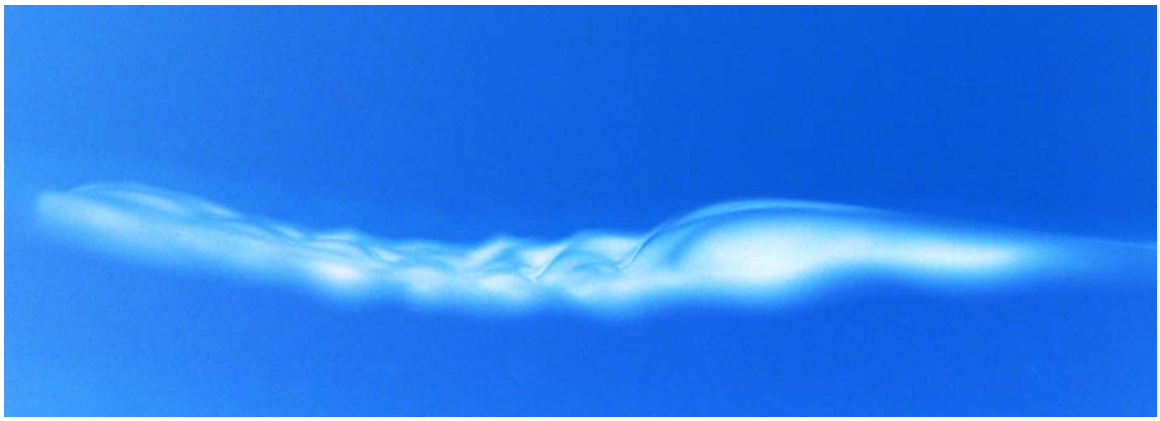
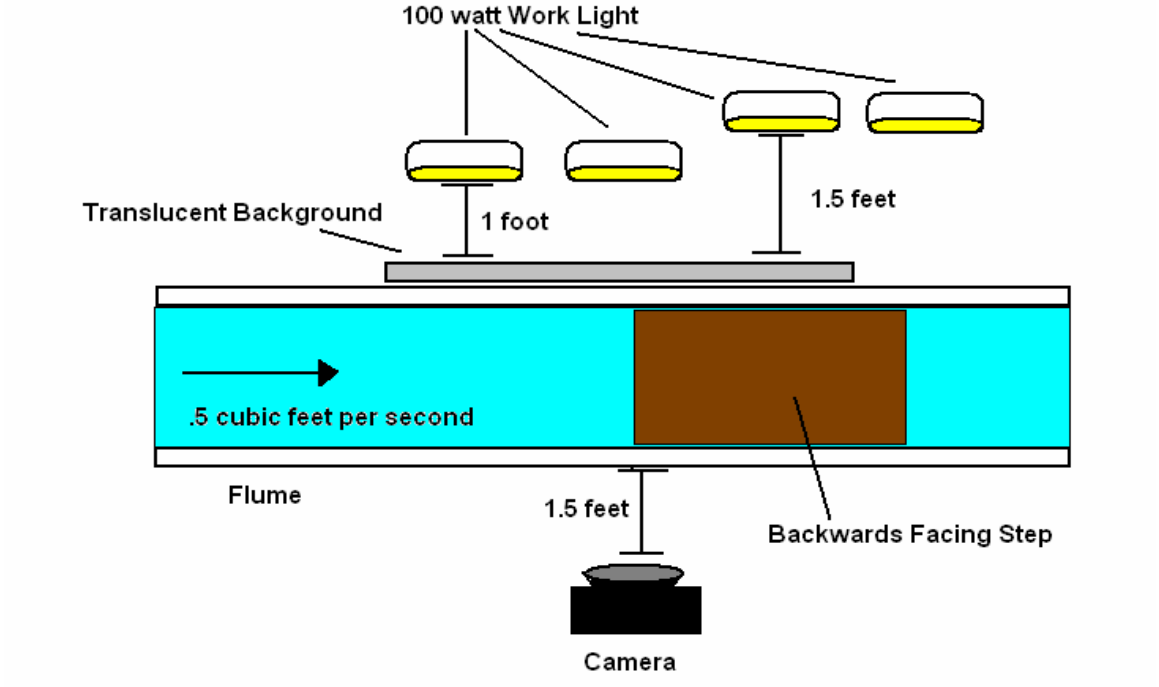
Flow Visualization: Group Project #2

