PROTOTYPE
FACULTY OF ENGINEERING AND APPLIED SCIENCE
Journal of Undergraduate Engineering Research and Scholarship

PT-13: Coastal and Ocean Engineering ENGI.8751 Undergraduate Student Forum
Faculty of Engineering and Applied Science, Memorial University, St. john's, NL, Canada March, 2013

Paper Code. (PT-13 - Reynolds)

The Role of Business and Engineering Decisions in the Deepwater Horizon Oil Spill

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ABSTRACT

On April 20th, 2010, the semi-submersible oil rig Deepwater Horizon exploded in the Gulf of Mexico, killing 11 crew members and allowing crude oil to spill continuously from the seabed. Despite numerous attempts to cap the leak, oil continued to flow into the Gulf for nearly three months before a solution was found and the well was finally capped.

Because deep water drilling is a relatively new phenomenon, the technical challenges involved in capping a wellhead beneath more than 1,500 metres of water were new and unexplored. Neither the United States government, nor BP, nor their subcontractors Halliburton and Transocean were prepared to deal with the fallout of a disaster of this magnitude.

After an investigation by the United States government, it was determined that BP and its partners were primarily responsible for the spill due to a series of cost-cutting measures. It was also discovered that BP made decisions that demonstrated a lack of business integrity, including hiding information from the public and the US government.

The following report will outline the circumstances that led to the explosion of Deepwater Horizon and describe the role of business and engineering decisions in allowing the spill. The report will then discuss changes that can be made to prevent reoccurrence of another disaster of this magnitude.

1 INTRODUCTION

Deepwater Horizon was a semi-submersible oil rig located about 41 miles (~66 km) from the Louisiana coastline [1] in a drilling area in the Gulf of Mexico known as the Macondo Prospect. On April 20th, 2010 the rig, owned and operated by Transocean and leased to BP, was drilling an exploratory well with a planned depth of 5,600 m [2] when hydrocarbons entered the riser of the well

and ignited. The explosion killed 11 people, injured 16 more, and the subsequent oil spill became the largest environmental disaster in US history [3].

Figure 1 – Location of the Deepwater Horizon [2]

2 ULTRA DEEP WATER DRILLING

Deepwater drilling is a relatively new phenomenon. As oil becomes scarcer, prices rise and it becomes increasingly economical to use new technology to drill for oil in ultra deep water (i.e. deeper than 7,500 ft, or ~2,286 m) [4].

While deepwater drilling allows access to previously untouched oil reserves, there are several risks inherent in the process. The most obvious, as evidenced by the Deepwater Horizon oil spill, is that it can be incredibly challenging to stop the free flow of oil from a wellbore into the ocean when there are several kilometres of water between the surface and the wellbore.

2.1 Technology

Most deepwater drilling operations use similar technology to reach reservoirs at great depths. From a drilling rig, a riser (vertical pipe) extends down to a blowout preventer (BOP) on a wellhead at the sea floor. From the wellhead, wells are drilled using drill bits of progressively smaller sizes. Each borehole is lined with metal casings, which also decrease in size as depth increases.

The blowout preventer (BOP) is a large valve at the surface of the wellhead that can seal off the borehole as drilling occurs. This is required if fluids such as oil or natural gas enter the wellbore. When the fluids propogate up the wellbore, they can threaten the safety of the rig. If this happens, the BOP is designed to slam shut to prevent the escape of these fluids until control of the wellbore is regained. To re-establish a safe pressure, drilling mud density in the wellbore is increased until enough fluid pressure is placed on the wellbore for drilling to resume [5].

To prevent gas from leaking up the outside of the well pipe, cement is pushed between the casings and the bedrock. To seal the space between casings (called an annulus), an o-ring (or liner hanger) is used [6]. A device called a shoe track is also placed at the end of the last casing during cementing to prevent flow from the annulus back into the casing [7].

