SPE/IADC-221426-MS

Evolving MPD with Human Factors Approach

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This paper was prepared for presentation at the SPE/IADC Managed Pressure Drilling and Underbalanced Operations Conference and Exhibition held in Rio de Janeiro, Brazil, USA, 17 – 18 September, 2024.

Abstract

MPD technique has been successfully used to enable drilling in harsh environments. Despite the benefits, it is still seen with some skepticism in scenarios where it is not mandatory. In part due to the MPD failures observed and the added complexity of MPD application, when compared to conventional operations.

During the evolution of the technique, with increased complexity and more challenging scenarios, a great effort has been applied to develop better training and competency of the teams, since many failures can be directly linked to human error.

However, a better look should be given to the technique with a Human Factor approach. Can we really expect human not to failure in a challenging scenario with a complex technique? Although great effort was made in building competency, human error still continues.

Training plays an important role on the MPD, but other aspects should be considered, such as: communication, responsibility for the task, suitability of the procedure to the task, among others. Therefore, it is crucial to consider other contributing factors like organizational (and industry), technological and environmental.

This paper presents human errors collected from more than 100 wells drilled in deepwater and proposes a complementary interpretation of the raw causes with focus on human factors, beyond the need for training. It shows that human errors are often the sign of organizational or technological issues and proposes methods to mitigate them.

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Introduction

Since beginning of drilling its complexity has increased substantially. Nowadays, the deep and ultradeep water presents a great complexity and low margin for errors, since any accident could be of catastrophic dimensions.

In the early days, while drilling was conduct by small teams with knowledge of the whole process, today it depends on different teams on the field and others onshore. A simple Bottom Hole Assembly (BHA) with bit, drill collars and heavy weights, used in the past, was enhanced with the addition of high technology tools.

In ultradeep water, equipment needs to work in higher pressure environments, with bigger dimensions, leading to more expensive operations.

With such an expensive operation and potential catastrophic outcome in case of failure, every project must be extensively studied prior to any equipment construction and operation, using failure analysis to identify risks and avoid (or mitigate) then.

Although the last paragraph says some basic understanding of what engineering is here for, there is still a gap that is usually not covered in the designing of equipment or planning operations: human error.

Thus, when failure analysis is conducted after an accident happens, the root cause frequently appears as human error and the accident investigation ends with some recommendations for training, substitution of the employee, add more items to procedures or the addition of some other useless safeguard.

The question that remains is: since we keep training the crew to the exhaustion, why mistakes continue to happen? This paper goes beyond the common interpretation of accidents root causes. It presents human errors collected from more than 100 wells drilled in deepwater and proposes a complementary interpretation of the raw causes with focus on human factors, beyond the need for training. It shows that human errors are often the sign of organizational or technological issues and proposes methods to mitigate them.

Drilling Evolution and Complexity

Drilling is basically the same as it was 50 years ago with rotation, circulation and hoisting systems, and the fundamentals that govern drilling practices have not changed (Johnson et al 2014). Though the fundamental drilling systems have remained, the control systems that are used to drive and operate the drilling systems have radically changed.

The evolution from onshore operations to offshore and then to deep water was possible due to limps in technology available (or developed). Nowadays, exploring ultradeep water fields still brings several challenges for drilling activities.

As deep as the water depth gets, each time it is necessary to increase subsea equipment robustness, followed by a better control system. It can be observed by the necessary change that occurred when passing from hydraulic actuated BOP to multiplex one. Riser string is getting heavier while needs to support its own weight and to have a high collapse capacity.

The increasing rigs capacity to operate with such heavy equipment and with contingency systems to avoid (or mitigate) accidents makes then more expensive and more complex.

In these scenarios, contingency systems are essential, since some offshore wells with capacity for producing over 60.000 bbls/d could lead to a catastrophic event with minimal mistake.

It is easy to go further on this analysis and through BHA evolution with high technology tools, mud designs, among others, to exemplify the evident complexity increase in the recent years.

