JNRC - Learning Opportunity Notification (LON) - 006

Incident Details		Incident Impact	
Incident	Deepwater Horizon (Macondo)	**People**	11 dead
Date of Incident	20-Apr-10	**Environment**	Pollution
Location/Country	Gulf of Mexico, USA	**Asset** (adjusted claim at the time of loss)	USD $685 million (Insured Loss)
Type of Incident	Control of Well	**Reputation**	Major reputational damage to Operator
Offshore/Onshore	Offshore		
Asset Type	Semi-Submersible		
Asset Status	Well-Drilling		
Immediate Cause	Inadequate Barriers		
Similar Root Cause Incidents	Montara/West Atlas		
Date Updated	19-Aug-22		

Incident Description

On the evening of April 20, 2010, a well control event allowed formation hydrocarbons to escape from the Mississippi Canyon Block 252 Macondo well onto Transocean's Deepwater Horizon semi-submersible drilling rig, resulting in explosions and fire and subsequent loss of the rig.

Prior to the event the drilling activities for the well were completed after productive oil and gas subsurface zones had been discovered and the crew was performing a series of steps to temporarily abandon the well. Abandonment activities would essentially plug the well so that the rig could move on to a new drilling site and a production installation could return to the Macondo site at a later date to extract the hydrocarbons. Conventionally during drilling operations, a drilling fluid column is used to provide hydrostatic pressure to counteract formation pore pressure and prevent uncontrolled influx of formation fluids into the wellbore and back to the surface.

In transitioning to temporary abandonment, cement plug barriers are installed to prevent this influx to allow the drilling fluid column to be removed. BP's temporary abandonment plan called for removal of most of drilling fluid column in the well before installation of a surface cement plug. Earlier, a critical cement barrier intended to keep the hydrocarbons below the seafloor had not been effectively installed at the bottom of the well, and the cement integrity test was not conducted in a way that provided a clear "pass" or "fail" result to the workers. Both BP and Transocean personnel on the rig misinterpreted the test results concerning the cement integrity, leading them to erroneously believe that the hydrocarbon bearing zone at the bottom of the well had been sealed when in fact it was not. When the drilling fluid column was removed, pressure gradually reduced above the hydrocarbon reservoir at the bottom of the well. Eventually, this action allowed hydrocarbons to flow past the failed cement barrier and up towards the rig.

Meanwhile, because of a failure to recognize the increase in fluids from the well, the crew continued to remove more of the drilling fluid column, causing both the hydrocarbon influx rate into the well and movement of hydrocarbons towards the rig to increase. The hydrocarbons continued to flow from the reservoir for almost an hour without human intervention or the activation of automated controls. The force of the hydrocarbons accelerating up the drilling riser resulted in well fluids gushing onto the drilling rig floor – also known as a "blowout". At this point, the crew took action to activate the blowout preventer (BOP). This safety critical element, located at the sea floor, temporarily sealed the well but could not stop the hydrocarbons that had already travelled above the BOP from releasing onto the rig.

Once oil and gas had risen above the BOP, the only action the crew could take was to divert it to a safer location than onto the rig floor. However, the flow from the diverter had been pre-set to route well fluids to the mud-gas separator rather than over the side of the Deepwater Horizon. The mud-gas separator was rapidly overwhelmed, as it was not designed to safely handle a flow of the magnitude of the Macondo blowout. As a result, drilling mud and hydrocarbons rained down onto the rig floor. The hydrocarbons found an ignition source, and explosions and fire ensued. Both manual and automated emergency systems within the blowout preventer were activated in an attempt to shear the drillpipe and seal the well. However, pressures in the well had caused the drillpipe to buckle, which inhibited the BOP from sealing the well.

Eleven people lost their lives and 17 others were injured from the fire and explosion. The fire, which was fed by hydrocarbons from the well, continued for 36 hours until the rig sank. Hydrocarbons continued to flow from the reservoir through the wellbore and the BOP for 87 days until it was eventually closed by cap on 15th July 2020. Relief wells were used to permanently seal the well which was effectively killed on 19th September 2010.

The incident resulted in a spill of national significance and the largest marine oil spill in history with approximately 5 million barrels of oil reported to have been spilt over the full course of the event.

