SPACERS AND THEIR APPLICATIONS IN PRIMARY CEMENTING

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ABSTRACT

Many factors are involved in successful completion of a well. It is well accepted that the best cement job possible is of prime importance. For a good cement job, the contamination of the cement by the drilling fluid should be minimized so that the cement can develop its desired properties. In addition, the drilling fluid should be thoroughly displaced from the annulus so that a competent sheath of cement can form a bond to both the pipe and the formation. When the drilling fluid is not thoroughly displaced, thus allowing commingling with the cementing composition, many undesirable results may occur.

Laboratory work and field results show that spacer fluids can be advantageous in assisting in keeping the drilling fluid and cementing composition separated and also aid in more effectively removing the drilling fluid from the annulus.

This paper identifies the properties that a good spacer should possess to function properly and discusses general practices in the use of spacers.

INTRODUCTION

With today's demand for hydrocarbons, it is essential that maximum production be obtained from each well. The success of drilling, completing, and producing a well can be influenced by several factors. Of the many factors involved in completing a well, obtaining of the best cement job possible is of prime importance. The life of the well and the amount of production can be influenced by the success of the cement job.

A good primary cementing job requires that the annular fluids be displaced from the annulus and replaced with the cementing composition. The inadequate removal of annular fluids may result in poor cement bond to formations and pipe, intrazone communication, pipe corrosion, and pipe collapse.

The cement, once in place, should:

1. Bond to pipe and formations
2. Isolate zones
3. Strengthen pipe
4. Protect casing from corrosion

To obtain efficient drilling fluid displacement and mud filter cake removal, a great deal of time has been devoted toward the development of spacers. Spacers are fluids which are placed between the drilling fluid and cementing composition during primary or secondary cementing.

This paper will indicate the advantages of using spacers.

GENERAL PRACTICE

A common practice in primary cementing is to displace the drilling fluid with the cementing slurry. Many times these two fluids are incompatible. When they become commingled at the interface, a very viscous mass may result which may be deposited for long intervals within the annulus. The resulting effect can be low displacement efficiency of the drilling fluid, contamination of the cement slurry, zone communication, and ultimately an expensive squeeze cementing operation. Even where the drilling fluid and cementing composition appear to be compatible, the drilling fluid may contain organic chemicals that can prevent adequate hydration of the cement. Typical results of the effect of drilling fluids on the compressive strength of cement slurries caused by dilation and chemical retardation are shown in Table 1.

TABLE 1—EFFECT OF MUD CONTAMINATION ON STRENGTH OF CEMENT

Percent Mud Contamination	12 Hours Compressive Strength at 230°F	
	15.6 lb/gal	17.4 lb/gal
0	2910	7010
10	2530	5005
30	1400	2910
60	340	2315

To obtain higher efficiency in drilling fluid displacement and to control contamination of the cementing composition, a good practice is to keep the annular fluid and cementing composition separated. This may be accomplished by the use of cementing plugs, washes, or spacers.

The primary difference between spacers and flushes is that spacers are designed with yield point which allows the incorporation of weighting and lost circulation materials. Separation of the annular fluids from the cement composition may be accomplished by the use of fresh water, brine water, chemically treated water, oil base flushes, and water- or oil-base spacers. These fluids may or may not be weighted as determined by downhole conditions. Some of the advantages and disadvantages of these fluids are as follows.

1. Precautions must be taken in the use of fresh water, because formation damage may occur from water blocks, emulsion blocks, and the hydration of clays present in the formation.
2. Brine flushes are generally designed for slurry compatibility and formation protection. The disadvantages of using brines are the emulsion forming properties of the brine and the incompatibility of the brine with drilling fluids.
3. Chemical flushes are designed to alter the properties of the hydrated clays in order to obtain a more efficient removal of circulatable mud and filter cake.
4. Oil base flushes are designed to protect hydratable clays and are primarily used to remove the circulatable mud which is normally an oil base system.
5. Spacers are designed to separate the drilling fluid and cement slurry, be compatible with both fluids, control formation pressures, and control zones of lost returns.

Importance of Thoroughly Displacing Drilling Fluid

Primary cementing of surface as well as protective and production casing strings should include all practical measures to ensure success.

