Optimization of Temperature Mitigation Workflow for MWD/LWD

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Introduction

In order to secure and deliver the contracted hydrocarbon supply to the Kingdom of Thailand, there is an ever increasing need to develop more geological prospects, especially those with marginal hydrocarbon assets. Sometimes wells are drilled with 175°C (347°F) MWD/LWD tools to deeper depths in areas where the maximum bottom hole static temperature (BHST) can be as high as 200°C (392°F). To deliver the wells with strict financial feasibility, the drilling tools are pushed to the limit of the technological envelope to maximize the drilling performance. The slim 6.125” production hole sections with lower heat dissipation capability (compared to larger hole sections) are usually drilled with aggressive drilling parameters with no active mud cooling system being deployed. With that, minimizing heat generation and temperature impact on MWD/LWD tools are the key objectives of the Temperature Mitigation Workflow.

To maximize rig efficiency and reduce MWD/LWD equipment failure rate, Chevron’s Drilling Measurement Team in collaboration with Sperry Drilling, Halliburton has defined the maximum operating time of the MWD/LWD tools during the temperature mitigation cycle based on both equipment operating limit specifications and financial feasibility. The analysis of the historical run data indicated that the reliability of the MWD/LWD tools was significantly impacted when the temperature mitigation cycle continued beyond the defined maximum operating time.

The optimized Temperature Mitigation Workflow not only allows wells to be drilled in deeper and hotter geological formations, but it also maximizes the MWD/LWD efficiency by operating within the technical specifications of the tools and also supports the MWD/LWD inventory management strategy for a large number of batch drilling projects. Statistical (probability) methods were applied in the MWD/LWD failure rate analysis for various combinations of downhole high temperature operating time and number of runs. These statistics can be used as an important reference for well design and operational decisions in the future.

Innovative Features

As the tools were consistently operated at the upper range of the performance envelope, the reliability statistics provided valuable data to Sperry Drilling’s Sustaining Engineering team to improve the reliability of the PCBAs (Printed Circuit Board Assemblies). Based on the failure analysis database, the common failure modes of the PCBA were identified. The design of the PCBA was improved by replacing susceptible components with alternatives, repackaging the relevant components or a complete redesign of the PCBA to eliminate the use of the susceptible components. The reliability of one major component of the MWD/LWD system has increased 75% in GOT operations for two consecutive years (2013-2014) through this collaborative methodology.

Before 2014, Chevron’s Thailand drilling team had to stop drilling ahead and circulate to cool down MWD/LWD tools when the temperature reached 165°C (329°F). With the reliability improvements on PCBAs and the optimized Temperature Mitigation Workflow, the drilling team started lowering RPMs to reduce frictional heat and circulating off-bottom to cool down the tools when the temperature reached designed operating limit. Once the temperature falls back to designed operating temperatures, drilling operations are resumed. This improvement minimizes total temperature stress exposure to the MWD/LWD tools, avoids temperature ramp ups and could potentially increase ROP.

Vibration (predominantly stick-slip vibration mode) is one of the main contributors of downhole heat generation. Drilling efficiency is reduced significantly when energy is dissipated as heat due to BHA vibrations. In real-time, the Drillstring Dynamics Sensor (DDS) provides real-time stick-slip and tri-axial vibrations data, enabling real-time modification of drilling parameters to mitigate downhole vibrations. With active real-time vibrations mitigation, the MWD/LWD tools experience less temperature exposure as less heat is generated downhole due to vibrations and lower operating time.

Increasing complexity of services being requested and the requirement to work in harsh environments has challenged the MWD/LWD business partner to enhance the traditional hourly based maintenance system. The Condition Based Maintenance System (CBM) is an integrated maintenance system which complements the hourly based maintenance with event based maintenance and parts replacement maintenance. CBM tracks the equipment history from initial build to end of life cycle while defining the maintenance schedule based on the drilling environment parameters. It provides real-time tool life management to improve the operational reliability of the MWD/LWD tools while optimizing the repair & maintenance cost.

With CBM, Sperry Drilling can predict in real-time the point at which the MWD/LWD tool reliability is significantly impacted by high temperature exposure using proprietary software. The information is integrated into the optimized Temperature Mitigation Workflow to define the maximum operating time during temperature mitigation cycles. This helps to minimize the risk that temperature stress exceeds the MWD/LWD tool limit. In addition, the information is used to drive the risk assessment process for the Drilling Team and the Asset Team, considering the risk of the MWD/LWD electronics if drilling continues at a high temperature range.

With known ROP and a temperature profile of the geological formation, the Drilling Team is able to define the maximum operating time above specific temperature to avoid the risk of MWD/LWD electronics failure. In addition to assisting in the real-time decision making process, the data also provides a quantitative methodology for the drilling team to improve MWD/LWD tool inventory management when drilling in such hostile environments, particularly those where downhole temperature will be the main restricting factor in developing deeper geological pay.

