

# **The Deepwater Horizon Accident**

An Analysis of BP's Failure at the Macondo Well

Group 4

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## Executive Summary

The overall objective of this report is to document and analyze the series of events leading up to the explosion of the Deepwater Horizon and the responses to the explosion with regard to the safety measures and protocols followed during the accident. The history of BP is discussed with regard to accidents caused by failure to comply with established safety procedures, including the Texas City Refinery Explosion in 2005, the Alaskan Oil Spill in 2006, and then the eventual Deepwater Horizon explosion in 2010. An analysis of these events show that negligence and malpractice conducted on BP's part led to the aforementioned disasters. This foreshadows the events of the Macondo well in which negligence (on both BP's and the United States Government's part) and financial stress induced the failure of mechanical barriers to seeping hydrocarbons into the drill pipe. Though the Deepwater Horizon rig belonged to Transocean and the cement job was performed by Halliburton, the lease operator for the Macondo well was BP and thusly is assigned an overwhelming majority of the blame for the catastrophic explosion. At least 8 layers of safety were breached, demonstrating a severe lack of responsibility on behalf of BP and the personnel aboard the Deepwater Horizon.

Following the explosion, the United States Government and the public had an ever-increasing tension-filled relationship with BP as the well gushed oil at an average of 70,000 barrels of oil per day for 87 days. Despite BP desiring to be transparent with the public and the government, BP was ultimately fined billions of dollars in damages and lost wages. Even though the spill has been capped and cleanup efforts have made considerable progress, the reputation of BP will never be what it used to be, especially after the two previous disasters before the explosion of Deepwater Horizon. Its status as one of the leading oil producers in the world is forever tarnished after this accident.

A similar accident occurring in Bhopal, India in 1984 is also analyzed. Though the accident in Bhopal involves the toxic and fatal release methyl isocyanate (MIC) vapors instead of flammable hydrocarbons, analogues between the Bhopal incident and the Deepwater Horizon incident are readily observed. Both incidents involve the responsible company not following proper safety measures due to financial stress and negligence. While BP is being held fully accountable by the United States Government, the former company Union Carbide did not suffer nearly the same amount of punishment for thousands of victims the Bhopal incident claimed. Nevertheless, both incidents reveal the consequences of malpractice and negligence on behalf of the operating company. To ensure that the engineering profession is not tainted by these travesties, stricter and more thorough practices of safety measures and procedures must be followed in future engineering endeavors.

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## 1. Introduction

Safety is an integral part of any business in any industry today. Some industries are more inherently risky than others, but due to the relatively large size of any industrial operation, extreme caution and care must be taken to successfully and safely produce the desired finished product. This is precisely the case with deep water oil exploration, especially as wells become deeper and the oil harder to reach. BP's Deepwater Horizon Rig was no exception to this increasingly dangerous trend.

The combination of an inherently risky and highly dangerous operation such as deep water oil extraction along with a company like BP, which has an abysmal safety record, has led to a disaster of catastrophic proportions. BP's inherently unsafe company culture coupled with negligence led to this disaster, which has been dubbed the worst oil disaster in the United States' history<sup>1</sup>.

The following will discuss the Deepwater Horizon incident, its root causes and the immediate causes leading up to it. It will analyze from governmental organizations, among others, what should and could have been done to prevent such a catastrophic incident. The report also includes a comparison to the 1984 Bhopal disaster, and how employee negligence in both cases led to these unfortunate disasters.

## 2. Background Information

The analysis of the accident at the Macondo well on April 20, 2010 provides incredible insight into the safety priorities and standards that the British oil company BP follows. While this report focuses on this specific accident, the lessons learned from the entire incident (beginning with BP's previous safety record through their present day relations with the United States) shines a broader light on how offshore drilling is approached across the globe. The importance of following an established set of safety guidelines and protocols is absolutely imperative when operating with such large equipment at such large depths with such volatile substances. With oil and gas still being the predominant source of energy around the world, accidents like the one with Deepwater Horizon are simply unaffordable for an innumerable amount of reasons. With sources spanning a wide sea of information (various news sources including the New York Times and the Washington Post and information from BP and the United States Government), the broad spectrum of the Deepwater Horizon accident is observed and made applicable and comparable to past, present, and future engineering disasters in which safety was not made a priority.

### 3. The History of BP

#### 3.1 BP's History and Track Record

##### 3.1.1 The History

BP began as the Anglo-Persian Oil Company, where it first began its search for hydrocarbons in the vast sandy regions of Persia (modern day Iran). BP went through many treacherous and tumultuous times, including the Great Depression and World War II. As exploration technology improved quickly throughout the 20<sup>th</sup> century, so did BP's size, production capacity, and clout amongst the dominant oil companies of the world. BP's oil exploration regions included Iran, Libya, Alaska and Scotland, among others<sup>2</sup>.

In 1987, BP purchased Sohio, an oil company in the US, and made it the keystone of BP America's operations. BP then merged with Amoco, then the largest natural gas producer in North America, in 1998. BP also acquired Burmah Oil, Castrol, and ARCO in 2000, and then purchased Aral from Germany in 2002<sup>2</sup>.

Like all other global oil companies of today, BP grew and expanded in a time when Safety standards also evolved drastically. It has an unfortunate safety record in the 20<sup>th</sup> century, including the capsizing of the BP oil rig Sea Gem, killing thirteen crewmen. At the close of the century in September 1999, BP also resolved charges for \$22 million for illegally dumping hazardous wastes on the Alaska North Slope<sup>3</sup>.

BP has quite a dismal safety record in the 21<sup>st</sup> century as well. It is insightful therefore to study how its evolved safety culture throughout the 20<sup>th</sup> century also failed to cope with the safety challenges of the 21<sup>st</sup> century, which led to perhaps even more catastrophic disasters that were seen in the 20<sup>th</sup> century. Examples of such devastating environmental and safety disasters are the 2005 Texas City Refinery explosion, the 200,000 gallon spill in Alaska in 2006, and lastly, the record-breaking tragedy in the Gulf of Mexico with the Deep Water Horizon explosion in early 2010<sup>1</sup>.

##### 3.1.2 BP's Safety and Environmental Track Record

For such a massive and global oil company, BP has one of the worst safety and environmental track records in its industry. Between 2005 and 2010 alone and before the Deepwater Horizon incident, BP had \$373 million dollars in fines alone. In the last three years BP was accountable for 97% of all "egregious, willful" violations that the Occupational Safety and Health Administration (OSHA) handed out. BP had 760 violations, Sunoco and Conoco-Phillips had eight while ExxonMobil had a mere one violation. BP was punished with the two largest fines in OSHA history because of these willful safety violations<sup>1</sup>.

BP has had huge impacts on the environments it operates in as well, such as with its 200,000 gallon spill into the Alaskan Tundra and the now well-known Deepwater Horizon Oil spill.

