

Chapter 4.8 | Kick Response

In the event of an unwanted influx of fluid or gas into the wellbore (a “kick”), the safety of a drilling rig turns on split-second responses by the rig crew.

The *Deepwater Horizon*'s crew did not respond to the April 20 kick before hydrocarbons had entered the riser, and perhaps not until mud began spewing from the rig floor. If the rig crew had recognized the influx earlier, they might have been able to shut in the well. But the crew still had response options even at the point that they eventually did recognize the kick. If the crew had diverted the flow overboard immediately, they might have delayed the ignition and explosion of the gas flowing out of the well. Instead, the crew sent the flow to the mud gas separator.¹ The mud gas separator was not designed to handle this flow volume and was overwhelmed. Sending flow to the mud gas separator, rather than overboard, therefore increased the risk that gas from the well would explode on the rig.

The crew appears to have followed standard Transocean procedures for dealing with hydrocarbon kicks. But those procedures were written to guide the crew's response to routine hydrocarbon kicks. They did not address extreme emergencies like the one the *Deepwater Horizon* crew faced on the evening of April 20. In the future, Transocean and other companies must provide better training and drills to ensure that their crews are prepared to respond quickly to low-frequency, high-risk events like the Macondo blowout.

Well Control Equipment

Blowout Preventer and Emergency Disconnect System

The last piece of equipment that can prevent hydrocarbons from flowing into the riser above the wellhead is the **blowout preventer** (BOP). As [Chapter 4.9](#) explains in more detail, the *Deepwater Horizon*'s BOP had several annular preventers, pipe rams, and shear rams that the rig crew could use to control flow coming from the well from going up the riser.

Most of the barriers in the wellbore, such as drilling mud and cement, block hydrocarbon flow without active supervision by the rig crew. By contrast, BOP elements are typically open during well operations. The BOP does not block flow unless the rig crew spots an influx and closes a BOP element, or an automated backup system activates the blind shear ram. [Chapter 4.9](#) explains the BOP's automated backup systems in detail.

In addition to directly activating the BOP rams, the rig crew can activate the blowout preventer's **blind shear ram** and disconnect the rig from the well using an **emergency disconnect system** (EDS).² In accord with Transocean policy, the rig crew had tested the *Deepwater Horizon*'s EDS at surface prior to deploying the blowout preventer at the Macondo well.³

Emergency Disconnect System. The crew can activate the emergency disconnect system (EDS) from either the driller’s control panel, the toolpusher’s control panel, or the bridge.⁴ Power and communication signals are sent from the rig to the BOP through multiplex (MUX) cables.⁵ The signals initiate a sequence in which pod receptacles de-energize and retract, choke and kill line connectors unlatch, the blind shear ram closes, and the lower marine riser package unlatches from the BOP stack,⁶ separating the rig and riser from the well. Once initiated, this sequence typically takes about a minute.⁷ Emergency disconnect is not generally considered a well control response. Rather, it is used in emergency dynamic positioning scenarios to separate the rig from the well. The rig may begin to “drift off” from its station if the rig loses power, or the rig may “drive off” if the dynamic positioning system mistakenly directs the rig to move away. The riser would likely be damaged if the rig drifted or drove off, potentially resulting in an uncontrolled release of hydrocarbons into the water.

