Cementing 7"x 9⅞" Production Casing at MC 252#1 Well

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1. The Latest BP Investigative Report – Flawed Cement Mix

The latest BP investigative report indicates from results of independent testing that the nitrogenated cement used on the 7 in x 9⅞ in tapered production string was likely flawed, and was likely to have suffered Nitrogen separation downhole.[1] Free Nitrogen gas thus generated could have weakened and channeled cement above the productive interval and perhaps even in the 7 in casing shoetrack before the cement could cure. Moreover, if separated Nitrogen commenced filling a sufficient height of channels in the cemented annulus, the productive zones could have been induced to flow hydrocarbons into the wellbore as well. Other faults pointed out for their best simulation of mix used were[1]:

a. Extra high fluid loss (also known to induce zonal flow after cementing).
b. Extra low yield point.
c. Extra long set time.

A virtual certainty is that zonal isolation was not achieved in the time frame needed to prevent a massive inflow and the blowout.

2. Better Cement Mix Could Have Been Planned, Mixed, And Placed

With only a little thinking "outside the box" by either BP engineering or Halliburton engineering, a much better mix could have been planned, mixed, and placed. And it would have honored the tenderness of fracture gradient in the open hole as well, or perhaps better than the Nitrogenated mix used. Had either engineering unit have done the brief research on the internet and made the 10-minute call to 3M Company that the author hereof did, they would have learned that 3M has a glass bead material readily available in quantity and for reasonable price that would have allowed as light a density slurry mix without Nitrogen as they planned with that complicated gas-laden system. It is similar to Halliburton's advertised Spherelite additive, but it has much better tolerance to prevailing pressures in very deep wells. Quoting from the 3M online product catalog,[2]

> "**Density Reducing Agents for Drilling Cements –** 3M™ Glass Bubbles HGS18000 are ideal additives for use in low density drilling cements. They can survive pressures of 18,000 psi, making them highly incompressible, and offer improved performance over aerated cements without the need for expensive compressors. Cement slurries made with HGS18000 glass bubbles have high compressive strength, minimal wait on cement (WOC) and provide increased yield per sack of cement."

The 3M material carries a trade name HGS18000. It is comprised of air filled glass beads competent up to 18,000 psi.[2] Ballpark cost FOB (Free on Board) 3M's Alabama plant is $3/lb. in bulk. Even if that cost is doubled in the process of transportation, profit, etc., the extra material

cost for mixing 60 barrels of 14 ppg slurry would be in the order of $15,000. The Nitrogen, complete with Halliburton specialist(s) to the rig to mix it, is likely in the same ballpark. But even if not, the advantages of an "all-solids", "just add water", "no chance for segregation" mix for a critical job like Macondo production casing are worth a consideration of paying the full price of admission. An example mix calculation and more details are shown in the Appendix.

3. The 7" X 9⅞" Production Casing Cement Job that Could Have Been

As Performed

The cement job as performed demanded a lot of choreography. First 7 bbl of base oil was pumped to keep ECD and final annular pressure down, then a water-based spacer (about 72 bbl according to non-citable source), then about 7 bbl of 16.74 ppg cap cement [volume inferred], then 48 bbl of 14.5 ppg Nitrogenated cement, then another 7 bbl of 16.74 ppg cement targeted for the 7 in casing racetrack—total 62 bbl of slurry.[3]

Potential Improvements

A single 14.0 to 14.2 ppg slurry lightened with 3M HGS18000 glass beads could have been run, spearheaded and followed by a simple 14.3 ppg water-based spacer. An additional 18 bbl of slurry (total 80 bbl) could have been run to place competent cement 500 ft into the 7 in x 9⅞ in protective liner bore. There were, after all, three burst plate assemblies imbedded into the wall of the 16 in protective casing at three separate points[4] to prevent dangerous pressure buildup in the annulus from temperature increases due to future production given the danger is production casing collapse.

4. Looking Forward

What is needed now is an operator working with one or more cementing service companies to get 3M HGS18000 glass beads incorporated into the cement design for future wells of this nature as a fully lab-tested suite of mixes which will be usable in a variety of circumstances. See Section 5 below. That should be a short, straightforward undertaking.

