A NEW FRICTION REDUCER FOR BRINES

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ABSTRACT

A new friction reducer was tested in various fluids to measure its performance in both a small-scale flow loop and a field-scale system. The polymer was dissolved into both fresh water and a 1% KCl brine, then pumped through 1½ inch diameter coiled tubing and straight pipe. Drag reduction as high as 84% was achieved in the straight pipe and as high as 69% in coiled tubing.

The study also included 7% KCl, 10 ppg NaCl and 11.4 ppg $CaCl_2$. A small scale flow loop, consisting of ½ inch diameter coiled tubing and straight pipe was used. There was good correlation between the fresh water friction pressures measured in the small scale flow loop and full scale system.The heavier brines generally required greater polymer loadings in order to achieve substantial drag reduction. In the 7% KCl, the Polymer A produced reductions in friction of up to 62% in coiled tubing and 77% in straight pipe. In the 10 ppg NaCl brine, drag reduction of 60% to 66% was obtained. For the 11.4 ppg calcium chloride brine, a polymer loading of 0.21 lb/BBl produced drag reduction of 49% in straight pipe and 52% in coiled tubing.

INTRODUCTION

A new synthetic polymer, designated as Polymer A, was developed for use as a thickener in completions, workover and stimulation applications. Early in its field use, it was recognized to have excellent friction reduction properties. A study was conducted for the purpose of measuring the capabilities of this polymer in reducing drag.

Friction pressure testing was performed for the Polymer A in various fluids, using both straight pipe and coiled tubing. Two different equipment systems were used, including a small-scale, ½ inch flow loop[1] and field-scale 1½ inch tubing[2].

It was found that pressure losses due to friction increased with brine density and viscosity. Addition of the Polymer A reduced friction pressures by up to 70% in coiled tubing and 84% in straight pipe.

EQUIPMENT

In evaluating the performance of the friction reducer for a broad range of applications in the oilfield, it was desirable to make measurements in both straight pipe and in coiled tubing. Two basic equipment configurations were used for this study.

Initial tests were conducted using 1½ inch OD tubing, having an internal diameter of 1.188 inches[2]. Fluid injection was accomplished using a triplex pump. The system was calibrated using fresh water. The polymer was added to the test fluids through the top of a 50 BBl paddle mix tank, and stirred for 15 to 30 minutes in order to allow for complete hydration. Samples were taken for viscosity measurement. The fluid was then injected at rates varying from 30 to 250 gpm. These rates were sufficient to produce Reynolds Numbers of 11,500 to 422,900 in the thickened fluids, assuring all fluids were in turbulent flow. The pressure drop was monitored across 160 ft of straight, horizontal pipe and across 1,000 ft of coiled tubing.

A small-scale flow loop[1] was used for the later tests, which allowed for rapid generation of friction loss data with a minimum amount of waste produced. This consisted of ½ inch OD stainless steel tubing, with an internal diameter of 0.453 inches. Fluid injection was accomplished using a progressive cavity pump. The pressure drop was measured separately across 10 ft. of straight and 18.83 ft. of coiled tubing. Fluid temperature and density was measured continuously. Friction measurements were made for the various base fluids prior to the addition of polymer.

MATERIALS AND PROCEDURES

The full-scale flow loop tests utilized fresh water and 1% KCl brines as test fluids. The polymeric friction reducer, designated Polymer A, was added at concentrations up to 0.21 lb/BBl. Four fluid systems were evaluated using the small-scale flow loop, including fresh water, 7% KCl, 10 ppg NaCl and 11.4 ppg $CaCl_2$ brines. The fresh water system was evaluated using the small-scale flow loop in order to provide a comparison of the data based on tubing geometry.

Polymer A is a synthetic, water soluble polymer. It was chosen for study because of its solubility in a wide variety of brines, its resistance to shear degradation and its excellent thermal stability. The polymer is produced as a dry powder. However, in the full scale tests, it was added to the base fluid as a particle suspension. This method provided a means of effectively dispersing and hydrating the polymer particles without the use of a dry additive system.

