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Group Project #1 - "Hele-Shaw Phenomena"

The interaction of fluids of differing viscosities is an interesting and fascinating phenomenon. When the interaction of fluids of differing viscosities can be captured in an artistic approach and with scientific purpose, an amazing image may be created. The photographic capture of fluid interaction was the primary purpose of Group Project #1. Our Flow Visualization Group consisted of five members: one art student and four engineering students. Our primary goal was to individually capture the "*Hele-Shaw Interaction"* and "Saffman-Taylor finger growth" phenomena and briefly explain what we saw and discuss background information relevant to the photograph. As a group, we successfully fulfilled all required criteria for this assignment and recorded some amazing and spectacular images. ***Image 1*** is the original unedited photograph and ***Image 2*** is the cropped and final format photograph of many that our group has taken as a whole.

Image 1: Unedited Original Photograph

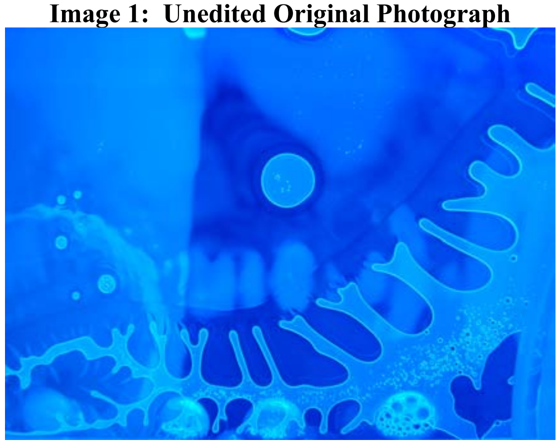
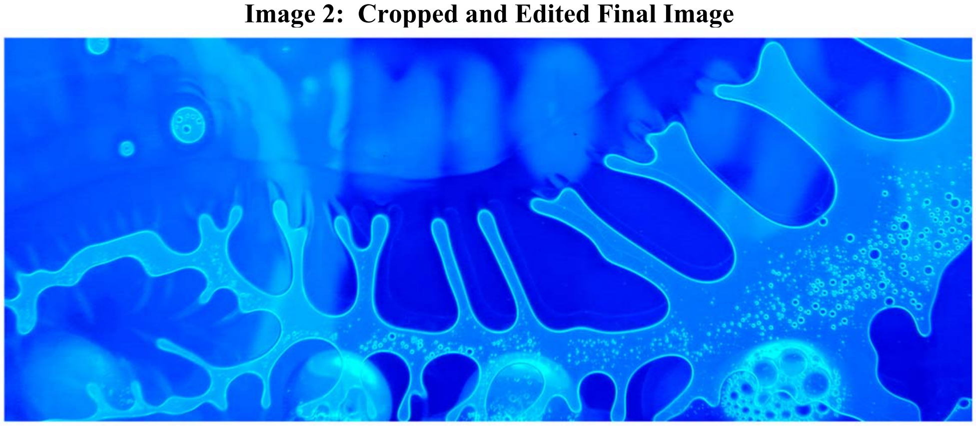


Image 2: Cropped and Edited Final Image



BACKGROUND INFORMATION:

Instabilities can occur when we consider systems with two immiscible fluids. When one fluid is driven into another in a small gap between two plates know as a Hele-Shaw cell, a moving interface is created. If the invading fluid is more viscous than the displaced fluid (e.g., oil displacing air), this interface becomes flat as it moves. However, when the invading fluid is less viscous than the displaced fluid (e.g., air displacing oil), the moving interface is unstable to small disturbances. These disturbances grow into "Saffman-Taylor fingers" which evolve in different ways, depending on the fluid forcing velocity. For small forcing, a single uniformly moving finger eventually dominates the system. As the forcing is increased, this finger narrows, but never decreases below one-half of the width of the system. As the forcing is increased further, the finger begins to split and create side branches, as shown in ***Figure 1***. The complexity of these secondary fingers increases as the finger velocity is further increased.[1]