Incident Analysis and Findings (including Causal Factors)

A complex and interlinked series of mechanical failures, human judgements, engineering design, operational implementation and team interactions came together to allow the initiation and escalation of the Deepwater Horizon (Macondo) incident. The Operator incident investigation (Ref. 1) surmised that the following critical factors had to have been in place for the incident to have progressed as was seen (refer to below schematics also):

Well integrity was not established or had failed

1. The well annulus cement barrier did not isolate the hydrocarbons. The annulus cement that was placed across the main hydrocarbon zone was a light, nitrified foam cement slurry. This annulus cement probably experienced nitrogen breakout and migration, allowing hydrocarbons to enter the wellbore annulus, and as such cement formulation was inadequate for intended service.

2. The well shoe track barriers did not isolate the hydrocarbons. Once hydrocarbons entered the well annulus, they migrated into the production casing via the shoe track. Two barriers in the shoe track failed being the shoe track cement and the float collar.

Hydrocarbons entered the well undetected and well control was lost

3. The negative pressure test which was used to verify integrity of well mechanical barriers including the failed shoe track was misinterpreted providing a false conclusion of sound well integrity and providing justification for removal of the heavy drilling fluid to leave the well “underbalanced” i.e., formation pore pressure exceeding wellbore pressure enabling influx to the wellbore.

4. Influx was not recognised until hydrocarbons were in the riser. Increases in drill pipe pressure were discernible at least 40 minutes prior to the rig crew taking action to control the well.

5. Well control response actions failed to regain control of the well. Well fluids were diverted to the rig mud gas separator instead of the overboard diverter line which reduced the time to respond and escalated the incident.

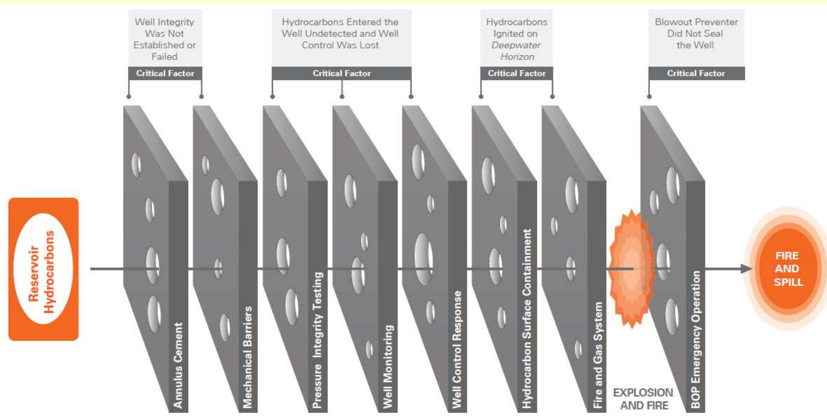
Hydrocarbons ignited on the Deepwater Horizon rig

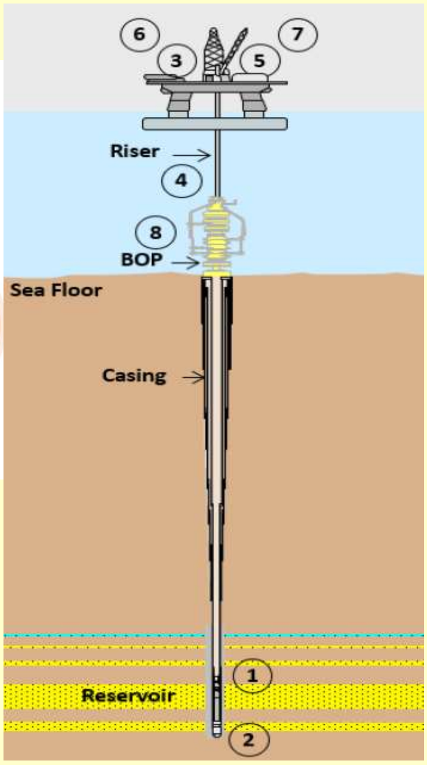
6. Diversion to the mud gas separator resulted in gas venting onto the rig. This increased the potential for gas to reach an ignition source.

7. The fire and gas system did not prevent hydrocarbon ignition.

The Blowout Preventer did not seal the well

8. The BOP emergency mode did not seal the well due to a combination of factors including faulty components, improper maintenance and impairment of the function from the explosion.





