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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 mmstb, and this is not the case.

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

Best estimate calcula
difference between th
pressures measured a
illustrated by the blac

The first alternative c
between the decaying
fixed ambient pressu
as indicated by the bl

Second alternative calculation use
between the measured BOP presse
seafloor pressure. This is indicate
on the left.

Given that the state of the BOP remained refa
conclusions about the state of the wellbore and reser
calculation of discharge based on the difference betwe
the red line of Fig. 6). This also yields 5.1 mmstb, ar
coefficient or productivity index. In this case, my be
the alternative value if the wellbore discharge coeffici
over the 86 days. Again, this is not the case. An
productivity index therefore also occurred within the
wellbore over most of the 86 days were substantially
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

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

[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 indices of 7.4 and 9.4 stbd/psi based on the nominal value of 49 stbd/psi and maximum pay zone of 86 feet used in that report. At this rate, the productivity index would reach 43.8 stbd/psi in 8.6 hours.

in less than 9 hours.[11] At this point, the cement barrier or other impediments would provide no significant restriction to flow from the reservoir into the casing. Subsequent erosion in this region therefore could not have influenced later flow rates.

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.

[11] Assuming that the cement remained reasonably intact, the likely mechanism for progressive failure is erosion. In this case, the rate of failure would not remain constant but would instead increase rapidly as small 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.

[12] "Dynamic Relief Well Kill for Macondo MC252 Blowout," SNL046-082105, O. B. Rygg, ADD Wellflow, AS, June 2010.

[13] Value of 37 stbd/psi is obtained from analysis of calculations by Tony Liao of BP presented in "BP-HZN-2179MDL04920969.xls." Value of 45 stbd/psi is from "Liao, Tony_20130111_Ex 11163.pdf." BP internal email from Tony Liao to Maria Nass, June 27, 2010.