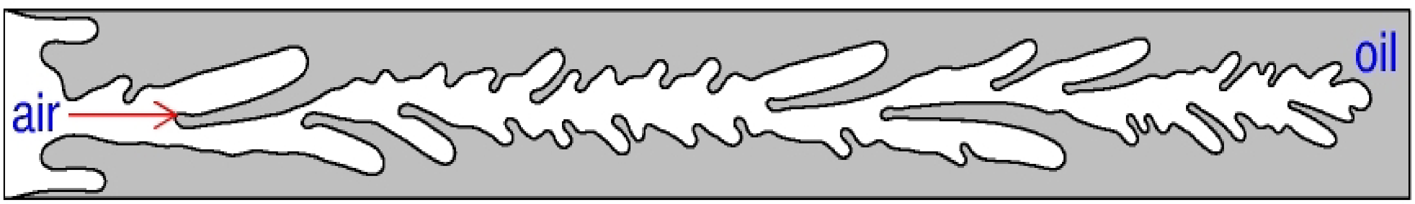


Figure 1: Model of Saffman-Taylor fingers created. Air is flowing from the left, displacing the more viscous oil. At this moderately high flow rate, secondary branching of the original finger occurs frequently. [1]

In short, the amount and degree of branching of the Saffman-Taylor fingers depends on the velocity of the impinging viscous fluid. The faster the impingement of the less viscous fluid, the more branching and therefore an increase in Saffman-Taylor fingering occurs. On the contrary, the slower the velocity, the less branching will occur. This is due to effective surface tension created between the Hele-Shaw cell plates and the ability of the branches to fracture as they move through the more viscous fluid.[2]

In this particular assignment, a less viscous fluid (air) impinged on a more viscous fluid (laundry detergent). Hence, Saffman-Taylor fingers were created through the Hele-Shaw phenomena and are visually represented in ***Image 1 & 2***. Moderate branching occurred within the Hele-Shaw cell denoting a moderate velocity of the impinging fluid. In addition, select tips of the Saffman-Taylor fingers are beginning to fracture into two fingers. This shows the propagation is continuing through the original branch and further impingement is occurring.

PHOTOGRAPHIC TECHNIQUE:

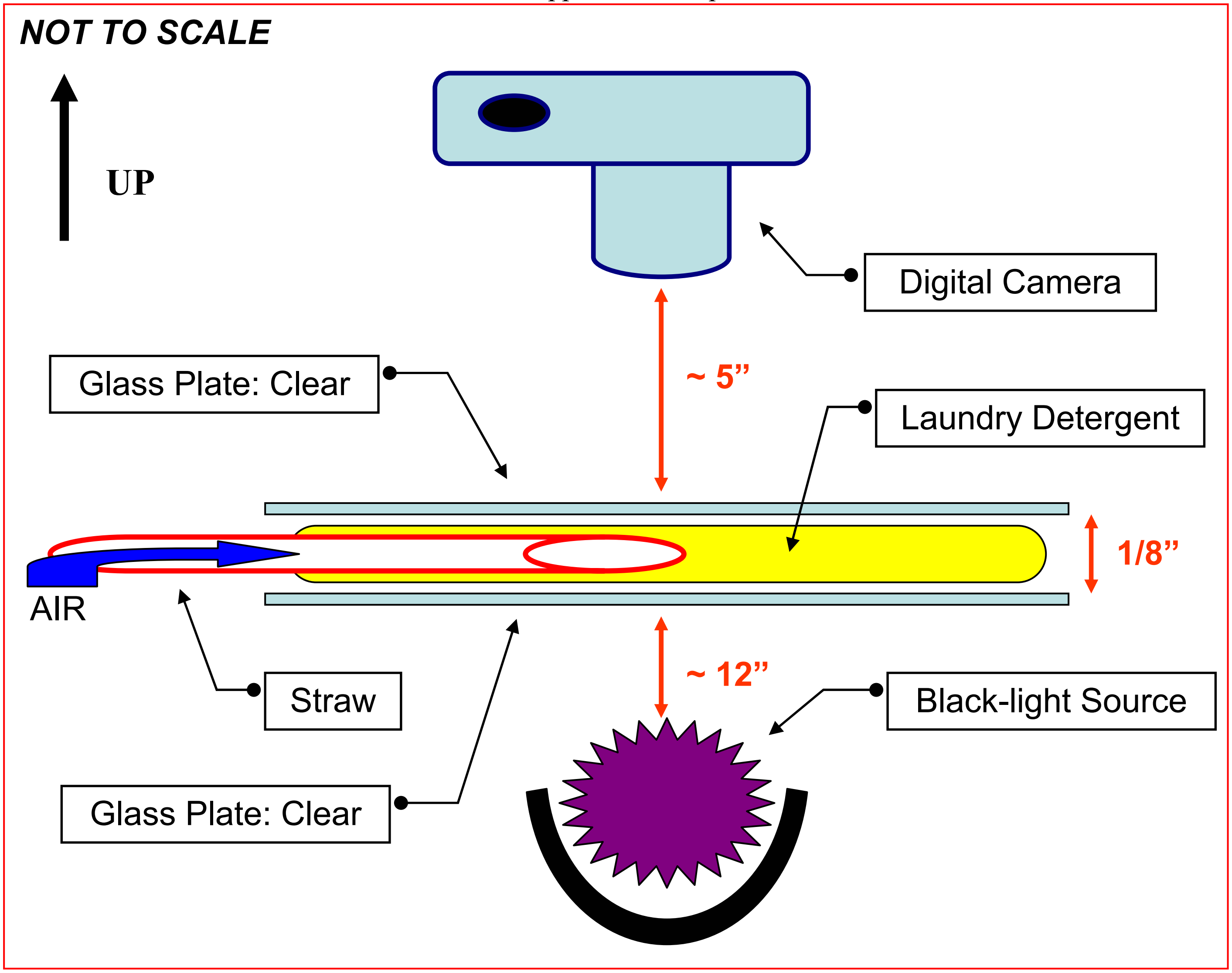
IMAGE SUMMARY:

