GOVERNMENT OF WESTERN AUSTRALIA

WorkSafe Western Australia Petroleum Safety

INFORMATION SHEET

Human factors: Case study – gas well blowout and fire

1 Introduction

This case study is based on the explosion and fire at the Pryor Trust Well in Pittsburg County, Oklahoma in 2018. This major accident event had catastrophic consequences as five workers were killed. The aim of this case study is to show how human factors can contribute to a series of events that lead to a major accident.

This case study details the accident that occurred, how human factors contributed and what corrective actions can be made to improve the overall effectiveness of the operator's safety management system.

2 Incident description

Onshore drilling operations were being conducted to extract natural gas from a reservoir. The site had good engineering controls during normal operations, which included the use of drilling mud (or drilling fluid) to aid in the creation of boreholes.

The drilling mud or fluid is pumped through the drill pipe at a pressure equivalent to the formation pressure to prevent formation fluids, such as gas, entering the wellbore from the reservoir/formation.

Operating conditions of drilling well based on formation and hydrostatic pressure

Safe/controlled drilling condition Formation pressure closely resembles hydrostatic pressure. Hydrostatic pressure prevents the escape of flammable gas/liquids. Drilling fluids will not be lost within the formation. Likelihood of well blowout is minimised.	
Underbalanced drilling Formation pressure greater than hydrostatic pressure. Flammable gas/liquids from the formation will enter the drill hole and escape with the drilling fluid. May result in a well blowout.	**Overbalanced drilling** Formation pressure less than hydrostatic pressure. Drilling fluid will enter the formation and as a result, drilling fluid will be lost. May result in a well blowout.

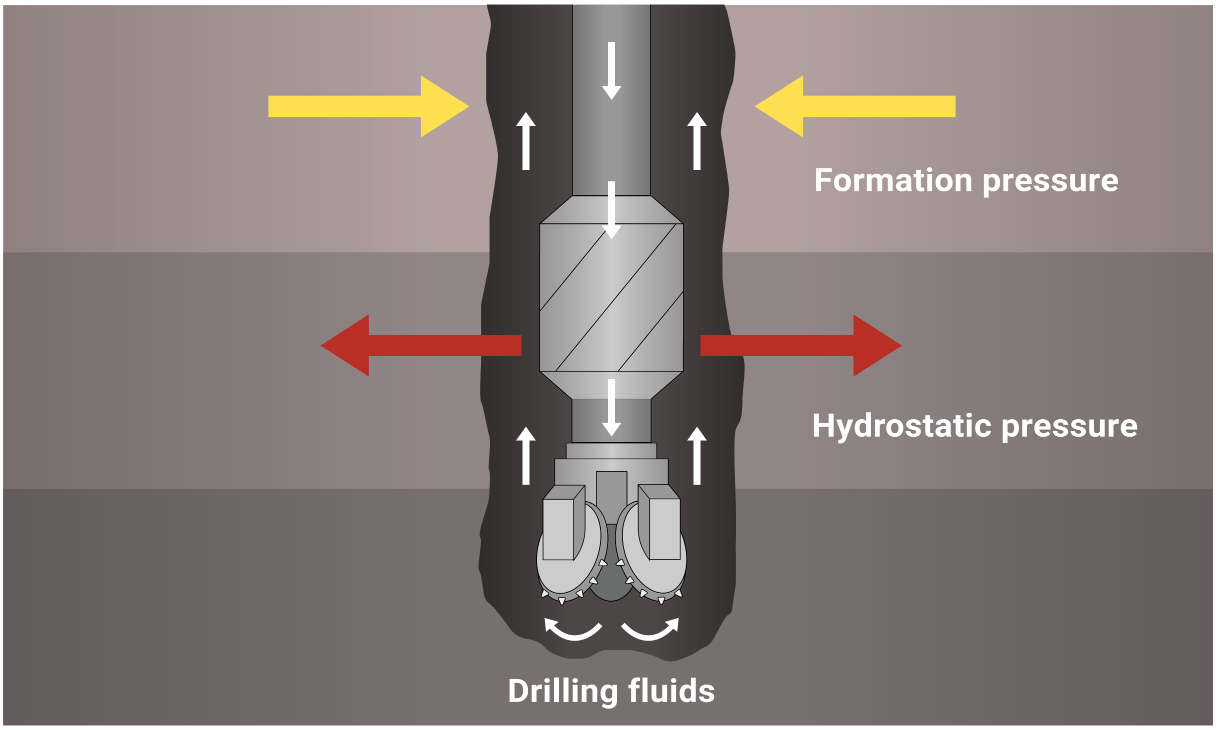

Diagram of drilling process using drilling fluid to create boreholes

During drilling operations, workers noticed elevated gas readings indicating gas had entered the well from the surrounding rock bed and was reaching the surface. As the gas reached the surface, it caused mud to spit out of the possum belly (flow line discharge tank), covering the rig and other equipment. To correct this, a decision was made to align the mud piping so that the extracted mud was routed to the mud gas separator. This activated the flare to ignite and dispose of the gas, which was reported to be around 6–9 metres high.

