



Use of Crosslinked Polymers in High-Density Brines

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This paper was prepared for presentation at the AADE 2004 Drilling Fluids Conference, held at the Radisson Astrodome in Houston, Texas, April 6-7, 2004. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

Abstract

This paper discusses the use of crosslinked polymers as a fluid-loss-control method in high-density brines, 15.0 lb/gal and higher. The ability to control fluid loss in brines of this density is extremely important to the operator because of the high cost of these brines. Historically, crosslinked polymers designed for heavy brines were not an option because when mixed in heavy calcium bromide (CaBr_2) and zinc bromide (ZnBr_2) brines, the temperature limitation was typically lower than 225°F. Additionally, most operators spot loss-control pills of a higher density than the wellbore brine so that the pills remain in place when spotted. However, specific case histories show that using a lighter-weight lost-circulation pill designed with a 14.2-lb/gal calcium bromide in wellbore brines up to 17.5 lb/gal is not only successful, but it uses polymers that are much more temperature stable. The crosslinking polymers used in the 14.2-lb/gal calcium bromide do not yield in high-density calcium bromide and zinc bromide fluids, and their temperature limit is 350°F. This paper documents three specific cases that clearly demonstrate that fluid-loss-control pills lighter than wellbore brines can be used successfully.

The results of an investigation addressing why these specific applications worked is also presented. The results demonstrate how crosslinked gels that can float in heavier brines are able to remain in place and accomplish the task of stopping fluid loss even though the gels may be subject to flotation in heavier wellbore brines.

Introduction

This paper presents the details of three applications in which underbalanced lost-circulation pills were successfully used. It will also detail the lab testing that was performed to gather information about why the practice of underbalanced crosslinked polymer pills was successful in the field.

Case Histories

Underbalanced crosslinked polymer pills have been used on a number of wells in the past few years. El Paso Production has insisted on their use for most of their completions against the advice of most companies providing the service.

The first successful application of the underbalanced pill was performed on the South Timbalier 189 Well #B-7. This particular pill was pumped after the initial perforation to the well with the initial losses measured at almost 20 barrels an hour. The completion fluid in the hole was a 15.6-lb/gal zinc bromide with a bottomhole temperature of 280°F. A 6-bbl crosslinked polymer pill was mixed with 14.2 lb/gal pure calcium bromide and spotted across the perforated area. The loss rate initially slowed to two barrels an hour and eventually stopped all together. The second application occurred after the frac pack on this same well. Another 6-bbl pill was pumped to remedy an initial loss rate of six barrels an hour. After the pill was spotted across the perforated zone, the well was static.

A crosslinked polymer pill was also spotted on the Louisiana State Lease 340 Well #1 after the initial perforation. The completion fluid was an 18.3-lb/bbl zinc bromide with a bottomhole temperature of 300°F. Initial losses after perforation were measured at almost 120 barrels an hour. After a 6-bbl crosslinked polymer pill blended with 14.2 lb/gal pure calcium bromide was spotted across the perforated zone, the well was static when monitored.

Lab Investigation

In the past, the completion fluid service provider on these wells had always stressed the importance of using a crosslinked polymer with a higher density than the wellbore fluid in a lost-circulation application. Using a higher-density pill would help ensure that the pill would remain in place even after sealing was achieved and no more fluid was moving into the perforations. This method has resulted in hundreds of successful operations. However, after some operators began using crosslinked pills at a density lower than the wellbore fluids, an investigation was launched to determine why the underbalanced placement was successful.

Test Apparatus

The test apparatus shown in Figure 1 was designed and assembled by personnel at the completion fluid service company's main research center. The apparatus is designed to simulate a wellbore in which fluid losses were occurring and a crosslinked polymer pill could be applied as a potential remedy. The apparatus consisted

of a 10-ft vertical section of plastic casing connected to a separate steel section that served as the casing/perforations section. The casing/perforations section consisted of a 3-ft joint of 4-in. casing containing 12 exit ports made of welded ¼-in. pipe collars. Each perforation port was fitted with a ¼-in. x 6-in. pipe nipple connected to a piping manifold through which all exiting fluids traveled. In that manner, a collective throughput rate could be monitored.

