Stable Foam Used as a Circulating Media in Wellwork Processes

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Stable foam used as a circulating media meets some urgent needs in wellwork. The success and effectiveness of the technique presented in this paper have been established by the completion of some 150 jobs in the Rocky Mountain—Mid-Continent area, and even more in California.

WHY USE FOAM

Basically, the use of foam permits circulation while performing various drilling, coring, deepening, drillouts, sand bridge removals, fishing jobs and various other downhole wellwork processes. These processes must be performed in an environment of low bottomhole pressures or in many cases with normal or high bottomhole pressures while working in porous formations.

Methods of achieving circulation under these conditions available to the industry in the past are undesirable because of:

1. the formation pollution and damage brought about by the "stuffing" of lost circulation material, solids and harmful fluids into the flow channels of the formation,
2. the loss of production in recovering substantial volumes of fluids while working in lost circulation or porous zones, and
3. the natural inability of a fluid to clean or improve the flow characteristics of a formation while "stuffing" its pores and flow channels full of junk.

The feasibility of the use of pre-formed stable foam will be explored more precisely as each application is considered. First, one must examine some of the physical characteristics of foam and the mechanics of generating it at the well site.

THE FOAM UNIT (FIG. 1)

The basic design of the foam unit includes certain basic elements essential to generate the foam, establish the circulation and degenerate the foam after it completes one cycle in the well bore. In other words, it is used one time around either in normal or reverse circulation, and then reduced to the liquid from which it was formed.

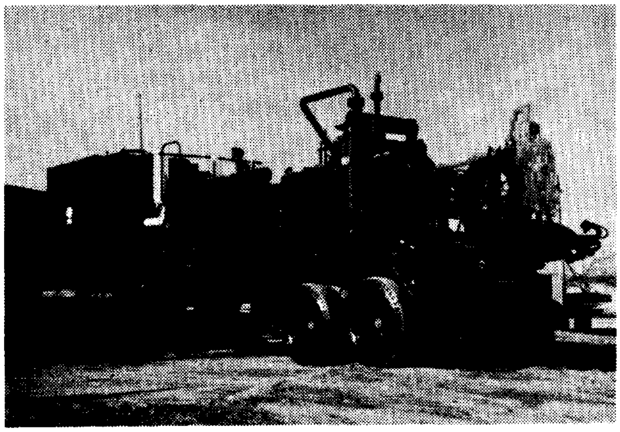

FIGURE 1

To accomplish the foam cycle, that is, GENERATE ... CIRCULATE ... ROTATE ... DEGENERATE ..., a mobile one-load unit is utilized. The typical unit consists of: (Fig.2)

1. Air compressor—425 cfm @ 400 psi WP with air chambers, after-coolers and scrubbers, along with necessary air-gas metering and pressure-recording devices
2. Power source for air compressor and after-cooler—350-hp prime mover (Power Unit No. 1)
3. Triplex pump, recommended size 3 in. x 5 in. with 5000 psi working pressure, along with a fluid meter
4. Power swivel for rotation
5. Hydraulic power system to drive power swivel, chemical pump, and triplex charge pump
6. Power source for items 3, 4 and 5; 350-hp prime mover (Power Unit No. 2)
7. Solution tank with three 20-bbl compartments
8. A foam generator (Fig. 3)
9. Adequate metering devices for chemicals, water and air (or gas)

10. Low-boy float for unitized installation of above
11. All equipment is mounted on a low-boy tandem trailer unit with prime mover. The estimated cost of the entire unit varies from $85,000 to $165,000.