Wildlife, fisheries and businesses located near the disasters have been permanently affected by these. The long-term economic and environmental impacts are still uncertain<sup>4</sup>. The information below will highlight BP's most recent safety blunders and showcase how BP's abysmal safety record is a stark indicator that the Deepwater Horizon incident was not actually an isolated case of negligence on the rig, but in fact a huge display of BP's lack of attention to safety and inability to improve its overall safety culture throughout the corporation<sup>4</sup>.

### *3.1.2.1 Texas City Refinery Explosion*

The BP Texas City Refinery explosion killed 15 people and injured 180. Employee error was determined to be reason for the explosion – considered one of the worst industrial disasters in recent U.S. history. The company incurred financial losses of over \$1.5 billion<sup>5</sup>.

BP's refinery in Texas City is the third largest in the U.S., extending over two square miles just outside of Galveston, TX. On March 23, 2005, BP workers and contractors began re-starting an isomerization unit that was shut down for repairs. They began filling a tower with gasoline, but the tower overflowed. The excess gas flowed into a back-up unit, but that also overflowed, sending a gush of gasoline into the surrounding air. The plume of gas created a vapor cloud near the ground, and was believed to be ignited by the engine of an idling truck nearby<sup>7</sup>.

BP initially explained that the disaster occurred largely due to operator error, and that there was “no evidence of anyone consciously or intentionally taking actions or decisions that put others at risk.”<sup>7</sup> Investigating officials however claim that is untrue. They claimed that the problems existing at the Texas City Refinery were not temporary nor were they small. It seems the problems were not only isolated to the explosion, but ran deep within the company's culture and practices<sup>7</sup>.

18 months after the explosion, Chemical Safety Board (CSB) investigators found problems all throughout BP's refinery: antiquated equipment, corroded pipes ready to burst, and non-functioning safety alarms. For the isomerization unit more specifically, three significant pieces of instrumentation, including alarms and safety mechanisms, were supposed to be repaired but were not fixed. What made matters worse was that management was aware of the needed repairs, showing the lack of an adequate safety culture in the company<sup>7</sup>.

Not only were key instrumentation issues not addressed, but BP failed to abide by its own refinery rules as well. Office trailers are required to be placed a safe distance away from any dangerous operation. Nevertheless trailers were placed in an open area right next to the unit being filled with gasoline. Moreover, BP neglected to inform the workers in those trailers of the inherently dangerous operation about to take place nearby<sup>7</sup>.

Much evidence also shows that BP had sufficient time to fix the safety risks present in the refinery before the catastrophe occurred. Much communication between the refinery and headquarters in London involved reports about Texas City's risks and need for significant repairs

and renovations throughout the refinery. The inability of BP to address its shortfalls in safety procedures and precautions demonstrates the amount of effort and time that the upper management sections of the company gave to creating a safer workplace with a more affective safety culture<sup>7</sup>.

Their lack of an adequate safety culture translated also into failed attempts to fix any clear errors that became apparent after the incident. In late 2009, four years after the refinery explosion, BP was fined \$87 million by OSHA for failing to correct the safety hazards identified in the 2005 incident. OSHA inspectors took note of 270 citations that BP failed to fix, and a whopping 439 new violations.<sup>3</sup>

Essentially, BP didn't learn from its costly mistakes. BP's Vice President for Safety & Operations John Mogford stated in a speech following the incident, "This was a preventable incident. It should be seen as a process failure, a cultural failure and a management failure."<sup>8</sup> Based on this information it is evident that the root cause of BP's disasters are not isolated operator or employee errors, but in fact a negligent safety culture that has failed to improve itself to meet the 21<sup>st</sup> century's demands on a global oil company the size of BP.

#### *3.1.2.2 Alaskan Oil Spill*

In August 2006, BP had to shut down the largest oil supply pipeline in the U.S., in Prudhoe Bay, due to corrossions in the pipelines. This environmental disaster echoes a very similar story to that of Texas City. The cause of the leaks was determined to be due to the cutting of costs for maintenance of the pipeline and other similar facilities<sup>3</sup>.

Moreover, BP had been notified to check the pipeline dating back to 2002. When the company finally decided to perform an inspection on the pipeline four years later, it was recorded that six-mile length in pipeline was in fact corroded and discovered the leak. As a result the company had to shut down the supply line, which caused one of the largest supply disruptions of oil in U.S. history. Moreover, BP was fined \$12 million for violating the Water Pollution Control Act. A congressional committee followed up by saying the incident could have been prevented, but that BP failed to due to shortcuts and cost-saving measures that were taken while operating the pipeline<sup>9</sup>. The eerie similarities prove by no coincidence that BP's inadequate safety culture and preference of profits over employee safety are two major root causes to BP's disasters.

#### *3.1.2.3 Deepwater Horizon Rig Explosion*

It seems the explosion that occurred on the Deepwater Horizon Rig was no exception to BP's continuous safety mishaps. One year before the accident, BP cut costs. The company lacked the necessary equipment and documents to perform an emergency shutdown, and took numerous shortcuts as will be seen later in the report<sup>9</sup>. BP did not follow the correct procedures or the correct testing, and as previously, it is reported that BP's negligence and lack of responsibility ultimately led to the huge oil spill<sup>10</sup>. The explosion led to an oil spill that took 87 days to cap,

along with up to 39 million gallons of oil spewed into the gulf. Hundreds of endangered sea turtles and sea birds, among other animals, were found dead along the shores of the gulf coast. The environmental impacts are devastating on marine life in general is equally as devastating<sup>11</sup>.

### 3.2 Reputation

Prior to many of BP's 21<sup>st</sup> century disasters, it had developed an impressive reputation as a company that could turn an impressive profit off of old assets acquired from other companies, such as the ones mentioned previously. It is one of the world's three largest oil companies, and made more money than any other company from old assets. Due to their continued negligence and extreme budget cutting however, BP naturally lost people, adequate equipment, appropriate maintenance procedures, and trainers – all necessary things to creating a safer work place<sup>7</sup>.

Cutting too many costs directly led to the Texas City explosion; BP chose not to install a flare on the isomerization unit, a device used to burn off excess gasoline. Prior to the ignition of the vapor cloud there were eight other gasoline releases on that same unit. As a result, it is precisely their desire to cut costs for increased profit that turned on them and tarnished their reputation<sup>7</sup>.

This eventual slack in caring for safety led to BP being regarded not only as the least safe major oil company, but one that didn't keep its promises either. BP marketed itself as the "greenest" oil company, using phrases such as "Beyond Petroleum" for their slogan<sup>10</sup>. The new logo of the blooming flower also served to demonstrate to the public that the corporation was investing in green alternatives and responding to the public's concerns about climate change<sup>12</sup>.

They developed that reputation among the many environmental organizations and separated themselves from other oil giants like ExxonMobil. With their recent events however, such as the 200,000 gallon oil spill in Alaska and the Deepwater Horizon rig, it seemed their claims and slogans were more of a sham<sup>10</sup>.