- Field of View: ~ 5 in.
- Distance from Object to Lens: ~ 6 in.
- Lens Focal Length: 7 mm
- Type of Camera: Digital – Sony DSC-T1
- Exposure Specifications
  - Shutter Speed: 1/8 sec.
  - Aperture (f-stop): F/3.5
  - Image Resolution: 1 MP
- Film Type & Speed: ISO-200
- Digital Manipulation: Minor Contrast, Focus & Sharpness Enhancement
- Printing: None

APPARATUS SET-UP:

Two horizontal glass plates were separated by 1/8" foam core inserts and bottom plate was supported on all four corners with upside down clear drinking glasses. 4 oz. of undiluted Tide laundry detergent was placed between and at center of glass plates. Lighting was provided by black-light placed between table and glass plates. A small coffee stirring straw was inserted between glass plates and directed to the center of the plates. At this point, a small amount of air was blown into the free end of the straw and allowed to exhaust through the other end. This forced air enabled the air to impinge into the more viscous laundry detergent and create a small air pocket between the glass plates. As additional air was forced into the Hele-Shaw glass cell, Saffman-Taylor fingers were created that propagated radially from the center of the straw. At this point, camera was focused, shutter speed was set and correct depth of field was obtained for a correct exposure by digital camera. A simplified schematic of apparatus set-up may be denoted by ***Figure 2***.

FIGURE 2: Apparatus Set-up Schematic



IN SUMMARY:

The captured image successfully reveals the Hele-Shaw cell phenomena and the creation of Saffman-Taylor fingers. In addition, the image is aesthetically pleasing and demonstrates appealing tonal qualities. Artistic cropping creates an abstract composition that enables a viewer to liberally interpret the image on a variety of different levels. A possible detraction from the image is lack of overall focus; however, a soft focus gives the image a dreamy and/or mystical appearance and may, in fact, add to the overall appeal of the image. Nonetheless, soft or sharp focus is entirely an individual preference. In all, this assignment was interesting and educational on the physics and dynamics behind fluid flow.

REFERENCES:

[1] http://chaos.ph.utexas.edu/research/genfluid.html ACCESSED: March 13, 2006

[2] P. Tabeling, G. Zocchi, and A. Libchaber, J. *Velocity Fluctuations of Fracture-Like Disruptions of Associating Polymer Solutions.* Fluid Mech. **177**, 67 (1987).