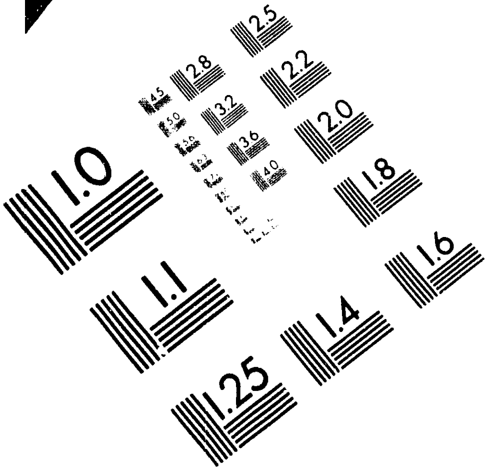

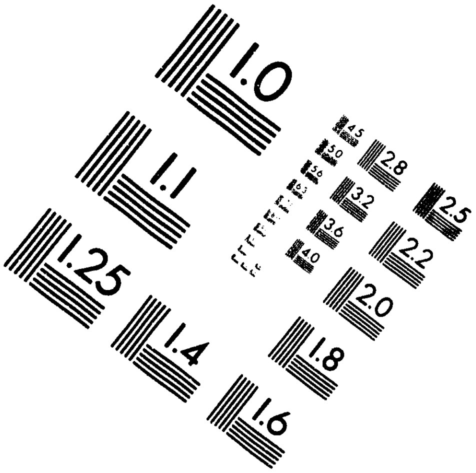

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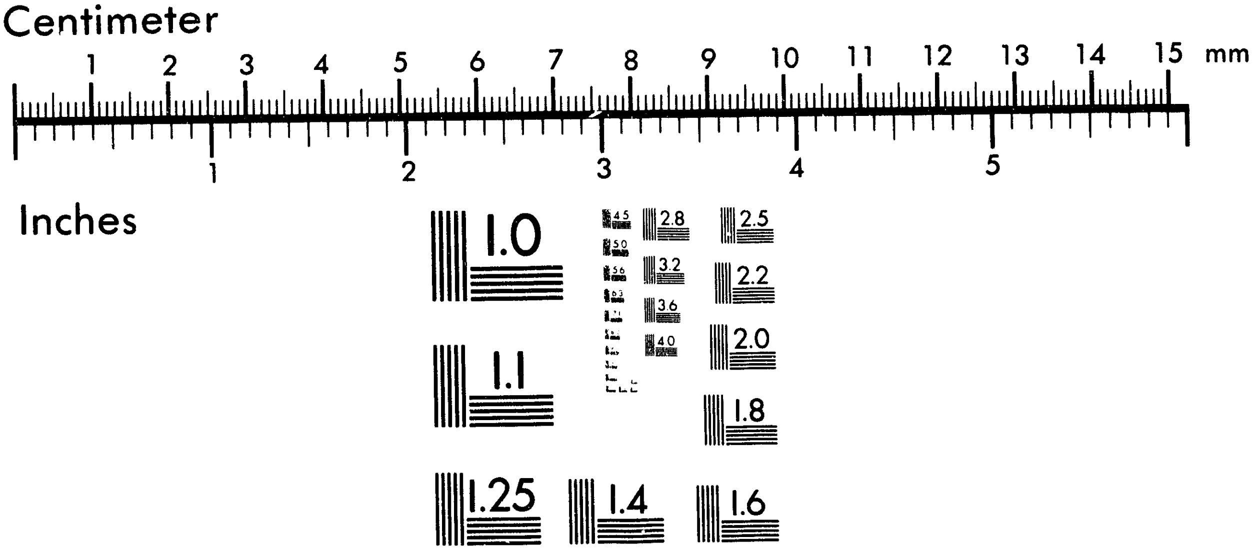

