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Separation Science and Technology

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713708471>

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A. I. Abubakar^a; J. O. Bello^{ab}

^a Department Of Chemical Engineering, Ahmadu Bello University, Zaria, Nigeria ^b National Research Institute for Chemical Technology, Zaria, Kaduna State, Nigeria

To cite this Article Abubakar, A. I. and Bello, J. O.(1991) 'Enhanced Coalescence of Emulsion in an Electric Field', Separation Science and Technology, 26: 10, 1329 – 1340

To link to this Article: DOI: 10.1080/01496399108050535

URL: <http://dx.doi.org/10.1080/01496399108050535>

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Enhanced Coalescence of Emulsion in an Electric Field

A. I. ABUBAKAR and J. O. BELLO*

DEPARTMENT OF CHEMICAL ENGINEERING
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA

Abstract

The action of an electric field on an emulsion produced effects like drop disintegration and promoted coalescence. High and low field intensities modify droplet displacements due to electrostatic forces. In this investigation a water-in-oil type of emulsion was prepared using distilled water and soap as the surfactant. After mixing, these emulsions were separated under an applied direct current high voltage electric field at a fixed 2.09 kV applied output voltage across the system. The time of coalescence, upper plate position, mixing time, and dispersion/coalesced phase volume interface are the parameters considered to influence the coalescence parameter and dispersion band hold-up. The results show that the prepared emulsion can be separated back into its bulk phases by using electric fields. The degree of separation depends on the applied voltage.

INTRODUCTION

Electrostatic methods are a means of improving phase separation if certain conditions are satisfied, and various type of electric fields facilitate coalescence between the droplets in a dispersion.

For this investigation, soap solutions were prepared at different concentrations, and kerosene was used as the continuous phase. The emulsion was prepared at different water/oil ratios, stirred at an impeller speed of 1200 rpm, and the mixing time was just long enough for the emulsion to form before it was transferred to a cylindrical cell. Coalescing time, dispersion/coalesced volume and interface under gravity, and electric fields were measured.

The purpose of this investigation was to separate the emulsion so formed into its original bulk components. The water-in-kerosene emulsion was formed in the presence of a soap solution as the surfactant. This separation

*To whom correspondence should be addressed at National Research Institute for Chemical Technology, P.M.B. 1052, Zaria, Kaduna State, Nigeria.

was to be aided by electric fields, in which the principal factor is droplet deformation. Gravity separation was compared with that under the electric fields.

The separation of emulsions is a fluid processing step which causes major difficulties in several industries; e.g., hydrometallurgy, crude oil operations where routine processing involves stable emulsions with water, and solvent extraction operations. Successful coalescence of the emulsion prepared in this work will be useful industrially. Crude oil contains mineral salts and water in the form of emulsion which needs to be separated before further processing. Electric fields offers a simple separation method. Similarly in the pharmaceutical industry, the use of electric energy could be found useful in separating some difficult emulsions, e.g., the extracts of materials from plants and tree-barks which sometimes require a very long time to separate. The use of a soap solution as the surfactant is justified because of what obtains when foams and emulsions are present during normal processing.

LITERATURE SURVEY

An emulsion is a relatively stable dispersion of a liquid in a second liquid in which it is sparingly soluble. The globules of the dispersed liquid in the usual type of emulsion (sometimes now called a macroemulsion) are usually between 0.1 and 10 μm in diameter. Microemulsions with drop diameters of 0.01 to 0.1 μm can also be prepared, and these are currently the subject of much fundamental research (1, 2) and new applications (e.g., oil recovery from porous rock). The two most common types of emulsion are "oil-in-water" (o/w) and "water-in-oil" (w/o), although it is possible to emulsify various pairs of immiscible liquids. Emulsions cannot usually be obtained without the presence of a third constituent, the emulsifying agent. This can be classified into two types, either according to their general chemical/physical nature or according to the type of emulsion which they promote (2, 3).

Emulsion can be prepared by agitating two liquids, leading in general to mutual penetration in the form of lamellae and threads which then break up into drops. The extent to which the respective liquids disrupt one another depends to a large extent upon the volume ratio, the viscosity, and the density of the two phases. Of other factors, low interfacial tension clearly facilitates break-up. The drops formed by agitation will rapidly coalesce unless stabilized by adsorption of the emulsifying agent, and equilibrium between break-up and coalescence is soon reached in its absence (1). Breaking of an emulsion involves creaming, which is regarded as a kind of sedimentation which causes an emulsion to separate into two layers,

one of which becomes richer in the dispersed phase while the other becomes richer in the continuous phase. Such stratification is due to the density difference of the oil and water phases.