Thailand E&P Industry Impact and Values

1. With successful optimized Temperature Mitigation Workflow, a total of 150 Dumb-Iron runs were potentially avoided from January 2014 to June 2015.

Dumb-Iron is a BHA with no downhole electronics. However, a Dumb-Iron run will require approximately 14 hours of trip time for changing out 175°C (347°F) MWD/LWD tools. Apart from that, a wireline logging run (Triple Combo configuration) complementing the Dumb-Iron run will incur in additional tool costs and approximately 6 hours of rig time. In addition, there are many instances when the wireline cannot reach the designated depth, hence the risk of loss of data to evaluate the pay and reserves. In some cases, where well collision risks are present in the production hole section, the dumb-iron run cannot be considered as an option.

Despite the recent emergence of 200°C (392°F) MWD/LWD tools, there are currently no commercially available 200°C (392°F) MWD/LWD formation density evaluation tools. Any use of the 200°C (392°F) MWD/LWD tools must be complemented by a wireline logging run to obtain sufficient formation evaluation data. Therefore drilling these wells with an efficient temperature mitigation strategy helps Chevron Thailand drill deeper wells and identify more reserves while operating tools within Technical Limit.

From January 2014 until June 2015, 3000 hours of rig time were potentially saved due to the implementation of the Temperature Mitigation Workflow.

2. Rig efficiency increased approximately 30% compared with prior drilling practice by applying the following practices:

- Real-time vibration monitoring to adjust drilling parameters and mitigate down hole stick-slip vibration.
- Increasing the temperature at which circulation is initiated to cool down the MWD/LWD equipment based on High Temperature Stress Evaluation improving MWD/LWD equipment reliability.

The BHA optimization and real-time vibration mitigation plan reduced downhole vibrations. Energy transfer to the drill-bit was more efficient. With more reliable MWD/LWD tools, the drilling team could continue drilling as deep as possible without lowering the RPMs until the MWD/LWD heated up to designed operating limit, decreasing the total high temperature exposure time. **Fig.1** is a particular case of Temperature Mitigation Rig Time Comparison between prior workflow and optimized workflow. This case indicates that the optimized workflow reduced on bottom drilling time by 2 hours and extra circulation time by 5 hours, saving a total of 7 hours rig time.

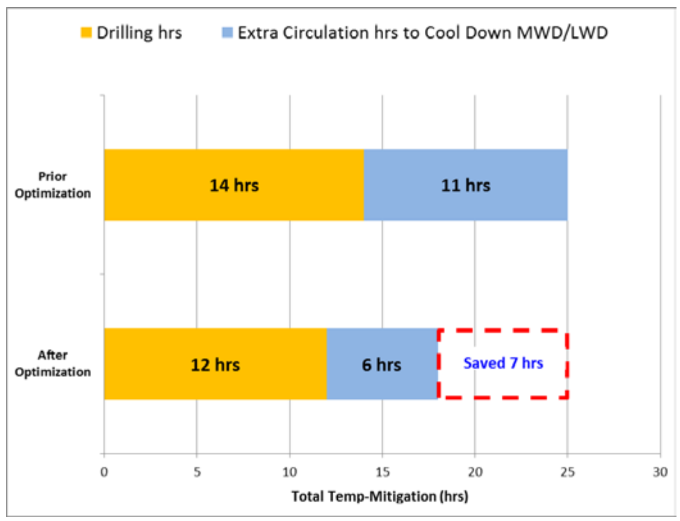

Fig. 1. Rig Time before and after implementation of workflow

3. Statistical analysis of MWD/LWD tool failure rates for various combinations of down hole high temperature operating time and number of tool runs.

Since 2014, the statistical analysis of the GOT MWD/LWD data indicates that the reliability of the electronics is reduced significantly when exposed to high temperature despite being operated within the temperature specifications of the MWD/LWD tools. Prolonged temperature exposure increases the failure rate. The remaining life of each MWD/LWD tool can be predicted from failure rate statistics. The failure trend (**Fig. 2)**, is extrapolated based on the existing historical failure data with continuous probability distribution. Based on the estimation results of failure rate, field operations have the capability to make a decision on whether to keep the tools running and temperature mitigate or trip out the tools due to high probability of failure or data loss. Business partner can also pre-schedule loading out tools to the rig site ahead of time and plan a certain level of repairs or maintenance to minimize tool turnaround time.