Moreover, the events involving the Deepwater Horizon explosion seemed to have capped the downward spiral of BP's image. Investors lost trust in the company, with their stock plummeting over 50% of its value before the explosion<sup>13</sup>. Moreover, BP's reputation with the general public of the U.S. was tarnished likely more than ever before in its history of operation due to the incident in the Gulf of Mexico. The general public has resorted to measures such as boycotting the company, even though the effect of such a boycott is thought to be negligible to the company. Numerous organizations such as political action committees and consumer watchdogs have made set-up formal anti-BP campaigns. Notable public figures as well, such as a Jesse Jackson, have regularly appeared at events to protest the company<sup>14</sup>.

BP's relationship with the U.S. government has been permanently hurt as well due to the oils spill<sup>15</sup>. BP's relationship with the government was already tarnished by incidents with events such as BP being fined \$303 million by the government for intentionally manipulating propane

prices in 2007. This was the largest commodity settlement fine ever in the U.S. EPA also fined BP in separate incidents in 1991 and 2000 due to its massive amounts of pollution into the atmosphere. As will be seen, the oil spill in the gulf only further ostracized the company in the eyes of the government<sup>3</sup>.

## 4. The Deepwater Horizon Explosion

### 4.1 Foreshadowing the Explosion of Deepwater Horizon

Several factors foreshadowed the catastrophic explosion and subsequent collapse of the Deepwater Horizon rig on April 20, 2010, starting from when BP obtained the operator lease for the Macondo well in Mississippi Canyon block 252 in March of 2009. A brief history of the Macondo well from when BP was the lease operator provides insight to BP's safety protocols and priorities.

#### 4.1.1 History of the Macondo Well

The Macondo well is located 50 miles southeast off the tip of Louisiana's Mississippi River delta in water at a depth of 4,992 feet. As previously mentioned, BP submitted exploration plans to the United States Department of Interior's Minerals and Management Services department (MMS) in March 2009. Drilling began on the well on October 7, 2009 using the rig Marianas, owned by the Swiss company Transocean.<sup>16</sup> The first 4,023 ft. of the well was drilled using this rig. One month later, the rig was damaged by Hurricane Ida and was sent away for repairs. At this time, Transocean's famed Deepwater Horizon rig (finished construction in 2001) was brought to the Macondo well in early February 2010.

One of the interesting aspects of the Macondo well is its location in the Gulf of Mexico. "Beneath the Gulf's seafloor is a mush of sand, shale and salt in formations that are geographically young, unsettled and fragile. Coupled with that are layers of sand that hold crude oil and natural gas under high pressure."<sup>16</sup> During drilling operations, "if oil and gas show alarming signs of wanting to 'kick up' and out of the well, as they did to Deepwater Horizon twice – once temporarily and later catastrophically – drillers can call for heavier mud<sup>16</sup>," however doing so in the Gulf of Mexico usually makes matters worse. "Pumping heavier mud in the Gulf runs the risk of fracturing fragile layers of sand and shale. If that happens, mud can quickly vanish into subterranean voids and leave a rig increasingly defenseless against a blowout."<sup>16</sup> This geographical complication would ultimately be determined to be one of the largest sources of the eventual explosion of Deepwater Horizon.

"In late February [of 2010], the rig was losing mud in a weak formation. When that happens, the most reliable [trick] is to continually reinforce a well with permanent sections of casing or with a liner and cement." This was done to Deepwater Horizon nine times.<sup>16</sup> A couple of weeks later in early March, the rig experienced a "double dose of trouble" when the "pressure of underground petroleum temporarily overwhelmed the mud, triggering alarms on the rig. At nearly the same time, the rig's drill pipe and drill bit became stuck in the well."<sup>16</sup> The rig recovered but lost an estimated several million dollars of lost drilling pipe and also lost two weeks of rig time. Once recovered, "the rig progressed another 4,955 feet before again losing mud to a weak formation."<sup>16</sup> "At a final depth of 18,360 feet [accomplished in mid-April 2010], Deepwater

Horizon again encountered a formation that swallowed mud.”<sup>16</sup> The continued drilling of the well in an unstable environment is in hindsight a red flag, however with multiple wells in the area and more than sufficient technology to drill in such environments, the decision to drill at the Macondo well is not a contributing factor to the eventual explosion.

Once the final well depth was drilled, the well and casing were sealed using nitrified foamed cement since it is lighter and is “less likely to fracture or break weak formations, as can happen with overly heavy mud, and drain away into underground voids.”<sup>16</sup> This foamed cement, though used to counteract the geological fragility of the Gulf of Mexico is believed to be the initiator for the series of the events immediately preceding the explosion of the rig. This will be discussed in further detail in a following section.

#### 4.1.2 Relationship between BP and the MMS

The Minerals and Management Service, a branch of the United States Department of Interior, is the agency responsible for granting drilling leases and permits to gas and oil companies for well development on American territory. It is believed (and is well documented) that the relationship between BP and the MMS (or between any oil company and the MMS) was less than professional. The MMS regulated 3,500 oil and gas platforms in the Gulf of Mexico with BP’s Macondo prospect being one of them. “CBS News investigative correspondent Sharyl Attkisson report[ed] that ‘[MMS] inspectors even went so far as to let oil companies literally fill out their own reports using pencils. MMS inspectors would write on top of the pencil in ink and then turn in the completed form.’”<sup>17</sup> The MMS is also supposed to provide recommendations to companies upon inspection visits to wells, however no recommendations were made to BP or Transocean dating back to 2006. The CBS report further documents that “too cozy” of a relationship exists between the MMS and oil companies via ties between workers who have moved between industry and government jobs “with ease...- friends who have often known each other since childhood.”<sup>17</sup>

*“MMS staffers accepted gifts from their oil industry friends -- trips to the Peach Bowl, invitations to skeet shooting, crawfish boils and hunting and fishing vacations. One employee inspected a company four times while negotiating a job there. Another may have been on crystal meth while he was conducting an inspection. Others had inappropriate humor and porn on their government computers.”*<sup>17</sup>

This documentation of the extreme unprofessionalism existing within the MMS and between the MMS and oil industry companies provides great insight into the safety standards practiced at wells across the Gulf prior to the explosion on April 20, and specifically at the Deepwater Horizon rig. BP frequently used its relationship with the MMS to obtain special exclusions from inspections and tests from the MMS. On April 6, 2009, the MMS granted BP’s lease at Macondo well a “categorical exclusion” from the National Environmental Policy Act (NEPA)<sup>18</sup>. At another time, “BP asked federal regulators at the MMS to delay a mandatory test of the blowout

preventer (BOP). The MMS first rejected their request for a delay, but then relented.<sup>19</sup> Kate Sheppard, a reporter who covers energy and environmental politics for the news source Mother Jones states that “it is becoming more and more evident that BP knew about numerous problems with this [Deepwater Horizon] drilling operation, but chose to proceed anyway. But it is also apparent that the MMS also knew about these risks and allowed the company to operate.<sup>19</sup>” An assessment of the rig made by the MMS states that “the most likely large spill would be 4,600 barrels and forecast that it would dissipate within 10 days and would be unlikely to make landfall.<sup>20</sup>” It is quite evident that the MMS failed to perform a thorough assessment of the rig and well given that the Deepwater Horizon spill resulted in a spill flowrate estimated at 60,000 barrels of oil per day that gushed for 87 days.<sup>21</sup> Had a proper analysis of the well been conducted with the goal of determining the worst-case scenario, further safety measures and procedures could have been implemented to ensure the prevention of such a colossal spill. Though much of the causes for the spill are a result of mechanical failures on the rig itself, had the relationship between BP and the MMS been more professional and strict, many of the mechanical components that failed on the Deepwater Horizon may have been noticed and corrected to comply with more rigorous safety standards, i.e. the standards the MMS were supposed to uphold.