The mechanical method of emulsion separation involves centrifugation, heating, freezing, and filtration through media which retain the emulsifying agent by adsorption. Emulsions can be broken chemically by the addition of a moderate quantity of a substance which stabilizes emulsions of the opposite type or which destroys the protective film around the globules and permits coalescence. Emulsion can also be broken by the application of intense electric fields, the principal factor involved being electrophoresis in the case of o/w emulsions and droplet deformation in the case of w/o emulsions.

Surfactant is a surface-active agents that, when present in a low concentration in a given system, imparts the property of adsorbing onto the surfaces or interfaces of the system. It alters the surface or interfacial free energies of those surfaces (or interfaces) to a marked degree. Ordinary soaps, which are alkali-metal salts of certain fatty acids such as palmitic, stearic, and oleic, are undoubtedly the best known and oldest surfactants.

Coalescence is the fusing together of an aggregate of globules to produce larger ones. A coalescence process using an electric field involves the formation of chains of drops prior to the actual coalescence since chains of drops are responsible for the conduction of current. The mechanism of chain formation appears to occur with all conducting particles immersed in a liquid of relatively high resistivity and subjected to an electric field. Chains of conducting particles in the insulating medium distort the electric field. Once a chain of large droplets is partly formed, the conducting path they provide acts as a local short circuit, and the potential differences across the gaps between groups of droplets become disproportionate to their length. Directed collisions and successful coalescence then occurs between drops attracted to each other by their unlike charges. Eventually the drops reach a size where they gravitate from the interelectrode region.

The coalescence parameter is defined as the percentage reduction in dispersion band depth caused by the field relative to that which occurred in the absence of an applied field. Hold-up is defined as the initial volume used to make the emulsion minus the aqueous band volume divided by the initial volume. The result is multiplied by 100 for the percentage.

An essential characteristic of a solvent extraction system is that one liquid phase is nonpolar or insulating relative to the other, more conducting polar phase. There is an important distinction in liquid-liquid dispersion, however, depending on whether they are of the "oil-in-water" or "water-in-oil" type. The difference is that the latter type has a continuous phase of an insulating character, e.g., kerosene, and therefore will sustain a high

voltage field and the polar liquid drops will retain any electrical charge they may acquire. This is a prerequisite for all electrical coalescence equipment, and it thus restricts their usage to the "water-in-oil" type of dispersions/emulsions (4, 5).

Recent investigations (4) into the use of dc high voltage fields for phase separation in systems containing a large volume fraction of a dispersed polar phase have resulted in the discovery that pulsed dc fields are very much more effective than a constant applied field, even when the pulsation frequency is much lower than might be expected.

EXPERIMENTAL PROCEDURE

The emulsion used for this investigation is a water-in-oil emulsion using distilled water as the disperse phase and kerosene as the continuous phase in the presence of soap as the surfactant. The ESAC 1 dc high voltage supply was calibrated by using a variable voltage regulator and avometer. Soap was crushed to fine particles, and soap solutions of different concentrations were prepared by using distilled water in a standard conical flasks of 250 mL capacity. The prepared solutions were then allowed to stand for 5–10 min to attainment steady concentration.

A known quantity of the prepared soap solution was measured into a 150-mL plastic beaker and the supplementary kerosene liquid was added to make up the desired water/oil ratio. This was then mixed by using a 4-blade stirrer at 1200 rpm. The emulsion that formed was transferred into a glass cell of 100 mL capacity. There was a fixed rubber cork in the bottom of the cell through which a metal rod of 1.6 mm diameter was centrally passed. The rod was welded to a brass plate of 27.0 mm diameter and which served as the earth electrode. The upper electrode was also of brass. The arrangement of the experimental set-up is shown in Fig. 1. The upper plate was positioned just above the dispersion/kerosene interface. The black lead of the ESAC 1 high voltage supply was connected to the bottom electrode to form the negative electrode, while the red lead was connected to the upper plate, making it the positive electrode.

As coalescence progressed, the upper plate electrode was kept in the dispersion/kerosene interface until all the dispersion band separated into aqueous and kerosene layers. The coalescing time, the upper plate position, the ESAC 1 voltmeter reading, and the aqueous interface were all recorded. The entire process was then repeated with different soap solutions and different water/oil ratios. Separations under gravitational forces were also investigated. Parameters such as coalescence parameter and hold-up were then calculated from the results.

