HIGH TEMPERATURE BLOCKING GELS FOR TEMPORARY WORKOVER OPERATIONS

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ABSTRACT

Blocking gels have been used in low temperature zones for many years. Blocking gels are employed in workover operations to isolate producing zones. The problems with isolating high temperature zones were mostly due to the insufficient or unstable rheological properties of the crosslinked blocking gels.

Recent developments of unique crosslinkers, stabilizers, derivative polymers and enzymes have provided significant contributions to the oil and gas industry. The combination of these advantages has led to the development of high temperature blocking gels, which enable temporary isolation of producing zones for extended periods of time at temperatures greater than 250°F. In addition, these blocking gels can be removed at any time without leaving damaging polymeric residue. Laboratory data demonstrates the effectiveness of the blocking gels as well as their ability to clean up in high temperature zones.

INTRODUCTION

Cellulose polymers have been used as blocking gels because of their good clean up characteristics.[1] Newly developed technology has yielded various polymers which have better rheological characteristics. Guar polymers due to their structure are generally more temperature stable than cellulose polymers.[2] Utilizing guar polymers in blocking gel applications provides us with the opportunity to extend the previous temperature limit. Recent studies and testing by various laboratories have shown that guar can be effectively removed from sand packs and formations using conventional and recently developed enzyme breaker technology.[3]

The guar polymer selected for high temperature blocking gel applications is a proprietary carboxymethylhydroxypropylguar. High molecular weight derivative guars such as this CMHPG make a more effective filter cake which improves stability and reduces fluid loss into productive zones with more efficiency than cellulose based polymers. Studies concluded that this unique CMHPG showed extreme stability across a wide pH range (3.0 - 12.0) and temperature range from 70°- 275°F.

The system uses guar technology in an innovative way. This blocking gel is mixed and pumped essentially unhydrated. This allows mixing and pumping at a low viscosity which minimizes friction pressures. The lower friction pressures allows placement using coiled tubing.

TEST METHODS AND RESULTS

Rheometrics

A rheometrics pressure rheometer was used to evaluate the stability of the blocking gel at 300°F. The fluid was subjected to continuous sinusoidal oscillatory shear. The amplitude of oscillation is kept small to minimize shear degradation. This method is considered nondestructive unlike steady shear measurements which typically degrade crosslinked gels, especially at higher temperatures.

The stress component of oscillatory shear is composed of two parts, one in phase with oscillation and the other out of phase. The in-phase component of stress is the energy storage modulus, G'. This modulus represents the elastic contributions of the fluid. The out-phase component is the energy loss modulus, G". It represents the viscosity contributions to the fluid. The dynamic viscosity is the quotient from the division of G' by frequency. A classical gel is defined as a semisolid that exhibits G' values that are both independent of frequency and exceed G" values.

The preparation of the blocking gel was also evaluated in this study. In the first test, 150 pounds of polymer per one thousand gallons was prehydrated prior to addition of crosslinker and heating. At temperature, the fluid was subjected to a dynamic rate sweep from 0.1 to 100 radians/second at 100% strain. The sweeps were conducted after 65, 220, 343 and 411 minutes of heating. The G' and G" values at 300°F suggests that at this temperature, the crosslink junctions are beginning to disassociate. The loss of G' and G" values over time suggest polymer decomposition. These results are shown in Figures 1 and 2.

In the second test, only 20 pounds of polymer per one thousand gallons was hydrated. The pH of the fluid was then raised to about 9.0 and the additional 100 pounds of polymer added. The additional polymer in the alkaline fluid did not hydrate and the solution remained thin. On addition of crosslinking agent and heat, the fluid finally viscosified. Dynamic rate sweeps were made after 54, 145, 256 and 398 minutes at 300°F. The G' values are much lower than those of the first test. The values are also frequency dependent suggesting that the fluid is not a true gel. After the first sweep, the G" values initially decline but afterward, the rate of decline is significantly reduced. Although less polymer was used, the G" values are also larger than those of the first test. The results are shown in Figures 3 and 4.

This behavior is due to the method of preparation. The unhydrated polymer, at best, only swells in the alkaline water. Heating increases the degree of swelling. Before fully hydrating, however, crosslinking at the swollen particle surface occurs inhibiting the release of polymer from the particle surface to the water. This results in the formation of small, solvated polymer domains. The swelling causes the particles to become plastic-like and deformable. In addition, the particle surfaces are sticky, allowing some association of these polymer domains.