At the well site, the unit is mechanically operated to generate the foam by introducing a measured amount of compressed air (or gas) into a carefully premixed solution of surfactant and water. This is accomplished by accurately metering a detergent such as NALCO's BF-1 in fresh water at a ratio of one to two parts of BF-1 to 100 parts of fresh water into a solution tank. This solution is then pumped at well injection pressure by the triplex pump into the foam generator, at the same time injecting into the generator a measured volume of compressed

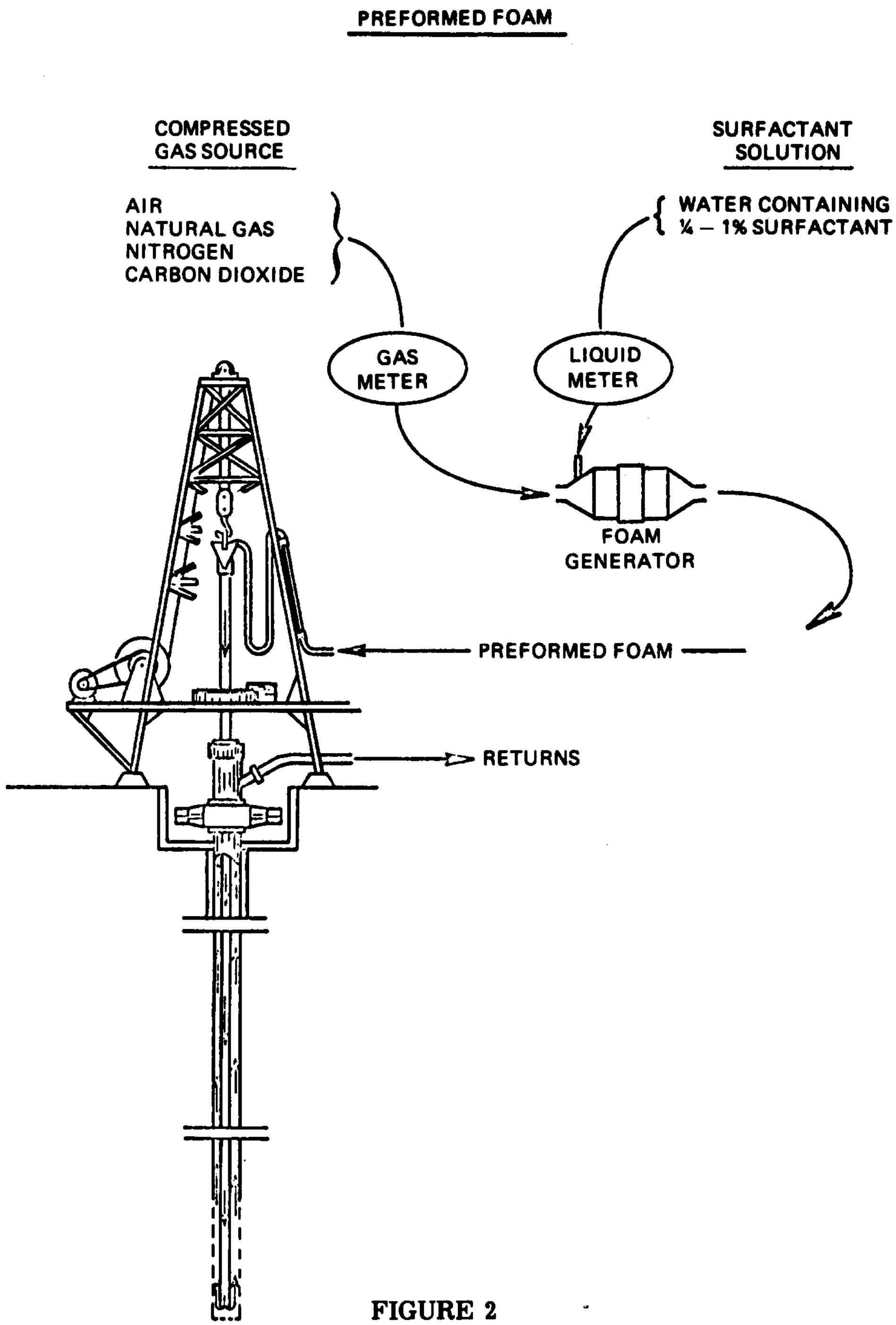

FIGURE 2

air. The generator vessel is designed to permit the continuous flow of the gas-liquid mixture through the agitator, discharging it as foam into the well injection line (Fig. 3). The foam is circulated through the well bore and back out the blooie line to the degenerator or to a pit where a defoamer is used.

