Primary Cementing Application Overview

We routinely cemented wells in western Oklahoma (Anadarko basin) with pressures to 20,000 psi at depths to 27,000 ft. Water was abundant in the Springer-Morrow sands and gas zone pressures fell to 6,000 to 10,000 psi within a year, creating water zone differentials of 5,000 to 10,000 psi. We had little water migration problems if we got a really good primary cement job. That said, getting a primary cement job was a nightmare and required that one of our cement specialists be on location to make sure the rig crews followed the procedures. We launched about 10 years of exhaustive cement work to improve the primary cement job. The effort was well documented and published – and, promptly forgotten whenever a cement specialist was not on location.

Amoco (mainly Robert Smith and Robert Beirute) did extensive work on improving the bond and the overall sealing ability of the primary cement job. We measured this with bond logs and followed many of these jobs up with longevity checks. The most important factors in obtaining a good primary cement job were (in order):

1. Pipe movement (both rotation and reciprocation) - the drillers hated to move pipe once it was on bottom, but the effects of pipe movement on the primary cementing quality could not be disputed. Even in low clearance holes, movement was critical.

2. Use of sufficient centralizers to keep the casing off the borehole wall was a primary concern. We ran a program to accomplish this, but had to often battle the drillers to get the centralizers run. We found the spiral, solid body centralizers to be very effective, especially when deviation passed about 10 to 15 degrees and when heavy wall pipe was used. Interestingly, with proper clearances, the centralizers actually made liner insertion much easier - but it was still a battle to overcome personal resistance and reluctance. Bow spring centralizers were rarely effective in anything but absolutely straight holes – no deviation at all.

3. Optimal borehole to pipe clearance was critical. For years we worked with rates, viscosities and flow regimes necessary to clean the mud cake before cementing to get effective bond and I believe there are a number of programs that were spawned by the cooperative work that deal with the results. We found that we could not sustain the flow turbulence target with cement, but depended instead on washes and spacers to clean and disperse the mud filter cake. We did find that clearances between borehole and pipe were critical. If you have a gauge hole, the cementing, of course, was greatly simplified. In washouts, we really had to work to get a bond - and were not too successful many times.

4. Washes and spacers, as mentioned, were very effective if you could identify the composition, thickness and hardness of the downhole mud cake. We looked at sand slurries, acids, mud solvents and dispersants, slick water and a few commercial fluids. Mud cake specific dispersants, pumped in turbulence and used with scratchers and pipe movement, were the most effective. The cleaned condition the washes/scratchers/pipe movement produced was also the most advantageous condition for causing pipe differential sticking - a pretty significant catch-22 problem. We tried to address it with longer stroke pipe movement (coupled with rotation) at first, followed by short stroke pipe movement of 6 to 10 feet at the end. When we had sufficient rat hole, this worked well - we could land the pipe within a few feet of where we designed without affecting the casing string design and invariably got an excellent cement job.

5. In formations with low frac pressures, we formulated cement slurries as low as 7.5 ppg and actually pumped several at less than 10 ppg. They were very effective. We found that necessary

cement strength was less of an issue that what we initially thought. We found that an eight hour compressive cement strength of 1000 to 2000 psi was adequate to preserve annular seal, nearly regardless of the pressure differential. Obviously, several feet (50 to 500 ft) of cement sheath was preferred for insurance, but I've seen 10 ft of excellent cement stop very high pressure differentials in the right conditions.