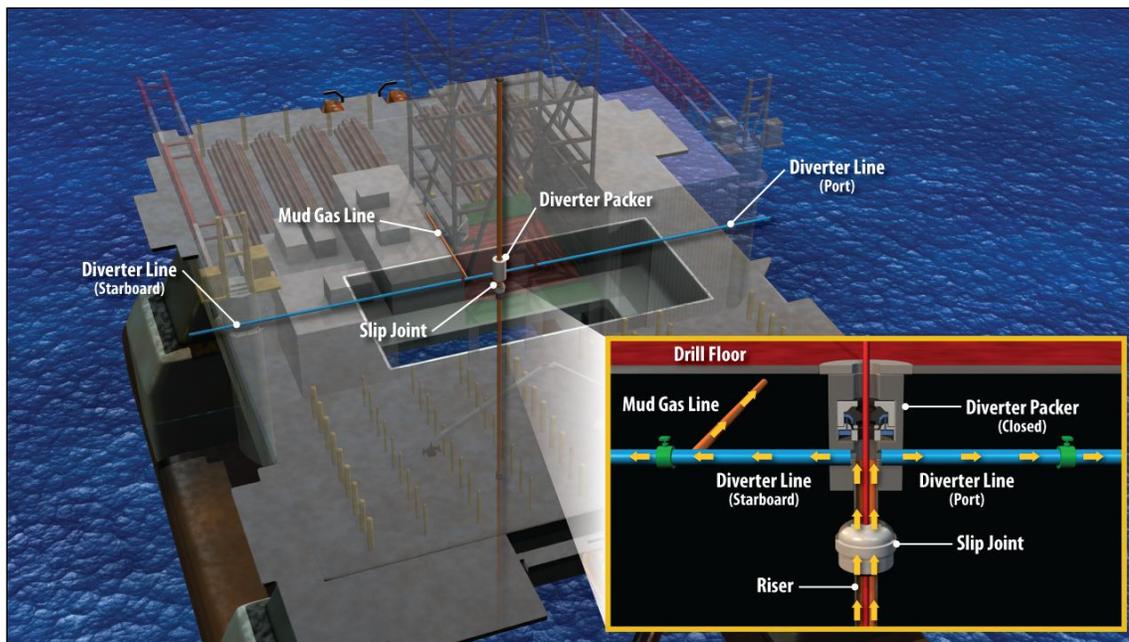
Once gaseous hydrocarbons move past the blowout preventer, they expand exponentially with decreasing depth⁸ and reach the rig within minutes.⁹ Timely BOP activation is therefore crucial to drilling safety.¹⁰ If the BOP is activated quickly, little or no gas will enter the riser and travel to the rig. Transocean advises its personnel: “If the volume of gas above the BOP stack is kept small by detection equipment and shut-in, then the gas can be safely handled at [the] surface.”¹¹ If this is not done, the consequences can be severe. On March 14, BP well site leader Jimmy Adams cautioned BP senior drilling engineer Mark Hafle: “Rigs have been burn[ed] down and people killed from gas in the riser.”¹²

Diverter and Mud Gas Separator

Transocean’s Well Control Handbook warns that “[l]arge amounts of gas above the BOP stack can rise rapidly and carry a large volume of mud out of the riser at high rates.”¹³ In those situations, the rig’s **diverter** becomes the last line of defense. The diverter on the *Deepwater Horizon* sat directly beneath the rig floor.¹⁴ It could prevent gas from flowing uncontrollably onto the drilling rig,¹⁵ in order to “keep combustible gases safely away from sources of ignition.”¹⁶

As [Chapter 4.7](#) explains, mud coming out of the well normally flows up the riser, through the mud cleaning system and into the mud pits. When the rig crew activates the diverter, an annular packer in the diverter closes around the drill pipe (or closes the open hole if no drill pipe is in the hole) and prevents flow up the riser and onto the drill floor. The *Deepwater Horizon*’s diverter packer had a 500 pounds per square inch (psi) working pressure rating,¹⁷ meaning that it could safely withstand 500 psi of pressure exerted by fluids flowing up the riser. Although the diverter is designed to handle worst-case scenarios,¹⁸ pressures above the pressure rating could cause it to fail and allow an influx to continue up the riser.

When closed, the packer forced flow to one of two 14-inch diameter **overboard lines**—one going to the port side of the rig, the other to starboard (see Figure 4.8.1).¹⁹ The rig crew could select the direction of overboard flow in order to discharge gas on the downwind side of the rig. The starboard-side overboard line was also connected to another pipe that led to the mud gas separator. The rig crew could close a valve in the starboard line in order to route flow from that line to the mud gas separator.²⁰

Figure 4.8.1. Diverter system.

TrialGraphix

On April 20, the rig crew diverted the influx to the mud gas separator rather than sending it overboard. That caused mud and gas to spray onto the rig from the derrick.

A mud gas separator consists of a series of pipes, valves, and a tank. When gas-bearing mud flows into the tank, the mud falls to the bottom of the tank while the gas rises. The mud flows out through a pipe in the tank bottom to the rig's mud pits. The gas flows out through a separate pipe. On the *Deepwater Horizon*, that pipe ran to a vent high atop the derrick where gas could discharge into the open air.