Some of the prime considerations in planning a good cement job are as follows:

1. Condition the drilling fluid
   a) Circulation
   b) Addition of chemicals
2. Pipe movement
3. Wall cleaners
4. Centralizers
5. Spacer fluids

Conditioning the Drilling Fluid

Considerable planning should go into the selection of a proper drilling fluid. Many fluids presently being used in drilling operations are not conducive to good cementing practices. These drilling fluids may have high yield points and high gel strengths which result in inadequate mud removal. Conditioning the mud system is a major driving force toward obtaining a good primary cement job. Lab tests indicate that decreasing the yield point and gel strength will increase the displacement efficiency.[1] There are methods available for determining the percent circulatable mud in the hole. One common method is to add a tracer material such as dye, radioactive materials, or inert particles (such as rice hulls) to the mud. The mud is then circulated, and the time required to complete one circulation is recorded. An approximate amount of circulatable mud contained in the annulus can then be calculated from the volume of mud in the tubular goods and the circulation rate.

Pipe Movement

Pipe movement, either rotation or reciprocation, can be advantageous in obtaining higher displacement efficiency of the drilling fluid and better placement of the cementing composition. Carter and Clark[1] state that pipe movement (rotation) gives better mud removal than no pipe movement. Later displacement tests have shown that pipe movement such as reciprocation can increase the displacement efficiency by 20 percent. In a test with no pipe movement, 43 percent of the mud was removed. In a similar test with the pipe reciprocated at 13 feet/minute, 60 percent of the mud was removed. Tests show that the cementing composition will find the path of least resistance through a high yield-point drilling fluid and will continue to follow that path. Pipe movement can be very beneficial in breaking the gel condition of the drilling fluid which will aid in cement placement.

Wall Cleaners

Research in the area of displacement mechanics indicates the use of wall cleaners (scratchers) is an aid to better mud displacement. The use of wall cleaners involves the inclusion of pipe movement which is also a driving force in obtaining good mud displacement. A comparison of three displacement tests show that no pipe movement with no scratchers gave 63 percent mud removal, pipe movement with no scratchers gave a displacement efficiency of 79 percent, and pipe movement with scratchers gave a displacement efficiency of 93 percent. Wall cleaners are beneficial as mechanical aids because, with pipe movement, the scratchers aid in breaking the gel strength of the mud. Maximum cleaning efficiency results from spacing the wall cleaners equal distances apart a few feet above, and below, through the zones to be cemented. Normally, three wall cleaners are attached to each standard length casing joint through the zone to be cleaned.

Centralizers

Displacement tests have shown that the use of centralized pipe can increase the displacement efficiency. The percent displacement efficiency will depend on factors such as the condition of mud and hole and the circulating rate. By using centralizers to center the pipe, cement can flow more uniformly around casing, tubing or liners and provide a more uniform cement thickness between pipe and formation. Normally, centralizers should be used through the productive zone as well as 40 feet above and below the zone. The centralizers should be placed on every collar through the zone.

Spacers and Their Functions

Spacer fluids can be broadly classified into two categories: oil base and water. Oil base spacers are those whose continuous phase is a hydrocarbon. These spacers include either true oil base or invert emulsion and may be formulated using either diesel or crude oil. Water base spacers are those having a continuous aqueous phase.

Spacer fluids may also contain materials to control loss circulation and materials to aid in removing mud filter cake.

Field and laboratory results show that a properly designed spacer can produce a higher displacement efficiency of mud and consequently a better cement job.

Spacers are unique fluids and should possess certain desirable properties to function properly. Some of the desirable properties of a good spacer are listed as follows.

1. Compatibility with well fluids contacted (drilling fluid and cement)
2. Separate fluids
3. Remove drilling mud and filter cake
4. Protect formations
   a) Control formation pressure
   b) Inhibit damage to water-sensitive shales
5. Not adversely affect properties of cementing composition or mud.

Compatibility

Many cements and cement additives (organic and inorganic) are available to the industry today. There are also many drilling fluids, which can vary from oil base, invert emulsion, polymer, bentonite dispersed, etc. The spacer must be formulated from components that will allow it to be compatible with various drilling fluids and cementing compositions.

There has been considerable discussion about the proper method of determining the compatibility between drilling fluid and cement. A common method has been to combine two fluids in a bottle and shake. This type of test is rather ambiguous and is only a visual test. Many times, even though fluids appear to be highly viscous, they may in fact be "pseudoplastic," and with some agitation, the viscosity decreases.

