Final Fateful Flaws

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1. Summary

In the final stages of the developing Deepwater Horizon blowout, some fateful flaws manifested themselves. The original design of the mud/gas separation system was flawed. The planning for its use as reflected in advance control settings were not appropriate and probably not monitored on a timely basis. Finally, regulatory requirements not to vent oil mud directly overboard may have been mindlessly honored to the detriment of safety.

2. What Probably Happened

As BP reported,[1] the returns already blowing strongly from the riser were routed to the rig's mud/gas separator unit rather than directly overboard through one of the 14 in diverter lines. As a consequence, the mud/gas separation unit was promptly over-pressured and, in general, overwhelmed. That resulted in dispersion of gas and liquids over a large area of the vessel, including into spaces not classified as explosion proof.[1] Although there is no record or testimony to prove it, it appears that the sealing packer on the riser slip joint leaked massively under the impetus of back pressure applied. First, there was active fire under the rig floor after the explosions according to testimony.[2] Second, there was testimony of hearing a high pressure gas release from that direction preceding the first explosion.[3]

The "Bly" report[1] states the opinion that had the riser returns been routed overboard to the starboard side instead of to the mud/gas separator, the majority of the hydrocarbons would have been vented safely overboard and there would probably have been time to consider other mitigation options to the situation.[4]

3. What Could Have Been Different

In the absence of runaway diesel power plants, drift off due to power loss, and the explosions and fires, such options would have included changing to the 500 psi rated packer in the slip joint, closing of the blind/shear (or variable) rams of the blowout preventer (BOP), disconnecting from the well at the BOP, or simply getting all hands off the rig if the well had continued to flow unabated up the riser despite their best efforts.

4. Why Did It Happen?

Routing of returns from the riser diverter are pre-selected on the control system panels to reflect the operators' judgment of where fluids ought to go for best rig and personnel safety in the event of a rapidly developing blow from the riser bore. Ordinarily, with water-based mud in use, the settings are pre-selected to route the fluids overboard to the prevailing leeward side of the vessel. Obviously, with weather or vessel heading changes, the pre-selection might need to be changed. On this occasion, the pre-selections were obviously made which would route the riser returns to the mud/gas separator as soon as the diverter packer was closed. When and how this pre-selection was done prior to the blowout, and how often this judgment was reviewed is not known. For certain, the Transocean Offshore Installation Manager (OIM) did not know. Here is a quote from the testimony "Q. In a well control situation, would you typically divert to the gas buster? A. No. Q.

Do you know if the rig floor tried to divert to the gas buster? A. I don't -- I don't know what they had lined up at the time on the pre-select." [5]

5. A Poorly Designed Mud/Gas Separation System

Figure 3 from the BP Report[1] is reproduced below as Figure 5.1 of this paper.