In the small-scale system, where multiple tests were run in rapid succession, and where both dispersion and hydration could be a problem, two different methods of adding the polymer were used. For the fresh water and 7% KCl fluids, the polymer was again applied as a suspension in order to promote dispersion and avoid lumping.

In the NaCl and the $CaCl_2$ brines, particle dispersion and lumping is of much less concern, whereas the rate of dissolution and hydration can be slow under ambient conditions. For these tests, a concentrated solution of polymer in the two base fluids was prepared ahead of time. The concentrate was made by weighing the necessary amount of water into a bucket and adding the required weight of salt or $CaCl_2$ to bring the fluid to the correct final density. The polymer was added to produce a final activity of 5 lb/BBl in the brine. In all of the tests, the Polymer A suspension or concentrate was added by weight to a measured volume of base fluid in order to assure that the final polymer loading could be accurately determined.

RESULTS IN THE FULL-SCALE FLOW LOOP

Fresh Water

The system was calibrated using fresh water, pumped at rates between 31 and 164 gpm. The resulting pressure drop ranged from 12 to 244 psi/100 ft, with less than 3% difference between the straight pipe and coiled tubing. The addition of Polymer A resulted in a considerable reduction in friction pressure in the coiled tubing. Figure 1 shows measured friction pressure for the fresh water system as a function of pump rate. The addition of only 0.03 lb/BBl polymer reduced the friction pressure in the coiled tubing from 244 psi/100 ft for fresh water at 165 gpm to 86 psi/100 ft. That is a reduction of 158 psi/100 ft. Figure 1 shows that the maximum amount of friction reduction was attained at a polymer concentration of between 0.03 and 0.06 lb/BBl. The drag reduction (DR) was determined for the various polymer loadings in the fresh water using Equation 1, the results of which are shown in Figure 2. Obtaining ΔP_{base} for this calculation at a given pump rate required curve fitting the friction pressure data of the particular base fluid.

$$DR = 1 - (\Delta P / \Delta P_{base}) \qquad (1)$$

In coiled tubing, the addition of Polymer A reduced drag by as much as 70%. Again, the optimum polymer loading appeared to be in the range of 0.03 and 0.06 lb/BBl. Similar results were obtained in the straight pipe, with drag reductions as high as 83% attained using 0.13 lb/BBl of the polymer.

1% KCl Brine

The potassium chloride brine produced slightly higher friction pressures in the coiled tubing than did the fresh water. At 152 gpm, the 1% KCl produced a pressure drop of 220 psi/100 ft in the coiled tubing. At the same pump rate, the fresh water produced 215 psipsi/100 ft. The addition of 0.13 lb/BBl Polymer A yielded a fluid viscosity of 1.8 cP. The effect of the polymer on friction pressure is shown in Figure 3. At 152 gpm, this loading of Polymer A reduced the friction pressure across the coiled tubing to 76 psi/100 ft, or by 65%. In the straight pipe, drag reduction was even more pronounced, ranging from 75% to 81%.

RESULTS FROM THE SMALL-SCALE FLOW LOOP

Fresh Water

This series of tests were run for the primary purpose of being able to compare data generated in the ½ inch tubing with that from the 1½ inch system. A baseline was run using fresh water, pumped at rates of 3 to 16 gpm, with friction pressures of up to 50 psi/10 ft in the coiled tubing and 39 psi/10 ft in the straight pipe. Addition of 0.06

lb/BBl of the Polymer A to the fresh water yielded a viscosity of 1.7 cP. This produced drag reduction of up to 61% in the coiled tubing and 76% in the straight pipe. Figure 4 shows the drag reduction for this fluid system as a function of Reynolds Number, and compares these values to those obtained for the same polymer loading in the full scale flow loop. In both flow loops, the fluid exhibited greater drag reduction in the straight pipe than in the coiled tubing. Figure 4 does show that there was very good correlation in the data generated in the ½ inch coiled tubing and that from the 1½ inch coiled tubing, with a close overlap of the data.