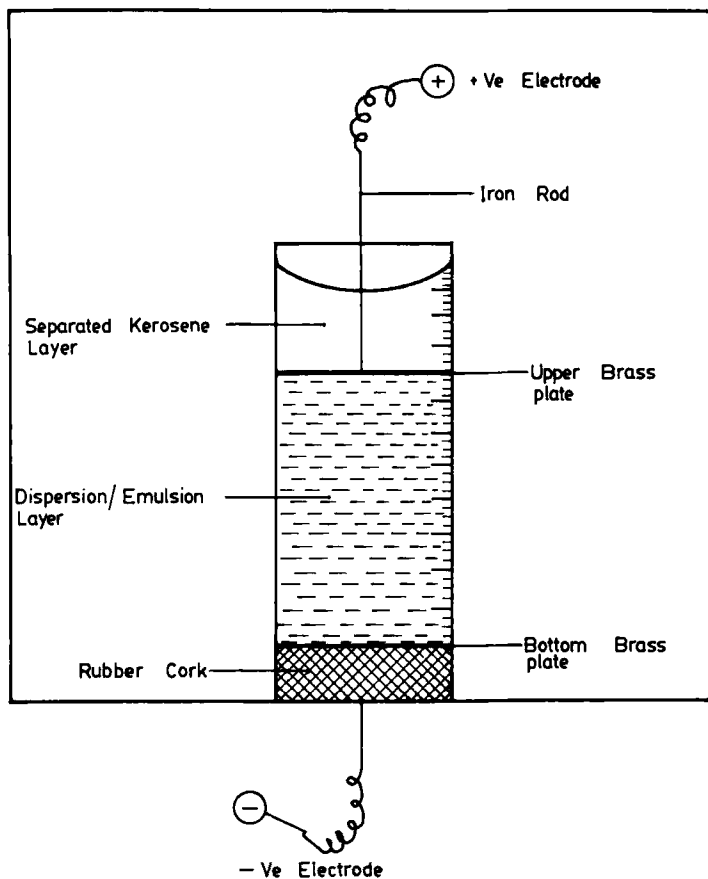


FIG. 1. Experimental set-up.

RESULTS AND DISCUSSION

The results of this investigations are presented in Figs. 2–7. From Fig. 2, an emulsion formed over the entire concentration range used can be separated into its bulk phase by using electric fields. Separation ranges from 58 to 95% recovery. It took 6 to 68 s to mix the system to form an emulsion, and the mixing time increased with an increase in the water/oil ratio, as shown in Fig. 3. The time taken for complete emulsion separation under electric fields ranged from 30 to 65 min as shown in Fig. 4. A minimum time was required at lower water/oil ratios, and the time needed increased as the water/oil ratio increased. This could be due to the increase

