<u>**Team Assignment 1**</u>

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The purpose of this image was to demonstrate the effects of a flowing stream of water on a droplet of dye. Initially, the intent of this project was to capture images of laminar gas-phase streamlines around an object. However, gases have a very low viscosity and dissipate quite easily, making it more difficult to capture the desired phenomena. Liquids have a much larger viscosity, causing a slower evolution of momentum within the system. Using a liquid-phase flow allowed us to capture a variety of interesting physical phenomena.

In order to show how a densely concentrated liquid dye evolves as it flows within water, my team and I set up the following apparatus.

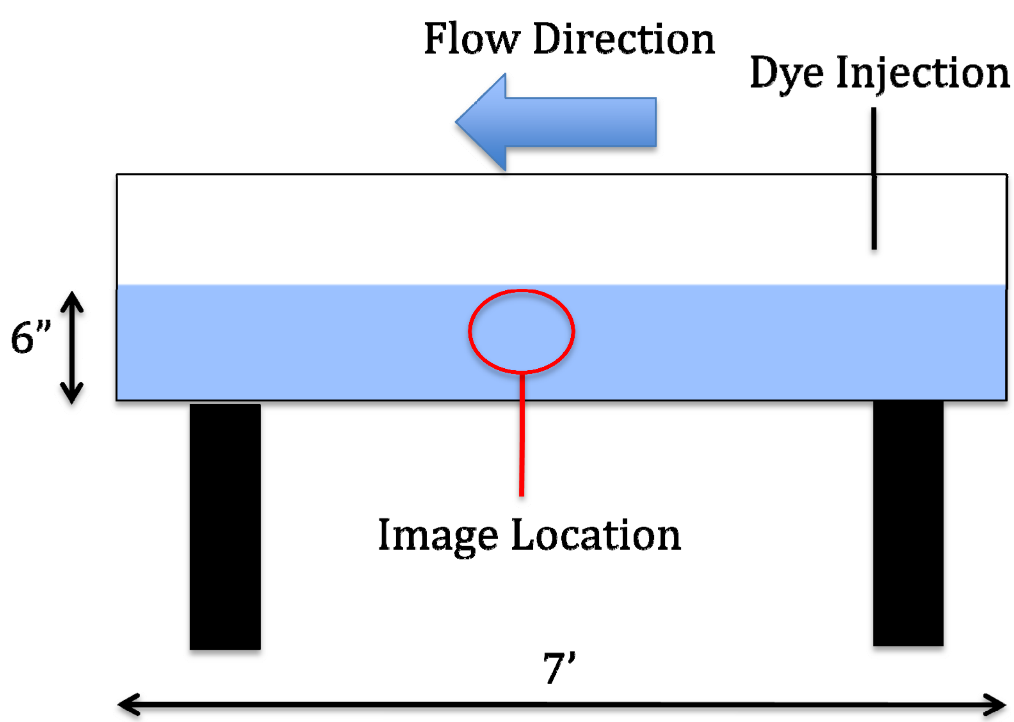

Figure 1: Flume apparatus

In this system, water was being pumped at approximately 10 GPM through a channel width of 3 in. The steady-state height of this flowing channel was 6 in. and the total length of the channel was 7 ft, as shown in Figure 1. Because the fluid is flowing through a rectangular channel, the Reynolds number of the system must be treated differently. The Reynolds number is the ratio of fluid momentum to viscosity, and it reveals the relative turbulence within a fluid. For the observed system, the Reynolds number is given by the following equation.

$$\mathrm{Re} = \frac{V\rho(4R_H)}{\mu}$$

In order to calculate the Reynolds number for flow in this channel, it is necessary to calculate the hydraulic radius, R_H [1].

$$R_H = \frac{Cross-\sec tional\ Area}{Wetted\ Perimeter} = \frac{WH}{2W+2H} = \frac{(3in)(6in)}{2(3in)+2(6in)} = 1in$$

The velocity of the stream can also be calculated by dividing the volumetric flow rate by the cross-sectional area perpendicular to the direction of flow.

$$V = \frac{(10\,\frac{gal}{\min})(\frac{1ft^3}{7.48gal})}{(3in)(6in)(\frac{1ft^2}{144in^2})} = 10.7\,\frac{ft}{\min}$$

The Reynolds number can now be calculated, which will reveal whether the system is turbulent or laminar [1].

$$\mathrm{Re} = \frac{(10.7\,\frac{ft}{\min})(62.3\,\frac{lbm}{ft^3})(\frac{4}{12}\,ft)}{(6.73\cdot 10^{-4}\,\frac{lbm}{ft\cdot s})(\frac{60s}{1\min})} = 5500$$

Flow is considered laminar when the Reynolds number is very low (Re~100). Because the Reynolds number is so high, it is appropriate to classify the flow in the image as turbulent.

As mentioned previously, the intent of this image was to capture interesting flow phenomena within a flowing channel. It is difficult to physically see turbulence within a flowing stream of water because water is transparent. By injecting green dye near the entrance of the stream, it was possible to physically see many interesting turbulent flow patterns and how they evolved over the length of the channel. The image was taken in a laboratory that was fully lit. Also, a high-wattage spotlight was used to illuminate the background. To create a strong contrast between the green dye and the background, our team chose a slightly yellow colored sheet to place as the backdrop. However, using an even lighter background color may have heightened the contrast.

The image was taken with the camera lens about 1 foot away from the flow phenomena, which allowed for a field of view of about 6 inches. Using a Nikon D60 digital camera, the overall height and width of this image (in pixels) was 3872x2592. In order to capture a high quality image, the following exposure specifications were set: ISO setting – 200, aperture – F5.6, and shutter speed – 1/100 sec. To obtain the cleanest, most representative image possible, iPhoto was used to manipulate photographic settings. I mainly altered the definition and shadowing effects of the picture to help bring out the turbulent nature of the system.

The image helps reveal a phenomenon rarely seen by the human eye. The turbulent flow of water occurs naturally all around; however, we need colors to physically perceive such a flow pattern. The turbulence shown within the green dye agrees strongly with the calculated Reynolds number for the system. It would be interesting to analyze the mass transfer effects within the channel. Because the flow is turbulent, I would expect the convective forces would cause more dissipation of the green dye than would the diffusive forces. Overall, I feel that my team and I achieved our goal of analyzing turbulent flow in a channel.

Reference:

1.) de Nevers, Noel. Fluid Mechanics for Chemical Engineers. 3rd Edition. McGraw-Hill 1997.