The particle's stickiness and the concentration of particles yield the higher viscosity fluid than that of the fluid made from fully hydrated polymer. A viscosity and temperature profile is shown in Figure 5.

Core Tests

Core tests were performed using a computerized permeameter (Figure 6). Initial permeability was obtained using filtered two percent potassium chloride at 275°F. A pore pressure of 500 psi was maintained using a back pressure regulator. The initial permeability was 77.23 md. The direction of flow was reversed and a flow of 2 percent potassium chloride was established. The blocking gel was injected using a volume equal to approximately 1 gallon per linear foot in a 6.75" hole. A differential pressure of 1000 psi was maintained during the test period of 114 hours. The removal treatment, 15% HCl with corrosion inhibitor and EDTA, was injected in the same direction as the blocking gel and allowed to stand for 20 minutes. The final permeability was obtained in the original direction. Core test results show an extremely low leakoff, a spurt loss of 0.0 gal/ft^2 and C_{III} of 0.00335 $ft/min^{1/2}$. Regain permeabilities were higher than the initial permeability due to acid stimulation of the Berea sandstone core. The core test shown in Figure 7, was acidized prior to the blocking gel test but still reacted slightly. Regain permeability for this test was 86.60 md or 112% regain.

Summary

Higher polymer concentration, above 150 pounds per one thousand gallons can be mixed and still have a pumping viscosity of below 30 cps at 511 sec^{-1}. This mixing procedure allows the blocking gel to reach the deep formations with less friction pressure than the fully hydrated cellulose counterpart. High temperatures cause a transition from this delayed partially hydrated state to a fully hydrated and crosslinked system. This technique yields more stability, lower fluid leakoff and less gel penetration into the formation matrix.

CONCLUSIONS

1. Stable rheological properties at higher temperatures for longer time periods.
2. Temporary isolation of productive zones without leaving damaging polymeric residue.
3. Lower friction pressures with low viscosity high yield blocking gel.
4. The ability to use coiled tubing placement of the blocking gel.

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References

1. Rickards, A.R., Tjon-Joe-Pin,R.M. and Boles, J.L.: "Enzymatic Breaker System for Nondamaging Removal of Cellulose - Based Blocking Gels," paper SPE 25488 presented at the Production Operations Symposium held in Oklahoma City, March 1993.

2. Davidson, R.L.: Handbook of Water-Soluble Gums and Resins, McGraw-Hill Book Company, New York (1980) 64.

3. Tjon-Joe-Pin, R.M., Brannon, H.D. and Rickards, A.R.: "Remedial Treatment for Poloymeric Damage Removal Provides Improved Well Productivity," paper SPE 25385 presented at the Asia Pacific Oil and Gas Conference and Exhibition held in Singapore, February 1993.

