Nonproductive time (NPT) caused by preventable tool failures in offshore drilling and completion can cost tens of millions of dollars per year. Historically, oil and gas operators have relied on their well delivery personnel (i.e., foremen, drilling engineers and/or operations superintendents) to work with vendors to investigate and document tool- and wellbore-related failures. In many cases, this type and level of support is appropriate and effective. However, investigations into high-impact NPT events involving complex tools and operations typically require more time and effort than well delivery personnel can reasonably dedicate, given that this work has to compete with well planning and real-time supervision activities. Without substantial operator support and influence, tool vendors may (often by necessity) not give sufficient focus to failure investigations and risk mitigation efforts. This approach to failure investigations has resulted in fundamental issues (i.e., root causes) not being identified and/or addressed, which in turn leads to additional tool failures and perpetuation of high levels of NPT.

Therefore, it is in the best interest of operators and vendors to assign high priority to failure investigation and risk mitigation work, dedicating the appropriate resources, establishing a fit-for-purpose infrastructure, and allowing the work to be an integral part of the well and tool/service delivery processes. The benefits to the operator are self-evident. The tangible benefits to the vendor come from the ability to demonstrate excellence in service provision to the operator, thereby strengthening the (contractual) relationship. Through active support and involvement in failure investigations driving down NPT, vendors can demonstrate that they are competitive from a total cost perspective, including not only the direct cost of goods and services but also the indirect costs associated with NPT.

In 2006, Shell initiated a focused effort to reduce NPT associated with failures of problematic drilling tools in its GOM operations. Such effort was deemed necessary since the level of NPT associated with tool failures was consistently high and showed no signs of abating. The company’s approach employs a flexible, fit-for-purpose root cause failure analysis (RCFA) process and a specialized team that is dedicated to investigate specific, high-impact NPT events via the RCFA process. This team is known as the root cause failure investigation (RCFA/TAT) team.

**Fig. 1.** RCFA process overview illustrating RCFA/TAT methodology.

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The team focuses its work scope and efforts so that the highest-impact events receive the most attention. For example, the team’s GOM drilling work scope is focused by selecting only those NPT events exceeding six hours of trouble time as candidates for follow-up. Failures in the drillstring and bottomhole assembly (BHA) exceeding six hours are investigated by default. For all other NPT events exceeding six hours, the team consults the key stakeholders (operations superintendent and drilling engineer) and determines the forward plan based on their input. NPT events lasting less than six hours are not considered for analysis except by special request by the key stakeholders. These smaller events are simply documented for impact and tracked in meaningful key performance indicators (KPIs) for trends.

Vendor failure response requirements have been established to provide clear expectations on communication milestones and deliverables and facilitate a smooth interface with each vendor’s existing failure investigation process. In particular, the vendor is expected to provide a post-teardown report after the tool is disassembled and initial analysis has been completed. Once the investigation has been completed and the corrective actions have been finalized, the vendor is required to furnish a final failure investigation report containing the finds and conclusions from the failure investigation and corrective actions/recommendations to prevent the reoccurrence of the failure.

The team focuses on long-term solutions applicable at a fundamental level. Solutions that require the vendor to implement supplemental procedures and/or operator-specific criteria are avoided. If the root cause of a failure in one tool can cause a failure in other types of tools, then the corrective actions are proactively implemented for the other applicable tools.

The team regularly communicates with the interested parties to ensure that a detailed and unbiased investigation is conducted and that appropriate corrective actions are implemented. The team provides a concise preliminary report to the key stakeholders after the tool disassembly and preliminary analysis has been completed. This preliminary report contains the findings/analysis, any immediate corrective recommendations and a tentative forward plan for the failure investigation.
The team compiles corrective actions and recommendations related to NPT events due to tool application and operational issues into risk mitigation reports. The information generated during failure investigations is disseminated throughout the organization via the various RCFA-based reports. The team also participates in weekly drilling and completions network meetings with well engineers to go over key updates, actions and recommendations for mitigating the risk of similar failures.

In addition to working with the well delivery teams and subject matter experts, the team also interfaces with the contracting and procurement (C&P) and quality services organizations within Shell. The team provides technical information on tool failures to C&P for accurate commercial resolution with vendors. The team participates in periodic vendor performance review sessions arranged by C&P, including service quality meetings and business performance reviews.

The team ensures that all confidential or restricted information obtained and reported (including sensitive vendor and/or well data) during failure investigation is closely managed and selectively communicated. Success depends on its ability to maintain good working relationships with vendors and well delivery teams, and such relationships depend heavily on responsible use of sensitive data.

**CASE STUDY**

A drillship drilling in the deepwater GOM abruptly lost communication with the downhole MWD/LWD/RSS suite. NPT cost in excess of $1 million was incurred as the rig had to pull the BHA out of the hole. The RCFA/TAT identified this incident during the daily review of morning reports for GOM wells. The drilling engineer in charge of the well was contacted to discuss RCFA initiation, review the operating conditions surrounding the incident and determine the potential implications (on operations and cost) of the failure. The team also contacted the vendor’s service coordinator to collect details of the failure and the MWD/LWD tool string and to review the real-time attempts to reestablish communication with the tools.

After gathering information about the failure and the tools involved, the team sent notifications to C&P and quality services to raise awareness of the incident and corresponding RCFA and to allow the necessary steps to be initiated for commercial resolution and for focused quality audits, as necessary.

