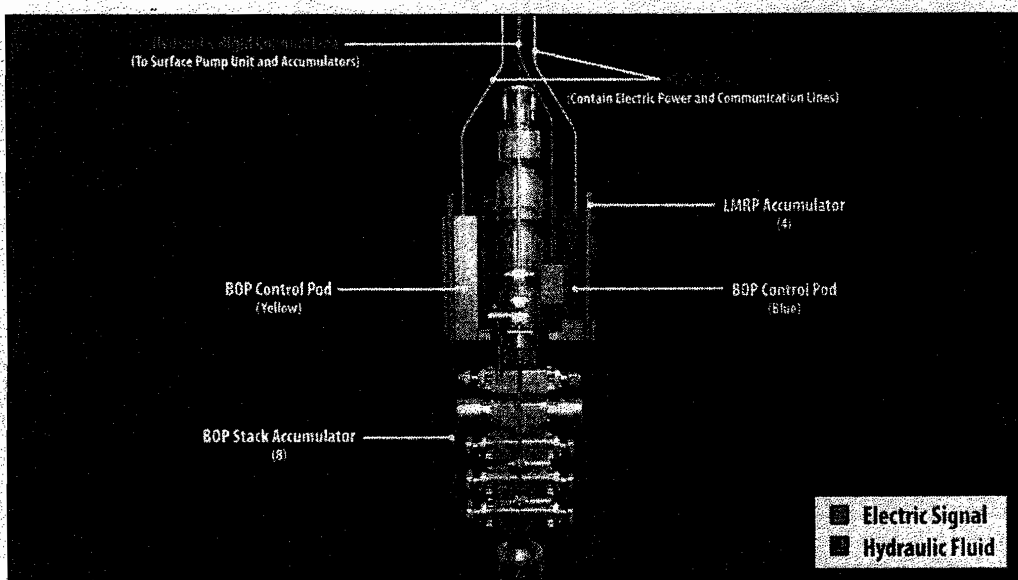
Automatic Mode Function (AMF)/Deadman

The **AMF** or **deadman** system is designed to close the blind shear ram under certain emergency conditions. The system should activate when all three of the following conditions are met:

- loss of electrical power between the rig and BOP;[57]
- loss of communication between the rig and the BOP;[58] and
- loss of hydraulic pressure from the rig to the BOP.[59]

Catastrophic events on a rig can create these conditions, or emergency workers can trigger them by using an ROV to cut power, communication, and hydraulic lines to the BOP (these components are labeled in Figure 4.9.7.).[60] The AMF will not operate unless rig personnel "arm" it at a surface control panel.[61] Notes from response crews and post-explosion analysis of the BOP **control pods** indicate the AMF system on the *Deepwater Horizon* BOP was likely armed.[62]

Figure 4.9.7. AMF system.



TrialGraphix

The AMF, or deadman, system is activated in emergency conditions.

Based on available information, it appears likely that the explosion on April 20 created the conditions necessary to activate the deadman system. The multiplex (MUX) cables, which carried the power and communication lines, were located near a primary explosion site in the rig's moon pool and would probably have been severed by the explosion.[63] The hydraulic conduit line was made of steel[64] and less vulnerable to explosion damage.[65] However, the BOP would have likely lost hydraulic power at least by April 22 when the rig sank, and the deadman should thus have activated by that date.[66] Response crew personnel also tried to activate the deadman on April 22 by cutting electrical wires using an ROV.[67] According to Transocean, the AMF activated the blind shear ram.[68]

Unclear Whether AMF Activated

It is currently not clear whether the AMF activated the blind shear ram. However, the Chief Counsel's team has identified issues that may have affected the AMF.

First, the universe of available test records may be limited because Transocean destroyed test records at the end of each well.[69] Second, the deadman system was not regularly tested.[70] Although Transocean's Well Control Handbook calls for surface testing the deadman system,[71] based on available evidence the AMF was not tested prior to deployment.[72]

Third, the deadman system relied upon at least one of the BOP's two redundant control pods (yellow or blue) to function. If both pods were inoperable, the system would not have functioned. The rig crew function tested and powered both pods at the surface in February 2010 prior to splashing the BOP.[73] But post-explosion examination revealed low battery charges in one BOP control pod and a faulty solenoid valve in another. If these faults were present at the time of the incident, they would have prevented the deadman and autoshear functions from closing the blind shear ram.

Low Battery Charge in the Blue Pod

In the event that electric power from the rig to the BOP is cut off, the BOP's control systems are powered by a 27-volt and two 9-volt battery packs contained in each pod.[74] These batteries power a series of relays that cause the pod to close the blind shear ram if there is a loss of power, communication, and hydraulic pressure from the rig.[75] BP tests suggest that it takes at least 14 volts of electricity to power the relays,[76] and a Transocean subsea superintendent has stated that the activation sequence may require as many as 20 volts.[77]

Tests on the blue pod conducted by Cameron after the blowout on July 3 to 5, revealed that battery charge levels may have been too low to power the sequence to shut the blind shear ram. The 27-volt battery was found to have only a 7.61-volt charge.[78] One of the 9-volt batteries was found to have 0.142 volts, and the other 9-volt battery had 8.78 volts.[79] If these battery levels existed at the time the deadman signaled the pods to close the blind shear ram, the low battery levels very likely would have prevented the blue pod from responding properly.[80] Transocean disputes whether the batteries were depleted at the time of the explosion. Transocean has suggested battery levels were adequate to power the AMF but, due to a software error, may have been left activated and discharged after the explosion.[81] The Chief Counsel's team has not received evidence in support of this assertion but anticipates ongoing forensic testing of the pods will evaluate expected battery levels at the time of the incident.

