Measurement of Interfacial Tension in Oil/Water/Dispersant Systems at Deepwater Conditions

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Oil Spill Response Research & Development Forum

January 10-11, 2012

2003 National Champions

2007 – We did it again!

Project Objectives

- Establish a laboratory apparatus capable of replicating the deepwater oil spill conditions for both density and IFT measurements.
- Measure the densities of hydrocarbon and water of different salinities at the representative conditions of pressure and temperature.
- Utilize the computerized pendant drop method to measure the hydrocarbon/water IFT at the deepwater conditions, with and without the addition of dispersant.
- Evaluate the effectiveness of chemical dispersants through the reduction in the hydrocarbon/water IFT.
- Quantify the effects of temperature, pressure and water salinity on the hydrocarbon/water IFT to fill the existing void in low temperature/high pressure IFT data.

Methodology

- Manufacture a specially designed optical cell to be used at low temperatures and high pressures (up to 20,000 psi); it will be constructed of titanium and Hastelloy parts with glass windows on opposite sides. The latter elements will allow the capture of drop profile images which will be used together with image analysis software to calculate the interfacial tensions.

- Measure live oil and brine densities using a PAAR DMA 45 density meter at deepwater conditions.

- Measure oil-water interfacial tension as a function of T, P and salinity (at varying dispersant concentrations) using:

  The pendant drop technique (with axisymmetric drop shape analysis of captured images of oil drops in water)

  The capillary rise technique (to measure low interfacial tensions expected with dispersants)

Experimental Methodology

Procedure

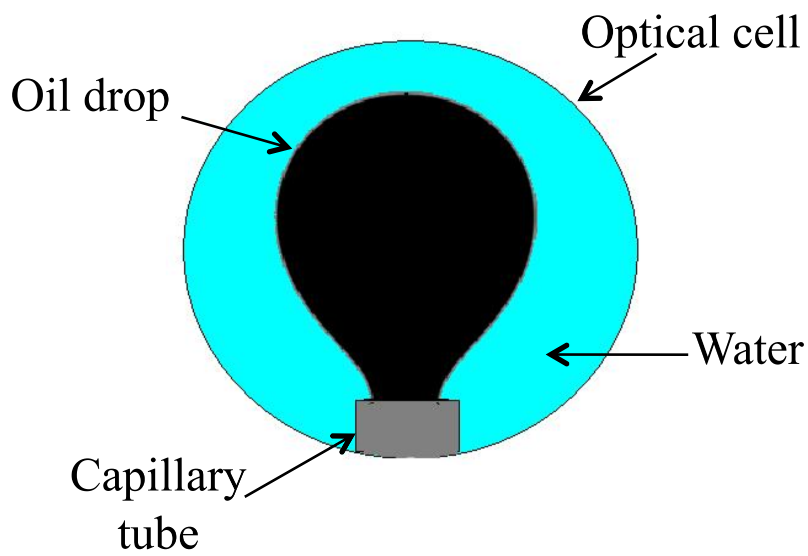
The pendant drop method

- The equilibrium shape of a hanging pendant drop is a balance between gravity which pulls the drop upwards by elongation, and surface tension which acts to prevent the growth of surface area and pulls the drop into a spherical shape.

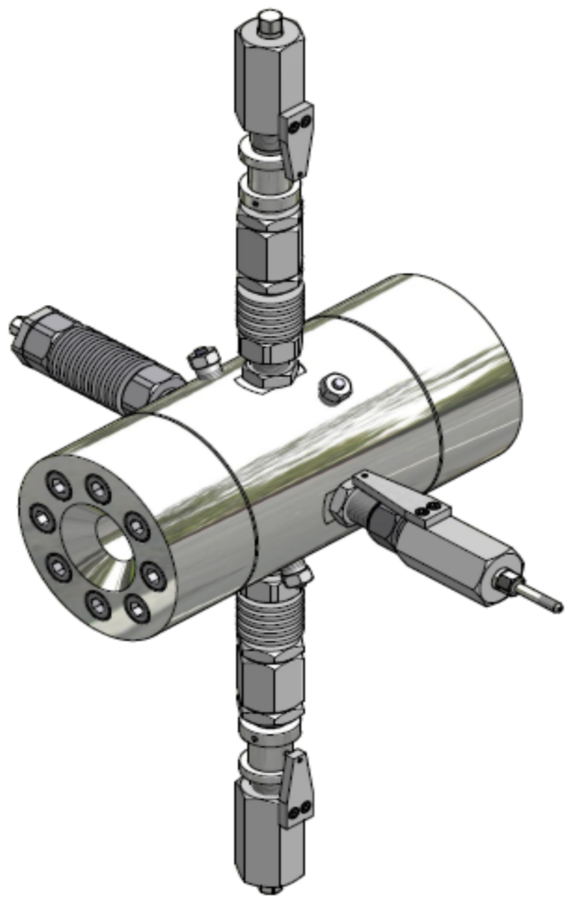
- The tendency of the interface to create the smallest surface area, gives rise to a pressure difference- capillary pressure- between the two fluids on either side of a curved interface:

$$\Delta P = \gamma \, (1/R_1 + 1/R_2)$$

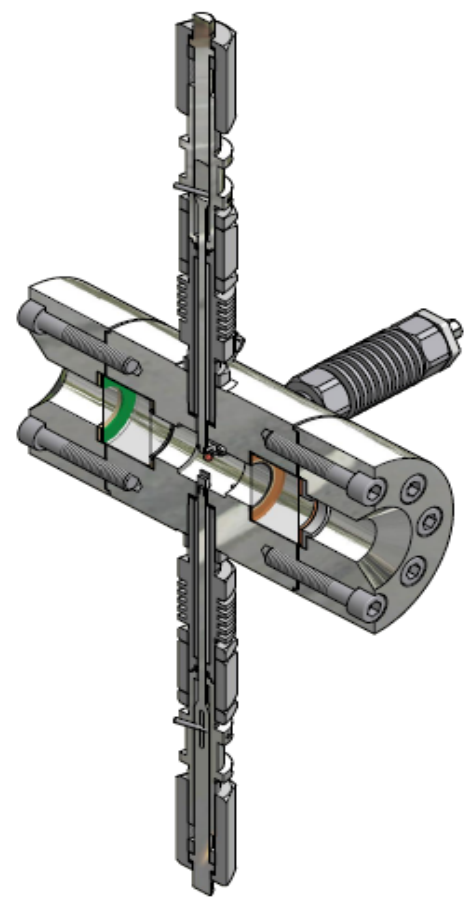
- A drop of oil is slowly introduced through a capillary tube into a water-filled optical cell. An image of the drop is captured just before it detaches from the tip of the tube using a digital camera. The image is then transferred to a computer for image analysis.