When using the diverter system, the crew's most important decision is whether to send the fluid influx overboard or to send it to the **mud gas separator**.²¹ The choice depends on the size of the hydrocarbon influx in the riser.²² The mud gas separator is the right choice for small quantities of mud and hydrocarbons. By separating mud from gas, it allows the crew to collect and reuse the mud rather than discharge it overboard and pollute the sea. Moreover, it vents gas out of a gooseneck pipe on the derrick at the center of the rig. But sending a large influx to the mud gas separator can create a large flammable cloud of gas over the rig.²³ If a sufficiently large and sustained influx of gas from the riser goes to the mud gas separator, ignition becomes more likely, with the potential for explosion.²⁴ As a result, it is inappropriate to send large flows through the mud gas separator.²⁵ In the event of a large hydrocarbon influx into the riser, the crew should send flow overboard through the downwind line.²⁶

Kick Response at Macondo

On April 20, gas moved through the *Deepwater Horizon*'s open blowout preventer and shot up the riser. As it rose, the gas expanded, pushing the mud and gas faster and faster toward the rig.²⁷ Sometime between 9:40 and 9:43 p.m.,²⁸ mud spewed from the rotary table,²⁹ sprayed onto the rig floor,³⁰ and shot up and out the crown of the derrick³¹ about 200 feet above the rig floor.

A Transocean representative likened the force of the gas to “a 550-ton freight train hitting the rig floor,”³² followed by a “jet engine’s worth of gas coming out of the rotary.”³³

The Rig Crew Sends the Influx to the Mud Gas Separator

After drilling mud began spraying out from the rig floor, the crew activated the diverter system.³⁴ Transocean toolpusher Jason Anderson was in the drill shack. He called BP well site leader Don Vidrine to say that the crew was taking action in response to mud coming back from the well.³⁵ It appears that rig personnel had previously set the valves on the diverter system to route diverted flow through the mud gas separator rather than overboard.³⁶ The crew may have done this to avoid inadvertently discharging oil-based drilling mud or other pollution into the Gulf of Mexico in violation of environmental regulations. Whatever the reason, it appears that the rig crew did not change the valve settings to route the flow overboard in response to the sudden mud influx.

Diverting flow to the mud gas separator stopped the flow of mud onto the rig floor within seconds. Micah Sandell, a Transocean gantry crane operator, testified: “I seen mud shooting all the way up to the derrick...then it just quit...I took a deep breath thinking, ‘Oh, they got it under control.’”³⁷

Any relief was temporary. Given the size of the influx, routing the influx to the mud gas separator rather than overboard made ignition all but inevitable. The capacity of a mud gas separator depends on the size of the outlet lines,³⁸ and these lines are generally not large enough to handle very high flow rates.³⁹ The Macondo blowout therefore quickly overwhelmed the *Deepwater Horizon’s* mud gas separator.⁴⁰ Sandell observed: “Then all the sudden the...mud started coming out of the degasser...so strong and so loud that it just filled up the whole back deck with a gassy smoke...loud enough...it’s like taking an air hose and sticking it to your ear.”⁴¹

A Weatherford specialist on the rig watched mud come out of the gas vent lines of the mud gas separator.⁴² Gas likely entered the line to the mud system, which would have sent gas to the pump room, the mud pit room, and the shaker room.⁴³ Components of the mud gas separator may have failed at that time as well.⁴⁴ There was little wind on April 20,⁴⁵ creating “worst-case” conditions for gas dispersion.⁴⁶ A flammable gas cloud started accumulating on the rig.

The Rig Crew Activates the Blowout Preventer

In addition to activating the diverter, the crew also attempted to shut in the well with the BOP’s annular preventer.⁴⁷ (Though there is evidence that the rig crew activated the lower annular preventer at 9:41 p.m., Transocean has recently contended the rig crew activated the upper annular, not the lower annular.)⁴⁸ At about the same time, Transocean assistant driller Stephen Curtis called Transocean senior toolpusher Randy Ezell to tell him that the well was blowing out, that mud was shooting through the crown on top of the derrick, and that Anderson was shutting the well in.⁴⁹ Pressure data indicate the crew activated a variable bore ram—or tightened the annular preventer—on the BOP at about 9:46 p.m.⁵⁰

Activating the annular preventer and variable bore rams are “normal and appropriate” responses to a typical kick.⁵¹ But this was not a typical kick. By the time the *Deepwater Horizon’s* rig crew attempted to activate the BOP, substantial volumes of hydrocarbons probably had already entered the riser, where they would have been rapidly expanding upward toward the rig.⁵² The flow rate of mud and hydrocarbons may have been high enough to prevent the annular preventer from sealing.⁵³