Available records suggest that Transocean did not adequately maintain and replace its BOP pod batteries.[82] Cameron recommends replacing pod batteries at least annually, and recommends yearly battery inspection.[83] Transocean itself recommends yearly inspection of batteries.[84]

An April 2010 Transocean ModuSpec rig condition assessment stated that all three pods had new batteries installed.[85] But internal Transocean records suggest that the crew had not replaced the batteries on one pod for two-and-a-half years prior to the Macondo blowout and had not replaced the batteries in another pod for a year.[86] This appears to have been a pattern: Company records show that rig personnel found all of the batteries in one *Deepwater Horizon* BOP pod dead in November 2007.[87]

Table 4.9.1. Control pod battery replacements (based on available records).[88]

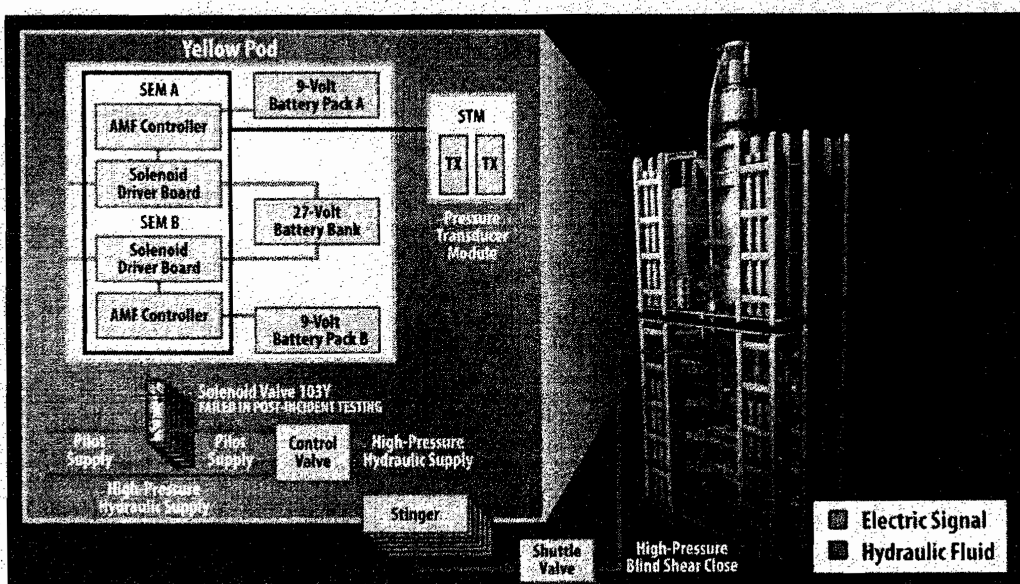
Pod	Battery Replacement Dates	Time Between Battery Replacements	Time Between Replacement and Blowout
Pod 1*	January 26, 2006; April 25, 2009	3 years	1 year
Pod 2	May 28, 2004; December 29, 2005; October 13, 2009	1-3 years	6 months
Pod 3	March 26, 2004; November 4, 2007	3 years	2.5 years

*The *Deepwater Horizon* had three pods for its BOP; at any given time, one was the "blue" pod, one was the "yellow" pod, and one remained on the surface.

Solenoid Valve Problems in the Yellow Pod

Control pods also rely on functioning solenoid valves (diagrammed in Figure 4.9.8). The solenoid valves open and close in response to electrical signals and thereby send hydraulic pilot signals from the pods to the BOP elements.[89] The pilot signals in turn open hydraulic valves, which then deliver pressurized hydraulic fluid into BOP rams to close them.[90] Each solenoid activates when electric signals energize one of two redundant coils in the solenoid.[91]

Figure 4.9.8. BOP's electrical schematic.



TrialGraphix

Tests on the *Deepwater Horizon*'s yellow pod revealed that the solenoid valve used to close the blind shear ram was inoperable.

According to maintenance records, the yellow pod's solenoids were changed on January 31, 2010.[92] However, tests on the yellow pod conducted by Cameron after the blowout on May 5 to 7[93] revealed that a key solenoid valve used to close the blind shear ram was inoperable.[94]

If this fault existed prior to the blowout, an alarm on the rig's control system should have notified the rig crew and triggered a record entry by the rig's event logger.[95] According to witness testimony, the rig crew believed the solenoid valve in the yellow pod was functioning as of April 20.[96]

Autoshear System May Have Activated but Failed to Shut in Flowing Well

Like the emergency disconnect system (EDS), the **autoshear** function is designed to close the blind shear ram in the event that the rig moves off position. The autoshear is activated when a rod linking the lower marine riser package (LMRP) and BOP stack is severed. The rod can be severed by rig movements; if the rig moves off position, it will pull the LMRP out of place and sever the rod. Rig personnel can also sever the rod directly by cutting it with an ROV.[97] Like the deadman, the rig crew must arm the autoshear system at the driller's or toolpusher's control panel.[98] According to BP's internal investigation, the autoshear function was armed at the time of the incident.[99] Transocean policy required its personnel to surface test the autoshear system before deploying the BOP, and the *Deepwater Horizon* rig crew conducted a test on January 31, 2010.[100]

Response crews used an ROV to activate the autoshear function directly by cutting the rod on April 22 at approximately 7:30 a.m.[101] According to BP, response crews reported movement on the stack, which may have been the accumulators discharging pressure and activating the blind shear ram.[102] Even if the autoshear did activate and close the blind shear ram, the blind shear ram did not stop the flow of oil and gas from the well.