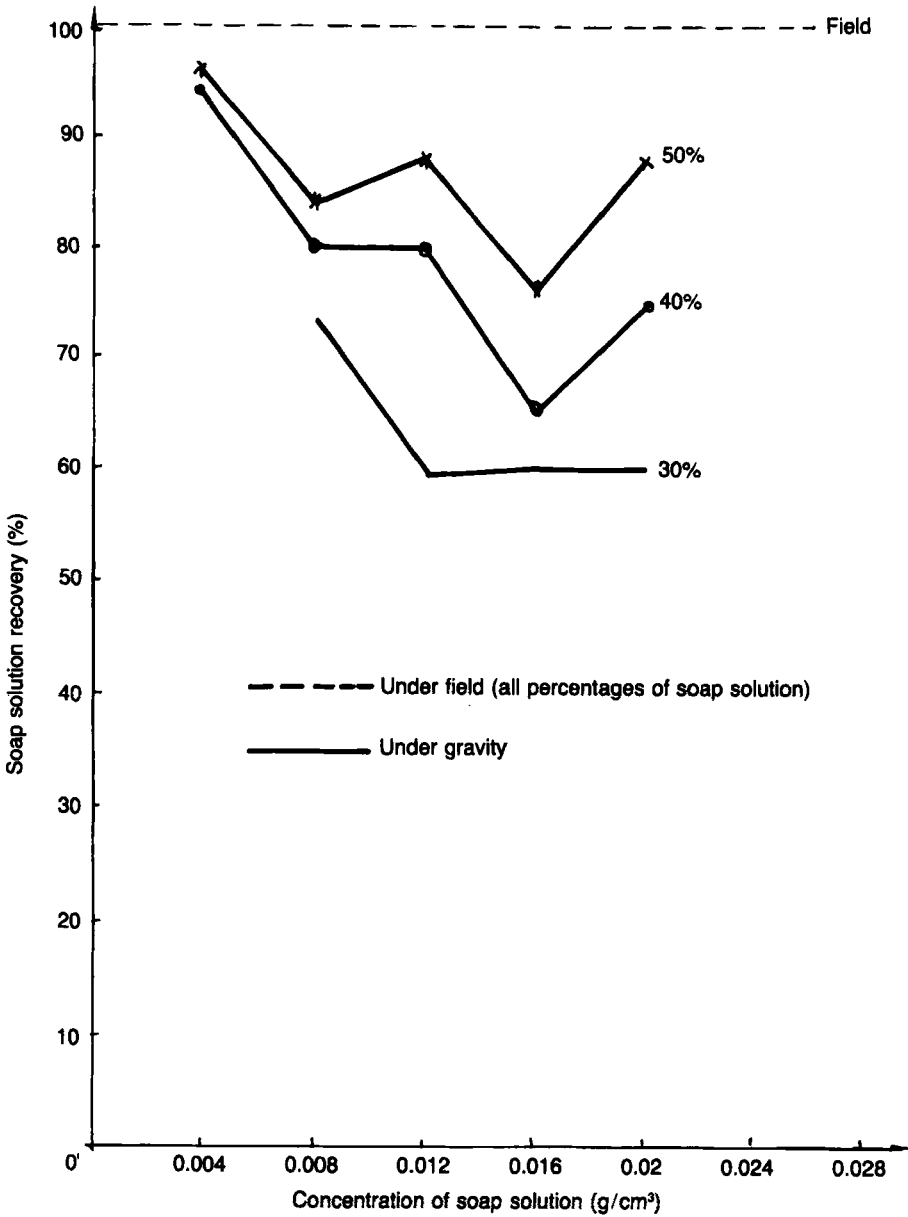


FIG. 2. Soap solution recovery under field and gravity.