Drilling continued, despite continuous flaring, until the workers had to stop to remove and change the drill bit. Prior to removing the drill bit, the drilling crew circulated the well by pumping mud down the drill pipe and up the well to the surface. At the end of the circulating process, gas was still entering the well and returning with the mud to the surface, causing continuous flaring. This indicates that the mud pressure could not prevent gas from entering the wellbore and that the well remained underbalanced.

Preparation of weighted pill

After circulating the well, workers planned to add a high-density fluid, known as weighted pill, above the top of the well to increase pressure in the wellbore and overbalance the well. The drilling engineer and two workers determined the size and density of the pill; however, there was a miscalculation and the weighted pill only replaced approximately 36 per cent of the annular pressure loss, meaning that the well would still be underbalanced after the pill placement.

Further to this, workers were told over the radio to make a 50-barrel 10-pound-per-gallon pill, but the communication was misunderstood and workers began preparing a 10-pound lost circulation material (LCM) pill instead of a weighted pill. Another worker noticed this mistake, but instead of starting over, weighting material was added to the already prepared LCM pill.

It is unknown if this work was endorsed by a competent person as the work crew was under time pressure as the well was underbalanced. There were no written work instructions to communicate safety-critical parameters, such as pill type and composition.

The drilling crew proceeded to pump the weighted pill into the wellbore at the required depth. After installing (spotting) the pill, a flow check was performed. This passed meaning it showed no gas flow. However, post incident review indicates that this was incorrect and a small flow of gas was occurring during the check.

Gas continued to enter the well and the pill did not produce the required hydrostatic pressure to prevent a gas blowout. As such, the well remained underbalanced as the control was not correctly in place.

Tripping out of well

Workers proceeded with tripping out the well (process of pulling the drill pipe from the well) to replace the drill bit. During this procedure, the workers were required to interpret data to ensure that the volume of the drill pipe being removed was replaced by mud in order to maintain adequate mud pressure in the well.

However, the driller was not effectively trained in using the new electronic trip sheet, which was used to help monitor for gas influx, and equipment was aligned differently than normal during the tripping operation. This caused confusion in interpreting the well data. Workers missed indications of the gas influx on several occasions, and failed to identify low mud volume and low mud pressure in the well.

Shortly after removing the drill bit from the well, workers saw that mud was shooting up steadily and getting closer to the rig floor. The driller told the rest of the crew that he was going to close the blind rams (emergency shut down), but before he could do so, the diesel oil-based mud and escaping gas caught fire.

Both the day shift and night shift drillers had deactivated the entire alarm system, due to nuisance alarms, which had also contributed to workers missing critical indications of the gas influx and imminent blowout. The alarm system had been sounding excessive non-critical alarms during the 14 hours prior to the blowout.

Five members of the crew were in the driller's cabin during the blowout and became fatally trapped by the fire as there was no safe escape route.

3 Findings and recommendations

Upon review of the investigation report, the following human factors were identified to have played a role in the accident.

Human factors

- Managing human reliability
- Training and competence
- Safety-critical communication
- Staffing and workload (including supervision)

The drilling engineer decided to use a weighted pill to provide additional hydrostatic pressure to the well. Together with two other workers, the drilling engineer calculated the pill size and density needed. The miscalculation of the size and density resulted in the pill failing to replace greater than the pressure loss exerted while removing the drill, meaning the well remained underbalanced (i.e. natural gas was still entering the wellbore).

This involved a knowledge-based mistake, as it was not recognised that the calculated weight and density of the pill would be insufficient to overbalance the well and stop the flow of natural gas into the wellbore. This error could have been prevented if written work instructions, which clearly outlined safety-critical parameters such as pill type and composition, were available.

The method chosen to rectify the issue was also not subjected to a supervisory review. This may have resulted in the issue being identified before the major accident event could occur.

The parameters for the weighted pill were communicated over radio and the communication was misunderstood with workers incorrectly preparing an LCM pill. This error could have been prevented by using standardised radio communication protocols for communicating safety-critical information.

Corrective actions

Managing human reliability:

- Conduct independent verification of safety-critical calculations.

Training and competence:

- Ensure training and competencies in site-specific equipment and skills are maintained.

