CEMENT TOPICS: SPACERS AND FILTRATION CONTROL ADDITIVES

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ABSTRACT

A test was developed to evaluate cement spacers under conditions simulating mixing in the field. The results have shown that some products did not support barite acceptably well.

Dynamic circulation tests demonstrated that spacers did not have the ability to remove mud filter cake as they are widely claimed to do. A test was developed to determine the effect of cement filtration control additives on the filtration from cement slurries through well-formed mud cake. It was found that the additives had little or no effect. Therefore their use in the field for primary cementing has been curtailed in some areas and is under review in others.

INTRODUCTION

Spacers

Figure 1 illustrates the use of cement spacers. They prevent contamination of the cement by the drilling fluid and significantly improve cementing operations in some geographical areas.

When cement is placed, the length of the spacer, in the annulus between the casing and wellbore, may be 1000 feet or more. The spacer often must be weighted with barite for pressure control during cement placement. Turbulent flow is generally considered to be the best flow regime for pumping the spacer unless the wellbore is badly washed out and then plug flow is sometimes used (1-4). The erosive effect of the moving column of spacer fluid cleans the drilling mud from the casing and nonpermeable sections of the formation and is often claimed to remove the mud cake from permeable sections of the wellbore.

Filtration Control Additives

In recent years, it has become common practice to add a filtration control additive to cement during primary cementing of casing and liners. It is often stated that the dehydration of the cement slurry resulting from fluid loss causes or contributes to the loss of hydrostatic pressure which may allow gas influx or gas migration, before the cement develops adequate compressive strength (5-8).

The API cement fluid loss test is used to determine fluid loss from cement slurries. A common specification is an API fluid loss of approximately 100 cc. The tendency has been to go to lower filtration rates -- rates less than 50 cc have been discussed in recent papers (7,8). The addition of the filtration control additives significantly increases the cost of the cement.

RESULTS

Spacers

Barite Suspension Under Mixing Conditions

The design flow regime and compatibility of the products tested are listed in Table 1. A test was developed to evaluate the mixing of these products as they would be mixed on a rig site, according to the directions furnished by the supplier. A schematic diagram of the test apparatus is shown in Figure 2. It utilized a one-gallon rectangular tank with a small centrifugal pump in one end. The pump was part of a standard laboratory temperature controller (Lauda model B1). A VG meter was placed in the other end to monitor the viscosity. The viscosity was determined as soon as the components were mixed and every 15 minutes thereafter, for a total time of 90 minutes. The temperature was controlled at 75°F.

The results are shown in Table 2. "STATIC, AGED" refers to control samples which were initially mixed by high-speed blending and aged overnight in a roller oven at 150°F. Note that most of these products reached a stable rheology by the time initial mixing was complete. Furthermore, the rheology provided by the product mixed in the tank was usually within experimental error of the blended and aged samples.

None of the unweighted products had any appreciable residue in the bottom of the tank at the end of the test, but some of the weighted products deposited a large quantity of barite. Barite settling data are summarized in Table 3. The "%" under "MIXING" was an estimate of the percent of barite left in the bottom of the tank at the end of the test. Note that barite settling during mixing correlated very well with the rheology of the products. The thinner products designed for turbulent flow all exhibited some barite settling during the mixing test. The thicker products which were not designed for turbulent flow generally did not have this problem, except for product G.

Figure 3 is a plot of the critical velocities calculated from the rheological data in Table 2. Using a velocity range of 150 to 350 fpm as a common range for cement placement in gauge and near-gauge holes, the spacers fell into two distinct categories--turbulent flow and nonturbulent flow. This division accurately represented the suppliers' information concerning the flow regime the products were designed for.

Barite Suspension Under Static Conditions

This test was performed in 500 cc graduated cylinders with products which were blended and aged. Tests were performed at room temperature (approximately 75°F) and 200°F. The level of settled solids was read every 15 minutes by noting the position of any phase boundary separating near the surface. The position of the phase separation was reported as a percentage of the total height of the sample. The results of the static settling tests are included in Table 3. Some of the spacers supported barite better under static conditions compared to the mixing test.

Filter Cake Erosion

It was known from other work concerning dynamic filtration from drilling fluids that once a filter cake had formed on a permeable core, as long as some positive overbalance pressure was maintained, the filter cake was relatively stable and difficult to remove. Calculations indicated that the overbalance force holding the filter cake on the surface of the formation was several orders of magnitude greater than the frictional force which would tend to dislodge it. As a result, it was not expected that spacers or cement slurries could remove the filter cake as long as overbalance pressure was maintained (6,9).

