Cased-Hole Pulsed Neutron Logging as alternative of Fluid Analysis Sampling Test in Mature Field Development

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To optimize the efficiency of operation in Mahakam as a mature field, the industry must improve the cost efficiency of maturing assets as compensation of the declining production and high fixed cost. one-phase-well (OPW) is one of the propose solution to tackle the producing hydrocarbon challenging in mature field, which is a well architecture without 9-5/8" surface casing. In OPW scheme, well is drilled in one section only using a diverter, no BOP, from surface to TD. For safety reason, the conventional pressure temperature fluid analysis (PT-FA) logging, as the ultimate method to determine the potential of reservoirs, can no longer be performed in OPW.

Indeed, PT-FA sampling log plays significant role in evaluation of fluid status identification. As alternative, a cased-hole Pulsed Neutron Logging (PNL) is then chosen to substitute PT-FA. It is challenging because in principal, those two logging completely have different objective and measurement. Before implemented in the next future OPW, comprehensive experiment has to carried out to convince that PT-FA logging can be displaced by PNL logging. PNL both conventional and advance, then were run in three recently drilled wells which have complete open-hole (OH) logs dataset along with fluid analysis (FA) and mudlog information

PNL is the interaction between neutron and formation, which corresponding primarily to the amount of hydrogen in the formation. In Mahakam, PNL always encounter field limited conditions such as tight formation (shally-sand typical) and fresh formation water sand. A conventional PNL for gas detection require high formation water salinity, so it is almost impossible to achieve the optimal condition. Advance PNL measure fast neutron and less dependence to salinity and provide better detail fluid identification in tight formation.

This paper will discuss the risk and uncertainties of using a cased-hole PNL logging to replace PT-FA sampling data in specific condition encountered in Mahakam area.

Keywords: OPW, PNL, PT-FA

INTRODUCTION

As the field enters into a later stage of its life, finding new and economic drilling targets are challenging. In line with spirit with cost optimization, any efforts have to be improved in order to keep the production decline rate to a minimum.
One-phase-well (OPW) is one of the propose solution to tackle the producing hydrocarbon challenging in mature field, which is a well architecture without 9-5/8" surface casing. In OPW scheme, well is drilled in one section only using a diverter, no BOP, from surface to TD. OPW design was first deployed in Tunu Field in 2019 to drill shallow zone wells. The success in Tunu leads to the plan to apply the method in Handil Field.

Despite the success, OPW architecture comes with some consequences. Since OPW is drilled using only diverter and Water-Based Mud (WBM), conventional open-hole formation tester and fluid sampling cannot be used for safety and hole integrity reasons. However, fluid identification bottom hole fluid sampling is important in Handil Field as it is required to distinguish between oil-bearing sand and water rise sand. Therefore, if OPW is to be applied in this field then an alternative to open-hole formation tester and fluid sampling is needed. Having reviewed internally the possibility of alternative method,

involving subsurface, drilling and well intervention team, it is concluded that Pulsed Neutron Logging (PNL) as the most feasible method for fluid identification.

In open hole operation, PT-FA logging have been commonly applied as significant tool to define pressure and reservoir fluid status. The primary objectives of real time sampling data in PT-FA are downhole identification of the formation fluids, formation pressure and fluid mobility. Fluid analysis test result in combination with open hole logs and geology correlation data play important roles in reservoir evaluation. PT-FA sampling is the recommendation method to choose as it is a direct downhole measurement.

Meanwhile, Pulsed Neutron Logs (PNL) is a cased-hole logging which represents the interactions between neutron and the matter (formation) as responds primarily to the amount of hydrogen in the formation. Historically, PNL was used to monitor and record the fluid contact changes when the well is being produced.

For production monitoring, PNL has been applied in Mahakam field for years with a conventional tool and methodology, using either pulsed capture (PNC) log for gas or carbon-oxygen (C/O) for oil detection. In Mahakam, PNL always encounter field limited conditions such as tight formation (shally-sand typical) and fresh formation water sand. C/O can be performed in fresh or unknown water salinity, while gas detection (PNC) require high formation water salinity, and thus in Mahakam environment, optimal condition is almost impossible to achieved.

Handil Field, Mahakam Delta

Handil field is located in the internal axis of the Mahakam delta. The main pay zone is Middle to Upper Miocene in age. The reservoirs are sandstones which have been deposited in distributary channels or as mouth bars. The structure is anticline and divided into two main compartments, namely North and South, by a sealing fault.

