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TECHNICAL PROGRESS REPORT

DOE Contract No DE-AC22-92 BC14886

Investigation of Oil Recovery Improvement by Coupling
an Interfacial Tension Agent and a Mobility Control Agent
in Light Oil Reservoirs

submitted by
Surtek, Inc.

Contract date: September 28, 1992

Anticipated Completion Date: September 30, 1995

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Report for the Period of
September to December 1993

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I. Objectives of Study

The study will investigate two major areas concerning co-injecting an interfacial tension reduction agent(s) and a mobility control agent into petroleum reservoirs. The first will consist of defining the mechanisms of interaction of an alkaline agent, a surfactant, and a polymer on a fluid-fluid and a fluid-rock basis. The second is the improvement of the economics of the combined technology.

This report examines the adsorption of alkali, surfactant, and polymer by rock.

II. Summary of Technical Progress

Solutions were dissolved in 1,000 mg/l NaCl except where designated.

Adsorption of Alkali and Surfactant - The adsorption of alkali and various surfactants onto crushed Berea sandstone were studied with no polymer addition to the solutions. Surfactants studied were described previously.¹ The following table shows the concentration of the surfactant in solution after 30 days contact with Berea Sandstone divided by the initial concentration.

Surfactant Type	Surfactant Consumption ----- 30 day C/C ₀ at 100°F -----			
	No Alkali	Na ₂ CO ₃	NaOH	Na ₃ PO ₄
Linear Alkyl Group Surfactants				
Polystep A-7	0.923	0.930	0.932	0.797
LXS-395	0.224	0.440	0.157	0.577
LTS-18	0.458	0.791	0.650	0.788
Linear Alkyl Group Surfactants - Alkyl Internally Bonded to Aryl Functionality				
Petrostep H-67	0.170	0.739	0.704	0.712
Branched Alkyl Group Surfactants				
Petrostep B-100	0.220	0.891	0.751	0.698
Chaser XP-100	0.764	0.627	0.457	0.656
Internal Olefin Sulfonates				
Neodol IOS 1517	0.910	0.911	0.606	0.809
Neodol IOS 1720	0.874	0.925	0.772	0.811
Alpha Olefin Sulfonates				
AOS 12	0.804	0.928	0.822	0.930
Bioterge AS-40	0.936	0.934	0.834	0.908
Sulfonated Linear Alkane				
Bioterge PAS 8S	0.940	0.954	0.968	0.960
Sulfonated Ethoxylated Linear Alkane				
Avanel S-30	0.823	0.603	0.793	0.695
Sulfated Ethoxylated Linear Alkane				
Neodol 25-3S	0.828	0.954	0.896	0.949

Surfactant consumption for surfactants dissolved without alkali was highest for the alkyl aryl sulfonates. Surfactant consumption increased with surfactant molecular weight with the exception of Neodol 25-3S and Chaser XP-100.

Addition of alkali to the alkyl aryl surfactant solutions resulted in a significant decrease in surfactant consumption with the exception of Chaser XP-100. NaOH was not as effective as either Na_2CO_3 or Na_3PO_4 in decreasing alkyl aryl surfactant adsorption.

Addition of alkali to the alkyl surfactant solutions did not change the surfactant adsorption for those surfactants which adsorbed at low rates. For those surfactants which adsorbed at higher rates, alkali addition decreased adsorption with the exception of Avanel S-30. Again, Na_2CO_3 and Na_3PO_4 were more effective in decreasing adsorption than NaOH.

The change in adsorption of surfactant with and without alkali generally did not change significantly with temperature. Figure 1 shows the adsorption for Petrostep B-100 combined with Na_2CO_3 .

Na_2CO_3 and NaOH in the absence of surfactant adsorbed at a C/C_0 of 0.971 and 0.924 at 100°F. When dissolved with above listed surfactants, neither alkali adsorption values were effected significantly. Increasing temperature to 150°F did not alter Na_2CO_3 adsorption either with or without surfactant but NaOH adsorption increased with increasing temperature in the presence and absence of surfactant.

