

# **THE FAILURE OF MONITORING PRIOR TO BLOWOUT**

**A working paper prepared for the CSB**

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February 23, 2011

## **Introduction**

The Macondo well accident happened because of the failure of several defences. One of those defences was a system designed to provide early warning of impending blowouts. The purpose of this paper is to examine how and why this early warning system failed. The argument will be that neither Transocean nor BP was serious about making it work.

Drilling operations require a constant circulation of fluids into and out of the well. Normally these flows are in balance, and any imbalance means trouble. The Macondo well began “flowing” a little less than an hour before the blowout, meaning that oil and gas had begun entering the well and moving upwards<sup>1</sup>. From this time onwards, more fluid was coming out of the well than was going in. No one, however, recognized what was happening, until the mud and gas began to spill out, uncontrollably, onto the rig floor.

This was very serious failure. It is fundamental to safe operation of a drilling rig that flows or kicks of this nature be detected rapidly and that the well be shut in, long before the escaping oil and gas gets to the surface. An elaborate system of monitoring was in place to ensure that this happened. The whole system failed on this occasion.

There were two groups with responsibility for monitoring flows. First, the drillers and their assistants were expected to monitor various instruments that could indicate whether the well was flowing. These people were employees of the rig owner, Transocean. Second, BP had employed another organization, Sperry Sun<sup>2</sup>, specifically to monitor all surface instruments that provided information about drilling<sup>3</sup>. A Sperry Sun employee, known as a mudlogger, was available at all times on the rig to carry out these duties. Sperry Sun had installed its own flow meter on the rig, but apart this particular device, it monitored the same data as the drillers. In short for the most part the data available to the drillers on their computer screens was also available to the mudloggers, on theirs.

Sadly, the Transocean employees with responsibility for monitoring these instruments were all killed in the explosion, so we have almost no information about what they did or didn't see in the period immediately leading up to the blowout. However the Sperry Sun mudloggers survived and have told their version of events to various inquiries. As a result we are in a good position to understand why it was that the mudlogger on duty at the time failed to recognize that the well was flowing, right up until the time that the rig was overwhelmed with mud and gas.

## **The available instrumentation**

There were a number of different ways observers could monitor the behavior of the well. Normally, fluids going into the well are drawn from an input tank or “pit”, while fluids

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<sup>1</sup> BP Report( p92) estimates that flow began at 2052. Mud began spilling onto the rig floor at 2140

<sup>2</sup> A subsidiary of Halliburton

<sup>3</sup> Down hole instruments were not part of this brief.

coming out the well go into an outflow pit. There are instruments that measure the levels in these pits. The volume in the pit receiving flow from the well should increase at the same rate as volume in the pit delivering fluid to the well decreases. If it increases at a faster rate, the well is likely to be flowing. There is even an alarm that can be set to indicate when volume changes in one pit are significantly different from volume changes in the other. This comparison of volume *in* with volume *out* is the most basic and also the most reliable indicator of whether a well is “flowing”.

A second type of instrument measures the rate of flow in the line coming out of the well. Transocean and Sperry Sun each had their own flow meters located at different points in the outflow line. These meters operated on slightly different principles, but neither could measure flow rate directly. In fact they needed to be recalibrated frequently to provide a measure of flow rate. Moreover, the Sperry Sun flow meter could not be recalibrated on the day in question because there was no drilling activity<sup>4</sup>. The result is that neither could be relied upon to measure flow rates reliably. What they did measure reliably was *change* in flow rate. . So, when the well began flowing, this should, in theory, have been indicated by the flow meters.

A third potential indicator of flow was the pressure being recorded in the well. However this was an ambiguous indicator: a flowing well might generate an increase in pressure in some circumstances and a decrease in pressure in others, and pressure could vary for quite unrelated reasons. As a result, pressure readings always needed to be interpreted carefully before any inferences were drawn.