A more realistic approach in determining the compatibility of two fluids is to measure the rheological properties on a multi-speed viscometer.

To the base fluid (fluid being contaminated various percents of contaminants are added and the rheological properties recorded. The need for running various percentages of contaminants can be seen in Figure 1. Test number three shows an increase in the apparent viscosity of a bentonite mud when contaminated with 10 percent by volume of spacer fluid. However, after 16 percent contamination, the apparent viscosity began to decrease.

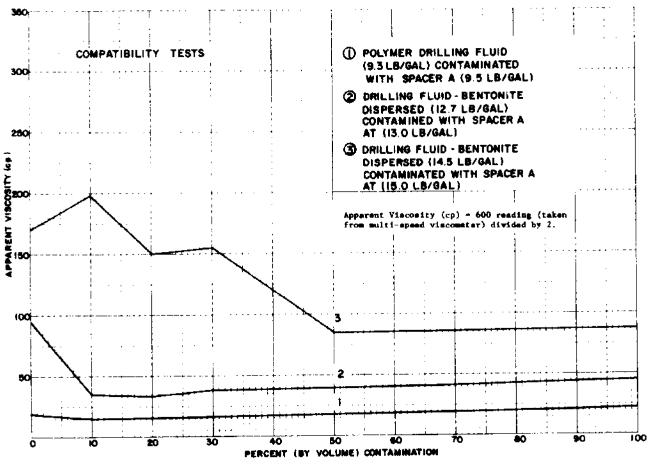

FIGURE 1

There are many variables to be found between wells and the fluids that are used to drill and complete these wells. As a result of these variables, the amount of commingling that will occur between the drilling fluid, spacer, and cement slurry is usually undetermined. A standard laboratory procedure for determining compatibility properties is as follows.

Procedure

A. Add contamination fluid to base fluid (fluid being contaminated) while mixing on a Hamilton Beach mixer or air mixer. Mix for 1 minute.
B. Measure rheological properties (600 through 3 rpm readings) at room temperature.
C. If incompatibility exists between any of the fluids, repeat compatibility test at 150°F, or if possible, use the temperature of the well under consideration.

Tests

1. Drilling Fluid and Cement Compatibility. (Drilling fluid contaminated with 0, 10, 20, 30, 50 and 100 percent* cement composition).
2. Drilling Fluid and Spacer Fluid Compatibility.
(Drilling fluid contaminated with 0, 10, 20, 30, 50 and 100 percent* spacer fluid.)
3. Spacer Fluid and Cement Composition Compatibility.
(Spacer fluid contaminated with 0, 10, 20, 30, 50 and 100 percent* cement composition).

* All contamination measured in volume percent.

Compatibility properties as recorded in Figures 1, 2, and 3 show the desirable effect of a spacer fluid and the undesirable effect of a cementing composition when commingled with various types of drilling fluids.