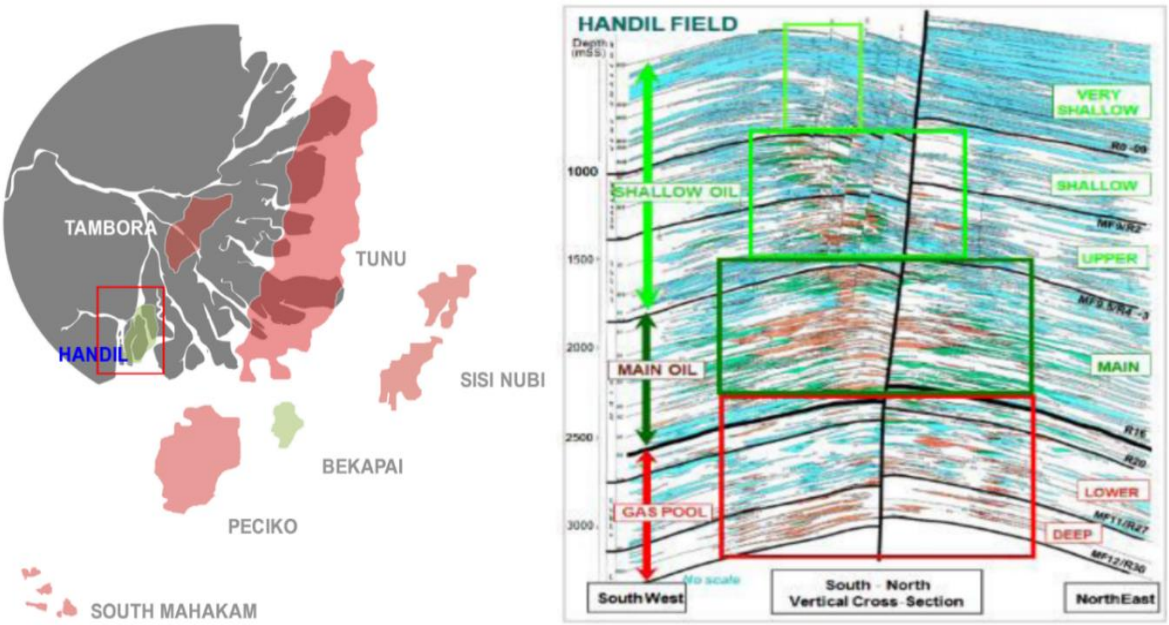

Figure 1: Handil Field

The reservoirs are found in depth between 200 mSS and 3500 mSS, covering an area of 40 square kilometers. Vertical construction of the reservoir sedimentation is divided into three different zones as follow (Herwin et al., 2007):

1. Shallow zone, down to 1500 mSS, has excellent permeability ranging from 200 mD to 2000 mD with very strong aquifers that maintains the reservoir pressures at their initial condition. However, the sands are poorly consolidated which require special sand control technique, prior to the production.
2. Main zone, between 1500 mSS to 2200 mSS, has permeability between 10 mD and 500 mD. The reservoirs are mostly having initial gas caps which have been preserved to maintain the reservoir pressure, especially since the aquifers are not as strong as the shallow's. The sands are normally well-consolidated; therefore, sand production is not an issue.
3. Deep zone, below 2200 mSS, contains mostly gas and decreases in quality with depth to permeability of several millidarcy.

Due to operational constraints, OPW can only be drilled to shallow zone reservoir target. This zone has typical fluid characteristic with low salinity (fresh) water. With this characteristic, it is difficult to distinguish the oil and water rise fresh water from the open-hole log as they have similar resistivity range. Therefore, open-hole fluid analysis is needed to avoid fluid miss-interpretation.

These two main issues highlight the importance of having fluid analysis in shallow zone wells and it needs to be addressed by the alternative method to be applied in OPW scheme so that the main purpose still can be achieved. The consequences of the fluid miss-interpretation are miss-estimation of the hydrocarbon reserves and poor perforation result. Poor perforation result will lead to lead inefficient cost as more remedial action needed.

Two alternative fluid analysis test PT-FA were also considered as candidates, which are Sonic and Cased-Hole Formation tester tools. It was verified that sonic is capable to detect gas only and is not capable to define oil. While the Cased-Hole Formation Tester is quite expensive with unclear information of tool capacity. Therefore, PNL was chosen as the best and appropriate tool to evaluate the formation behind casing (based on experiences as well in Mahakam Field/Area).

Pulsed Neutron Log

Pulsed neutron logging is the interaction between neutron and formation. High energy neutron burst to the formation and during the journey (interaction with atom of material), neutron losses some energy. Every decay of neutron energy is recorded by the detectors. The detectors detect photon gamma ray emitted from nucleus (atom of material). By detector, the interaction is then sorted by energy and time. The tool responds primarily to the amount of hydrogen in the formation. Hydrogen is the primary element that control fast neutron propagation. The amount of hydrogen contained in the water, oil and gas can be correlated to porosity. Since neutrons and gamma rays are able to penetrate oil well tubing, casing and cement layer, pulsed neutron logging is attractive for monitoring formations in production wells.