Schematic Drawing of the Newly Designed Optical Cell



3D View

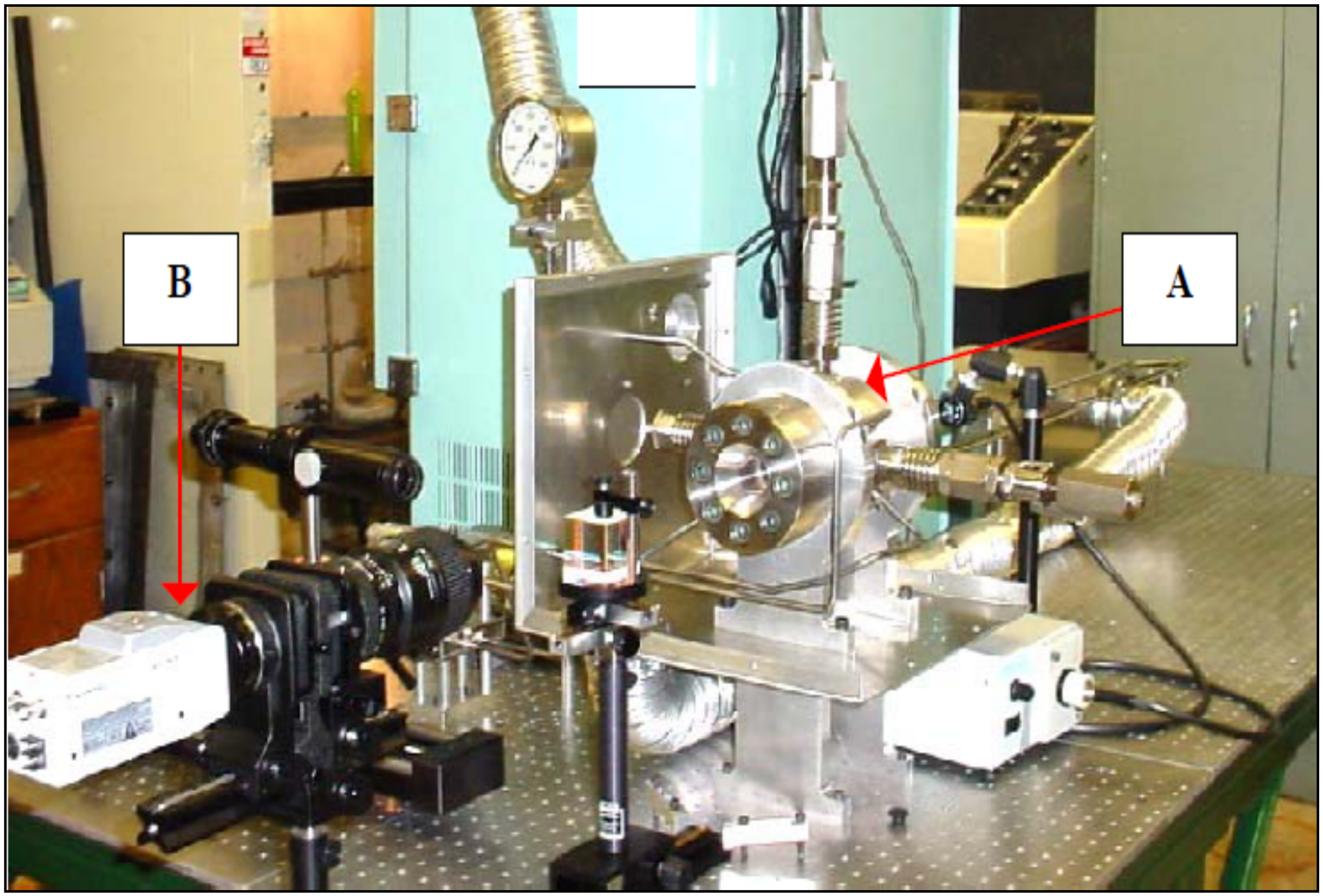


Length-Wise Cross-Section

Experimental Methodology

The Low Temperature/High Pressure Optical Cell Apparatus

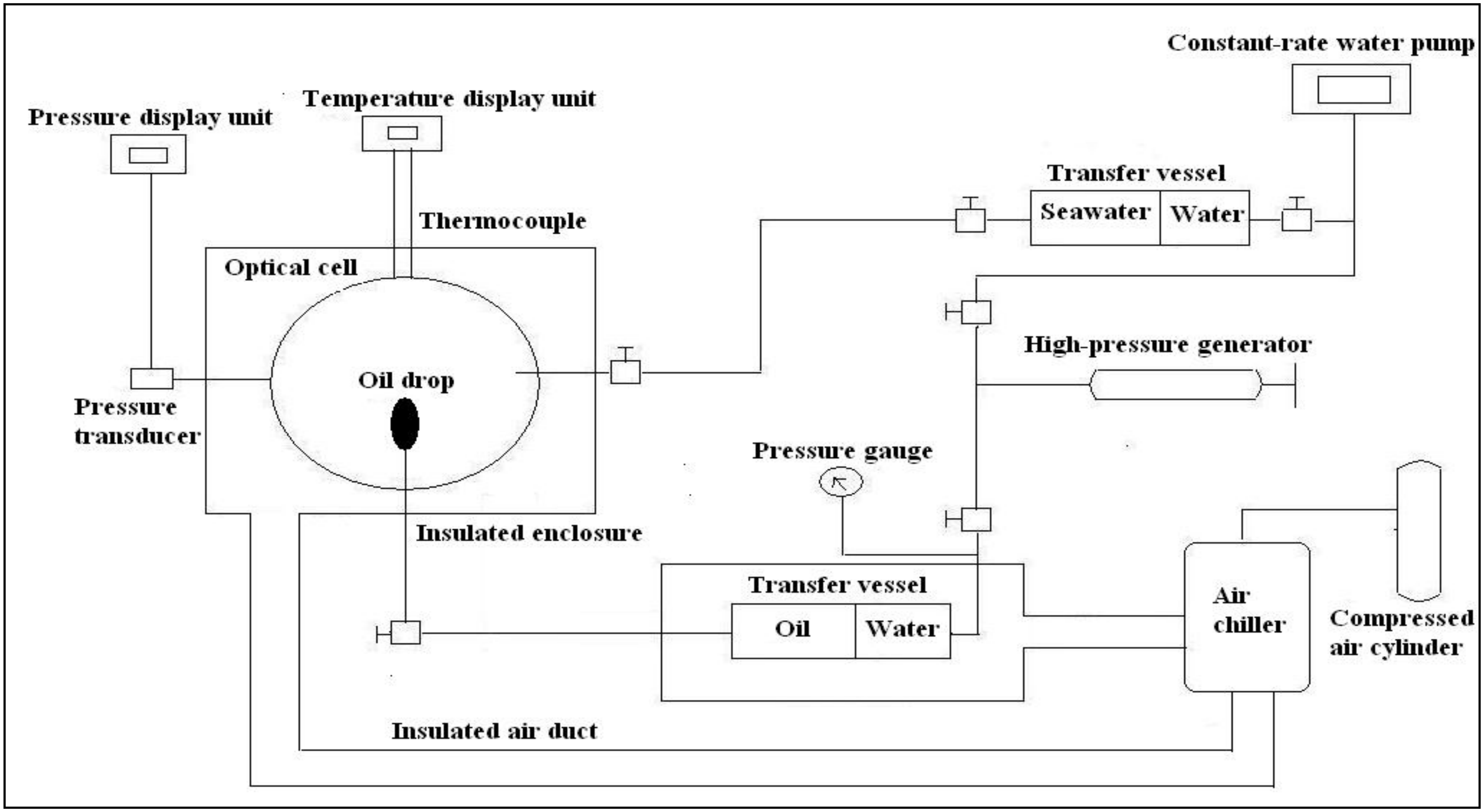
Air chiller



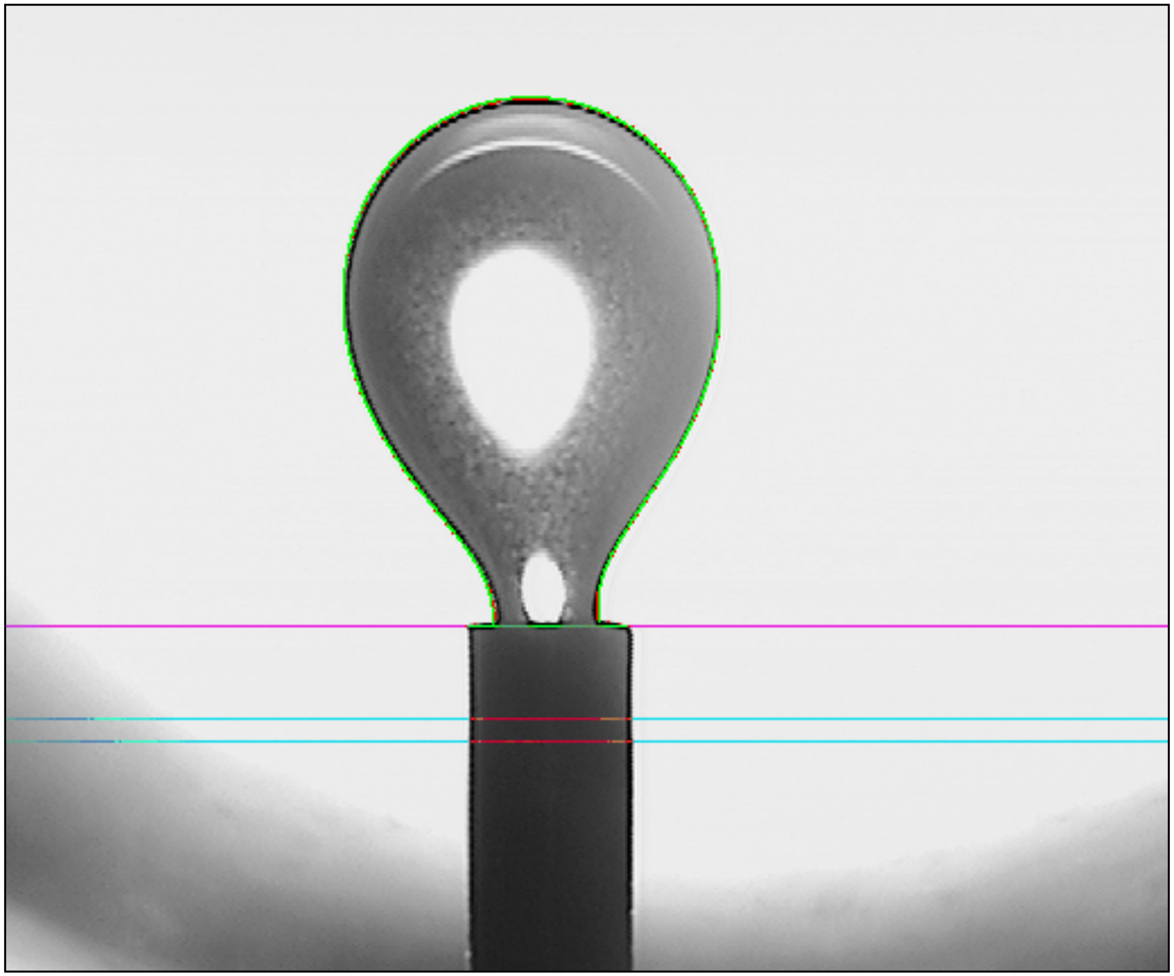
A – Optical cell B – Digital camera

Experimental Methodology