To test this hypothesis, four filter cake erosion tests were performed under dynamic conditions. A schematic diagram of the test instrument is shown on Figure 4. The first three tests utilized water as the spacer and the fourth utilized unweighted product B. According to current wisdom, they should provide aggressive conditions for filter cake erosion.

The first three tests utilized very soft filter cakes formed from 25 ppb bentonite gel with no further additives and the fourth test utilized a more normal filter cake formed from a lignosulfonate-thinned field mud with starch added to control the fluid loss. The resulting filter cake was much harder and tougher than the filter cakes from the bentonite gel. The filter cakes were formed under static conditions on a synthetic core of approximately 150 mD at room temperature and an overbalance pressure of 500 psi. During the dynamic tests the overbalance pressure was 500 psi, the fluid velocity was 250 fpm, the temperature was 100°F and the contact time was 5 to 10 minutes.

The results are given in Table 4. The erosion of the filter cake was small, even under the most aggressive conditions and with filter cake of very poor quality. When the overbalance pressure was completely released, leaving a residual back pressure of 50 psi, the filter cake was still stable under dynamic conditions.

Filtration Control Additives

This work utilized a static test which simulated conditions in the wellbore during the interval after the cement was placed but before it began to develop compressive strength. Three commonly-used commercial cement filtration control products were evaluated. Products J and L were suggested for low temperature applications and K was for higher temperatures. Three drilling fluids were used to form the filter cake for these tests:

1. A dispersed, laboratory fluid consisting of 25 ppb bentonite and 6 ppb chrome lignosulfonate with the pH adjusted to 10.5 with caustic.

2. A tophole field mud thinned with the same additions as the laboratory fluid described above.

3. The same field mud diluted to a rheology consistent with shallow drilling, but with no further additions.

Filtration from a Cement Slurry Through a Mud Filter Cake

This test utilized standard API 500 cc double-ended cement fluid loss cells. During each test, a cellulose filter paper, normally used for the drilling fluid HTHP test, was placed over the 325 mesh screen on the bottom of a cell. Drilling fluid was placed in the cell and filtrate was collected at room temperature and 1000 psi nitrogen pressure for 30 minutes. Then the drilling fluid was poured from the top of the cell with rinsing. A cement slurry was prepared according to the API procedure and carefully poured into the cell without disturbing the filter cake. The rest of the procedure was identical to a standard API cement fluid loss test. The fluid loss from the cement was collected for 30 minutes at the test temperature with an applied pressure of 1000 psi. A normal level of care provided reproducible results with an overall relative standard deviation of approximately 10%.

The results are summarized in Table 5 and Figures 5-7. The properties of the drilling fluid filter cake and the fluid loss from the cement slurry through the filter cake are given on the table. In the column under "FILTER CAKE," "Fluid Loss" represents the volume of filtrate collected when the filter cake was formed. "Water Perm" represents the average fluid loss of plain water (or dilute $CaCl_2$ solution) through a filter cake at 1000 psi and the temperature used for the cement fluid loss test. In the columns under "CEMENT FLUID LOSS," "RT" is the room temperature (approximately 75°F). "Product Conc" is the concentration of filtration control additive as a percentage of dry cement, and "Fluid Loss" is the fluid loss from the cement slurry. Note that all filtrate volumes were multiplied by 2, according to API convention.

The filter cake had a dramatic effect on the fluid loss from cement slurries. Without it, the filtration control additives were effective at reducing the fluid loss from cement slurries through the 325 mesh screen of the standard API test. When a filter cake was present, the filtration control additives had little or no effect. The fluid loss from the cement slurry was the same, within experimental error, as the water permeability of the drilling fluid filter cake, except for product L.

DISCUSSION

Spacers

The results of the mixing tests supported the observations from the field that barite settling was a problem and allowed us to compare different products under the same conditions using a relatively simple test. The results have been successfully used by Texaco Operations to minimize settling problems in the field.

Some spacers provided better barite support under static conditions when compared to mixing conditions. Evidently the shear rate from the stirring in the mixing test was sufficient to shear thin some products to the point that barite was not supported efficiently, but the stirring rate was not great enough to keep the barite supported directly. The power of the pump motor per gallon of spacer, used for the mixing tests, was the same order of magnitude (but somewhat higher) compared to one offshore installation which was visited during this study. No survey was made of mixing facilities on different rigs, but a great deal of variability was cited by Operations.