## **4.2 The Explosion**

An analysis of transpiring events, starting from approximately a week before the explosion up to the explosion itself, provides insight into sources for failure, the propagation of that failure, and the eventual termination of spewed oil 87 days later. Using documentation from BP and the investigative panel from the United States Government among other third party sources, the chain of events is provided and analyzed to determine which safety protocols were not followed and/or overlooked during the drilling process.

### **4.2.1 Events Leading to the Explosion**

On April 9, 2010, the final well depth of 18,360 feet was reached at which point a long string production casing (13,293 feet) was installed. This is opposed to the more commonly practiced method of using several shorter lengths of casing reinforced with a liner. On the afternoon of April 19, 2010, the cement job was started which was contracted out to Halliburton. As mentioned previously, nitrified foam cement was pumped into the annulus and non-foam cement was pumped to the shoe track. After this, the pump pressure was bled off.<sup>22</sup> On the morning of April 20<sup>th</sup> (the day of the explosion), a positive pressure test was conducted on the drill pipe which was the first test on the well’s integrity. The drill pipe was pressurized (except for the shoe-track at the bottom of the well because of the presence of the top wiper plug) and tested for leaks to the outside of the well. No pressure leaks were observed. Later in the afternoon, a negative test was performed on the well, which was the second test for the well’s integrity.<sup>22</sup> The purpose of the test was to place the well in a controlled, under-balanced state to test all mechanical barriers (including the cement). This was performed by displacing some of the

“mud” (a dense slurry of substances that essentially serves as a liquid plug for the well) with a spacer followed by seawater. After displacement, the upper annular preventer was closed and an attempt to bleed the system to 0 psi was made, however fluid in the riser was leaking past the annular preventer.<sup>22</sup> At 5:08 PM, the hydraulic closing pressure for the annular preventer was increased to 1900 psi to create a tighter seal against the drill pipe. The riser filled with 50 barrels of mud to replace the volume of fluid leaked past the annular preventer. At 5:27 PM, the drill pipe valve was opened and the pressure reduced to 0 psi by bleeding off 15-23 barrels of sea water.<sup>22</sup>

Once this test was finished and accepted, the same test needed to be performed on the kill line to meet permit requirements. In this case, the drill pipe valve was closed and testing was reconfigured for flow to be monitored on the kill line. The kill line valve was opened and 3-15 barrels of sea water was bled off. The line was then closed and the drill pipe pressure gradually increased.<sup>22</sup> To confirm that the line was full, seawater was pumped into the kill line, which was then routed to a mini-trip tank where less than 1 barrel of seawater was bled off. When this happened, flow stopped. After 30 minutes, the drill pipe pressure still remained at 1400 psi. This phenomenon was explained as the “bladder effect,” or annular compression, and the negative test was (wrongly) accepted.<sup>22</sup> As a result of the incorrectly accepted test, normal operations to temporarily abandon the well were carried out, despite the lack well integrity. This would later prove to be another source for the explosion.

The operations for abandoning the rig began at 8:00 PM by opening the annular preventer and placing the well in an overbalanced condition, preventing further influx into the well bore from the surrounding reservoir. Displacement of the drilling fluid with sea water continued until the well went underbalanced, i.e. the well started to flow again. During this process, the pressure in the drill pipe should have decreased since the heavier mud was being replaced with the lighter seawater, however the pressure instead increased by 100 psi.<sup>22</sup> Had the integrity of the well actually been established, the pressure would not have increased. BP estimates that the drill pipe gained 39 barrels of fluid during this pressure increase. The increase in pressure was noticed; however no actions were taken to inspect the anomaly. Instead, the sheen test (a test to ensure that no free oil is entrained in the fluid from the negative test as it is discharged to sea) was performed. The pumps were shut down when the spacer reached the surface and the sheen test was performed. The spacer was determined to be acceptable to discharge, however during this test, the drill pipe pressure increased by 246 psi in a 5 minute time-span.<sup>22</sup> The rig abandonment operation was continued with the continued displacement of mud with seawater at 9:14 PM.

At 9:31 PM, the mud pumps were shut down and the drill pipe pressure increased by 556 psi in the span of 5 minutes.<sup>22</sup> The significant increase in pressure was noticed by rig personnel and over the next 2 minutes, an attempt was made to bleed the drill pipe to investigate the increase in pressure. Once this was done, mud started to overflow onto the rig floor.<sup>22</sup> In the event that an overflow like this would occur, the leaked fluid would be sent to the diverter onboard the rig. However, the diverter was closed and the mud was instead sent to the mud-gas separator (MGS).

At the same time, rig personnel closed the annular preventer and the drill pipe pressure increased from 338 psi to 1200 psi over a 5 minute period. The annular preventer failed to seal the annulus however and a slurry of hydrocarbons and mud discharged onto the rig and overboard. At 9:47 PM, the first gas alarm sounded, indicating that a cloud of gas had developed on the rig and was spreading around the rig. A roaring noise and vibration of the rig was then observed, thought to be the blowout preventer (BOP) sealing around the drill pipe. This caused a sharp increase in the drill pipe pressure to 5730 psi.<sup>22</sup>

Shortly thereafter, the rapidly growing gas cloud reached the aft starboard (back right) quadrant of the main deck, entering the air intakes for the engine room. The cloud also dispersed under the deck and into the engine room enclosures. At this time, electrical power was lost and there were two explosions, one which happened at the same time the power went out and the other occurred approximately ten seconds after the first.<sup>22</sup> The explosion was most likely induced by the gas cloud entering the engine room and finding a source of ignition from the moving engine parts. The resulting blast pressure wave caused extensive damage to the starboard side of the rig, damaging the MUX cables that allow communication between the rig and the BOP. As a result, the hydraulic line powering the BOP was damaged, resulting in the BOP not fully sealing the well. The loss of power is also believed to have caused the rig to drift off station, resulting in the BOP seal breaking from the drill pipe and allowing the continuous flow of hydrocarbons up through the riser.<sup>22</sup>

At 9:52, rig personnel activated the emergency disconnect sequence from the bridge in a desperate attempt to disconnect the riser from the BOP stack. However, the emergency disconnect system did not function (whether due to poor design or damage from the explosion is unknown) and the riser did not unlatch from the BOP. With the rig unable to disconnect from the well and gushing hydrocarbons, the order to abandon ship was given at 10:00PM and the rig proceeded to explode shortly thereafter.<sup>22</sup>

#### 4.2.2 Reasons for the Explosion

With the chronology of events leading to the explosion, an analysis of key errors and malfunctions can be made in order to prevent a similar catastrophe from happening in the future. BP's self-internal investigation of the accident yields 8 key findings that led to the explosion of Deepwater Horizon. There is also a five-item list of decisions made by BP that a United States Federal Committee made following an investigation of the accident. Between these findings, a comprehensive assessment of the explosion can be made with regard to the events and actions taken by rig personnel aboard Deepwater Horizon.