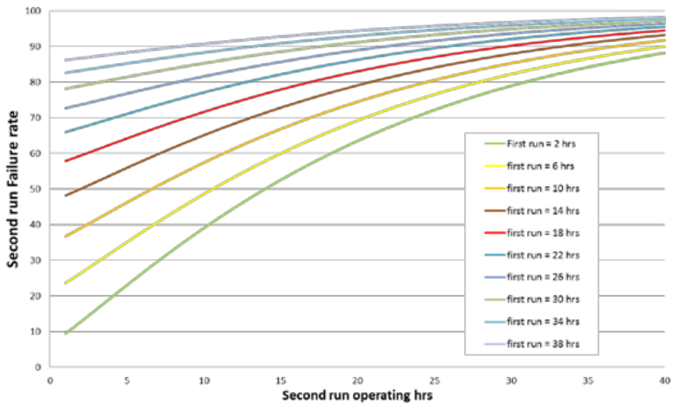

Fig. 2. MWD/LWD Second Run Failure Rate (Operating in High Temperature)

4. MWD/LWD Cost Comparison Toolkit was created utilizing the reliability data and cost structure of 175°C (347°F) and 200°C (392°F) MWD/LWD and dumb-iron BHAs.

Extended drilling operations with temperature mitigation increase the total operating time at high temperature range and impact the reliability of the MWD/LWD equipment. With additional circulating time and slower ROPs during the temperature mitigation cycle, the total drilling cost is higher. A Cost Comparison Toolkit **(Fig. 3)** can help the drilling engineer to easily calculate the tool's total run cost and extra operating time at high temperature with different scenarios and provides data to support Temperature Mitigation, or running 200 C (392 F) tools followed by a open hole wireline triple combo run.

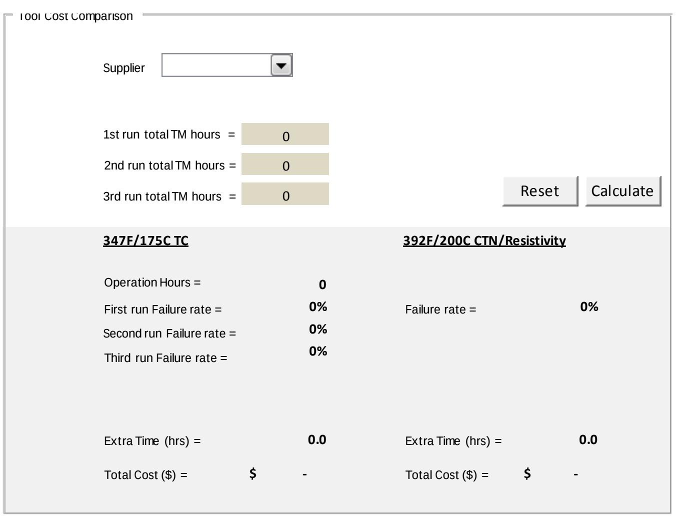

Fig. 3. Cost Comparison Toolkit for MWD/LWD selection

Health, Safety and Environment (HSE) Impacts

Manual handling is still one of the main HSE risks for personnel operating on the drill floor. By limiting trips for MWD/LWD failures or Dumb-Iron BHAs, risk exposure can be reduced. The MWD/LWD equipment failures due to high temperature exposure were reduced after the implementation of the optimized Temperature Mitigation Workflow. Trip for Failure (TFF) was reduced from 13.2% (2013) to 5.5% (since 2014). As a result, the manual handling risk for personnel working on the drill-floor was reduced.

Reasons This Project Should Win The Award

1. The optimized Temperature Mitigation Workflow has the following unique features which can be applied by any operator drilling in high temperature environments:
    1) MWD/LWD life management helps Drilling Project Teams estimate tool utilization and manage inventory in planning phase.
    2) Real-time MWD/LWD life monitoring helps optimize total run length, and minimizing NPT due to downhole electronics failures.
    3) Cost Comparison Toolkit of MWD/LWD tool- type selection, enables cost management for each run, BHA component selection and well drilling program.
    4) Decision tree and risk assessment help the drilling team to increase work efficiency (office and rig site) in high temperature drilling operations.
    5) Optimize temperature mitigation cycle and minimize cumulative temperature impact to the MWD/LWD equipment to achieve maximum drilling efficiency.
2. The Temperature Mitigation Workflow provides the means to define the maximum operating time at a specific temperature range to mitigate related equipment failures, complementing the maximum static temperature specifications of the MWD/LWD equipment. The project demonstrated that MWD/LWD equipment reliability is affected by both factors: downhole temperature and exposure time to high temperatures. The implementation of the workflow in the field also verified the MWD/LWD real-time life management system, and supported the PCBA design parameters using actual run data for the first time.
3. The optimized Temperature Mitigation Workflow was identified as a best practice for the MWD/LWD business partner and Chevron. A similar approach can be implemented for other districts or business units that operate in high temperature environments to improve its MWD/LWD equipment reliability and ultimately, reducing NPT, optimize equipment use and total well drilling costs.