During cement placement, the contact time of the flowing cement slurry against the mud filter cake would be much longer than the spacer. The erosion of the mud filter cake by the cement slurry may be more significant than erosion by the spacer, but it would still be small compared to the forces exerted by the overbalance pressure. A published dynamic filtration study from circulating cement slurries cited evidence that drilling fluid filter cake was resistant to erosion by the cement slurry (6).

Filtration Control Additives

The lack of effectiveness of filtration control additives to reduce filtration from cement slurries through mud filter cakes supported observations from the field that the additives did not always prevent gas migration problems. As a result of this work, some Texaco Operations have cut back or eliminated their use of filtration control additives in cement in some areas, with no detectable differences in the success of cement jobs. Filtration control is recommended in areas where high quality filter cakes are not formed on permeable zones as, for example, where drilling is done with air, gas or brine. Filtration control is also recommended for squeeze cements.

The API cement fluid loss test, utilizing a 325 mesh screen as the filtration medium, was originally developed to determine fluid loss from squeeze cement slurries, and we recommended its continued use for this purpose. During the work reported here, the cellulose filter paper normally used for drilling fluid HTHP tests was used for the sake of convenience and standardization. Some prior work indicated that the filtration medium used for fluid loss tests from drilling fluids did not affect the rate of fluid loss through the filter cake under normal conditions (9).

There is a possibility that when filtration control additives are used for primary cementing applications, they perform some function(s), other than filtration control, which improves the properties of the cement. For example, they may provide thixotropic or delayed gel strength properties (4,10). If so, then the appropriate properties should be understood and measured when formulating the cement.

CONCLUSIONS

1. Commercial weighted spacers vary in their ability to support barite during mixing and pumping operations.

2. A relatively simple test could be used to evaluate the ability of weighted spacers to support barite during mixing.

3. When cake-building drilling fluids are used under normal overbalanced conditions, spacer and cement placement does not remove the drilling mud filter cake, from permeable sections of the wellbore.

4. The rate of filtration from the cement is controlled by the permeability of the mud filter cake and commercial cement filtration control additives have no significant effect on the filtration rate.

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Table 1
Spacers Tester

PRODUCT CODE	FLOW REGIME	COMPATIBILITY WITH CEMENT
A	TURBULENT	COMPATIBLE
B	TURBULENT	REACTIVE
C	LAMINAR	COMPATIBLE
D	TURBULENT	COMPATIBLE
E	LAMINAR	COMPATIBLE
F	TURBULENT	COMPATIBLE
G	PLUG	COMPATIBLE
H	TURBULENT	COMPATIBLE
I	LAMINAR	·COMPATIBLE

Table 2
Rheology of Spacers

PRODUCT	WEIGHT	PLASTIC VISCOSITY			YIELD POINT			GELS
		Mixing		Static	Mixing		Static	Static
		Initial	90 Min	Aged	Initial	90 Min	Aged	Aged
(code)	(ppg)	(cp)	(cp)	(cp)	(pphsf)	(pphsf)	(pphsf)	(pphsf)
A	9	4	3	3	1	5	2	1/4
	16	13	12	13	2	4	2	4/12
B	9	2	3	3	1	0	1	1/2
	16	13	14	22	0	0	0	4/135
C	9	6	7	7	30	25	23	14/17
	16	30	31	34	61	64	60	23/25
D	9	4	5	9	4	5	4	4/12
	16	13	15	22	4	5	0	1/5
E	9	9	8	7	31	29	26	14/17
	16	28	37	37	57	48	63	26/30
F	9	31	29	39	10	7	11	1/2
	16	77	72	76	25	19	27	4/8
G	9	25	26	31	31	36	33	6/12
	16	90	74	62	100	87	57	26/71
H	10	10	8	13	5	2	0	1/1
	16	26	22	41	2	1	0	1/1
I	10	92	90	87	32	33	36	12/12
	16	60	80	95	38	80	41	9/10

Table 3
Barite Settling

PRODUCT CODE	TEMP (deg F)	MIXING CONDITIONS SETTLED (%)	RESULTING DENSITY (ppg)	STATIC SETTLED (%)
A	75	3.9	15.7	11
	200	—	—	9
B	75	39.4	13.2	2
	200	—	—	8
C	75	0	16	0
	200	—	—	0
D	75	14.5	15.0	18
	200	—	—	24
E	75	0	16	0
	200	—	—	0
F	75	13.3	15.1	0
	200	—	—	2
G	75	13.8	15.0	0
	200	—	—	0
H	75	25.8	14.2	25
	200	—	—	19
I	75	0	16	0
	200	—	—	0

