FOAMED CEMENT -- THEORY AND PRACTICE

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ABSTRACT

Foamed cement is a relatively new concept to oil/gas well completions. Foamed cement slurries produce good results provided several factors are considered. This paper will present several job design factors which help provide good results. It will also discuss several practices which should be avoided.

INTRODUCTION/DISCUSSION

This paper discusses the use of foamed cement slurries for casing cementing. Foamed cements can have several applications but presently wells which have severe lost-circulation problems are the best candidates since the cement can be designed so that the cement will exert equal or less hydrostatic pressure than the fluid used to drill. Using foamed cement, the casing can be cemented over most intervals in a single stage. This usually saves time over a two- or three-stage cement job and avoids the possible problems associated with stage cementing.

These lightweight foamed slurries can be effectively used at densities from 7 to 11 lb/gal. Foamed slurries have no depth or temperature limitations. At greater depths, where there is more pressure and higher temperature, the slurry simply requires more or less gas to maintain the desired density in the annulus. This paper will discuss only foamed cementing operations which maintain a constant foamed cement density in the annulus.

Common extenders which reduce slurry density by requiring extra water can reduce slurry density to about 10 lb/gal.[1] Further density reduction will produce a cement with almost no compressive strength. Hollow ceramic spheres[2] and hollow glass spheres[3] can provide cement slurries with densities in the seven-pound-per-gallon range and good compressive strength but, since the spheres can collapse, these extenders have pressure limitations.

The foamed cement technique has been used on intermediate strings and production strings. Covering possible pay zones with foamed slurries is not recommended unless it is one of the heavier density foamed slurries. If the possible pay zones are all near the bottom of the well, tailing in with a conventional slurry is recommended. If possible pays exist all up and down the hole, extra consideration must be given to this problem.

Bringing the foamed cement slurry to surface is normally not recommended. If the gas reaches the surface at low pressure, it will expand rapidly and can create severe problems. For that reason, a mud spacer and/or cement cap is recommended. This fluid cap should be heavier than the foamed slurry and should contain the foamed slurry beneath it. As an added precaution, the blowout preventer system should be operational and returns should be monitored closely throughout the job. If an increase in returns is experienced, the blowout preventer hydrils or pipe rams should be closed and the job continued with returns going throughout the blowout preventer choke system. At the end of every foamed cement job, the backside should be shut-in and the pressure monitored until the slurry is set. The pressure should be bled off only as needed during the setting process. All pressure should be bled off after the cement has come to a complete set. The backside should be shut-in long enough to be sure the cement is set at the top of the cement column.

Quality control during the cementing placement is very important. Without it, the evaluation of the job would be virtually impossible.

The normal method used to change the surface density of the foamed cement slurry, in order to maintain an approximate fixed density in the annulus, is to vary the nitrogen injection rate. To accomplish this, the cement slurry must be pumped at a constant density and at a constant flow rate. A batch cement mixer is recommended on foamed cement jobs to help provide a constant slurry density. A minimum of two mixing/pumping trucks is required. While one truck is mixing and placing the slurry in the batch mixer, the other is being fed the slurry from the batch mixer and pumping it downhole at a constant rate. The foaming agent is added to the suction side of the high-pressure triplex pump. The nitrogen is added downstream of the triplex pump.

The use of a special foam generator downstream from the nitrogen injector provides a homogeneously foamed slurry throughout the job and helps maintain extremely small, uniform gas bubbles.

The other necessary pieces of quality control equipment required on a foamed cement job are a downstream densitometer and pressure gauge. These will be downstream from the foam generator. The downstream density is used to adjust the nitrogen injection rate and to provide the desired density in the annulus.

CEMENT - TECHNICAL INFORMATION

In order for the foamed cement slurry to perform as designed, the foam must be stable. If this is the case, each individual gas bubble in the cement slurry will be completely surrounded by cement slurry until it sets. The cement can have a high porosity but maintain low permeability (Table I). Also, the slurry will provide adequate compressive strength, even at low densities (Table I).

All cement slurries will not provide stable foams. Thus, slurry design is very important. Conventional slurries at 14.2 lb/gal have a yield of 1.24 cu ft/sk of cement and require 6.20 gal H_2O/sk of cement. The retarder used in the foamed slurry does not affect the foam properties appreciably. Thus, the same slurry can be used over a wide temperature range by changing the amount and/or type of retarder.

Although other gases could be used, nitrogen, due to its ease of handling, has been the most commonly used in foamed cements.

It is important that the foam bubbles remain discrete and do not collect together and start forming larger bubbles. If the bubbles collect, the slurry may separate into a nonhomogeneous mixture of gas and slurry. The proper choice of slurry and surfactant, along with the foam generator, will produce a stable foam. This foam is very stable, until the slurry starts to thicken due to the setting process. Once the slurry thickening starts, if the foam is moved, the foam can destabilize and large gas bubbles can form. For this reason, the slurry must be in place before thickening has progressed appreciably. The time at which thickening starts has been called the Point of Departure (POD). Therefore, in addition to knowing the thickening time of a foamed slurry, the POD is also important.