Jake Lilevjen and Tyler Harrison



Context and Purpose:

Hydraulic jumps are very interesting phenomena. They are seen many places in everyday life ranging from drinking fountains, gutter systems, bath tubs and also occur on a larger scale in tidal waves. Often the phenomenon of a hydraulic jump is created intentionally to reduce the kinetic energy of rivers. The purpose of this project was to capture any interesting fluid phenomena by use of a flume. It was after trial and error of many different experimental arrangements that this hydraulic jump was produced. Variation of flow rates, water heights and different interference objects were used before capturing this very pleasing result. The production of this image was done in a very well illuminated flume with a translucent plastic background. We found the phenomena to be very interesting, in fact during the course of the experiment many engineering students stopped to inspect the phenomena for themselves.



Flow Apparatus and Physics:

A flume with a submerged wooden block impediment (weir) was used to create the fluid flow shown. The flume is a rectangular open channel 4" wide. The weir is 5" tall, and wide enough to completely block the water passage through the flume. Water flows down the flume and flow is interrupted by the wooden block. Flow builds upstream from the weir until the water overflows the "dam." Once this happens, a steady hydraulic jump is formed a short distance down from the leading edge of the block. Whether this phenomenon happens or not is strongly dependent upon the flow itself, and is characterized by the Froude number. The Froude number is a ratio of the inertia and gravitational forces acting on the fluid. The gravitational forces drive the flow down the flume, while inertial forces carry momentum and energy. A hydraulic jump is a fluid phenomenon that occurs when the flow is supercritical ($F>1$). This means that the inertial forces are greater than the gravitational forces, and some energy must be lost. The way the fluid loses this energy is to create a hydraulic jump. The water level rises and kinetic energy from the higher inertial flow is transformed into potential energy. Flow after the hydraulic jump loses energy and becomes subcritical ($F<1$). It is because of this energy loss that engineers sometimes use this technique to control the velocity of flows in spill ways by building concrete obstructions in the path of the flow. The estimated Froude number in this experiment is 1.8, based on a volumetric flow rate of 0.25 cubic feet per second. Also based on this flow rate, the depth of the channel over the weir of 1 inch, and the shutter speed of the camera, a fluid particle moves a distance of 0.02 inches. This is a small distance (~ 0.5% of the field of view), so the picture is well spatially resolved relative to our viewing area.

Visualization Technique:

As was mentioned before a hydraulic jump is a phenomenon that is commonly seen in nature and man made devices. Often the medium, in our case water, must be held constant to some extent. The manner which was used to limit our flow to two directions was the rigid boundaries of the flume and a back facing step. This held the flow of the medium constant in all directions except the direction of flow and any vertical displacement. These boundary conditions forced the large amount of free flowing liquid into a smaller channel thus producing the hydraulic jump. As the water is forced over the backwards facing step the free flowing water has no where else to go and thus converts some of its forward moving kinetic energy to vertical displacement or potential energy. The lighting used to produce this image was four 100 watt work lights positioned at 30 degree angles behind the translucent plastic background and overhead lights in the room. Even with this large amount of lighting the image was dark. Also the image had what would seem to be poor resolution. This poor resolution can be attributed to the diffusion of light as it travels through the width of the hydraulic jump.

Photographic Technique:

This photograph was produced using a Nikon D50 digital camera (6 Megapixel resolution). The camera was held at a distance of 2 feet from the wave, and the picture was taken with the focal length set at 55 mm. This creates a field of view that is about 3.5" wide by 2.3" tall. The shutter speed was $1/500^{th}$ of a second, with an f-number of

f/5.6. The sensitivity of the camera was set at an ISO of 1/30. Once the original photograph was taken, it was modified using Photoshop to crop out unwanted background and invert the colors, yielding the blue and white picture shown. The final dimensions after cropping were 2485x888 pixels, or a resolution of 2.2 Megapixels.

What the Image reveals:

The image captures the phenomena of a hydraulic jump. It captures something which is commonly used by humans to control the forces of nature. Besides the scientific value of the image there is an aesthetic value contained in its simple beauty. What I dislike about the image is the poor resolution of the jump itself. Although the image lacks fine resolution by the use of the inverting function in PhotoShop the image transforms in to something that one might find in the sky not the laboratory. The aspect of the image which needs the most improving is its sharpness and resolution. If we were to conduct this experiment again and had all the available resources we believe it would be worth while to produce a hydraulic jump between two liquid mediums of different density.