Each perforation pipe nipple was partially filled with resin-coated sand to simulate the formation permeability. In Test 1, the fill sand was 70/170-mesh silica sand. For Test 2, the pipe nipples were filled with 12/20-mesh resin-coated sand.

Fluids were driven through the model using a Model 3-LO Moyno pump and/or air pressure. Initially all fluids and the crosslinked polymers were pumped into the model, but when the fluid losses were under control or stabilized, the system was shifted to air-pressure drive. This shift was accomplished by employing a standpipe filled with brine that was air-pressured into the model. For safety, the model also was fitted with an emergency pop-off valve set at well below the pressure rating of the plastic casing and fittings. Further, a computer data acquisition system was used to monitor the pressure during the flow tests.

Test Procedure

The following steps were performed in each fluid-loss simulation test. All portions of the simulation tests were performed at room temperature.

1. The model was filled with water and checked for leaks.
2. The leak-free model was drained and refilled with 10.0 lb/gal calcium chloride (CaCl_2) brine.
3. The 10.0-lb/gal CaCl_2 brine was circulated through the model with all perforations open.
4. A base circulation rate at approximately 15 psi was measured.
5. Several other rates were measured at other pressures as time permitted.
6. The crosslinked polymer pill was mixed according to the formulation in Table 1.
7. When the crosslinked polymer had crosslinked, which was indicated by a color change to pink, it was pumped into the model.
8. The crosslinked polymer pump rate was sufficient to force the crosslinked polymer gel to progress toward the bottom of the model to help overcome the floating tendency.
9. Flow rates were continually recorded as the crosslinked polymer arrived at the perforations.
10. The pump pressure was allowed to rise, approaching 90 psi to help force the crosslinked polymer into the sand-filled perforation pipes.
11. Several flow rates were measured to determine the point of stable circulation rate with the

crosslinked polymer in place.

12. When the rate appeared to stabilize, the rate at 15 psi was again measured.
13. The system was changed to air drive at approximately 80 psi, and then the model was shut in with the perforations left open. The tests were terminated at the end of either one hour or when the air-drive water column was empty.

Two scenarios were evaluated using this testing procedure. In one test, the pipes used to simulate the sand-filled perforations were filled with 70/170-mesh quartz sand. In a second test, the perforation pipes were all filled with highly permeable 12/20-mesh quartz sand. In both tests, the density of the crosslinked polymer was 8.6 lb/gal and the density of the wellbore brine was 10.0 lb/gal. Both cases represent an underbalanced crosslinked polymer application.

Conclusions

In both tests, the underbalanced crosslinked polymer application demonstrated that brine losses can be abated in a wellbore situation without recurring losses from crosslinked polymer gel flotation. The following conclusions can be deduced from the measurements taken and the observations made during these tests:

- Crosslinked polymer gel can be expected to enter the well pipe string in a highly fragmented state as a result of pumping.
- Crosslinked polymer gel clumps can be expected to progress through the pipe at the speed of the fluid being pumped.
- As crosslinked polymer gel clumps enter each perforation, they have a plugging effect.
- As long as fluid is moving from the wellbore into the perforations, the bulk of the crosslinked polymer gel pill will not float, but rather, it will remain across the perforated zone.
- After fluid losses are significantly reduced, the density imbalance begins to take over and the main mass of lighter crosslinked polymer gel starts to migrate up the pipe string.
- The only crosslinked polymer that appears to successfully block the fluid flow (stopping fluid losses) is that which has been deposited inside the perforation cavity and into the formation sand.
- The crosslinked polymer inside the perforation cavities tends to build a filter cake against the formation sand and is thereby lodged in position by intrusion into the sand matrix and by being segregated from the wellbore fluids. This filter cake tends to build up very quickly after the first entry of the crosslinked polymer.

These test results provide a clearer understanding of why the underbalanced method has been commonly

reported as being successful. This paper documents that only the quantity of crosslinked polymer gel needed to fill the perforations is actually required to significantly reduce fluid losses. This amount is probably less than 5% of the volume required to fill the casing across the perforated interval. It was observed that the crosslinked polymer recovered from inside the perforation cavities was quite strong and appeared to have undergone some dehydration against the sand plug inside each perforation pipe. The fact that eventually much of the lighter-weight pill did migrate up the casing had no effect on the degree of perforation sealing that was attained. Crosslinked polymer gel was found in most of the perforation pipes removed. After Test 1, the whole testing system was flushed with water before any disassembly began. Residual gel masses were still found in the perforation pipes.