Potential Reasons the Blind Shear Ram Failed to Seal

Figure 4.9.9. Erosion in the BOP.

BP

Erosion above the blind shear ram on the BOP's kill side.

Flow Conditions Inside the Blowout Preventer

Even if the blind shear ram activated, it failed to seal the well. One possible explanation is that the high flow rate of hydrocarbons may have prevented the ram from sealing. Initial photos from the recovered BOP show erosion in the side of the blowout preventer *around* the ram, which was a possible flow path for hydrocarbons, as seen in Figure 4.9.9.[103] Therefore even if the ram closed, the hydrocarbons may have simply flowed around the closed ram.

Presence of Nonshearable Tool Joint or Multiple Pieces of Drill Pipe

As discussed above, the ram may not have closed because of the presence of a tool joint across the blind shear ram. If a tool joint or more than one piece of drill pipe was across the blind shear ram when it was activated, the ram would not have been able to shear and seal the well. Though preliminary evidence suggests these factors may not have impacted the blind shear ram's ability to close, the Chief Counsel's team cannot rule out the possibility of such interference.[104]

Accumulators Must Have Sufficient Hydraulic Power

The *Deepwater Horizon* blowout preventer had subsea **accumulator bottles** that provided pressurized hydraulic fluid used to operate different BOP elements. If the hydraulic line between the rig and BOP is severed, these accumulators must have a sufficient charge to power the blind shear ram.

The lower marine riser package had four 60-gallon accumulator bottles were on.[105] On the BOP stack, eight 80-gallon accumulator bottles capable of delivering 4,000 psi of pressure provided hydraulic fluid for the deadman, autoshear, and EDS systems.[106] These tanks were continuously charged through a hydraulic rigid conduit line running from the rig to the blowout preventer.[107] Should the hydraulic line disconnect, the tanks contained compressed gas that could energize hydraulic fluid to activate the blind shear ram. The rig crew checked the amount of pre-charge pressure in the accumulators prior to deploying the BOP in February.[108] However, the available amount of usable hydraulic fluid in the accumulators at the time of autoshear and AMF activation is unknown. If the charge levels were too low, the accumulators would not have been able to successfully power the blind shear ram.[109]

BP's internal investigation suggests accumulator pressure levels may have been low based on fluid levels discovered post-explosion.[110] Responders discovered 54 gallons of hydraulic fluid were needed to recharge accumulators to 5,000 psi.[111] BP's investigation suggests a leak in the accumulator hydraulic system may have depleted available pressure levels but not to levels that would have prevented activation of the blind shear ram.[112] Response crews observed additional leaks from accumulators during post-explosion ROV intervention.[113]

Leaks

It is relatively common for BOP control systems to develop hydraulic fluid leaks on the many hoses, valves, and other hydraulic conduits in the control system. Not all control system leaks affect the ability of the BOP to function: Because BOP elements are designed to close quickly, a minor leak may slow, but not likely prevent, the closing of the BOP.[114]

Even if a leak is minor, rig personnel must first identify the cause of a leak to ensure that more severe system failures do not occur.[115] Constant maintenance, inspections, and testing are required to prevent and detect such leaks.[116] Leaks discovered during surface testing should be repaired before deployment.[117] If rig personnel discover a leak after deployment, they must decide whether the leak merits immediate repair. Raising and lowering a BOP stack is a complicated operation with risks of its own; taking this action to repair a minor control system leak may actually increase rather than reduce overall risk.[118]

Leaks May Have Been Unidentified Prior to Incident

According to Transocean senior subsea supervisor Mark Hay, the *Deepwater Horizon*'s BOP had no leaks at the time it was deployed at Macondo.[119] Even if no leaks existed when the BOP was deployed, rig personnel identified at least three leaks in the months before the blowout after the BOP was in service.[120] And rig personnel identified several more leaks during response efforts that according to independent experts were not likely created during the explosion.[121] It is possible leaks developed during the response effort. But it is also possible leaks already existed and the rig crew had not identified or analyzed the impact of the leak.

A leak on the ST lock close hydraulic circuit (leak 3 in Table 4.9.2) may have prevented ROVs from pumping enough pressure to fully close the blind shear ram.[122] Both BP and Transocean have suggested that a leak on the ram lock circuit (leak 4 in the table) may be proof that the blind shear ram in fact closed.[123] Ongoing forensic testing will likely determine if leaks on the BOP control system otherwise affected the BOP's functionality, though it is unlikely these leaks prevented the BOP from sealing.