In addition to activating the annular preventers or pipe rams, the crew could have activated the blind shear ram to cut the drill pipe and shut in the well.⁵⁴ The blind shear ram can be activated directly by the rig crew from the control panels, seen in Figures 4.8.2 and 4.8.3.⁵⁵ There is no evidence the rig crew attempted to activate the blind shear ram prior to the explosion.⁵⁶

The rig crew’s response generally followed the procedures that Transocean’s Well Control Handbook specified “upon taking a kick.”⁵⁷ The “shut-in” procedure in the handbook that applied to the April 20 situation specifies that the rig crew should first close the “annular” and then close “pre-determined rams” later if necessary.⁵⁸ The handbook’s shut-in procedures do not offer any specific guidance on the use of the blind shear ram. (The handbook elsewhere advises that the blind shear rams may be used “only in exceptional circumstances.”⁵⁹) By closing the annular preventer and then a variable bore ram, the rig crew thus appears to have followed Transocean procedures.

Gas Ignites Minutes After Mud Reaches the Rig Floor

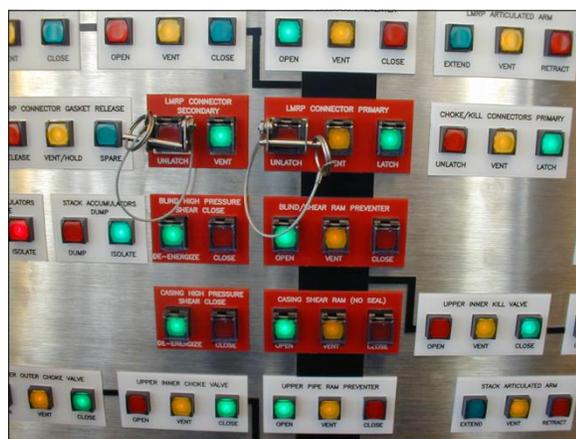
The first explosion occurred at about 9:49 p.m.⁶⁰ Ezell was on his way to the rig floor when the explosion “threw [him] against the wall in the toolpusher’s office.”⁶¹ “Debris” covered him.⁶² Transocean performance division manager Daun Winslow was smoking in the coffee room when he felt the walls suck in and the roof panels collapse on top of him.⁶³ The explosion injured several of the rig crew⁶⁴ and likely killed the men on the rig floor instantly.

The precise source of ignition may never be known. Most of the equipment on a drilling rig is not classified to protect against ignition.⁶⁵ One of the engines likely exploded first—or at least shortly after an initial explosion. Transocean motor operator William Stoner testified that he heard gas hissing and Engine 3 starting to overspeed before the first explosion.⁶⁶ The engine revved higher than Mike Williams, Transocean’s electronics technician, had ever heard before.⁶⁷ Engine 6 was also on and began to rev.⁶⁸ Transocean chief mechanic Douglas Brown testified that the first explosion came from the direction of Engine 3.⁶⁹ After the explosion, the exhaust stacks, wall, handrail, and walkways around Engine 3 were all missing.⁷⁰ Seconds after the first explosion, another explosion occurred.⁷¹ Parts of the rig were in flames.⁷² Fewer than 10 minutes, and perhaps as few as six minutes, had elapsed since mud first hit the rig floor.

The Rig Crew Attempts to Activate the Emergency Disconnect System

After the explosions, crew members elsewhere on the rig attempted to activate the emergency disconnect system. Transocean subsea supervisor Chris Pleasant rushed to the bridge and informed Transocean Captain Curt Kuchta that he was activating the emergency disconnect.

Figures 4.8.2 and 4.8.3.
BOP control panels on the rig floor and bridge.



BP

The blind shear ram can be activated from the BOP’s control panels on the rig floor and bridge.