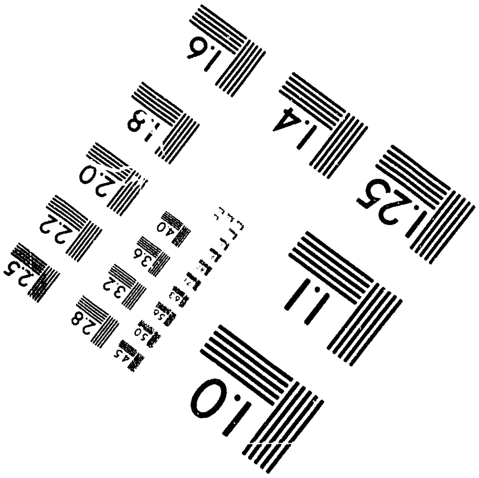

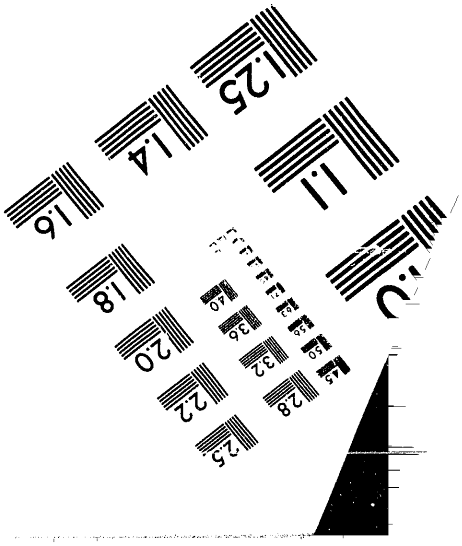

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SURFACTANT-ENHANCED ALKALINE FLOODING FOR LIGHT OIL RECOVERY

Contract No. DE-AC22-92BC14883

Illinois Institute of Technology
Chicago, IL

Contract Date: Sept. 1992
Anticipated Completion: Sept. 1993
Goverment Award: $150,000
(Current year)

Principal Investigator:
Darsh T. Wasan

Technical Project Officer:
Jerry F. Casteel
Bartlesville Project Office

Reporting Period: March 31-June 30, 1993

OBJECTIVE

The overall objective of this project is to develop a very cost-effective method for formulating a successful surfactant-enhanced alkaline flood by appropriately choosing mixed alkalis which form inexpensive buffers to obtain the desired pH (between 8.5 and 12.0) for ultimate spontaneous emulsification and ultra-low tension. In addition, the novel concept of pH gradient design to optimize flood water conditions will be tested.

SUMMARY OF TECHNICAL PROGRESS

Last quarter[1] we have investigated the mechanisms responsible for spontaneous emulsification in alkali/acidic crude oil systems with and without added surfactant. We have observed that the roll cell size and formation time depend strongly on the pH and ionic strength of the alkaline solution. For a particular roll cell size, the addition of surfactant causes the cells to take longer to form, causing an interfacial resistance to mass transfer and making the interface more rigid. We have shown that interfacial turbulence is a necessary but not sufficient condition for spontaneous emulsification. Low interfacial tension is also a necessary condition.

This quarter a microwave interferometric procedure was developed for the determination of low water content (0.5 to 10 vol%) of water-in-oil macroemulsions. The apparatus operates at a frequency of 23.48 GHz in the K-band microwave region. The procedure is based on the large differences in dielectric properties between water and oil, and it utilizes the variation in phase shift as sample path length is varied. Measurements are accurate to within 0.5 vol% water.

MATERIALS AND EXPERIMENTS

The oil phase consisted of a blend of 19.2% carbon tetrachloride in 80.8% light mineral oil of which was made a 2% solution of Span 80. The water-in-oil emulsion was made with deionized water and ranged from 0 to 10%. The emulsion was prepared by drop-wise addition of water into the stirring oil phase. All solutions were made on a volume (v/v) percent basis.

The microwave interference dielectrometer constructed and described by Perl et. al (1) was used in this study. Operation was at a frequency of 23.48 GHz. The teflon cell used to contain the sample was modified for temperature control. Experiments were carried-out at 30 ^{o}C.