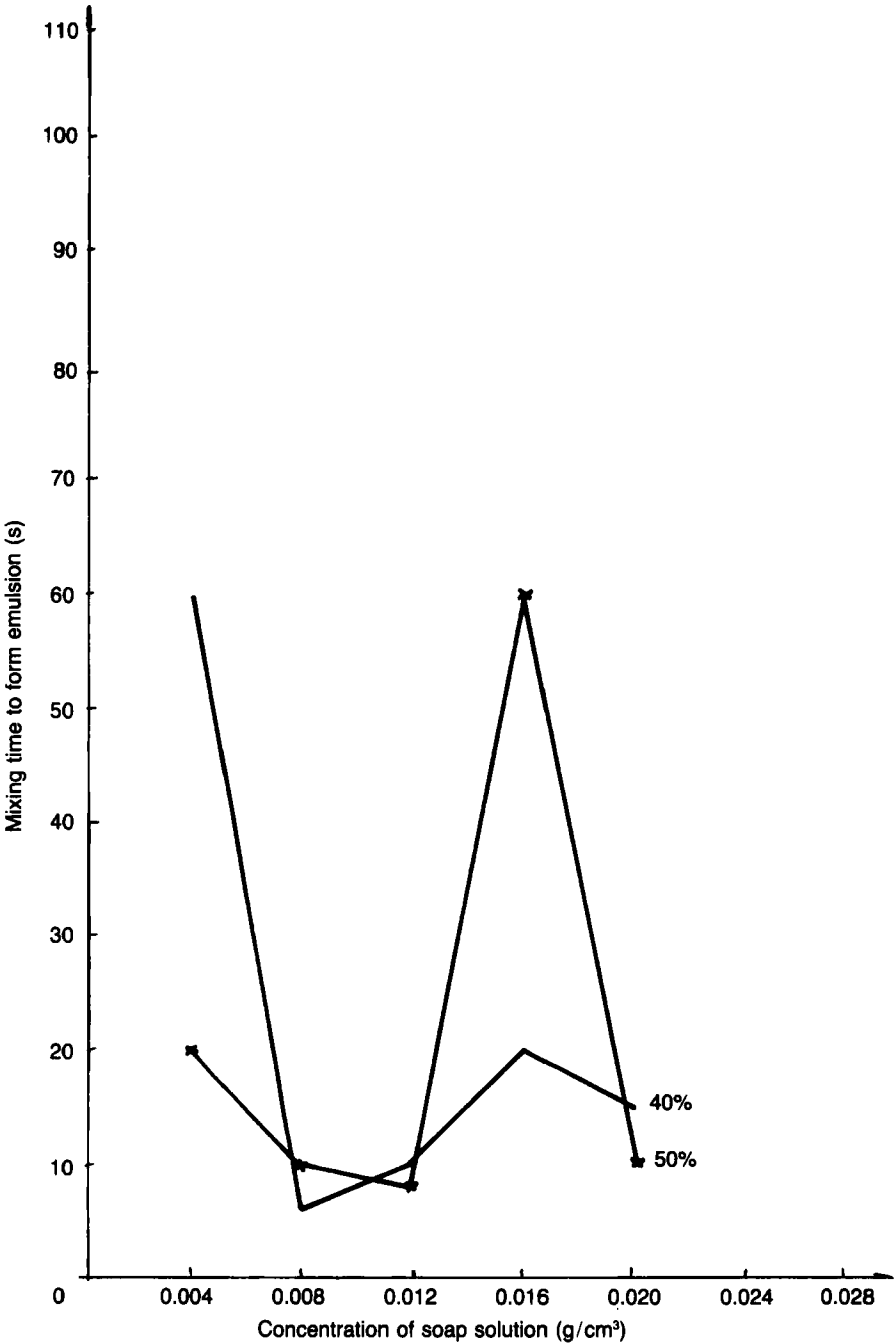


FIG. 3. Mixing time to form emulsion.