Will it cure every ill and guarantee zonal isolation? Of course not. But it can be expected to contribute to the solution rather than adding to the problem.[5]

5. Late Breaking News

It turns out that both Halliburton and Schlumberger were in on the ground floor (steering and contributing committee members) for testing and development of high-pressure-tolerant glass beaded cement as studied by Cementing Solutions, Inc. (CSI) for the Department of Energy as early as year 2002.[5] Note that in that time frame, the glass beads were rated maximum of 10,000 psi. Later,[6] they were available with pressure tolerance as high as 18,000 psi.

Halliburton are touting the glass beaded cements under the trade name Tuned Lite cement.[7] Why on earth this was not considered for cementing the production casing at M.C. 252#1 is a complete mystery.

Note that the author does not own any direct interest in 3M Company who make the beads, nor in Halliburton, nor in BP, nor, for that matter, any of the oil well service companies except as they may be incidentally part of a mutual fund in which he has an interest—not even sure there.

6. References

1. BP, "Deepwater Horizon Accident Investigation Report," September 8, 2010, 58, 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. Personal communication by phone, Gary Marsh to Rob Hunter with 3M, August 24, 2010. Also see http://solutions.3m.com/wps/portal/3M/en_US/Oil-Gas/Home/Prod_Info/Prod_Catalog/?nid=JQ80Y7PYDFbeB4XBZ0P1DBgl.
3. BP, op. cit., 55.
4. BP, op. cit., 19.
5. Fred Sabins, "Ultra-lightweight Cement Slurries Improve Cement Performance," GasTIPs, Fall 2008, 2, http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSu7zK1fslxtU48m1mY_Uev7qe17zHvTSevTSeSSSSSS-- .
6. Fred Sabins, "Ultra-light Hollow Glass Spheres Improve Cement Slurry Performance for Lightweight Cement Applications," Cementing Solutions, Inc., April 2004, 2, http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UuZjcFSLXTt48TXLXftEVuQEcuZgVs6EVs6E666666--.
7. Halliburton. "Tuned Light ™ Cement," http://www.halliburton.com/ps/Default.aspx?navid=202&pageid=629.

Appendix – Use of High-Pressure-Tolerant Glass Beads for Cement

Composition

If you want to use, say, 60 barrels of 14 ppg cement composed from Class H cement mixed at 16.5 ppg base slurry lightened with 0.6 bulk density beads, the following computations will prevail:

To mix 1 bbl of final mix, the proportions are calculated as follows:

Density of base cement = 16.5 x 42 = 693 lb/bbl
Density of beads (absolute) = 0.6 x 8.33 x 42 = 209.92 lb/bbl
Density of final mix = 14 x 42 = 588 lb/bbl
Absolute volume of base = V_{base}
Absolute volume of beads = V_{beads}

$$V_{base} + V_{beads} = 1 \text{ or } V_{base} = 1 - V_{beads}$$

$$(1-V_{beads}) \times 693 + V_{beads} \times 209.92 = 588 \text{ lb}$$

Hence V_{beads} = 0.217 bbl and $Weight_{beads}$ = 45.62 lb.
And V_{base} = 0.783 bbl and $Weight_{base}$ = 542.62 lb.

Weight 1 bbl mix (calculated) = 588.25 lb, i.e., within the rounding errors of the target.

Mixing 60 bbl of final 14 ppg mix would require about 2737 lb of beads.

If the cost/lb is twice that FOB 3M Alabama plant, the cost of beads = 2737 x $6/lb = $16,423. Note that about 20% of other constituents are replaced, and those replaced constituents would definitely not be free.

Advantages

a. Doubtless other additives would be used in the base mix and the water ratio may need to be adjusted somewhat for addition of the beads, but the prospect remains very favorable to obtain lightweight slurry with good curing time, strength, and other characteristics at reasonable extra cost.

b. Schlumberger Cementing Services offers lightweight, non-Nitrogenated slurry they claim is applicable to wells with up to 10,000 psi bottom hole pressure. Author suspects that they use glass beads similar to the 3M product noted, but with less crush resistance. They claim prompt curing times and substantial cured strength.