The microwave transmission equations (1) are given for the real part of the complex dielectric constant as

$$\epsilon' = \left(\frac{1}{A} + \frac{2\beta_g\left(\frac{\Delta L}{\Delta t}\right)}{\beta_o A}\right)^2 \qquad [1]$$

Where, $\Delta L/\Delta t$ is the slope of the phase shift versus path length. Also, $\beta_g = 2\pi/\lambda_g$ and $\lambda_g = 1.597$ cm as determined by slotted line measurements of the distance between successive minima. Here, $\beta_0 = 2\pi/\lambda_0$, where $\lambda_0 = C/F$ and C is the speed of light and F is the frequency. Therefore, $\lambda_0 = 1.278$ for F=23.48 GHz. Also,

$$A = \left[\frac{1 + \left(1 + (\epsilon''/\epsilon')^2\right)^{\frac{1}{2}}}{2}\right]^{\frac{1}{2}} \qquad [2]$$

Eqn. [1] then becomes

$$\epsilon' = \left[\frac{1}{A} + \frac{(1.601)\left(\frac{\Delta L}{\Delta t}\right)}{A}\right]^2 \qquad [3]$$

and the imaginary part is given by

$$\epsilon'' = \alpha_s \sqrt{\epsilon'} A (0.0469) \qquad [4]$$

where, α_s is the slope of the attenuation versus path length.

As reported by Perl et. al. (1), the determination of the complex dielectric constant requires an iterative solution to solve Eqns. [3] and [4], which convert the experimentally measured attenuation and phase shift into real and imaginary parts of the complex dielectric constant. Eqns. [3] and [4], however, can be combined to obtain an exact solution given by

$$\epsilon' = \left[1 + 1.601\left(\frac{\Delta L}{\Delta t}\right)\right]^2 - [0.0234\alpha_s]^2 \qquad (5)$$

and

Where, ε' and ε'' are the real and imaginary parts of the dielectric constant.

$$\epsilon'' = 0.0469\alpha_s[1 + 1.601(\frac{\Delta L}{\Delta t})] \qquad (6)$$

RESULTS AND DISCUSSION

The ability to determine on-line moisture content and structure of dispersed systems is important in a number of areas, such as, cost-effective drying in process industries, bound moisture determination for safety of food and drugs, dryness of crude oil, emulsion type and composition determination, such as in the treatment of oily sludge or in-line process control.

The dielectric constant of a sample containing water can be determined accurately down to about 10% water content, using microwave interferometry (1). This arises because the attenuation of the sample is low when the moisture level is low. The detection limit of the instrument is reached when attenuation of the sample equals the instrument noise. The noise can arise from several sources. The principle contribution to noise arises from multiple reflections from the sample surfaces. Our purpose is to develop a technique for determining the low water content (0 to 10 vol%) of a water-in-oil emulsion using microwave interference dielectrometry.

Microwave transmission dielectric interferometry as a tool to measure water content operates on the basis of a large difference in the dielectric constants between the dispersed (i.e., water) phase and the continuous (i.e., oil) phase. At 23.45 GHz, the real part of the dielectric constant for water is 33.28 (1) and that for oil is 2.

In the determination of the real and imaginary parts of the complex dielectric constant, the slotted line for signal phase shift and precision attenuator for signal amplitude is balanced after insertion of the sample into the dielectrometer. The slope of the attenuation versus path length (see Fig. 1) and the slope of the phase shift versus path length (see Fig. 2) can be used to calculate the complex dielectric constant. However, resonance effects become very pronounced at low water content. Resonation takes place mainly between the sample surfaces, which causes an oscillation of the attenuation as path length is varied as shown in Figure 1 for a 3% water-in-oil emulsion. As a result, the complex dielectric constant cannot be determined.

Figure 2 shows that the phase shift varies linearly with the path length at low water content. If this slope is plotted versus water content, the results can be seen in Figure 3. Figure

3 shows that phase shift measurements alone are accurate enough to determine water content to within 0.5%.