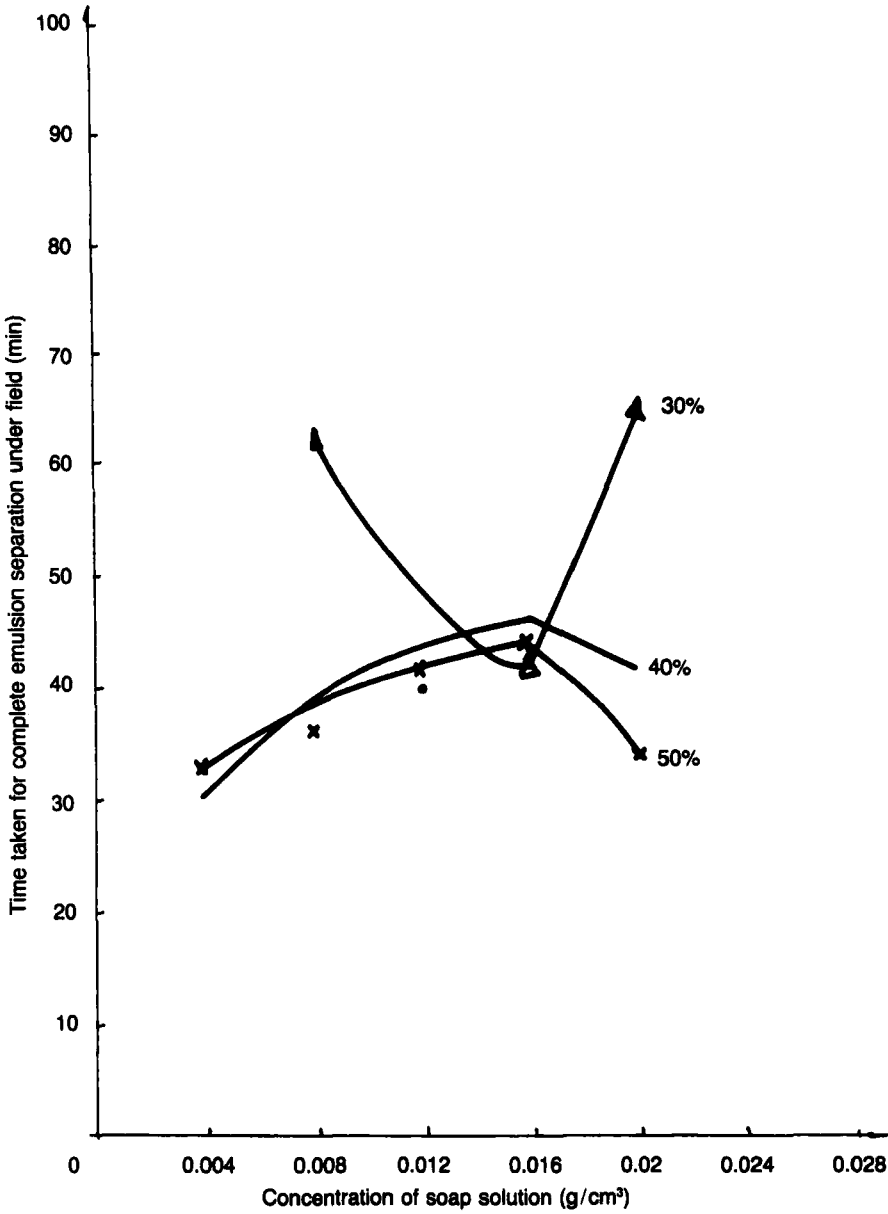


FIG. 4. Time for complete emulsion separation under field.

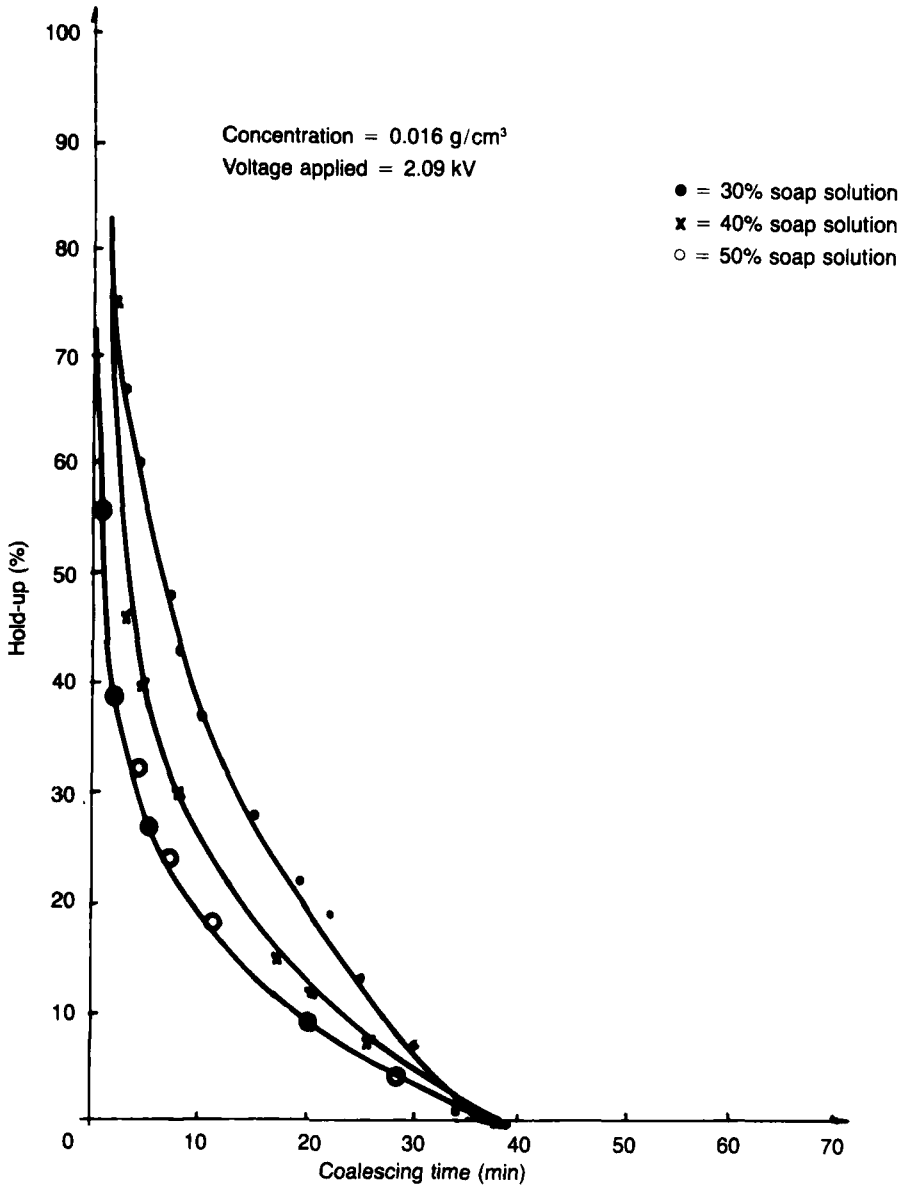


FIG. 5. Hold-up at 0.016 g/cm^3 and various percentages of soap solution used.