The Low Temperature/High Pressure Optical Cell Apparatus



DSA Match to Pendant Drop Profile

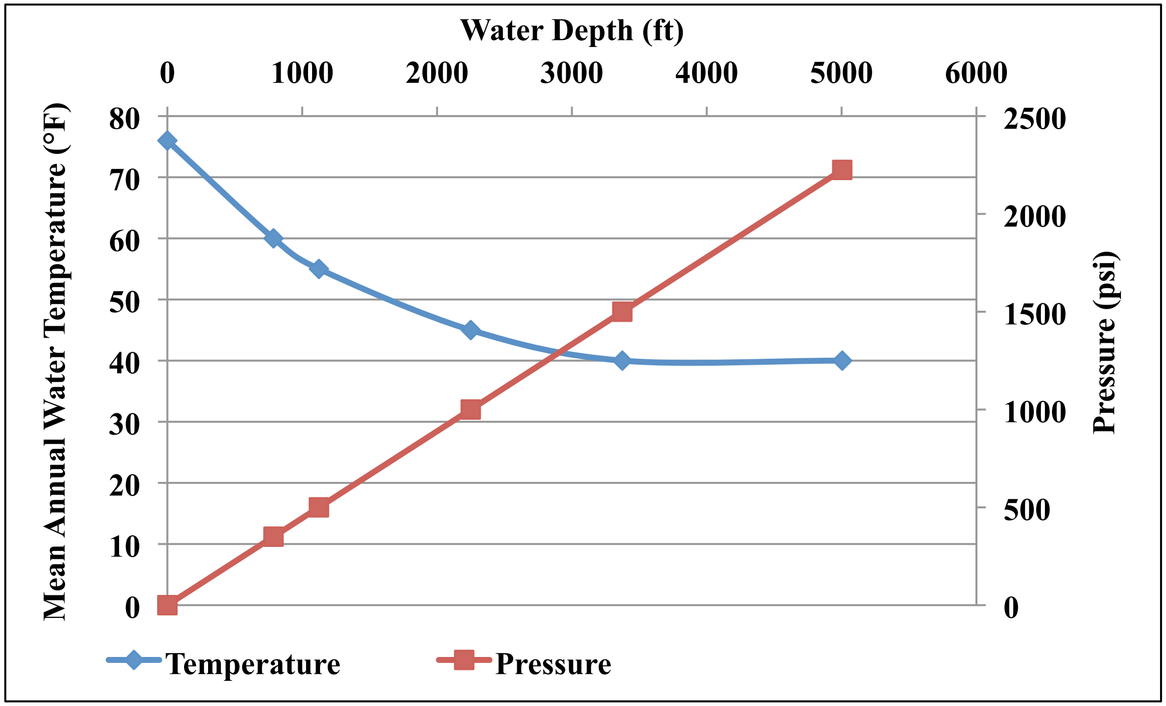


The green curve tracing the periphery of drop denotes the calculated image, whereas the top horizontal line defines the tip of the needle. The bottom two horizontal lines are used to determine the magnification of the system based on the outside diameter of the needle.

