A REVIEW OF THE USE OF FLUID LOSS ADDITIVES IN CEMENTING OPERATIONS IN THE PERMIAN BASIN

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INTRODUCTION

The use of fluid loss additives in cementing is by no means a new idea. The industry utilized bentonite early on in cementing compositions to help control water loss to permeable formations. One of the first organic polymer-type fluid loss additives was carboxymethyl hydroxyethyl cellulose.[1] It was used when introduced in primary cementing. Shortly thereafter the use of fluid loss additives was extended to squeeze cementing.[2] From that time, about 1961 to the middle 1970s, fluid loss additive compositions were changed to be able to handle varying downhole and surface conditions. In the mid-1970s a new concept, fluid loss additives for high-water-containing cement, was introduced. Up to this time, fluid loss additives (organic) were seldom placed in the high-water-containing lead slurries but mainly in the tail-in slurries being placed across pay zones. From the mid-1970s to the present, continued improvement in fluid loss additives has been made as well as advances in dynamic testing of fluid loss additives.[3] There is still room for improvement in the area of fluid loss additives themselves because they need to be able to perform under all types of conditions. What fluid loss additives need to be able to handle is any combination of permeability, temperature, pressure, differential pressure, and slurry composition, yet still give any degree of fluid loss control predictably and economically. Obviously, this is quite an assignment and that is why each service company has several different fluid loss additives. It also stands to reason that fluid loss additives are expensive since they are polymers. It is, in fact, not uncommon for fluid loss additives to cost as much per sack of cement as the cement itself. Thus, fluid loss additives should be used with common sense, and hopefully, the following discussion will tie together several aspects of fluid loss control into one comprehensive package and give insights into when to use fluid loss additives, how much to use, and what type to use. Most of the information in this paper is not new, but it has not been covered in one place and especially with a bias towards the Permian Basin.

DISCUSSION

Primary Cementing

Primary cementing of a conventional string of pipe usually consists of pumping either a single high-density cement system or a combination low-density cement system followed by a higher-density tail system. A very common practice in the Permian Basin is to pump the cement system as designed, then shut down to clean up lines to the wellhead, and then drop the top plug and start displacement. There are several reasons this is desirable, and they need not be discussed, but it is not all that rare that when pumping resumes and when the displacement fluid catches up to where the cement has come to rest, a large pressure spike is encountered (Figure I). Sometimes the pressure required is too great and either the job terminates or a formation is fractured and the cement is displaced, in part or whole, but there is no circulation to the surface. There are two possible causes for this: either excessive gel strength of the cement or excessive fluid loss of the cement.

Excessive fluid loss is the cause most of the time in the Permian Basin. Inspection of pressure charts where a spike occurs can alert the operator that a major problem is likely if changes in slurry composition or technique are not made. Cement in a static state starts to build up filter cake in the annulus and can bridge the annular gap and prevent future movement of the slurry. The cement, though static for 10 minutes or less, can cause this problem. If the plug were dropped on the fly, the fluid loss would still be occurring, but the filter cake would be broken off and circulated out as long as fluid movement occurs. Pieces of cement filter cake have been observed from the flow line when circulating cement to the surface. It is very rare to see bridging occurring while pumping, but it does happen[4] (Figure II), and in this case keeping the slurry moving is essential. The use of fluid loss additives almost always eliminates these types of problems and gets a normal-looking pressure chart (Figure III). The fluid loss additive is, however, normally needed in the lead slurry and not the tail slurry since the lead slurry is the one in the annulus when the slurries come to rest. A simple hydrostatic and volume calculation can determine approximately where the slurries are when they come to rest.

Some of the other factors in this type of phenomenon are that all of the slurry properties are changing when fluid loss occurs. Obviously, if the water is being forced into a permeable, low-pressure zone, slurry volume is being lost and slurry density is increasing. It is not unusual to see a 12.0-ppg slurry pumped into a well and see a 13.5-ppg slurry exiting the surface flow line. This slurry will also be very viscous, since it was designed to be pumped at 12.0 ppg. This just naturally requires more cement slurry to be pumped in order to circulate cement because the 12.0-ppg slurry has a yield @ 2.60 cu ft/sk while the 13.5-ppg slurry has a yield of @ 1.75 cu ft/sk. Now it becomes more obvious why rules of thumb, such as caliper plus 5 to 100 percent excess, are very valid. There are other reasons for pumping an excess of slurry, but they need not be covered in this discussion. In some cases excesses, including cementing costs, can be greatly reduced when fluid loss additives are used.

