IMPROVED LOAD RECOVERY AND PERMEABILITY TO OIL by USING FLUID RECOVERY SURFACTANT

Melissa A. Scott
Smith Energy Services a Division of Smith International, Inc.

INTRODUCTION

One of the problems encountered in stimulating low pressure and/or low permeability sandstone reservoirs is recovery of the treatment fluid. Some wells have low bottomhole pressures and in many cases these pressures are so low as to give little or no aid in treatment load recovery. Reservoir permeability is determined by the relative number and size of pores as well as by the size and continuity of the pore intersections. Permeability is unique to a particular reservoir and cannot be altered by stimulation. Sandstone pores often contain water, creating capillary pressure which effectively prevents or restricts the passage of fluids.

The interaction of aqueous based stimulation fluids and low pressure and/or low permeability reservoirs often results in less than desirable recovery of treatment fluids. A new surfactant technology has been developed to improve load recovery percentages.

THEORY

Capillary pressure (P_c) in a gas well is the pressure drop across the water-gas interface. Capillary pressure is defined by the LaPlace-Young equation[1] as:

$$P_c = \frac{2\sigma_{lv} \cos\theta}{R_m}$$

where: σ_{lv} is the liquid-vapor interfacial tension (surface tension),

θ is the contact angle between the liquid and the solid surface, and

R_m is the mean radius of curvature of the liquid-vapor interface as found within a porous matrix.

In addition to the pressure drop across the water-gas interface, another surface interaction to consider downhole is the interaction of water and silicate particles. Ordinarily, the contact angle of water and silica is minimized (0^o), producing a maximum COS θ (COS =1). Since in the capillary pressure equation P_c is a function of the cosine of θ, it is possible to negate capillary pressure by achieving a contact angle of 90^o (COS 90^o = 0).[2] A surface so altered is said to be non-wet,[3] i.e. not oil-wet and not water-wet. Although this situation is theoretically to be expected, due to the heterogeneity of actual reservoir rock, a totally non-wet condition can never exist.

Fluid Recovery Surfactant

Fluid Recovery Surfactant (FRS) is a cationic fluorocarbon surfactant which is designed for use in a prepad prior to an aqueous fracturing treatment. Laboratory results have indicated that it is also effective in the body of the fracturing fluid following the surfactant-laden prepad. When sandstone pore intersections contain water thereby creating capillary pressure, the surfaces are said to be water-wet. Use of 100% methanol as a prepad,[4] (or a methanol/2% KCl water blend) aids in dewatering the sandstone, thus conditioning the surface prior to adsorption of the FRS. In order to reduce capillary pressure within a pore space, FRS is designed to alter the contact angle between the sandstone and water (from $\cos 0^{\circ} = 1$ to $\cos 90^{\circ} = 0$), making the silicate particles non-wet. The non-wet surface of the sandstone should decrease fluid leak-off and increase permeability to oil.

LABORATORY EXAMINATION

A. Horizontal Sand Columns

For laboratory examination of different treatment fluids, two glass columns (6" long and 4/16" I.D.) were packed with equal weights of 80-100 mesh silica sand slurried in 2% KCl water.

Procedure:

1. From a common vessel with a diminishing hydrostatic head, flow a measured volume of 2% KCl through each sand column to equally saturate both columns and to establish an initial flow rate.

2. Flow one pore volume of the desired treatment fluid through each column. (One pore volume is not necessarily representative of actual reservoir rock exposure, but it provides a relative comparison for laboratory purposes.)

3. From a common vessel with a diminishing hydrostatic head flow #2 diesel for a specified time through both columns. Record the time elapsed before oil is seen discharging from the sand column. This time is directly related to load recovery time. Record the total amount of fluid recovered in a specified number of minutes in order to calculate oil recovery rate.

Results

See accompanying load recovery time (Fig. 1) and oil recovery rate (Fig. 2) graphs.

Discussion

100% Load Recovery Time

From the 100% load recovery graph, note the ascending order of load recovery times. The best result is 100% methanol containing 0.3% FRS and the worst result is 2% KCl. Note that the 75%/25% and 90%/10% (KCl/methanol) blends showed equal load recovery times. When 0.3% FRS is added to each of these two blends, the 75%/25% (KCl/methanol) blend's load recovery time is less than the 90%/10% (KCl/methanol) blend.

Oil Recovery Rate

Surprisingly, the rate of oil flow through the packed sand column after the 100% methanol treatment was more rapid than 100% methanol containing 0.3% FRS. The 100% methanol systems were examined through berea sandstone to validate this data and will be presented in the next section of this paper.