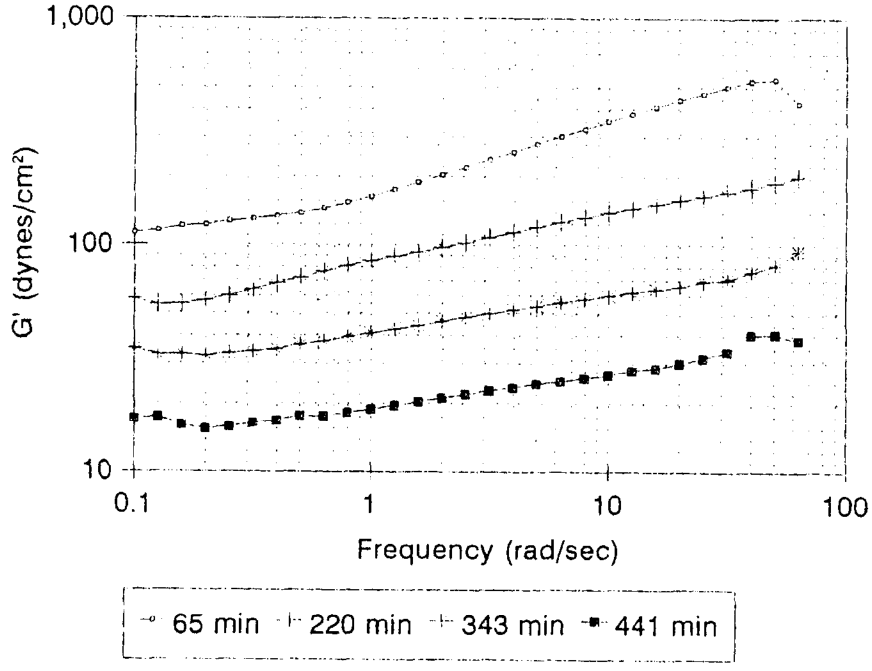


Figure 1 - 150 PPT blocking gel
G' over time at 300° F

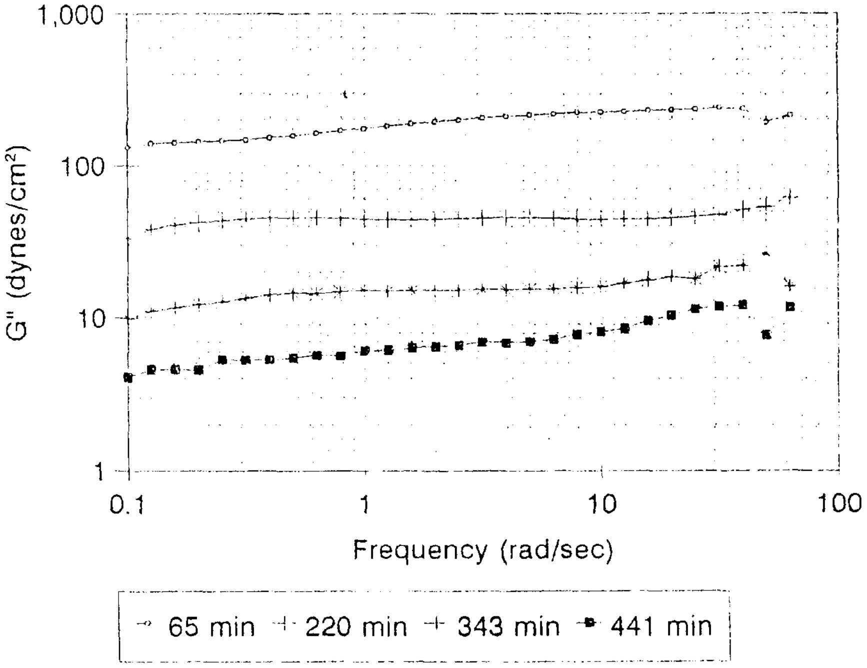


Figure 2 - 150 PPT blocking gel
G" over time at 300° F

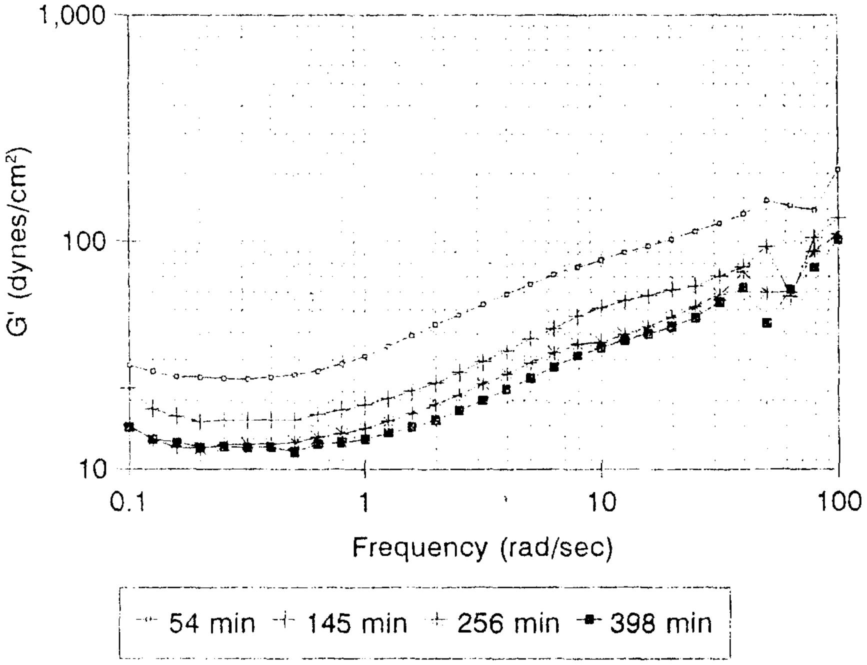


Figure 3 - 120 PPT blocking gel
G' over time at 300°F