When all the previous components are combined, it becomes evident the actual complexity of drilling operations. To control and operate all these systems, the teams are segmented in order to have specialists for each task, resulting on the creation some interface issues among each team.

MPD system and operation take it to another level, since highly integrated systems are required (Johnmorten et al 2010).

To deal with the increasing complexity, companies tend to standardize exhaustingly and each time there a more procedures being created, and more points of attention are added to the ones that already exist. The problem is that you often need humans to read, interpret and act based on these procedures. So, there is no surprise when something is done different from what it was intended.

Failure Analysis on MPD Operations

Drilling and engineering have evolved substantially, and risk analysis are always conducted to avoid and mitigate risks in offshore operations. A MPD ready rig, for example, has many equipment and lines different from a conventional one (figure 1) and integration of all these equipment is a matter of concern for the industry (Hovland et al 2017). This adaptation is always preceded by HAZID/HAZOP, in order to take into account all the risks associated with the new system and equipment.

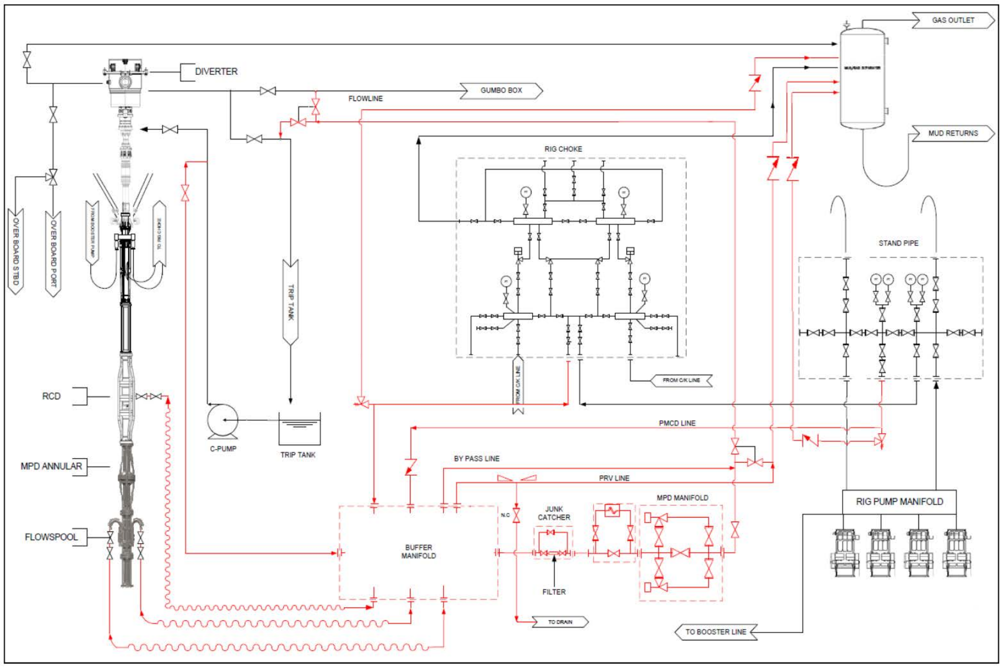

Figure 1—General Piping and Instrumentation Diagram

A new equipment built also goes through the FMEA/FMECA. BOP and other equipment have their maintenance based on reliability analysis. Companies runs exhaustingly tests on MPD Control Systems prior to its use (John-morten et al 2010).

Operations have its risk analysis prior to spud in and other Job Safety Assessment whenever something goes different from what was planned.

Nevertheless, none of these analyses consider human error as what could possibly go wrong. Thus, they fail to propose measures to avoid failures over a human factor approach, it means, since humans are part of the system, they will act and response according to the context in which they are.

Human Error Historical Data

To analyze MPD operations in a more profound manner, data from more than 100 wells was gathered. This data was used to analyze the whole historical data. When data is presented for the recent years, the assumption is made that from this point and beyond, all MPD suppliers (and drilling contractors) and Petrobras teams have had enough training and technology was mature enough.