SUMMARY

Simple exact solutions to the transmission equations have been derived, thus allowing determination of complex dielectric constant without time consuming iterative procedures. Moisture levels are shown to be detectable with an accuracy of about 0.5 volume percent water content using microwave interferometric dielectrometry. The ease of obtaining the data, the noninvasivity of the measurement technique, and the rapidity with which results are obtainable makes low water content determination using dielectrometry highly desirable in comparison to a wet technique such as Karl Fisher titration.

PRACTICAL APPLICATIONS

The interferometric dielectrometer is a useful tool for monitoring two-phase oil/water saturation in porous media. The dielectrometer can also be used to detect emulsion type and water content. It is also useful in monitoring the dryness of the post-produced crude oil.

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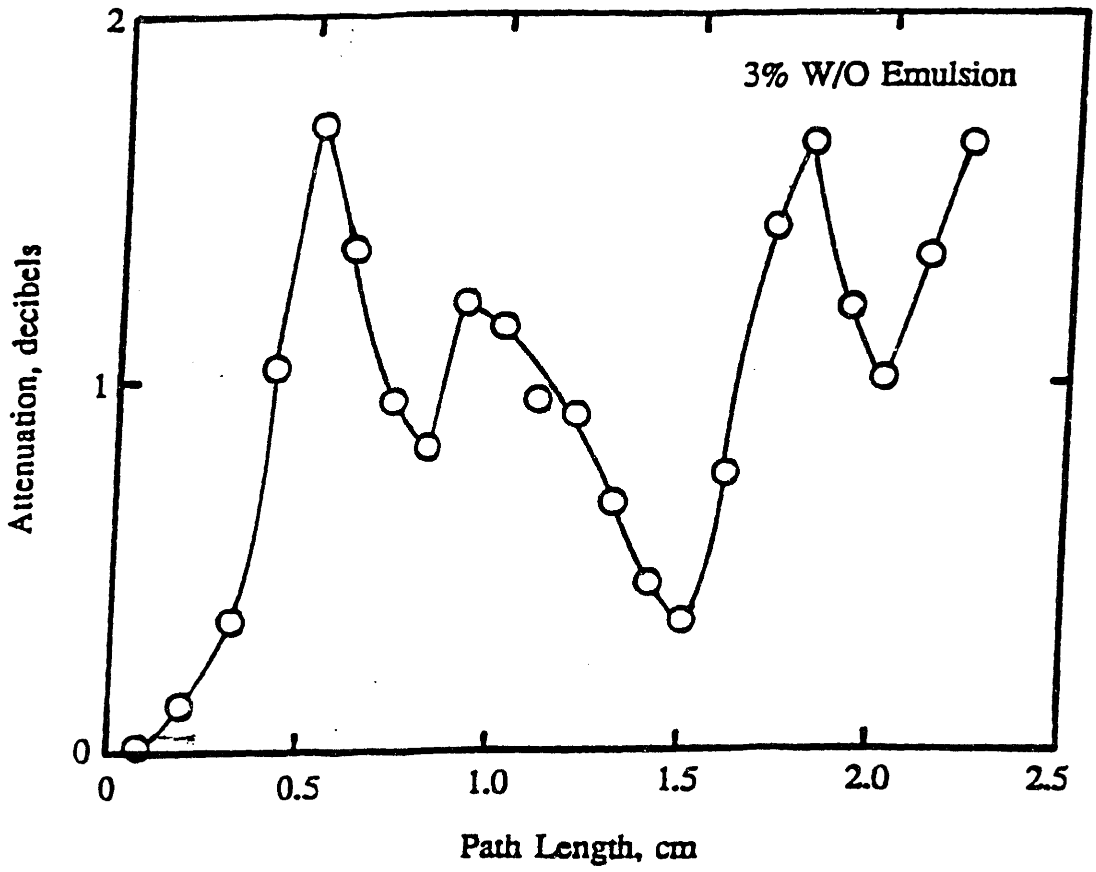

Figure 1. Attenuation Versus Path Length at 23.48 GHz and 30 °C.