Root Causes

1. Inadequate crew training (data interpretation, well control practices and hazard identification).

2. Failure to verify availability of the two redundant auto mode function (AMF) systems which initiate closure of the blind shear ram in the BOP.

3. Inadequate design (and/or use) of the mud gas separator – this was used rather than the overboard divertor, and not designed for a gas-in-riser event or blowout.

4. Inadequate leadership – focus on personal safety rather than process safety.

5. Poor communications between operator and contractors – which failed to recognise the complexities of the operations to hand particularly concerning cement slurry design.

6. Inadequate regulatory regime – conflicted and rules based.

Root Causes

Equipment Failure				Human Performance				Other	
Repeat Failure		Unexpected Failure		Human Engineering	X	Training	X	Sabotage	
Preventive/Predictive Maintenance	X			Procedures	X	Management System	X	Natural Peril	
Design	X			Communications	X	Quality Control		Other	
Equipment/Parts Defective	X			Immediate Supervision	X				

Lessons Learned

Procedures and Engineering Technical Practices

- Negative pressure testing requires clear definition and criteria for success within procedures for verifying well integrity barriers
- Design and testing of cement slurries is a key barrier and should follow API recommended practices or equivalent
- Consider use of proven automated well control modules
- Gas detection, particularly from multiple sensors should automatically activate ESD systems
- Blast protection should be designed in direct response to analysis of hazards associated with operations
- Fire water supply pumps should have an independent power supply, and not be vulnerable to loss of electrical power in an emergency situation.

Training and Competency

- Consistent well control training programs are essential for all staff associated with drilling and completion activities including operator and contractor staff alike. Training should ideally include for simulator training that can specially assess kick detection and kick response, and address decision making within complex systems.

Process Safety Performance Management

- Well integrity, well control and rig safety critical equipment KPIs should be varied to include a range of leading and lagging indicators which should include loss of containment, overdue schedule critical maintenance on BOP systems
- Management of change should be exercised over any change to well design, well monitoring and temporary/permanent abandonment plans
- Risk assessment for major accident risks to be conducted, and to include worst case scenarios and in this case should have included the temporary abandonment plans
- HAZOP studies should incorporate reviews of surface gas and drilling fluid systems including surface system hydrocarbon vents for location and design suitability
- Incident investigations should be widely shared across organisations, and systems in place to demonstrate communication and learning across global organisations
- Industry bodies have a major role to play to ensure dissemination of incident findings to a wider audience – i.e., IOGP established a Well Control Lessons Learned process in the aftermath of Macondo
- Safety systems should only be bypassed in exceptional circumstances, and subject to senior leadership oversight.

Cementing Services Assurance

- Ensure adequate QA/QC process is in place for services rendered by cementing service providers including compliance with industry standards and competency of personnel.

Well Control Practices

- Well control and monitoring practices require clear definition and bridging between operator and contractor policies and procedures
- Well control and monitoring practices should be subject to regular audit and reinforced by well site leaders
- Large pressure differences between the outside and inside of drillpipe can cause effective compression and bending or buckling of the drillpipe inside the BOP, with a potential to compromise BOP function.

BOP Design and Assurance

- BOP systems should have minimum levels of redundancy and reliability stipulated
- Remote Operated Vehicle (ROV) intervention in the event of an emergency for subsea environments should have a clear pre-determined plan in place including emergency options for shearing and sealing the wellbore in event of a blowout.

Emergency Response

- Command and control responsibilities during an emergency should be documented and have an absolute clarity for all persons on board
- Emergency drills should cover a range of drill scenarios (ideally dictated by events identified as part of a rigorous risk assessment) and include for work case scenarios.

Regulatory Oversight

- Offshore regulatory oversight of process and personal safety should not be conflicted with other responsibilities, and should place an emphasis on industry for managing major hazards and empower proactive regulatory oversight.

References

1. BP Deepwater Horizon Accident Investigation Report (September 2010).

2. Safe Influx Deepwater Horizon Incident Evaluation of the Breached Barriers (August 2021).

3. US Chemical Safety and Hazard Investigation Board, Explosion and Fire at the Macondo Well (Volume 1).

4. US Coast Guard – Report of Investigation into the Circumstances Surrounding the Explosion, Fire, Sinking and Loss of Eleven Crew Members Aboard the MODU Deepwater Horizon, Volume 1.

5. Marsh 100 Largest Losses in the Hydrocarbon Industry (March 2020).