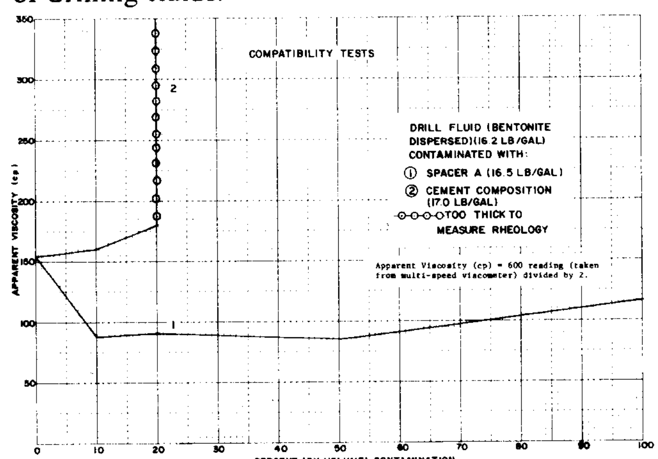

FIGURE 2

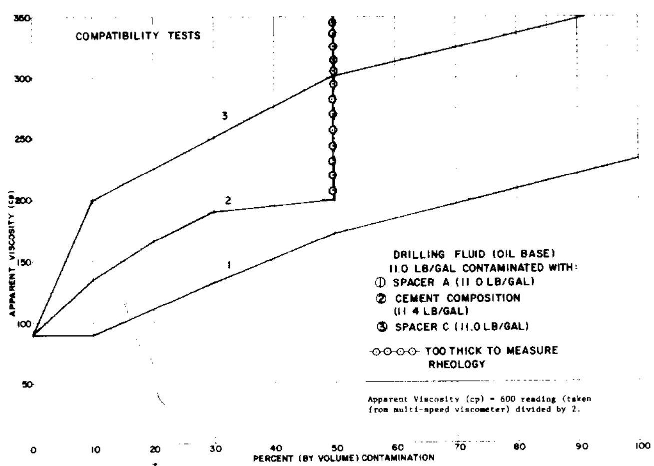

FIGURE 3

Fluid Separation

There is a need to keep the drilling fluid and cement slurry separated. Laboratory results show that the cementing composition can be separated from the drilling fluid by placing a spacer between these two fluids. The spacer is designed so that it functions much like a piston and the yield point (lb/100 sq ft) should equal or exceed the yield point of the drilling fluid. The yield point will not only function to keep the drilling fluid and cement slurry separated, but it will also aid in displacing the drilling fluid and carrying these solids as they are removed from the well.

Weight is also important in separating the two fluids. Normally, it is desirable for the spacer weight to be between that of the drilling fluid and that of the cement slurry. Test results in Table 2 show that an unweighted spacer would not maintain separation of a 18.0 lb/gal mud and 18.5 lb/gal cement slurry, but when the spacer was weighted to a weight between the two fluids (18.2 lb/gal), they remained separated. Another important factor in using a weighted spacer is its ability to control formation pressure and thus reduce gas cutting of the cement slurry.

Barite is the most common weighting component for spacer fluids; however, calcium carbonate or iron carbonate may also be used as weighting material. The carbonates may easily be removed by interaction with acid.

Drilling Fluid and Filter Cake Removal

There are varied opinions about the removal of filter cake from the bore hole. In some wells no damage would occur if all the filter cake was removed from the formation face. In other wells where the formations are unconsolidated or contain hydratable clays, it would be desirable to leave at least the thin, tough portion of the filter cake. This prevents heaving or sloughing of the formations and to control fluid loss to the formations.

The spacer should be designed to either chemically or physically displace the mud and remove some of the mud filter cake. Laboratory results show that spacers can aid in removing the mud and filter cake when it is formulated to contain a surfactant or an angular material. The importance of the yield point (lb/100 sq ft) of a spacer fluid has been discussed; it is a very important spacer property in allowing an angular material to function properly. As the spacer fluid is pumped through the well, the yield point must be maintained through the temperature range of the well, so that the angular material will remain suspended but also allowed to move within the spacer fluid to provide an abrasive action.

Consideration should also be given to the volume of spacer used. It is desirable to use a volume of spacer that will give at least three minutes contact time in the annulus. Past experience has shown that many times an inadequate volume of spacer was used and the spacer became overloaded with solids. The excess solids contained in the spacer could prevent the spacer from functioning properly through the remainder of the job.

TABLE 2—SEPARATION TEST

Spacer Weight (lb/gal)	Test Results
(Unweighted)	Oil base mud supported spacer but spacer did not support cement slurry and the two fluids became one.
(18.2)	Oil base mud supported spacer and spacer supported cement slurry.

Procedure

(1) Poured into (7/8′ ID x 48″ long) tube, 150 ml oil base mud (18.0 lb/gal).

(2) Poured on top oil base mud, 50 ml spacer fluid, unweighted and at 18.2 lb/gal.

(3) Poured on top spacer fluid, 150 ml cement composition at 18.5 lb/gal.

NOTE: Yield point of spacer, unweighted and weighted, was approximately the same.

Protect Formations

The drilling fluid and cementing composition will usually contain chemicals to protect water-sensitive shales and control fluid loss to formations. Spacer fluids should be designed to protect water-sensitive formations and control fluid loss. If fluid loss is not controlled and filtrate is lost from the spacer, the spacer effectiveness could be hampered. Table 3 shows the desirable fluid-loss properties of three spacer formulations.