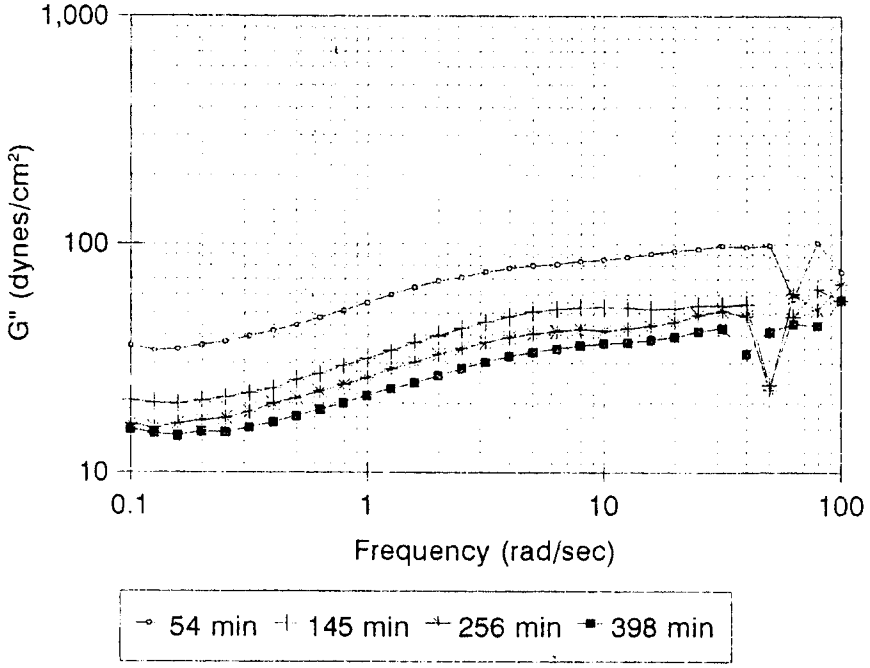
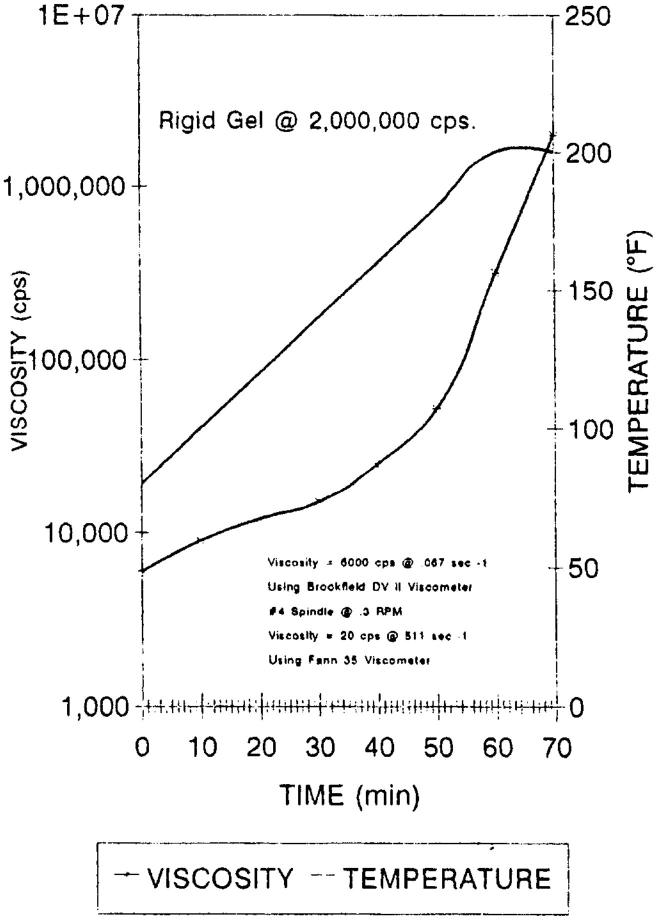


Figure 4 - 150 PPT blocking gel
G" over time at 300° F



Viscosity = 6000 cps @ .067 sec -1
Using Brookfield DV II Viscometer
#4 Spindle @ .3 RPM
Viscosity = 20 cps @ 511 sec -1
Using Fann 35 Viscometer