7% KCl Brine

No baseline test was run for the 7% KCl system. The friction pressure for the base fluid in these test conditions was calculated using the friction factors derived from the Drew et al.[3] correlation for the straight pipe and the Srinivasan et al.[4] correlation for coiled tubing. These correlations produced a good fit to the fresh water data and, because of the close similarity in fluid properties between the 7% KCl and fresh water, were judged to provide an adequate approximation. For the coiled tubing, the friction pressure (psi/10 ft.) was calculated according to Equation 2. For the straight pipe, Equation 3 was used to estimate friction pressure.

$$\Delta P_{CT} = 0.3421\ (\text{Rate})^{1.8063} \tag{2}$$

$$\Delta P_{SP} = 0.3006\ (\text{Rate})^{1.7732} \tag{3}$$

The drag reduction as a function of injection rate and Polymer A loading is shown for the straight pipe in Figure 5. At a concentration of 0.1 lb/BBl, the Polymer A produced a reduction in friction pressure of up to 77% at 20 gpm in the ½ inch straight pipe. This graph indicates that higher loadings of Polymer A were still producing lower friction pressures, and that an optimum loading was not reached in these tests. In the coiled tubing, the spread in data was less, indicating an optimum loading of around 0.06 lb/BBl Polymer A, with a resulting maximum drag reduction of 62% at 20 gpm.

10 ppg NaCl Brine

The 10 ppg NaCl brine produced friction pressures of up to 47.2 psi/10 ft in coiled tubing and 37.3 psi/10 ft in straight pipe. Adding Polymer A had the expected result of reducing friction pressures, as shown for the coiled tubing test results in Figure 6. A polymer loading of 0.13 lb/BBl appears to be an optimum loading for these conditions, reducing the friction by 55%, with minimal additional friction reduction produced with higher polymer concentration. In the straight pipe, however, significantly more friction reduction was obtained by increasing the polymer loading from 0.13 lb/BBl to 0.21 lb/BBl, producing a maximum drag reduction of 66%.

11.4 ppg $CaCl_2$ Brine

The 11.4 $CaCl_2$ brine produced 78% higher friction pressure than the fresh water and 45% more than the 10 ppg NaCl brine in coiled tubing at a rate of 12 gpm, as shown in Figure 7. The effects of Polymer A on the friction loss of the 11.4 $CaCl_2$ brine in coiled tubing can be seen in Figure 8. Successively higher loadings of Polymer A led to greater friction reduction. At 12 gpm, the addition of 0.21 lb/BBl Polymer A reduced the friction pressure from 52.8 psi/10 ft for the base fluid to 29.8 psi/10 ft, which was a 44% reduction. There is no indication that this is an optimum loading, but the data suggests that greater drag reduction might be achieved with higher polymer concentrations. Slightly less drag reduction was achieved in the straight pipe using this polymer loading, with a DR of 49% attained at the maximum test injection rate of 17.5 gpm.

CONCLUSIONS

Friction pressure tests were performed using both field-scale and laboratory scale equipment. There was relatively good agreement in the results obtained from both apparatus for the fresh water tests. That agreement provides some degree of confidence in the ability to scale up the data generated on the smaller equipment for field use. The advantage of the small-scale flow loop rests in the ability to quickly run multiple tests, with minimum material usage and waste generation.

The base fluid tests in the small-scale flow loop showed that the heavier brines produce successively higher friction pressures. In comparison to the fresh water, the 10 ppg NaCl brine produced 23% greater friction at a given injection rate. The 11.4 ppg calcium chloride brine produced up to 78% greater friction pressures than the fresh water under the same conditions.

