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Sealing Challenging Fracture with Acid Soluble Fluid Loss Control Pill

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Abstract

Here we designed a calcium bromide based post-perf solids-laden pill with moderately small particles to seal a 3-mm wide and 6-in deep fracture, yet not prone to bridging in the downhole tools. Based on biopolymer chemistry modified to withstand the elevated temperature of 250-260°F in a prolonged time and challenging brine density, the fluid exhibits very good solids suspension with no sagging while it maintains pumpable viscosity. The pill was validated to be able to effectively seal the fracture under a high overbalance of 4000psi. Core flow tests demonstrated that the pill can be easily cleaned up with acid solution to achieve 96% clean-up efficiency.

This development, tailored to the requirements of Gulf of Mexico deep water environment drilling and completions, met the operator's design requirements. When implemented this solution should resolve the reliability problems encountered previously.

Introduction and Fluid Design

Intersecting large fractures can result in excessive drilling fluid losses, compromise well control, complicate fluid management, and increase project costs (Gibson et al. 2011). We were approached by clients to develop a calcium bromide based post-perf solids-laden pill to seal a 3-mm wide and 6-in deep fracture. The pill is requested to be in the density range of 10.5-13.4ppg using $CaBr_2$ brine. It needs to be stable at 250-260°F and have close to 100% clean-up with acid solution. The fluid loss control pill used previously from another supplier caused severe solids sagging and tool plugging issues.

Typically to seal such a wide fracture, very high concentration of crosslinked polymer like a derivative cellulose needs to be used, which normally cannot withstand at high temperatures, is incompatible with divalent heavy brines, and often requires a long period of clean-up time. (Gibson et al. 2011, Hardy 1997, Chang et al. 1998)

Considering the client's requests, a new solution was required. The fluid loss control pill was designed based on modified biopolymer chemistry and employed carbonate as bridging solids to build a robust yet acid cleanable system (Table 1).

To seal a large fracture, the selection of bridging package distributions was important. Carbonates with various particle size were selected and optimized to ensure a quick buildup of the bridging cake to seal the fracture and maintain cake integrity under the differential pressure required.

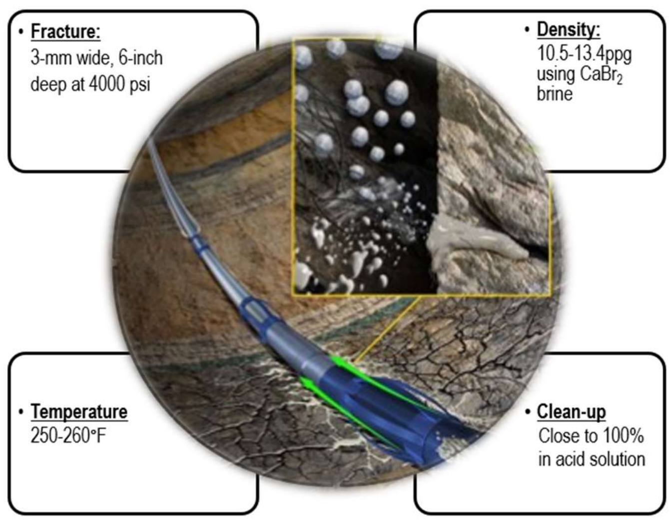

Figure 1 – Project Parameters

Table 1 – Base Pill Components

Component
$CaBr_2$ Brine
Modified Biopolymer
Viscosifier
pH Adjuster
LSRV Booster
Thermal Extender
Carbonate

Table 2 – Rheology Profile of Base Fluids

Fan35 at 120°F	12.5ppg Brine Based Pill		11.1ppg Brine Based Pill	
	Fresh	After 5-day aging at room temperature	Fresh	After 5-day aging at room temperature
600 rpm	309	321	297	321
300 rpm	219	228	210	225
200 rpm	180	186	177	186
100 rpm	129	132	129	138
6 rpm	30	30	39	42
3 rpm	21	21	30	30