Captain Kuchta replied, “[c]alm down, we’re not EDSing.”⁷³ Nevertheless, with the backing of Vidrine and Transocean offshore installation manager (OIM) Jimmy Harrell, Pleasant initiated the emergency disconnect at approximately 9:56 p.m.⁷⁴ It appears that the panel’s electronic signals responded, but there was no indication of hydraulic flow closing the blind shear ram.⁷⁵ The low accumulator alarm was sounding, indicating a loss of surface hydraulic power.⁷⁶

The Chief Counsel’s team believes that by this time the explosion had already damaged the MUX cables connecting the rig and the blowout preventer, preventing the command from reaching the stack.⁷⁷ Pushing the EDS button does not appear to have activated the blind shear ram or the remainder of the emergency disconnect system. This left the rig attached to the riser. Gas continued to flow up the riser, fueling the fires on the rig.⁷⁸

Technical Findings

If the Rig Crew Had Recognized the Kick Earlier, They Could Have Shut in the Well Before Gas Entered the Riser

The crew would have been able to prevent gas from reaching the rig if they had recognized the influx before gas entered the riser and responded by shutting in the well. At that point, closing the annular preventer or the variable bore ram should have controlled the kick and stopped flow. By the time the *Deepwater Horizon* crew actually did recognize the influx and activate the blowout preventer, hydrocarbons had almost certainly entered the riser and begun expanding rapidly upward toward the rig.

The *Deepwater Horizon* crew recognized that there was an anomaly, but they did not identify that anomaly as a kick. If rig personnel suspect a kick, they perform a flow check and shut in the well.⁷⁹ The same cannot be said for responses to anomalies. The *Horizon* crew suspected that something was amiss when they shut down the pumps at 9:30 p.m. Over the next 10 minutes or so, they conducted diagnostics and discussed the anomalous pressures they were seeing. Only after hydrocarbons had entered the riser, and about when mud started emerging from the rotary, did the crew act to shut in the well. Apparently, the crew did not suspect a kick until 10 minutes after they detected the anomaly. A more conservative initial approach to the anomaly—of shutting in *first* and investigating *afterward*—would have resulted in rig personnel shutting in the well while hydrocarbons were still confined to the wellbore and thereby preventing the blowout.

By the time the crew activated the annular preventer, mud and hydrocarbons may have been flowing through the BOP at a high enough rate to prevent it from sealing.⁸⁰ Data on drill pipe pressure indicate that the annular preventer did not achieve shut-in pressure. Only 1,200 psi registered,⁸¹ well below what would have been required.⁸² Later, the drill pipe pressure climbed above 5,500 psi.⁸³ That appears to have been due either to tightening of the annular or to activation of the variable bore ram.⁸⁴ Though the well may have been shut in by 9:49 p.m.,⁸⁵ it appears that there was already a substantial volume of gas above the BOP at this time because this is when the first explosion took place.

Previous modifications to the BOP may have compromised the ability of the lower annular preventer to seal the well. (As noted above, Transocean has recently contended the rig crew activated the upper annular and not the lower annular. If true, modifications to the lower annular would not have affected the BOP’s performance during the blowout.) As discussed further in [Chapter 4.9](#), BP asked Transocean in 2006 to modify the lower annular to a “stripping” annular.

This change reduced the rated working pressure from 10,000 to 5,000 psi,⁸⁶ and allowed the rig crew to raise or lower pipe through the BOP while the annular was closed. The 10,000-psi-rated annular body was not replaced.⁸⁷ While the stripping annular would still be able to close in pressures above 5,000 psi, it is not clear whether it would completely seal at these higher pressures.⁸⁸

Diverting Overboard Might Have Delayed the Explosion

The rig crew should have diverted the flow overboard when mud started spewing from the rig floor.⁸⁹ The flow of mud at this point was tremendous—it shot 200 feet up to the crown of the derrick. That should have prompted the crew to take immediate emergency measures.

Transocean's Well Control Handbook advises that "at any time, if there is a rapid expansion of gas in the riser, the diverter must be closed (if not already closed) and the flow diverted overboard."⁹⁰ The handbook also provides: "[I]f large volumes of gas have entered the riser, it will flow rapidly on its own and there will be no way to control it by adjusting the circulation rate. Then, the surface gas and liquid rates become very high, especially as the gas bubble reaches surface and *the flow **must** be diverted overboard.*"⁹¹

Although mud flow at the rig floor does not always mean that gas is in the riser, the *Deepwater Horizon's* crew should have assumed that this was the case for two reasons. First, the fact that *mud was spewing* from the rig floor after the crew had displaced the well with seawater down to 8,367 feet below sea level should have indicated that hydrocarbon flow had already proceeded a substantial distance up the well. Second, and more significantly, the high mud flow rate and volume should have warned the crew that the kick was severe and prompted them to send the influx overboard.