##### 4.2.2.1 BP Findings

BP's internal investigation<sup>23</sup> cites 8 reasons leading to the eventual explosion. The first two are categorized by the well integrity failing to be established. The first reason is that the annulus cement barrier did not isolate the hydrocarbons while the second is that shoe track (at the bottom

of the well) barriers also failed to isolate hydrocarbons. The annulus cement barrier was the nitrified foam cement discussed earlier, used because of the fragile nature of the sands surrounding the well. It was believed that the cement slurry was weak in design and in the quality assurance tests performed on it. The cement job was contracted out to Halliburton who made the cement slurry according to BP's specifications; however Halliburton did not perform extensive tests on the cement prior to implementation of the cement in the well. Later tests of the slurry failed to be stable in each test, due to high nitrogen content in the cement. The shoe track failure was attributed to failure of the cement in the shoe track and the float collar which is designed to prevent fluid from entering the casing. This failure is likely due to poor design of the float collar and/or quality of the cement in the shoe track.

The next set of findings are categorized by the influx of hydrocarbons rising through the well undetected and ultimately causing loss of control to the well. The first of these are that the negative pressure test on the kill line was wrongly accepted (as mentioned earlier) when in fact the well was leaking. Because of this, hydrocarbons entered the well undetected until they reached the riser at which point it was too late to make any significant changes with the pipe itself. Actions were taken to try and gain control of the influx of hydrocarbons (bleeding the drill pipe), however the pressure of the well was too high to prevent the flow of hydrocarbons on to the rig.

Once on the rig, BP cites the diversion of hydrocarbons to the mud gas separator (instead of the then shut off overboard diverter line) and the failure of the fire and gas system to prevent ignition of the hydrocarbons as further errors made. The placement of the mud gas separator (MGS) allowed for the hydrocarbons to be directed onto the rig and to create gas clouds on the rig instead of overboard, away from potential sources of ignition. The venting systems onboard most likely directed the gas vapors beyond electrically classified areas, such as the engine room where the cloud found a source of ignition.

The last finding made was the failure of the BOP to fully seal around the well. Despite three emergency methods set in place for operation of the BOP, none of them worked. The first method of operating the BOP was through the emergency disconnect sequence which was designed to disconnect the riser from the well and seal the wellbore. Due to the fire and explosions, the sequence was disabled. This appears to be the result of a design flaw since an emergency system should be designed to operate under emergency conditions. The second method was through the BOP control pods. These pods were designed to automatically seal the well upon loss of hydraulic pressure to the BOP (which happened). However, one of the pods had a fault in a critical solenoid valve while the other had batteries with insufficient charge. These problems had existed prior to the accident. The third method of closing the BOP was using a remotely operated vehicle to close the blind shear rams, however these also failed to seal the well.

It is quite apparent that with 8 critical errors occurring in series that BP failed to ensure a safe environment aboard the rig. The compounded risk resulting from each of these errors drastically increases the likelihood for an accident to occur. Even just the presence of one of these errors produces a risk for an accident. The investigation states that “a complex and interlinked series of mechanical failures, human judgments, engineering design, operational implementation and team interfaces came together to allow the initiation and escalation of the accident.”<sup>23</sup>

#### *4.2.2.2 U.S. Federal Committee Investigation*

A letter<sup>24</sup> from the United States Government investigation committee to Tony Hayward (CEO of BP at the time) highlights five main findings in errors committed by BP. The first of which is the decision of BP to use a well design with few barriers to gas flow. These barriers are the ones outlined in BP’s investigative report discussed previously. The second finding states BP’s decision to use only 6 centralizers to prevent channeling during the cementing process as opposed to the recommended number of 21 centralizers. BP claims that this was not a contributing factor to the explosion since the flow of hydrocarbons did not come from up the annulus, therefore making the well sufficiently centralized.<sup>22</sup> BP also claims that the company had 15 other centralizers on the rig but were incorrectly identified as being the wrong type of centralizer.<sup>22</sup> The letter suggests other reasons, quoting Halliburton’s recommendation to use 21 centralizers and an excerpt from a BP official’s email, saying “it will take 10 hours to install them [centralizers]...I do not like this.”<sup>24</sup> Another BP official stated that “who cares, it’s done, end of story, probably will be fine” after recognizing the risks to proceed with an insufficient amount of centralizers. Regardless of the real reason for not using the recommended amount of centralizers, the decision to use such a drastically lower amount of centralizers than recommended demonstrates the company not ensuring a safe environment for rig personnel.

The third finding states BP’s failure to run a cement bond log to evaluate the effectiveness of the cement job. On the morning of the explosion, BP had a crew from Schlumberger to perform a cement bond log after finally heeding Halliburton’s recommendation; however BP crew told them that their services were not needed. With this knowledge, it is apparent that BP knew of the poor cement job in the well yet still declined to perform a cement bond log. This is quite negligent on BP’s part and is simply unacceptable practice in that environment.

The fourth finding highlights BP’s failure to fully circulate the drilling mud throughout the well before starting the cement process. Usually, this is done to ensure that gas influxes are not present, that gas pockets are not entrained in the drilling mud, and to eliminate drilling debris from the mud to prevent contamination of the cement. BP chose to not perform this safety step and only partially circulated the mud before quickly performing the cement job in the well.

The final finding made by the committee comments on BP’s failure to secure the well-head with a lockdown sleeve before allowing pressure on the seal below it. Since BP chose to use a long production casing as opposed to several shorter casings with connecting liners, few barriers to

gas flow up the annular space existed: the cement at the bottom of the well and the seal at the well-head on the sea floor.<sup>24</sup> By using an insufficient amount of centralizers and refusing to perform a cement bond log to test the integrity of the cement, the only other testable barrier was the lockdown sleeve above the well seal. Had the lockdown sleeve been deployed, it may have prevented the seal from being blown out by the hydrocarbon pressure.

Many of the shortcuts used by BP were fueled not just because of coincidental ignorance, but instead on deliberate negligence. The federal committee comments

*“BP appears to have made multiple decisions for economic reasons that increased the danger of a catastrophic well failure. BP repeatedly chose risky procedures in order to reduce cost and save time and made minimal efforts to contain the added risk.”<sup>24</sup>*

At the time of the explosion, BP was significantly behind schedule. Since the rig plus operation costs totaled over \$1 million per day, the company was desperate to make up lost time in whatever way possible. These delays most likely came from the drilling issues BP had in the previous months with the fragile formations of the Gulf bed. As a result, BP ultimately set the stage for the eventual explosion of the Deepwater Horizon.