Table 4.9.2. Leaks on the *Deepwater Horizon* blowout preventer (partial list).

	Leak	Time of Identification
1	Test ram, pilot leak on yellow pod open circuit shuttle valve[124]	Pre-explosion (February 23, 2010[125])
2	Upper annular preventer, blue pod leak on the hose fitting connecting the surge bottle to operating piston[126]	Pre-explosion (February 19, 2010[127])
3	ST lock close hydraulic circuit leak (this is in the same hydraulic circuit as the blind shear ram)[128]	Post-explosion (April 25, 2010[129])
4	Blind shear ram ST lock circuit leak[130]	Post-explosion (April 26,2010[131])
5	Lower annular preventer open circuit[132]	Pre-explosion (date not available[133])

Identified Leaks Not Reported to MMS

Even if forensic testing concludes leaks on the BOP control system did not impact functionality, it is not clear BP and Transocean adequately responded to known leaks. According to Transocean senior subsea supervisor Owen McWhorter, "the only thing I'd swear to is the fact that leaks discovered by me, on my hitch, were brought to my supervisor's attention and the Company man's attention."[134]

Under 30 C.F.R. § 350.466(f), drilling records must contain complete information on "any significant malfunction or problem."[135] This provision may require control system leaks or other anomalies to be recorded in daily drilling reports and thus subject to review by MMS inspectors.[136] At least two of the leaks identified pre-explosion were not listed in daily drilling reports. A pilot leak on the test ram open circuit shuttle valve (leak 1 in the table) was not mentioned in the daily drilling report for February 23.[137] However, the leak was reported in BP's internal daily operations report from February 23 until March 13.[138] BP wells team leader John Guide and BP regulatory advisor Scherie Douglas made the decision not to report the leak to MMS, a failure which Guide admits was "a mistake in hindsight."[139] BP well site leader Ronnie Sepulvado also admits this leak should have been noted in the daily drilling report but stated that it was not reported because the leak did not affect the ability to control the well since it was on a test ram and the test ram was still operable.[140]

The rig crew failed to include at least one other known leak in the daily drilling reports. Although the rig crew discovered a leak on an upper annular preventer hose fitting (leak 2 in the table) on February 19,[141] the leak was not listed on the daily drilling report.[142] Although subsea personnel in the past had been required to produce documentation on the leak so that the leak could be explained to MMS, McWhorter was not asked to produce documentation for this leak.[143] A failure to report these leaks potentially violated MMS reporting regulations.[144]

Inconsistent Response to Identified Leaks

There is little industry guidance as to what constitutes an appropriate response to minor leaks.[145] It appears the rig crew was able to identify the cause and impact of some leaks but not others. Evidence indicates both BP and Transocean personnel assessed the leak on the test ram shuttle valve (leak 1 in the table) and determined the ram would still function properly.[146] Records appear to indicate the rig crew planned to further evaluate this leak when the rig moved from Macondo to the next well.[147]

In response to a leak on an upper annular hose fitting (leak 2 in the table), the rig crew appears to have isolated and monitored hydraulic pressure.[148] The crew eventually measured this leak at 0.1 gallons per minute.[149] Sepulvado noted the leak on his office white board.[150] Although the leak was later erased from the board, Transocean crew questioned whether the leak was resolved and a similar leak was still present during post-explosion ROV intervention.[151] According to witness testimony, the rig crew never determined the source of a leak on the lower annular (leak 5 in the table).[152]

BOP Recertification

Recertification of a blowout preventer involves complete disassembly and inspection of the equipment.[153] This process is important because it allows individual components to be examined for wear and corrosion. Any wear or corrosion identified can then be checked against the manufacturer's wear limits.[154] Because this process requires complete disassembly of the BOP at the surface, it can take 90 days or longer[155] and generally requires time in dry dock.[156] Industry papers suggest that "the best time to perform major maintenance on a complicated BOP control system [is] during a shipyard time of a mobile offshore drilling unit (MODU) during its five-year interval inspection period."[157] The *Deepwater Horizon* had not undergone shipyard time since its commission.[158]

MMS regulations require that BOPs be inspected in accordance with American Petroleum Institute (API) Recommended Practice 53 Section 18.10.[159] This practice requires disassembly and inspection of the BOP stack, choke manifold, and diverter components every three to five years.[160] This periodic inspection is in accord with Cameron's manufacturer guidelines, and Cameron would have certified inspections upon completion.[161]

The *Deepwater Horizon* Blowout Preventer Was Not Recertified

It was well known by the rig crew and BP shore-based leadership that the *Deepwater Horizon* blowout preventer was not in compliance with certification requirements.[162] BP's September 2009 audit of the rig found that the test ram, upper pipe ram, and middle pipe ram bonnets were original and had not been recertified within the past five years.[163] According to an April 2010 assessment, BOP bodies and bonnets were last certified December 13, 2000, almost 10 years earlier.[164]

Although the September 2009 audit recommended expediting the overhaul of the bonnets by the end of 2009 and emails between BP leadership discussed the issue,[165] the rams had not been recertified as of April 2010.[166] A Transocean rig condition assessment also found the BOP's diverter assembly had not been certified since July 5, 2000.[167] Failure to recertify the BOP stack and diverter components within three to five years may have violated the MMS inspection requirements.[168] An April 1, 2010 MMS inspection of the rig found no incidents of noncompliance and did not identify any problems justifying stopping work.[169] The inspection did not identify the fact that the *Deepwater Horizon*'s BOP had not been certified in accordance with MMS regulations.[170]

