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What you need to know to drill a high pressure, high temperature well

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SUMMARY

The challenges in drilling a high pressure and high temperature (HPHT) well are unique to every opportunity. The key to successfully drilling an HPHT well is to utilise the appropriate people, technology and design at the appropriate time. To do this it is critical to know the questions that need solving. Knowing and answering these questions cannot be effectively achieved without accessing subject matter experts in several disciplines including drilling, petrophysics and data acquisition and integrating into a coherent plan.

Key words: HPHT, data acquisition, petrophysics

INTRODUCTION

The drilling and data acquisition practices for High Pressure and High Temperature (HPHT) wells vary widely from standard wells. The high pressure, high temperature environment has the potential to injure people, damage or destroy tools and be a complex challenge for well control. Successful and safe drilling whilst evaluating HPHT wells is a significant challenge to both the drilling and petrophysics disciplines. As the business environment changes across the industry, more HPHT wells will be planned. In recent times, few HPHT wells have been drilled globally hence best practice guidelines may only address niche topics and not be current for recently introduced tools.

In the process of standard well design, petrophysical data acquisition is not included in detailed well design until the final stages. For HPHT wells however, it is critical to get the petrophysics discipline involved throughout the entirety of the planning, execution and assessment phases.

This paper establishes a holistic workflow by collating many seemingly disparate cross discipline elements into a coherent, easy to understand guide to successfully execute an HPHT well. The aspects where petrophysical involvement is critical include; planning, logistics, contract tendering and management, internal and external stakeholder management, data acquisition program and efficient communication protocols. Each of these key aspects requires customisation to the specific well in order to facilitate accurate, timely and cost-effective decisions. As every HPHT well is unique to achieve the required customisation of each of these elements requires knowing the correct questions in the context of the well so appropriate responses can be selected.

WHAT IS AN HPHT WELL?

An HPHT well depends on many factors. The most obvious factors are Pressure and Temperature. However, the situation can be more nuanced than that. For example, what do the well construction and data acquisition contracts state for HPHT conditions? Older generation tools may have lower temperature ratings and therefore could incur either an HPHT surcharge or require moving to an expensive new tool which is out of the existing pricing framework and consequently have to negotiate the pricing.

When selecting appropriate tools most engineers and petrophysicists look at specification sheets and choose appropriately for the well conditions. However, in HPHT wells, tools can often suffer increased failure rates as they approach their maximum temperature specification whilst not exceeding the design limit. For example, a recent well drilled in the Carnarvon Basin had a Logging While Drilling (LWD) tool rated to 150 degrees Celsius (°C). When the internal tool temperature exceeded 140°C, the tool experienced intermittent communication failures. These issues ceased when the temperature was reduced by pulling the tool up the well and increasing the mud flow rate. Once the internal temperature of the tools was reduced the well was successfully drilled to TD.

HOLISTIC VIEW OF DRILLING AN HPHT WELL

In mature basins the data to draw on to design a well is comprehensive with little uncertainty. Consequently, data acquisition during drilling is of low value and focused on formation evaluation of the target reservoir. However, in some well types including HPHT wells the construction requires significant and constant data acquisition to select the appropriate design as drilling operations unfold, e.g. drilling in salt prone basins where there are large pressure differentials between stratigraphic units. To optimise casing selection and placement, data acquisition of mud weight and drilling parameters is constantly needed to determine the formation stratigraphy, the fluid pore pressure, the rock type, the borehole pressure and temperature.

To achieve this data acquisition relies on, 1) optimising the well design and data acquisition, 2) appropriate and cost-effective technology and, 3) knowledgeable people with an efficient communication framework. Delivering each one of these elements individually is not complex, however the challenge of integrating all elements is critical to successfully deliver an HPHT well as any deviation outside of this overlap may lead to an undesirable drilling outcome.

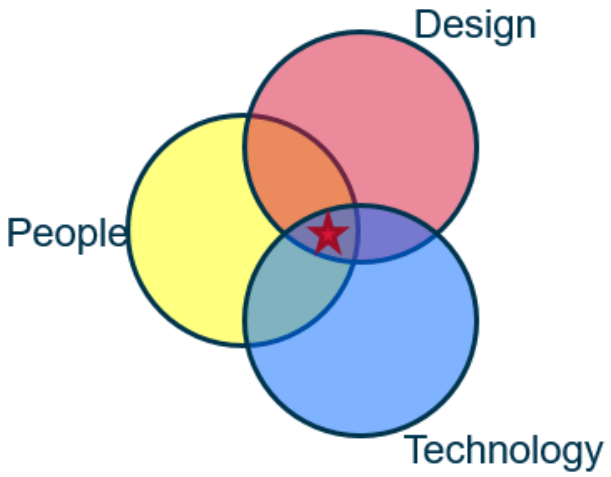

Figure 1. Holistic view of drilling an HPHT well.

CONTRACTING STRATEGY

Contracting scope and strategy is always related to well execution and in drilling HPHT wells it becomes even more important to get clarity in the details. Most obviously this needs to encompass the equipment required to do the job and their cost. Anything required after the contract has been signed can attract significant charges therefore knowing the scope of work so an accurate technical assessment can be done is critical to a good commercial outcome. The commercial assessment needs to be done in the light of whether the HPHT well is to be done as a single well or as a campaign. A campaign can only offer synergies in reducing mobilisation fees and long term tool rentals if these are captured in the contracting strategy at the start of engagement with the marketplace.