Conventional PNL tool consists of two detectors and produce either pulsed neutron capture (PNC) logs for saline water environments or carbon-oxygen (C/O) logs for reservoirs with either fresh or unknown salinities. C/O is recorded during high energy neutron (inelastic/fast neutron), while PNC is recorded during thermal neutron (low energy neutron). Main product of PNC is well-known as Sigma, defined as the ability of material to capture the thermal neutron). Most effective element to capture the thermal neutron is chlorine, NaCl. The effectiveness of PNC is dependent on (high) salinity of formation water.

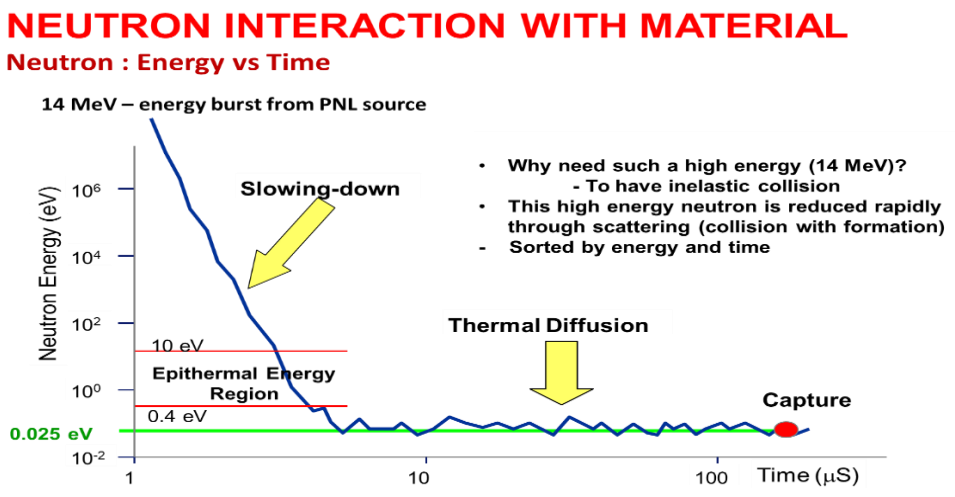

Figure 2: Neutron Interaction with Formation

An advance PNL method is a three-detectors tool and developed to detect and quantify gas saturation behind casing under a variety of condition. Gas detection is recorded during inelastic phase (high energy neutron), so it is essentially salinity-independent (bypassing the limitations of conventional sigma measurements). Another distinction is that gas-sensitivity is improved and works well in tight formation. The measurement technique of C/O is basically still similar to the conventional technique (two detector), but there is improvement in environmental correction and data processing.

PNL is still considered as the most appropriate cased-hole log method for alternative to the PT-FA in Handil field. OPW using one single casing and therefore uncertainty of the environmental correction can be reduced. Reservoir property especially porosity in shallow Handil is within range of PNL tool specification. Another advantage of PNL is the energy spectrum and energy decay (versus time) based measurement. It is a different principle compare to wireline open hole log, which is statistic-based (count rate logs). It is expected that PNL provide different point of view and support fluid identification from wireline open hole interpretation.

Fields Assessment

PNL assessment was performed in three selected wells. The consideration of choosing these well as trial wells are as follows:

- these are new wells with no perforation has been conducted
- the wells target is shallow zone, the same target as OPW
- PT-FA data are available as reference to be compare with PNL interpretation.

One of the issue before running the PNL is salinity. Mahakam field/area is a fresh water environment. Therefore, the gas detection by using conventional PNL will not be optimal and impossible to produce the quantitative analysis. However, to have comprehensive trial, the conventional PNL is still proposed to be run simultaneously with advance PNL. In fact, conventional PNL is much more economic in terms of operation cost compare to advance PNL

As summary results of the assessment, PNL is a feasible alternative replacing PT-FA, with some uncertainties. However, it is normal for every logging process, including the PT-FA logging, to have some uncertainties.

The advance PNL is more sensitive to detect gas formation compare to conventional PNL. Sigma as gas measurement tool in conventional PNL is not suitable for fresh water environment, especially in the quantitative measurement, even though in running in the good properties reservoir.
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In oil indicator, C/O log, the difference between advance and conventional is not significant. Advance C/O log offer more detail log signature, especially in tight or thin reservoir layer. Carbon is not only found in oil, but also in shale, casing steel, rubber and other borehole production component. The good lithology and well jewelry understanding, is one of the key to distinguish C/O anomaly derived from oil saturation and others. So that the oil detection uncertainty can be reduced

Summary results of the assessment:

- PNL is a feasible alternative logging to replace PT-FA measurement with some uncertainties. However, it is common to have some uncertainties in every logging.
- 70% of PNL fluid interpretation is match with PT-FA results.
  PT-FA logging was performed in 60 points.
- The PNL result can be interpreted after the processing and finalizing were conducted, for 2-3 days since the the logging job completed. While the PT-FA data can be interpreted with no time gap as it is a real time logging data
- In the fresh water formation, it is not possible to implement the saturation measurement with Sigma, as a product of the conventional PNL log.

Reference

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