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SEVENTH QUARTERLY REPORT
U.S. DEPARTMENT OF ENERGY

SURFACTANT DEVELOPMENT FOR ENHANCED OIL RECOVERY

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Prepared by

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SEVENTH QUARTERLY REPORT

This is a seventh quarterly report on the Surfactant Development for Enhanced Oil Recovery project. It summarizes the work carried out for the quarter ending September 30, 1995.

OBJECTIVE

The long term objective of this project is to develop surfactant system(s) that will be suitable for enhanced oil recovery. The developed system will be expected to be stable at high temperatures and exhibit high salinity tolerance.

SUMMARY OF TECHNICAL PROGRESS

Aqueous dihexadecyldimethylammonium bromide (DHDAB) surfactant was used to form an emulsion with samples of crude oil (Burbank Crude Oil) supplied by Phillips Petroleum Company. Influence of the surfactant concentration in the uptake of the oil in the aqueous phase

was studied. It was observed that as weight of the surfactant solubilized in the oil-water system increases the volume of oil solubilized in the aqueous phase increases. Viscosity of the emulsion was also observed to increase with an increase in the weight of surfactant added. A co-surfactant, n-butyl alcohol was added and its effect was to reverse the observation described above. The uptake of aqueous surfactant into the oil phase was very evident. Salinity scan of this system showed that the addition of sodium chloride, NaCl, produced a middle phase whose volume increased with an increase in the amount of salt added. Also there was observed, a remarkable high salinity tolerance. Rheology of the emulsion showed typical non-Newtonian behavior. The emulsion was observed to exhibit a pseudoplastic profile. The shear-thinning profile was evident from the observed viscosity-shear rate experiment.

Influence of Surfactant Concentration on the Oil Uptake

In the fourth quarterly report of this project we reported that double-chain surfactants showed good potential as candidates for enhanced oil recovery projects. Of the double chain surfactants analyzed, dihexadecyldimethylammonium bromide showed greater potential. In this report we have emulsified Burbank Crude oil in water using this surfactant. Figure 1 shows a plot of the observed ratio of volume fraction of oil to water as a function of surfactant concentration. In this experiment the volumes of oil and water were each kept constant at 5.0 mL. As can be seen in this figure, the observed ratio decreased asymptotically as the surfactant concentration increased. This means a steady solubilization of oil into the aqueous phase of the emulsion. However, when a co-surfactant, n-butyl alcohol, was added to the system, an opposite effect was observed. See Figure 2. In this experiment the volume of the alcohol was kept

constant at 5.0 mL so also was the volume of the oil. However, the volume of water was kept constant at 15.0 mL. The figure shows an increase in the ratio of volume fraction of oil to water up to the surfactant concentration of about 1.7 %, at which point there was equal volume of oil and water and appears to be leveling off. However, as the concentration increased beyond 2.5 %, the increase in the water uptake was again observed. It is remarkable to observe that, although the volume of water was three times more than that of alcohol, the observed volume of the oil phase was much higher. In this case also, the surfactant was mainly solubilized in the oil phase, in direct contrast to what was observed in the absence of alcohol.