### **Displacing the riser**

A critical activity was occurring in the lead up to the blowout – the riser was being displaced. A riser is the section of piping between the rig floor and the sea floor that has to be removed before the rig can move on to its next assignment. Before removing it, the mud in the riser must be replaced with sea water. Mud is the industry term for the drilling fluid used in the well. Its density varies, but in this case it was more than one and half times the density of sea water<sup>5</sup>. At some point in this process of replacing mud with water, the weight of the mud in the riser would no longer be enough to counterbalance the pressure of oil and gas in the reservoir, and the well would become underbalanced. At this stage it would flow, unless there were physical barriers in place, such as a cement plug. On this occasion there were no effective physical barriers in place, for reasons that are not discussed in this paper.

The rig began replacing the mud in the riser at 8.02 pm and, if we accept BP’s estimate, the well began flowing at 8.52. Mud and gas overflowed onto the deck of the rig 48 minutes later at 9.40

The Sperry Sun mudlogger saw nothing in this 48 minute period that told him that the well was flowing. The question is: *what stopped him seeing?*

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<sup>4</sup> DWI Dec 7 Keith, p27

<sup>5</sup> Chief Counsel report, p150

### **Simultaneous activity during the critical period**

The rig was engaged in simultaneous operations that night in preparation for its departure to another assignment. There were two separate activities that took place in the critical 48 minute period that made it almost impossible for the mudlogger to do his job.

#### *1. Emptying the trip tanks*

One of these simultaneous operations was the emptying of mud from a so-called trip tank. Emptying the trip tank was not itself an issue. The problem was that the flow from this tank was sent to the “active” pit, that is, the pit currently being used to receive mud from the well. In other words, the flow from the well into the active pit was augmented by flow from the trip tank. As a result, the amount of mud in the active pit could no longer serve as an indicator of what was coming from the well, and furthermore, any increase in rate of flow from the well that might have registered on the flow rate meter was masked by the flow from the trip tank. In short, emptying the trip tank into the flow line completely undermined the two most important indicators on which the mud logger relied.

When the drillers began transferring mud from the trip tank to the active pit at 8.30, an alarm went off, indicating excess flow. The mudlogger contacted the drillers, to ask what was happening and was told that they were emptying the trip tank<sup>6</sup>. He later told an inquiry that he was not happy with this situation, as it meant that he could not monitor flows effectively,<sup>7</sup> but he believed there was nothing he could do. He knew that, like all employees, he had a right to stop the job for safety reasons, but he did not perceive any imminent danger, so he did not consider this option<sup>8</sup>. At some point the drillers stopped emptying the trip tank but they started again at 8.59 and continued to 9.06. Throughout this period the mudlogger attributed all anomalies in flow rates to the emptying of the trip tank<sup>9</sup>.

On one other occasion the logger called the mud engineer about a gain in mud and was told that they were emptying the mud from sand traps into the active pit<sup>10</sup>. This occurred just prior to the critical 48 minute period, so it did not, itself, contribute to the masking of the flow once it had started. But it is indicative of the lack of any concern that evening for the ability of the mudlogger to do his job.

The other indicator that might have provided some clue about the behaviour of the well was the pressure reading at the top of the well. The mudlogger noted erratic pressure

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<sup>6</sup> DWI Dec 7 Keith p240

<sup>7</sup> DWI Dec 7 Keith p94

<sup>8</sup> DWI Dec 7 Keith p238

<sup>9</sup> DWI Dec 7 Keith p218,9

<sup>10</sup> DWI Dec 7 pm Gisclair, p85, DWI, Dec 7 Keith p180; Chief Counsel’s report, p176

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readings and called the drillers about this. He was told that the drillers were “staggering the pumps”<sup>11</sup>. He had not come across this before and made no further inquiries.

Not surprisingly, the mudlogger ended up attributing all the pressure and flow anomalies he saw during this time to the activities of the drillers<sup>12</sup>. In short, for at least the first fourteen minutes after the well began to flow, other activities occurring on the rig masked whatever evidence there may have been that the well was flowing.

## 2. *The spacer overboard*

Transfers from the trip tank were completed by about 9.06. Had things returned to normal at that point there is a possibility that the instruments would have begun registering more clearly that the well was flowing. However, almost immediately the flow out from the well was diverted overboard into the sea, thereby bypassing both the active pit and the Sperry Sun flow monitor. This meant that it was completely impossible to measure either the total volume of liquid coming out of the well, or the rate of flow of that liquid. From this point on, the mudlogger was effectively blind. How did this happen?

