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Real-time data offers critical tool to redefine well control, safety

Complete, timely interpretation of well data a key opportunity for industry to improve process safety, ensure well containment

By David Pritchard, Successful Energy Practices; Jesse Roye, Digital Oilfield Solutions; Lillian M. Espinoza-Gala, consultant

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The industry has historically viewed real-time data (RTD) as it relates to drilling optimization. Recent catastrophic events have proven that loss of containment and process safety require a different approach for the use of RTD. The industry has a focus on well control and rightfully so, but the focus should not be about well control; it should be about avoiding well control events. Well control events are increasing, and RTD can be used as predictors of wellbore stability, whether open hole while drilling, flat time or cased hole while removing barriers.

This article will have a focus on each of these critical path dynamics in operations. Staying off the preventers is more important than engaging the well control equipment. The industry should never rely solely on well control equipment but engage best available and safest technologies and practices to ensure reliability and consistent operation. The know-how of prevention, as well as containment, is critical to process safety.

Further, recent court cases have proven that it is incumbent on operators to ensure alignment of operations prior to execution. Service providers must establish benchmark protocol for equipment design and execution reflected in the RTD. What are the limits of the equipment? What are the non-comprised absolutes of well control? What constitutes barrier removal and verification of zonal isolation? What are the process safety STOP issues and when should management of change be engaged and how is this influenced by RTD? How are we training our planning and execution personnel, and how can RTD supplement a gap in training and overcome the Great Crew Change? Finally, from a rig worker’s perspective, what does safety really mean?

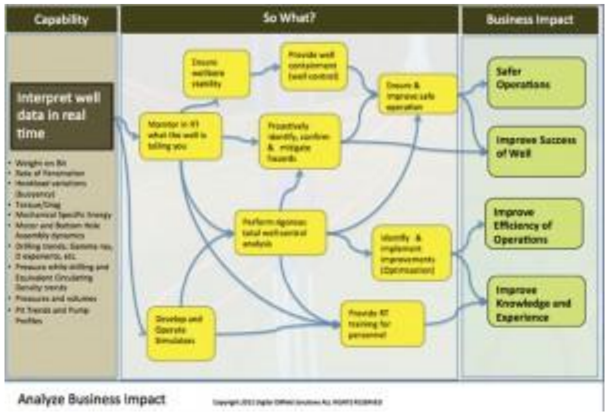


Figure 1: Monitoring real-time data can help to enhance hazards avoidance and well containment, thus leading to safer operations, enhanced efficiency and improved knowledge and experience.

<u>Background</u>

Currently in our industry, RTD is primarily used to improve efficiency and drive down costs. However, this is a secondary issue to hazards avoidance and well containment, which can be achieved by the correct use of the same data. If one assumes an annual US $2 billion operator deepwater budget and that nonproductive time (NPT) and efficiency can be improved holistically by 25% overnight, it would take more than 40 years to pay out a single Macondo catastrophe, based on the assumed final direct cost of US $40 billion for demonstration purposes.

However, it is not just about money but also lives, assets, the environment and other industries. Everyone must work at the speed of ensuring process safety, not the speed of saving money. This is the mindset the industry should develop, and it should be top-driven from boardrooms.

To ensure reliability and safety, a paradigm shift isrequired in terms of real-time data monitoring and utilization. This involves the realization key elements:

• All well control events are predictable and avoidable, both in rotating and flat time (logging, casing cementing) operations;

• The more complex the geological environment, the more uncertain the pore pressure and fracture gradient. Geomechanics information and prediction must be constantly updated in face of the data being generated. Drilling trends can be excellent predictors of changing wellbore stability models while drilling. Effective monitoring helps ensure the successful navigation of the drilling margin;

• Monitoring must evolve to be proactive. Multiple specialists should be involved in the real-time recognition of prescient hazards;

• Real-time data not only can improve process safety but can also improve decision quality around issues such as management of change and risk management;

• Data systems must use intelligent agents as recognized alerts to ensure process safety before the event occurs. It is not about early kick detection; it is about avoiding or preventing the kick altogether.

• Industry wellsite leaders are challenged in their ability to effectively monitor key drilling parameters. Prior to Macondo, available time was being eroded by new well complexity. Post-Macondo, their available time to monitor drilling conditions has been eroded by the necessary administrative requirements of well-construction operations and new Safety and Environmental Management Systems (SEMS). For those who may be old enough to remember what Well Listening means, they are challenged not only with drilling the well but mentoring a younger generation unfamiliar with the art and science of rotary drilling.