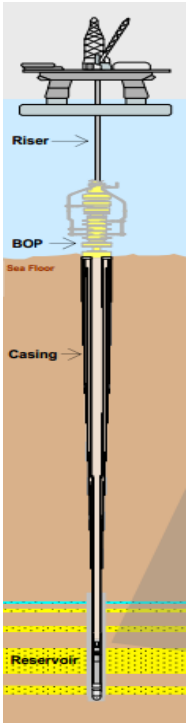

Figure 2 – Deepwater drilling schematic [7].

2.2 Regulations

The Minerals Management Service (MMS) was the United States government service responsible for the management and regulation of oil, gas, and mineral services on the outer continental shelf at the time of the Deepwater Horizon disaster. This service earned most of its revenue from the lease of federal lands for mineral exploration [8]. Following the Deepwater Horizon disaster, there was considerable review of MMS policies and decisions, including the role they played in allowing the disaster to happen.

3 EQUIPMENT FAILURE

A series of equipment and technology failures led to hydrocarbons entering the riser and igniting, causing the explosion. They were found to be as follows:

3.1 Cement

Contractor Halliburton was responsible for design and placement of the cement mixture. Lightweight slurry was required due to limited pore pressure in the area. To achieve the required low density, foamed cement was used. The mixture was created by injecting nitrogen gas into the concrete, which also causes “increased slurry compressibility, increase set-cement elasticity, and the flexibility to vary density during operations” [9]. There were some major risks associated with this cement design and placement, including the fact that the foam was relatively unstable, and was subject to contamination because such a small volume was used. These risks were known and accepted by both BP and Halliburton.

Because nitrogen broke out of the cement slurry, the cement failed and hydrocarbons were able to escape through the shoe track and back into the riser. In addition to the cement failure, an additional check valve failed, allowing hydrocarbons to enter the riser. This valve failure has also been confirmed by Macondo static kill data [7].

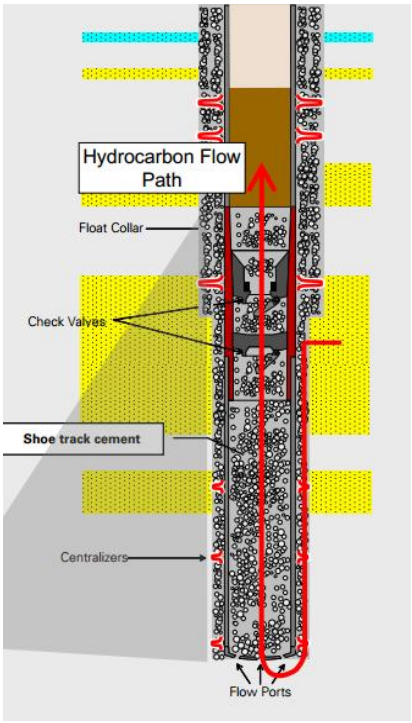

Figure 3 – Hydrocarbon escape into riser [7].

3.2 Fire and Gas System Failure

The systems in place to prevent ignition of hydrocarbons failed. Certain parts of the rig were electrically classified, meaning that in the event that hydrocarbons made it to the rig; they were expected to be contained to these areas. For this reason, the use of electricity and possibility for an igniting spark was carefully limited.

The hydrocarbons reached areas of the rig beyond where they were expected. Once hydrocarbons had penetrated beyond electrically classified areas, any spark could have caused ignition. One hypothesis is that the on-line engines were the source of ignition [7].

3.3 Blowout Preventer Emergency Mode Failure

The BOP was designed to seal the wellbore and shear casing if necessary. That is, in the event of loss of control of pressure in the well. In this case, the emergency closure mechanism of the BOP failed. At 9:41 PM on April 20th, the annular BOP closed but did not seal the annulus [7].

After the explosion, electrical and hydraulic lines to the BOP were damaged and it appears to have reopened completely. From that point, no subsequent efforts to seal the BOP were successful and crude spilled continuously from the well.

4 BUSINESS AND ENGINEERING DECISIONS

4.1 Government Regulations

In February of 2009, BP filed a 52-page report with the MMS detailing their exploration and environmental impact plan stating that it was "unlikely that an accidental surface or subsurface oil spill would occur from the proposed activities." No subsequent environmental impact study was submitted beacause the MMS exempted BP from this requirement [10].