The water being pumped into the well was separated from the mud it was displacing by a spacer fluid designed to prevent the mud and water from mixing. Under environmental regulations fluid that had been used as a spacer in this way could be discarded overboard, provided it passed an on-the-spot environmental test. BP had some left-over fluids on the deck of the Deepwater Horizon and in order to be able to dispose of them overboard it decided to use them as spacer. The result was that spacer pumped into and out of the well was twice the amount that would normally have been used. This strategy was checked and approved by BP’s environmental department on shore, but there was no consideration given to the impact that this would have on logger’s ability to monitor the flow<sup>13</sup>.

At 9.08 the spacer arrived at the surface and the pumps were stopped. A sample of spacer was taken away to be tested to ensure that it indeed satisfied environmental requirements and could be diverted overboard. Two minutes later, before the test results had come back, the flow path was changed, so that when the pumps resumed the spacer would go overboard. During this two minute interval before the flow path was diverted, the flow meter registered flow.<sup>14</sup> Some residual flow could be expected during this period, but the flow pattern was slightly different from the normal pattern of residual flow<sup>15</sup>. This was perhaps the clearest indication that the well was flowing, but it was not conclusive<sup>16</sup>, and in any case the window of time in which it was visible was so fleeting as to be easily missed. After that two minute interval the flow from the well went overboard and was no longer visible to the Sperry sun flow meter.

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<sup>11</sup> DWI Dec 7 Keith p216

<sup>12</sup> DWI Dec 7 Keith p 211, 213, 218 219

<sup>13</sup> DWI July 19 Bertone, pp 276, 310, 337; DWI Aug 26, Sims, p232; DWI July 23 Smith, p365; DWI July 19, Bertone, p275

<sup>14</sup> BP report p 93

<sup>15</sup> Chief Counsel’s report, p178

<sup>16</sup> DWI Dec 8 am Robinson, p280

At 9.14 word came back that the spacer had passed the test and the pumps were started again to pump the spacer overboard. This continued for the next 16 minutes until 9.30. This was a total of 20 crucial minutes during which the mudlogger was entirely unable to monitor the flow out of the well.

At 9.31 the pumps were stopped. It is not clear why. In any case, either at this point or within a minute or two, the drillers noted some pressure anomalies. They discussed these anomalies for about five minutes, after which they began an investigation. Specifically, at 9.36 they opened the drill pipe to bleed off pressure and at 9.38 they closed it again to see what might then happen. Two minutes later, at 9.40, mud and gas overflowed onto the deck. At 9.41 they took emergency action to try to close the well down.

It has been suggested that the drillers should have tried to shut down the well immediately they recognized the pressure anomalies. But given what they knew at the time, their actions were not unreasonable. It is generally agreed that pressure anomalies do not necessarily mean that a well is flowing and that it is necessary to investigate such anomalies before taking more decisive action<sup>17</sup>. The problem was that by this stage, time was against them and they were overwhelmed before they had a chance to understand what was happening.

There is one additional factor that needs to be addressed in considering the role of the mudlogger. At approximately 9.00pm he went off on a 15 minute toilet/coffee break. He notified the drillers, effectively indicating that they would need to shoulder some additional monitoring responsibility during this time. All employees need to be able to take breaks of this nature and it is just a tragic irony that this break occurred at a time when telltale indications were emerging that something was amiss. It cannot be concluded however that had he been on station during this period he would have identified what was happening. A subsequent expert analysis of the flow and pressure data that were available to the mudlogger at the time concluded that these data did not unequivocally indicate that the well was flowing. Moreover, the analyst said that if he himself had been confronted with the data available at the time, he could not be sure that his own behavior would have been any different from that of mudlogger<sup>18</sup>.

To recapitulate, during the 48 minute period before the blowout when the well was flowing, the pit level monitoring system and the Sperry Sun flow meter were effectively out of action for all but a couple of minutes. Activities on the rig had defeated the two most important monitoring systems available to the mudlogger. This is the principle reason the mud logger failed to detect that the well was flowing.