One key aspect of data collecting that allow this analysis is to gather all data from failures, with or without NPT and segregate then according to MPD utilization, i.e., when it is part of the first barrier or not, and if the error result in loss of well integrity. These invisible occurrences (that do not impact on NPT) make it possible to analyze the system in a more profound manner.

Although these failures are important to be analyzed for all operations, when MPD is part of the first barrier it becomes more important, since the loss of wellbore pressure will result in an influx. Figure 2 presents data for human errors for wells drilled since 2020, in which MPD was part of the first barrier. Human errors represent 24% of the total events (figure 3)

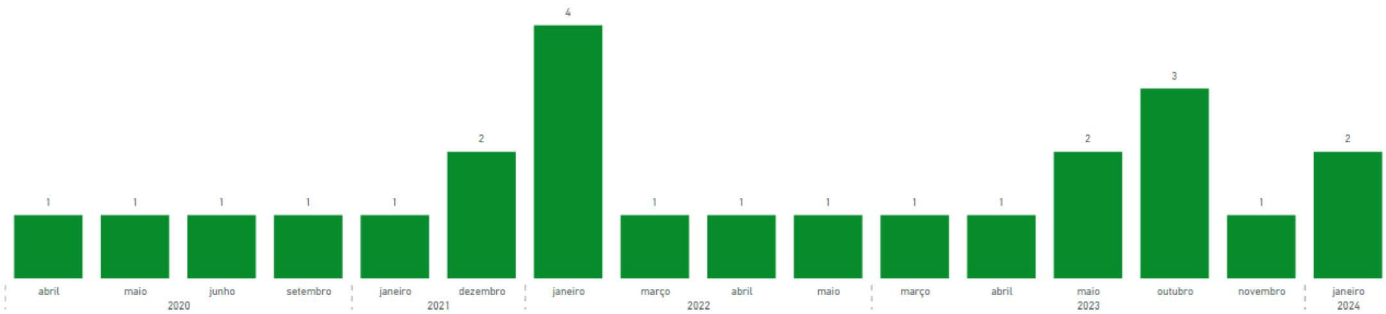

Figure 2—Nº of human errors events when MPD was part of first barrier

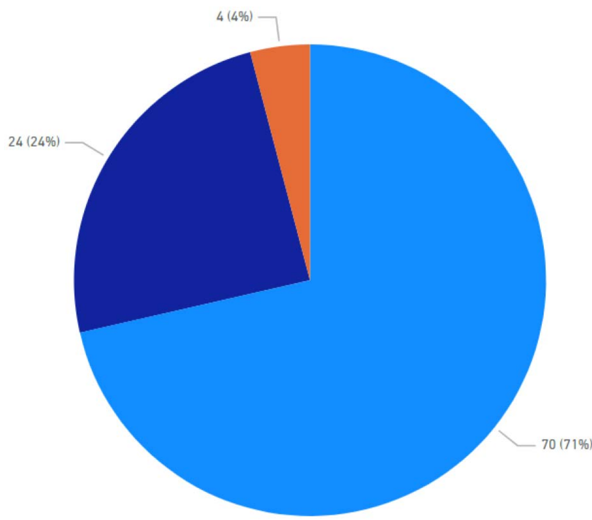

Figure 3—Failures in MPD as first barrier: 24% Human; 4% Project; 71% Equipment

Nevertheless, not all of these occurrences result in loss of the primary barrier, due to MPD system robustness, as showed in figure XX. When an error occurs, even with MPD as part of the first barrier, Control System can overcome most of the problems. Still, it is important to notice that human error is responsible for 37% of total events when first barrier is lost, i.e., it has a higher impact on maintenance of well integrity in comparison with its impact in total number of failures (figures 4, 5, 6).