"Condition-Based Maintenance"

Transocean did not recertify the BOP because it instead applied "condition-based maintenance."[171] According to Transocean's Subsea Maintenance Philosophy, "[t]he condition of the equipment shall define the necessary repair work, if any."[172] Condition-based maintenance does not include disassembling and inspecting the BOP on three- to five-year intervals,[173] a process Transocean subsea superintendent William Stringfellow described as unnecessary.[174] According to Stringfellow, the rig crew instead tracks the condition of the BOP in the Rig Management System and "if we *feel* that the equipment is—is beginning to wear, then we make...the changes that are needed."[175] Transocean uses condition-based monitoring to inspect all of its BOP stacks in the Gulf of Mexico.[176] According to Transocean witnesses, its system of condition-based monitoring is superior to the manufacturer's recommended procedures and can result in identifying problems earlier than would occur under time-based intervals.[177]

The Chief Counsel's team disagrees. Condition-based maintenance was misguided insofar as it second-guessed manufacturer recommendations, API recommendations, and MMS regulations.

Moreover, the decision to forego regular disassembly and inspection may have resulted in necessary maintenance not being performed on critically important equipment. As discussed in Chapter 4.10, the Rig Management System used to monitor the BOP was problematic and may have resulted in the rig crew not being fully aware of the equipment's condition. Given the critical importance of the blowout preventer in maintaining well control, the Chief Counsel's team questions any maintenance regime that could undermine the mechanical integrity of the BOP.

Technical Findings

As discussed above, this report does not make any conclusive findings regarding whether and to what extent the *Deepwater Horizon*'s BOP may have failed to operate properly because forensic testing is still ongoing. At this point, the Chief Counsel's team can only identify possible reasons why the BOP's emergency systems failed to activate.

The possibilities include:

- explosions on the rig may have damaged connections to the BOP and thereby prevented the rig crew from using the emergency disconnect system to successfully activate the blind shear ram;
- ROV hot stab activation may have been ineffective because ROVs could not pump at a fast enough rate to generate the pressure needed to activate the relevant rams; and
- BOP control pods may have been unable to activate the blind shear ram after power, communication, and hydraulic lines were severed; low battery levels in the blue control pod and solenoid faults in the yellow control pod may have prevented pod function.

Even if activated, the blind shear ram did not seal in the well on April 20 or in subsequent response efforts. Possible reasons for failing to seal include:

- the high flow rate of hydrocarbons may have eroded the BOP and created a flow path around the ram;
- the BOP's blind shear ram may have been mechanically unable to shear drill pipe and shut in the well because it was not designed to operate under conditions that existed at the time. For instance, the ram may have been blocked by tool joints or other material that it was not designed to cut;
- subsea accumulators may have had insufficient hydraulic power; and
- leaks in BOP control systems may have delayed closing the BOP, though it is unlikely that they prevented the BOP from sealing. Leaks may have existed on the BOP control system but not been identified. Identified leaks were not reported to MMS and may have been inconsistently monitored.

Management Findings

Whether or not BOP failures contributed to or prolonged the blowout, the Chief Counsel's team has identified several major shortcomings in the overall program for managing proper functioning of the BOP stack.

- MMS regulations require only one blind shear ram on a BOP stack. But blind shear rams cannot cut the joints that connect pieces of drill pipe, which comprise a significant amount of pipe in a well. The Chief Counsel's team agrees with a 2001 MMS study that two blind shear rams would mitigate this risk.
- MMS approved the testing of the *Deepwater Horizon* blowout preventer at lower pressures than required by regulation. Though testing at lower pressures is in accord with industry practice, most tests of the blind shear ram did not establish the ability of the equipment to perform during blowout conditions with large volumes of gas moving at high speed through the BOP into the riser.

