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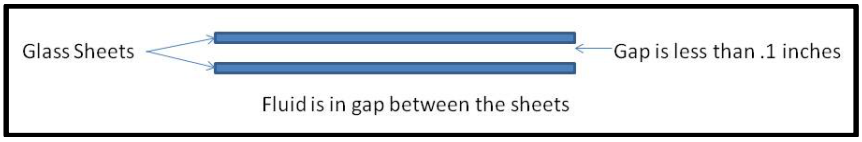
Flow Visualization Spring 2013
Second Group Image
4/4/13

Glycerin in Hele-Shaw Cell

For the forth image for my flow visualization course my group chose to focus on fluids in a Hele-Shaw cell. We used several different fluids mixing them with food coloring for stronger contrasts and changing the light and background until we all felt we have a solid image. At first I really wanted to capture the classic Saffman-Taylor instability image that people usually look for when using a Hele-Shaw cell, though when it came around to picking my final image, I went with a much simpler run that we did with glycerin and some blue food coloring. Though it doesn't capture the instability that I was originally shooting for, my image capture the really fine flow that was happening in the glycerin as we where separating the two parallel plates Hele-Shaw cell. Hans Loewenheath and Grant Boerhave helped out with my image.

Below I will describe what a Hele-Shaw cell looks like, as well as the layout of where my image was taken from in relation to the cell. A Hele-Shaw cell is an apparatus that has two large parallel plates that you can inject fluid between, and then control the distance between the plates. The apparatus that we used was two sheets of glass about 2.5 ft x 2ft, the gap between the sheets were controlled but four screws that contacted the top plate and then as you turned the screws, they would raise of lower the top sheet in relation to the bottom sheet. Here is a close up diagram of a Hele-Shaw cell.



Hele-Shaw Cell Diagram

The cell that we were using was also on legs to that we could light it from underneath, using two halogen work lights. Below is a diagram of how we set up our shots. The camera is on a tripod that spans the apparatus so that my shot is from directly about the top sheet of glass.

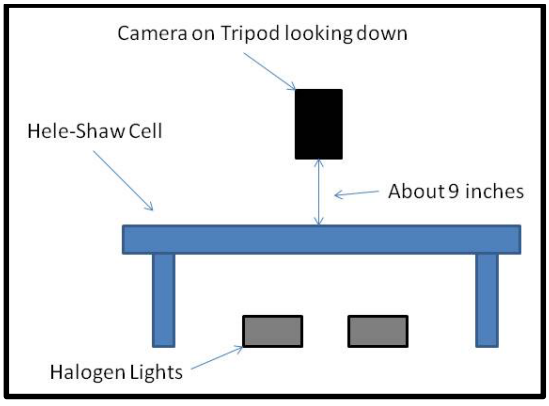


Image Setup

There are some really interesting relationships that can be invested gated with Hele-Shaw cells, though they require more exact measurement than were taken during our experiments and due to this I will be unable to perform them on the trials that we did. The flow relationship that I am going to discuss is the

velocity profile in the vertical direction and that as the gap distance approaches zero, and how it drops out to zero. $u = velocity\ profile, \nabla p = p(x, y, t), local\ pressure, \mu = fluid\ viscosity, 2H = gap\ between\ plates, z = \pm H$