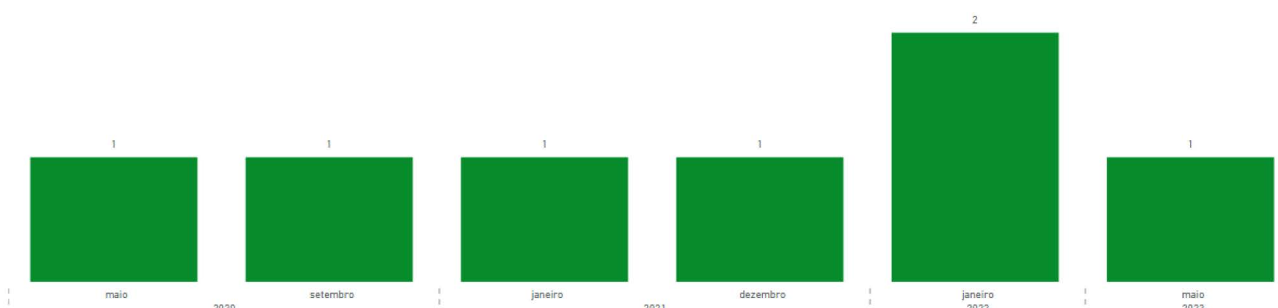

Figure 4—Nº of human errors events when first barrier was lost

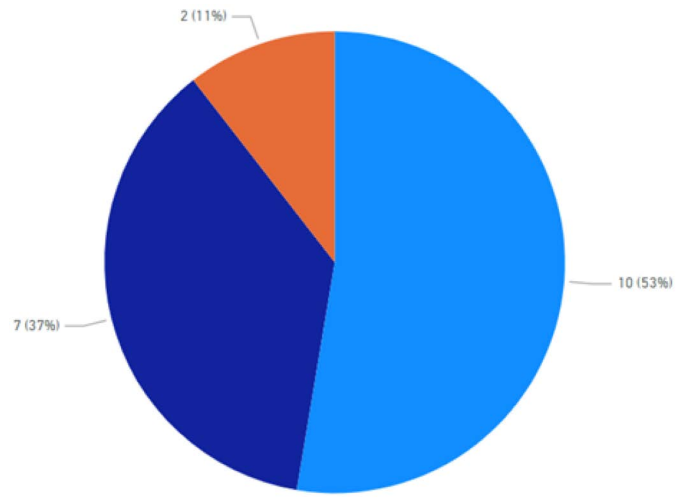

Figure 5—Failures in MPD when first barrier is lost: 37% Human; 11% Project; 53% Equipment

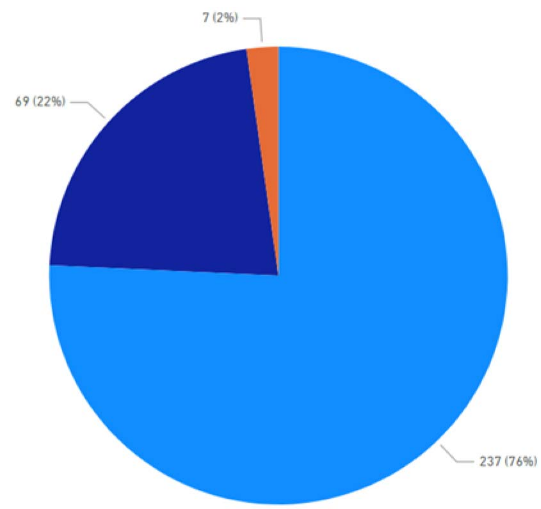

Figure 6—Total MPD failures: 22% Human; 2% Project; 76% Equipment

From 2020, MPD on DP rigs was more mature and the industry was ready to carry on in a more structured way: training requirements was increased for suppliers of the service. Rig crew was being trained not only in classroom, but also on simulators. Standardizes had been realized (API 92s, API 92M) and all necessary internal procedures were available. The number of operations had increased, as it can be seeing in figure 7.

Despite all of this effort, we see the same number of human errors occurring now and then (figure 8). In this figure, NPT due to human error is represented as percentage of total MPD time of the wells. Errors in operations continues to happen and does not seem to be decreasing. Which raze the question: Is training and procedures enough to avoid human error?