While the Chief Counsel's team finds that the rig crew should have sent the influx overboard immediately, doing so may not have prevented an explosion. Two factors determine whether diverting flow overboard would have prevented an explosion: (1) the ability of the diverter packer, overboard lines, and other equipment to handle the flow rate and volume, and (2) the way in which gas dispersed away from the rig.⁹²

With regard to equipment capabilities, currently available information leads the Chief Counsel's team to conclude that the diverter packer probably would have been able to handle the flow rate and volume during the blowout, though it is not certain. The diverter packer on the *Deepwater Horizon* was rated to withstand 500 psi of pressure. Two post-blowout computer models commissioned by BP for its internal investigation offer perspective on the forces that may have been exerted on the diverter packer during the blowout; the Chief Counsel's team is not aware of any other modeling that has been performed at this time. One model predicts that the maximum pressure exerted on the diverter packer during the blowout was 145 psi,⁹³ not even close to the packer's limit. Another model indicates that the pressures may have been much higher, peaking at 500 psi.⁹⁴ But even under that scenario, the diverter packer probably would not have failed. That model only predicted that the packer would have been subject to 500 psi for an instant,⁹⁵ and this type of equipment can generally handle pressures beyond rated capacity for a short period of time. Moreover, if the rig crew had sent the influx overboard, the pressure on the diverter element likely would have been even lower.⁹⁶ The Chief Counsel's team therefore believes that the diverter packer probably would not have failed if the rig crew had sent the influx overboard.⁹⁷

Though the diverter packer probably could have withstood the blowout flow rate and pressure, the **slip joint** could have failed. The slip joint sat below the diverter packer, permitting the rig to heave vertically while maintaining the riser connection to the sea floor. It had two modes: a low-pressure mode with a 100 psi working pressure⁹⁸ and a high-pressure mode with a 500 psi working pressure.⁹⁹ If the slip joint had been in low-pressure mode, it would have been vulnerable to failure.¹⁰⁰ That would have allowed gas to escape into the moon pool area of the rig. Additionally, because the diverter packer does not seal off the riser, there is a possibility that gas could have also traveled up the drill pipe and onto the rig.

With regard to gas dispersion, the calm wind conditions on April 20 would have limited the rate at which gas dispersed away from the rig. The wind speed was low, about 2 to 4 knots.¹⁰¹ The wind also appears to have been blowing from starboard to port,¹⁰² though the precise direction is difficult to ascertain.¹⁰³ Because of this, gas flowing out of the starboard overboard line would have stayed close to the rig and perhaps even blown back onto the rig rather than drifting away.¹⁰⁴ Nevertheless, diverting overboard would have substantially reduced the risk of ignition of the rising gas and given the rig crew more time to respond.¹⁰⁵ An MMS study of offshore blowouts between 1992 and 2006 found that the “success rate for diverter systems was very high...16 of the 20 diverter uses were considered successful because the desired venting of gas was sustained until the well bridged.”¹⁰⁶

The Chief Counsel’s team concludes that diverting flow overboard likely would have sent a substantial amount of gas off the rig.¹⁰⁷ This may not ultimately have prevented an explosion but probably would have given the rig crew more time to respond to the blowout. BP has concluded that “diversion of fluids overboard, rather than to the MGS, may have given the rig crew more time to respond and may have reduced the consequences of the accident.”¹⁰⁸ Transocean agrees that “diverting overboard might have delayed the explosion....”¹⁰⁹

Management Findings

Transocean Should Have Trained Its Employees Better on How to Respond to Low-Frequency, High-Risk Events

There are at least three explanations for why the crew did not immediately divert the flow overboard.