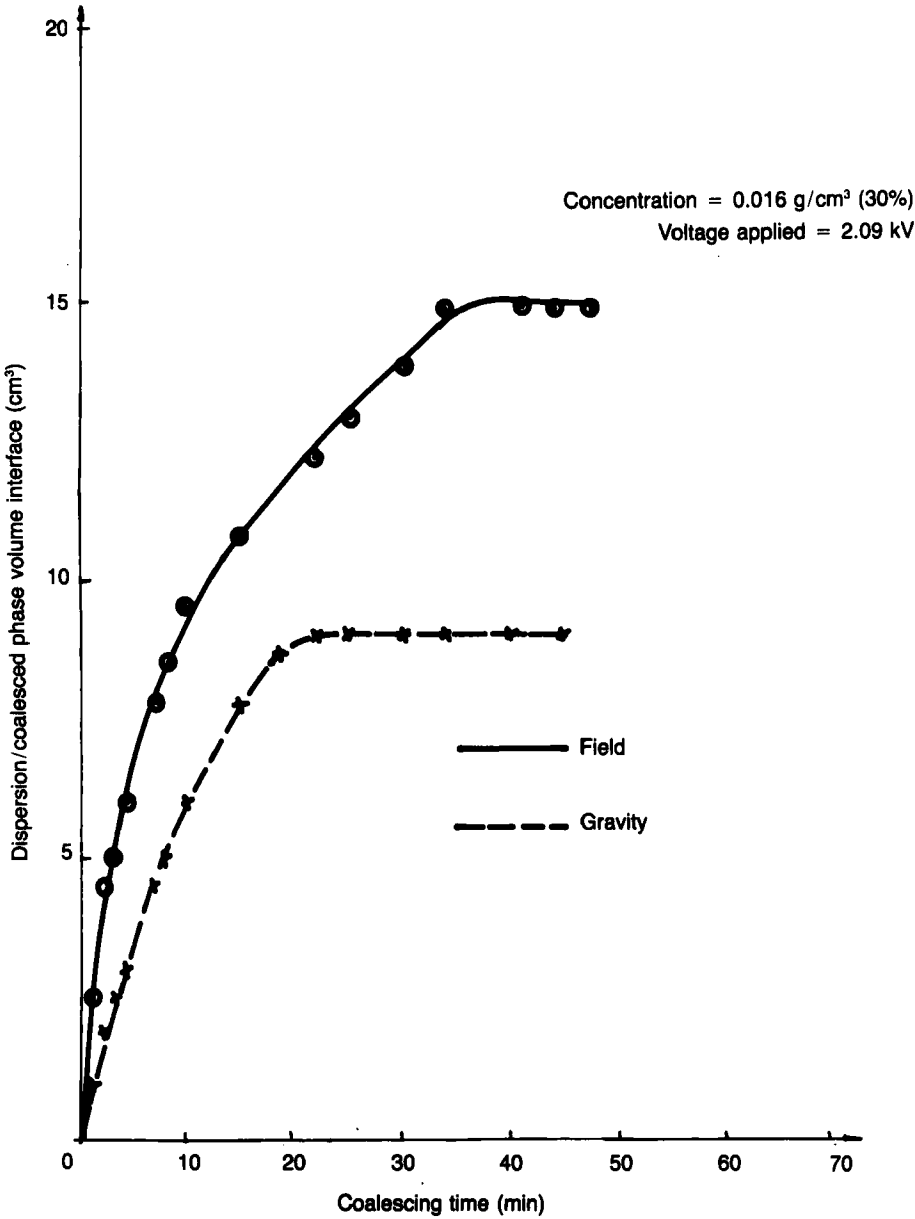


FIG. 6. Dispersion/coalesced phase volume interface.