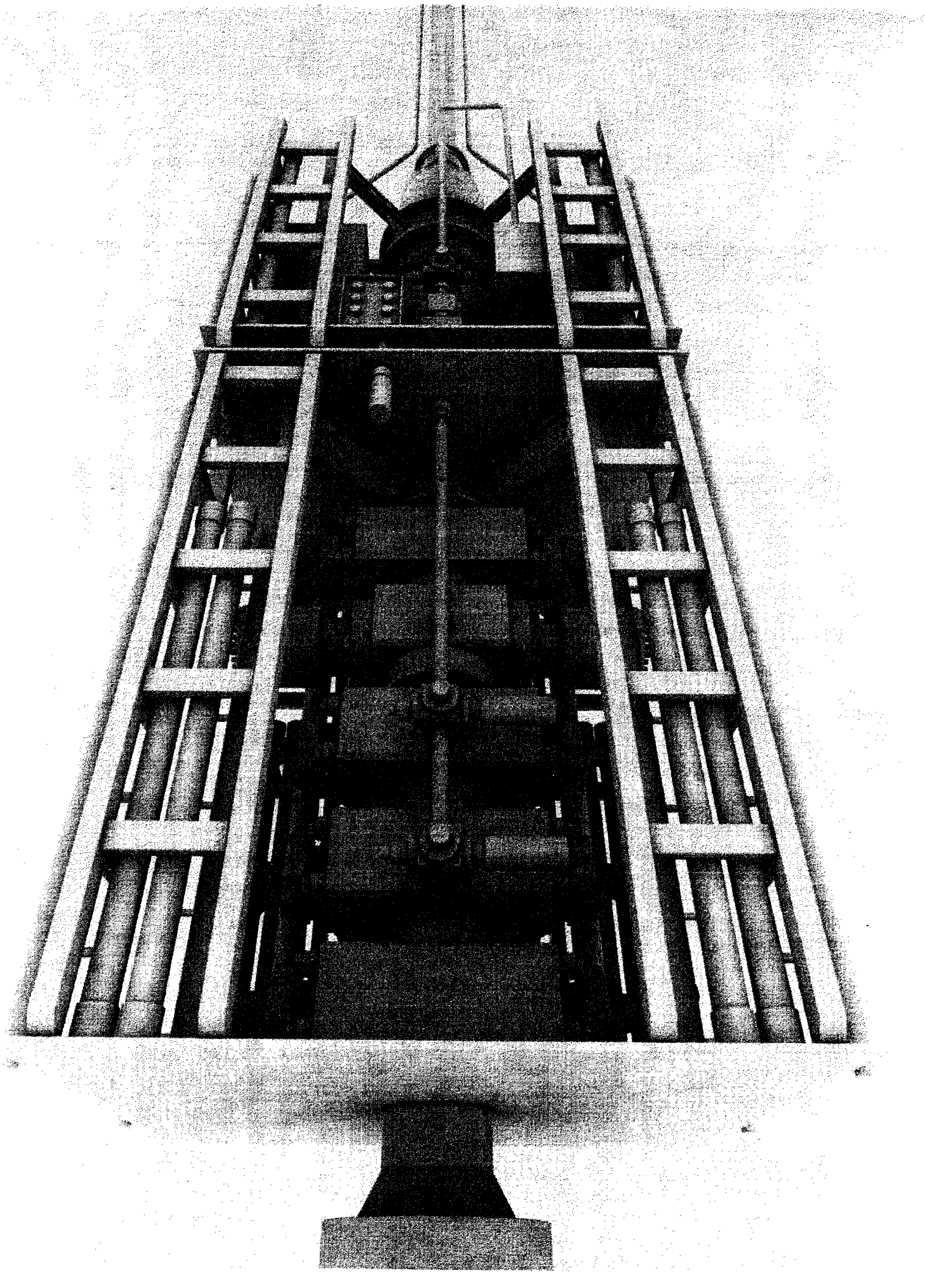
- Transocean's practice of destroying test records at the end of each well creates unnecessary information gaps that may undermine BOP maintenance.
- Critical BOP equipment on the *Deepwater Horizon* may have been improperly maintained. The BOP ram bonnets, bodies, and diverter assembly had not been certified since 2000, despite MMS regulations, API recommendations, and manufacturer recommendations requiring comprehensive inspection every three to five years. Transocean and BP's willingness to disregard regulatory obligations on a vital piece of rig machinery is deeply troubling.

Table 4.9.3. Modifications to the *Deepwater Horizon* blowout preventer.

Date	Modification
November 2001	Control pod subsea plate mounted valves changed from 1-inch to 0.75-inch valves.[178]
October 2002	Increased power supply to control pod subsea electronic modules (SEMs) to higher amp. rating.[179]
December 2002	ST locks modified.[180]
January 2003	Three high-shock flow meters were installed in BOP control pods, replacing ultrasonic flow meters.[181]
January 1, 2003	Changed retrievable control pods to nonretrievable control pods.[182] *This required the LMRP to be retrieved to surface in order to perform maintenance on control pods.*[183]
November 2003	New high-interflow shuttle valve replaced on LMRP and BOP stack.[184]
May 2004	Control pod regulators modified.[185]
June 2004	Control pod subsea electronic modules (SEMs) software upgraded by Cameron.[186]
July/August 2004	New rigid conduit manifold installed and riser-mounted junction boxes removed.[187]
August 2004	Cameron conduit valve package replaced with ATAG conduit valve package.[188] *This isolates LMRP accumulators if pod hydraulic power is lost.*[189]
August 2004	Fail-safe panels on choke and kill valves removed from LMRP and BOP stack.[190] *Valves will close only by spring force.*[191]
November 2004	"Add a second pod select solenoid functioned by an existing pod select switch—to add double redundancy to each control pod."[192]
December 2004	AMF/deadman accumulators: "[T]he pre-charge required on the subsea accumulators is 6800 psi while the maximum working gas pressure for subsea bottles is 6000 psi. This will mean different fluid volumes than are normal on the BOP control system."[193] The deadman accumulators "have now become part of the subsea accumulators since the deadman system has been modified.... There will be little appreciable differences in the system operability but it is important to know how the reduced pre-charge and extra accumulators work on the system."[194]
December 2004	Lower variable bore ram converted to test ram.[195] *A test ram holds pressure from above, instead of below.*[196] *Possibly overlooked relabeling ROV hot stab connections, resulting in ROVs activating test ram during post-explosion efforts to close the BOP.*[197]
February 2005	Control pod modified: "[R]eplace all unused functions on pod with blind flanges. Possible failure points resulting in stack pull."[198]
September 2005	Control system pilot regulator: "[R]eplace pilot regulator with a better designed, more reliable regulator leaks. (Gilmore is a larger unit and will require a bracket to be fabricated for mounting.)"[199]
February 2006	Control panel: "Modification to Cameron control software to sound an alarm should be a button stay pushed for more than 15 [seconds]. If a button is stuck and not detected it will lock up panel."[200]