The Polymer A was found to be a very effective friction reducing agent in both fresh water and in a number of brines. In fresh water, drag reduction of up to 70% was attained in coiled tubing and up to 83% in the straight pipe, with only 0.06 lb/BBl Polymer A. In the 7% KCl, Polymer A produced drag reduction of up to 62% in coiled tubing and 77% in straight pipe. Increasing the brine density appears to also increase the amount of Polymer A required to produce a given level of friction pressure reduction. Obtaining 60% drag reduction in the 10 ppg NaCl required a concentration of 0.13 to 0.21 lb/BBl Polymer A. In the 11.4 $CaCl_2$ brine, 0.21 lb/BBl Polymer A achieved up to 49% drag reduction, but the data indicated that higher concentrations might produce an even greater reduction in friction pressure.

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NOMENCLATURE

BBl = barrels
$CaCl_2$ = Calcium chloride
cP = centipoise
CT = Coiled Tubing
DR = Drag Reduction
ft. = feet
gpm = gallons per minute
KCl = Potassium chloride
Lb/BBl = Pounds per barrel
MM = Million
NaCl = Sodium chloride
OD = Outside dimension, inches
ppg = pound per gallon
psi = Pounds per square inch
Q = Injection Rate, gpm
SP = Straight Pipe

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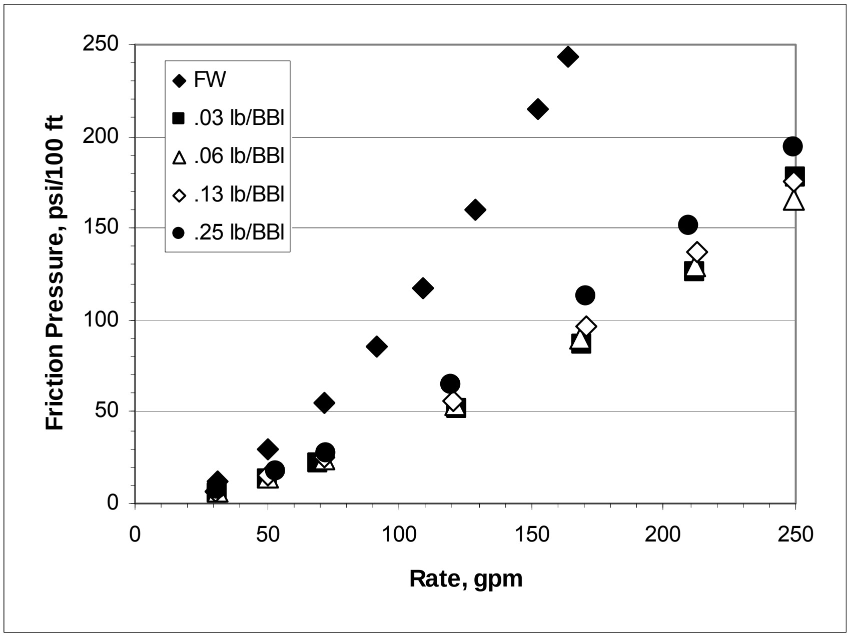

Figure 1 - Friction pressures for fresh water in 1½ inch coiled tubing, with various loadings of Polymer A.