PHYSICAL CHARACTERISTICS OF FOAM

Pre-formed foam (i.e., the foam is formed prior to entering the well), is a gas-liquid dispersion in which the liquid is the continuous phase and gas is the discontinuous phase. It is formed by the dispersion of a large amount of air into a small amount of liquid. This results in a low-density and high-viscosity circulating medium with a high lifting capability.

Foam is not a mist or a froth, but an air-liquid dispersion that must be described by terms we are unaccustomed to as compared to other circulating liquids and gases. The term LIQUID VOLUME FRACTION (LVF) expresses both density and bubble size. It expresses the relative proportion of each phase (gas and liquid) in the dispersed mixture. The liquid-volume fraction is expressed as follows:

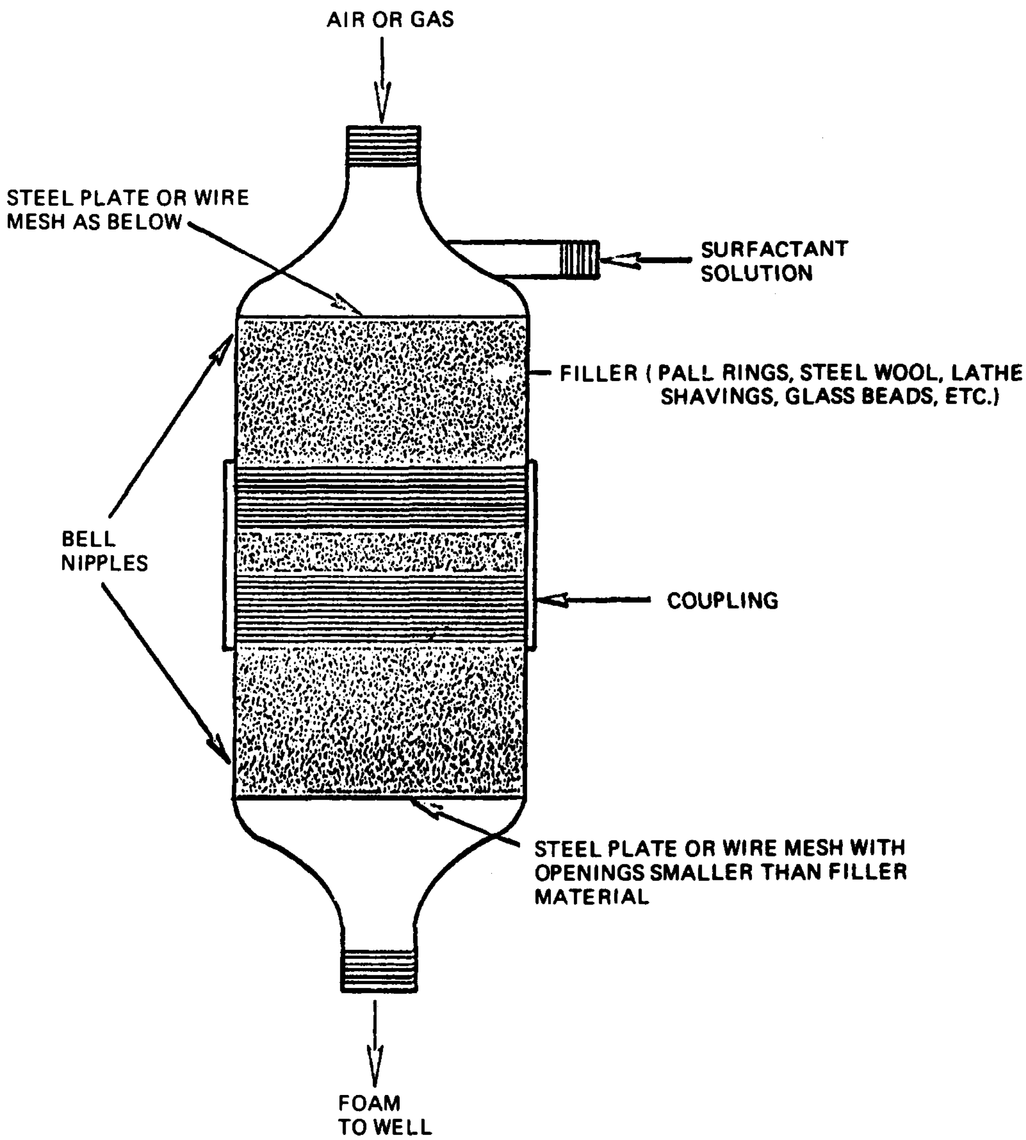

FIGURE 3

$$LVF = \frac{V_1}{V_g + V_1}$$

V_g = Volume of gas at pressure and temperature
V_1 = Volume of liquid at pressure and temperature

