ARMFIELD OPEN CHANNEL FLUME OBSTACLES AND DYE INJECTION SYSTEM

DANIEL CAHN AND JEAN DORIOT

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ABSTRACT

This project contained a few different assignments aimed for a flume. The first assignment was to design obstacles. These obstacles have to allow dye to flow off the top of the obstacles without interrupting the flow. The second assignment was to design a box that fits a syringe pump. Along with these two main assignments there was one other small tasks needed to be fulfilled, this was obtaining a slightly translucent background to cover one side of the flume for taking photographs. After brainstorming a pipe was designed into a hook in order to pass through obstacles and releasing the dye at the top to minimize flow obstruction. The box with gear racks was also designed successfully and the background was made using a shower curtain.

INTRODUCTION

A course in flow visualization was offered in the Spring of 2003 to Engineering and Fine Arts students at the University of Colorado at Boulder. In this class the students were to create different fluid flows with a selection of fluid apparatus. One of the main apparatus was the Armfield Open Channel Tilting Water Flume (Figure 1) housed in the ITLL. This flume is open on the top and has clear walls to see the behavior of the water that is pumped and controlled through a gate valve. It has a 2.5m x 76mm x 250mm channel bed that allows the water to flow in a laminar or in a turbulent way [1]. Obstacles may be placed inside the Armfield Water Flume to study the transport of fluids by creating different flows, some of which end up being artistic.

Figure 1: Armfield Water Flume [1].

To be able to watch the different phenomena of the flow in the water flume a part of the flow needs to be darkened or seeded with dye. When a part of the flow is darkened, we can watch the behavior of the flow by looking at the boundary between the darkened and the transparent flow.

The Armfield Water Flume still needed to be modified for several reasons. First, the clear walls made it difficult to see the activity between the darkened and the transparent flow. Second, some obstacles were not the right size of the flume and the fluid goes in between these obstacles and the walls which also disturb the outcome of the flow. Finally, the step of applying the dye to the water was very difficult to do without disturbing the natural flow in the flume. Students tried several ways to inject the dye, but they usually ended up disturbing the natural flow.

The following paragraphs describe the design and manufacturing processes used to create new objects for the flume that emit dye, as well as a hook design to secure the objects in the flume. A complete dye injection system using a rebuilt syringe pump will be described last.

DESIGN AND MANUFACTURING

Hook:

The original obstacles for the flume are held in place with a ¼ " hook diameter that passes through the bottom of the flume. We realized that if the dye had to be inserted without disturbing the flow, it had to be inserted through the same hole that the hook utilizes. We had a few ideas about how to do this. Our first idea was to use two holes. One hole would act as a hook as the original does and the other hole would contain tubing for the dye. Another idea was to use the original hook and bring the tubing from the top of the flume. This did not work because it disrupted the flow and we figured we could simplify just like we figured for the first idea. Next thought was to make the hook and the tubing one piece. Our first idea with this was to use a metal rod with a hole in it and have a shape on top that fit flush into the top of the obstacle. Although this was a good idea, our final idea is the simplest and highly functional. We ended up using a pipe that acted as a hook when threaded into the top of the obstacle. This design is simple, creates a flush surface on top, no flow disruptions, and can be used interchangeably with all newly design obstacles. In order to design this we needed to have threads on a pipe and an obstacle that had threading tapped onto the top. Here is how we designed and manufactured the hook.

We designed a pipe of equal diameter of the original hook that was threaded on one of its ends and beveled on the other. We bought an aluminum pipe with a ¼'' outer diameter and a .19'' inner diameter from Mcguckin's Hardware store. To make sure we could thread the top of the pipe without penetrating through the wall we used a standard thread of 28 threads/inch of UNF. The machining for the threading was done with the lathe in the ITLL. Moreover we used the lathe to shave .001'' off the outer diameter in order to create a smooth surface that easily fit into the hook holes of the flume and obstacle without struggle. The final diameter is .249''. To see a picture of the threaded pipe refer to figure 2.