#### **4.3 Immediate Response**

After the explosion of the rig, BP initially did not publicize it nor were they entirely honest about the effects of the spill. BP had surveillance of the gushing hydrocarbons at the sea floor for their own use, however it wasn't until the intervention of Rep. Edward J. Markey (D-Mass., chairman of the Energy and Environment Subcommittee of the Energy and Commerce Committee) for BP to publicize the live feed a month after the explosion.<sup>25</sup> It is understandable for BP to not initially publicize everything about the spill immediately so as to prevent a mass uproar from the media and the American public, however doing so with an accident of that magnitude is unacceptable. Once the live feed was made public, scientists were able to analyze the video and determine that “around 70,000 barrels of oil leaked out of the broken pipes a day, not the stated 5,000 barrels a day.”<sup>25</sup> While it is difficult to determine an estimate of the mass flow rate of oil more than a mile underwater, there is still a rather large discrepancy between BP's first estimate and scientists' estimate. This discrepancy shines a negative light on BP, causing them to appear to make the spill seem not as catastrophic as it really was. Nevertheless, cooperation between BP and the United States Government continued to develop as more information was discovered; a credit to BP desiring to be publicly open about their mistake(s) in American waters.

## 5. The Aftermath

### 5.1 BP's Response

#### 5.1.1 Environmental

With an explosion like that of Deepwater Horizon, the environmental impacts are devastating. It was originally reported that 1,000-5,000 barrels were being released per day, and then the estimates continued to increase to 12,000, 19,000, and upwards to 53,000 barrels per day. Overall, about 5 million gallons of oil was spilled into the gulf with just less than one fifth being captured and contained.<sup>37</sup>

Many methods were implemented to try to capture the oil. Ideas poured into BP's command center from concerned citizens who wanted to help. People called in with ideas of using WetVacs, hair, and clothes to soak up the oil. To contain the spill, much of the oil was burned under controlled conditions. BP reports that over 265,000 barrels have been burned in controlled surface burns.<sup>36</sup> Large skimmers were used to recover approximately 9 million gallons of oily water.<sup>38</sup>

The most widely used methods in trying to clean oil spills was in using dispersants. Dispersants are polymer type chemicals that are used to separate colloids, in this case clumps of oil. When the oil is broken apart into smaller particles, which fall below the surface, it can disperse into the ocean and be eaten away by bacteria that are naturally present.<sup>28</sup> Tar balls can be a naturally occurring phenomenon in the ocean and they are decomposed by microorganisms in the same way that the oil that is broken up by the dispersant is decomposed. The dispersant that was used in the BP explosion became a source of controversy because the EPA reported that the dispersant being used was too toxic. By April 24<sup>th</sup>, 1,900 gallons of dispersant has been used on the oil that had escaped to the surface.<sup>26</sup> Dispersants do not however completely solve the environmental issue because adding them to the water can affect the ocean life. Dispersants are many times applied to the oil that is in the deep ocean, meaning under the water, to break it down before it reaches shore and affects the beaches and wildlife that reside there. The EPA states that they "know dispersants are generally less toxic than the oils they breakdown, but the use of dispersants is an environmental tradeoff."<sup>28</sup> The amount of dispersant that was used for this oil spill was the largest amount that had ever been used for a spill. The EPA also reports that while dispersants may be toxic, they are applied in small amounts, at rates of about 5 gallons per surface acre. The dispersant that is used underwater is applied anywhere from a depth of 10 feet to 4,000 feet.

#### 5.1.2 Economical

BP has already had to pay extraordinary amount of money to the families, and companies along the gulf coast affected by the spill. BP reports that they have spent over \$8 billion dollars to date, including clean up costs, claims, unemployed rig workers' funds, Gulf Coast Research, and fines

to the government. Much of the payments that BP has made have come from donations to universities in the gulf coast region, so they can conduct research.

One main allocation of money that BP has made is to the clean-up efforts. A month and a half after the spill, BP announced they would establish a \$360 million escrow account to fund the reconstruction of a section of Louisiana barrier islands.<sup>26</sup> While the government had to pay for some efforts of the clean-up because the Coast Guard was involved, BP had to create a \$20 billion fund over three and half years to met some of the cost clean-up requirements. By July 16, over 32,000 people had received claim benefits totaling over \$200 million dollar.<sup>26</sup> Many of those who received benefits were local fishing companies and tourists companies whose lively hoods depending on being able to use the resources of the Gulf of Mexico off the Louisiana coast. A major issue that arose from these small companies was having the proper receipts to file for claims. Many of these small fishing companies didn't keep proper receipts of profits made, and this made filing claims to BP very difficult for them because to receive the benefits of the claims payout BP would have to see appropriate paperwork.

The government also had to have talks with BP about how much they would be charged, and how much money they would have to set aside to aid those affected by the spill. BP had a bill of \$32.2 billion from the government for the costs of spilling, including the money set aside for the claims requests. While BP has a yearly revenue of over \$200 billion, they said they would sell up to \$30 billion worth of assets to help offset some of the costs.<sup>27</sup> They also announced that no dividends would be paid out for the 2010 fiscal year. Stockholder took a big hit with the Deepwater Horizon explosion. Before the explosion BP stock was at about \$59 a share. By June 25, shares had plummeted to just \$27 a share.<sup>39</sup> This greatly hurt BP employees who had much of their retirement money in stock. Since the low point in June, the stock has risen back up to about \$41 a share.

### 5.1.3 Restoring the BP Reputation

One of the aspects of this accident that truly affected BP most as a Fortune 500 company was the blow they took to their reputation. When a well-known company has a major accident in which many people are killed and there is a major environmentally damaging aspect, their reputation is immediately tarnished, and they lose trust with many of their consumers. Trying to gain trust back is very difficult, but is necessary if they want to remain a strong company and on the forefront of the oil and gas industry. From the first day of the spill, BP has stated that they are trying to appear as transparent as possible. They have said that they want people to know what they are doing and they don't want to hide any of their finding from the people whom this spill affected.

BP has taken the angle that tries to reach each individual person affected by the spill. BP took out a full page ad in the main section of the Houston Chronicle. The ads appeared every day since the beginning of disaster occurred. Many of the ads show a BP employee who states they

are from the Gulf Coast region and that their family has also been affected by the spill. The employee states that they are working hard to help the community (Gulf Coast region) because it is their home as well. BP has been very open for the most part with the information they have released relating to the causes and effects of the spill. BP set up their own internal investigation team to help them understand what exactly went wrong and how they can avoid such accidents in the future. While the American people were initially very upset with accident, their interest in the topic seemed to disappear quite a bit by the time the well was capped in July. With the oil leaking stopped, many citizens lost interest in the subject and stopped following the most recent developments.

