Fully engineered foam-cementing process improves zonal isolation

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A MAJOR GULF of Mexico (GOM) operator cemented 3 wells with low fracture and temperature gradients using lightweight foamed cement. To help ensure job success, the operator followed a fully engineered, controlled, premium (ECP) zonal-isolation process.

The low, variable density and relatively high strength of the foamed cement helped the operator achieve long-term hydraulic bonds and zonal isolation by preventing hydrostatic pressure damage. The cement's high displacement efficiency also helped ensure uniform cement coverage in a well with low annular velocity.

In addition to establishing proper bonds and zonal isolation, the ECP isolation process allowed the operator to adjust the slurry density during the job as needed. The effectiveness of the ECP isolation process helped the operator avoid costly remediation work on the wells.

BACKGROUND

The primary requirements for oilwell cement are to (1) bond and support casing, (2) restrict fluid movement between formations, and (3) seal lost-circulation zones. The following factors, however, commonly cause failure of conventional cement:

- Mechanical shock from pipe tripping;
- Casing expansion and cement compression during pressure testing;
- Pipe expansion or contraction caused by cycles in production pressures and temperatures.

Such stresses can cause conventional cement to break down, creating flow paths and allowing pressure to accumulate in the annulus. Sustained casing pressure (SCP) results when pressure returns on the annulus after fluid from thermal expansion is bled off and the valve is closed. SCP compromises well integrity and may cause loss of well control.

The compressible, ductile nature of foamed cement allows it to flex and absorb stresses that often damage conventional cement. The flexibility of foamed cement can help increase the life of a cement job by maintaining the integrity of hydraulic bonds, preventing the formation of a microannulus, and eliminating stress cracking.

FOAMED CEMENT

Foamed cement is a mixture of cement slurry, foaming agents, and a gas [usually nitrogen (N2)]. If mixed properly, foamed cement forms a stable, lightweight cement slurry that looks like gray shaving cream.

The slurry is first mixed and pumped downhole; then, proportional amounts of a foaming agent and stabilizer are injected into the slurry. To shear the slurry and create foam, operators inject the N2 into the mixture at a high pressure. A sample foam-generation setup is provided in Figure 1.

When the N2 is introduced into the cement slurry with sufficient energy to create discrete gas cells, physical stabilization results (the gas is stabilized as small cells, or bubbles, within the slurry). The bubbles are not interconnected and do not coalesce (Figure 2), resulting in a