The most fundamental definition of process safety is that of ensuring containment. In the case of drilling and completions operations, that means well control. Process safety management (PSM), a regulation promulgated by the US OSHA, is an analytical tool focused on preventing releases of any substance defined as “highly hazardous.” This concept certainly can be extended to oil and gas well operations within the context of ensuring that the well is constantly under control.

As well complexity increases, the risk for well control events increases disproportionately. Even the term well control, which should be related to the performance of oilwell operations in a controlled manner, became more associated with the operations necessary to fix a situation once control is already lost. Often the industry depends on blowout preventers as execution tools rather than the fail-safe tools for which they are designed. If one constantly slams on the brakes of a car at high speed, eventually the brakes are sure to catastrophically fail, or at the minimum, fail to operate timely or accurately. Relying on the blowout preventers as an execution tool is not good for the hardware, and operating in crisis mode is psychologically and physically exhausting and distracting for the rig crew.

Real-time data offers the ability to improve process safety. Figure 1 shows the relationships between real-time data and the impact on operational outcomes.

There are justifiable considerations for automation using real-time data. This is valuable and part of the natural evolution, including removing people from harm’s way. Successful realization of automation, however, will first require effective subsurface recognition and avoidance of geohazards and the use of real-time data to navigate the drilling margin.

Safety Training Observation Program (STOP) has become a proactive tool in the industry for personal safety, and it should be applied to operations in general. Real-time monitoring should evolve to this level, not necessarily in terms of declaring “STOP” but in creating the ability to notify that conditions are or may become abnormal. As mentioned, all well control events are predictable.

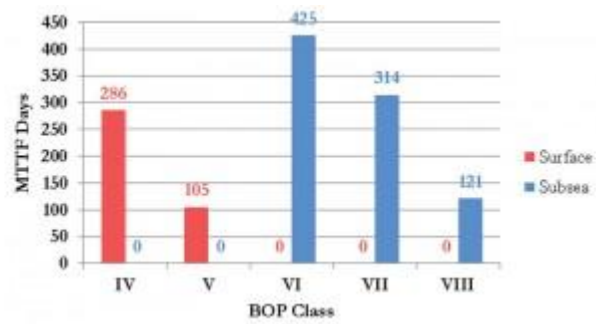


Figure 2: A joint industry project looking at BOP reliability for US GOM wells found improvements from 2004 to 2006; however, failure rates remain a factor that industry must continue to address in order to improve process safety.

There are no worldwide industry standards regarding acquisition or monitoring of real-time data, even though the industry could substantially benefit from such standardization as other industries have. Industry standards would help ensure that regulations are more effective. The more proactive the industry is, the less the necessity of regulatory involvement.

Parts of the industry may be reticent to develop these types of standards for fear of losing competitive edge; however, this is secondary to process safety. Ensuring process safety is fundamental to industry viability.

Best available and safest technologies (BAST)

This is much more than a term; it is a regulatory requirement for SEMS: “It is also incumbent upon the operator to use BAST (Best and Safest Technology) as per 30 CFR 250.107(c).” Risk assessment is fundamental to drilling and completion operations. The safety matrices of many companies do not include cost as an issue, as there is not a price that can be placed on human life and the environment. In fact, the essence of BAST is:

“A literal understanding will connect it with a ‘spare no expense’ doctrine, which prescribes the acquisition of the best state-of-the-art technology available, without regard for traditional cost-benefit analysis. In practical use, the cost aspect is also taken into account.”

In addition to robust RTD systems and compliance, the industry should investigate:

• Casing and tubulars designs, which do not compromise issues such as maximum anticipated shut-in pressure (MASP);

• Casing designs that undoubtedly protect all surface strings. This not only applies to operations such as deepwater but also unconventional shale development where fracturing technology has become a critical issue. Proving 100% containment in mechanical integrity of a cased-hole system and long-term containment is crucial;

• Cementing practices and zonal isolation verifications without compromise;

• Detailed plans and procedures containing proactive checklists, especially for safety-critical issues such as barrier removal;

• Plans and procedures that ensure “stop, look and listen” irrespective of cost-cutting demands;

• Speed when drilling and completing is not the primary issue. Process safety is the paramount issue;