Table 4
Filter Cake Erosion

SPACER	CAKE CONSISTENCY	CIRCULATING TIME (min)	INITIAL THICKNESS (ins)	FINAL THICKNESS (ins)	EROSION (ins)
WATER	SOFT	10	1/8	3/32	1/32
WATER	SOFT	10	1/8	3/32	1/32
WATER	SOFT	10	5/16	3/16	1/8
B	HARD	5	3/32	3/32	0

Table 5
The Effect of Mud Cake on
Fluid Loss from Cement Slurries

TEST	FILTER CAKE			CEMENT FLUID LOSS			
(#)	Drilling Fluid	Fluid Loss (cc)	Water Perm (cc)	Temp (°F)	Product Code	Product Conc (%)	Fluid Loss (cc)
1	None	N/A	N/A	RT	J	0	1200
					"	.6	220
					"	.9	84
					"	1.2	42
2	Disprsd Lab Mud	10	6	RT	J	0	7
					"	.6	6
					"	.9	5
					"	1.2	5
3	Disprsd Fld Mud	7	5	RT	J	0	5
					"	.6	5
					"	.9	5
					"	1.2	5
4	Nondspd Fld Mud	20	10	RT	J	0	11
					"	1.2	9
5	None	N/A	N/A	200	K	0	1250
					"	1.0	110
					"	1.5	71
6	Nondspd Fld Mud	24	38	200	K	0	46
					"	1.0	43
					"	1.5	43
7	None	N/A	N/A	RT	L	0	1300
					"	.5	34
					"	1.0	12
					"	1.5	6
8	Nondspd Fld Mud	25	23	RT	L	0	14
					"	.5	11
					"	1.0	11
					"	1.5	11

