Drilling hazard management: Integrating mitigation methods

Part 3 of 3: Many drilling hazards can be mitigated or avoided using casing or liner drilling, managed pressure drilling or solid expandable liner technologies.

David Pritchard, Successful Energy Practices International; Patrick L. York, Scott Beattie and Don Hannegan, Weatherford

Managing drilling hazards requires understanding how the incorporation of mitigating practices and technologies into the well design can improve the risk profile and add value. To achieve this understanding, risk assessment must be applied to the mitigating practices and technologies under consideration. From a drilling hazard management (DHM) perspective, adding value means improving both the risk profile and the cost-benefit balance of the overall operation from a risk-adjusted perspective. Any new mitigant must decrease the likelihood of the risk event occurring, and the risk-adjusted cost should be financially beneficial to the overall operation. It is therefore important to understand how technologies can improve the ability to mitigate and manage risk and can improve the ultimate value of a well.

APPLYING FIT-FOR-PROBLEM TECHNOLOGY

The many and varied technologies available to assist in drilling complex wells are often underutilized. In light of the workloads imposed on today’s drilling engineers and well supervisors, it has been easy to apply familiar tools that have generally worked in previous well situations rather than investigate and apply the most fit-for-problem technology. Conversely, applying technology for technology’s sake is seldom the best approach; often, implementing good drilling practices may be the best solution to the current challenge.

As highlighted in the two previous installments of this article series, the most prudent approach involves two steps: first, identify well objectives that are specific, measurable, achievable, relevant and timely, or SMART; second, develop a thorough understanding of the uncertainties and risk mitigants.

Studies conducted over the past decade have shown that about 50% of drilling hazards resulting in nonproductive time (NPT) can be either avoided or mitigated using good drilling practices such as “well listening.” Most of the other half of drilling hazards can be mitigated or avoided through the use of drilling with casing (DWC)/drilling with liner (DWL), managed pressure drilling (MPD) or solid expandable technologies. These technologies are only a few of many in the drilling professional’s tool box, and none should be considered a panacea.

Because multiple resources exist that detail the workings of these technologies, this article provides only a brief review of how they work, then focuses on how DWC/DWL, MPD or solid expandable systems can be applied to a real example to substantially reduce well risk and cost in a set of complex wells within a very complex reservoir.

Drilling with casing/liner. DWC or DWL can be deployed to reduce risk in many hole sections or casing sizes and is a relatively simple, safe and inexpensive insurance when drilling through trouble zones.

With DWC, the casing string is used as the drillstring instead of drill pipe. Since the 1950s, it has been common in some areas of the world to drill in the final tubing string and cement in place with the drill bit still attached. Modern DWC started in the early 1990s and differs from previous applications in that it is not limited to the final string. To date, this technology has been used in about 2,000 applications. With the exception of a few experimental wells, casing has been used to drill specific sections of the wellbore rather than the entire hole.
Defining the term "drilling trouble zones," the first choice for drilling trouble zones is another question. DWC also eliminates other NPT involved in operations and are considered status quo by many who pioneered the root concepts. Compared to conventional rotary drilling with jointed pipe, solid expandable systems were initially developed to reduce drilling costs, increase production of turb-constrained wells, and enable operators to access reservoirs that were otherwise too risky to penetrate. Although the first related patent was issued in 1865, it wasn't until the mid-1990s that operators in the Soviet Union successfully expanded corrigated pipe with pressure (hydro-forming) and roller cones to patch openhole trouble zones. This transitional system and its relevant application further motivated the evolution of expandable technology.

The nature of the wellbore itself dictates what expansion solutions and tools are applicable. Once it is determined to drill, log and isolate Target 1 high pressure and consider isolation contingencies.

The wellbore string includes, in addition to expandable technology, the constant bottomhole pressure system as a design contingency. Typical drilling problems that can be mitigated with an expandable liner solution include:

- Inadequate hole stability
- Poor isolation across multiple zones
- Underpressured formations
- Overpressured formations
- Overexposed hole as a result of drilling issues, equipment failures, prolonged tripping, etc.
- Underpressured formations
- Close fracture gradient/pore-pressure tolerances
- Poor cement bond
- Remediation for casing that was inadvertently set shallow.

In contrast to a lost-set resort application, expandable systems may be used as a field installation string as an integral part of the well's basis of design. This proactive approach enables the system to be installed over the trouble zone or above the zone that needs intervention in response to drilling problems over the trouble zone. With either scenario, the basis of design is maintained. Whether an expandable system is used as part of the planned contingency purposes, the technology saves hole size, compensates for unplanned events, and allows for flexibility in well planning.

The following real-well example illustrates the effective planning and application of the technologies discussed above. This well was one of a set of wells to be drilled through very complex formations near the foothills of a mountain range. Defined goals for the well included the following:

- Maintain less than 2° inclination at casing point (about 2,000 ft).
- Drill Section 1 formations to about 6,600 ft MD. Build a 9 5/8-in. casing.
- Drill Sections 3 and 4 to the top of pressure ramp to about 13,000 ft MD. Directionally drill tangent section from 7,000 ft to about 11,400 ft, and then continue drop section with dogleg severity limited to 3°/100 ft.
- Run WLD tools to obtain accurate geological data.
- Stay vertical (less than 3° inclination) and maintain azimuth to reach the target according to the drilling plan.
- Drill, core, log and isolate Target 1 high pressure and consider isolation contingencies.
- Use mud ball to set DST.

Fig. 3. Target 2 depleted formation and consider contingencies for high differential pressures and stress.