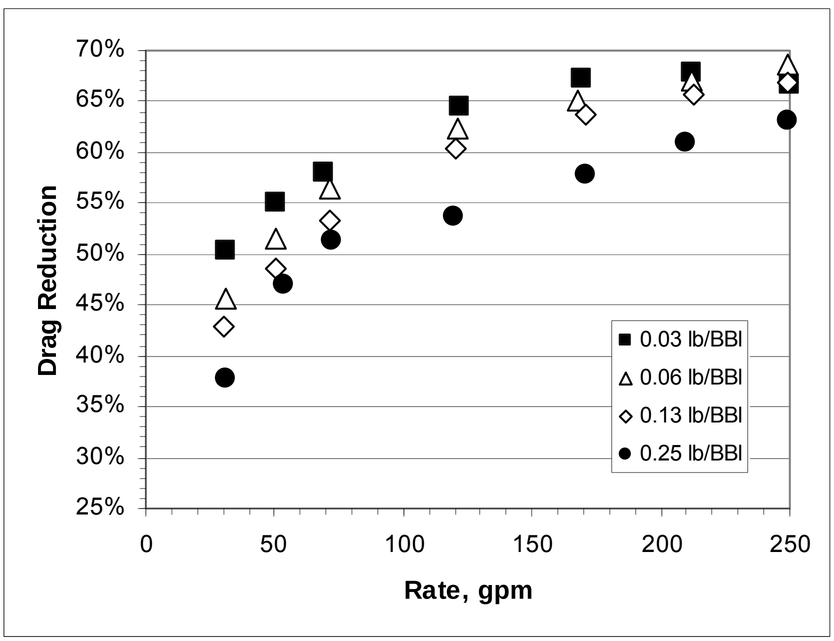

Figure 2 - Drag reduction for fresh water in 1½ inch coiled tubing, with various loadings of Polymer A.

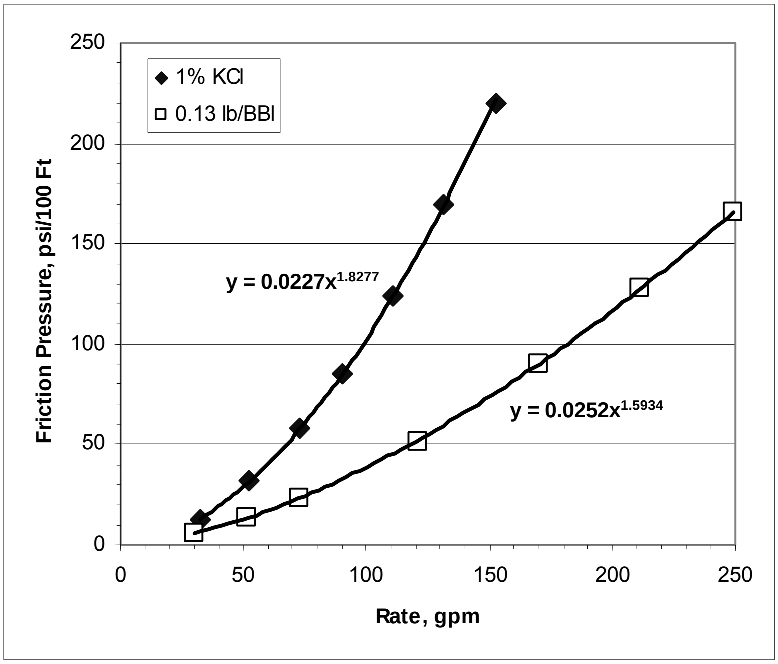

Figure 3 - Friction pressures for 1% KCl brine with 0.13 lb/BBl Polymer A and base fluid in 1½ inch coiled tubing.