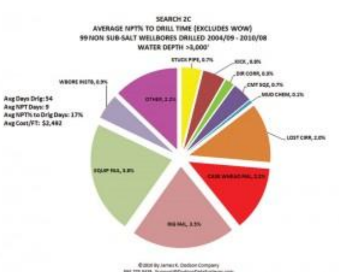
• Other technologies, such as managed pressure drilling in closed-loop systems, to reduce the risk of an uncertain drilling margin;

• All operations should have robust risk assessments, and this begins in the planning phases of well operations and in regard to health, environment and safety. Cost should not be a factor; and

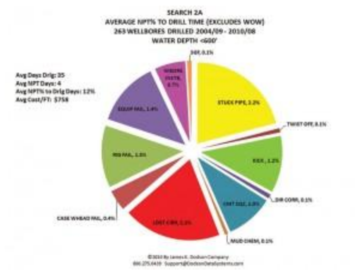
• Management of change should always be recognized in real time and risk assessed, even if it means suspending operations. Fundamentally, any change in scope or critical path constitutes management of change.

What are the statistics: Wellbore stability and process safety?

Ensuring a stable wellbore is the precursor of process safety. To its credit, the industry has made enormous improvements and technology advancements in rig floor management, equipment and automation. Real-time data reflects every drilling parameter related to these technologies, such as:



Industry metrics show that the percentage of nonproductive time to drill time increases significantly as water depth increases. For 263 wells drilled in less than 600 ft of water (Figure 3, top left), drilling days averaged 35 and NPT days averaged four. Average percent of NPT to drilling days was 12%. For 99 wells drilled in more than 3,000 ft of water in a non-subsalt environment (Figure 4, top right), drilling days averaged 54 and NPT days averaged nine, and NPT-to-drilling days was 17%. For 65 subsalt wells drilled in more than 3,000 ft of water (Figure 5, left), drilling days averaged 97 while the average number of NPT days went up to 29. The NPT to drilling days was 30%.



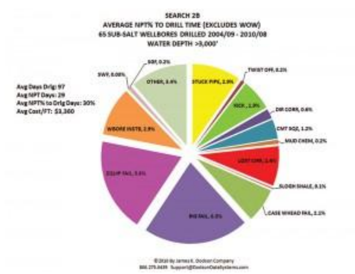
• Weight on bit;

• Rate of penetration;

• Hookload variations (buoyancy);

• Torque/drag;

• Mechanical specific energy;



• Motor and bottomhole assembly (BHA) dynamics;

• Drilling trends, gamma ray, D-exponents, etc;

• Pressure while drilling (PWD) and equivalent circulating density (ECD) trends;

• Pressures and volumes; and

• Mud log data, gas or hydrocarbon levels, mud weight and lithological trends.

The typical real-time system has a multitude of tracks, all reflecting drilling trends and/or flat time conditions. Industry technology and efficiency gains have been so great that questions should be raised: Are we out-drilling our ability to properly recognize and address changing wellbore stability conditions? And are we allowing time to interpret the data? This is not to suggest we should slow down or lose efficiency but that we use data to facilitate reliable and safe operations. “Stop, look and listen” comes to mind.

The problem with the plethora of data available today is that viewing screens are limited, and numerous variables can influence the understanding and interpretation of wellbore stability. Further, complex drilling operations require more multidisciplinary input, such as earth science interpretations of changing wellbore stability model uncertainties.

All of this data is critical, and no single piece of data will necessarily yield a good decision. Rather, the totality of the data must be considered, and if the drilling conditions are changing, for example, increasing ROP, this could be a result of several factors and justifiably could lead to a "flow check."

However, what if the operation is "time" drilling with controlled ROP and the well is becoming underbalanced? What if the faster ROP is simply lithology-related and yet the mud weight is incorrectly increased? What if the well is being displaced with simultaneous operations, confusing pit volumes? How can real-time data be monitored and used to ensure process safety concerning test procedures?

The point is that all data must be considered. Complete and timely data interpretation is critical.

Figure 6: The industry has done a good job of improving personal safety by focusing on "slips, trips and falls," although efforts to ensure process safety have not been as robust.