Experimental Methodology

Experimental design

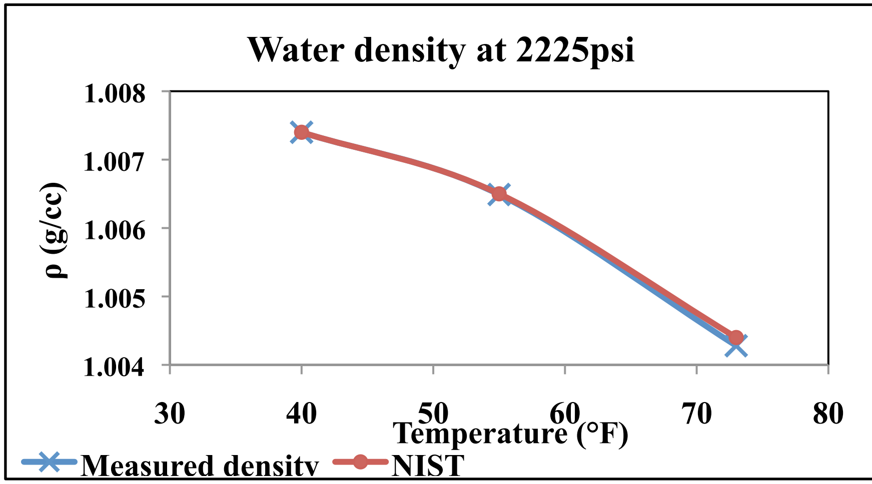
- Representation of the deepwater oil spill conditions of pressure and temperature.
- Temperature values were obtained from the National Oceanographic Data Center.
- Pressure was estimated assuming an average seawater density of 1.025g/cc, typical of GoM waters [www.nodc.noaa.gov].