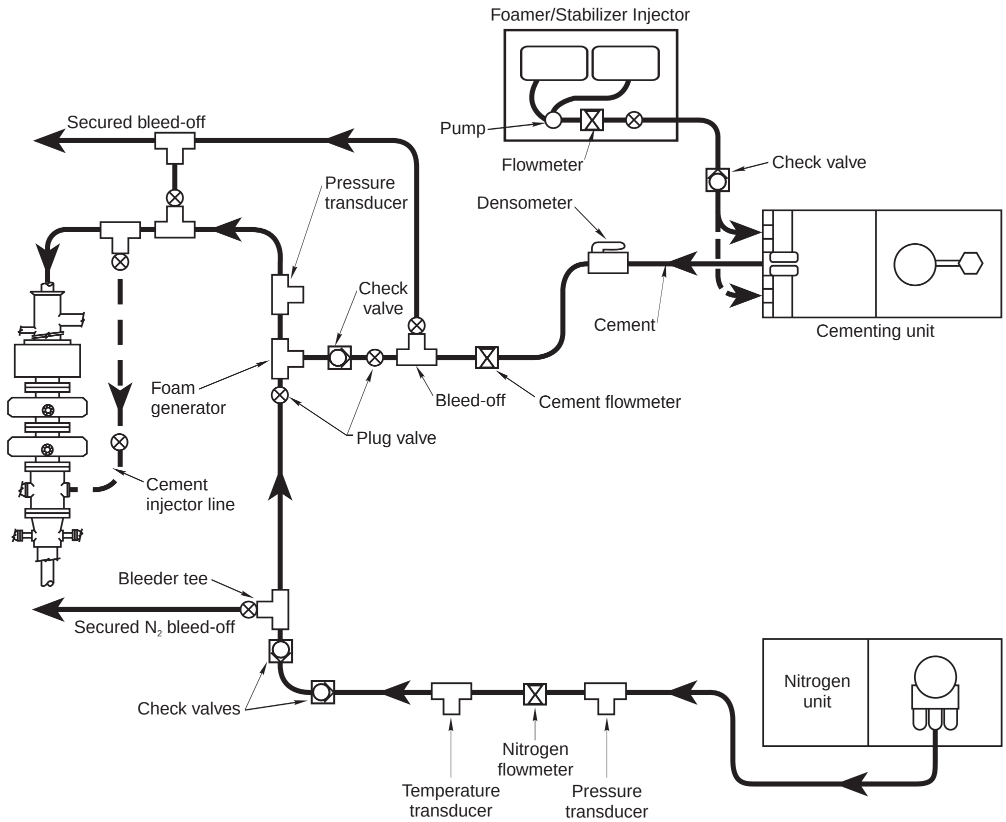

Figure 1: Sample foam-generation set up. The slurry is first mixed and pumped downhole. Then, proportional amounts of a foaming agent and stabilizer are injected into the slurry. To shear the slurry and create foam, operators inject the nitrogen into the mixture at a high pressure.

low-density cement matrix with low permeability and relatively high strength.

Foamed cements can help support both primary and remedial cementing functions for offshore and onshore situations, as indicated in the following list:

• Foamed cements offer a low-density alternative to conventional cements. For example, slurries can be foamed to a density as low as 4 lb/gal. Low-density foamed cements (4 to 15 lb/gal) can be placed more easily across weak formations, helping prevent lost circulation and fallback problems;

• With some cement additives, foaming creates a synergistic effect that enhances the properties of the additives. This effect is evident with some fluid-loss additives, lost-circulation materials, and latex;

• The density of foamed cement is variable. Its ductility allows for expansion and pressure maintenance during hydration, thus helping provide long-term zonal isolation. As the cement expands, it can fill washed-out hole sections and megadarcy lost-circulation zones without formation breakdown;

• The improved mud-removal capacity of foamed cement also helps enhance zonal isolation. Because of its ductility, foamed cement can provide casing support for the life of the well.

THE ECP ISOLATION PROCESS

The ECP isolation process helps deliver high-quality, controlled, stable foamed cement. With the ECP process, on-site specialists regulate every aspect of cementing. Factors including design parameters, slurry stabilization, and slurry composition are continually monitored. Such job engineering helps maximize benefits like mud displacement and helps prevent problems like high-pressure and weak zones.

To help ensure premium foamed cementing, the ECP isolation process provides the following built-in quality-control factors:

• Cement job-simulation software: Control units for each aspect of cementing are preprogrammed based on the output of the job-simulation software. The software furnishes an overview of possible cement programs and provides real-time analysis during cementing;

• Laboratory testing: Laboratory tests can help identify potential problems, such as fluid incompatibilities;

• Cement blends: Each slurry is tailored to meet job specifications;

• Data acquisition: Data acquisition can provide valuable downhole information when last-minute decisions must be made;

• Certified personnel: A team of specially trained, on-site specialists with a record of successful cementing jobs manage each aspect of the job;

• Full automation: Factors such as density control, the N2 rate, and foamer/surfactant injection are automatic. All equipment is linked together to provide an integrated, electronic communications loop that operates according to the rate of slurry production;

• Cementing best practices: The cementing team follows well-established, effective procedures to achieve optimal results.

CASE HISTORIES

The formation types and prejob conditions of the wells in the following 3 case histories influenced the operator's decision to use foamed cement. The characteristics of each well follow:

Case History 1: The formation consisted of water sands with multiple high-permeability streaks. The well was stable with minor flows.

Case History 2: The formation contained oil and gas sands. The mud was gas-cut from 14.5 to 14.3 lb/gal with 892 units of gas.

Case History 3: The formation contained multiple gas sands. The mud was gas-cut during drilling.

CASE HISTORY 1

The operator wanted to cement a 13 ⅜-in. protective casing in a well with a small probability of shallow water flow to prevent problems with the hydraulic bond or long-term zonal isolation. The operator requested that the slurry be energized to mitigate flow potential and that the density be flexible enough to be changed quickly, if needed. Using the ECP isolation process gave the operator the option of changing the slurry weight in the field to help prevent the hydrostatic pressure from breaking down the previous casing shoe.

Because the well had low fracture and temperature gradients, the job required a high-strength, lightweight slurry. The service company used a 16.3-lb/gal premium lead cement for the base fluid, which was foamed to 11.5 lb/gal with 520 scf/bbl of N2. The tail fluid contained the same base slurry foamed to 14 lb/gal with 232 scf/bbl of N2. Even at the low displacement rates, the foamed cement's displacement characteristics helped ensure good radial coverage in the high hole angle. The N2 was then cut off, and the 16.3-lb/gal base slurry was used for the shoe track.