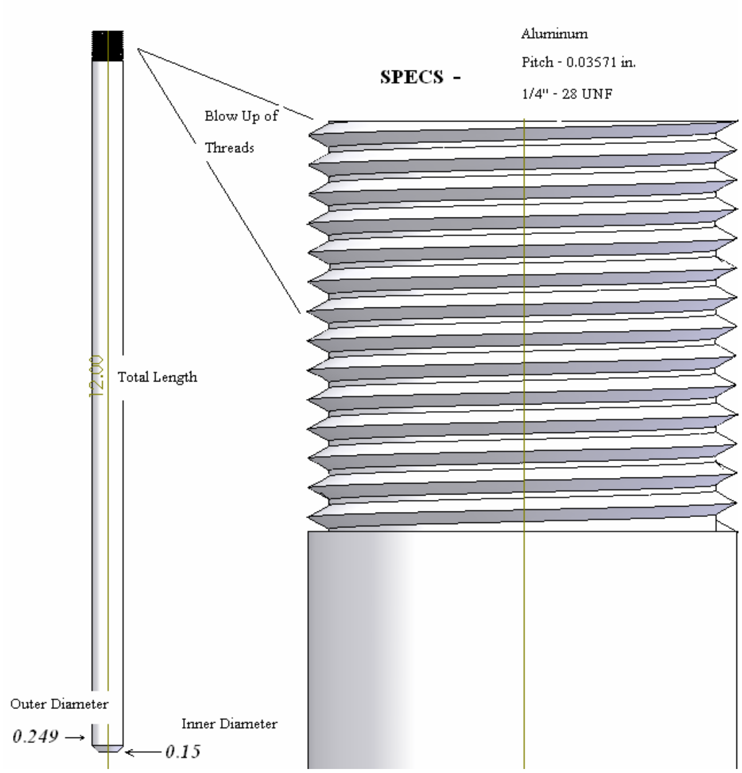


Figure 2: threaded pipe/hook

Using this newly designed hook we designed two obstacles, a wall-like structure as well as a wavy structure. The design process for these obstacles will be explained next.

Wall Obstacle:

This wall obstacle is seen on the top right in Figure 2 and creates an obstruction to simulate the flow over a wall.

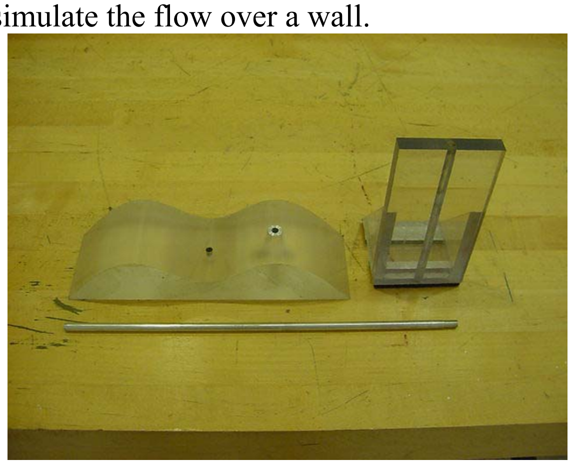


Figure 3: obstacles with hook – wave (top left), wall (top right), pipe/hook (bottom)

The basic structure consists of the wall, base, and two triangular supports all made with polycarbonate. The dimensions for these can be seen in the appendix. The first step after designing the part involved machining each part individually with the manual mill of the ITLL. Then it was necessary to tap the threads into the piece simulating the wall. In order to fit the thread design of the hook, the holes in the wall and wave were made by tapping ¼’’ 28 -UNF threads into the top of them about ¾’’ deep. Then from the other side of the objects we drilled a hole of 0.26’’ until the hole met the tapped threads. This process of drilling a hole slightly larger than 0.25’’ allows the hook for an easy fit into the object. It should be noted the tapping process should be repeated a few times so that all the plastic is removed from the obstacle and no friction is created when trying to screw in the pipe. The next step is to glue the pieces together using IPS Weld On 3. Make sure to let dry for at least 24 hours. Finally, putting some Styrofoam weather stripping on the bottom creates a good seal between the obstacle and the hook hole to protect from leaking. An o-ring can also be used effectively. The pipe can then be manually screwed into the obstacle and used as both a pipe and hook (refer to figure 3) by clamping the other side of the hook to the outer side of the flume.

