclear authorities. Uncertainties in the entire drilling process tend to create problems which in an undesired condition can result in a stuck tool with nuclear sources inside. For such matters, precautions must be attempted to avoid nuclear source abandonment in a well. If all efforts fail to retrieve the radioactive materials from the stuck tool and source abandonment becomes the only possible option, procedures based on nuclear regulation must be followed and nuclear authorities must be notified at once.

INTRODUCTION

Background

The fact that oil price is sky rocketing, explorations for oil and gas are expected to reach their peak activities. The demands of competitive and high quality drilling operation in oil and gas industries drive innovations in oilfield services providing formation evaluation. Advanced services for drilling operation in achieving successful exploration are badly required. Formation data acquisition plays an important role during the drilling and exploration process. As part of advanced technology in oilwell drilling, Logging while Drilling (LWD) has become one great advantage in oil and gas exploration activities. LWD provides an accurate and timely formation evaluation in exploration and production business. Supported by powerful interpretation software, an integrated LWD tool sets a new standard in safety and efficiency, and reduces formation evaluation uncertainty.

Introduction To Logging While Drilling:

LWD, according to Oilfield Glossary, means the measurement for formation properties during the excavation of the hole, or shortly thereafter, through the use of tools integrated into the bottomhole assembly. The benefits of LWD, Despite its risky and expensive operation, allow measurements of formation properties before drilling fluids invade deeply. In wellbores where conventional wireline tools are difficult to run, such as in highly deviated wells, LWD proves to be dependable.

LWD priorities tend to reduce the distance from the bit to LWD sensors which can decrease environmental effects on measurements and reduce waiting time for acquisition and interpretation of data required for key decision.

Any full LWD operations involve a great deal of job specific design due to real time acquisition and integration with the drilling process. Thus any steps taken must be very well communicated to contractor engineer in term of data acquisition options and constraints and should be technically included in all job planning activities.

Data transmission processes in LWD are basically performed in two ways: data transmission within the downhole assembly and data transmission to surface. Tools readings can either be stored in downhole memory or transmitted to surface using mud pulse telemetry. Whenever required the two methods can be combined by storing some data in memory and transmitting some in real time. Yet in the case of data supply exceeding data transmission capacity, only key data is transmitted uphole whilst the rest of some sensors output shall be stored downhole. Another way of transmitting data for real time reading is by taking a limited data sample, for example one in every four readings to be sent uphole. The remaining of data readings will be stored to be downloaded to computer once the memory-pack within the tool is brought to surface. The data known as recorded mode data is the complete version of the formation data downhole to be presented in final report. Based on the limitation in real time data transmission that it is impossible to send the entire data readings, the quality of real time data is not at its best. However, it should be sufficient for observation purpose during the drilling process.

Picture.1 Pressure sensor installed on the choke manifold to receive pulses containing data sent from downhole

In general, analog data from LWD are converted to binary form downhole. Data are transmitted by using a flow-restricting mechanism in the drilling-fluid flowstream and produce positive or negative pressure pulses which are then transmitted through the mud column inside the drill pipe, read at the surface by pressure sensors and later on recorded and processed. Data transmission can also be performed by using rotary valve pressure-pulse generators, which alternately restrict and and open the drilling-fluid flow, causing varying pressure waves generated in the drilling-fluid at carrier frequency which is proportional to the rate of interruption. Downhole sensor-response data are transmitted to the surface by modulating this acoustic carrier frequency.

Data taken from the sensors within the LWD tools are then to be correlated to the depth of the formation associated to the driller’s depth data. Another surface sensor is attached to the driller’s draworks as a depth sensor. All data will be set to a referenced time frame so accurate results are to be expected.

Picture. 2 Depth sensor attached to the driller’s draworks

LWD was firstly developed to identify penetrated strata and to confirm the location of the bit with respect to the formation instead of having to rely on the measured depth. Development of LWD itself was basically inspired by the Measurement while Drilling (MWD) used to measure drilling-related properties, such as inclination and azimuth, which are essential in directional drilling apart from additional measurements such as torque, weight on bit (WOB) and temperature. Those parameters taken through MWD allow drillers and drilling engineer to monitor downhole drilling performance parameters in real time, which are important as well to support the success of LWD process. In most cases LWD can be run in combo with MWD.