Figure 9 shows data from 2020 for all human error events (with or without NPT). The first interpretation would be that the assumption that MPD is a mature technology should be questioned according to the chart. But this paper offers a different alternative: the tools used to develop human competency cannot avoid or mitigate errors in the actual stage of development.

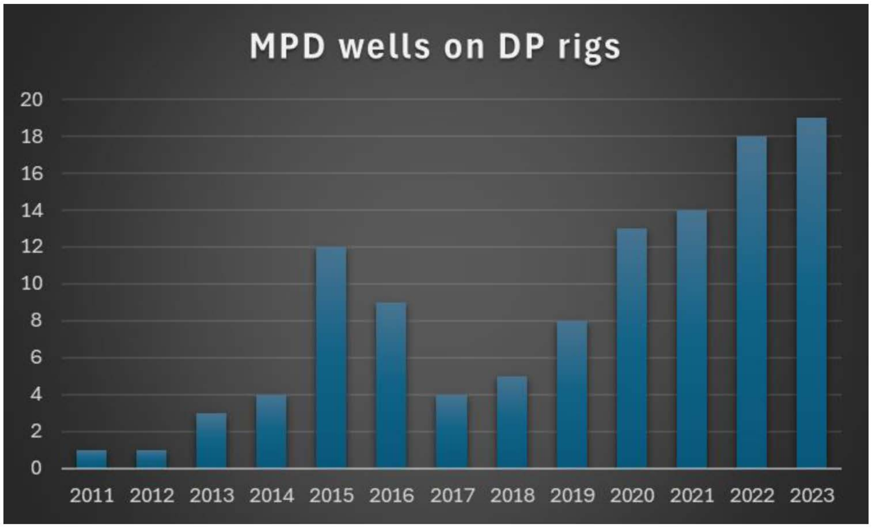

Figure 7—Number of MPD wells since 2011

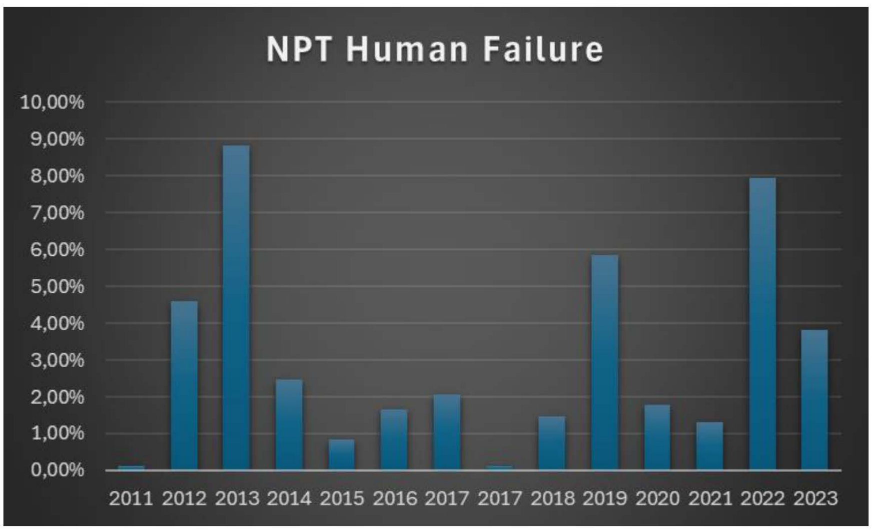

Figure 8—NPT due to Human Error as percentage of total MPD time

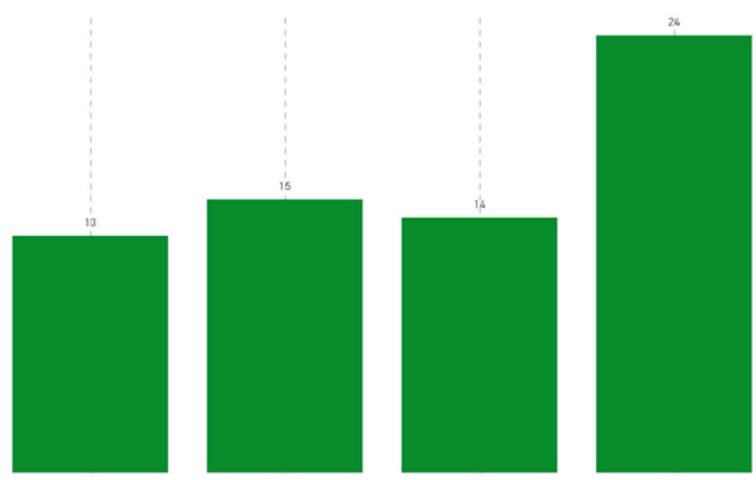

Figure 9—Total MPD Human Errors

All data presented shows that with the actual approach for human errors it is only possible to get to a certain level of performance. Training the teams in classroom and simulators allowed to increase substantially the performance and mitigate errors but cannot guarantee absence of mistakes. If the objective is to eliminate them, other approach should be made.

Limitations of current solutions

The solutions commonly brought to mitigate human error are increase training of the crew and include requirements and observations in procedures. As discussed before, it does not change the possibility of the failure to occur, rather it tries to increase robustness of the last barrier, that is the operator.

Since human cognition is limited and it is impossible to account for all the possible outcomes on the operation, it is utopic to believe that human will have enough time to read (or watch) failure reports, understand what was read, absorb the information and apply to subsequent operations. With the increase in complexity discussed before, there is not enough training time that can guarantee absorption of all this knowledge.