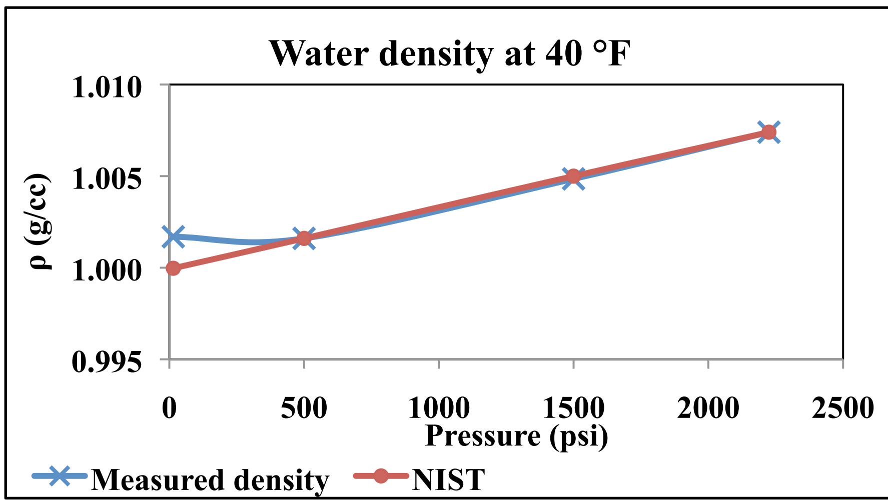
Example Results

Density meter calibration

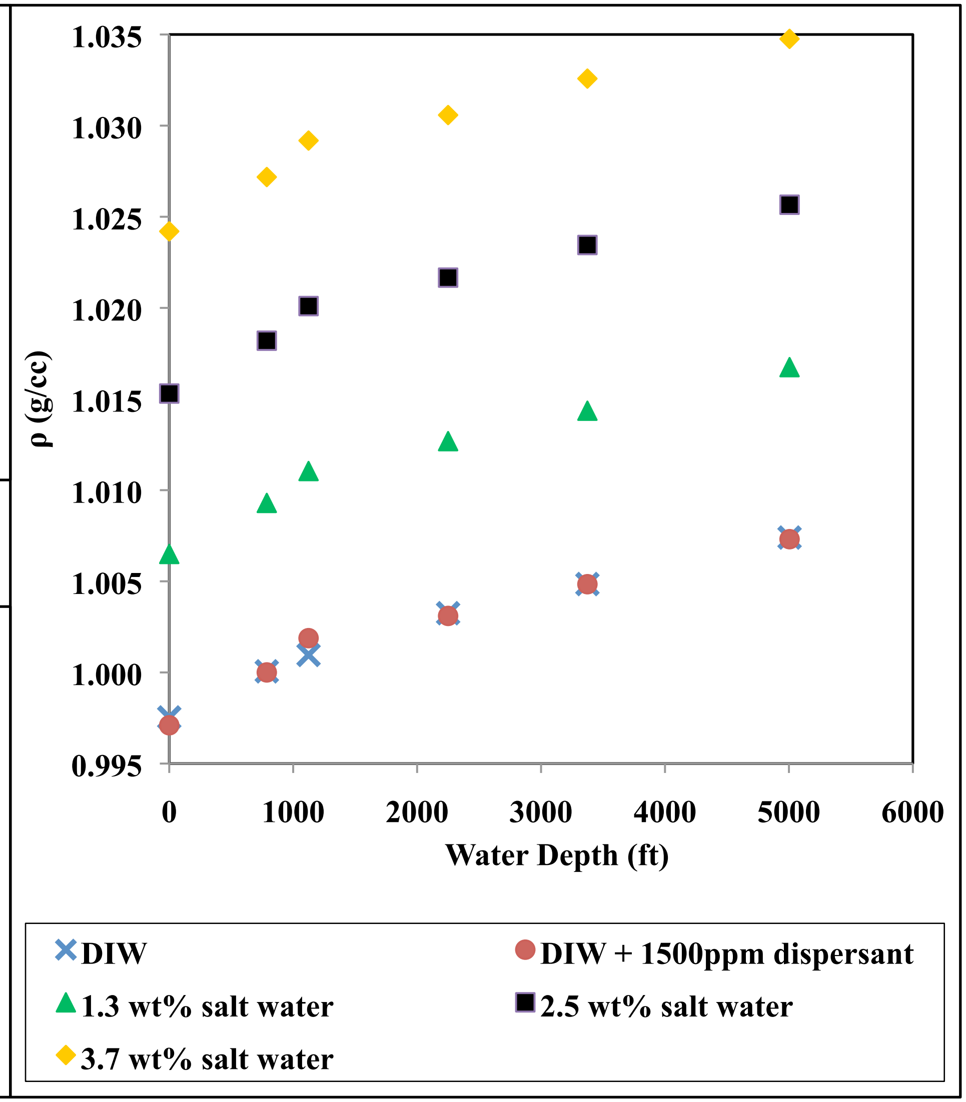
Temperature variation



