P-FA78

CEMENTING SERVICE BULLETIN

09/21/18

P-FA78 (PETROCHEM – FOAMING AGENT)

TECHNICAL DATA

FOAM CEMENT SUMMARY:

Fluids in wellbores exert hydrostatic pressure on different points-down-hole. The hydrostatic pressure is dependent upon the fluid column height and the density of the fluid. Formations which are very weak or which contain holes or VUGS are able to support the hydrostatic pressure from only very light fluids. Some of these formations will not even support a column of water. Conventional cements mixed with water must always have a density in excess-of 8.33 lbm/gal; thus, frequently it is not possible to place such slurries in a wellbore. Foamed cement has been developed to allow cementing in such cases.

Foamed cement can be a solution for cementing problems related to formations which are fractured (or which have a low fracture gradient), highly permeable, VUGGY or cavernous. Applications include primary cementing, remedial cementing, lost-circulation and annular thermal insulation.

Foamed cement uses base cement slurries, gaseous nitrogen and surfactant to create a homogeneous ultra-lightweight cement system. Since nitrogen is inert, it does not affect the chemical properties of the slurry. The base cement slurry density is reduced by the addition of nitrogen and the surfactant provides the foam-generation/stabilization properties. The amount of nitrogen required is a function of the desired in-situ foam density and the hydrostatic pressure exerted on the foamed slurry.

Ultra-lightweight, foamed-cement densities will provide relatively good set compressive strength and low permeability as compared with other lightweight-cement systems. In addition, foamed-cement slurries exhibit good fluid-loss properties and good durability under high-temperature and high-pressure conditions.

Since foamed cement contains a gas and is compressible, foamed-cement applications are more difficult to design and to execute than conventional-cement systems. The successful results of a foamed-cement job depend on proper design of the foamed cement and correct execution utilizing specialized and additional equipment.

SLURRY DESIGN

1. An efficient means of generating foamed cement in the field.
2. A new surfactant system to enhance foam stability.

INTRODUCTION

Foams are usually characterized by their foam quality (FQ) which is the ratio of gas volume to the total-system volume expressed in percent. Foam quality is easily derived from the base slurry density (DBS) and the foamed-cement density (DFC):

$$FQ = \frac{DBS - DFC}{DBS}$$

New laboratory equipment has been built which allows foamed cement to be mixed and the engineering properties studied under simulated field conditions. New software has also been developed to identify the critical parameters and their relative influence on the optimization of the design of a job.

The new Laboratory equipment built is to mix foamed cement at any quality ranging from 0% to 70% at a pressure below 1,000 psi. The foam can be cured in a cell at temperatures as high as 302°F (150°C). This equipment may be available at commercial API oil well laboratories.

Stability and compatibility tests should always be performed prior to any foamed cement job. A simple way to test the compatibility of a surfactant with cement additives is to proceed as follows:

Pour 1 cm3 of P-FA78 surfactant in 100 cm3 of the water which will be used for the base slurry. This water should also contain all the soluble additives that ultimately will be used in the cement. Foam the mixture one minute in a closed WARING blender at 12,000 RPM. Pour the foam in a graduated cylinder. The foam should occupy at least 600 cm3 and the half-life of the foam should be longer than six minutes (half-life is defined as the time required to get 50 cm^3 of liquid at the bottom of the foam column).

When this test is performed in the presence of salt, it becomes evident that salt reduces the stability of aqueous foams but P-FA78 foams are more stable. Therefore, P-FA78 should be used whenever the mix water has a high salinity.

Tests should also be performed with the base slurry. A minimum 70% foam quality should be obtained. To perform this test, prepare the base slurry following the API procedure. Add the surfactant and mix gently one minute in the WARING Blender at a very low speed (900 RPM). Keep a slurry volume in the blender which corresponds to 30% of the blender volume. Close the blender and mix for one minute at 12,000 RPM. Foam should occupy the entire volume of the blender.

This foam should remain stable until the cement sets, i.e., no bubble should be seen bursting at the surface and no difference in density should be observed from the top to the bottom of the set foam slurry.

These tests require a minimum of equipment and must be performed prior to any foamed cement job. This procedure of testing foam generation and stability in a WARING blender at atmospheric pressure is quite dramatic. A foam system which is stable under these conditions will be more stable in the high-pressure and high-shear environment encountered in the field.

Tests were performed to evaluate the compatibility of surfactants and antifoam agents. Antifoam agent was added to the mix water of the base slurry while the foaming agent was added to the slurry. 300 cm3 of base slurry was mixed in a closed WARING blender having a volume of 1150 cm3. The maximum foam quality was evaluated by measuring the quality of the foamed cement obtained.

The results clearly indicate that antifoam agents are detrimental to the stability of foamed cement. However, if excessive foaming is encountered in the tank during a job where the cement is batch mixed, it is better to add some antifoam agent and solve this problem than to stop the job.

THICKENING TIME

Determination of the thickening time for foamed slurries is complicated by the fact that even in highly-stable foamed systems, once slurry thickening begins, mechanical agitation breaks the foam structure and large unstable bubbles form. This means that foamed slurries must be at rest in the desired annular interval prior to the onset of appreciable thickening.