The criteria for the successful use of an underbalanced crosslinked polymer pill in a well appears to include the following:

- Fluid losses need to be high enough to draw gel into the perforations.
- A positive flow must exist at first or the gels will bypass the perforations.
- Some crosslinked polymer gel needs to enter the formation matrix to a depth of an inch or so.

- Pressuring up on the fluid column during placement helps ensure dehydration of the crosslinked polymer leading edge. The dehydration establishes a concentrated gel mass anchored in place by gel fingers extending into the sand matrix.

Underbalanced crosslinked polymer pills continue to be applied successfully and have an established track record on dozens of wells that meet the criteria described above. Testing will continue in a range of fluid densities to learn if the performance of the underbalanced crosslinked polymer pills varies in different types of completion fluids.

Acknowledgments

The authors extend a thank you to the members of the Halliburton laboratory in Duncan, Oklahoma, for their work and contribution to this paper. Without their assistance this paper would not have been possible. A special thank you is also extended to Clay Cole, formerly of Halliburton, without whom this testing would have never even been started.

Table 1—K-MAX Formulation Mixed for Tests 1 and 2

Components	Density (lb/gal)	Specific Gravity	Actual Volume gal (mL)	Mix % Volume	Contributing Weight
Water	8.337	1.000	8.62 (862)	86.2	862 gm
CaCl ₂ brine	11.6	1.391	0.90 (90)	9.0	125.22 gm
CaBr ₂ brine solution	15.0	1.799	—	—	—
CaCl ₂ , CaBr ₂ solution	14.2	1.703	—	—	—
ZnBr ₂ solution	19.2	2.303	—	—	—
CaCl ₂ brine	11.6	1.391321	—	—	—
200 Be HCl	9.66	1.158635	0.05 (5)	0.5	5.79 gm
WG-33 Constant	9.2712	1.112001	0.43 (43)	4.3	47.82 gm
EG or PG	8.67	1.039893	—	—	—
Totals	—	—	10 (1,000)	100	1,040.83 gm
Composite Sp. Gr.	—	—	—	—	1.041 gm/cc
Composite Density	—	—	—	—	8.68 lb/gal

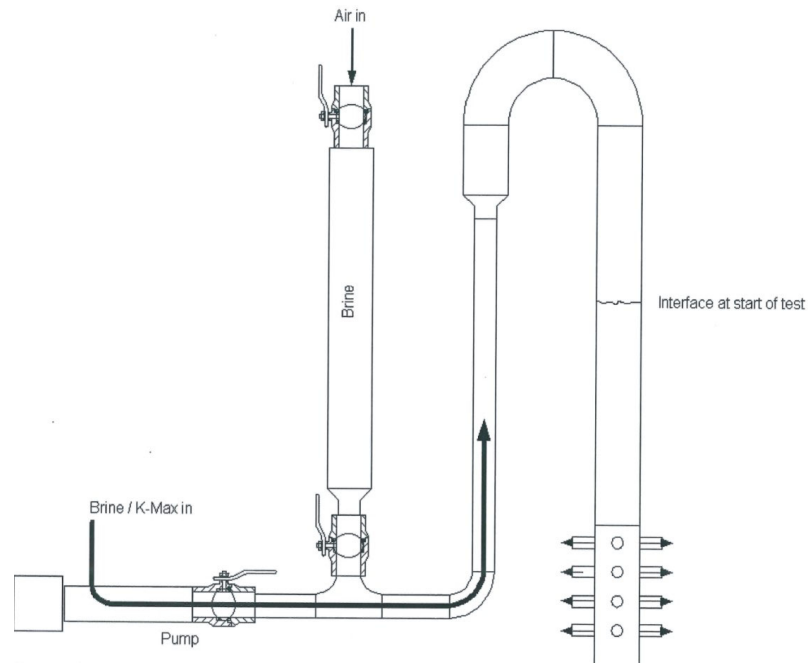


Fig. 1—Test apparatus.