

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 (BP) used in my best estimate and alternative calculations.



Best estimate calculations are based on the different pressure illustrations.

The first between fixed and as indicated. Second between seafloor on the

Given conclusions calculated the red coefficient the alternative over the wellbore over most of the 86 days w

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 13 and 16.5 feet, corresponding to effective productivity indexes of 7.4 and 9.4 mbd/psi based on the nominal value of 49 mbd/psi and maximum pay zone of 86 feet used in that report. At this rate, the productivity index would reach 43.8 mbd/psi in 8.6 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 I. Here the time between riser 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 responsible flow rates over the 36 hours from these results, I conclude most 3.3% to the overall

data, and the quality of the and checks. These were errors, and good agreement rate from scratch a second acted errors in the original joint those of the original have demonstrate that my n. accurately describes all rates regardless of which are over the 86 days. My uses used by BP during the ed by my methodology.

was determined empirically heless, it falls very close to believe that the reservoir and the methodology yields

are is erosion. In channels opened

and fluid velocities increased. The 9 hour estimate thus very likely represents an upper bound on the time to complete elimination of any resistance to flow by the cement or other down-hole restriction

¹¹ "Dynamic Relief Well Kill for Micocondo MC-252 Blowout," SNL-046-082105, O. B. Rygg, ADD Wellflow, AS, June 2010.

¹² Value of 37 mbd/psi is obtained from analysis of calculations by Tony Liao of BP presented in "BP-HZ-2179MDL04020903.xls." Value of 45 mbd/psi is from "Liao, Tony, 20130111_Ex_11163.pdf" BP internal email from Tony Liao to Mario Niss, June 27, 2010.