### **Other simultaneous activity**

Earlier in the afternoon another activity took place on the rig which prevented the mudlogger from monitoring the flow out of the well. For nearly four hours, from 1.28pm

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<sup>17</sup> DWI, Dec 8 Robinson, p150, 285

<sup>18</sup> DWI Dec7 pm Gisclair, p63,4

to 5.17 pm mud from the well was transferred directly over the side of the rig to a supply vessel, the Bankston, without passing through the active pit. Again this meant the mudlogger's capacity to monitor the well was severely limited. This was outside the critical 48 minute window when the well was flowing, so there is no suggestion here that had this transfer not been occurring the outcome would have been different. However it is symptomatic of the attitude of the rig staff. They clearly did not see a need to monitor the well carefully during these final stages and were happy to allow other activities to interfere with the capacity of the loggers to do their work.

Interestingly the mudlogger on duty at this earlier time expressed concern about this at a start of shift meeting. Her concern was effectively dismissed. However she was told that she would be notified when mud transfer to the Bankston had been completed, so that she could resume her duties. She was never so notified.

Despite the reservations of the mudloggers<sup>19</sup> simultaneous activity of this nature appears to have been the norm. As one Transocean employee said: "pumping to the boat was just something the rig did"<sup>20</sup>. Moreover, these simultaneous operations were happening at the same time as a group of senior executives from both BP and Transocean were visiting the rig. Interestingly, they did not question what was happening. Indeed one of these senior executives, himself a very experienced driller, chatted with an employee who was off-loading the mud to the support vessel. He asked the employee about the immediate risks this activity posed to him, but he did not question the activity itself<sup>21</sup>, suggesting that there was nothing abnormal about the practice. Even if this inference is disputed, what is clear is that the personnel on the rig that afternoon had no sense that what they were doing might be in any way questionable or that they should desist while these senior executives were on board.

### **The "sea chest"**

There is one other feature of activities that afternoon and evening that made it more difficult to monitor the well. The sea water being pumped into the well was not in fact coming from a pit where the level could be monitored, but from a so-called sea chest, where it could not. The only way to know how much sea water was going into the well was by doing calculations based on pump rate. It is not clear in the interview evidence why this was occurring but it obviously further undermined the capacity of the loggers to compare what was coming out with what was going in<sup>22</sup>.

### **The drillers' perspective**

As already noted, the drilling crew also had a responsibility to monitor flows in and out the well. Because they were killed, little is known of what they were doing or seeing in

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<sup>19</sup> One of them said the extent of simultaneous activity was contrary to Transocean policy. (DWI Dec 7Keith p 39)

<sup>20</sup> DWI July 9, Bertone, p350

<sup>21</sup> CSB Sept 28, Sims, p14,15

<sup>22</sup> DWI, Oct 8, Gisclair, p127; Dec 7 pm, Gisclair, p 56,7

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the final 48 minutes. The simultaneous activities would certainly have prevented them comparing the volumes going in and out the well, just as it did the mudloggers. However their flow meter was not located at the same position as the Sperry Sun flow meter and was not bypassed when the flow was routed overboard in the last half hour before the blowout. Theoretically, therefore, had they been attending to their flow meter it might have given them some indication that flow was increasing, although, given the limitations of their flow meter there is no certainty about this. What we do know is that from 9.17 onwards they were distracted by another task, trying to bring a damaged pump back into operation.

### **Explaining simultaneous operations**

Simultaneous operations were occurring because the crew of the Transocean were in a rush. Tank cleaners were coming on board at midnight and the mud needed to be moved before they started work<sup>23</sup>. The cleaning was a prelude to moving the rig to its next assignment.

There is some disagreement about whether this tight schedule contributed directly to the sense of urgency that evening. According to one employee: “it was just passed around by other people that this well was taking too long and they were in a hurry to complete it so they could move on to the next”<sup>24</sup>. Chief Counsel for the Oil Spill Commission, doubts that the schedule itself was a factor, although he acknowledges that the rig was under “time pressure”<sup>25</sup>

There is no doubt that generally speaking time was money<sup>26</sup>. The drilling and completions group within BP had been set the goal of driving costs down by 7%<sup>27</sup> which of course meant using rig time as efficiently as possible. The whole bonus system focused strongly on cost reduction which provided an ever present pressure to speed. This applied to both BP and Transocean staff<sup>28</sup>.