Figure 5 - Hydration rate of 80 ppt blocking gel

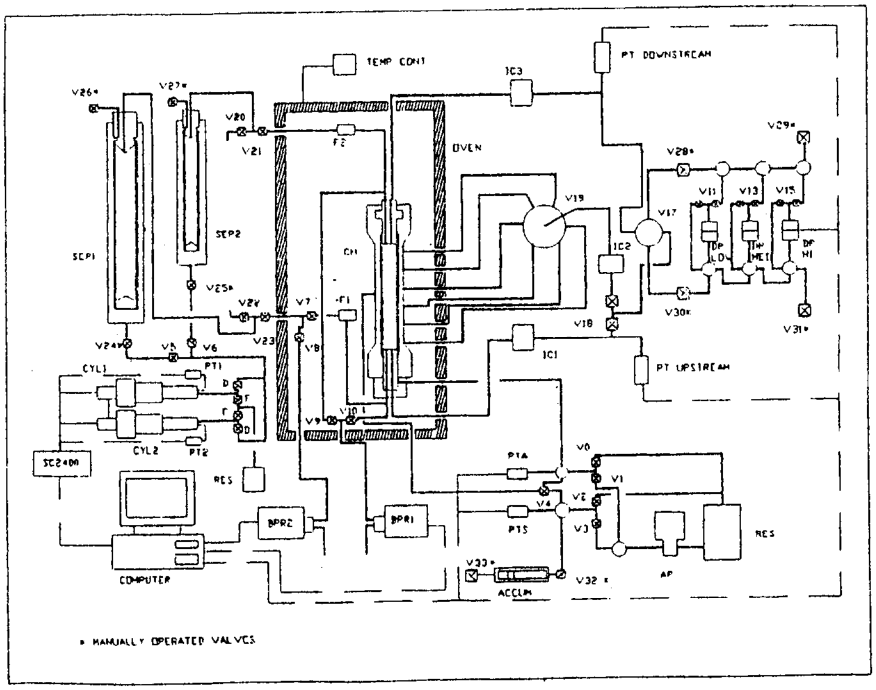


Figure 6 - Plumbing schematic for FDS-100 system

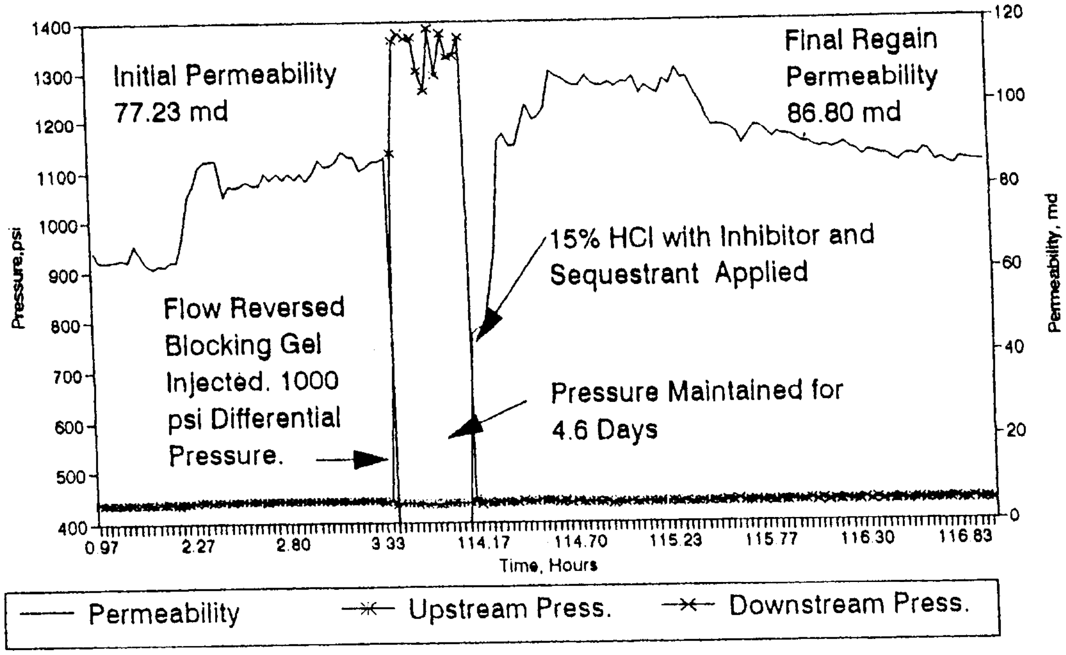


Figure 7 - Core Test
Permeability damage at 275 deg F