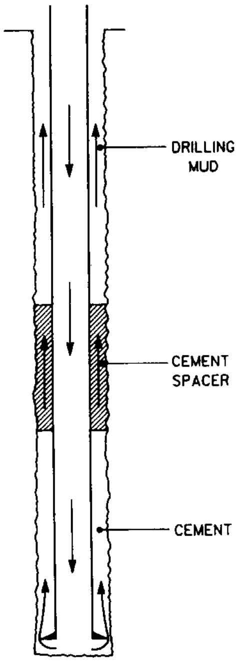

Figure 1 - Pumping spacers

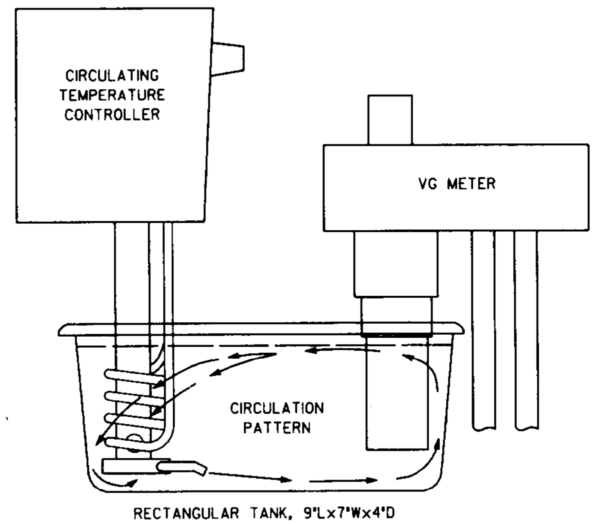

Figure 2 - Spacer mixing test

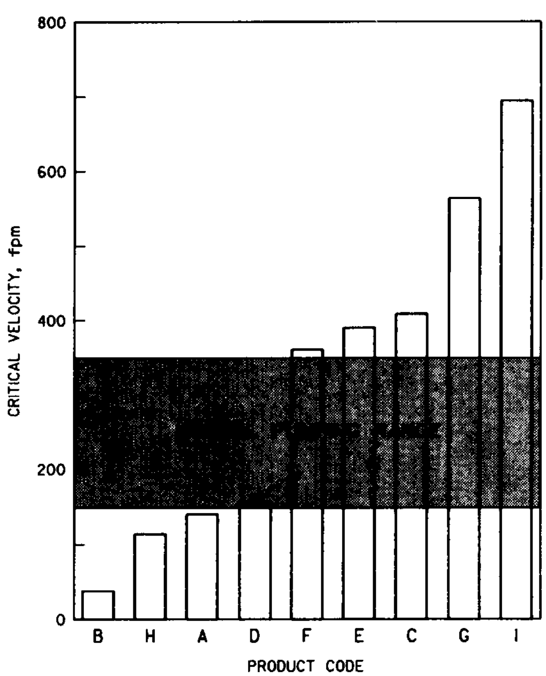

Figure 3 - Critical velocity
for turbulent flow

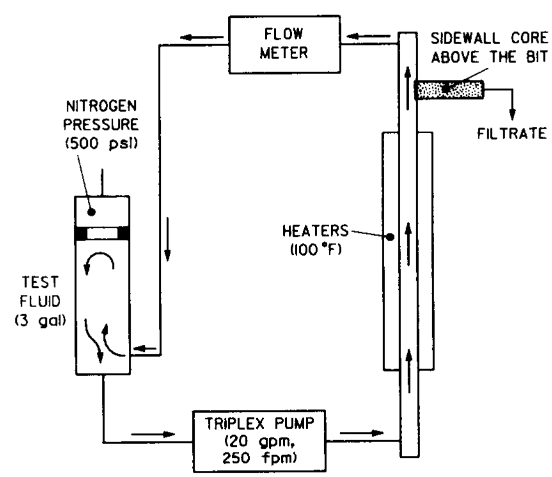

Figure 4 - Dynamic filtration
test instrument

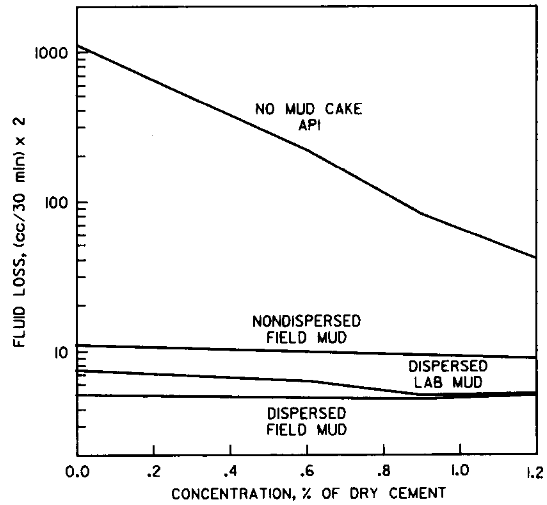

Figure 5 - Effect of mud cake on fluid loss (Product J at room temperature)

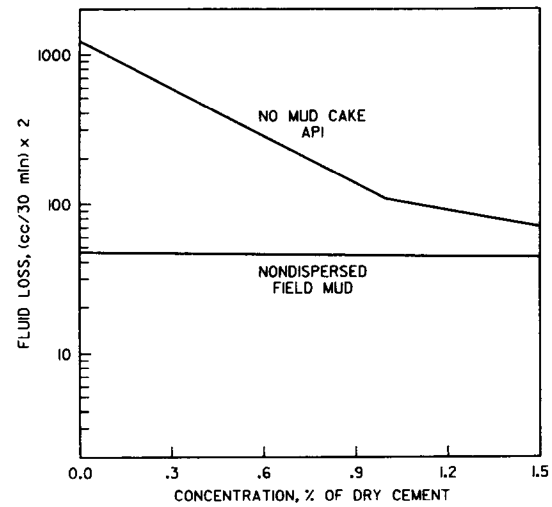

Figure 6 - Effect of mud cake on fluid loss (Product K at 200°F)

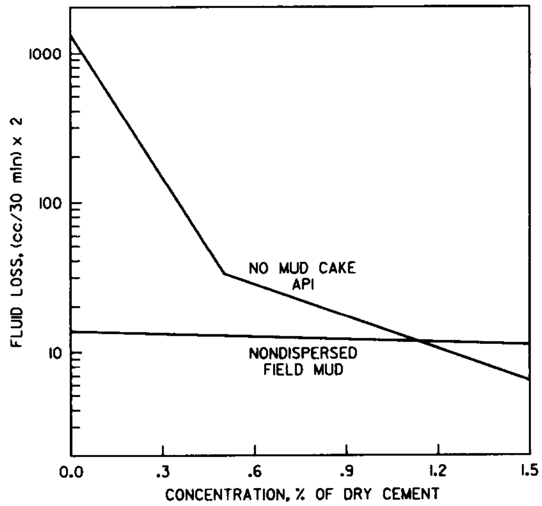

Figure 7 - Effect of mud cake on fluid loss (Product L at room temperature)