Deepwater Horizon Accident Investigation Report

September 8, 2010

Executive Summary

This is the report of an internal BP incident investigation team. The report does not represent the views of any individual or entity other than the investigation team. The investigation team has produced the report exclusively for and at the request of BP in accordance with its Terms of Reference, *and any decision to release the report publicly is the responsibility of BP. It has not been prepared in response to any third party investigation, inquiry or litigation.*

In preparing this report, the investigation team did not evaluate evidence against legal standards, including but not limited to standards regarding causation, liability, intent and the admissibility of evidence in court or other proceedings.

This report is based on the information available to the investigation team during the investigation; availability of additional information might have led to other conclusions or altered the team's findings and conclusions.

At times, the evidence available to the investigation team was contradictory, unclear or uncorroborated. The investigation team did not seek to make credibility determinations in such cases. In evaluating the information available to it, the investigation team used its best judgment but recognizes that others could reach different conclusions or ascribe different weight to particular information.

In the course of the investigation, members of the team conducted interviews, and this report draws upon the team members' understanding of those interviews. The investigation team did not record or produce verbatim transcripts of any interviews, nor did the team ask interviewees to review or endorse the notes taken by the interview team members. There were at least two team members present during each interview and, in utilizing information gathered from interviews, the team has taken into account the presence or absence of corroborating or conflicting evidence from other sources.

The report should be read as a whole, and individual passages should be viewed in the context of the entire report. Discussion or analysis that is based, to any extent, on work carried out by third parties—for example, on laboratory or consultant reports commissioned by the investigation team (refer to the appendices of this report)—is subject to the same qualifications or limitations to which that work was subject.

Graphics are occasionally used to depict information and scenarios; these may be simplified or not to scale and are intended only as an aid to the reader in the context of the discussion that they support.

Wherever appropriate, the report indicates the source or nature of the information on which analysis has been based or conclusions have been reached. Where such references would be overly repetitive or might otherwise confuse the presentation, evidentiary references have been omitted.

Executive Summary

On the evening of April 20, 2010, a well control event allowed hydrocarbons to escape from the Macondo well onto Transocean's *Deepwater Horizon*, resulting in explosions and fire on the rig. Eleven people lost their lives, and 17 others were injured. 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 blowout preventer (BOP) for 87 days, causing a spill of national significance.

BP Exploration & Production Inc. was the lease operator of Mississippi Canyon Block 252, which contains the Macondo well. BP formed an investigation team that was charged with gathering the facts surrounding the accident, analyzing available information to identify possible causes and making recommendations to enable prevention of similar accidents in the future.

The BP investigation team began its work immediately in the aftermath of the accident, working independently from other BP spill response activities and organizations. The ability to gather information was limited by a scarcity of physical evidence and restricted access to potentially relevant witnesses. The team had access to partial real-time data from the rig, documents from various aspects of the Macondo well's development and construction, witness interviews and testimony from public hearings. The team used the information that was made available by other companies, including Transocean, Halliburton and Cameron. Over the course of the investigation, the team involved over 50 internal and external specialists from a variety of fields: safety, operations, subsea, drilling, well control, cementing, well flow dynamic modeling, BOP systems and process hazard analysis.

This report presents an analysis of the events leading up to the accident, eight key findings related to the causal chain of events and recommendations to enable the prevention of a similar accident. The investigation team worked separately from any investigation conducted by other companies involved in the accident, and it did not review its analyses, conclusions or recommendations with any other company or investigation team. Also, at the time this report was written, other investigations, such as the U.S. Coast Guard and Bureau of Ocean Energy Management, Regulation and Enforcement Joint Investigation and the President's National Commission were ongoing. While the understanding of this accident will continue to develop with time, the information in this report can support learning and the prevention of a recurrence.

The accident on April 20, 2010, involved a well integrity failure, followed by a loss of hydrostatic control of the well. This was followed by a failure to control the flow from the well with the BOP equipment, which allowed the release and subsequent ignition of hydrocarbons. Ultimately, the BOP emergency functions failed to seal the well after the initial explosions.

During the course of the investigation, the team used fault tree analysis to define and consider various scenarios, failure modes and possible contributing factors.

Eight key findings related to the causes of the accident emerged. These findings are briefly described below. An overview of the team's analyses and key findings is provided in *Section 4. Overview of* Deepwater Horizon *Accident Analyses*, while *Section 5.* Deepwater Horizon *Accident Analyses* provides the detailed analyses. Refer to *Figure 1. Macondo Well*, for details of the well.