Effect of Cation on Adsorption Surfactant - The effect of replacing sodium ion with potassium and ammonium ion on adsorption of alkali and surfactant was determined by dissolving the chemicals in KCl and NH_4Cl and using either potassium or ammonium based alkalis and surfactants. The adsorption data at 100°F are summarized in the following table. The alkali designation XOH are NaOH, KOH, or NH_4OH as appropriate for the surfactant or brine cation. No designation next to the surfactant indicates the sodium based solution, a K designates potassium and NH_4 designates ammonium based solutions. The polystep surfactants are sodium (A-7), potassium (A-15-30K), or ammonium (B-7) based dodecyl benzene sulfonate.

		Surfactant Consumption		
		----- 30 day C/C_0 at 100°F -----		
Surfactant Type	Cation	No Alkali	X_2CO_3	XOH
Linear Alkyl Group Surfactants				
Polystep A-7	Na	0.923	0.930	0.932
Polystep A-15-30K	K	0.853	0.701	0.630
Polystep B-7	NH_4	0.708	0.967	0.903

		Surfactant Consumption		
		----- 30 day C/C ₀ at 100°F -----		
<u>Surfactant Type</u>	<u>Cation</u>	<u>No Alkali</u>	<u>X₂CO₃</u>	<u>XOH</u>
Branched Alkyl Group Surfactants				
Petrostep B-100	Na	0.220	0.891	0.751
Petrostep B-100	K	0.701	0.621	0.497
Petrostep B-100	NH ₄	0.675	0.760	0.796
Alpha Olefin Sulfonates				
Bioterge AS-40	Na	0.936	0.934	0.834
Bioterge AS-40	K	0.903	0.887	0.922
Bioterge AS-40	NH ₄	0.934	0.940	0.946

Any benefit of altering the cation in the alkaline plus surfactant or surfactant solution appears to be solution specific.

Adsorption of Alkali, Surfactant and Polymer - Bioterge AS-40, Petrostep B-100, Polyacrylamide, Xanthan Gum, Na₂CO₃ and NaOH were selected to study adsorption with all three components. The following table shows the alkali consumption as polymer and surfactant are blended into the solution.

		Alkali Consumption		
		----- 30 day C/C ₀ at 100°F -----		
<u>Alkali Type</u>		<u>No Polymer</u>	<u>Polyacrylamide</u>	<u>Xanthan Gum</u>
No Surfactant				
Na ₂ CO ₃		0.971	0.911	0.924
NaOH		0.924	0.907	0.949
Add Bioterge AS-40				
Na ₂ CO ₃		0.918	0.885	0.885
NaOH		0.882	0.935	0.926
Add Petrostep B-100				
Na ₂ CO ₃		0.862	0.911	0.908
NaOH		0.885	0.946	0.976

From this table the following observations can be made:

- Na₂CO₃ adsorption increases when dissolved with polyacrylamide and xanthan gum
- NaOH adsorption increases when dissolved with polyacrylamide and decreases when dissolved with xanthan gum
- Na₂CO₃ and NaOH adsorption increases when dissolved with either Bioterge AS-40 or Petrostep B-100
- Relative to alkali adsorption alone, Na₂CO₃ and NaOH adsorption increases when dissolved with both surfactant and polymer

- Relative to alkali dissolved with polymer, Na_2CO_3 adsorption increases when Bioterge AS-40 is dissolved in the solution but is essentially unchanged when dissolved with Petrostep B-100. Polymer type has a minimal effect. NaOH adsorption appears to decrease with surfactant addition to the alkali plus polymer solution.

Polymer adsorption as alkali and surfactant are blended into the solution are shown in the following table.

<u>Polymer Type</u>	Polymer Consumption ----- 30 day C/C ₀ at 100°F -----		
	<u>No Alkali</u>	<u>Na₂CO₃</u>	<u>NaOH</u>
No Surfactant			
Polyacrylamide	0.879	0.933	0.762
Xanthan Gum	0.981	0.974	0.873
Add Bioterge AS-40			
Polyacrylamide	0.906	0.922	0.949
Xanthan Gum	0.945	0.960	0.942
Add Petrostep B-100			
Polyacrylamide	0.912	0.902	0.955
Xanthan Gum	0.876	0.974	0.948

From this table the following observations can be made:

- Polyacrylamide adsorption decreases when dissolved with Na_2CO_3 while xanthan gum adsorption is unchanged. Co-dissolution of both polymers with NaOH increased adsorption.
- Surfactant addition to the polymer solutions decreased polyacrylamide adsorption but increased xanthan gum adsorption.
- Relative to the alkali plus polymer solutions, surfactant addition decreased polymer adsorption for the NaOH solutions and slightly increased polymer adsorption with the Na_2CO_3 solutions.
- Relative to the surfactant plus polymer solutions, Na_2CO_3 and NaOH generally decreased adsorption of polymer.

