LIQUID POLYMERS FOR IMPROVED FRICTION PROPERTIES OF COMPLEXED AND NON-COMPLEXED FRACTURING FLUIDS

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INTRODUCTION

The use of polymer additives to obtain lower friction pressures in tubular goods has long been an accepted practice which has focused attention on friction-pressure drop as a major factor in job design.[1] Pressure limits set by pipe strength, as well as economic limits on horsepower, often determine the maximum obtainable rate. This rate may not be sufficient to give the most efficient stimulation treatment. The effective use of these polymer friction reducers has allowed higher rates within pipe pressure limits, leading to more successful stimulation treatments without increases in horsepower costs. Many treatments being performed today would be impossible without the use of friction reducers.

The most widely used friction reducers are guar gum and cellulose derivatives, i.e., HEC, and polyacrylamides. The polyacrylamides are superior as friction reducers.[2,3,4,5] However, guar gum and cellulose derivatives offer the added advantage of viscosity control of fracture leak-off at moderate concentrations. Leak-off control and proppant placement techniques[6] led to the use of highly viscous gels and eventually to the development of the high viscosity complexed gels. The increase in viscosity, however, was generally observed to be accompanied by an increase in friction pressure. Although these fluids offered high viscosity, fluid loss control, perfect proppant support, thermal stability, etc., an improvement in friction properties was desired.[7,8] Even with 50-60 percent friction reduction, desired injection rates are difficult to achieve within pressure limits of tubular goods or at acceptable horsepower costs, especially in small-diameter tubing. Earlier attempts to improve the friction properties of these viscous fracturing fluids were directed toward the addition of the more efficient polyacrylamides to these fluids. Such attempts were unsuccessful. This lack of success was attributed to materials-handling problems and hydration problems.

Recent advances in polymer technology have offered the polyacrylamides in liquid form. Unlike the traditional powdered polymers, the liquid polymers are prehydrated. They do not form lumps when added to water; thus handling and mixing are facilitated. Furthermore, the addition of liquids can be more uniformly controlled. With the advent of these new polymers, experimentation was resumed. Recent field trials have shown that these liquid polymers can significantly alter the friction properties of both complexed and non-complexed fracturing fluids.

EXPERIMENTAL

The liquid polymer chosen for experimentation was selected on the basis of its proven performance as a friction reducer for water and brines, as well as for its chemical compatibility with the fracturing fluid. Field trials were conducted using the liquid polymer (designated LFR) as an additive to a moderate-concentration, non-complexed water-based gel. On two jobs in particular, conditions (tubing size, rate, depth, etc.) permitted a direct comparison of the gel containing LFR versus the gel without this additive. The results were very encouraging because friction reduction for the gel containing LFR was as high as 72 percent (compared to water), while friction reduction for the gel without LFR was approximately 52 per cent.

Although some difference in friction reduction from one job to another is quite normal, the gross 20 percent difference indicates that LFR improves the friction properties of the gel. Additional experimentation was directed toward complex gels.

The situation which led to experimentation with LFR was fracturing the Wilcox formation in Webb and Zapata counties in South Texas. Most of the wells are completed with small-diameter tubing and packer set in 5-1/2-inch casing or liner. Stimulation of the formation usually consists of fracturing with 60,000 to 100,000 gallons of water-based complex gels at a pump rate of 10 bpm. The surface treating pressure is dependent on the fluid used and the depth at which the Wilcox occurs in this highly faulted area. Surface treating pressures in excess of 9,000 psi are not uncommon, with 10,000 psi being the maximum pressure established by most operators.

The fracturing fluid used in the field trials was a complexed water-based gel because this gel met requirements for economy, thermal stability, proppant support, etc. However, it was apparent that an improvement in the friction properties of the gel would be a definite advantage.

Characteristics of the gel are shown below:

Viscosity at 511 sec^{-1}	128cp
Flow Behavior Index, n′	0.370
Consistency Index, k′	0.136 $lb_f\text{-}sec^{n'}/ft^2$
Friction Reduction in 2-7/8-in. - 2.441-in. ID Tubing	60 percent at 15 bpm

For the first field trial, a well was selected that was to be treated with 60,000 gal of the complexed gel. The predetermined rate was 18 bpm through 7, 644