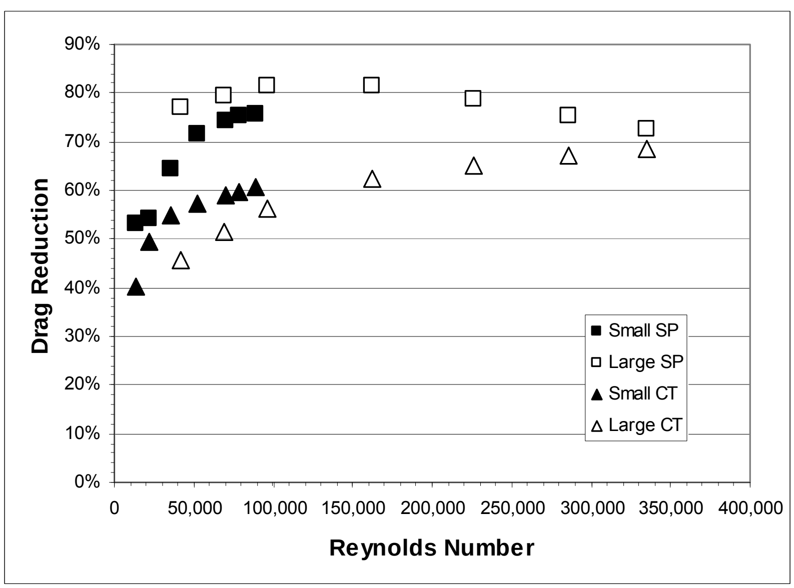

Figure 4 - Drag reduction by 0.06 lb/BBl Polymer A in fresh water in both large and small scale flow loops. There was good correlation in results between systems.

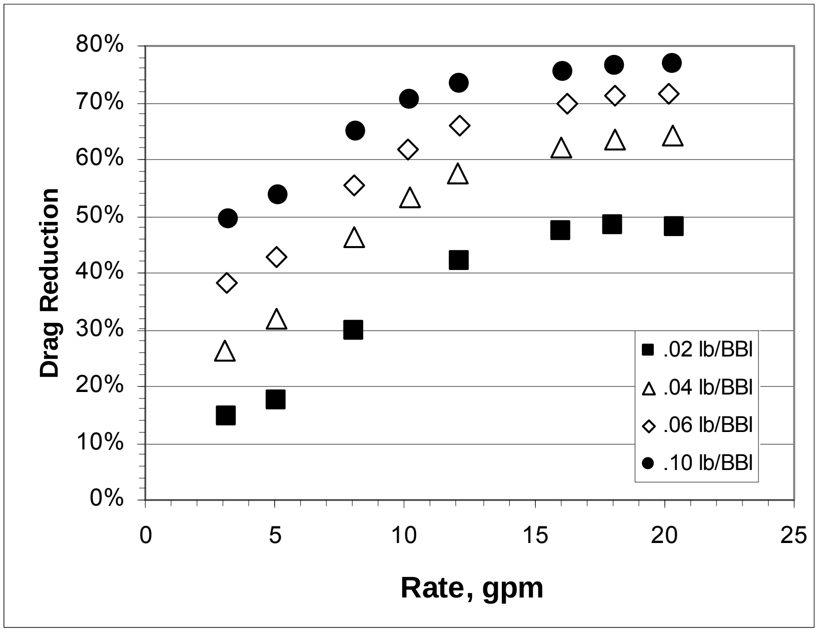

Figure 5 - Drag reduction of Polymer A in 7% KCl in ½ inch straight pipe.

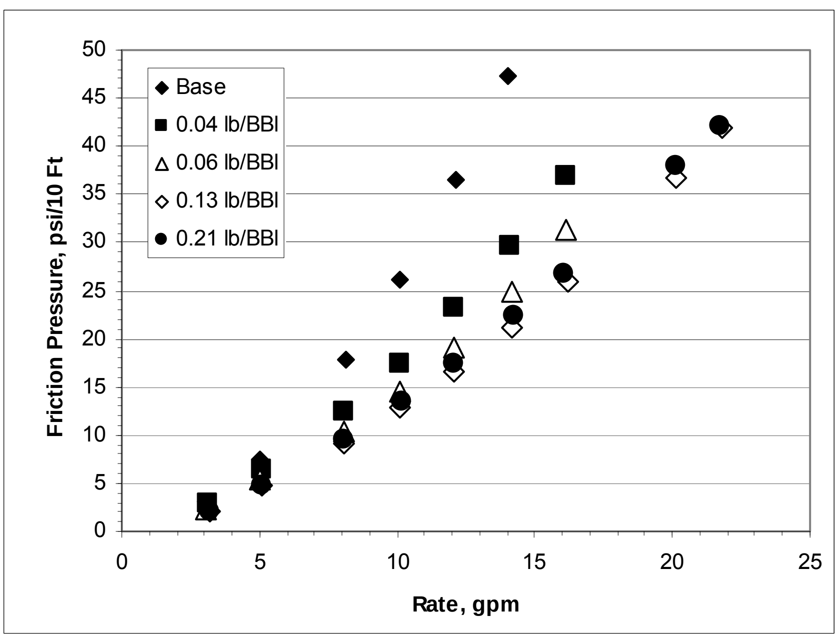

Figure 6 - 10 ppg NaCl brine in ½ inch coiled tubing with varying loadings of Polymer A.