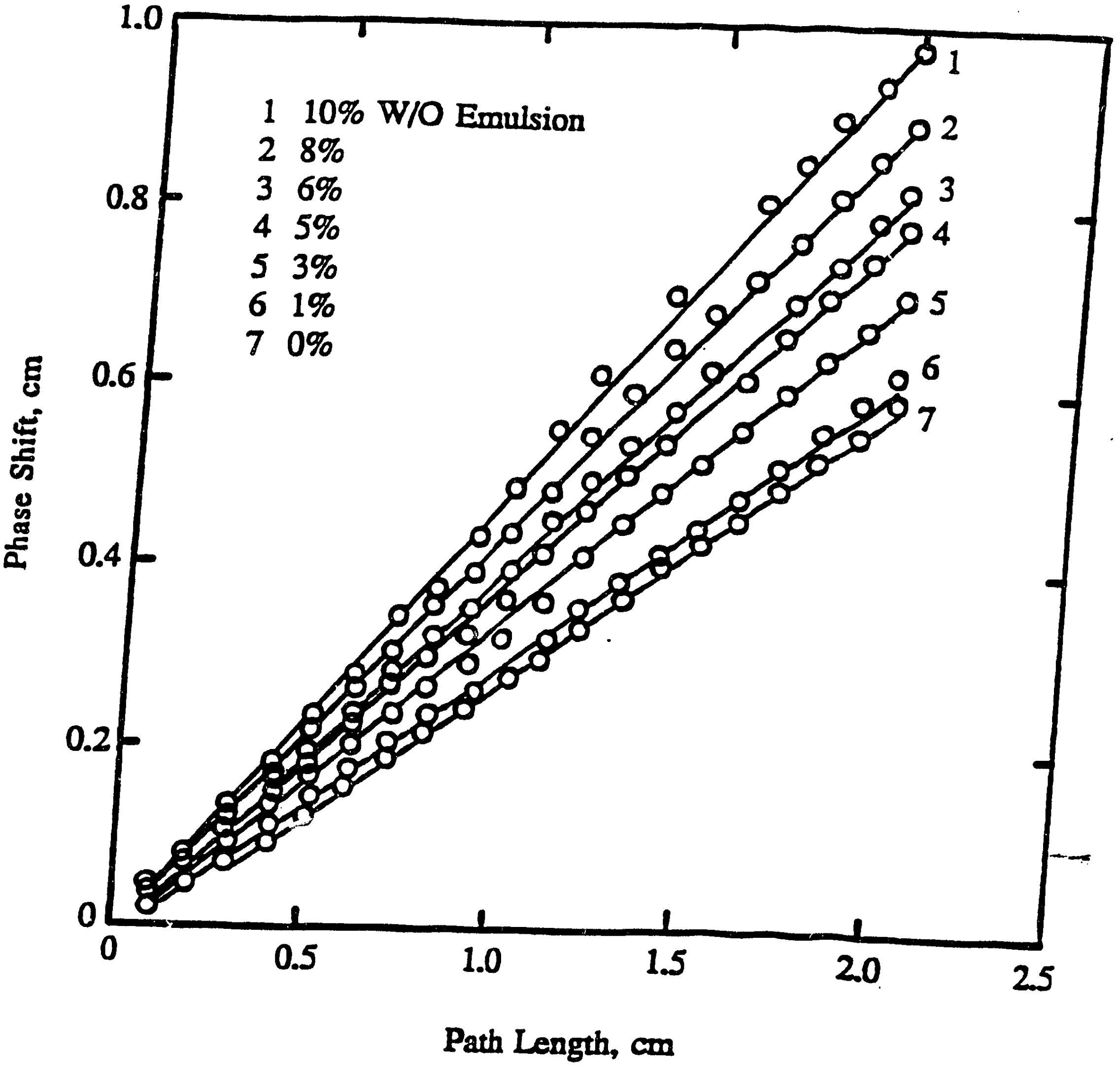

Figure 2. Phase Shift Versus Path Length at 23.48 GHz and 30 °C.

