Team Project 3
Weir Mirror

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I. Introduction

For the group project 3 image our team decided to work with the flume. I went into this project knowing that I wanted an image comparing a ventilated and unventilated nappe. The nappe is the sheet of water flowing over a dam or similar structure.[1] In the flume used to create this image, a sharp-crested weir is used to obstruct the flow. I tried a few different ways to pair the two images together including just a simple top and bottom. In the end I mirrored the ventilated nappe image over the horizontal axis and then stacking the images. The final image shows both the ventilated and unventilated nappe in an interesting manner that still MODELS the differences.

II. Flow Apparatus

The flume in the basement of the ITLL created the flow in the image. The flume used is shown in Figure 1. Water would flow down the flume and then get pumped back to the beginning. The angle of the flume could be controlled, and for our trials it was set at around 5 degrees above the horizontal. In addition to the angle, the volumetric flow rate could also be controlled. The volumetric flow rate for both the ventilated and unventilated nappe was about $1.0\frac{Liters}{second}$.

Figure 1- The flume used to conduct the trials to produce the images. Fluid flows from left to right in this image.

III. Flow Explanation

The flow over a weir can be characterized in two different ways, ventilated and unventilated nappe. As previously mentioned, the nappe is the sheet of water flowing over the weir. If the nappe is unventilated, then the sheet of water will remain attached to the back of the weir. Looking at the edited image, shown in Figure 2, the top portion of the image shows an unventilated weir. When the weir is ventilated, the nappe is detached from the weir, and a pocket of air separates the nappe from the weir. This can be seen in the bottom section of Figure 2.

Figure 2- The Final image. It shows the ventilated nappe on the bottom portion, and the unventilated nappe on the top.

The ventilated nappe's flow pattern is relatively simple to explain. Since there is an air pocket, the water as the water flows over the weir, its velocity down the flume will also carry the water over the air pocket. The flow is similar to projectile motion in that the fluid will move in the x-direction (down the flume) in addition to the y-direction (vertically).

The unventilated nappe is much more complicated. Figure 3 displays only the unventilated nappe. Note how the fluid at the top of the weir moves over the weir and then appears to be sucked back to the weir. This phenomenon is caused by pressure. When no air is allowed to enter the region between the nappe and the weir, there is no way for the nappe to become detached.

Looking at these two images, it is interesting to note that the Reynolds number is roughly the same for both types of flow. The Reynolds number[2] is defined as;

$$Re = \frac{\rho v d}{\mu}$$

In this equation, ρ and μ are density and viscosity, respectively. Both of these are the same for both trials because the water temperature was unaffected as the experiment progressed. Diameter is defined as d. The velocity is about equal for both situations because the flow rate was constant. Although the cross sectional area in which the water flows slightly changes, the difference will not have a significant impact on the velocity. Therefore since all the terms of the Reynolds number will remain constant, the Reynolds number will stay the same for both cases.

IV. Visualization Technique

In order to visualize the flow, the water was simply dyed green. Typical food coloring available at any grocer in the area was used as the dye. The dye has properties similar to that of water, also so little was used that the dye had no effect on the fluid properties or flow of water during the trials. The lighting for the image was just the ambient lighting in the ITLL. The basement of the ITLL is so well lit and all the walls are white and reflect light; this creates an environment that is great for imaging.

V. Photographic Technique

A Canon EOS20D on a tripod was used to take this image. An exposure time of 1/10seconds was paired with an F-stop of f/5.6 for this image. The ISO was a bit high at 400, but the image does not look grainy, so the ISO was not too high. These settings returned a crisp image with great colors. The exposure time was a bit long (even with the high ISO) for a typical image of flowing fluid; however, since the flow was very steady, there were not any problems capturing an accurate image of the fluid flow.

The camera was set up on the side of the flume. The camera was positioned to be straight across from the sharp crested weir so the flow over the weir would be centered in the frame. The weir is approximately 4.5inches tall, so the entire frame for this image is 8x12inches.