Foaming in itself produces little effect upon thickening time. In practice, API test procedures to establish retarder schedules using un-foamed base slurries (containing the surfactant) appear valid. The point in time when initial thickening is observed (point-of-departure or P.O.D.) represents the maximum pumping time available before destabilization will occur. To accelerate or retard a foamed cement slurry, any accelerators or retarders may be used.

PERMEABILITY AND COMPRESSIVE STRENGTH

The engineering properties of foamed cement are affected by the quality of the foam, PSD (pore size distribution), brand of cement, density of the base slurry, curing conditions and nature of the additives which are used in the base slurry.

Great care should be taken in extrapolating the results obtained on foams prepared at atmospheric pressure to foams having the same density but different PSD (pore size distribution) since the permeability is quite important.

For each foam quality (e.g., density), measurements have been made on two samples having different pore-size distributions. One was generated at atmospheric pressure in a WARING blender, and the other at 1,000 psi at high shear.

Permeability increases with foam quality (% gas). When bubbles are small and their distribution uniform, this increase is very progressive. If the bubbles are non-uniform, the permeability remains fairly low and then increases sharply. This transition occurs between 10 and 11 lbm/gal with Class G cement. Therefore, it seems that in the case of non-uniform bubbles, a percolation threshold occurs around 35% quality.

Compressive strength is also affected by the PSD (pore size distribution) but to a lesser extent. Foams having a broad PSD (pore size distribution) have better compressive strengths than those having the same density but smaller bubbles. The difference tends to decrease with density and that foams having a density as low as seven pounds/gallon still develop a compressive strength of 500 psi. Below five pounds/gallon, a set foam is no longer solid and easily falls apart.

Other parameters that influence permeability and compressive strength are the brand of the cement and the density of the base slurry. The same density, a foam-slurry prepared with Class C cement has better properties than a foam-slurry prepared with a Class G cement. The base slurry density can be adjusted by changing the water/cement ratio. However, avoid using a water/cement ratio which would produce an unstable-base-slurry.

The same mechanisms that produce free water will contribute to segregation in foamed slurries. Also make sure that changing the water/cement ratio does not cause trouble during the mixing of the base slurry in the field.

Measurements have also been performed on foamed cement prepared at 1,000 psi at room temperature and cured at 150°F (66°C). In wells where the cement is exposed to temperatures exceeding 230°F (110°C), it is necessary to add 35% Silica Flour (BWOC) to the base slurry to prevent strength retrogression and increased permeability.

The concentrations of P-FA78 surfactant remain the same. The presence of silica promotes the development of a new crystalline phase which can be seen as needles growing inside the bubbles. The net effect is that permeability is decreased while quality remains below 35%.

Foamed cement has also been cured at temperatures as high as 392°F (200°C) and pressures around 8,000 psi. Results showed a slight decrease in compressive strength and permeability compared to samples of the same density cured in less drastic conditions. The durability of the foam should not be less than the durability of the base slurry.

FLUID-LOSS

Fluid-loss experiments have been conducted using a modified cell of 540 cm3 with the standard BAROID cement-testing screen (325-mesh). The pressure inside the cell was a constant 1,000 psi at ambient temperature. For neat cement foamed at various qualities, fluid loss decreases as quality increases. For a constant foam quality, fluid loss also decreases when the P-FLA/S (Petrochem Fluid-Loss-Salt Additive) concentration is increased.

No laboratory experiment has been performed with other Petrochem fluid-loss additives. The same rule applies as for any other additive, first check the foam quality and stability of the foamed cement in which the additives are incorporated.

CONCLUSIONS

Roughly speaking, the engineering properties of foamed cement can be summarized in the following way:

1. Foamed cement slurry can be generated, circulated, compressed and extended without affecting its stability as long as the foam quality does not exceed 80%.
2. Set foamed cement presents good cohesion when the quality remains below 70%.
3. Compressive strength of 500 psi can be reached at qualities lower than 50%.
4. Above 35% quality, the permeability of foamed cement increases dramatically due to interconnection between bubbles.
5. Foamed cement has good fluid-loss properties and good durability under high temperature and high pressure conditions.

FIELD MIXING PROCEDURES

Proper mixing of foamed cement requires the following three separate operations to be correctly executed at the same time.

1. The base cement slurry is mixed at the design density and pumped at the design rate(s).
2. The P-FA78 solution is added to the cement slurry at the design rate(s) and/or concentration.

3. The nitrogen is pumped at the design rate(s).

4. Detailed instruction on how to achieve all of these requirements is left up to operation experience.

5. The intention of this information is to address only the base cement slurry and PFA78 designs.

6. Laboratory equipment has been built to mix foamed cement at any quality ranging from 0% to 70% at a pressure below 1,000 psi. The foam can be cured in a cell at temperatures as high as 302°F (150°C). This equipment is generally available at commercial API testing laboratories. However, it has improved our knowledge considerably of foamed cement behavior and our understanding of its properties.

PRODUCT	**FORM**	**SG.**	**PACKAGING**
P-FA78	Yellow Liquid	1.03	55 Gals/Dr. & 265 Gal. Tote