Note that both the 75%/25% and 90%/10% (KCl/MeOH) blends' oil recovery rates were higher when 0.3% FRS was added. It should also be noted that 2% KCl with 0.3% FRS fared better than both the 75%/25% and 90%/10% (KCl/MeOH) blends. The plain 2% KCl water treatment resulted in the slowest oil recovery rate.

B. Berea Sandstone Core Study

In the packed sand column oil recovery rate data, the 100% methanol without FRS fared better than methanol with FRS. This warranted verification as to FRS's effectiveness in improving the permeability of a silica matrix to oil.

Another method of laboratory examination was undertaken that perhaps better simulates downhole conditions than packed sand columns; that is flow through Berea sandstone cores. An attempt was made to simulate a prepad treatment followed by frac fluid. Only 100% methanol prepads with and without FRS were examined, followed by 2% KCl water (simulating frac fluid) with and without FRS. See Figure 3 for a diagram of the core flow apparatus used.

Procedure:

1. Drill Berea core plugs in 2% KCl water.

2. Vacuum saturate core plugs in fresh water.

3. Insert core plug into core sleeve and set temperature at 70^{o}F and confining pressure around the core plug at 500 psi.

4. Establish initial permeability by flowing kerosene through the core plug.

5. In the opposite direction of flow, flow methanol then KCl.

6. In the original direction of flow, flow kerosene to establish final permeability and to calculate the percentage of damage or improvement caused by the treatment.

Results

See Table I.

Discussion

MeOH containing 0.3% FRS followed by 2% KCl containing 0.3% FRS showed the greatest improvement in permeability to kerosene. Improvement was also seen using MeOH containing 0.3% FRS followed by 2% KCl. No significant difference in improvement was noted using MeOH followed by 2% KCl containing 0.3% FRS or MeOH followed by 2% KCl.

CONCLUSIONS

1. A cationic fluorcarbon Fluid Recovery Surfactant has been developed, which when added to a methanol prepad, creates an essentially "non-wet" sandstone surface, thus maximizing load recovery potential and oil recovery rate.

2. Laboratory data obtained from sand packs indicate that using the Fluid Recovery Surfactant in 100% methanol provides optimum load recovery potential.

3. Although a treatment of 100% methanol showed the quickest oil recovery rate through packed sand columns, 100% methanol containing 0.3% Fluid Recovery Surfactant fared considerably better than any of the other methanol/KCl blends with and without the Fluid Recovery Surfactant.

4. Laboratory data obtained from Berea sandstone cores indicate that methanol prepads containing the Fluid Recovery Surfactant allow greater permeability to oil when the following aqueous 2% KCl solution is also treated with Fluid Recovery Surfactant.

5. Case histories were not available at the time this paper was written. Case histories will be included when the paper is presented.

ACKNOWLEDGEMENTS

The authors wish to thank David L. Holcomb and Ed Callaway for their advice and assistance in this study. Thanks are also extended to John McLane and Bob Ewing for their support and Dorothy Patterson for her patience while typing this manuscript.

FOOTNOTES

[1]LaPlace, P. S.: "Theory of Capillary Attraction", Supplements to the book Celestial Mechanics, translated and annotated by N. Bowditch (1839), Reprinted by Chelsea, NY, 1966.

[2]Penny, G. S., Soliman, M. Y., Conway, M. W., and Briscoe, J. E.: "Enhanced Load Recovery Technique Improves Stimulation Results", paper SPE 12149 presented at the Technical Conference and Exhibition, San Francisco, California, October 5-8, 1983.

[3]Amyx, J. W., Bass, D. M., and Whiting, R. L.: Petroleum Reservoir Engineering, McGraw-Hill, Inc., New York City, NY (1960), 133-209.

[4]Ortiz, Joseph, McLane, J. E.: "Low pH Methanol: An Alternative for Stimulation in Water Sensitive Tight, Dirty Sandstones", paper SPE 12502 presented a the Formation Damage Control Symposium, Bakersfield, California, February 13-14, 1984.

100% LOAD RECOVERY
(time elapsed before oil was discharged through packed sand columns)

A. 100% MeOH/0.3% FRS
B. 100% MeOH
C. 75%/25% (KCl/MeOH)/0.3% FRS
D. 90%/10% (KCl/MeOH)/0.3% FRS
E. 75%/25% (KCl/MeOH)
F. 90%/10% (KCl/MeOH)
G. 2% KCl/0.3% FRS
H. 2% KCl