The change in slurry density and viscosity can have drastic effects on the equivalent circulating density seen by fragile formation. Also these cement rheology and density changes will make it impossible to calculate displacement characteristics with any degree of confidence.

This type of bridging, etc., is very common in the Permian Basin, and it is probably caused by the fact that the formations have relatively high effective permeability but, in many cases, low formation pressures. This allows a large differential pressure toward a formation with good permeability, and thus a problem exists. If this formation is the pay zone, a potential formation damage problem from cement filtrate could also exist.[5] Bridging phenomenon has been noticed repeatedly in Spraberry and San Andres wells in several counties which include Gaines, Andrews, Ector, Ward, Crane, Midland, Glasscock, Upton, and Reagan Counties.

As to how much fluid loss additives to use to prevent this fluid loss from occurring, a good answer probably does not exist, but as small a concentration as 0.3 percent by weight of cement has prevented the major problem of bridging from occurring. This small concentration does not eliminate the leak-off problem but just reduces leak-off to a point where placement is not a problem. This 0.3 percent additive concentration would show no control at all in a standard API fluid loss test (>1000 cc/30 min) but must exhibit control downhole. At the other end of the spectrum, if an API fluid loss value of 100 cc/30 min or less at bottom-hole circulating temperature and 1,000 psi differential pressure can be obtained, slurry density and yield, as well as rheology, will not change appreciably on most wells in the Permian Basin. Formation damage could only be eliminated entirely if no leak-off at all occurred and an acceptable amount of leak-off will vary drastically with the types of formation encountered, mud filter cake, permeability, and differential pressure.

Stage cementing should be looked at carefully because if the first stage cement is brought back up over the tool, it could be static for several minutes before the opening bomb reaches the tool, and if the cement has dehydrated and bridged, the second stage cannot be pumped. For that reason, the first-stage slurry brought back up over the tool is critical and needs some fluid loss control. It should also have low-gel strength and sufficient working time to be circulated out of the hole, but also, it must set at the tool in the required circulating time.

Foam cementing slurries containing small discrete gas bubbles would seem to be a natural for having fluid loss control. Unfortunately, the same bridging phenomenon can occur with foam slurries as conventional slurries, and for that reason, fluid loss additives should be recommended in foam slurries. Foam is usually used because low density is required. Thus, loss of water and density increases are not desirable.

Gas migration after cementing is also to a large degree controlled by fluid loss of cementing slurries.[6] Gas migration can occur when pressures are allowed to equalize due to filtrate leak-off of cement slurries. Once pressures equalize, gas can flow. To eliminate this from happening, it only stands to reason the fluid loss value needs to be extremely low (<50 cc/30 min) because a small amount of volume loss in a noncompressible system can result in a large pressure drop/equalization. Fluid loss additives should have very little effect on a microannulus-type of gas flow.

Liner cementing often incorporates gas flow as well as narrow annular clearance. The annular clearance and bridging problem can be taken care of by the addition of fluid loss additives to get <100 cc/30 min fluid loss, but the control of gas needs fluid loss values down in the range of <50 cc/30 minutes. Care must also be taken to ensure that the slurry obtains at least 250 psi at the top of the liner in 8-12 hours after placement. In order to achieve this, on some extremely long liners with large temperature differentials between the top and bottom of the liner, fluid loss additives and retarder will have to be carefully chosen to give the desired properties.

SQUEEZE CEMENTING

Squeeze cementing is also an area which requires fluid loss additives in many cases. The exact amounts of which can vary all across the board. In the easiest of cases, which is squeezing off perforations, the goal is to get cement into every perforation and then have the cement dehydrate and leave a solid buildup or node of cement solids in the perforation and the pipe. In order to insure that cement goes into each perforation and does not dehydrate prematurely on some of the upper perforation, fluid loss additives are incorporated in the slurry. It is desired to get cement into every perforation, but then it must dehydrate in a reasonable time period of working with the cement. If it did not dehydrate, it would look like a squeeze because there would be no leak-off and, thus, no surface pressure drop, but because there is no solids buildup, the well can backflow upon releasing the packer. The exact quantity of fluid loss additive is going to depend upon the permeability of the formation up against which one is squeezing and the differential pressure applied to the cement at the perforations. As one works with squeezing in a given area, this type of information could then be related to an API fluid loss value for a given rock permeability and differential pressure at a given temperature, but at the present time there is very little of this type of information available. As it turns out in the Permian Basin, after discussions with people working in various areas, at best a general rule can be obtained. The rule is that if one is squeezing a limestone or dolomite, which usually have moderate matrix permeability, an API fluid loss value of about 300 cc/30 min $\pm$ 50 cc/30 min will give a good squeeze. If squeezing in sandstones, which usually have higher matrix permeability, a fluid loss value of about 150 cc/30 min $\pm$ 50 cc/30 min will give a good squeeze. Remember, this is just a very, very crude starting point and needs to be changed as more data becomes available.