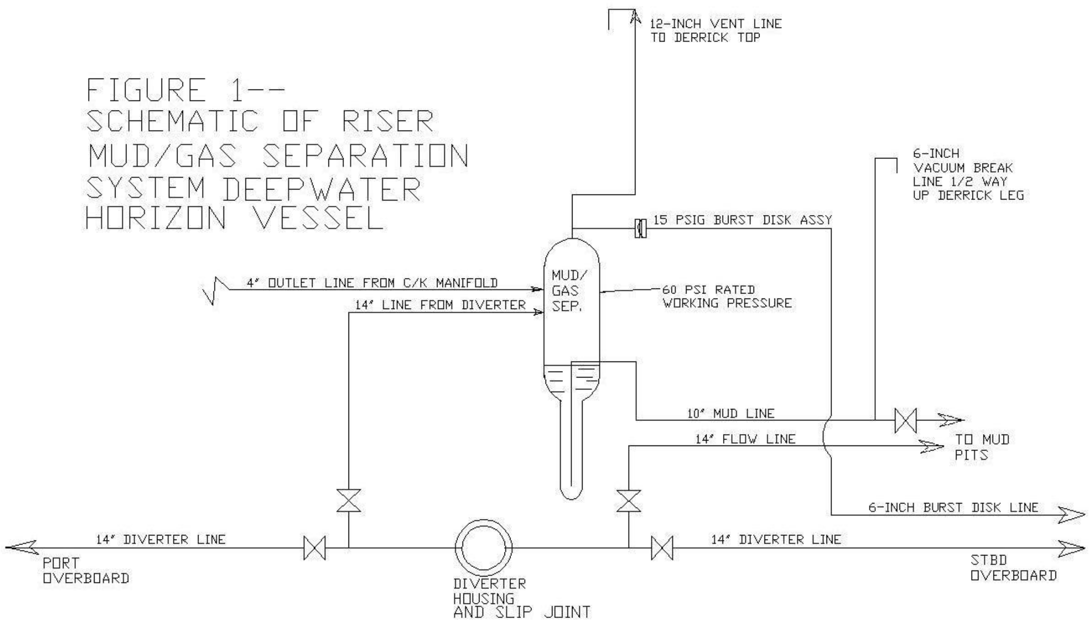

Figure 5.1 – Schematic of a riser mud/gas separation system Deepwater Horizon vessel[1]

In the author's opinion, there are several built-in problems with the Deepwater Horizon system.

a) The mud/gas separator serves both the riser and the choke/kill manifold. This could lead to cross-flow between the two systems if both are handling well fluids and cause supreme confusion about what is happening where. Ideally, if there is a kick with some gas having gotten into the riser before detection, the well can be shut in, the diverter system activated, and thereafter, most attention directed to killing the well under the BOP while letting the fluids in the riser do what they will while exiting though their separated system.

b) The capacity to handle large flows from either source is greatly limited by the 15 psig burst plate assessed to be needed to protect it from overpressures and by the hydrostatic fluid leg at the bottom outlet. The latter provides only 20 psi retention with 14.1 ppg mud before gas would blow out the lower outlet to the mud pits and also out the vacuum break line. Presumably, the 15 psig burst plate would have burst in such an event, but just the back pressure of a large gas flow

[1] BP, *Deepwater Horizon Accident Investigation Report*, September 8, 2010, 115, http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/incident_response/STAGING/local_assets/downloads_pdfs/Deepwater_Horizon_Accident_Investigation_Report.pdf.

exiting the long 6” burst plate relief line could exceed the liquid leg capability.

c) The turnovers on the vent line for gas and on the vacuum break could direct gas and any carried-over liquids down onto the rig.

d) Lastly, the vent line for the 15 psig burst plate goes only to the starboard side of the vessel. If wind or vessel shift makes starboard the windward side, gas could be carried right back over the vessel after it exits the vent line.

6. A More Trustworthy Mud/Gas Separation System

Figure 6.2 shows a generalized scheme which has been used on rigs with which the author is familiar.