Another explanatory factor is the state of mind of rig personnel that day. As far as they were concerned the job was over. The well had been drilled and it had twice been declared safe, once when the engineers announced that the cement job had been successful (see earlier working paper) and again when the BP man on the rig declared that the negative pressure test had verified that the well was safe. They were now just finishing up and, from their point of view, it was unnecessary to monitor the well closely. If simultaneous activities interfered with the job of the mud loggers, so be it.

This attitude is surprising given Transocean’s history. In April 2001 Transocean issued an operational advisory about the need to monitor carefully when “displacing to an

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<sup>23</sup> DWI Dec 7, Keith p 40

<sup>24</sup> DWI May 26, Brown p112

<sup>25</sup> p353

<sup>26</sup> Discussed in the Chief Counsel’s report , pp245-7.

<sup>27</sup> DWI Dec8 pm Spraghe, p50

<sup>28</sup> DWHI Aug24Winslow, p182



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unbalanced fluid”. The advisory was a result of a “well-control event on a Transocean rig which occurred due to a failure of a tested mechanical barrier”<sup>29</sup>, exactly what happened at Macondo.

Another such incident occurred on December 23, 2009 in the North Sea, just four months before the Macondo blowout, while Transocean was completing a well for Shell<sup>30</sup>. On this occasion, rig staff were displacing the mud in the riser with seawater, just as they were at Macondo. They had previously carried out a negative pressure test on the well which they declared a success, just as happened at Macondo. They then apparently stopped monitoring and were caught by surprise when mud overflowed onto the rig floor. Fortunately, they were able to shut in the well before an uncontrolled blowout or fire occurred<sup>31</sup>.

After the 2009 incident Transocean created a powerpoint presentation warning that “tested barriers can fail” and noting that the “risk perception of barrier failure was blinkered by the” negative pressure test. It concluded that high vigilance is necessary when operating underbalanced with one barrier, exactly the situation at Macondo<sup>32</sup>. Transocean eventually issued another operations advisory to its North Sea fleet on April 14, six days before the Macondo incident. Among other things the advisory admonished:

"do not be complacent because the reservoir has been isolated and tested. Remain focused on well control and good well control procedures"<sup>33</sup>.

Apparently neither the power point nor the advisory had been sent to the Deepwater Horizon. Indeed a Transocean executive with responsibility for the Deepwater Horizon was not even aware of the incident until some time after the Macondo event<sup>34</sup>.

It is clear that Transocean had not done nearly enough to embed the lessons of either 2001 or 2009 in its organization. In particular, after the 2009 incident, it failed to ensure that drillers in its fleet were effectively monitoring wells in the final stages, and it failed even to ensure that information about this incident arrived on its rigs in the Gulf of Mexico. So it was that those responsible for Deepwater Horizon operations could continue to view monitoring as dispensable during the final riser displacement stage. The policy of issuing advisories is clearly vacuous. What is need is a commitment to *enforcing* those advisories. Transocean evidently had no such commitment.

### **Inadequate technology**

One other factor contributed to the monitoring failure, namely, the very technology by which the monitoring was done. The Presidential Commission put it well<sup>35</sup>:

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<sup>29</sup> DWI Dec 9 am Caducci, p170,1

<sup>30</sup> DWI Dec 9 pm Caducci, p76

<sup>31</sup> Most of the information on this incident and the response to it comes from the Presidential Commission report, p 124

<sup>32</sup> The exact meaning of the 2-physical-barrier policy is not discussed here.

<sup>33</sup> DWI Dec 9 pm Caducci, p99

<sup>34</sup> DWHI Aug24Winslow, p122

In the future, the instrumentation and displays used for well monitoring must be improved. There is no apparent reason why more sophisticated, automated alarms and algorithms cannot be built into the display system to alert the driller and mudlogger when anomalies arise. These individuals sit for 12 hours at a time in front of these displays. In light of the potential consequences, it is no longer acceptable to rely on a system that requires the right person to be looking at the right data at the right time, and then to understand its significance in spite of simultaneous activities and other monitoring responsibilities.

What the Commission is saying, bluntly, is that this was a set up for failure.