The final image is a combination of two images. Before being combined, both images underwent a little bit of Photoshop processing. The curves feature was used to make the background a bit whiter. In the original image, there were a few water droplets on the side of the flume that were distracting. The clone stamp tool was used to eliminate these droplets to get a clean final product. Before combining the images, both were cropped slightly so the images would be the same size and the weir would be in the same location in each image. Since the

images were shot using a tripod, this was rather simple. Once both images were fully processed, the image of the ventilated weir was mirrored about the horizontal axis. Then the images were combined into one image to create the final product with dimensions of 3417x4282 pixels. Figure 3 shows a comparison of the original images and the final image.

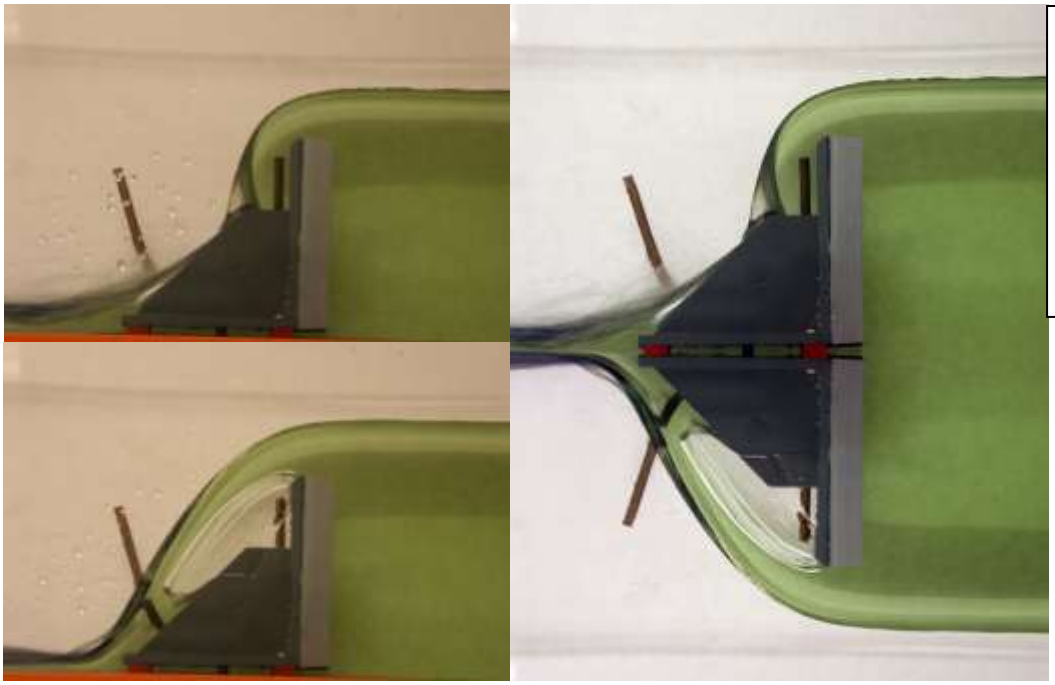

Figure 3- Side by side comparison of the original images and the final image.

VI. Conclusion

I am very pleased with my final image for the final group project. The image shows the big difference between the ventilated and unventilated nappe. I really like that the image appears as if it is a mirror even though the image is really two totally separate images. This is a cool effect because it really adds a nice artistic touch to the image without losing any information about the fluid flow. The image does a great job of showing the fluid physics because the image is clear, and it is easy to decipher what is happening in the image. The image totally fulfilled my intent of comparing the different types of flow over a weir. The only think I would like to improve is to have a little bit wider of an image so that it would be easier to compare the upstream and downstream heads of the two different flows. For future work, it would be awesome to see dye injected directly into the flow just before the weir. This would hopefully give the viewer a better idea of the velocity of the fluid as it approaches the weir. My image can't really show the velocity profile and that is something I think would be interesting to see.

VII. References

1. "Nappe - Definition of Nappe by the Free Online Dictionary, Thesaurus and Encyclopedia." *Dictionary, Encyclopedia and Thesaurus - The Free Dictionary*. Web. 24 Apr. 2011. <http://www.thefreedictionary.com/nappe>.
2. Munson, Bruce R. *Fundamentals of Fluid Mechanics*. New York: John Wiley, 2009. Print.