A third-party engineer represented the team during the initial phases of the disassembly/examination of the tool string. The failure was localized to the pulser of the MWD tool. Detailed examination of the pulser components revealed that a guiding structure was bent. Metallurgical examination revealed fatigue cracks propagating from a geometric change in the guiding structure. These fatigue cracks caused the component to bend, resulting in high bending loads in the pulser mechanism. After this stage of analysis was complete, the vendor and the third-party engineer provided teardown reports describing the findings and conclusions from the preliminary analysis to the RCFA/TAT.

The team organized a post-teardown meeting with the vendor to discuss the findings of the disassembly/examination, operational history of the failed pulser, recent trends in pulser reliability, immediate corrective actions and recommendations, and the forward plan for the failure investigation. It was decided to critically review the design, material selection and quality assurance and control (QA/QC) process for the guiding structure. The RCFA/TAT prepared a preliminary report and submitted it to the well delivery team (WDT). The report was also sent to Shell’s technical experts and engineering team leaders. The incident was discussed in a weekly drilling network meeting so that other drilling engineers and operations superintendents would be aware of the failure and that an RCFA investigation was in progress. The information gathered during the investigation was also communicated in the quarterly RCFA awareness bulletin.

The vendor’s engineering group conducted a review of the design and material used for the guiding structure. The RCFA/TAT also discussed the QA/QC procedures and replacement schedule of guiding mechanisms with the QA group. The RCFA/TAT and the vendor’s failure response group organized weekly teleconferences with the vendor’s engineering and QA groups to discuss the progress and findings from each stage of the investigation.

It was discovered that the design of the guiding structure contained an abrupt change in geometry, creating a location of stress concentration where the fatigue cracks initiated and propagated. The vendor agreed to modify the design to remove these abrupt changes in geometry. Discussions with the vendor’s QA group revealed that the failed guiding structure was manufactured before the latest manufacturing upgrades were implemented, making the component more susceptible to fatigue. Per the vendor’s QA/QC procedures, the guiding structure was visually inspected during pulser disassembly and was re-used (in the same or another pulser) if it passed the inspection process. The RCFA/TAT concluded that a visual examination would not be sufficient to detect fatigue cracks due to the size and geometry of the component. Based on the technical justification provided by the RCFA/TAT, the vendor agreed to modify the replacement procedure of the guiding structure. The vendor now replaces guiding structures with new ones during pulser disassembly.

The vendor agreed to the RCFA/TAT’s request to evaluate the design, inspection procedures and replacement schedule of components in the pulser assembly and other MWD/LWD tools that accumulate fatigue during normal operation. The vendor also agreed to the team’s request to review the inventory of these components and discard any components that do not meet the acceptable design versions. The team continued to receive regular updates as the vendor’s engineering and QA groups conducted the design and inspection reviews.
A failure response meeting was organized with the WDT, C&P and the vendor to discuss the failure investigation, the corrective actions and the implementation plan for the corrective actions. The WDT informally agreed with corrective actions and the timeline for implementing them. After the failure response meeting, the RCFA/TAT lead investigator authored a formal RCFA report containing the results of the investigation, the corrective actions and the timeline. Following an internal review, the corrective actions and implementation plan documented in the report were sent to the vendor for review/approval. After obtaining the vendor’s approval, the RCFA report was sent to the WDT, technical experts and GOM engineering team leaders.

After the WDT formally approved the RCFA report, it was forwarded to RCFA teams operating in Asia-Pacific and Europe. These teams discussed the failure incident and the corrective actions with the respective vendor workshops in those regions, thus ensuring that the local workshops were aware of the corrective actions and implementation plan and would provide suitable tools to the operator’s regional operations.

The RCFA report was archived with the NPT event in Shell’s daily reporting system and was also published in the RCFA/TAT’s website. RCFA closeout notifications were sent to C&P, quality services and the vendor to formally close the investigation from a technical perspective, to facilitate closeout from a commercial perspective and to focus follow-up quality audits.

**ANALYSIS AND TEAM IMPACT**

Since inception, the team’s efforts and related vendor efforts have facilitated a significant and sustained reduction in NPT associated with tool failures. For example, during the three years of this initiative, failure frequency for GOM drilling tools has declined 60%, from five to less than two failures per month., Fig. 2. As a percentage of total drilling rig-hours and costs, actual NPT for GOM drilling tools has decreased by 50% and 66%, respectively. This significant NPT reduction has translated to yearly multi-million-dollar savings for the operator.

Success in the GOM provided justification to expand the RCFA/TAT model throughout North America. The process was implemented for land operations during the fourth quarter of 2008, resulting in a 20% reduction in NPT costs thus far. It was implemented for GOM completions in the second quarter of 2009, and preliminary analysis of the associated NPT data over the past year indicates a similar downward trend to that seen for GOM drilling tools.

The process has also been accepted as a global best practice. Shell’s Asia-Pacific and European (North Sea) regions have adopted the RCFA/TAT methodology with appropriate fit-for-purpose adjustments in each region. Early results from these regions are favorable and support the value of the process. The methodology’s expansion has enabled the different teams to share alerts and corrective actions for tool failures worldwide so that repeat failures can be avoided globally.

**THE AUTHORS**

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Every well is different. Each presents unique challenges, and each offers hidden risks, including the threat of mechanical or structural failure while drilling. Ensuring the integrity of your drilling equipment is a key step in mitigating this risk of downhole failure while operating. Whether drill string, landing string or casing & tubing, TH Hill can recommend and execute the optimal quality assurance plan for your drilling program. Based on the criticality of your operation, we will define the necessary inspection plan and third-party monitoring requirements to best balance your investment in quality assurance with the likelihood of failure. We will also work directly with your vendors to ensure timely delivery of qualified equipment to the rig. Our exacting attention to quality at the individual tool level can help you avoid costly non-productive time as you drill your next well.

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