TABLE 3—FLUID LOSS

250°F — 500 psi

Spacer	Weight lb/gal	Fluid Loss ml/30 min
A	12.0	7
	15.0	12
B	12.0	5.2
	15.0	11.8
C	12.0	30
	15.0	24.4

No Adverse Effect on the Properties of Cementing Composition or Mud

The chemicals selected to formulate a spacer should be such that the rheological and fluid loss properties of the drilling fluid and cementing composition would not be adversely affected. It is especially important that the contact of the cement slurry by the spacer have minimum effect on the hydration properties of the cement slurry.

Field Results

Case No. 1 — An increase in zone isolation during treatment after cementing has been found. Previous attempts in cementing to isolate zones had not shown good success.

The wells with T.D. around 3700 feet have three production intervals in the Salem lime formation. The breaks on an example well are at 3650 feet, 3550 feet, and 3500 feet. Normally, a small acid clean-up is run on the smaller zone, followed by the acid frac on the middle zone. On the last well, where the cementing program was changed to include mechanical pipe movement, spacer fluid, and a change in the cementing composition, complete zone isolation and bonding has been attained during stimulation, showing definite improvement over past completion techniques.

Case No. 2 — An improvement in cement bonding has been accomplished with the use of spacers in the Illinois basin.

Mud weights in the area range from 8.6 to 9.0 lb/gal and cementing compositions are usually run at 14.1 to 14.6 lb/gal.

Figure 4 shows a cement bond log from the area. The log indicates very poor cement-to-formation bond and is a typical example of a well where an attempt was made to displace the mud with the cement slurry.

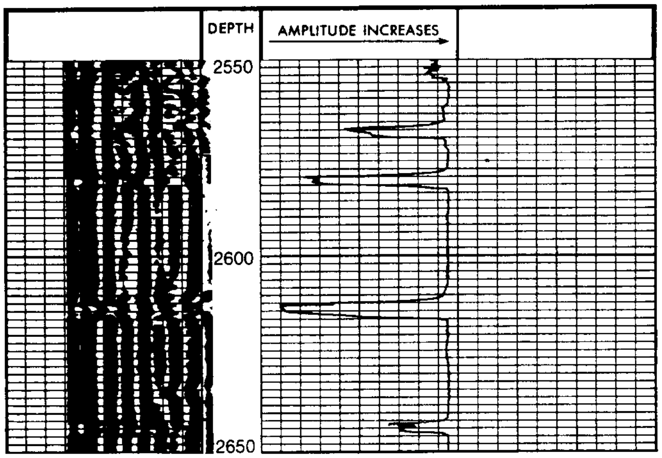

FIGURE 4

The cementing program was changed to include a spacer which is normally run in this area at a weight of 9.0 to 9.5 lb/gal. A definite improvement in cement-to-formation bond can be seen after the use of the spacer as shown in Figure 5.

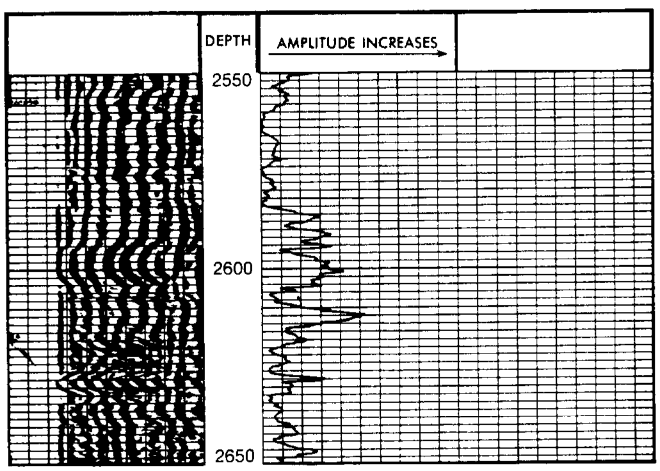

FIGURE 5

CONCLUSIONS

A properly designed spacer and flush can increase mud displacement efficiency by maintaining separation of the drilling fluid and cement slurry.

Spacers and flushes promote better mud removal and play an essential role in obtaining good cement-to-formation bond and reduce gas cutting of the primary cement by controlling the weight of the spacer.

The compatibility problems between drilling fluids and cement slurries can be eliminated with the use of a spacer.

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