1 **The annulus cement barrier did not isolate the hydrocarbons.** The day before the accident, cement had been pumped down the production casing and up into the wellbore annulus to prevent hydrocarbons from entering the wellbore from the reservoir. 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. *The investigation team concluded that there were weaknesses in cement design and testing, quality assurance and risk assessment.*

2 **The shoe track barriers did not isolate the hydrocarbons.** Having entered the wellbore annulus, hydrocarbons passed down the wellbore and entered the 9 7/8 in. x 7 in. production casing through the shoe track, installed in the bottom of the casing. Flow entered into the casing rather than the casing annulus. For this to happen, both barriers in the shoe track must have failed to prevent hydrocarbon entry into the production casing. The first barrier was the cement in the shoe track, and the second was the float collar, a device at the top of the shoe track designed to prevent fluid ingress into the casing. *The investigation team concluded that hydrocarbon ingress was through the shoe track, rather than through a failure in the production casing itself or up the wellbore annulus and through the casing hanger seal assembly. The investigation team has identified potential failure modes that could explain how the shoe track cement and the float collar allowed hydrocarbon ingress into the production casing.*

3 **The negative-pressure test was accepted although well integrity had not been established.** Prior to temporarily abandoning the well, a negative-pressure test was conducted to verify the integrity of the mechanical barriers (the shoe track, production casing and casing hanger seal assembly). The test involved replacing heavy drilling mud with lighter seawater to place the well in a controlled underbalanced condition. In retrospect, pressure readings and volume bled at the time of the negative-pressure test were indications of flow-path communication with the reservoir, signifying that the integrity of these barriers had not been achieved. *The Transocean rig crew and BP well site leaders reached the incorrect view that the test was successful and that well integrity had been established.*

4 **Influx was not recognized until hydrocarbons were in the riser.** With the negative-pressure test having been accepted, the well was returned to an overbalanced condition, preventing further influx into the wellbore. Later, as part of normal operations to temporarily abandon the well, heavy drilling mud was again replaced with seawater, underbalancing the well. Over time, this allowed hydrocarbons to flow up through the production casing and passed the BOP. Indications of influx with an increase in drill pipe pressure are discernable in real-time data from approximately 40 minutes before the rig crew took action to control the well. The rig crew's first apparent well control actions occurred after hydrocarbons were rapidly flowing to the surface. *The rig crew did not recognize the influx and did not act to control the well until hydrocarbons had passed through the BOP and into the riser.*

5 **Well control response actions failed to regain control of the well.** The first well control actions were to close the BOP and diverter, routing the fluids exiting the riser to the *Deepwater Horizon* mud gas separator (MGS) system rather than to the overboard diverter line. *If fluids had been diverted overboard, rather than to the MGS, there may have been more time to respond, and the consequences of the accident may have been reduced.*

6 **Diversion to the mud gas separator resulted in gas venting onto the rig.** Once diverted to the MGS, hydrocarbons were vented directly onto the rig through the 12 in. goosenecked vent exiting the MGS, and other flow-lines also directed gas onto the rig. This increased the potential for the gas to reach an ignition source. *The design of the MGS system allowed diversion of the riser contents to the MGS vessel although the well was in a high flow condition. This overwhelmed the MGS system.*

7 **The fire and gas system did not prevent hydrocarbon ignition.** Hydrocarbons migrated beyond areas on *Deepwater Horizon* that were electrically classified to areas where the potential for ignition was higher. *The heating, ventilation and air conditioning system probably transferred a gas-rich mixture into the engine rooms, causing at least one engine to overspeed, creating a potential source of ignition.*

8 **The BOP emergency mode did not seal the well.** Three methods for operating the BOP in the emergency mode were unsuccessful in sealing the well.

- The explosions and fire very likely disabled the emergency disconnect sequence, the primary emergency method available to the rig personnel, which was designed to seal the wellbore and disconnect the marine riser from the well.
- The condition of critical components in the yellow and blue control pods on the BOP very likely prevented activation of another emergency method of well control, the automatic mode function (AMF), which was designed to seal the well without rig personnel intervention upon loss of hydraulic pressure, electric power and communications from the rig to the BOP control pods. An examination of the BOP control pods following the accident revealed that there was a fault in a critical solenoid valve in the yellow control pod and that the blue control pod AMF batteries had insufficient charge; these faults likely existed at the time of the accident.
- Remotely operated vehicle intervention to initiate the autoshear function, another emergency method of operating the BOP, likely resulted in closing the BOP's blind shear ram (BSR) 33 hours after the explosions, but the BSR failed to seal the well.

Through a review of rig audit findings and maintenance records, the investigation team found indications of potential weaknesses in the testing regime and maintenance management system for the BOP.