There are many varied types of squeeze jobs, and in each case, it needs to be determined as closely as possible what the problem truly is and then design a cement system with fluid loss control to meet those needs. For instance, if it is desired to place cement in a channel, the fluid loss values need to be very low to prevent premature bridging, and this slurry may be followed by a cement slurry containing no fluid loss additive to bridge and hold the slurries in place. When squeezing liner tops where cement was not brought back into the liner lap, slurries containing little or no fluid loss additives are desirable because one hopes to fracture the rock and bridge cement solids from the fracture all the way back up into the liner lap to prevent gas from moving up the lap area. Small gas leaks at liner laps where cement was brought up into the lap probably cannot be squeezed with cement because it is usually a microannulus, and cement solids cannot penetrate this small clearance. When squeezing in zones such as anhydrite and salt which have essentially no permeability, it is very hard to dehydrate slurries, and no fluid loss additives should be incorporated in the slurry.

When a cement slurry has a fluid loss value below 100 cc/30 min, it is an effective fracturing fluid, and unless there is a lot of permeability or differential pressure, bridging of cement solids will be extremely slow. If it is difficult to get surface pressure on a squeeze job, then slurries containing a larger amount of fluid loss additive will only compound the problem. In conclusion, determine the problem to be squeezed and use good judgment as to the amount of fluid loss control required for each individual squeeze application.

CONCLUSIONS

1. Cement slurries are dispersions of solids in water.

2. Water loss changes the water-to-solid ratio.

3. Water loss changes the slurry density.

4. Water loss changes the slurry yield.

5. Water loss changes the slurry viscosity from thin, to thick, to unpumpable.

6. Fluid loss additives help prevent premature job termination.

7. Fluid loss additives help insure proper fill-up in the annulus.

8. Fluid loss additives help prevent loss of circulation due to density increases and friction increases.

9. Fluid loss additives allow a cement that is designed to be placed in turbulent flow to actually be placed in turbulent flow because rheological changes are minimized.

10. Cementing job pressure charts can give a good insight into when a problem exists on the job in progress or when the potential exists for future problems.

11. Slurry filtrate leak-off can cause formation damage.

12. Fluid loss additives are expensive and should be utilized properly.

13. Fluid loss additives should be utilized in slurries placed across stage tools.

14. Fluid loss additives should be considered in foam cement formulations.

15. Fluid loss additives are very instrumental in prevention of annular gas flows prior to final cement set.

16. Fluid loss additives are usually needed on liner cementing applications.

17. Fluid loss additives may or may not be required on squeeze cementing operations because each case must be given special attention.

ABBREVIATIONS

1) API--American Petroleum Institute
2) cc/30 min--cubic centimeters per 30 minutes
3) cu ft/sk--cubic feet per sack
4) ppg--pounds per gallon
5) psi--pounds per square inch
6) >--greater than
7) <--less than

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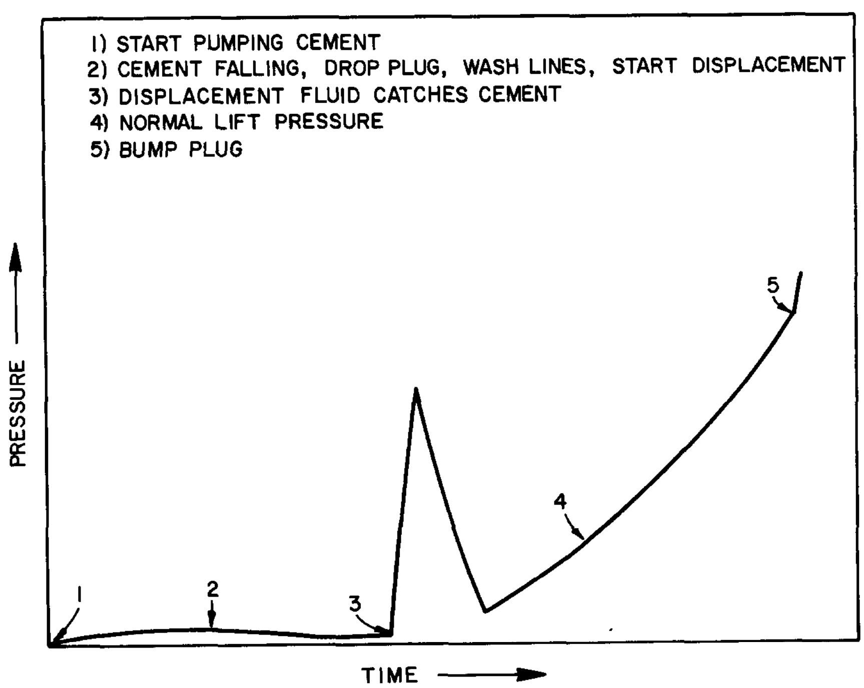