Table 4.9.3 (continued)

Date	Modification
June 26, 2006	Installed new repair kit in autoshear valve. New repair kit came with new rod and the rod was too long, had to use old rod.[201]
July 2006 (proposal for modification approved)	At BP's request, the lower annular preventer was changed to a stripping annular.[202]
January 2007	AMF/deadman—Cameron will remove the SEM from the MUX section to replace the pipe connectors (customer provided) and to install the AMF/deadman modification kit.[203]
September 2008	Riser flex joint replaced.[204]
June 10, 2009	Software changes made to allow all functions that were previously locked out from any of the BOP's control panels to become unlocked whenever the EDS command was issued from any control panel.[205]
August 3, 2009	Autoshear valve replaced with new Cameron autoshear valve.[206]
2010	Combined the following ROV hot stab functions:[207] blind shear ram close; ST lock close; and choke and kill fail-safe valves.



Chapter 4.10 | Maintenance

A deepwater drilling rig like the *Deepwater Horizon* has literally thousands of pieces of equipment that need routine monitoring and repair.[1] The *Deepwater Horizon*'s crew performed more than 550 preventative maintenance jobs each month on the *Deepwater Horizon* and had spent more than 30,000 work hours on maintenance in the 10 months prior to the explosion.[2]

In some respects the *Horizon* appeared to be operating quite well. The rig received several safety awards[3] and a place inside Transocean's "excellence box," which compares rigs based on safety performance and equipment downtime.[4] BP wells team leader John Guide described the rig as BP's most successful in terms of performance,[5] and one reason leaders from BP and Transocean were visiting the rig on the day of the blowout was to recognize the rig's high performance.[6]

It is nevertheless possible that poor maintenance contributed to technical failures. According to pre-explosion BP emails, the rig was "getting old and maintenance has not been good enough."[7] Most notably, Chapter 4.9 of this report explains that certification of blowout preventer (BOP) equipment was overdue and that if blowout preventer maintenance was inadequate, it could have affected the ability to shut in the well. Other issues may have affected maintenance but, based on available information, likely did not contribute to the blowout.

Transocean's Rig Management System

Transocean had in place comprehensive procedures and systems for scheduling, implementing, and monitoring maintenance.[8] Like all Transocean rigs, the *Deepwater Horizon* used the computerized "**Rig Management System II**" (RMS), which Transocean had implemented as a result of its merger with Global Santa Fe.[9] Transocean personnel used RMS to schedule maintenance work based on information including equipment data, maintenance records,[10] information on certification and surveys,[11] and risk assessments.[12] Based on these materials, the automated system generated preventative maintenance[13] items for the rig.[14] The rig crew would perform these tasks and then record their completion in the system.[15] Transocean's goal in using the system was to ensure consistency, consolidate information, and facilitate personnel movement from rig to rig.[16]

While the Chief Counsel's team interviewed *Deepwater Horizon* crew members who found the RMS useful (despite the fact that it "definitely had some bugs in it") and who used it daily,[17] the team also found evidence to suggest that the system had problems. Transocean installed the RMS on the *Horizon* in September 2009,[18] but according one witness it was "still a work in progress" at the time of the blowout.[19] For instance, while the system produced thousands of preventative maintenance orders for Transocean's fleet,[20] many orders were disorganized, erroneous, or irrelevant to individual rig crews. The *Deepwater Horizon*'s rig crew was forced to actively search the system for the *Deepwater Horizon*'s maintenance items and to continually submit requests to remove duplicate maintenance orders or orders meant for another rig.[21] The system also generated work orders for equipment that had already been repaired, leaving the rig crew to determine if work orders generated by the system actually needed to be performed.[22] According to chief engineer Stephen Bertone, the rig crew "went through them as much as [they] could just poking through the system, but...there were still issues with it."[23] According to assistant driller Allen Seraile, the system was chaos at one time.[24] Chief electronics technician Mike Williams described the system as "overwhelming."[25]

The crew expressed confusion regarding the new system and concerns about its implementation. In a March 2010 Lloyd's Register survey, crew members stated that system changes to the RMS and other rig systems were ineffectively implemented.[26] They thought that new systems were introduced too frequently and before the previous system was understood.[27] The rig crew also thought there was insufficient support to implement changes and that system changes required a level of technical capability not typically available throughout the rig.[28] An April 2010 Transocean assessment also found that the maintenance system was not understood by the crew.[29]

Competing Interests Between Drilling and Maintenance

The rig services contract between BP and Transocean specifies that shutting down the rig to perform certain types of maintenance will trigger financial consequences. BP paid Transocean a daily operating rate of $533,495 for the *Deepwater Horizon*, but under the contract BP was not obligated to pay for time in excess of 24 hours each month spent on certain equipment repairs.[30]