The inclusion of all notes and observations to the procedures are also of limited benefit to operations, and an extensive discussion can (and should) be made whether to increase or decrease quantity of information on it. On one hand, having it with detailed information allows the person to follow step by step, avoiding missing any small action needed. On the other hand, worker will rely on following only what is written, and will not be aware of other issues that might impact on the job or might appear during execution. Besides, shortcuts tend to take place when many successive actions are needed.

To exemplify the limitation of this approach, let's use the RCP measurement as an example. This operation requires pressure loss being measured in choke and kill line while drilling. MPD system uses flow in measured in the mud pumps and calculates pressure loss in annulus, to apply Surface Back Pressure (SBP) to maintain a Constant Botton Hole Pressure. Thus, the correct calculation for the annulus friction loss relies on the correct input on the flow in. Historical data shows that, sometimes, a mud pump aligned to the choke line was incorrectly set (by the operator) in MPD control system as pumping through the drillstring. It induces the system to miscalculate the SBP required and reduces BHP, leading, sometimes, to an underbalanced situation.

Analyzing these cases, it was noted that MPD operators was experts and well trained, and procedures was also very complete and had this observation written. So, what would be the explanation for this event?

Rather than blame operator, it was implemented a screen showed in figure 10, making it possible for the driller to check visually if the correct pumps were set in MPD system. Since then, this error ceased to happen.

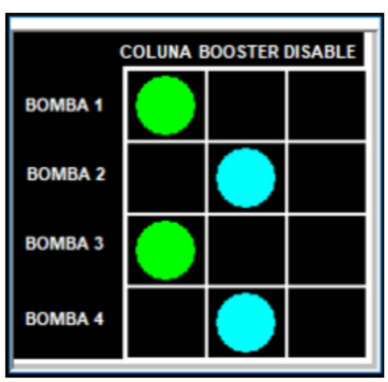

Figure 10—Screen implemented in drillers cabin

Human Factors Approach

In short, Human Factors is a concept related to individual, social, technological, organizational, and contextual factors which can influence human performance in all organizational levels (IOGP, 2022). A Human Factors approach can be applied to well operations regarding to identify what issues make the work difficult during daily job. A possible strategy is underpinned by Social Science by adopting interviews and/or focus groups.