BP has dedicated themselves to donating \$25 million to Louisiana, Alabama, Mississippi, and Florida to aid in the oil spill contingency plans.<sup>27</sup> Profits from the oil recovered in spill would also be donated to these states to help with cost of clean-up, and protection of wildlife. They committed another \$500 million to the National Institute of Health under its Gulf of Mexico Research Initiative to study the effects of the spill on public health. The studies would be conducted by an independent study group to ensure the results would not be bias.

When events such as the spill occur, major changes have to occur within a company to show the public that they are restricting their organization to become better and stronger. When major accidents occur, usually the CEO has to take responsible for it because they are the face and name of the company. To show the public that they were taking the accident seriously and BP fired their CEO, Tony Hayward. He was replaced by Bob Dudley. When Bob Dudley took over, he wanted to show the world that BP was handling the situation internally and that they were going to make major improvements to ensure that something like Deepwater never occurred again. Dudley immediately ordered for restructurization of the company by breaking their upstream division in 3 separate companies- Exploration, Development, and Production. Before the restructurization, the upstream division was a single entity.

To improve their image within the eyes of consumers, BP had to restore their reputation and earn back the trust of the people. By maintaining a sense of transparency to the people, they were able to earn some of that trust back. While being transparent may seem like the smart decision at times, it can also make things difficult at points. When the report came out about BP knowing all these procedure that weren't followed correctly, it showed the public and the government that they were negligent in their responsibilities as an employer. This document showed that they knowingly placed their employees in harm's way. So creating a sense of transparency being good and bad press.

## **5.2 The United States Government's Response**

### **5.2.1 Environmental**

When an environmental disaster occurs in the United States, one of the first responders are the United States Coast Guard. For the BP spill, the Coast Guard helped to rescue and locate

the workers after the explosion, and they aided in the clean up process. President Obama said in response to the spill: "Every American affected by this spill should know this: Your government will do whatever it takes, for as long as it takes, to stop this crisis."<sup>27</sup> The US Government has a duty to aid in the time of crisis, and the spill created panic along the gulf coast in the days following the accident. One issue that arose with the spill was how to contain and capture as much of the oil as possible so as to lessen the damage as much as possible. To establish a presence in the gulf the Coast Guard made a Regional Command Center and Joint Information Center in New Orleans, La.<sup>40</sup> The Coast Guard provided large booms, and skimmers to aid in containment and clean-up. While the government would have to originally foot the bill for the clean-up efforts, BP would ultimately be responsible for the billions of dollars spent.

President Barack Obama established a Gulf Coast Ecosystem Restoration Task Force and intergovernmental council. The main focus of the group is to "create a more resilient and healthy gulf coast ecosystem, while also encouraging support for economic recovery and long-term health issues."<sup>29</sup> To aid the Restoration Task Force, President Obama appointed EPA Administrator Lisa Jackson as the chair of the task force.<sup>40</sup> Secretary of the Navy Ray Mabus was appointed to head the integrated Gulf Restoration Effort.

### 5.2.2 Economical

With costs accumulating due to clean-up, the government had to cover some of the original costs for the operation. The President also has the job of resorting hope along the gulf, and reassuring the American people when it is safe to visit the gulf again. On August 5<sup>th</sup>, President Obama and his family visited Florida and said "as a result of the cleanup effort, beaches along the Gulf Coast are clean, they are safe, and they are open for business." When the president makes a comment like the for mentioned, it reassured the people that the gulf is back open for business. The Gulf Coast was hit very hard economically due to the loss of much of their business during the peak summer season.

The oil pollution act lays out the laws for penalties from an oil spill:

**§1002(a)** Provides that the responsible party for a vessel or facility from which oil is discharged, or which poses a substantial threat of a discharge, is liable for: (1) certain specified damages resulting from the discharged oil; and (2) removal costs incurred in a manner consistent with the National Contingency Plan (NCP).<sup>33</sup>

The article from the oil pollution act clearly outlines that BP is responsible for the damages resulting from the spill. One issue that BP has to deal with is the issue of who is truly to blame. Halliburton was in charge of the cementing job on the TransOcean rig, but untimely it is BP who was responsible for checking their work. The government has a special committee that is performing a detailed investigation into all the responsible parties. Since BP was renting the rig, and was drilling for the oil, they are the main responsible party.

### 5.2.3 Hearings

In the hearing for the oil spill President Obama announced that he was ordering an executive establishing a National Commission of the oil spill. The National Committee on Deepwater Horizon Oil Spill and Offshore Drilling was headed by Florida Governor Bob Graham and former Administrator of the Environmental Protection Agency William K. Reilly.<sup>27</sup> A final report is due from the committee on January 12, 2011. The main areas of inquiry are The Macondo Well Explosion and Drilling Safety, Role of Offshore Oil Drilling in Domestic Energy Policy, Regulatory Oversight of Offshore Drilling, Oil Spill Response, Spill Impacts and Assessment, Restoration Approaches and Options.<sup>34</sup> In the hearings, BP was told by the government that they needed to be even more transparent in what information they were giving to the public and the government. President Obama stated “As I said yesterday, BP is ultimately responsible under the law for paying the costs of response and cleanup operations, but we are fully prepared to meet our responsibilities to any and all affected communities.”<sup>31</sup>

### 5.2.4 How Offshore Drilling is Affected

#### *5.2.4.1 Obama’s Initiative*

President Barack Obama wants to wean the US their dependence of oil. He saw the Deepwater Horizon as a perfect opportunity to ban offshore drilling in the United States. The Secretary of the Interior and the President issued a six month moratorium on deepwater drilling stating that “The six month moratorium on deepwater drilling will provide time to implement new safety requirements and to allow the Presidential Commission to complete its work...Deepwater production from the Gulf of Mexico will continue subject to close oversight and safety requirements, but deepwater drilling operations must safely come to a halt. With the BP oil spill still growing in the Gulf, and investigations and reviews still underway, a six month pause in drilling is needed, appropriate, and prudent.”<sup>35</sup> Many companies and employees were upset with this moratorium. Large oil and gas companies have billions of dollars invested in offshore drilling, and with the new rule, they could still be involved in the production process but they could not participate in exploratory drilling. The Moratorium Notice to Lessees and Operators (Moratorium NTL) ordered the the lessees and operators to “cease drilling new deepwater wells, including wellbore sidetrack and bypass activities; and prohibited the spudding of any new deepwater wells.”<sup>35</sup> The Moratorium NTL defined “deepwater” as depths greater than 500 feet.

#### *5.2.4.2 Oil Companies' Response*

As expected, many offshore companies were deeply troubled with the news of the moratorium. Not only were the large well known companies hurt by the action, but smaller companies were also affected. The smaller family-owned business were hurt most because they didn't have any other source of income other than that of off shore profits unlike large companies such as Shell. The banning of offshore drilling also would affect the state of Louisiana which receive \$3 billion annual from the offshore oil industry. Over 320,000 jobs in Louisiana are supported by the oil and gas industry and \$12.7 billion are made yearly in household earnings.<sup>41</sup>

There were many fears that the moratorium would increase the United States dependence on foreign oil; 30% of the domestic output of oil in the United States is from the Gulf of Mexico. The original law suit against the government came from Hornbeck Offshore Services; many other companies proceeded to join in the law suit.