Pressure variation

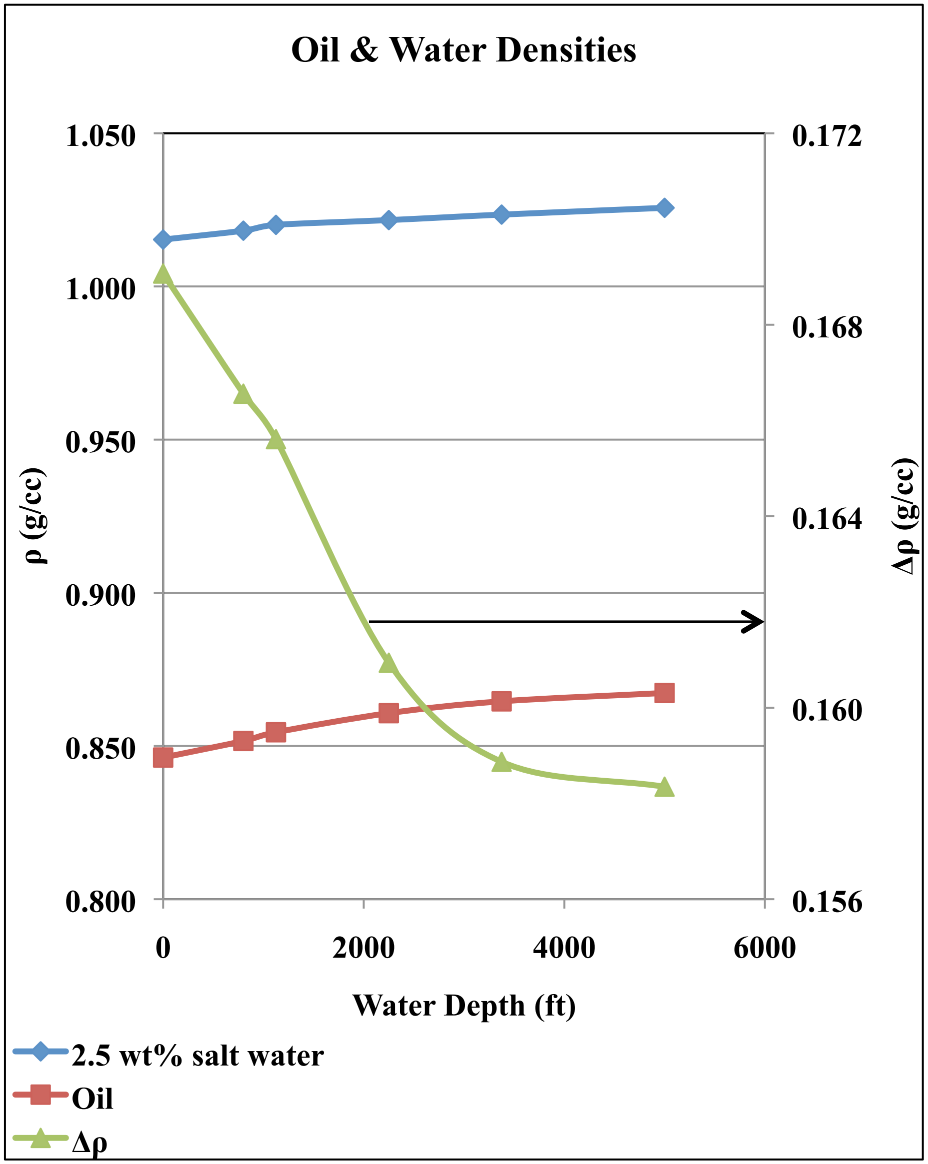


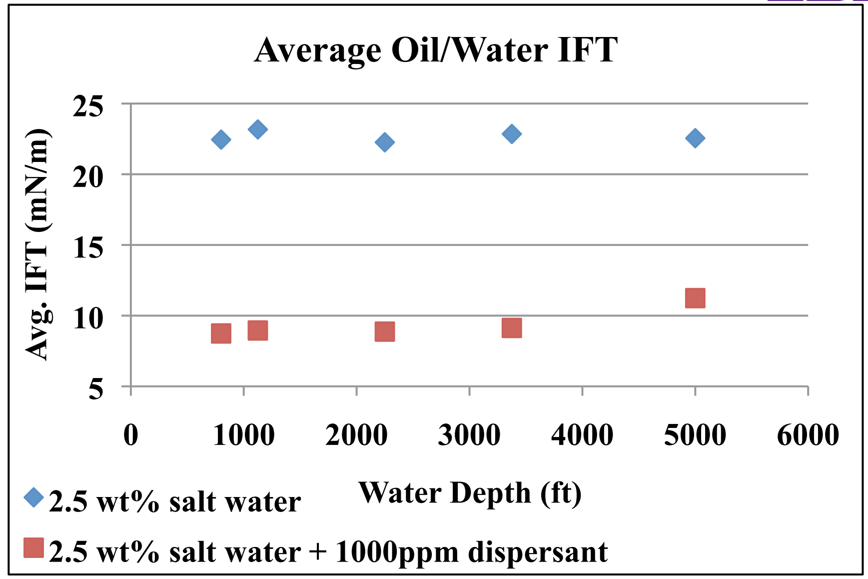
Water depth, salinity and composition variation