Drilling management is risk management

Risk management is beginning to be recognized as fundamental to drilling management. No matter how robust the planning processes and procedures, wellbore stability models are still predictions that constantly change due to uncertainties inherent to the drilling process. Too often it is presumed that these changes do not impact the risks of achieving the overall well objectives safely and reliably. Real-time data can and should be instrumental in terms of recognizing and addressing changes, commonly referred to as management of change and the resultant risks.

Risk can't be eliminated, but it can be managed and mitigated. For example, using real-time data, stability models can be updated with actual drilling conditions and projected casing points can be changed.

Recognizing and addressing risks is an evergreen process, and real-time centers should be proactive in management of change and risk analysis. Lessons are only as good as the validating information. Trend changes should be important for developing any new or revised well procedures or programs going forward. For example, applying correct mud weights, rheology and general drilling dynamics in forward operations would make it less arbitrary and safer. Contrarily, misapplications of the same lessons can lead to inducing hazardous conditions:

Excess Mud Weight > Excess ECD > Ballooning > Losses > Mud Barrier Compromised > Potential Kick Follows > Well Control Operation

In this sense, drilling management must include a component of managing existing risks. The tool for this process is the correct use of real-time data, including constant monitoring, accurate interpretation and timely preventive actions.

Well managed operations do not necessarily correlate with procedures that will slow down the drilling and completion processes. For deep wells drilled in the Gulf of Mexico deepwater and ultra-deepwater, wellbore instability accounts for 26% to 56% of nonproductive time (Table 1). These numbers were derived from industry metrics.

Second, even with so much lost time, the industry is still experiencing loss of circulation, fluid gains, wellbore instability and other situations that can result in loss of well control or even total loss of the well. Careful management would only result in more efficient, less costly, safer and faster operations, not the opposite.

Undoubtedly, drilling uncertainties increase with complexity, which is all the more reason to stop, look and listen to the well and understand what has changed in the predictions and what current drilling conditions are telling us.

In 2008, several industry groups established a task force to define the work scope for a joint industry project to study BOP reliability experienced for wells drilled in the US Gulf of Mexico from 2004 to 2006. Although the results indicated improvements over time and even showed that subsea systems had lower failure rates than surface systems, the question still must be asked: Given the consequences of failure demonstrated by the Macondo incident, are the rates noted in Figure 2 acceptable?

To think past the Macondo incident, we must consider that the global deepwater rig fleet has increased by 300%. Have competency and reliability increased in the same manner? Are challenges and warning signs associated with persistent nonproductive time in deepwater operations being ignored? Why does the industry accept the current failure rate on BOPs and control systems?

There is also a degradation of failure rates by the more complex, deeper water systems as delineated by Class VIII systems, the most complex of deepwater systems.

The following issues should be addressed:

• Why are our critical systems so heavily people-dependent?

• Why do we accept these metrics?

• Why do we choose misperceived speed over the reliability of real-time data?

• Can the industry really expect to be safe with the current relationship model between operators and drilling contractors, between regulators and operators, and between operators and other service providers?

• Are we failing to recognize that the operator is in fact the operator and fully accountable?

To achieve process safety, industry must attain a paradigm shift. Well drilling operations, with all the risks and decision making involved, must not be the responsibility of one single individual but a process provided by a multidisciplinary team, driven as operator culture.

<u>Why is real-time data so important?</u>

First, all well control events are predictable, regardless of drilling margin uncertainties. That is, if drilling is not so fast, realities in the real-time data can be interpreted on a timely basis. Real-time data establishes drilling trends, which can be extrapolated to the extremes of failures to breaches of process safety. One simple example is exceeding the natural fracture gradient due to overburden of the well. No amount of wellbore strengthening can holistically overcome a breached fracture gradient. Well control becomes hierarchical:

Excess Mud Weight > Excess ECD > Ballooning > Losses > Mud Barrier Compromised > Potential Kick Follows > Well Control

There are at least five key tiers of RTD that are critical:

1. Establishing bandwidths of alerts and engaging STOP actions when necessary.

2. Establishing safe design limits of tool operability within the confines of given well operating bandwidths, for example:

a. Hole cleaning PWD/ECD;

b. Hole-section tolerance STOPs to safe limits when approaching either boundary of the drilling margin, that is, the low side of pore pressure/stress and the high side of fracture gradient. In the US Gulf of Mexico, this is a regulatory requirement;

c. Limits for exceeding tool design limits and trends, such as motor pressure differential;

d. Tool design limits, such as reaming and drilling connection or tool torque, or float collar conversion pressure differential limits.