PLANNING

Planning cannot commence without knowing 'What Questions Need to be Answered'. Knowing and answering these questions cannot be effectively achieved without accessing subject matter experts in several disciplines including drilling, petrophysics and data acquisition and integrating into a coherent plan.

The first question to ask is 'When do You Need the Data?'. This answers the question on whether to acquire data on LWD or Wireline. LWD data is favoured in drilling HPHT wells for multiple reasons yet there are significant caveats. In favour of LWD is that you get the data instantly for real time decision making. You can also have some control of the temperature of the tools thereby protecting them from damage. There are two significant and obvious caveats; 1) not all data types can be acquired via LWD, 2) the replacement value of all of the LWD tools in the drill string can be significant. A Bottom Hole Assembly (BHA) with a comprehensive data acquisition suite can be worth over $10 million and if mud circulation is lost and the tools exposed to temperatures higher than their maximum rating then then operator may be liable for Damaged Beyond Repair charges. Hence it is critical to discuss LWD acquisition properly with all stakeholders and it always needs to be anchored around the value of that information.

Once the acquisition program has been decided then tool mobilisation and preparation occurs. Tool mobilisation can be tricky at times but for HPHT wells it is always complex as these tools are rare. Often tools will need to be sourced from several geo-markets and only once they all arrive in the base can they be assembled into a single toolstring and checked for functionality. Issues experienced with mobilisation can frustrating and often out of direct control of both the operator and the contractor, e.g. customs.

Lastly, planning focussed solely on the data acquisition ignores the purpose of the acquisition; data is only good when it is communicated to the correct people at the required time. Hence it is highly recommended working up communication strategies, having clearly defined roles for 'Deciders' in making significant decisions.

EXECUTION

LWD data acquisition is favoured due to it being available for real time decision making. However, the caveat with LWD in formation evaluation is depth uncertainty particularly in deep wells. In drilling deep wells with hard formations the pipe compresses and stretches impacting accurate depth determination and thus preventing a quality assessment of the reservoir. Wireline acquisition is largely free of these effects and therefore it still plays a critical role in accurate data acquisition.

Conversely wireline acquisition has problems not experienced by LWD tools. Unlike the LWD environment where the tools can be cooled by mud circulation wireline tools are run in a static borehole with the borehole temperature frequently being at formation temperature and thus being a very hostile logging environment. To add to this problem is the complexity that the static borehole temperature cannot be measured prior to running the first toolstring with the temperature being estimated from a regional geothermal gradient. If the wireline tools are run and they get close to or even exceed their maximum temperature rating then it is possible the data may not be satisfactorily acquired and there is a real risk of Damaged Beyond Repair charges. To assist with this dilemma a recommended method is to do an intermediate wireline run to acquire static borehole temperature data to update the temperature gradient and thus increase the accuracy of the predicted static bottom-hole temperature at final TD. The recommended time to do this intermediate wireline acquisition is on a bit trip nearing final TD and the recommended data type is VSP as this is not needed to be acquired to the final well TD to achieve successful acquisition.

If failures do occur then repair facilities are critical to have at the wellsite. Any decision making on whether to pursue acquiring the data and risking further damage need to be made in the context of not just the value of the data in the well currently being drilled but also in the larger context of whether the well is a stand-alone well or part of a campaign where the tools are needed for subsequent wells where the value of acquisition is greater.

Formation evaluation can be highly problematic as input parameters can be unknown. Assuming parameters and doing interpretation sensitivities can be useful but can also end up producing a large range in the evaluation creating difficulties in assessment of the target reservoir. Thinking creatively and using negative data can add as much value as positive data. An example of thinking creatively is that in normal wells it is

impossible to get core data from within the well and use it for real time decision making whilst drilling that well. But in deep wells with very slow rate of penetration with large timeframes for frequent bit trips then by doing an intermediate wireline run Sidewall Cores can be acquired and quickly sent to the nearest laboratory with analysis conducted to gain critical data to improve the accuracy of the interpretation. For negative data, pre-tests are acquired for valid formation pressures yet comparing rock type with valid vs tight pretests will inform decisions to be made on probe and packer selection for acquiring pressures and samples in subsequent wireline runs.

As important, or arguably more important, than the data is the people who use it. HPHT wells can be extremely challenging and in drilling one the timeframes may exceed what was planned. If this occurs staff may need to be rotated through operational roles to provide relief. This solves a problem yet presents the subsequent problem that the replacement person is fresh to the project. It is critical that the replacement have both a similar skill set and are familiar with the nuances of data acquisition in the well being drilled.

CHALLENGES

HPHT wells have a myriad of challenges and if planning has been appropriate then a suitable, timely answer is available. The key point emphasized in the planning stage is to 'Know What the Question Is'. If/when the well changes scope and therefore the questions to be answered change then an immediate reframe is required. The reframe needs to involve the key stakeholders and SME's that were used in the planning stage.

CONCLUSIONS

Drilling an HPHT well is a unique challenge combining technical and commercial elements with the challenge being heightened in that they are very infrequent for most Operators and Contractors. SME's and equipment for HPHT wells is rare. Yet despite these significant challenges drilling an HPHT well can be done successfully and safely. The key lies in integrating design, technology, and people to understand 'What Questions Needs to be Answered' and to keep on doing this assessment iteratively.

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