The LVF determines to a degree the gel-strength, viscosity, density and bubble size. Maximum lift occurs when the LVF is between 0.02 and 0.2. In the event of formation fluid intrusion, the LVF is maintained on the low side. The optimum LVF is 0.1, resulting in a dry low annular velocity, low pressure operation.

The density of such a foam is approximately 0.8 lb/gal with a hydrostatic pressure of approximately .04 psi per ft of height.

FOAM IN DRILLING, DEEPENING AND CORING

Low annular velocities maintained in foam circulation facilitate large hole drilling. In fact, foam drilling applications found their origin with the atomic energy storage wells in Nevada. The application adapts itself to drilling in water-sensitive shales, broken shales where large diameter washouts are common, and drilling in permafrost.

Experience in drilling in hard formations in the Four-Corner area proved to be as fast or faster than with air or gas and without the downhole fire problem or problems created by high annular velocities.

The effective permeability of a formation is a function of not only rock characteristics but also the degree of contamination in the flow channels, whether natural or artificial. Radial flow formulas establish that the slightest blocking has a material effect on the MER of a producing section.

With this in mind, the producer has found the foam circulation application practical in the drilling of the production or injection zone of a new well or in deepening to new zones, the advantage being that one is not stuffing the porous zone with either solids, liquid carrying solids or liquid pollutants.

Low-density foam makes it possible to drill the formation with the pressure gradient downward from the formation in the well bore rather than upward from the well bore into the formation.

Experience in coring with foam was obtained from 10 wells in the Howard-Glasscock Field area. Recovery was from 90 to 100 percent and the core laboratory stated that they had never received cleaner cores. Coring rates were less than one-half that of mud coring rates.

FOAM IN SAND CONTROL

The presence of sand bridges and sand fillup is one of the most common problems encountered in oil and gas production throughout the world today. Experience has established that foam can remove sand at a rate 10 times that of oil, water or mud. For example, when foam was used, sand washed out at a rate of 350 lb/bbl while with water the rate was 35 lb/bbl.

In formations where the sand grain size range will vary as much as 40 percent in 60 percent of the sample, some sand stabilization can be accomplished by foam circulation. After a period of approximately 48 hours the sand grains tend to bridge and stabilize. This cannot be achieved where the sand grains are fairly uniform. A study of the sieve analysis of the sand will reveal the probability of sand stabilization.

There are available on the market various resins or other binding agents to consolidate or stabilize sand. However, success ratios have been low and some laboratory analyses indicate the failure was due to the presence of contaminants on the sand grains. Foam circulation should precede any sand consolidation.

Examinations of sand screens or other sand-containing mechanical devices establish that a substantial part of the plugging of the screen element is caused by extraneous materials. Screen life can be extended with foam circulation prior to any screen setting.

FOAM IN CLEANOUTS AND FISHING JOBS

The problem of removing debris from shot holes in low-pressure reservoirs dates back more than 50 years and still remains a serious stumbling block to well preparation in secondary recovery programs. Foam circulation effectively cleans out debris in shot holes. Recently in the Permian Basin area, a producer had scheduled two wells, which had been shot in years past, to be cleaned and deepened 130 ft each. An AFE was prepared allocating 12 days per job. These time estimates were based on years of documented records. Foam circulation accomplished the actual cleanout and deepening time in twelve hours per well.

In shot-hole cleanouts, removal of debris from shelves in the formation presents some problems. The maximum hole diameter for effective foam cleanout is approximately 50 in. Some jet washing has been accomplished.

