Teams 2

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For the second team project, one of my teammates, Andrew Van Der Volgen, suggested visualizing and photographing a Karman Vortex Street. To achieve this goal, we worked with a flume available to students in the University of Colorado Integrated Teaching and Learning Lab (ITLL). The entire team worked together on the pictures. For my particular image, I injected our highlighter dye from the top, and Finn Ostrem took the picture. Andrew provided the light source in the form of a LED work light.

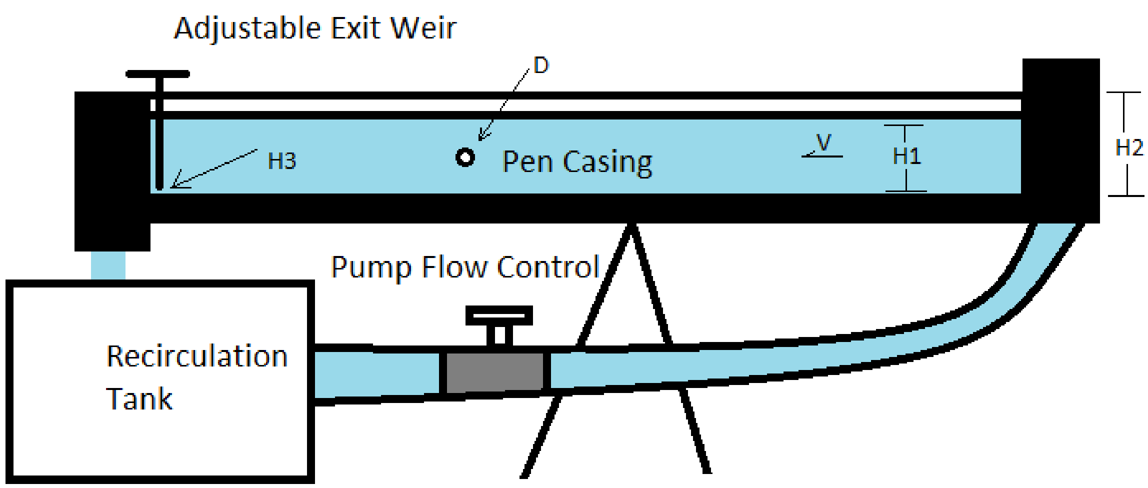

Figure 1: Flume setup used to create the Karman Vortex Streets

Figure 1 shows the flume apparatus used to produce my chosen image. The flow in this case was flow over a submerged object, the barrel of a ball point pen. All dimensions can be found below in Table 1. The flow rate and thus the velocity of the flow was controlled in two locations, primary control comes through a valve at the exit of the pump. The adjustment of this valve is not smooth and hard to control. The exit weir has an adjustable height that can allow for much finer tuning of the flow rate up to a point. At after H3 is less than half a centimeter, the exit flow starts to surge and disrupts the nice laminar flow of the channel. It is hard to quantify how much to adjust the pump flow valve to achieve our desired flow rate but using the weir it can be attempted. The exit weir was adjusted to be 8mm above the base of the channel and pump was adjust such that the level of the water was constant.

Table 1: Flume Dimensions

H1	28 cm
H2	30.5 cm
H3	.8 cm
W	7.6 cm
D	.81 cm
V	4 cm/s

The ideal Reynolds number for creating the Karman Vortex Streets occurs at Re = 150 [1]. Based off our flow parameters and the Reynolds Number equation, we can compare our Re to the ideal Re.

$$\mathrm{Re} = \frac{VD}{\nu}$$

The valued used in this calculation are V = 4 cm/s, D, the pen diameter, is .81 cm, and the kinematic viscosity of water [2] is 0.0112 cm^2/s. This gives us a Re of 289. This means that our vortex streets will not be the ideal two dimensional ones but three dimensional. This occurs above an Re of 200 [3].

The vortex street forms because as a fluid particle moves towards the leading edge of the submerged cylinder, the pressure rises from the free-stream pressure to the stagnation pressure. This high pressure zone forces fluid flow around the cylinder as a boundary layer develops. At the widest section of the cylinder, the boundary layers separate from the side of the cylinder and form two shear layers down-flow from the cylinder. Since the innermost layers move much more slowly, the shear layers roll into the wake of the cylinder. [4]

To visualize our flow, ink from a Sharpie Highlighter was used with a home-made injection nozzle, Figure 2. The highlighter ink was extracted from the pen first by removing the upper portion and then poking a hole in the base. Water was then run through the highlighter chamber until no ink emerged and this rendered dye was then diluted with water 2:1. The injection nozzle was created with a length of wire hanger that had a narrow diameter tube zip-tied to the hanger. Above the water, the second end of the tube attached to a syringe that had the highlighter dye in it.

Figure 2: Dye injection system to allow for the visualization of the flow.

The lighting employed for the shoot was an 800 Lumen LED work light that was placed directly over the water channel pointed downwards. A black piece of velvet was used as the backdrop to create a uniform black background.

Table 2: Image Parameters

ISO	400
Focal Length	32 mm
Aperture	f/5.6
Shutter Speed	1/320 sec
Image Size	3368 x 1988

To produce my image, a Canon SL-1 DSLR was used with an EF-S 18-55mm 1:3.5 – 5.6 IS STM Zoom lens. All relevant camera settings can be found above in Table 2. The original image was 5184 x 3456 and cropped down to 3368 x 1988. Because the diameter of the pen can be seen edge on, we can easily assign scale to the image. The pen diameter takes 200pixels and is .81 cm in diameter, this means that our conversion factor is .0405 mm/pixel. This makes the entire field of view 13.6 cm. The digital manipulations to the image included blacking out the background and adjusting the curves to remove the green and change the pink highlighter die to orange. Figure 3 shows what the original image looked like.

Figure 3: Original Image.

I feel like I came out with a great image from this project. We were able to capture the desired Karman Vortex Streets nicely and with the final editing came up with great image.

References

[1] Taneda, Sadatoshi., 1959, “Downstream Development of the Wakes behind Cylinders” The Physical Society of Japan, http://journals.jps.jp/doi/abs/10.1143/JPSJ.14.843

[2] Munson, B., Okiishi, T., Huebsch, W., Rothmayer, A., 2013, “Fundamentals of Fluid Mechanics”, Wiley

[3] Espeyrac, Lionel., Pascaud, Stephane,. 2002 “Strouhal Instability - Von Karman Vortex Street“ http://hmf.enseeiht.fr/travaux/CD0102/travaux/optmfn/gpfmho/01-02/grp1/phy_know.htm

[4] Kempler, Steven., ND, “SCIENCE FOCUS: VON KARMAN VORTICES“ NASA, http://disc.sci.gsfc.nasa.gov/education-and-outreach/additional/science-focus/ocean-color/science_focus.shtml/vonKarman_vortices.shtml