There are at least two aspects of the Commission's comments worth developing here. The first is that the data collected do not provide unambiguous indicators of what is happening. They must be interpreted in the light of whatever other activities are occurring on the rig. We have already noted several ways in which volumes and flow rates are directly affected by other activities. One other activity mentioned by witnesses was movements of the crane. Such movements can alter the balance of the whole rig, resulting in variations in flow rates. This can make it more difficult to identify whether the well is flowing. For example, the erratic flow that occurred at 8.20, about half an hour before the well began to flow, was attributable to a crane movement<sup>36</sup>. Similarly, waves can affect the rig balance and hence the readings generated by the sensors<sup>37</sup>. As a result, in order to understand charts showing rig sensor data, the viewer must have very good understanding of what else is going on at the time. The analyst who was asked by the joint inquiry to interpret the rig data in the period just before the blowout needed an extensive briefing from the mud logger on duty at the time before he was able to do so. There is an important implication here. Making data available contemporaneously in BP offices, as was done with the Sperry Sun data, is of little help to those ashore in understanding what is going on, unless they are in frequent phone contact with the rig<sup>38</sup>. But the main point is that a monitoring system that is so very sensitive to other activities is a less than satisfactory way of monitoring the behavior of the well itself.

There is a second aspect of the Commission's comments worth emphasizing, namely, the primitive<sup>39</sup> nature of the flow meters used by both Transocean and Sperry Sun. The Transocean indicator was a paddle or flapper, inserted into a horizontal flow line. With no flow, the paddle would hang vertically, but as flow increased the paddle would rotate in the direction of flow –the greater the flow the more acute the angle of the paddle to the direction of flow. For a given angle, flow rate could be calculated, but this yielded only an estimate, not a reliable measure. As for the Sperry Sun flow meter, it was an acoustic instrument that measured depth of fluid in the horizontal segment of the flow line. So if a

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<sup>35</sup> P 121

<sup>36</sup> DWI Dec7 pm Gisclair p84

<sup>37</sup> DWI Dec7 pm Gisclair, p93,4

<sup>38</sup> DWI Dec 7 pm, Gisclair, p108

<sup>39</sup> The contrast between the relatively primitive technology involved in mud monitoring and the highly sophisticated, automated technology by which the rig dynamically positioned itself is striking. The former was primitive in comparison to the latter.

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small amount of fluid was sitting stationary in the line it registered as a flow<sup>40</sup>. Again, therefore, the readings from this instrument needed to be calibrated. In short, these were relatively crude instruments compared, for example, with the sophisticated navigation instruments by which the rig dynamically positioned itself. Clearly the technology of well monitoring has not kept pace with other aspects of drilling technology.

There is an important conclusion to be drawn here. Given that inferences from the data depend on additional information about what is going on, these monitoring systems do not lend themselves to automation. If the Commission's vision of a more automated system is to be realized, radically different and more sophisticated technology will need to be developed.

## **Conclusion**

The well monitoring system failed to provide warning of imminent blowout because the neither Transocean nor BP was serious about ensuring that this function could be carried out effectively. The rig was engaged in simultaneous operations, in order to finish the job as quickly as possible and the system of monitoring was sacrificed to this end. Transocean had issued advisories about the need for vigilance in these final stages of drilling a well, but it did not enforce these advisories and the practice appeared to be completely contrary to these advisories. Likewise, although it had employed Sperry Sun to provide additional monitoring services, BP seemed unconcerned about whether the mudloggers were in a position to provide these services. Apart from the mudloggers themselves, no one seemed interested in monitoring the well in the final hours. People had been lulled into a false sense of security by the presumed success of both the cement job and the negative pressure test. All that remained was to finish the job as quickly as possible and move to the next location.

The policy of defence in depth requires that multiple defences be in place - both physical and procedural. The rationale is this. No one defence is perfectly reliable, but if several fallible defences are in place, the probability that all will fail simultaneously is almost infinitesimally small. Unfortunately, that is not how people thought about things on the rig. The view was that if one physical barrier was in place and tested, then all other defences were redundant and dispensable. This is the thinking that lay behind the failure of the monitoring system.

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<sup>40</sup> DWI Dec7 pm Gisclair, p16