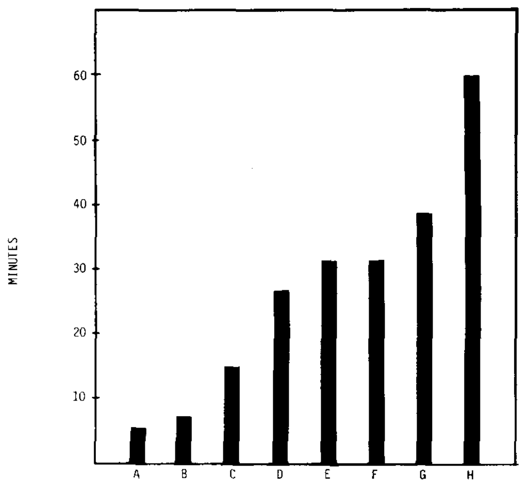

Figure 1

OIL RECOVERY RATE
(rate of oil flow through packed sand columns following treatment fluids)

A. 100% MeOH/0.3% FRS
B. 100% MeOH
C. 75%/25% (KCl/MeOH)/0.3% FRS
D. 90%/10% (KCl/MeOH)/0.3% FRS
E. 75%/25% (KCl/MeOH)
F. 90%/10% (KCl/MeOH)
G. 2% KCl/0.3% FRS
H. 2% KCl

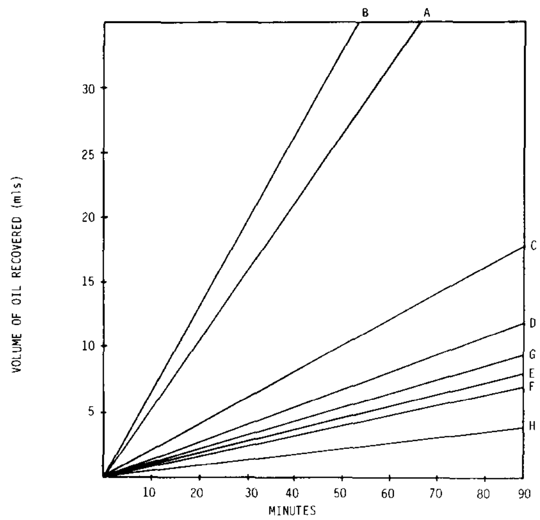

Figure 2

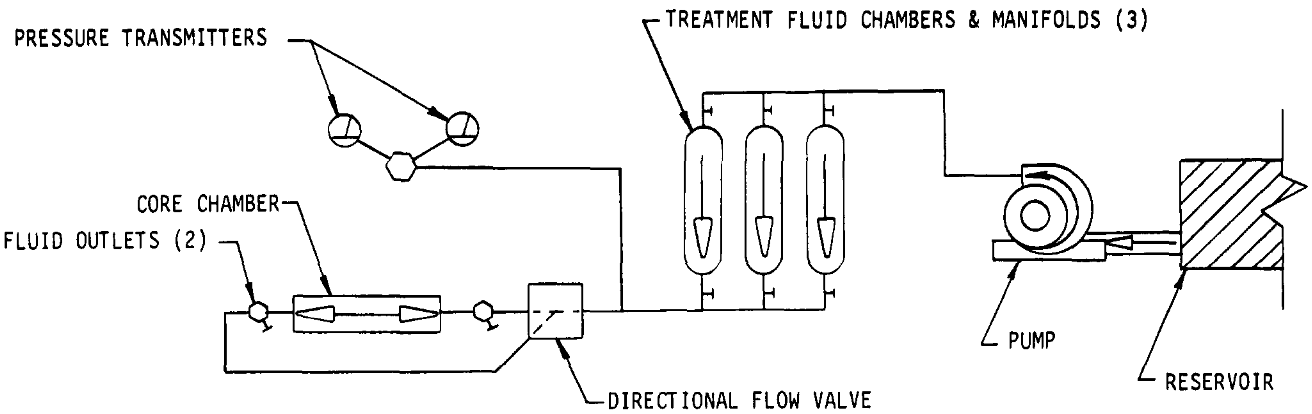

Figure 3 - Core flow apparatus for Berea sandstone core study

Table 1

Berea Sandstone Core Permeability Study

Initial Permeability	Treatment Fluid	Final Permeability	Percentage of Improvement
1. 173.6 md	MeOH containing 0.3% FRS followed by 2% KCl containing 0.3% FRS	252.7 md	+45.6%
2. 91.9 md	"	132.1 md	+43.7%
3. 209.8 md	MeOH containing 0.3% FRS followed by 2% KCl	251.8 md	+20.0%
4. 116.3 md	"	140.9 md	+21.2%
5. 172.7 md	MeOH followed by 2% KCl containing 0.3% FRS	187.9 md	+ 8.8%
6. 86.7 md	"	92.7 md	+ 6.9%
7. 215.3 md	MeOH followed by 2% KCl	227.3 md	+ 5.6%
8. 131.2 md	"	142.8 md	+ 8.8%