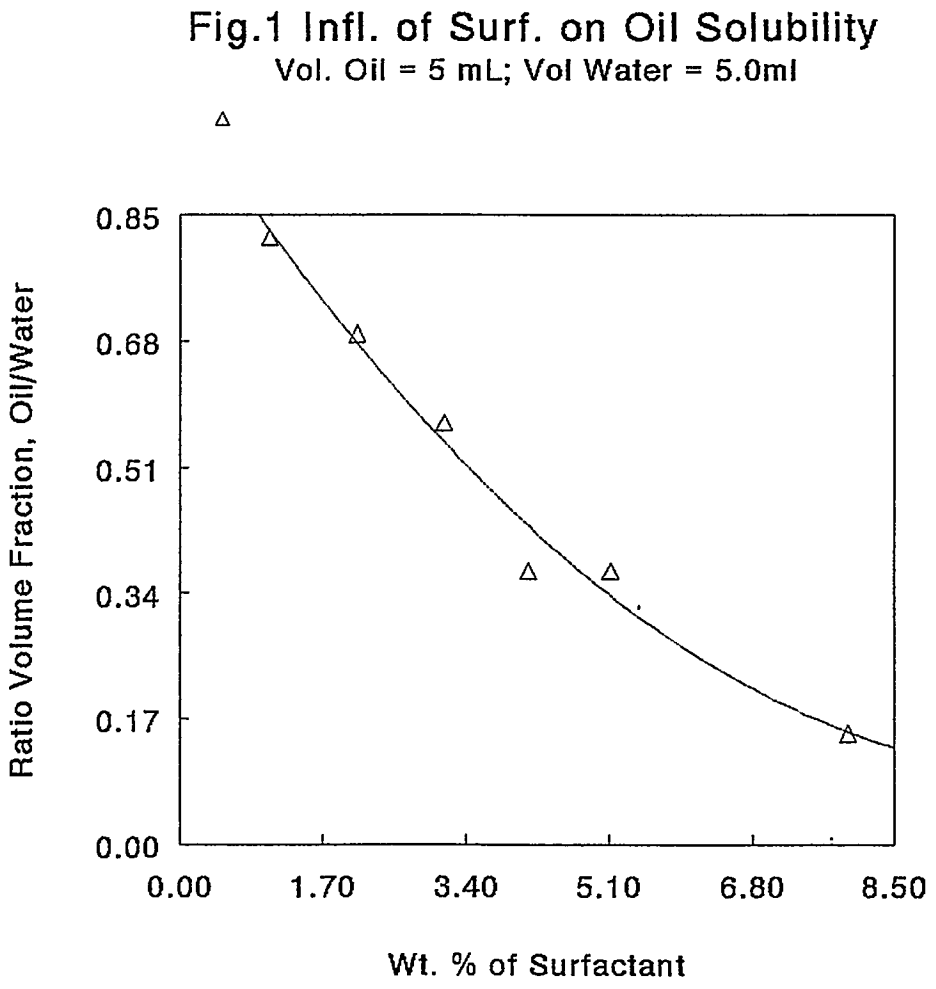
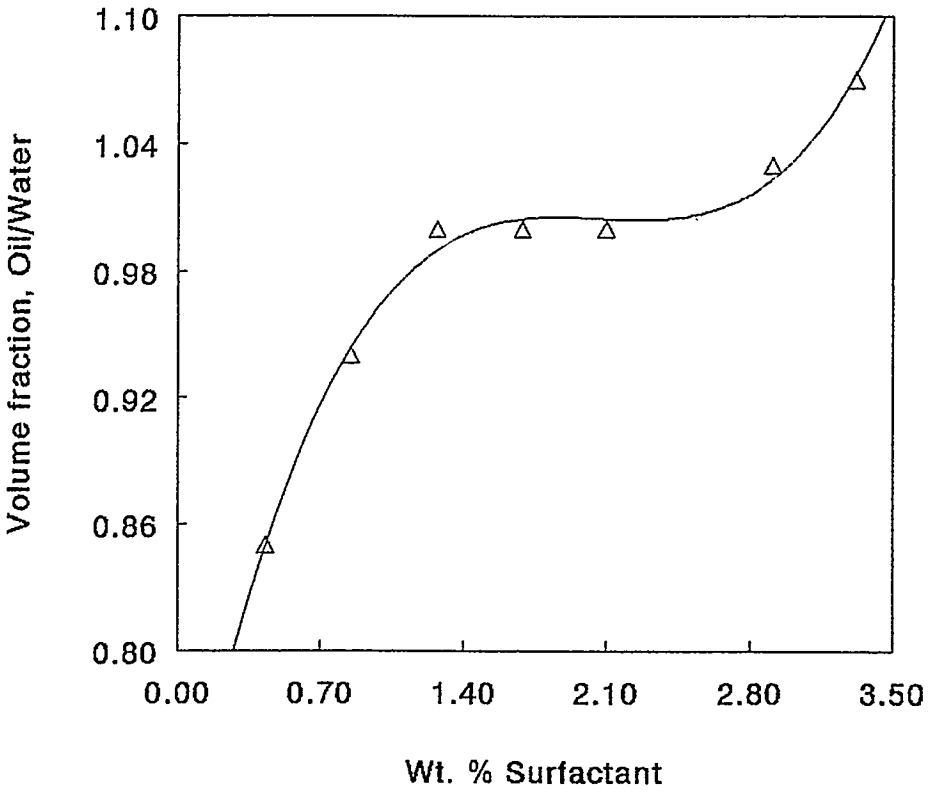


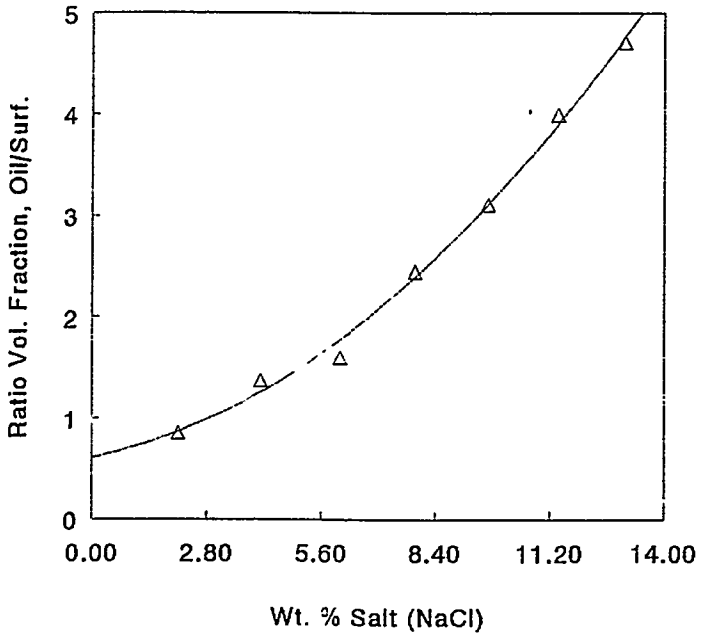
Fig.2 Infl. of Butanol on Phase Behavior
of Oil; Oil=5 mL; n-BuOh=5 mL, H2O=15 mL