Understanding how people cope with complexity, ambiguity, and uncertainty during normal operations is paramount to shed some light on improving opportunities (Conklin, 2012). Moreover, a Human Factors approach may contribute to a proactive approach to organizational learning while opening room to opportunities for success. Indeed, an organization must pursue its goals, what the organization wants to survive and create wealth for stakeholders (Ackoff, 1998).

In this spirit, Human Factors is a philosophy towards embracing business complexity and cooperation among stakeholders and the organization, understanding why people do what they do and the way they do it. In such a reasoning, solutions for the challenges people face need to be designed in a systems approach manner, considering how the relations between the parts would be affected along with the operations (Dekker, 2011).

Despite the fact that this paper focus on automatic MPD system, it is surprising how much can be improved with this approach. As discussed before, MPD complexity makes it impossible for one person to be totally aware of all the MPD particularities in an operation. Thus, communication and interface between teams are extremely present. Besides, different teams take care of different parts of MPD system, leading to the certainty: At some point, the action expected will differ from the action intended in the procedure.

Real Case Study

A Human Factors approach starts considering that accidents are not anomalies but responses from how a given system is conceived and operated. Furthermore, every complex system like an organization operates under constraints, scarce resources, pursuing multiple objectives, attempting to reconcile conflicting goals. Then, successful or not outcomes emerge from the very same source: the banality of daily life (Vaughan, 1996).

The above-mentioned idea guides the Human Factors approach towards a humble and curious inquire, attempting to explore what makes the job harvest. In other words, the Human Factors strategy remains on understanding normal work and addressing systems thinking solutions. The following example may illuminate this issue.

A dynamic positioned 6th generation drillship was in cold stack and had been hired for a 4-year contract. During his first drilling operation, a 170 bbl salt water kick (of great intensity) was noted, and the well was closed in 16 minutes. The maximum allowable influx volume was defined on 10 bbl. The traditional investigation model would seek for previous failures while looking for answers and, probably, culprits. In short, a big problem stems from several small ones. Differently, a Human Factors approach will study how the emergence of such an event makes sense regarding the history and context involved.

Interviews were conducted with practitioners at different companies and organizational levels, leaving room for a plurality of perspectives (Morrison & Milliken, 2000). Then, interviews were analyzed using proper techniques, seeking for regularities and cues related to understand normal work. The following story was socially constructed by interviews and information:

The rig was out of contract in the past two years and was rehired by the same client. There was only a minimal maintenance team onboard. The rig navigated to a new location, closer to the client base. An almost entire new crew was hired, including the drilling department crew. At the same time, the client was developing a new growing business plan, also contracting another two new drillships from the same contractor, increasing the market competition for workforce.

In such a reality, more time was demanded by the contractor to fill the onboard positions, including a call for some people off of the market for a while. There was a challenge to turn a group into a team, because they had never ever worked together, coming from different companies or unemployed period. During the rig preparation process, some disagreements arose, and more personnel changes were made, increasing the turnover.

Moreover, there was a need to update the modern drilling system, which was totally new for part of toolpushers, drillers, and assistant drillers. To make things more complex, a MPD system was being commissioned and planned to be used during the first well of this drillship. The rig navigated to drill the first well in the client´s bigger oil field, expecting to deliver the well construction on time due to production schedule.

The drilling operations started and the salty sector above the production zone was planned to be drilled with MPD assistance. This strategy was defined because this was the first drillship´s operation with a new crew. Even the company men had the basic MPD theoretical certification, without previous practical experience. So, the drillers. It is not mandatory to drill the salt sector with MPD, because no influx is expected. The MPD availability was provided to increase the crew expertise on MPD ops.

During the night, the drilling operations were in normal settings. The mud engineer ordered the derrickman to transfer some amount of mud from the active tank to another mud pit. It is normal. At the same time, the MPD operator noted an increasing volume variation in the active tank and discussed this issue with the driller. However, because the mud transfer, which both MPD operator and driller were not updated by the derrickman. The company man joined the discussion, lasting for another 5 minutes. During this period, the driller was attempting to recover playback information to make sense on what was going on.