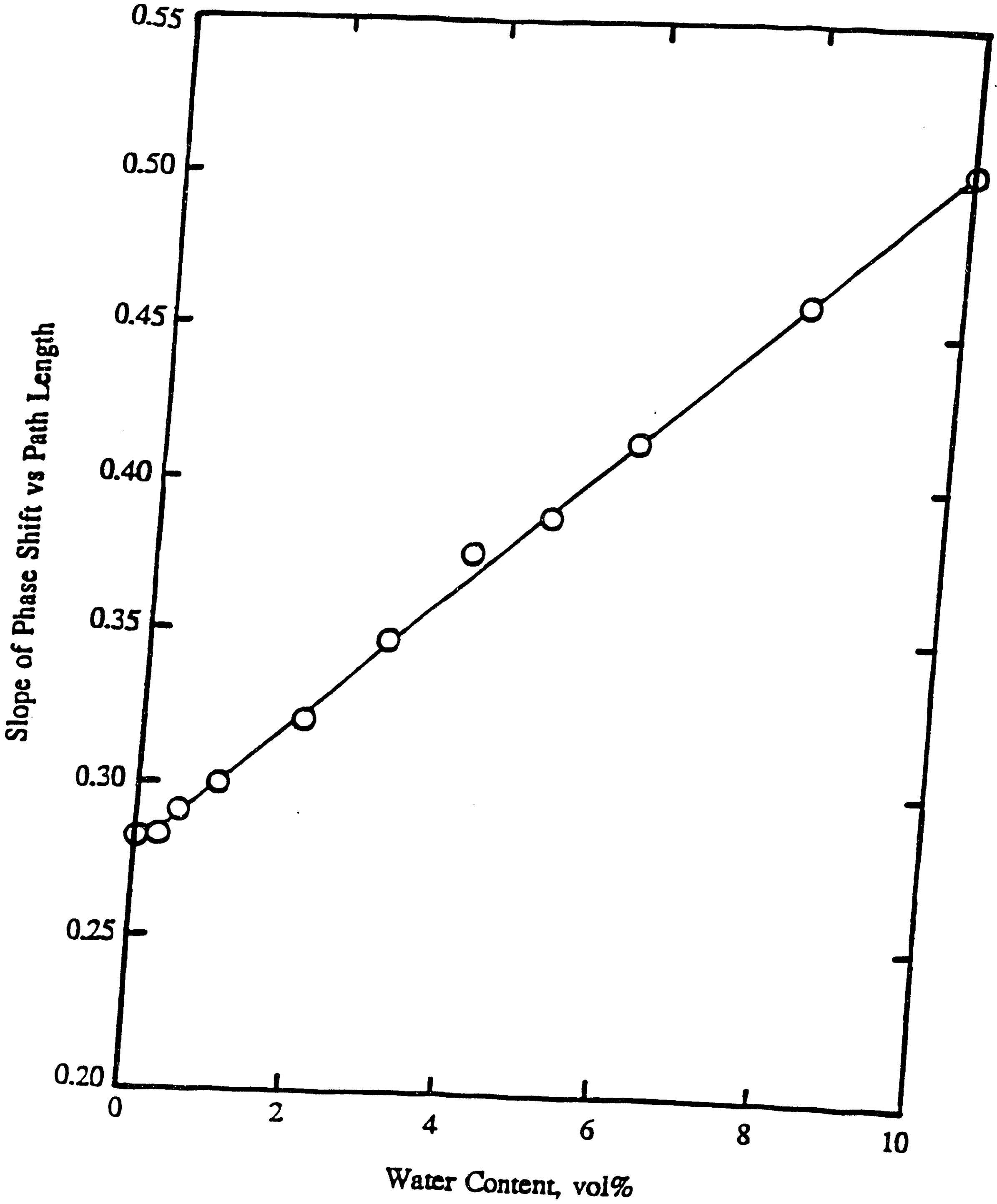

Figure 3. Slope of Phase Shift Versus Path Length as a function of water content at 23.48 GHz and 30 °C.

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