Louisiana judge Martin L.C. Feldman issued an injunction on the moratorium stating that it would hurt drill-rig operators and suppliers, and that the government didn't have the sufficient evidence to prove a ban this large was needed.<sup>32</sup>

## 6. The Accident in Bhopal and Relation to Deepwater Horizon

The Union Carbide India Limited (UCIL) plant manufactured SEVIN pesticide (Union Carbide trade name), whose active ingredient is 1-naphthyl-N-methylcarbamate. It is a type of Carbaryl, whose manufacturing process involved two highly reactive and flammable reactants, methyl isocyanate (MIC) and alpha naphthol. MIC is toxic, and volatile. In 3<sup>rd</sup> December, 1984 about 41 metric tons of MIC was released from the UCIL in Bhopal due to a runaway reaction created by the contamination of a storage tank-610 with a substantial amount of water. The maximum exposure limit (TLV-TWA) for it during an 8 hours period is 0.02 ppm (20 parts per billion).<sup>42</sup> Although the safety relief valve activated at designated pressure, all other downstream measures to mitigate an external release of MIC to the surroundings were on stand-by (a caustic scrubbing tower) or out-of-service (a flare tower). Furthermore, a water curtain spray designed to mitigate releases did not reach the elevation of the release plume. This gas spread slowly with very stable weather conditions towards south during the early morning hours. 200,000 among 900,000 populations within the city were exposed to MIC contaminated air.

Individuals begin to experience severe irritation of the nose and throat at exposures to MIC above 21 ppm. The LC50 for rats exposed to MIC vapors in air for 4 hours is 5 ppm. In humans, exposure to high concentrations can cause enough fluid accumulation in the lungs to cause drowning. At lower levels of exposure, the gas affects the eyes and lungs. It acts as a corrosive agent, eating away at moist vulnerable tissue, such as mucous membranes and eye surfaces. Long-term effects also exist. MIC has a boiling point of 39.1°C and a vapor pressure of 348 mm Hg at 20°C. As such, it is quite volatile and it will easily enter into the surroundings at very high concentrations. With a molecular weight of 57, about 2 times that of air MIC has a higher vapor density compared to air.

Two causes are extensively under investigation. One is the entrance of water through an isolation valve into the storage tanks via a pipeline of 300m long during water cleaning process but the line had not been dried off according to the “Water Washing Theory”. Other suspicion was sabotage, by connecting a water hose to piping that directly entered into the storage tank and purposely admitted water.

But the root causes were due to management decisions, which are given below<sup>43</sup>:

- Neglecting a flare system in repairing it.
- Putting a scrubber system on stand-by to save on operating expenses.
- Removing coolant from the refrigeration system of the MIC storage tank, this is used for cooling it.
- Insufficient emergency planning and lack of community awareness of the potential impact of MIC on the community by the people operating the plant.
- Lack of communication with community officials about the incident.

- Insufficient community planning, allowing a large population to live near this hazardous toxic manufacturing plant.
- Careless about the relief valve of the effluent downstream treatment system, when it was over pressurized and gas leak due to internal reaction.

The 3 MIC storage tanks were surrounded within the earth for insulation. Tank 610 that was over pressurized was removed from its underground vault. The stem of the gate valve that fed the process vent header located above in the pipe rack indicated full closure. The scrubber system of stainless steel is in good condition after more than 20 years. The flare system was kept out of service for several weeks due to a corroded pipe replacement project. Even though, less priority was given on repairing it since the plant was not manufacturing MIC at that time. It has a control room with state-of-the-art equipment and files for operating instructions with safe work permits. This room's location was 100m away to the west of the plant isolated from the process area.

Mercury and other surface pollution has contaminated groundwater and rendered the drinking water in Bhopal hazardous. This is a major catastrophic issue. But Bhopal Plant people regard the MIC release as minor case relative to the long-term environmental effects.

UCIL still claims similar to BP incident on their website that this accident was caused by the individual irresponsible act and error in his or her work like flooding the MIC tank 610 with water. The foundation for the company's position in this report by the public relationship firm, Arthur D Little, paid for by UCC. In spite of this they claim to be an "independent investigation". The actual case is that MIC is a highly volatile gas which must be stored at zero degrees centigrade in a close container. But for boost up production and money saving reasons, the refrigeration unit in the factory had been shut down as per directions from Union Carbide headquarters in Danbury, USA. Any escaping MIC should have bypassed into a caustic-soda scrubber to be neutralized which was also shutdown and not operating on the night of the disaster. Moreover, the pilot flame which is needed to burn out the rest of toxic gases, was kept off and the pipeline to the flare tower were disconnected. Water sprayers designed to take care of leaks in the atmosphere by providing mist curtain which lift the toxic gases above safety height did not have sufficient pressure to maintain the work. Therefore sabotage claim is unsustainable. Even if it were included as credible, the hazardous design of the plant and the deliberate lack of safety systems as well as cost-cutting are sufficient to underline the liability of the UCC corporation like in the case of BP.

## 7. Conclusion

The Deepwater Horizon explosion and oil spill was a completely preventable accident that took the lives of 11 civilians and damaged the eco-system along the Gulf of Mexico. BP's track record had not been blemish free before the explosion of the Deepwater Horizon, and their reputation was very much tarnished by the accident. Previous to Deepwater, BP has had accidents in Texas City, Texas ending with 15 deaths and a pipeline leak in Alaska in which over 200,000 gallons oil was spilled.

Problems with the Transocean rig were prevalent from the beginning. With money being a main concern, many safety aspects were over looked, many of which aided in the occurrence of the accident. Many of the issues were due to mechanical errors that were present because of human negligence. There were over 8 layers of safety that failed in order for the explosion to occur, showing the obvious lack of responsibility on the part of BP.

After the accident occurred, BP had major trust issues with the American people. They had to pay billions of dollars in compensation for people along the coast, and they will continue to pay billions of dollars in penalties from the American government. Their reputation will never fully recover, even though they have been "transparent" with the citizens of the world about what events lead to the accident.

The Union Carbide accident that occurred in India in 1984 had similar issues like those of Deepwater Horizon. Both accidents had major issue with management and equipment failures due to human errors. Money was a large concern for both companies, and forced them to cut corners. This in turn ended up costing them more than could have ever imagined. The negligence in safety due to cost cutting, destroyed not only people jobs and source of income, but took many lives in the process.

Ultimately, had proper safety measures and procedures been conducted in both scenarios, not only would lost lives and equipment be spared, but so would the hefty financial payments and reputations of each company. Cutting corners is never an acceptable practice, and the consequences of doing so are clearly displayed by these two engineering disasters.

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