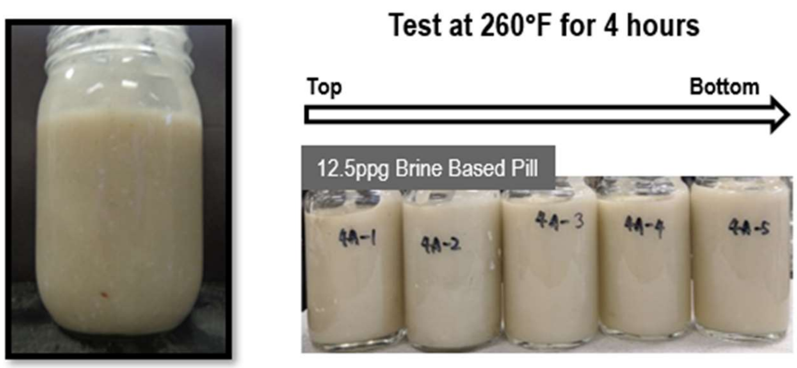

Figure 2 – Sag Test with 12.5ppg Brine Based Pill
Density of #1: 14.06ppg; #2: 14.04ppg; #3: 14.03ppg; #4: 14.21ppg; #5: 14.12ppg

Tests and Results

Rheology Properties:

Two pills were formulated and prepared following this philosophy of design starting from 12.5ppg $CaBr_2$ brine or 11.1ppg $CaBr_2$ brine to satisfy different operation needs. As shown in Table 2, both FLC pills showed pumpable and good viscosity to suspend carbonate lost circulation materials. The rheological properties maintained well after 5 days of aging at room temperature.

Sag Test:

To ensure that large bridging particles can be suspended at BHT (260°F) for 4 hours, we performed the sag test as describe below: 1) transfer the FLC Pill to Teflon sleeve, pressurize the aging cell, then static age at 260°F for 4 hours; 2) after sample cools down, use spoon to transfer fluid from top to bottom evenly into 5 jars (respectively from #1 to #5 on Figure 2); 3) measure pill density in each jar using pycnometer. As shown in Figure 2 and mud density, no obvious solids' sag was observed.

Fracture Sealing Test:

Our intent is to provide fluid loss control by forming an impermeable seal at the entrance of the fracture. The laboratory testing method is to use an in-house built Fully Automated Advanced Slot Test (FAAST) device. A photo of this device is depicted in Figure 3. When in operation, its pressure increases in steps of 250 psi/minute up to a max pressure of 4000psi. This test is performed at room temperature.

The fracture is simulated by a metal disc with a specific slot size, e. g. 1mm, 2mm, or 3mm. The slotted disc is assembled at the top of the tester. As the pill is pumped through the disc, the fluid loss control particles form a seal across the slot. A data logger precisely records the pressure achieved and volume of test fluid lost over time. If the pill can seal the slot, pressure inside the tester will increase in a staircase like pattern until reaching 4000psi, and there will be a minimal volume of fluid lost. If the FLC pill cannot seal the slot, or if the seal failed as pressure increases, the fluid will pass though the slot and into the cylinder standing under the tube connected to the outlet of the test cell. The device uses a test fluid volume of 350ml.

The pressure and fluid loss data recording for successful pill formulations can be seen in Figure 4-5. There was some seal instability observed as pressure increased, but both pills were able to hold 4000psi without losing the total volume of test fluid. When the seal failed, it was able to quickly reform without substantial fluid loss. The temporary partial seal failure is due to the shape and material properties of $CaCO_3$. Because the particles are very angular, they are point loaded when they