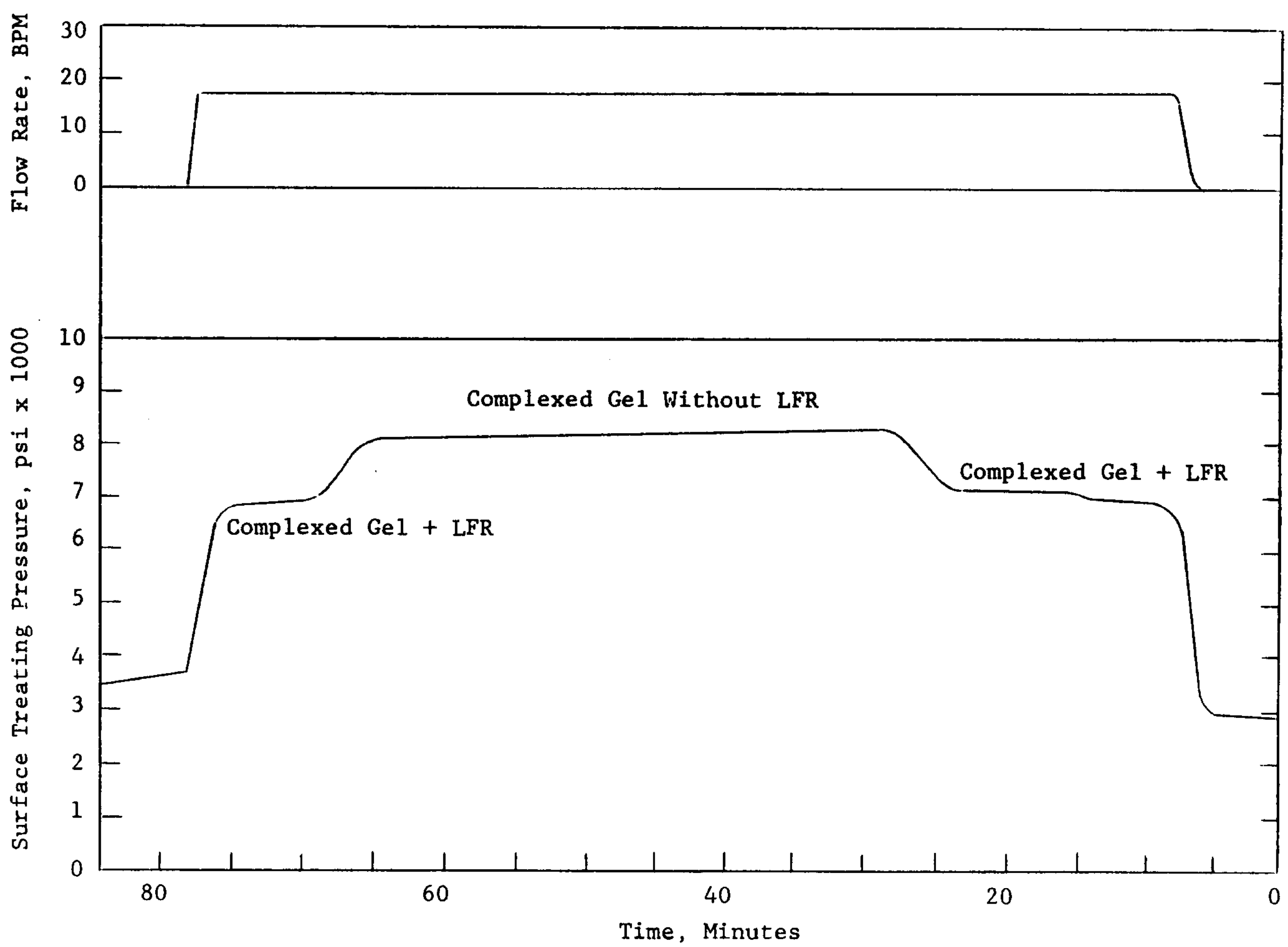

FIG. 1—REPRODUCTION OF STIMULATION TREATMENT CHART FOR COMPLEXED GEL CONTAINING LFR.

ft of 2-7/8-inch tubing. The 4-1/2-inch casing was perforated from 7,245-7,255 feet. The base gel was prepared by batch mixing in 500 bbl tanks. Of the total 60,000 gallons, 40,000 gallons contained LFR at a concentration of 2-1/2 gallons per 1000 gallons of gel. As shown in Figure 1, an injection rate of 18 bpm was established for the gel containing LFR. Upon switching to the tank without friction reducer, the surface treating pressure increased by 1100 psi. Later in the job sequence an 1100-psi decrease was observed as the tanks were switched back to the gel containing LFR. The observed pressure differential resulting from the use of the liquid polymer increased friction reduction from 54 percent to 66 percent. Successive field trials indicated even better results, and LFR became an integral part of the formulation of fluid in that area.