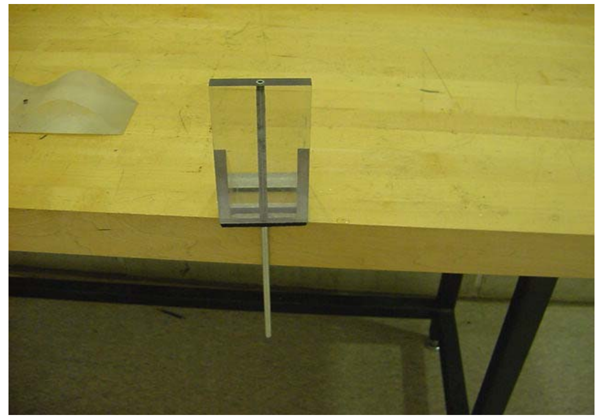


Figure 4: Hook screwed into wall

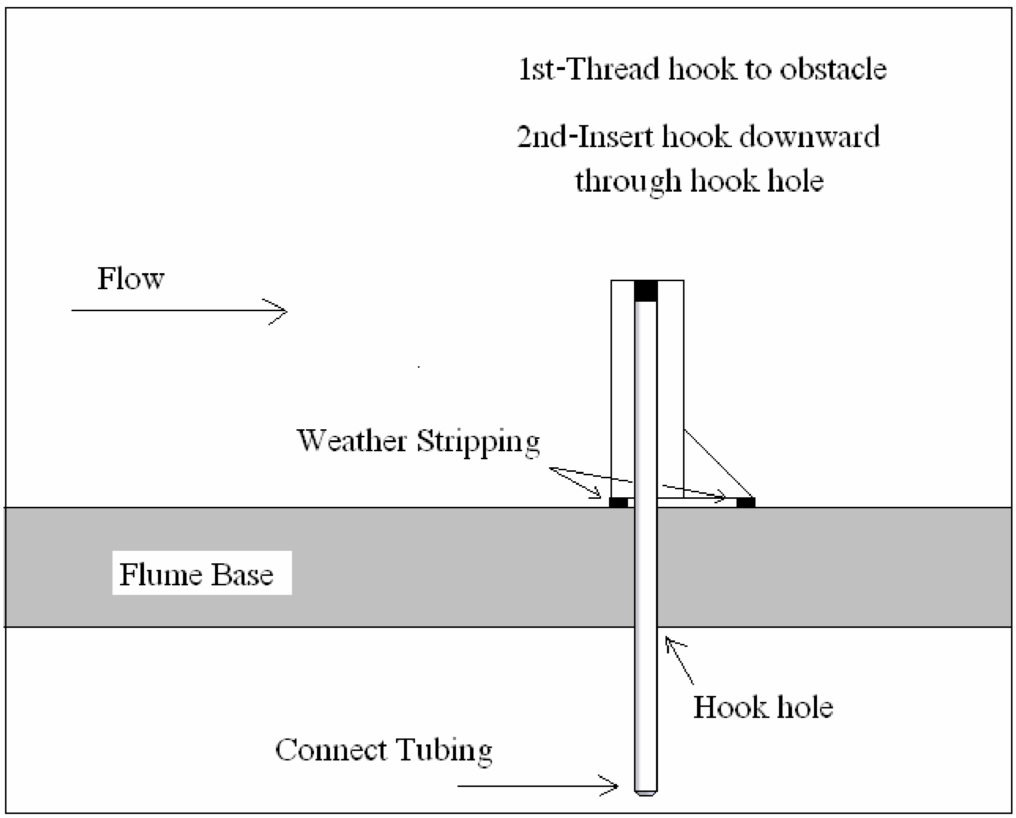


Figure 5: How hook is screwed into an obstacle in accordance with the flume

The tubing (connected to a syringe pump) is then fit around the beveled end of the pipe where the dye enters to directly pass through the pipe on its way to the top.