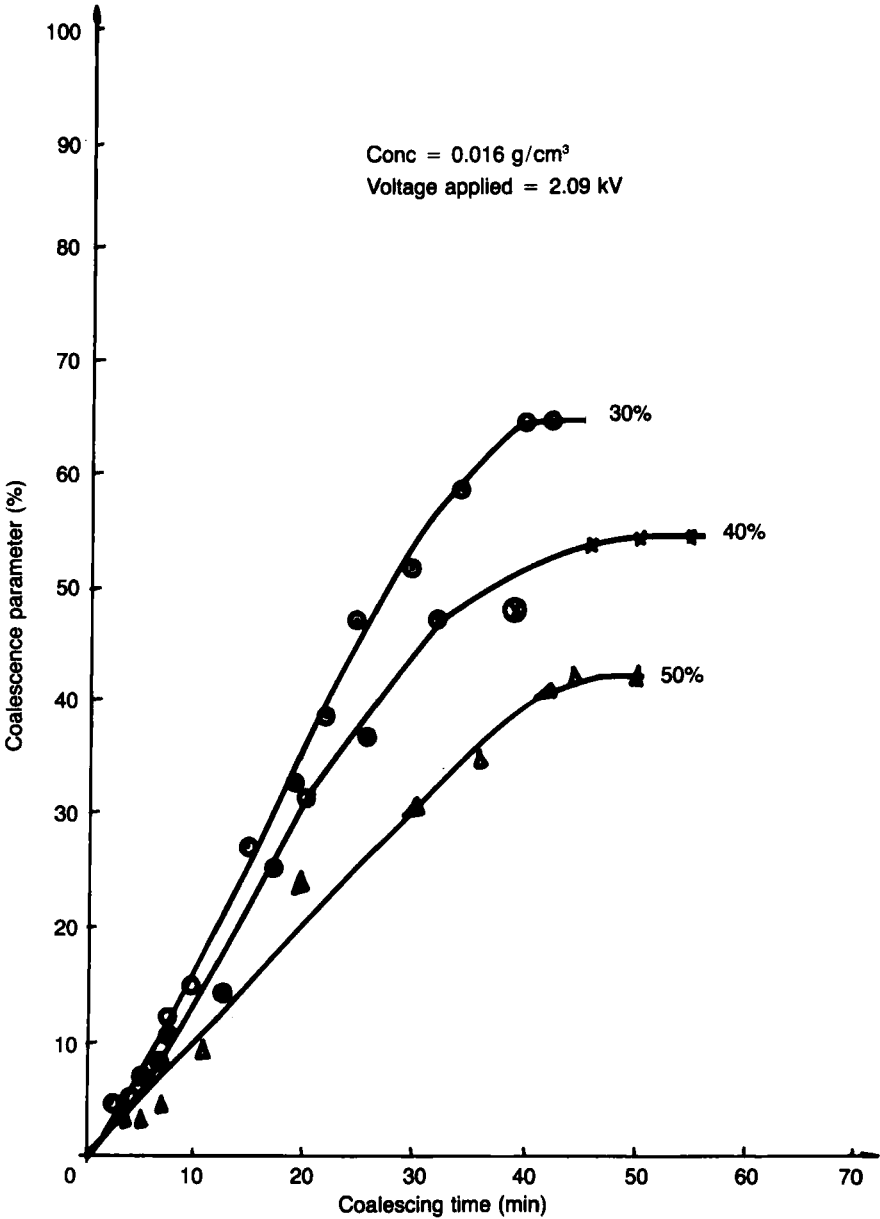


FIG. 7. Coalescence parameter at fixed concentration and applied voltage.

in distance between droplets and the lower viscosity at lower water/oil ratios.

Figure 5 shows that for a constant coalescing time the hold-up increases with a decreasing percentage of soap solution when an electric field is applied. This could be due to the increasing distance between droplets as the amount of soap solution used decreases, which means more time is required for separation. However, an increase in concentration has reduced the time for separation. This could be due to increased viscosity and the formation of bigger droplets at an increased soap solution concentration, because larger droplets can more easily unite upon application of an electric field. The dispersion/coalesced phase volume interface has no appreciable difference for gravity separation compared with electric field separation at low coalescing time. However, at higher coalescing times the difference is appreciable. This is shown in Fig. 6.

Figure 7 presents the coalescence parameter for different soap solutions used under an electric field. As the coalescing time increases, an appreciable difference exists in the coalescence parameter, which increases with a decreasing percentage of soap solution.

CONCLUSIONS

1. Electric fields enhance coalescence rates between small drops so that drop sizes suitable for gravity separation are more speedily attained.
2. For all the concentrations of soap solutions used, 100% recovery was attained in the electric field.
3. The coalescence parameter increased with an increase in coalescing time.
4. The coalescence parameter increased with a decrease in the percentage of the soap solution used.
5. It is possible to coalesce an emulsion of water-in-oil completely by using an electric field.

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Received by editor October 19, 1990