Information from field tests has been sufficient for preparation of a friction-pressure chart for LFR gel in 2-7/8-inch tubing, as shown in Figure 2. For comparison, this figure also includes friction-loss data for this gel without LFR. The figure shows that

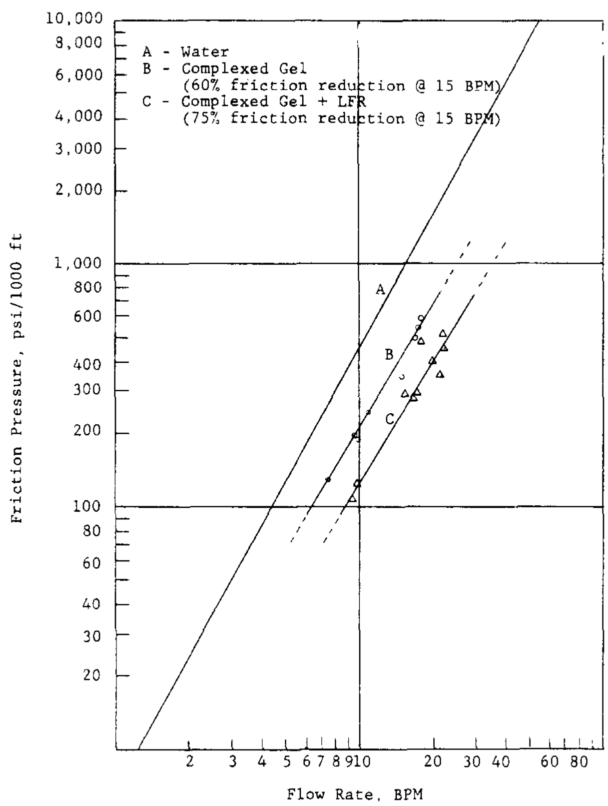

FIG. 2—EFFECT OF FLOW RATE ON FRICTION PRESSURE FOR 2-7/8 in. - 2.441-in. ID TUBING

friction reduction of approximately 75 percent (compared to water) is obtained when LFR is used while only 60 percent reduction is possible without this additive.

CONCLUSION

The successful application of the liquid polymer has significantly modified the friction properties of non-complexed and complexed gels. Many jobs are being performed in the 8000-psi range that would otherwise have been in the 9500-psi range. In addition, much higher rates within pipe maximums have been possible. Successful stimulation treatments in excess of 20 bpm in 2-7/8-inch tubing have been performed.

Field experimentation is continuing in an effort to define the effect of liquid polymer concentration on the amount of friction reduction possible. Programs are currently being established to extend this application to other gel systems.

REFERENCES

1. White, G.L.: Friction Pressure Reducers in Well Stimulation, *J. Pet. Tech.*, August, 1964, 865-868.
2. Pruitt, G.T. and Crawford, H.R.: Effect of Molecular Weight and Segmental Constitution on the Drag Reduction of Water Soluble Polymers, The Western Company Report No. DTMB-1, Contract NONR-4306 (00), April, 1965.
3. Pruitt, G.T., Rosen, B., and Crawford, H.R.: Effect of Polymer Coiling on Drag Reduction, The Western Company Report No. DTMB-2, Contract NONR-4306 (00), August, 1966.
4. Whitsitt, Norman, Harrington, L.J., and Crawford, H.R.: Effect of Wall Shear Stress on Drag Reduction of Viscoelastic Fluids, The Western Company Report No. DTMB-3, Contract NONR-4306 (00), June, 1968.
5. Sitaramaiah, G. and Smith, C.L.: Turbulent Drag Reduction by Polyacrylamide and Other Polymers, *Soc. Pet. Engr. J.*, June, 1969, 183-188.
6. Harrington, L. and Hannah, R.R.: Fracturing Design Using Perfect Support Fluids for Selected Fracture Proppant Concentrations in Vertical Fractures, Paper SPE 5642, 50th An-

nual Fall Meeting, Dallas, Sept. 28-Oct. 1, 1975.

7. Hannah, R.R. and Matson, B.G.: A Family of Viscous Gelled Water Systems Featuring Moderate Polymer Loadings and Low Residue on Breaking, Paper SPE 6380, to be presented at 1977 Permian Basin Oil Recovery Conference, Midland, March 10-11, 1977.
8. Hannah, R.R. and Baker, J.R.: A New Non-damaging, Aqueous Cross-linked Gel with Improved Fracturing Properties and Perfect Proppant Support, presented 23rd Annual Meeting, Southwestern Petroleum Short Course, Texas Tech University, Lubbock, April, 1976, 123-128.