Wavy Obstacle:

The original idea for the design of the obstacle was a wavy block (seen in figure 2). For making the obstacle, first, we had to make a block for it. We started out using a big acrylic block that was of no cost to us because it was scrap from the ITLL Manufacturing Center. Two persons were needed for the process because the acrylic block was too heavy for just one person to lift. Note for later applications that the original block used does not have to be big, it just needs to be larger than the object being designed. The block was then cut using the Vertical Band Saw and the Table Saw of the Manufacturing Center. After obtaining first a rough piece the block was finished in the Bridgeport 2-Axis Mill. The final design for the shape of this new object was done using the program Solid Works. This file was imported to another program used for the Milltronics 4-Axis CNC Mill in the manufacturing center. Mark Eaton, Manufacturing Center Manager, did all the settings in the program for being able to run the mill for creating the wavy obstacle. It took about four and a half hours for the mill to make the wavy surface on the acrylic block that was previously prepared. The next step was to drill the holes for the pipe. We made a separate file for the two holes in the obstacle. But when the mill tried to drill the first hole something went wrong and it broke the object. The error could have been that we used a wrong tool. So, we made another block but this time we changed the dimensions of the width of the block to make the obstacle fit better in the flume. Even though the dimensions were changed we used the same files that we had for the mill. We decided that it was easier and better to drill the holes manually in the mill. One of the holes of the second obstacle went wrong so Mark fix it by making a bigger hole and putting a metal cylinder on it with a press fit, and with a hole in it of the right size for the pipe. Even though it was a mistake we recommend doing the same for future objects because due to friction it lasts longer than a hole in the material of the object.

Weather Stripping:

One of the objectives was to seal the space between the sides of the obstacles and the flume walls so that the water passing through the sides won't disturb the flow. We tried weather stripping and encountered a problem where the distance in between the flume walls diminished gradually from top to bottom. The first trials with the stripping failed because it became too tight and the obstacles got stuck. For future work, we found that an obstacle width of 2.65 inches using weather stripping (Styrofoam) of thickness 0.2 inches should work perfectly.

Photography Process:

For the photography process we used a digital camera checked out from the ITLL. The name of the camera is "DUDE" and it is a Digital Mavica camera of model MVC-FD85. It has a capability of 1.3 megapixels and the pictures were all taken between 4 and 5 inches of the outer wall of the flume. The setup of the flume for each obstacle was practically the same. The first step involved filling a bucket full of 750 ml of water and then adding 20 drops of blue food coloring. Using this colored water mixture we sucked the liquid through tubing into a 0.55'' (inner diameter) syringe. Once the syringe is full of liquid, the syringe is ready to be placed in the syringe pump and the end of the tubing to be connected to the hook. For our photos we set the syringe pump to the highest rate at 11 (This setup can be seen in figure 5).

Figure 5: Photo Setup

The flume flow rate we set somewhere between .1 to .2 L/s. The exact rate is hard to determine because of the measuring tool on the flume. It is also important to make sure that all lights above and around the flume are turned on and the background (beige curtain made of polyester) is clamped to the flume. The only difference between the two obstacles when taking photos is the height to stack the blocks at the exit of the flume. For the wall the blocks were stacked to 8’’ and the wave to 4’’. With this information the replication process for taking pictures of the obstacles in the flume is possible. To view a sample of pictures taken refer to the appendix.