The team did not identify any single action or inaction that caused this accident. Rather, 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. Multiple companies, work teams and circumstances were involved over time.

The investigation team developed a series of recommendations to address each of its key findings, and these recommendations are presented in this report. (Refer to *Section 6. Investigation Recommendations*.) The recommendations are intended to enable prevention of similar accidents in the future, and in some cases, they address issues beyond the causal findings for this accident. These recommendations cover contractor oversight and assurance, risk assessment, well monitoring and well control practices, integrity testing practices and BOP system maintenance, among other issues.

With this report, the investigation team considers the *Terms of Reference* of this investigation fulfilled. (Refer to *Appendix A. Transocean Deepwater Horizon Rig Incident Investigation Into Facts and Causation [April 23, 2010].*)

Additional physical evidence may become available following the recovery of subsea equipment. Ongoing activities, investigations and hearings may also provide further insight. BP will consider how best to examine and respond to further evidence and insights as they emerge.

It may also be appropriate for BP to consider further work to examine potential systemic issues beyond the immediate cause and system cause scope of this investigation.

Finally, given the complex and interlinked nature of this accident, it may be appropriate to further consider its broader industry implications.

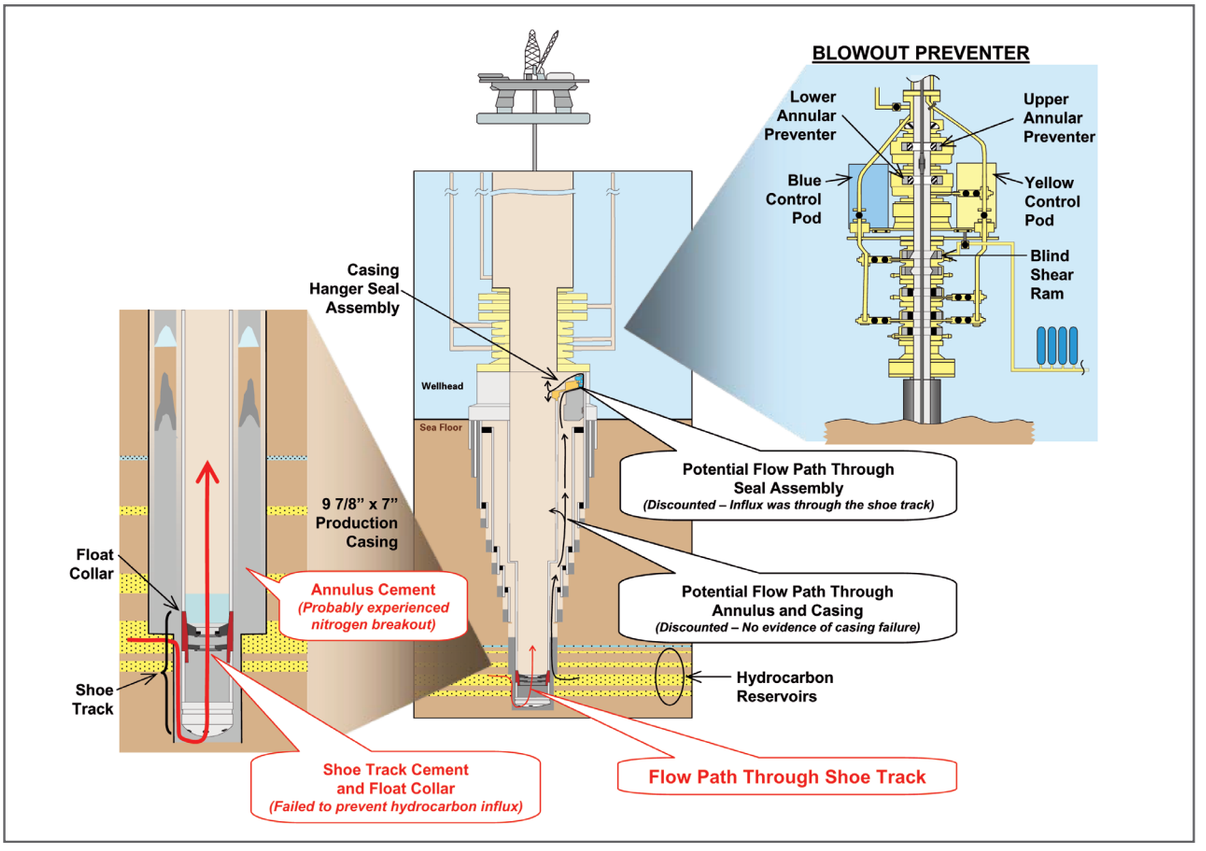

Figure 1. Macondo Well.