Safety-critical communication:

- Implement radio communication protocols for communicating safety-critical information, such as 'repeat-back procedures'. This helps to commit information to memory and provides an opportunity for the sender to identify that the message has been understood correctly and to correct any error.

Staffing and workload, including supervision:

- Ensure that individuals on shift have the necessary competencies to complete the task.
- Review supervision resources to ensure an appropriate level of supervision is provided for the tasks being undertaken.

Human factors

Usable procedures

Training and competence

The drilling rig was having difficulty in controlling the gas pressure and a number of measures were implemented, which included changing the composition of drilling mud and using weighted pill. However, all these safety-critical tasks were incorrectly considered to be routine operation.

Drilling continued with flaring around 6–9 metres. Crew members proceeded with removing the drill out of the wellbore to replace the drill bit while there was inadequate mud pressure to prevent the flow of gas entering the drill hole.

No formal guidance was provided to workers on how to distinguish between routine operations and emergency or non-routine operations properly. Additionally, the operating company did not specify the barriers required during operations, or how to respond if a barrier was lost. This contributed to the performance of underbalanced operations that the drilling rig and crew were not equipped or trained to perform.

The drilling contractor did not test its drillers' abilities in detecting indications of gas influx, which is a safety-critical aspect of well control. The absence of this testing may have contributed to drillers not detecting the significant gas influx leading to the blowout.

Corrective actions

Usable procedures & training and competence

Emergency response plan:

- Identify specific and distinct scenarios that will be considered as emergency or non-routine operation.
- Ensure adequate resources are allocated to these scenarios.
- Regularly practice these scenarios (desktop as well as practical) to ensure familiarity with these safety-critical scenarios.
- Establish written processes to deal with these scenarios in a timely manner.
- Ensure workers who perform safety-critical roles have the required training and competency.

Human factors

Usable procedures

Designing for people

Health and safety culture

When the blowout was occurring, workers on the rig took shelter in the driller's cabin (dog house). These workers became trapped and suffered fatal injuries. The driller's cabin was not adequately designed to allow for easy escape, having only two exits which both led back onto the drill flow (where the blowout and fire was occurring). In addition, one of the exit doors was hinged in a way that it impeded quick evacuation, as when the door was opened it blocked the escape path.

The workers choice to retreat to the driller's cabin was inconsistent with the emergency response procedure implemented by the company. Management had given little time to providing emergency response training and drills were often missed or incorrectly performed.

Workers did not have the necessary training to adequately deal with the occurring emergency, which likely led them to taking refuge in the driller's cabin.

Corrective actions

Training and competence:

- Ensure emergency response training and competency is maintained. Drills should be undertaken that cover a range of different scenarios workers might encounter and be practised regularly.

Designing for people:

- Incorporate the principles of human factors into the design of work environments.
- Provide multiple escape routes.

Health and safety culture:

- Improve leadership commitment to health and safety through the provision of adequate resources, time and visible felt leadership strategies in which the priority of safety over production is a key message.

Human factors

Safety-critical communication

Health and safety culture

Given that the main control for preventing a blowout is to maintain greater pressure within the wellbore compared to the surrounding reservoir, all communication regarding maintaining this pressure should be considered safety-critical. This would include the creation of the weighted pill that was being used to rectify the underbalanced well situation.

Workers solely communicated this information via radio. This resulted in one of the workers mishearing the orders and created confusion around the proposed composition of the pill. Additionally, it was not communicated back to supervisors or shift leads that the pill had been created using improvised measurements.

The safety-communication methods used were not optimal to ensure that the task was undertaken correctly. As the work instructions were not written down, there was confusion about what was supposed to be done. Furthermore, the informal communication of the initial order may have contributed to workers failing to communicate actions back to their supervisor.

Corrective actions

Safety-critical communication:

- Develop usable procedures and associated job aids, particularly for safety-critical tasks.
- Establish communication processes, including radio communication protocols, to ensure that all information is given clearly and accurately (e.g. 'repeat-back' procedures). This helps to commit information to memory and provides an opportunity for the sender to identify that the message has been understood correctly and to correct any error.

Health and safety culture:

- Develop a health and safety culture in which workers feel safe to report concerns without fear of negative consequences.

4 Additional information and resources

- *Human factors fundamentals for petroleum and major hazard facility operators: Guide*
- *Human factors self-assessment guide and tool for safety management systems at petroleum and major hazard facility operations*
- *Human factors: Usable procedures: Information sheet*
- *Human factors: Five principles of human performance: Information sheet*
- *Human factors: Integrating human factors into bowtie analyses of major accident events and major incidents: Information sheet*
- *Human factors: Integrating human factors into major accident events and major incident investigations: Information sheet*

WSJun23_1255