Drill and complete both targets with non-damaging fluids. As discussed in the first installment of this article series, these wells were drilled using the SmartWell wellbore design: The seismic and off-well information integrated complex geology: depth uncertainty due to seismic resolution; trajectory passing up, down and cross-dip; and uncertainty in the types of hydrocarbons present. The development strategy was such that the same formations were encountered several times by the prospective wellbore due to severe faults and geophysical events that occurred during and subsequent to their deposition. Fig. 3.

Purpose of technical limit analysis. The initial well re- quired a plan to implement good drilling practices and without applying technology mitigants, this time was reduced to 216 days. However, the subsequent technical limit analysis highlighted additional opportunities to further reduce the drilling time. The purpose for the technical review of the wells to be drilled was to understand:

- What depth hazards existed and what created them.
- How these hazards existed or mitigated.
- What additional technical and operational improvements could be made to further reduce the drilling time.
- The geotechnical environment.
Risk/consequence profiles of all hazards had to be developed; these would provide a baseline to derive a risk-assessed cost-benefit analysis of the hazard mitigation.

Technical limit-setting using both good drilling practices and a variety of cutting-edge technologies indicated that drilling time to TD could be reduced by almost half, from 216 days to 115 days, Fig. 4.

Reducing risk and improving drill time. The following summarizes the opportunity that exist to improve the well economics through the applications of the DWL, MPD (pressurized mudcap) and solid expandable technologies.

Drilling the top hole section with casing curves verticality and stability, and uses a rock strength that is well within the range of cutter technology. It removes three days’ drilling time and enables the ability to extend the shoe depth. In addition, using DWL in this application improves lost-circulation tolerance for the next hole section and simplifies the drilling margins.

Using DWL as a “hole cleaning while drilling” method, after conventionally drilling the last two hole sections for the drilling liners, ensures that theseliners successfully reach their total depths. Additionally, this application facilitates well stability under MPD conditions while minimizing running and cementing risks, lost time, NPT and flat time.

Using pressurized mudcap drilling from the top of the hole down eliminates the risk of up to 33 days’ lost time; the risk-adjusted cost-benefit balance is at least a 11%.

Applying this MPD method also eliminates the risk of losing over 13,500 bbl of expensive oil-based mud in the top hole. Additional benefits include better control of controlling stresses while accepting losses; elimination of the need for turbine drilling with unlagged bits, especially where temperature is not an issue; and the ability to use cheap, expendable water-based mud—because losses become non-consequential, cuttings cure loss zones and the cap controls caving. Figure 5 indicates the areas of the well where the DWLC/WDL and pressurized mudcap were applied to watch the trouble zones.

The application of openhole expandable liner in either 7½-in. x 5½-in. size (resulting in a post-expanded ID of about 8 in.) allows a liner to be installed below the 9-in.

TABLE 1. Risk analysis conducted on the example well for liner drilling, mud-cap drilling and expandable drilling liners

<table>
<thead>
<tr>
<th>Risk</th>
<th>Paid loss in hole section</th>
<th>Stuck pipe in hole section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>Non-productive time</td>
<td></td>
</tr>
<tr>
<td>1.02</td>
<td>Slight losses</td>
<td></td>
</tr>
<tr>
<td>1.03</td>
<td>Severe losses</td>
<td></td>
</tr>
<tr>
<td>1.04</td>
<td>NPT but able to retrieve drilling equipped with 576-ft length</td>
<td></td>
</tr>
<tr>
<td>2.01</td>
<td>NPT, retrieve drilling</td>
<td></td>
</tr>
<tr>
<td>2.02</td>
<td>NPT, retrieve drilling</td>
<td></td>
</tr>
<tr>
<td>2.03</td>
<td>Pipe mistransfer</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Geologic map of the example well.

Fig. 4. Comparison of conventional and technical-limit drilling curves.

Fig. 5. Drilling curves with DWC/DWL and pressurized mudcap drilling technologies applied in the upper hole sections.
conventional casing string. This expandable solution allows for mitigating the trouble zone while enabling the running of a 7-in. (or smaller) string of conventional casing, adding an extra casing string without loss of hole size. However, within the 8½-in. hole section (which requires under-reaming the hole section over the trouble zone by 1 in. if the expandable liner is to be installed) the formation is extremely hard. This was evidenced by highly worn impregnated bits; stabilizers out of gauge; difficult conventional reaming and torquing; drillstring stalling (not turbine); highly worn turbine bearings; a high percentage of sandstone in cuttings; and the fact that overbalance was greatest when pore pressure was at its lowest values.

To effectively evaluate the uncertainties of using each technology being considered, a comprehensive risk analysis must be performed including the technology and its particular application within the well. Table 1 presents the risk analysis conducted on the example well for liner drilling and mud-cap drilling (to mitigate risk of fluid loss) and the use of expandable drilling liner (to mitigate risk of stuck pipe).

**CONCLUSION**

The key to mitigating and managing risk lies in understanding the importance of a stage-gated planning process, developing SMART objectives, and acknowledging and defining possible uncertainties and risk applied to practices and technologies. Successful drilling hazard management depends on a cognizant and deliberate recognition of the project’s risks. If executed effectively, the process yields a comprehensive awareness that provides a foundation to not only mitigate and manage risk but optimize operations. Risk assessment should be conducted for any operation, and the process implemented should be used to critically challenge each facet of the well design.

To this end, it is important to understand how practices and technologies can improve both risk management and the ultimate value of the well.

**LITERATURE CITED**