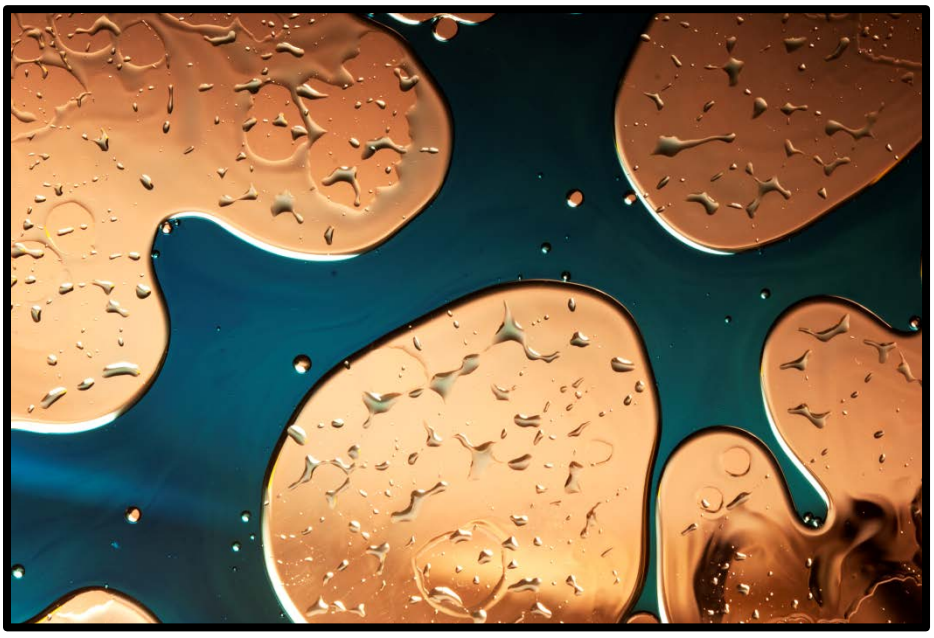
$$u = \nabla p \frac{z^2 - H^2}{2\mu}$$

As the gap closes to zero, the velocity field can be considered a two dimensional field (x and y), so when the above equation in integrated over z you can get the governing equation of fluid in a Hele-Shaw cell:

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} = 0$$

Though I was unable to get enough information during our experiment to do this analysis, it is interesting and sort of related that in my image you can see different levels of glycerin. There is the dark blue section which is the fluid that is touching the top and bottom plates, but then in the lighter section there are droplets that are just in contact with the bottom plate.

For a visualization technique I had to use dye to bring out the flow patterns in the glycerin, it worked really well in this image that I chose. We first mixed the glycerin and dye in a cup and then put it on the bottom plate. We then carefully placed the top plate on making sure the fluid didn't spread out too much. Using the screw spacers, we then messed with the gap between the two plate until an interesting flow came along and then we captured out image. There is detail on the level of the full image of 3800 pixels and on the level of 5ish pixels at the edges of fluid as well as the flow lines within the fluid. So with the dye technique I was able to get a three decade spatial resolution for this image. I was very pleased with how sharp a focus we could get and the detail represented.



Final Image

My final image was not cropped down at all and only had the color curve adjusted slightly. The adjustment was to bring out the flow lines in the dark blue sections of the glycerin and to make the

edges of the glycerin very well defined. We use a Nikon D60 for our pictures with a Micro- Nikkor 1:2.8 lens, so the whole image is only looking at about 1.5 in x 2 in, with the camera about 9 in. off the surface of the top plate. Below is a table summarizing the settings that were used for the image, the main thing that I was changing during the photo shoot was the shutter speed. Most of the changes were done for lighting reasons, making sure that there was enough light but that nothing was getting over exposed.

Field of View	1.5 x 2 in
Distance to Object	9 in
Camera	Nikon D60
Lens	Micro-Nikkor 1:2.8
Focal Length	105 mm
Dimensions (original and final are same size)	3872 x 2592 pixels
Aperture	f-stop 5.4
Shutter Speed	1.3 sec
ISO	100

I am really pleased with how image came out, so glad that I was about get detail down on the 5 pixel range of the flow within the large glycerin section. With a macro lens you can really get down to the detail that you want to see in the fluid. Plus having the Hele-Shaw cell as a pretty stationary experiment, it was a reasonable easy image to capture. The only difficult part was when moving the plate that we could stop then when an interesting image arose. The image that I got was what I was looking for, and other than having some problems lighting at first, everything when really smoothly.

Sources:

Wikipedia, Hele-Shaw Flow. http://en.wikipedia.org/wiki/Hele-Shaw_flow