Figure I—Idealized pressure chart

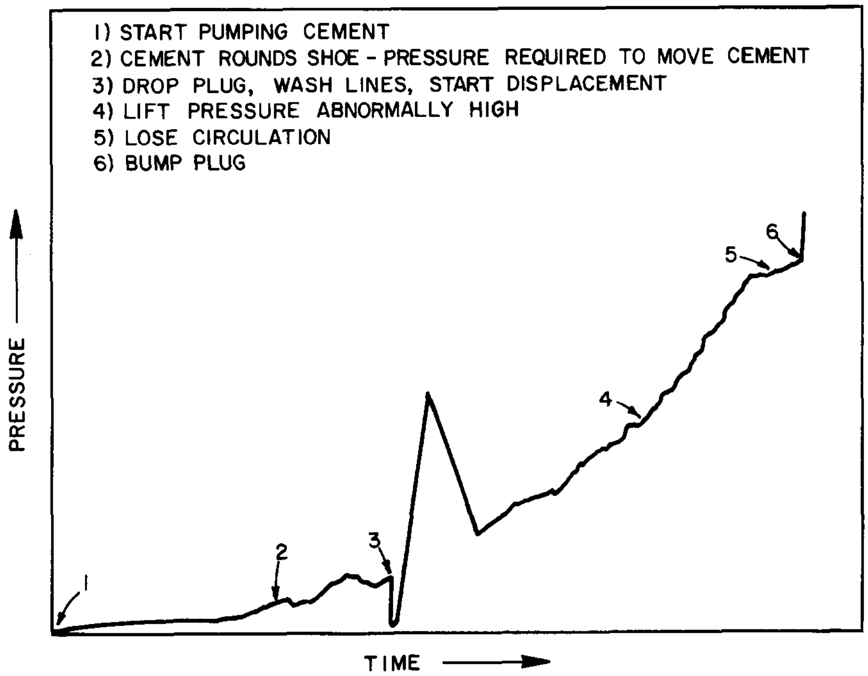

Figure II—Idealized pressure chart

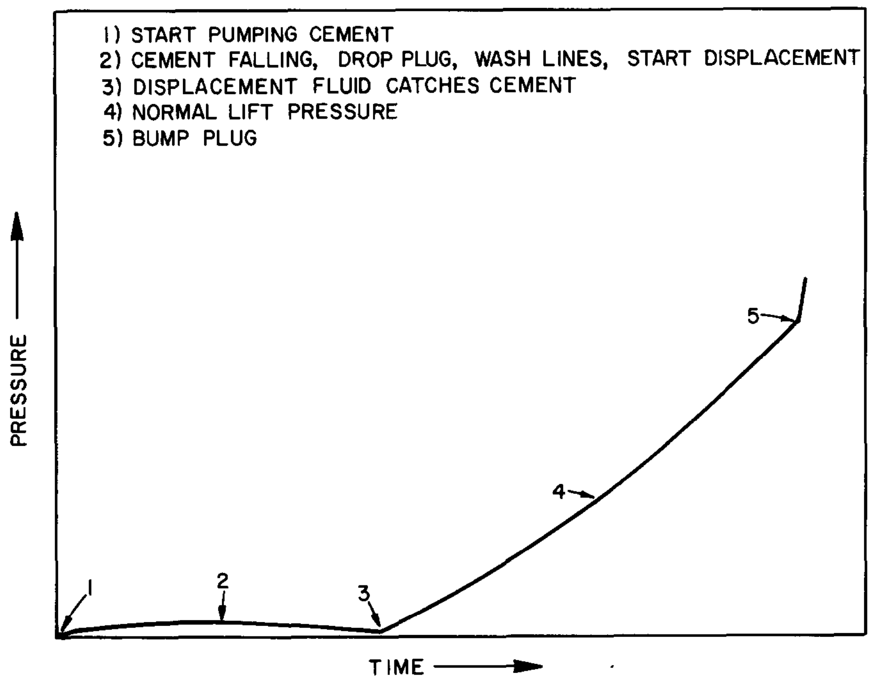

Figure III—Idealized pressure chart