Influence of Salt

In the fourth quarterly report we indicated that of all the salts evaluated, NaCl produced a higher middle phase which is considered advantageous for enhanced oil recovery project. In this report we show that the system under study not only produced a middle phase when sodium chloride was added, but also showed a remarkable ability to tolerate very high concentration of the salt. Figure 3 shows a profile of the volume fraction of oil to surfactant. In this experiment, the surfactant-salt weight ratio was kept constant at 0.2. The aqueous volume fraction was essentially constant at all salt concentrations at 0.6. The system makeup was the same as was used for the case of alcohol. As can be seen in this figure, there is shown an asymptotical increase in the ratio of the volume fraction of oil to surfactant as the salt concentration increases. We note here that during the surfactant concentration effect, described earlier, no middle phase was observed. The appearance of the middle phase upon addition of salt is quite common, however, the high salt concentration that was very well tolerated by this system is remarkable. Up to 4.0 grams (15.0 %) of salt was used in the experiment with no visible precipitation of the salt.

Fig.3 Infl. Salt on Oil Solubility
Vol.: Oil=5 mL; Water=15 mL; BuOh=5 mL



Rheology of the Burbank Crude Oil Emulsified by Aqueous DHDAB

Preliminary rheological study of the emulsion formed by the Burbank Crude Oil and DHDAB was carried out. In this experiment the emulsion was made up as follows: 13 mL of 0.02 M DHDAB and 3.0 mL of Oil. Figures four and five show that the system exhibits non-Newtonian behavior. This is manifested by the shear-thinning profile observed when observed viscosities were plotted against shear rate. The viscosity decreases as the rate of shear increases. Also the plot of shear rate versus shear stress also help to confirm the non-Newtonian neoplastic structure of this system.

Fig.4 Rheology of Burbank Oil
14 % Oil, 15 mL 0.02 M Surfactant

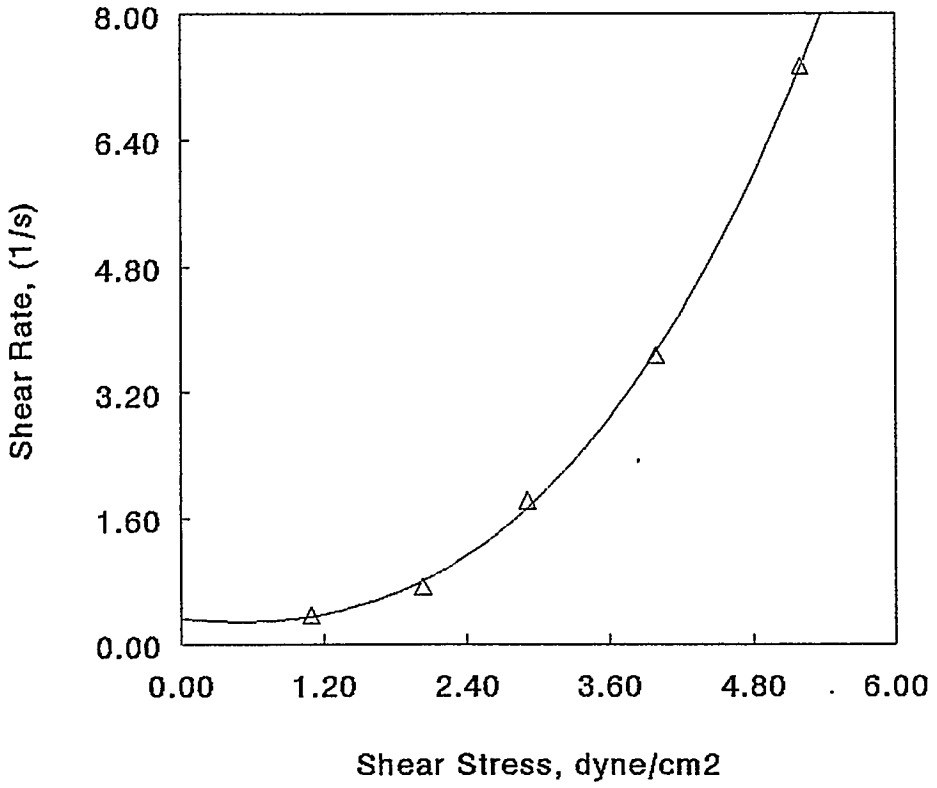


Fig.5 Rheology of Burbank Oil
14 % Oil, 15 mL 0.02 M Surfactant