LOGGING WHILE DRILLING WITH NUCLEAR SOURCE

Recent LWD technology, developed by oilfield services companies, allows several measurements to aid identification of formation fluids-gas, oil and water such as thermal neutron capture cross section

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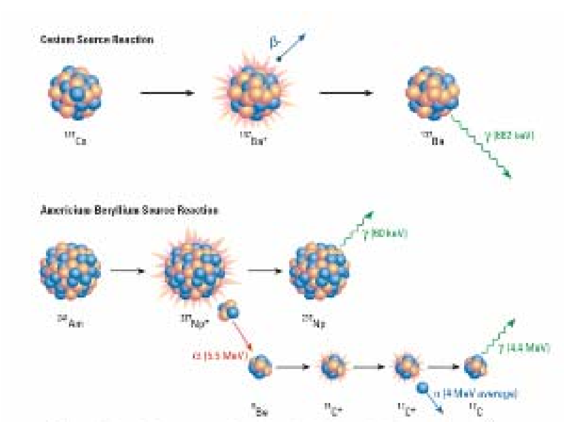
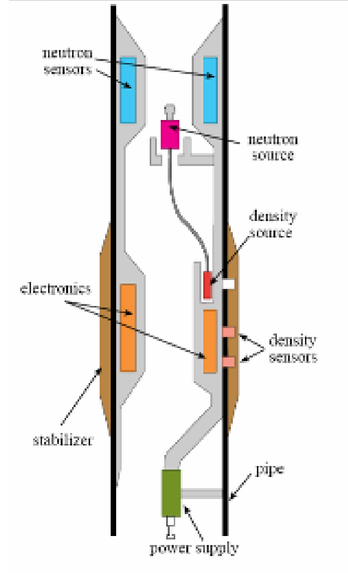
measurement to determine probability for a thermal neutron to be captured by nuclei in the formation. The capture of neutron causes the emission of gamma rays. The decay of gamma ray signal is measured to determine the average thermal neutron capture cross section, or sigma, of the formation to characterize the fluids in the pore space near the wellbore. Formations with high-salinity water have high sigma, ∑, due to large thermal neutron cross section in chlorine (Cl), while formations with oil, gas or fresh water commonly show lower sigma values. Sigma can be then used to calculate water saturation, $S_{w.}$ A different method to assess formation fluids is measurement of hydrogen index (HI), as a base of neutron porosity measurements. LWD, in this type of measurements, provides better possibility to correct neutron porosity value as the tools are typically centered in the borehole and thus gives higher degree of borehole correction. Density and porosity data are main parameters to be taken by LWD with nuclear sources.

Common LWD tools employing nuclear sources use americium-241 beryllium (AmBe) and cesium-137 (Cs-137). Cs-137 is used mainly for density logging tools of which the density data are taken through the gamma-ray emitted by the source resulted from the decay of Cs-137 to an excited state of Ba-137 through beta-emission of an electron from nucleus, which sequentially will decay to its stable state through the emission of single gamma-ray with energy of 662 keV. AmBe radioactive sources are used mostly in neutron-porosity logging tools; Am-241 serves as the source of alpha particles as it decays to an excited state of neptunium (Np-237) which will reach its ground state through the subsequent emission of a 60 keV gamma ray. A small fraction of the alpha particles emitted by the Am-241 react with the Be-9 surrounding the Am-241 nuclei. The reaction results in the formation of of a short-lived excited state of carbon (C-13), which emits a neutron and transforms itself to an excited state of carbon-12 (C-12).



Picture 3. Reaction of nuclear sources used in logging tools

Some conditions must support the rate of penetration (ROP) chosen in relation to the real time data transmission and specifically the aspects of nuclear sources use concerning health, safety and environment.



