1 Introduction

A turbulent wake was captured behind a cylinder in a water flume, injecting food coloring upstream of the cylinder to illuminate the von Krmn vortex street, which consists of a wake shedding vortices in an alternating fashion [1, 2, 3]. The final image captured is shown in Figure 1.

Figure 1: Final image of turbulent wake behind a cylinder

2 Photographic Technique

The shot was set up using CU Boulder's flume. Stage lights were used with a white background to focus the picture of the turbulent wake. A low shutter speed was used to prevent motion blur and a low ISO was used to prevent image quality corruption. The camera settings used are shown in Figure 2.

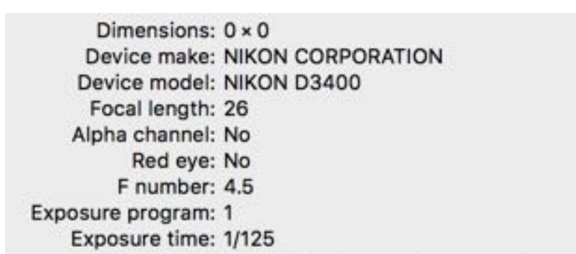

Figure 2: Settings used to capture image

Figure 3: Original, unedited image

The show is roughly 9 x 12 inches. The colors in the original photo were inverted the supersaturated. This was done to better see the vortex dymanics. The image also was rotated 180 degrees so that the flow went from left to right. The original image is show in Figure 3.

Care was taken to inject dye so that it matched the local flow properties. The dye has a slightly greater density. The process of dye injection is illustrated in Figure 4.

3 Relevant Physics

The Reynolds number is a dimensionless number that describes the ration of convective to dissipative forces [4]. It can be caluclated as:

$$Re = \frac{uL}{\nu} \tag{1}$$

where u is a characteristic velocity, L is a characteristic length, and ν is the viscosity of the fluid.

The von Krmn vortex street is known to form at low Reynolds numbers [5], when dissipation dominates convection, and at high Reynolds number [6], when convection dominates. The flow rate of the flume was measured as 97 liters per minute and the cross-sectional area of the wetted flume was calculated to be $220mmx3" = 0.0167m^2$. Therefore, the average velocity was $0.1m/s$. Using the

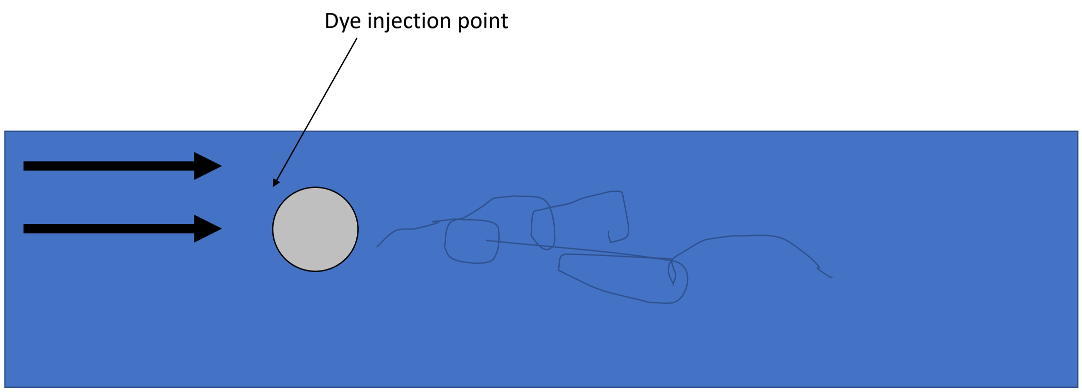

Figure 4: Dye injection process.

average velocity as the characteristic velocity, the pipe diameter (3 inches) as the characteristic length, and the viscosity of water ($\nu = 0.0000010533 m^2/s$), the Reynolds number is about 6800. If we use the height of the water (220 mm), which represents the largest possible eddy size, the Reynolds number is about 21000. Both of these Reynolds number correspond to convection dominating the flow dynamics should be considered turbulent flows.

4 What the image reveals

The image reveals the chaotic nature of the von Krmn vortex street. The wake behind the cylinder dances up and down. The image captured a sharp transition from an downwards-leaning wake to a wake aligned with he flow. Designing to account for the behavior of wakes is challenging, and it is important to keep this strange behavior in mind.

References

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