Figure 3 – Fully Automated Advanced Slot Test (FAAST) device

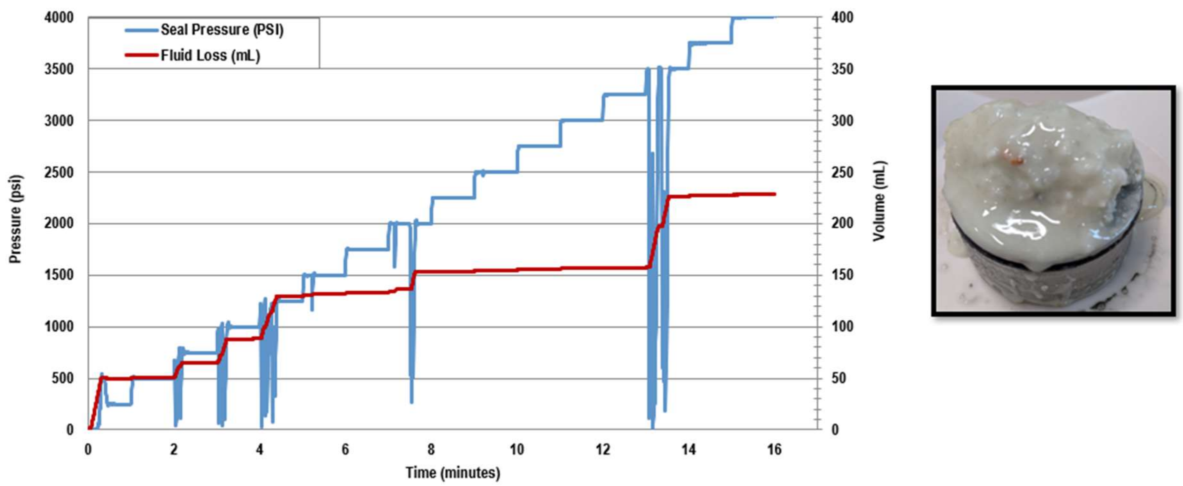

Figure 4 – Ambient fracture sealing test data using FAAST device and 3mm Slot Disc with 11.1ppg $CaBr_2$ Pill Under Up to 4000psi

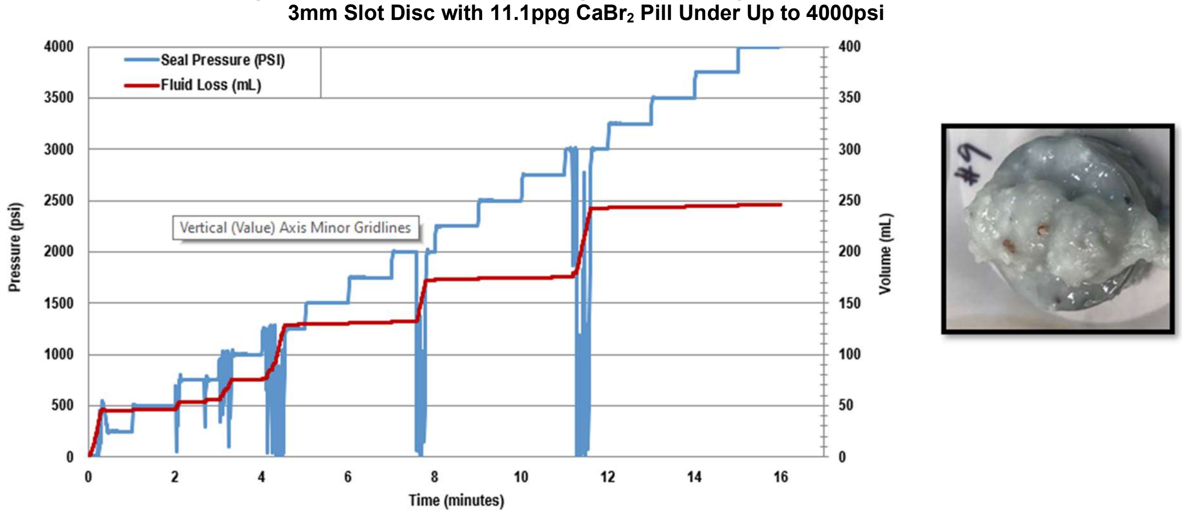

Figure 5 – Ambient fracture sealing test data using FAAST device and 3mm Slot Disc with 12.5ppg $CaBr_2$ Pill Under Up to 4000psi