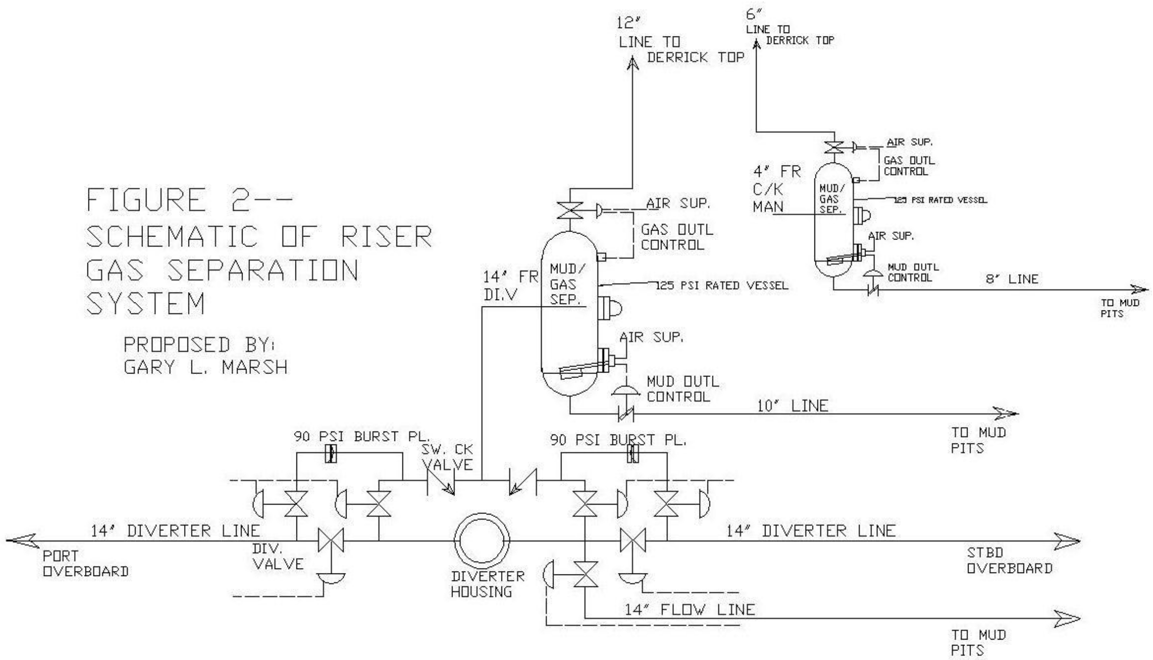

Figure 6.2 – Schematic of riser gas separation system, Proposed by Gary L. Marsh

Principal advantages of the system include the following:

a) Higher pressure rated vessels, and separate ones for riser and C/K manifold service.

b) Positive liquid level controls to prevent gas underflow to the mud outlet.

c) Throttled gas outlet control to exert modest pressure on the vessel to prevent maximum expansion of the gas until it is in the vent.

d) Higher pressure burst plate protection to tolerate a substantial fraction of diverter, slip joint, and separator vessel capability before relief occurs.

e) Relief of the bulk of relieved effluent to the same side of the vessel pre-selected to vent them.

f) Complete isolation of riser gas separation system if fluids need to be vented directly overboard because of extra high back pressure in the separation system.

It is noteworthy that MI Swaco makes a super-sized, pressure-liquid level-controlled mud/gas separator suitable for riser gas service and a more modest sized one for C/K manifold service.[6] In the author's opinion, all deepwater drill vessels should have these or equivalent ones installed.

7. Recommendations

1) All deepwater drill vessels should have a large pressure-liquid level-controlled mud/gas separator to serve the riser and a second, entirely separate, smaller version of that to serve the C/K manifold.

2) Diverter control systems should routinely use "direct overboard" pre-selection to start a control operation, and then assess from the actual outflow whether the mode can be shifted to go through the riser mud/gas separator. This is regardless of whether oil or water based mud is in use. BOEMRE should recognize that rig and personnel safety should trump environmental concerns in these cases.

3) Diverter control systems should be programmed to automatically shift slip joint packer selection to the highest pressure rated mode available at the same time the diverter packer is closed. If the slip joint has only one mode, the program should automatically increase the closing pressure on the slip joint element by, say, 150% of that used in day to day operations.

4) Mud/gas separation equipment should be routinely tested, once every 120 days or less by injecting an air (or Nitrogen) and liquid mix into them at the highest available rate. If air is used, purging with Nitrogen should be done afterward.

5) Separators should have mud or gelled water pumped through them and operation of all diverter valves should be verified at least every other week (with the BOP testing).

8. References

1. BP, *Deepwater Horizon Accident Investigation Report,* September 8, 2010, 109. http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/incident_response/STAGING/local_assets/downloads_pdfs/Deepwater_Horizon_Accident_Investigation_Report.pdf.
2. Testimony of Christopher Pleasant, Transocean Subsea Engineer to The Joint United States Coast Guard Minerals Management Service Investigation, Friday, May 28, 2010, 122.
3. Testimony of David Young, Transocean Chief Mate to CG/MMS Board, Wednesday, May 12, 2010 , 291.
4. Op. Cit. (1), 128.

5. Testimony of Jimmy Harrell, Transocean OIM to CG/MMS Board Thursday, May 27, 2010, 137.
6. MI Swaco Super Mud/Gas Separator Description. http://www.oilandgasonline.com/product.mvc/Mud-Gas-Separator-0001.