Picture 4. Anadrill LWD with nuclear tool design for Density/Porosity data reading

LWD tools, especially those to be loaded with nuclear sources, are designed in such a way so that sensors and electronics can endure the enormous shock and vibrational forces related with drilling. To produce better quality for nuclear LWD, tool designs must integrate sensors to reduce toll lengths, enabling multiple sensors to be packaged in a single collar. Shorter tools of LWD has also been developed to improve tool reliability, wellsite efficiency gains and resulting in measurements taken closer to the bit while drilling is ongoing process.

As the main motivation to run LWD tools is to gather information about the reservoir as early as possible, it is also important to use other formation parameters—depth, net thickness, porosity, S_w and permeability—to characterize potential reservoir. Despite so many limitations in LWD measurements, such as real-time software tools performing data quality control and comprehensive formation evaluation which have been lacking in the past, steady progress has been employed to address tool limitation.

RISK ASSESSMENT IN LWD WITH NUCLEAR SOURCES

LWD operations particularly those using nuclear sources have their main concerns related to health, safety and environmental aspects. Extraordinary steps should be included to limit exposure of radioactive emissions. Specific procedures for storing, handling and using radioactive sources must be taken into

account. Nuclear authorities regulate the storage, regular testing and eventual disposal of these sources.
Procedures implemented during the LWD operation using nuclear sources include the process of loading and unloading the logging sources to the respective LWD tool. Compared to similar tools used in wireline, the process of loading and unloading logging sources in LWD tool is more complicated, more time-consuming and required more personnels to make up and break down LWD equipment.

Picture 5. Making up LWD tools on the rig floor

In general LWD operations involve risks as much as it is involved in the drilling process itself. Occasionally some undesired conditions occur resulting in stuck tools housing the nuclear sources. Some main problems that may cause the incidents vary from borehole problems or irregularities, such as keyseat; drilling fluids problems; or even natural disasters like earthquakes. The worst condition that may happen is that the radioactive sources can not be recovered and the only way possibly taken is to leave or abandon them in a well, a special well-plugging is highly required and monitoring procedures must be taken to minimize environmental impact. At any such case, nuclear authorities must be notified immediately.
Mainly for safety reasons, Schlumberger LWD tool has an annular loading system that allow sources to be fished through the drillpipe using wireline. It eliminates the possibility of abandoning sources in the tool should the tool become stuck downhole. Consequently the procedure of fishing sources adds time to the entire process, yet it reduces the risk of the source damage, therefore reducing risk to the environment. Almost 85% of problems in stuck tools sources can be recovered, compared to successfully recovered stuck-bottomhole assembly (BHA) which reach only 35% of the time. One thing to be considered in case such problem arises, operators have to choose between retrieving the sources and spending more time trying to recover the whole BHA.

Considering that AmBe for emitting neutron and Cs-137 for emitting gamma-ray used as logging sources present great risks during operations based on the half-life of americium (Am-241) is 432 years, whilst cesium (Cs-137) has a half-life of 30.2 years, a major environmental concern exists when in rare cases tools containing radioactive sources must be abandoned in a well. Comparing the two commonly used sources in LWD with nuclear sources, Am-241 has certainly greater risk than Cs-137, not only from the much longer half-life but also from the decay Am-241 can produce to neptunium (Np) which will continue to emit high-energy alpha articles and has a half-life of more than 2 million years. It is obvious that any abandoned tools containing radioactive sources in a well create risk especially when the sources left are AmBe. The neutron emission from the abandoned sources are relatively more difficult to shield and tend to be more damaging to living cells.

CONCLUSION

The use of radioactive nuclear sources in logging facility, particularly in LWD is inevitably expanding. Demands of better data formation evaluation both in real time as well as recorded mode for higher quality have already driven more advanced technology in LWD with nuclear sources. Despite the limitations for real time data observation during LWD constraining rate of penetration (ROP) and other parameters for drilling operation in order to achieve high quality data readings. Risks involved in the success of the whole process must be taken seriously due to the fact that radioactive materials are involved. Health, safety and environment concerns play a very important role during the operation. Regulations regarding drilling and exploration procedures as well as in nuclear use procedures must be fully applied to avoid undesired conditions which may result in source abandonment in a well.

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