Finally, the MPD supervisor arrived at the dog house and shout to the driller to close the well. The driller did it. The final amount of influx was calculated 170 bbl of salt water in 16 minutes. A traditional investigation may point out a driller´s human error, proposing actions like a stand down for safety, more training, adding more details to a procedure, and so on. In sum, it makes the sharp-end people feels guilty by naming, blaming, and shaming them. Differently, a Human Factors approach recommends improvements at the systems level, seeking for collaborative recommendations – because an individual alone cannot move a whole system.

The central question underpinning this investigation is "how does it make sense?" There is not a single answer, but several contributing factors as follows:

- **Team Building:** The onboard group acted as a group instead of team, regarding the small amount of time available to develop it.
- **Expertise on handling new equipment:** the recent drill system upgrades require more time of practice to become an expert.
- **Expertise on MPD operations:** despite drillers and company men being formally certified on MPD ops, it was their first contact with real MPD field operations.
- **Standard phraseology:** the informal way communications are normally handled in O&G industry impaired the understanding of what was going on. Moreover, drillers cabin should have a layout that allows the communication between driller and MPD operator.
- **Sterile cockpit:** the environment of the doghouse is normally prone to distractions while allowing anyone to get in.
- **Crew change practices:** each group discuss specific topics by its own, creating an environment of structural secrecy (Vaughan, 1996).
- **Awareness of salt kick possibility:** All safety analysis pre job had the risk of kick in the salt layer mentioned. Yet it was not observed during drilling, i.e., crew did not believe the parameters were really indicating an influx, rather than some misalignment or transference between tanks.

- **Driller overload:** The amount of information the driller receives makes it impossible to process and absorb all of them. The addition of MPD equipment and procedures makes it more challenging.

There were several recommendations. However, this work will highlight two due to its broadness and political difficulty to negotiate because of the number of stakeholders involved and the effects on the project budget. The recommendation was written as follows:

When drillships coming from a cold stack period, it is mandatory to perform a warm-up period, revenued by the client. The duration and complexity of the warm-up will depend on the planned rig schedule.

The above recommendation focused on the three first contributing factors listed. It supports the purpose to enhance the relation between diverse actors and stakeholders ahead of the first well. As discussed previously, the scenario of ultra deepwater drilling involves a great number of companies (drilling contractors, service providers, supply chain) and also risks.

The implementation of the recommendation is somewhat difficult because involves stakeholders with multiple and conflicting goals. Changes must be made on organizational level. Indeed, it is a political arena. Actually, the discussion is ongoing.

Conclusions

Although drilling remains basically the same after so much time, Managed Pressure Drilling in DP rigs brings an increase in operations and equipment complexity. This complexity requires competencies that overcome human capacity and try to cover this gap with increasing training hours or numerous procedures have shown to be unsuccessful.

Despite the importance of training and procedures, they are limited when it comes to human errors, since human behavior and decision-making will depend on the job being performed and environment, with its complexity, ambiguity, and uncertainty, as presented in previous sections.

In this scenario, it is important to guide human behavior by changing the context in which they are. It means approaching unintended events understanding why people acted the way they did and what led to that behavior. To do so, it is necessary to analyze the daily job and what are the difficulties faced by the crew.

At some level, organizational and cultural changes must be made, not only in MPD operations teams, but also in the company and industry.

The paper presented an alternative interpretation for human errors and proposed an alternative for avoid or mitigate them. Rather than consider MPD an immature technology or that we are not there yet, it is proposed that the tools being used to develop human competency are not sufficient for what we intend.

Moreover, this shows that the actual approach for human errors it is only possible to get to a certain level of performance. Training the teams in classroom and simulators allowed to increase substantially the performance and mitigate errors but cannot guarantee absence of mistakes. If the objective is to eliminate them, companies should pursue human factors approach and maybe some organizational and cultural level of change might be necessary.

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