3. Establishing intelligent agents, driven by levels of alerts. For example, torque spikes normally increase with trend tracking to underbalanced conditions, a potential breach of primary barrier, and conversely, ROPs trend increase. Taking each separately, one might think that there is a bit or BHA problem with torque issues, or that drilling lithology changes are promoting

improvements in ROP. Taken together, however, an entirely different interpretation can emerge: The well is becoming underbalanced, and the hierarchy of well control is about to become reality.

There is, of course, a plethora of combinations of intelligent agents; nonetheless, if one is to ensure process safety, they cannot be ignored.

4. BOPE, casing and casing seat tests, particularly related to hole section MASP.

5. Monitoring barrier removal and replacement and ensuring avoidance of well control events at all stages of operations.

Any change in any of the above could initiate STOP actions, constitute management of change and certainly impose new risks that must be analyzed and evaluated.

Embracing these changes requires a paradigm shift in drilling and completion operations. On the surface, it will be opined that these changes will add enormous time to drilling and completing, but the reality of not engaging the full capabilities of RTD has a cost far greater than misperceived drilling speed and efficiencies. In fact, it can be argued that the reduction in NPT would already more than pay for any time spent verifying and ensuring process safety while drilling.

As Figure 9 shows, as water depth increases, the number of days with wellbore stability increases, particularly in a sub-salt environment. Any event of wellbore instability has the potential of becoming a well control event.

Events related to wellbore instability	General populations: 263 wellbores <600 ft of water	65 subsalt wells: WD > 3000 ft	99 non-subsalt wells WD > 3000 ft
Stuck pipe	2.20 %	2.90 %	0.70 %
Wellbore stability	0.70 %	2.90 %	0.90 %
Loss circulation	2.30 %	2.40 %	2.00 %
Kick	1.20 %	1.90 %	0.80 %
Total (%)	6.40 %	10.10 %	4.40 %
Total wellbore instability (days)	2.24 days	9.797 days	2.376 days
Total NPT* days	**4**	**29**	**9**
Instability % of NPT days	**56.00 %**	**33.78 %**	**26.40 %**
Average days to drill	**35**	**97**	**54**
Kick days	**0.42**	**1.843**	**0.432**

Table 1: For deep wells drilled in the US Gulf of Mexico deepwater and ultra-deepwater, wellbore instability accounted for 26% to 56% of nonproductive time. Procedures that ensure well-controlled operations do not necessarily slow down the drilling and completion process but should lead to more efficient, less costly and safer operations.

Impact on indispensable work force

The US Geological Survey (USGS) began certified training for offshore supervisors in drilling and production in 1979 that instructed rig workers that they have ultimate responsibility, and they have known for years they have authority to STOP work if they recognize an action that could lead to an accident or loss of well control or release of hydrocarbons. These training sessions instructed offshore workers that even if orders came from shore or a supervisor, an unsafe operation should be shut down and they would not be reprimanded for overriding instructions.

Throughout Gulf of Mexico operations during the 1970s into early 1982, however, the USGS had no real power to back up the offshore work force.

In 1982, the US Department of Interior created the Minerals Management Service. The oil bust drastically reduced the offshore work force, and most training programs created during the 1970s got shelved. Larger operators created newer safety programs focused on “slips, trips and falls,” and by and large the industry has done a good job of improving safety in that regard.

However, efforts to ensure process safety have not been as robust. The work force should be able to suggest or even demand STOP with confidence where potential breaches in process safety are recognized. These personnel are well trained for the most part and often recognize what seems to be the right thing to do. However, they are often reluctant to react or question authority. Ironically, this not only applies to our work force in general, but now, even high-level manager and engineers are being sequestered or threatened with criminal actions. Therefore, this dilemma reaches across the industry at all levels.

Efforts are ongoing to improve environmental compliance, such as the Marine Well Containment Corp and other groups improving containment and spill response equipment. Undoubtedly, these efforts well help the environment in terms of containment, but not in cases such as breach of the entire external casing system. The ability to holistically contain any blowout is an engineering design issue, and averting kicks is an RTD best practice issue that should be embedded in well plans and procedures. Eliminating blowouts altogether during drilling and completions operations is a matter of engaging tried-and-proven practices through robust use of RTD.