The cement was successfully placed across the zones of interest. The mechanical properties of the foamed cement, which can enable it to resist stress cracking during the life of the well, are expected to help the operator maintain the hydraulic bond, resulting in a long-term seal across the zones of interest. The ECP isolation process saved the operator $375,000 in rig and shoe-squeeze costs.

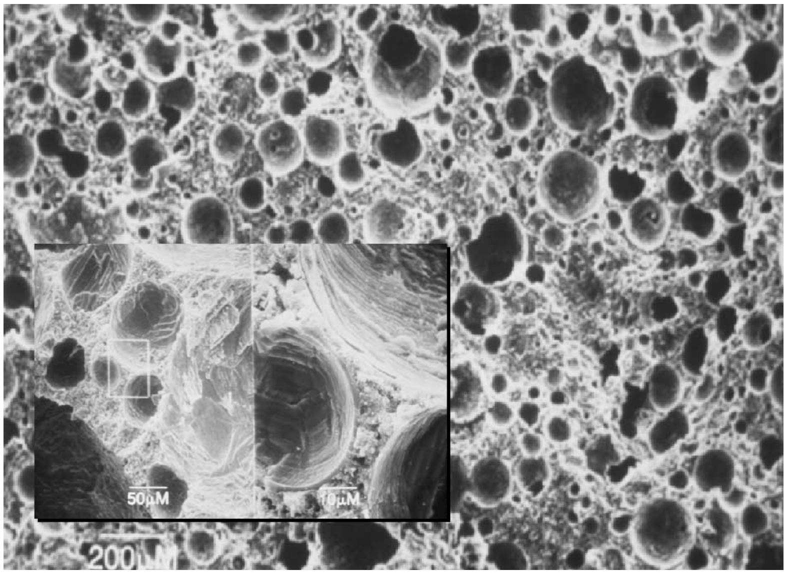

Figure 2: Microphotograph of a foamed cement sample. When N2 is introduced into the cement slurry with sufficient energy to create gas cells, the gas is stabilized as small cells, or bubbles, within the slurry. The bubbles are not interconnected and do not coalesce, resulting in a low-density cement matrix with low permeability and relatively high strength.

CASE HISTORY 2

The operator wanted to ensure uniform cement coverage of a highly compatible sand in the annulus to prevent the sand from subsiding, which could cause the production liner to buckle, jeopardizing the well.

The operator chose the ECP isolation process to deliver foamed cement to the wellbore. The high displacement efficiency of the foamed cement helped ensure good cement coverage, even at the low annular velocities dictated by the wellbore geometry. The flexibility of the cement's density helped ensure exact placement of the cement.

To verify the zonal isolation and evaluate the cement bond for a correlation between cement integrity and compaction failure point, the operator requested a postjob log. Because standard evaluation methods would not be effective, the service company used a complete acoustic borehole-imaging (ABI) device to obtain the bond-log information and statistical-variance plots to interpret the data.

The service company successfully cemented a 7 5/8-in. production liner with the ECP process on the liner tack and used conventional cement slurry for the top-of-liner squeeze. Because of the effective mud displacement, long-term hydraulic bonds and zonal isolation are expected. The ECP process saved the operator more than $10,000,000 in remediation and drilling costs.

CASE HISTORY 3

The operator wanted to cement a 7 5/8-in. production liner to ensure long-term hydraulic bonds and zonal isolation. Because the well had low fracture and temperature gradients, the job required a high-strength, lightweight slurry.

The operator chose a liner for the casing design. The service company tacked the liner with foamed cement and performed the top-of-liner squeeze with conventional cement. The foamed cement helped ensure effective coverage despite the well's low displacement rate and high hole angle (73°).

The service company successfully placed the cement across the zones of interest and saved the operator $450,000 in rig and block-squeeze costs. Using the ECP isolation process enabled the operator to benefit from the foamed cement's high displacement efficiency and variable density. Long-term isolation of zones and proper hydraulic bonds are expected.

SUMMARY

Foamed cement is commonly used for its light weight and relative high strength, its high displacement efficiency, and its variable density. The ECP isolation process of delivering premium foamed cement can achieve zonal isolation and proper hydraulic bonds for the life of the well.

ABOUT THE AUTHORS

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