

## Probing the impact of particle wetting on hydrate formation for flow assurance application

*The purpose of this research project is to test the hypothesis that as hydrophobicity of solid-stabilized surfactant increases, hydrate formation decreases. In addition, hydrate formation at various water fractions will be investigated.*

**Background:** Clathrate hydrates are formations of hydrocarbon guest molecules engaged in a network of hydrogen bonded water molecules. Typically, clathrate hydrates form under high pressure and low temperature in environments containing both oil and water. After initial formation, the hydrate structures bond to each other and can agglomerate. These conditions are sometimes met in deep-water oil and gas pipelines, forming plugs and preventing flow. The oil and gas industry spends millions of dollars annually attempting to prevent and break hydrate plugs (Sloan 2003). As the industry continues to develop deeper offshore oil and gas reserves, this number will continue to rise. Several methods currently exist to prevent hydrates, including anti-agglomerants, thermodynamic inhibitors, and surfactants, but the formation and prevention of hydrates continues to be a developing field of research (Karanjkar et al. 2012). Seeking a better understanding of hydrate formation would assist in creating more economical prevention methods and improving upon existing methods.

**Research Plan:** In order to gain insight into the process of hydrate formation, this research project will focus on structure II hydrates utilizing cyclopentane as a guest molecule, while manipulating the variables of water fraction, and surfactant type. Results will be measured against control samples for each experimental condition. To analyze how the water fraction affects the formation of hydrates, samples will be prepared containing percentages of water based on volume ranging from 10% to 90% at increments of 10% to simulate varying conditions of an oil reserve. For experimental trials, the remaining portion of the solution will be light mineral oil and cyclopentane in equal proportions and a constant, small amount of surfactant to decrease the surface tension and create a stable emulsion. The three types of surfactant to be investigated are Aerosil R974, Aerosil R972, and Aerosil R816, which are solid surfactants listed in order of decreasing hydrophobicity. For control trials, mineral oil will be used entirely instead of cyclopentane, though the amount and type of surfactant will remain the same. Because only cyclopentane can be used as a guest molecule, formation of hydrates is not expected for samples with only mineral oil, though it will still form an emulsion with water, making it an ideal control fluid.

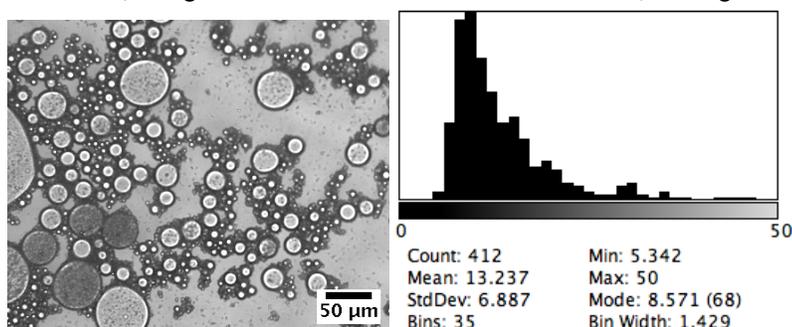


Figure 1 is a microscope image of water droplets in a continuous fluid of oil from a similar project I worked on over the summer as a research assistant. Figure 2 is the droplet distribution in microns from obtained from the analysis of Figure 1, produced using ImageJ software. This research project led to a manuscript in preparation for review and eventual publication. This technique and learned skills will be utilized for my proposed research.

**Expected Results:** To obtain results, the samples will be mixed at a specific rate and time with a homogenizer, which will be kept constant for all trials. Then samples will be viewed under a microscope connected to a computer. After chilling for 24 hours, hydrate formation is expected to occur for the experimental trial. All images will be analyzed with ImageJ software to determine mean droplet diameter and create histogram representations (above) of the distributions of the droplet sizes. The histograms will give insight into hydrate crystal morphology, which is signaled by changes of the distribution of droplets after hydrates have been formed. The data is expected to verify which water fraction yields the most favorable conditions for forming hydrates. Information on surfactant effect and wettability is expected to test the hypothesis that as surfactant hydrophobicity increases hydrate formation decreases. The results from these experiments should provide data that can lead to a better, possibly more economical method of hydrate prevention in pipelines using surfactants, which would significantly benefit petroleum companies. In addition, this project could inspire further research of surfactant effect on hydrate formation utilizing a flow loop simulation of a pipeline. This project is also intended to continue my undergraduate research and begin the journey to graduate school.

### Resources:

- Graduate student mentor and faculty mentor
- Olympus BX53 polarized optical microscope
- Homogenizer (up to 20,000 RPM)
- Temperature-controlled chiller

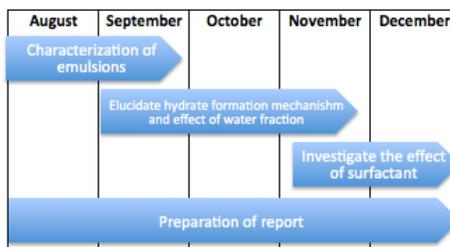


Figure 3 shows the anticipated timeline of events throughout the fall semester.

Karanjkar, J. L., J. Morris (2012). "Surfactant Effects on Hydrate Crystallization at the Water–Oil Interface: Hollow-Conical Crystals." *American Chemical Society* **12**: 3817-3824.

Sloan, E. D. (2003). "Fundamental principles and applications of natural gas hydrates." *Nature* **426** (November 2003): 353-359.