Surfactant adsorption as alkali and polymer are blended into the solution are shown in the following table.

<u>Surfactant Type</u>	Surfactant Adsorption ----- 30 day C/C ₀ at 100°F -----		
	<u>No Polymer</u>	<u>Polyacrylamide</u>	<u>Xanthan Gum</u>
No Alkali			
Bioterge AS-40	0.936	0.933	0.942
Petrostep B-100	0.220	0.527	0.431

<u>Surfactant Type</u>	Surfactant Adsorption ----- 30 day C/C ₀ at 100°F -----		
	<u>No Polymer</u>	<u>Polyacrylamide</u>	<u>Xanthan Gum</u>
Add Na₂CO₃			
Bioterge AS-40	0.934	0.929	0.905
Petrostep B-100	0.891	0.569	0.465
Add NaOH			
Bioterge AS-40	0.834	0.917	0.920
Petrostep B-100	0.564	0.347	0.348

From this table the following observations can be made:

- Petrostep B-100 adsorption decreases significantly when either alkali is added to the solution. Na₂CO₃ is more effective than NaOH. Bioterge AS-40 adsorption is not effected by Na₂CO₃ addition to the solution but increases with NaOH.
- Addition of either polyacrylamide or xanthan gum does not alter the adsorption of Bioterge AS-40 but decreases the adsorption of Petrostep B-100.
- Relative to the surfactant plus polymer solutions, addition of Na₂CO₃ did not change surfactant adsorption while NaOH increased Petrostep B-100 adsorption. NaOH addition had a slight effect on Bioterge AS-40 adsorption.
- Relative to the surfactant plus alkali solutions, Petrostep B-100 adsorption increased with both alkalis when either polymer type was added to the solution. Bioterge AS-40 adsorption did not change with Na₂CO₃ and decreased with NaOH.

The adsorption characteristics of the various chemicals from 72 to 150°F are characterized in the following manner.

- Na₂CO₃ adsorption did not change with temperature dissolved with and without polymer and surfactant.
- NaOH adsorption increased with increasing temperature. Added polymer, surfactant or a combination of polymer and surfactant retarded the increase of NaOH adsorption.
- Polymer adsorption characteristics generally did not change with increasing temperature, the exception being Na₂CO₃ plus surfactant addition to polyacrylamide solutions, as shown in Figure 2.
- Alkyl aryl sulfonate (Petrostep B-100) adsorption decreased with increasing temperature while alpha olefin sulfonate (Bioterge AS-40) adsorption was unchanged. Figure 3 shows the Petrostep B-100 adsorption change with temperature when co-dissolved with polyacrylamide and alkali.

Effect of Increasing Salinity on Chemical Adsorption - To determine the effect of salinity on chemical adsorption, the chemical make-up water NaCl concentration was increased to 5,000, 10,000 and 20,000 mg/l and the adsorption tests repeated. Alkali adsorption generally was greater as the NaCl concentration increased. Polymer adsorption declined as the salinity increased with the exception of Na₂CO₃ plus Petrostep B-100 plus polyacrylamide. Surfactant adsorption was generally greater as the concentration of NaCl increased. Surfactant dissolved without alkali or polymer were the exceptions.

III. Continued Evaluations

Future studies will investigate changes in relative permeability due to alkali plus surfactant and polymer addition to the displacing fluid. Oil recovery efficiency by alkali plus surfactant and alkali plus surfactant plus polymer solutions will be investigated as well as changes to improve the economics of oil recovery.

IV. References

1. Contracts for field projects and supporting research on ... Enhanced Oil Recovery, Reporting period January to March 1993, number 74, DOE/BC - 93-2.

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Figure 1

Effect of Temperature on Surfactant Adsorption
versus Time

0.2 wt% Petrostep B-100 + 1.0 wt% Na_2CO_3

Figure 2

Effect of Temperature on Polymer Adsorption Co-Dissolved with Alkali and Surfactant

Figure 3

Effect of Temperature on Surfactant Adsorption Co-Dissolved with Alkali and Polymer