The MMS has since been restructured, but an investigation into the incident has criticized the MMS for the above decisions, also noting that the MMS relied too heavily on industry assertions about the safety of ultra deepwater drilling and that they "failed to create and apply a program of regulatory oversight that would have properly minimized the risk of deepwater drilling" [8].

4.2 Testing

One of the major reasons for the series of events leading to the explosion was the lack of adequate testing procedures during drilling. Three major test procedures, if properly implemented, could have prevented the disaster. These were the cement bond log, the negative pressure test, and the blowout preventer testing regime.

- Cement bond logs are sonic tests that measure that amplitude of acoustic signals through cement to determine the quality of the bond between cement and casing. On the day of the explosion, BP cancelled cement bond logs at 7:00 AM. The cancellation of the test, which would have cost $128,000 and taken less than twelve hours, produces a cost savings of $118,000 [11];
- Negative Pressure tests are used to check the integrity of the shoe track, casing, and wellhead seal assembly. This simulates the case of temporary abandonment, where seawater displaces a portion of the well. These tests were not properly standardized at the time of the accident. Despite large bleed volumes during the test, the results were incorrectly determined to be acceptable [7]. Proper standardization of this testing procedure could have prevented the erroneous acceptance of data;
- BP also internally recognized some weaknesses in their testing regime for the BOP. Simple modifications to the testing regime and maintenance management may have found errors with the BOP before it failed to shut off the well [7]

4.3 Cost-Cutting Decisions

Leading up to the accident, several employees of BP expressed concerns about the safety of actions and procedures undertaken at the well. Decisions appear to have been made in an attempt to save time and money. These include:

- On April 1st, employee Marvin Volek warned that BP's use of cement was against their best practices [6];
- For the last section of the wellbore, Halliburton recommended a liner and tieback casing that provided four redundant barriers to flow. BP opted for a cheaper design with fewer flow barriers, saving $7 to $10 million. This change was approved by the MMS [6];
- Centralizers are used when cementing a well to ensure that casing is centred in the borehole. An off-centre casing can lead to weak points in the cement sealing. Despite Halliburton's recommendation to use 21 centralizers when cementing, BP decided to use six in the interest of saving time and money [6].

4.4 Outcomes and Legal Implications

As a result of the explosion, spill, and subsequent cleanup efforts, all three parties (BP, Halliburton, and Transocean) faced a variety of charges. The criminal charges were primarily related to the spill and cleanup efforts. The criminal charges from the blowout included two charges of manslaughter against BP site engineers, and 11 felony counts against BP for the 11 dead workers [12].

The final US government report released in 2011 placed most of the blame with BP for the testing failures and the inadequate cement job, though it ultimately declared Halliburton and Transocean partly at fault [13]. All three contractors are still involved in litigation today, and the legal battles have not ended. BP has also been temporarily banned from contracts with the US government due to "lack of business integrity" [13].

Another finding of the US government report was that regulations were insufficient and that inspectors were not properly trained to recognize the cost-cutting measures BP had undertaken. As a result, the MMS was eventually broken up into three departments – the Bureau of Ocean Energy Management, the Bureau of Safety and Environmental Enforcement, and the Office of Natural Resources Revenue [14]. This helped to alleviate allegations of conflict of interest between the MMS and resource companies, and to ensure that regulations were reformed to ensure property safety for personnel and the environment during deepwater drilling.

5 CONCLUSION

The Deepwater Horizon explosion was a result of a combination of many factors including inadequate government regulation, poor design decisions, too many last-minute changes to plan, lack of understanding of technical data, and aggressive cost-cutting measures. The United States government sent a clear message by pursuing civil and criminal charges against responsible parties and by temporarily banning BP from contracts with the US government.

Changes must be made to both business culture and government oversight procedures to prevent a repeat of the Deepwater Horizon tragedy. As deepwater drilling resumes in the Gulf of Mexico, the disaster remains in the minds of those responsible for environmental impact and human safety.

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