Cement slurries which tend to produce stable foams are normally somewhat viscous. If the viscosity of the slurry is low, the foam produced could be unstable. If the starting slurry is viscous, most cementing additives can be used. However, each combination of additives must be checked for its effect on foam stability.

Foams used for fracturing, acidizing, etc., have always been considered to have low fluid-loss properties. However, the addition of conventional fluid-loss additives to foamed cements should still be considered to provide for proper slurry placement if the possibility of annular bridging is anticipated.

MUD DISPLACEMENT

The ability of a foamed cement, with a density lower than the mud density, to properly displace drilling mud is not well understood. It is felt that the use of a viscous spacer fluid with a density between that of the mud and foamed cement is a desirable design factor. The spacer should contain a foaming agent. Then, if the foamed cement does channel through the spacer, the resulting combination will be a stable foam. The stability of spacer/cement foams must be checked. A simple bottle shake test will do. To perform this shake test, a foamed cement at atmospheric pressure is prepared at the desired density and diluted with various ratios of spacer fluid containing a foaming agent. After shaking, note whether the resulting slurry occupies more, less or the same amount of space. If the resulting slurries occupy more space or the same amount of space, the spacer should not cause the foamed cement to break if some channeling does occur.

If the well is being drilled with a mud which contains oil, the mud should not come in contact with the foamed cement. Oil usually has an adverse effect on foam stability.

Ordinarily, chemical washes should not be used in contact with foamed cements because they can reduce the viscosity of the cement and destabilize the foam.

The use of an unfoamed cement cap on top of the foamed cement has been used successfully. It should be heavier than the foamed cement and also heavier than the mud.

Whether a conventional cement slurry lead, spacer or both are used, probably at least 500 ft of annular volume, as a minimum, should be used.

In general, foamed cement should not be designed to come closer than 1,000 ft to the surface, because of the possibility of channeling. Also, the nitrogen expands very rapidly at pressure less than about 1,000 psi.

The volume of cement to be used should be calculated from caliper logs whenever possible. Unlike conventional jobs which normally take a caliper log volume plus 10% to 25% excess, the true hole volume should be calculated on foamed cement jobs with no excess provided. This is because washout areas are probably not displaced completely by foamed cements and, thus, fill-up can be higher on foamed cement jobs than it would be on a conventional job.

CALCULATIONS

These jobs are not difficult to calculate but there are a lot of computations. Therefore, it is recommended that a computer program be used to help avoid the possibility of errors when calculating a constant-density foamed cement job.

Another important item must be considered. When the job is finished, the designed amount of hydrostatic pressure will be correct, but prior to having the cement in place, the column will exert more than the pressure designed. Therefore, always design these jobs with a safety factor added. In other words, if the well can only stand 4,000 psi on bottom, design the job so that when completed, the hydrostatic column on the backside will be well below the 4,000-psi limit. This should help eliminate the loss of circulation during the job.

EVALUATION OF RESULTS

Conventional bond logs and temperature surveys do not adequately show the foamed cement column. A radioactive tracer can be added to the spacer or first part of the foamed cement slurry to determine the cement top. If a radioactive material is not desirable and no loss of returns occurs during the job and no N_2 breaks out of the foamed cement during or after the job, it can be assumed that the slurry height is near the design point.

A nonconventional bond log for foamed cements is currently being designed for the evaluation of foamed cement performance.

CONCLUSIONS

Foamed cement is a very good technique to apply to wells with lost-circulation problems. It is, however, different from conventional cements and must be treated as such. More thought must be given to the design of each job to help ensure success.

REFERENCES

1. Parker, P. N. and Clement, C.; "Basic Cementing," Part 2, **Oil & Gas J.**, March 14, 1977.

2. Ripley, H. E., Harms, W. M., Sutton, D. L., and Watters, L. T.; "Ultra-Low Density Cementing Composition," Petroleum Society of CIM, Paper No. 80-39-19.

3. Smith, R. C., Powers, C. A., and Dobkins, T. A.; "A New Ultra Light Weight Cement with Super Strength," presented at the 1979 SPE Annual Technical Conference and Exhibition, Las Vegas, Sept. 23-26.

TABLE 1
TYPICAL DATA FOR 14.2 LB/GAL SLURRY

	Foam Quality at Atmospheric Pressure	Permeability (7 days at 80°F)	Compressive Strength (7 days at 80°F)
7 lb/gal	51	117 md	145
8 lb/gal	45	0.5 md	225
9 lb/gal	37	< .001 md	375
10 lb/gal	29	< .001 md	550
11 lb/gal	23	< .001 md	740

Ultimate compressive strength will normally be at least three times the seven-day, 80°F compressive strength.