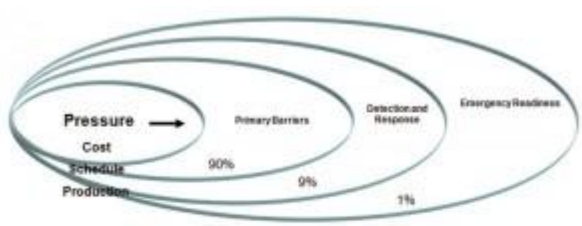
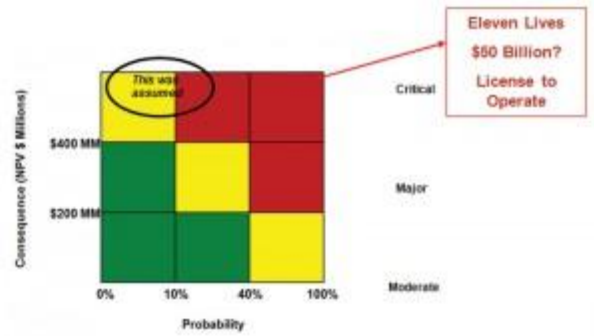


Figure 7 (above): This model presented at a 2010 industry conference was used to explain to senior management the principles of well control and how it relates to process and personal safety. To keep people safe, barriers must be maintained to safeguard against unintended releases of pressure, hydrocarbons, noxious gases or stored energy. Figure 8 (below): Lives and billions of dollars were lost in the Macondo incident. To prevent the same incident from happening again, the industry must look to a paradigm shift in terms of real-time data monitoring and utilization. Complete and timely data interpretation will be critical to good decision making.

Conclusion

The basic physics of drilling has not changed, but as the industry embarks on this new domain of deepwater well complexity, the basic methods of communicating and even thinking and processing data streams on smartphones and with laptops presents challenges to basic human communication, yet also offers immense capabilities that could not be imagined just a few years ago.

Process safety introduces a new concept to offshore workers. It is a core belief that must be transmitted from the CEO and board of directors down through shore management and engineering to offshore rig workers that everyone across company and contractor company lines must work at the speed of safety, not the expediency of profits. Speed has proven not only counterproductive but counterintuitive. HSE professionals can verbally define process safety, but it will take time for each company to understand and institute it.



People are being encouraged to speak up if they notice an unsafe operation regarding personal safety, but as Macondo proved, that is not true of process safety. Employee voices must be heard. Many simply lack the confidence in their knowledge of the total operation, and there are many others who lack basic knowledge of what these complex operations entail. This is another reason why RTD is so critical in regard to ensuring process safety.

The need for onshore RTD monitoring centers for operators, service companies and government regulators has never been greater. There is a real need, even a demand, for a second set of eyes to be watching for changes in the drilling parameters to help the drilling crews and loggers avoid the kicks and well control situations. Proactive intervention enables well control avoidance and minimizes well control events. Merely reacting to well control situations is not acceptable.

As the industry embarks on this new domain of deepwater well complexity, RTD monitoring centers can provide the safety cushion as the aging seasoned drilling professionals work to prepare the next generation to lead on this new frontier in upstream operations of the Golden Zone of Hydrocarbons.

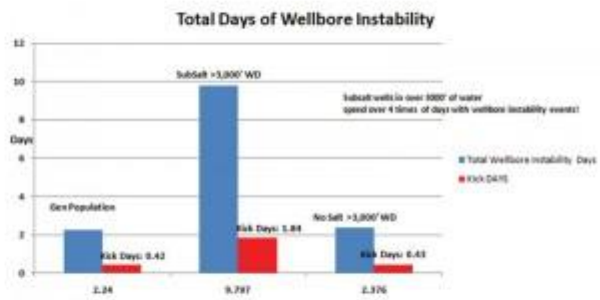


Figure 9: As water depth increases, so do the number of days with wellbore stability, particularly in a subsalt environment. Subsalt wells drilled in over 3,000 ft of water have more than four times the number of wellbore instability days.

Finally, offshore workers are struggling to understand personal safety and process safety while dealing with the challenges of new company and client expectations. Safety is a huge issue, but the question is not new: How safe is safe enough? With every mention of Macondo on the news, the trauma is reawakened. The irony is that, until the industry addresses systems reliability completely, beginning with robust well monitoring, continual re-awakening is exactly what is needed until cultures change, and that begins in the boardrooms.

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