Scale removal using bit and scrapper on producing and injection wells was successfully performed on eight wells in the Iraan, Texas area. This was accomplished in an average of two days per well. The conditions were such that circulation could never be achieved without extensive use of lost circulation material and possibly not then.

Foam has been successfully used in some difficult fishing jobs including liner jobs, packer drillouts and casing patch jobs. In fact, foam use was developed for the most part in liner removal and settings in the Bakersfield-Taft area of California. The sand removal capability of foam along with the pressure gradient conditions created and the lubricating effect of the surfactant have made liner jobs substantially less expensive and success more probable. More than 500 jobs have been successfully done at an average of one-half the cost of conventional liner cutting and pulling.

Cementing of liners in the presence of low pressure or extremely porous (or fractured) zones by conventional methods has been done with only a modest degree of success or not at all. Foam is now being used in the spotting of cement behind the liner in adverse conditions in the low pressure zones.

Washover operations using foam have been performed in a number of wells without difficulty. There is evidence that such fishing jobs are some of the best applications of foam.

FOAM IN SMALL TUBING WORK

Workovers utilizing small tubing (i.e., 1-½-in. OD or less) have been successfully done with foam circulation. The application of foam reduces to a nominal figure the pressure drop in the string during circulation. For example, the pump pressure using liquids in a 9000-ft well would be in excess of 5000 psi, while with foam circulation it could be achieved with 1000 psi.

Recently, a company in California completed a workover program on 184 wells in the Elk Hills Field using 1-in. OD, jointed pipe with foam, and made this statement, "The development of stable foam has permitted a new approach to well servicing which prevents formation damage while permitting the full range of downhole production work to be accomplished."

The continuous tube combined with foam opens new horizons for well workovers. They eliminate for the most part the necessity of a drawworks, derrick, pits and pumps. Workover derricks will go down the same path that standard derricks have gone, that is, to the salvage heap.

FOAM IN HIGH-PRESSURE WORK

Foam circulation applications are not limited to low well pressure conditions. Some operators have successfully used foam with wellhead pressures in excess of 2000 psi and depths in excess of 11,000 ft. In experimental work, low LVF stable foam has been generated with a 10,000 psi injection pressure.

A computer program has been successfully developed which accurately predicts injection and bottomhole circulating pressures. This computer program permits assembling the proper equipment to do the required work and provides a basis for field operating control.

Continued research and development in the use of high-pressure foam will broaden the application of foam circulating processes.

FOAM OFFSHORE

With the ever-increasing need for environmental protection, oil as a circulating media is becoming prohibitive in offshore workovers. Foam is not only more effective but is nonpolluting. It is biodegradable, easily controlled, and requires the handling of only small volumes of liquids. It is contained in a closed system and its reuse is not required.

Experience in offshore work in the Santa Barbara channel fields has been costly. When used with reel tubing or in snubbing operations with 1-in. jointed pipe, economics have proven to be far superior than with conventional workover methods.

The continued development of continuous tubing used in conjunction with foam should revolutionize offshore workover practices.

SUMMARY

Foam circulation in wellwork processes has not yet become a standard procedure. The record of successful jobs with consistent evidence of increased productivity of the wells along with the substantial savings in well workover cost indicates a rapid growth in the application of stable foam in well workovers.

TABLE 1

FOAM REPORT

Type Job	No. Jobs	Average Cost	Comments
Deepening	61	$1,147.52	Average 50' new formation per well
Coring	6	1,945.34	Average 50' well
Fishing	4	2,491.49	On temporarily abandoned wells
Redrill	34	2,110.05	Shotholes
Sand Removal	14	837.38	Some sand stabilization
Scale Removal	5	1,008.57	Water injection wells
Liner Cementing	7	3,858.03	Successful cement jobs
Drill In — New Well	4	2,250.76	New well completions
	135 Total Jobs		

The application is not limited to one particular type of well or well problem. The industry is fast recognizing these facts and there is every indication that its acceptance will be universal.

Foam circulation is another step forward in the overcoming of economic and ecological problems that producers are faced with today.

ACKNOWLEDGMENTS

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