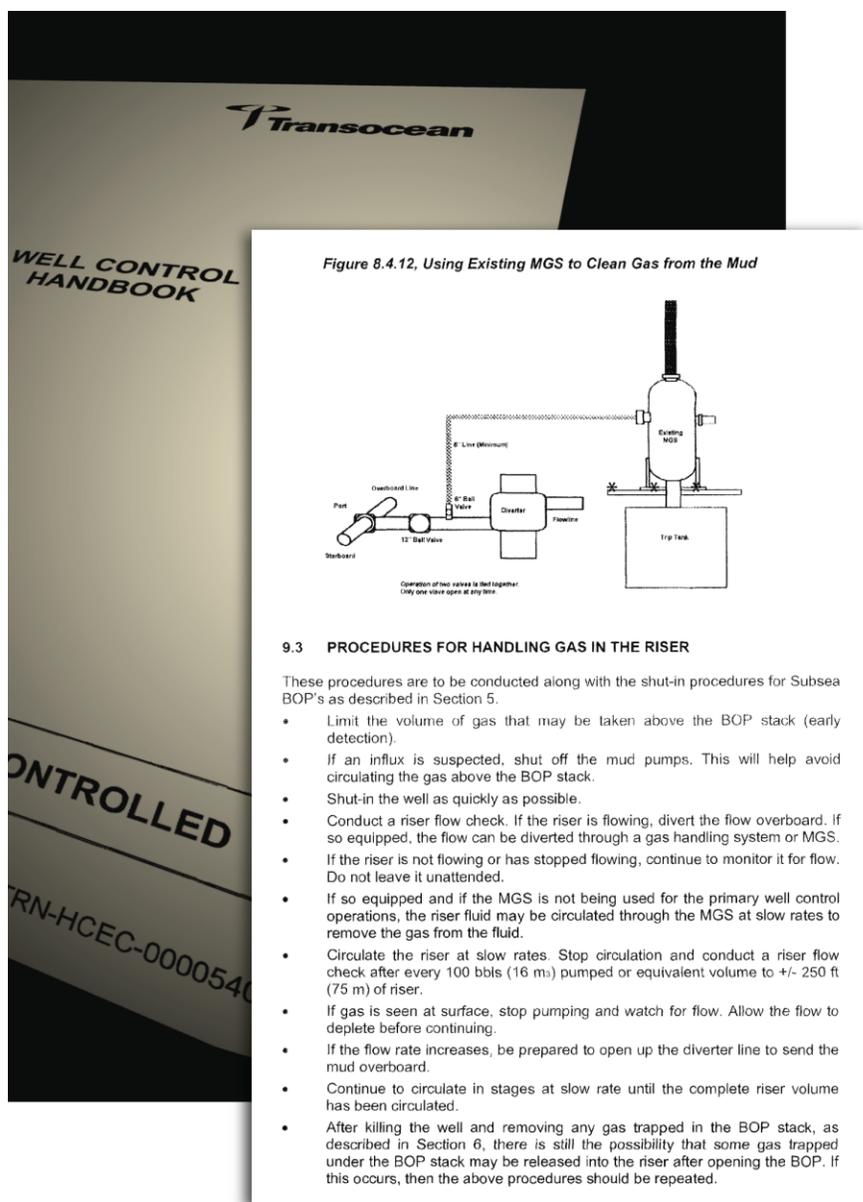
- First, the crew may not have recognized the severity of the situation, though that seems unlikely given the amount of mud that spewed from the rig floor.
- Second, they did not have much time to act. At most, the drill crew had six to nine minutes after mud emerged from the rig floor before the first explosion.
- Finally, and perhaps most significantly, the rig crew had not been trained adequately regarding how to respond to such an emergency situation. It appears that the crew followed the procedures for dealing with a kick set forth in Transocean’s Well Control Handbook. Those procedures were inadequate given the circumstances.¹¹⁰

Transocean has highlighted to the Chief Counsel’s team the “extensive curriculum of courses” available to its rig crew, including courses on well control.¹¹¹ Transocean contends that the

“initial response...was the appropriate first normal response”¹¹² and that the “crew utilized the proper sequencing.”¹¹³ The Chief Counsel's team recognizes that the rig crew may simply have done what it had been trained to do. But that assertion indicates the inadequacy of the crew's training and guidance in the first place.

Though Transocean's protocols provide that a severe influx should be sent overboard, the sequence of “procedures for handling gas in the riser”¹¹⁴ (Transocean document shown in Figure 4.8.4) specifically recommends the overboard line—instead of the mud gas separator—only in the ninth step after actions such as monitoring for flow and circulating the riser. Here, there was *no time* to get to the ninth step.¹¹⁵ In the future, well control training should include simulations and drills for low-probability, high-consequence emergency events and well-control protocols should specifically address such emergencies.¹¹⁶ ♠

Figure 4.8.4. Transocean's “procedures for handling gas in the riser.”



Transocean