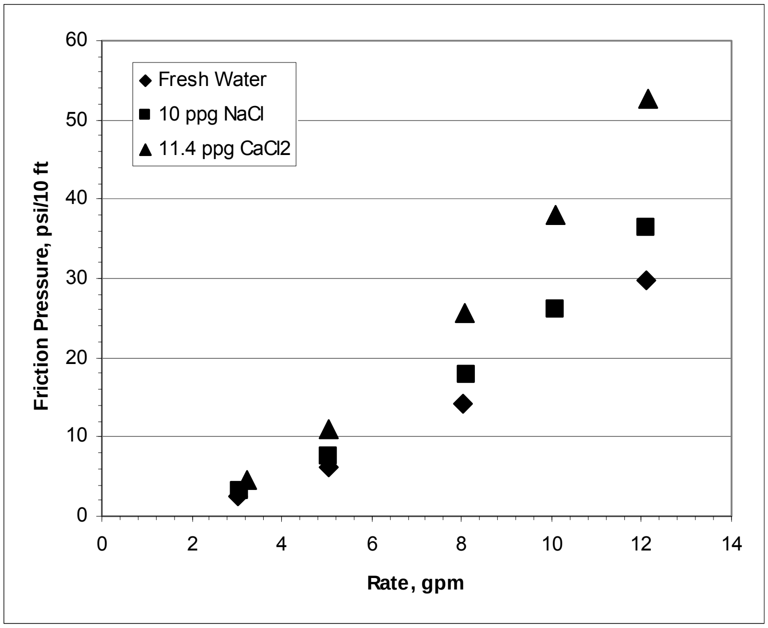

Figure 7 - Friction pressures for base fluids in ½ inch coiled tubing.

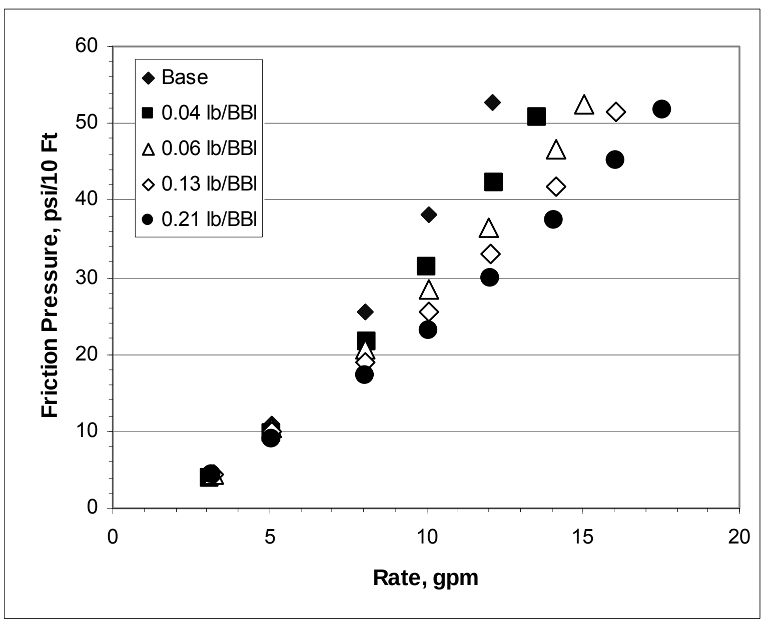

Figure 8 - 11.4 ppg CaCl2 in ½ inch coiled tubing, with varying loadings of Polymer A.