The Chief Counsel's team cannot be certain whether these provisions or other financial pressures influenced maintenance decisions. However, some of the rig crew raised concerns that drilling priorities took precedence over planned maintenance.[31] The *Deepwater Horizon* had never been to dry dock for shore-based repairs in the nine years since it had been built.[32] BP and Transocean appear to disagree as to whether financial considerations influenced this decision. While Guide suggested the *Horizon* did not go to dry dock because Transocean insisted on being paid its daily rate during repairs,[33] Transocean operations manager Daun Winslow testified that any necessary repairs would have been made regardless of financial constraints.[34]

Lack of Onshore Maintenance

Some maintenance can only be performed when a rig is moving between well sites or when the rig is brought into shore.[35] But the *Horizon* had never been to dry dock since it was built in 2001. Transocean instead conducted "Underwater Inspection in Lieu of Dry-docking" (UWILD) and other at-sea inspections.[36] In the March 2010 Lloyd's Register survey some of the rig crew expressed concern that the lack of dry dock time could generally undermine equipment reliability.[37] According to the survey, the maintenance department was looking forward to a scheduled dry dock visit in 2011 "to carry out evasive [preventative maintenance] routines that they normally could not do."[38] Lack of time in dry dock may have resulted in a lapse in BOP certification.[39]

Following company policy,[40] Transocean commissioned an inspection in April 2010 to assess equipment and prepare for the rig's scheduled 2011 shipyard maintenance.[41] The inspection found that some problems identified in September 2009 remained unaddressed and identified several new maintenance issues.[42] As of April 2010, Transocean documents listed 35 critical items of equipment that either were in bad condition, had shown excessive downtime, had passed manufacturer wear limits, or that the manufacturer no longer supported.[43] As discussed in Chapter 4.9, the list included BOP elements that had passed their certification date.[44] According to witness testimony, Transocean had decided to extend the *Horizon*'s anticipated time in dry dock because of the number of repairs necessary.[45] The Chief Counsel's team requested but was not able to obtain a list of repairs scheduled for the *Horizon*'s 2011 dry dock visit.

Maintenance Audits and Inspections

The *Horizon* was subject to audits and inspections by various government and private entities, including BP,[46] Transocean,[47] MMS,[48] the Coast Guard,[49] the American Bureau of Shipping,[50] and the Marshall Islands (the ship's flag state in 2010).[51] These audits varied in scope and duration. Both BP and Transocean had a vested interest in keeping the *Horizon* in working order. Witness testimony describing the response to a fall 2009 audit indicates collaboration by both companies to ensure necessary repairs were made.

Transocean Resolved Many Maintenance Issues Identified in the September 2009 BP Audit

In September 2009 BP audited the *Deepwater Horizon*'s drilling equipment and the vessel itself.[52] The audit found 390 maintenance jobs overdue and identified some of those as high-priority items.[53] BP estimated that the work would require 3,545 man-hours of labor.[54] The audit may have overestimated the sheer number of jobs that were overdue because of errors and duplicates in the RMS system, which Transocean had recently installed.[55] BP asked Transocean to undertake certain repairs before allowing the *Horizon* to resume operations.[56] A few days later, BP determined that the rig was operational,[57] and the rig resumed operations on September 22, 2009, five days after the audit ended.[58]

BP and Transocean increased communication and coordination to monitor implementation of outstanding audit recommendations.[59] For example, auditors communicated conditions to the rig crew during the audit itself in order to ensure that certain repairs were made promptly.[60] BP and Transocean held weekly meetings to track progress,[61] and Guide or well site leaders signed off on corrective actions taken in response to the audit.[62] By March 30, 2010, 63 of 70 had been completed, progress BP described as "commendable."[63] Twenty-six other outstanding items were in progress and deemed not safety-critical.[64]

BP and Transocean Believed the Rig Was in Safe Working Order

At the time of the blowout, both BP and Transocean believed the *Deepwater Horizon* was in safe operating condition.[65] Well site leader Ronnie Sepulvado did not believe there were serious outstanding safety issues,[66] and neither he nor the other well site leaders indicated that the vessel was unsafe to operate.[67] Guide recognized that the rig was operating safely and making very good progress on addressing audit items.[68]

An April 1, 2010 MMS inspection of the rig found no incidents of noncompliance and did not identify any problems justifying stopping work.[69] But, as discussed in Chapter 6, the inspection did not identify that the *Deepwater Horizon*'s BOP had not been certified.[70]

Maintenance Findings

Inspections, audit programs, and statements by rig- and shore-based leadership indicate that BP, Transocean, and government regulators believed the *Deepwater Horizon* was in safe operating order at the time of the blowout. With the exception of potential BOP maintenance issues, the Chief Counsel's team found no reason to believe that maintenance problems may have contributed to the blowout. However, the Chief Counsel's team believes the following issues may have compromised the rig's maintenance regime:

- Transocean's RMS system may have complicated routine maintenance and monitoring. The rig crew appears to have been confused about the system, and the system issued duplicate and erroneous maintenance instructions; and
- the fact that the *Deepwater Horizon* had never been in dry dock may have delayed or prevented certain repairs that could only have been done onshore.