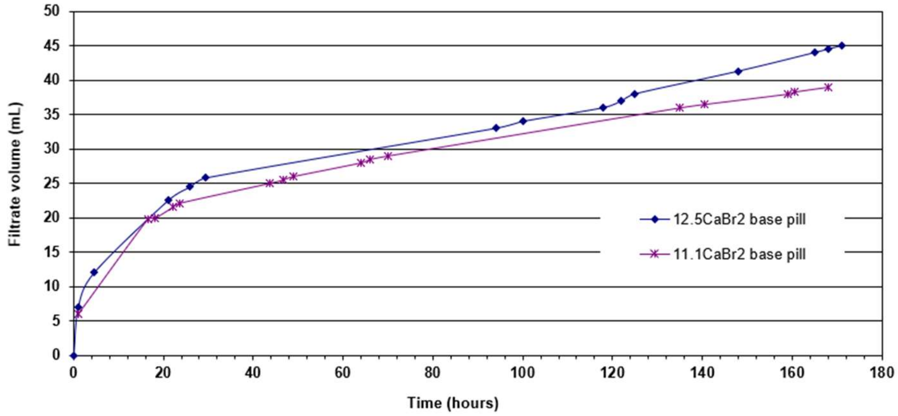

Figure 6 – 7-Day Static Fluid Loss Test on FAO-50 Aloxite Disc at 260°F and 500psi

Figure 7 – Acid clean-up test (left: spent fluid; right: residue on disc)

form a seal. This stress concentration combined with the brittle nature of the material leads to shear failure of the particles. While this can be mitigated to some extent by increasing the particle size, this can cause plugging issues when pumping through downhole tools.

7-day Fluid Loss Test at BHT:

After fluid formulation was finalized, 7-day fluid loss control test at 260°F was conducted. As shown by the results in Figure 6, both pills can provide good fluid loss for 7 days or longer on an Aloxite disc with about 50µ pore size.

Breaker Test (clean-up test):

The acid solution intended to be used in the field is water containing 10% formic acid and 10% acetic acid. This acid solution was used to soak the filter cake generated in the HTHP fluid loss test. After soaking for 24-hour at 260°F under 250 psi pressure, it's found that the filter cake has completely turned into filterable liquid. There are remaining solid particles that are obviously $CaCO_3$. Due to the limitation on the total amount of acid that can be put into the HTHP cell, there was not enough acid to dissolve all the $CaCO_3$ in the filtercake, but other components have completely degraded. Figure 7 shows pictures of the spent fluid (degraded filtercake residue and breaker solution) and the disc after the breaker test.

The actual Return Perm (Core Flow) Test was conducted in the third party lab. One liter of FLCP based on 12.5ppg $CaBr_2$ was provided to test for acid cleaning and return perm. Result was very good, being ~96% return perm.

Conclusions

We developed the solid-laden FLC system with below properties:

- This FLC pill can successfully seal 3-mm slot under 4000psi pressure in lab environment.
- This FLC pill is stable and can provide good fluid loss at 260°F for 7 days. It won't cause the sagging issue encountered before.
- This FLC pill can be built with 11.0 ~ 13.8ppg $CaBr_2$ brine. When brine density changes, adjust the concentration of formulation components to achieve proper rheology to provide enough suspension to bridging particles as well as maintain pumpability of the pill.

- Core flow test conducted by the third party lab showed ~96% return permeability, which indicated the formulated fluid won't cause any damage to the formation.

Nomenclature

BHT = *Bottom hole temperature*
FAAST = *Fully automated advanced slot test*
FLC = *Fluid loss control*
HTHP = *High temperature high pressure*
LSRV = *Low shear rate viscosity*
PPA = *Permeability plugging apparatus*

References

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