

were not significantly affected by erosion within the BOP since use of the reservoir and BOP pressures accounts for this possibility while use of the reservoir and ambient pressures does not. Any erosion in the BOP that affected flow rates therefore had to occur over the first few days such that the state of the BOP over the great majority of the 86 days was comparable to that at shut-in on July 15. If not, the alternative discharge based on the reservoir and ambient pressures would significantly exceed my best-estimate value of 5.0 mmhd, and this is not the case.

Figure 6. Schematic showing pressure differences (ΔP) used in my best estimate and alternative calculations.



Best estimate calculations are based on the difference between reservoir and BOP pressures. Alternative calculations are based on the difference between reservoir and ambient sea pressures. The first between fixed and mobile sea levels. Second between sea floor and the BOP.

Given the conclusions of the red team analysis, the alternative calculations over the 86 days of the wellbore over most of the 86 days is the state of the cement barrier in the wellbore performed for BP by Add Energy. It indicates that whatever down-hole restriction resided in wellbore debris, the float collar, or cement barrier. For continued failure at this rate, I estimate that the

¹⁰ From "Deepwater Horizon Accident Investigation Report," September 8, 2010, Appendix W, Case 7, Page 54. To match data and observations, the pay zone was increased from 11 and 16.5 feet, corresponding to effective productivity indices of 7.4 and 9.4 stbd/pu based on the nominal value of 49 stbd/pu and maximum pay zone of 86 feet used in that report. At this rate, the productivity index would reach 43.8 stbd/pu in 3.6 hours.

over the 86 days. Again, this is not the case. Any variation in the wellbore discharge coefficient or productivity index therefore also occurred within the first day or so such that the state of the reservoir and wellbore over most of the 86 days were substantially the same as the state on July 15. And, this includes the state of the cement barrier in the bottom of the well. This view is also supported through calculations performed for BP by Add Energy that address the period just preceding the initial explosion. Under conditions that most closely replicate measured pressures and observable events, their analyses indicate that the effective productivity index increased by over 25% between 21:00 and 21:30 on April 20.¹⁰ This indicates that whatever down-hole restriction existed at that time was failing rapidly, regardless of whether this restriction resided in wellbore debris, the float collar, or cement barrier. For continued failure at this rate, I estimate that the productivity index would further increase to my best-estimate value

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These conclusions rigorously apply only for the period from May 8 to July 15, the dates over which BOP pressures were measured. While I conclude that erosion in the BOP during this period did not significantly affect flow rates or the cumulative discharge, erosion in the first few days following the blowout certainly did. The methodology I use here cannot address this early erosion directly, but can instead provide an alternative calculation of flow rates and discharge in the first few weeks based on the times at which various rams were closed. This is described in Appendix 1. Here the time between rams collapse on April 22 and the first BOP pressure measurements on May 8 is broken into a number of periods defined by closing the various rams. I then calculate the flow rate and discharge for each period using the difference between the reservoir and ambient sea pressures and the state of the BOP at that time. This yields a cumulative discharge between April 22 and May 8 that agrees with the value from my best-estimate calculation within 0.22 mmhd. Taking into account reasonable flow rates over the 36 hours from these results, I conclude that the cumulative discharge is most 3.3% to the overall

and the quality of the data and checks. These were errors, and good agreement from scratch a second set of errors in the original data. Those of the original data demonstrate that my analysis accurately describes all flow rates regardless of which wellbore was used over the 86 days. My analysis used by BP during the investigation was determined empirically. It falls very close to the values I believe that the reservoir and the methodology yields

¹¹ Value of 37 stbd/pu is obtained from analysis of calculations by Tony Liao of BP presented in "BP-HZN-2170MDE04922069.xls." Value of 45 stbd/pu is from "Liao, Tony, 20110111, Ex 11163.pdf." BP internal email from Tony Liao to Maria Nass, June 27, 2010.