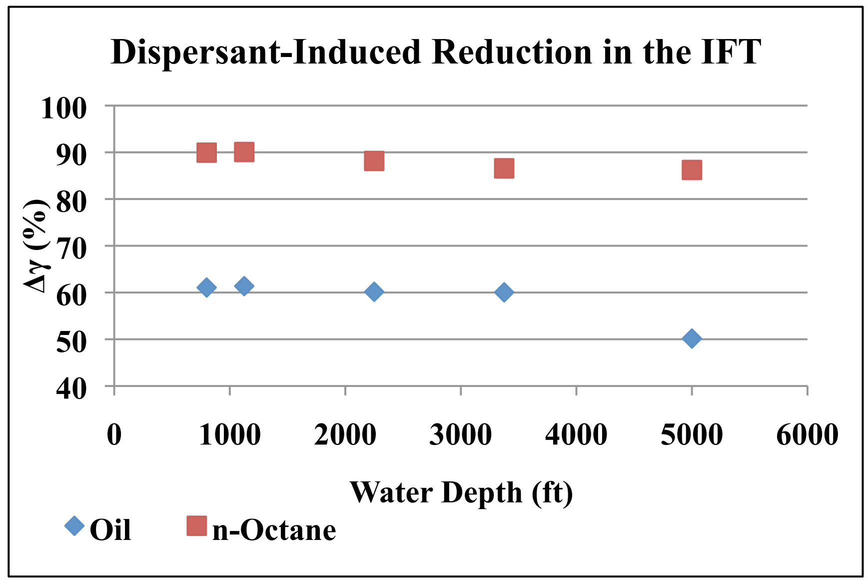


Example Results

Water depth variation

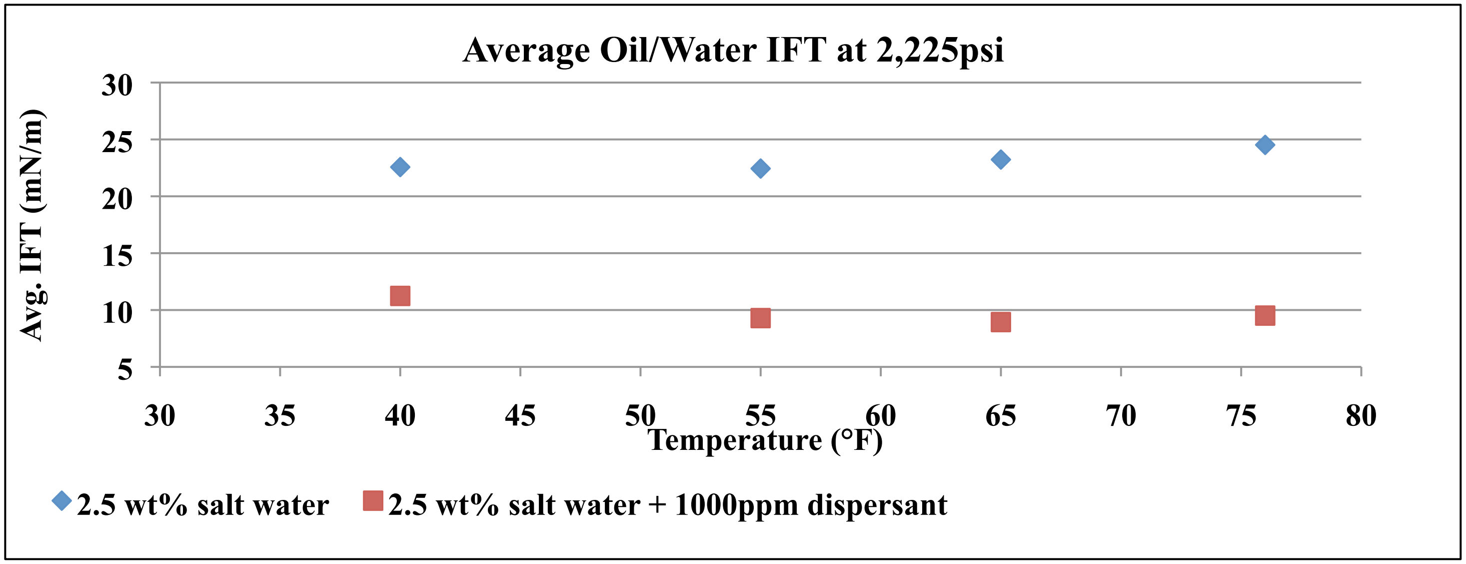


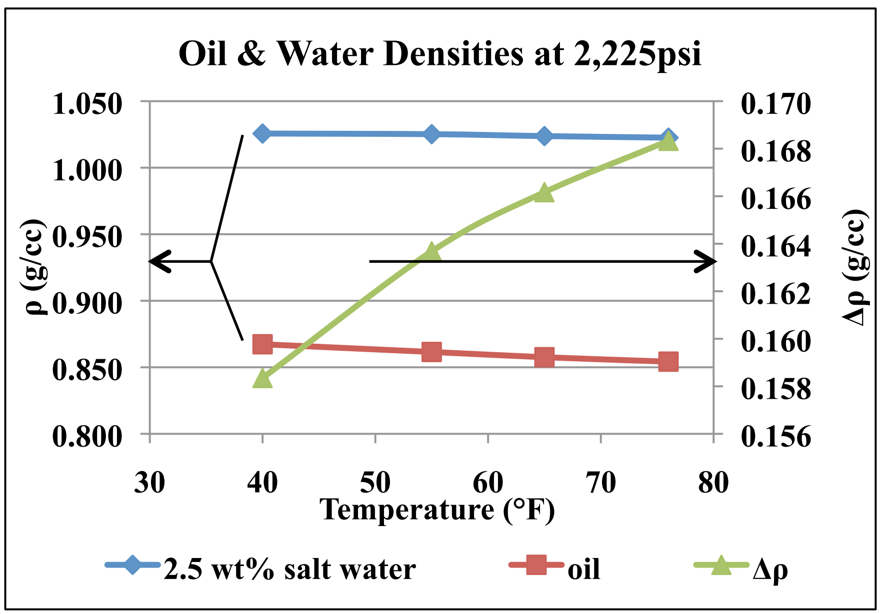


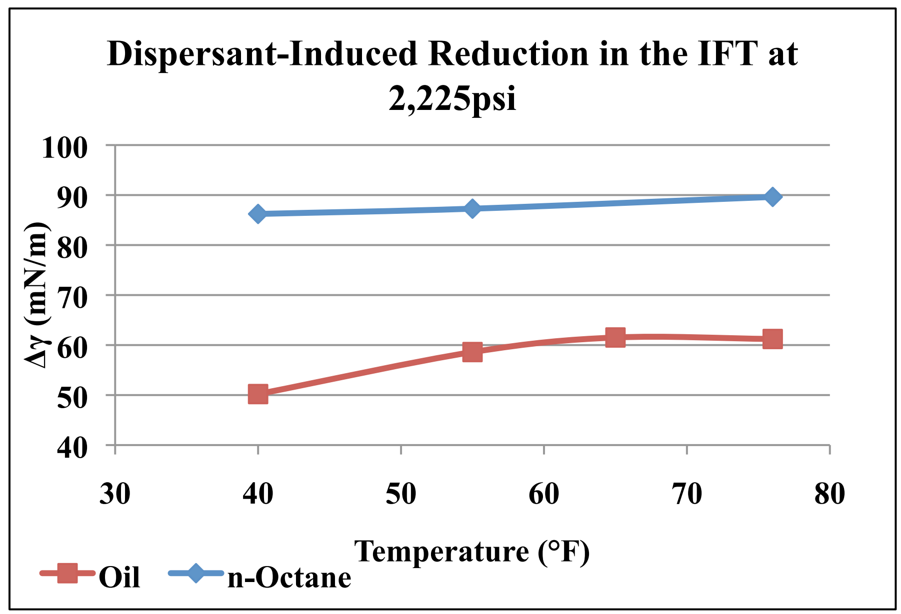


Example Results

The effect of temperature

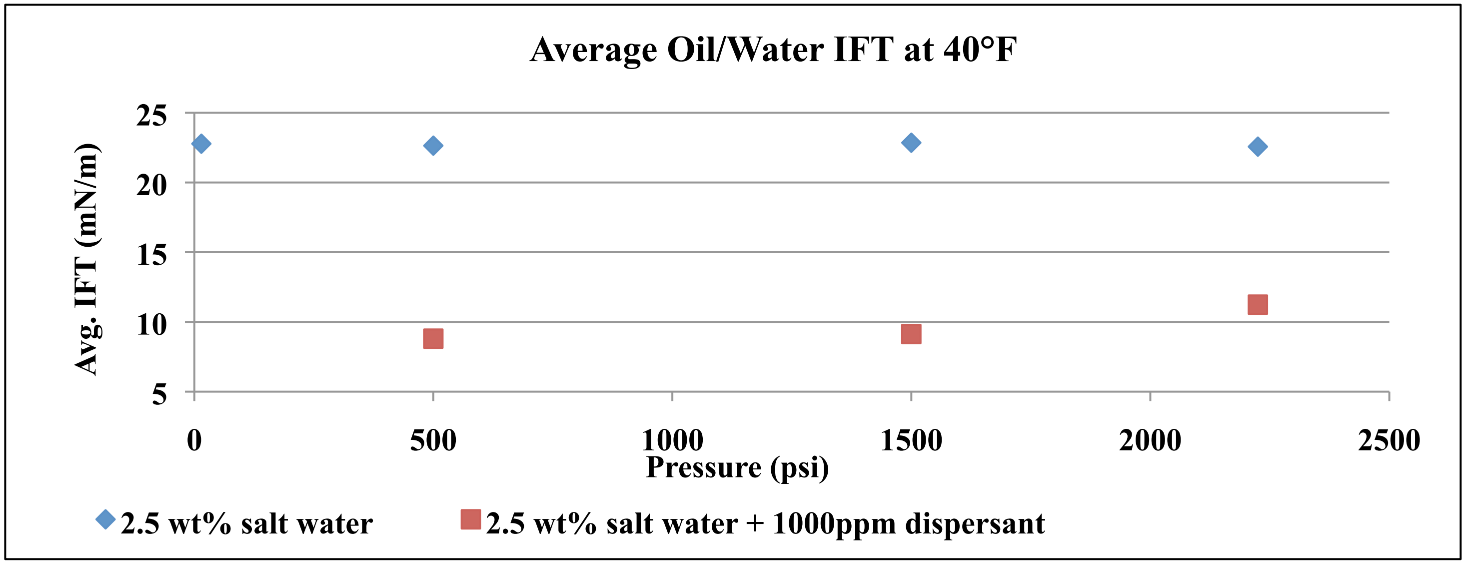


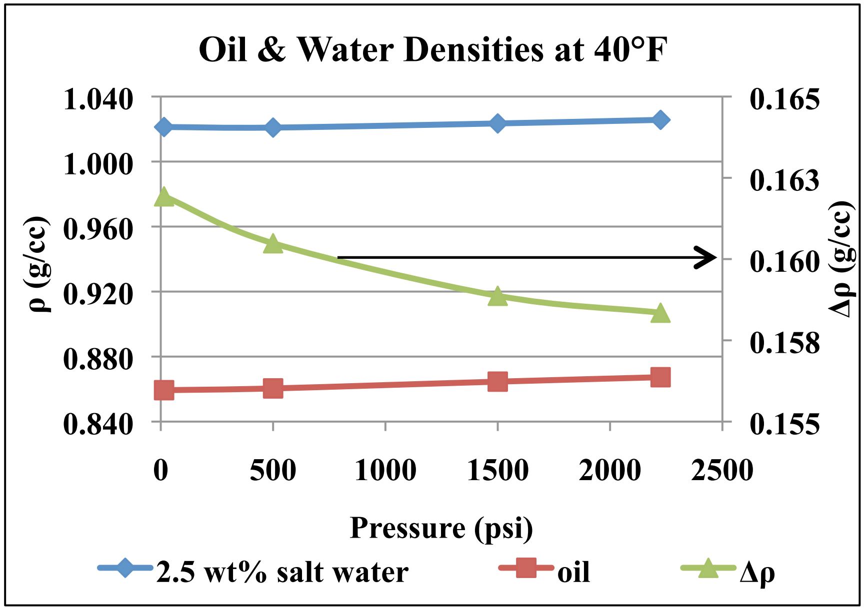


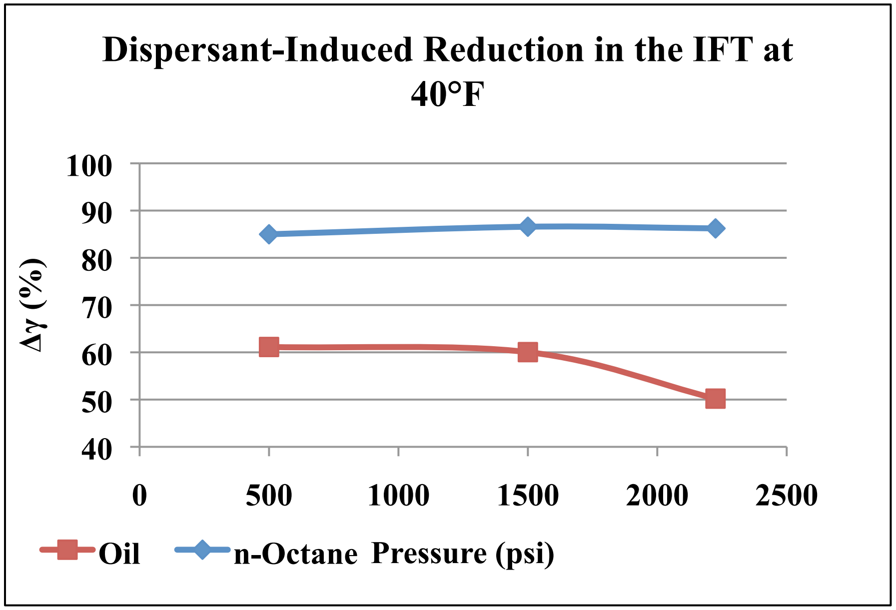


Example Results

The effect of pressure







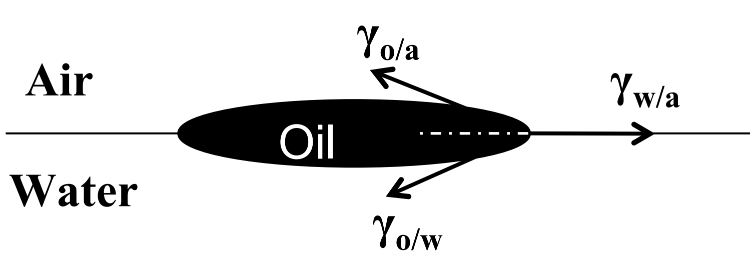
Future Work

- Additional experiments are to be conducted comprising a wider range of values for each variable to confirm the trends observed so far.
- Evaluate the effect of water salinity. (Ongoing...)
- The spreading behavior of oil on the water surface is to be evaluated through the measurement of oil/air and water/air interfacial tensions, with and without dispersants. On the water surface, the nature of distribution of oil is controlled by the spreading coefficient:

$$S_o = \gamma_{w/a} - \gamma_{o/w} - \gamma_{o/a}$$

+ve S_o ⟶ Oil spreads as a thin film

-ve S_o ⟶ Oil adapts the shape of a lens



Acknowledgements

- This research was made possible by a grant from BP/The Gulf of Mexico Research Initiative.
- Dr. Kalliat T. Valsaraj of the Department of Chemical Engineering at LSU.
- Mohamed Abdelrahim for conducting the experiments.
- Fenelon Nunes, Mauricio Toscano, Dayanand Saini, Yu Zheng and Ruiz Paidin for their technical assistance.

Questions?

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