Syringe Pusher Box:

The dye is injected with a syringe and the syringe is actuated by a syringe pump. Its function is to push the plunger of the syringe at a constant speed so that the dye is injected at a constant flow rate. We are using a syringe pump from the lab which was missing a part, a box with gear racks. Both parts can be viewed in figure 6-a and 6-b.

Figure 6-a: syringe pump – gears (top) with gear racked box

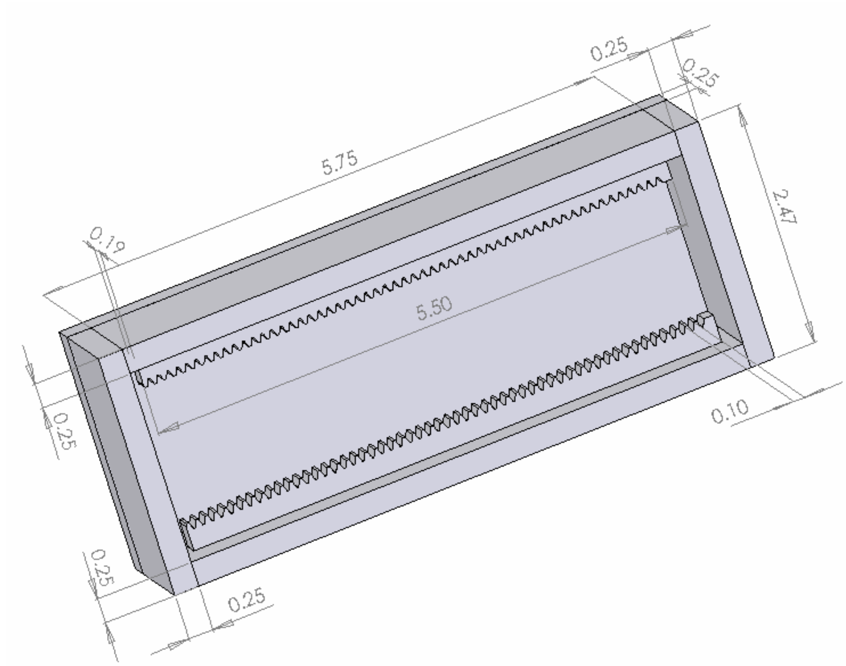


Figure 6-b: Dimensions of pusher box

This box is actuated by two gears of the syringe pump so that it moves at a constant velocity actuating the syringe. Our job was to make a new box for it. The critical part was the gear racks of the box. We designed the gear racks using a program called GearTrax. The program was given to us by the Co-Director of the ITL, Lawrence E. Carlson, and he also helped us to learn how to use the program. This program takes the data about the gears and creates a model in Solid Works. So we had to learn to use Solid Works in order to be able to make a design for the gear racks. The problem we encountered with GearTrax is that it does not create gear racks. Using the dimensions of the gears of the syringe pump in GearTrax we solved this problem by making a spur gear with 10,000 teeth with the necessary pitch diameter for the gears. By making it so big, the teeth were straight enough to be considered a gear racks. But it still had a little curvature. To fix it we took one of the teeth and made a linear pattern to create the gear racks. We made a drawing of the rack in solid works so that it could be used in the Laser Cutter machine in the Manufacturing Center of the ITL.

The other parts of the box were designed in Solid Works. We use the laser cutter to make these parts as well. The parts were designed for using an acrylic material with ¼ in. thickness. When we went to the laser cutter there was not enough space on the material that we were going to use, so we used another material to make it. The problem encountered is that this new material was less thick than the one we were going to use first. Due to this thickness difference, the gear box is a little loose when placed in the gears of the syringe pump, but it still works well.

CONCLUSION

Our main concern at the beginning of the project was to design a mechanism capable of injecting a dye in the water flow in the Flume without interrupting the flow. For our application, flow visualization, the flow needs to be laminar or as stable as possible. Using a new hook we could replace the existing hook and successfully accomplish the specifications for the dye injection. As well as the dye injection process we also designed a gear track to replace the old one on the syringe pump.

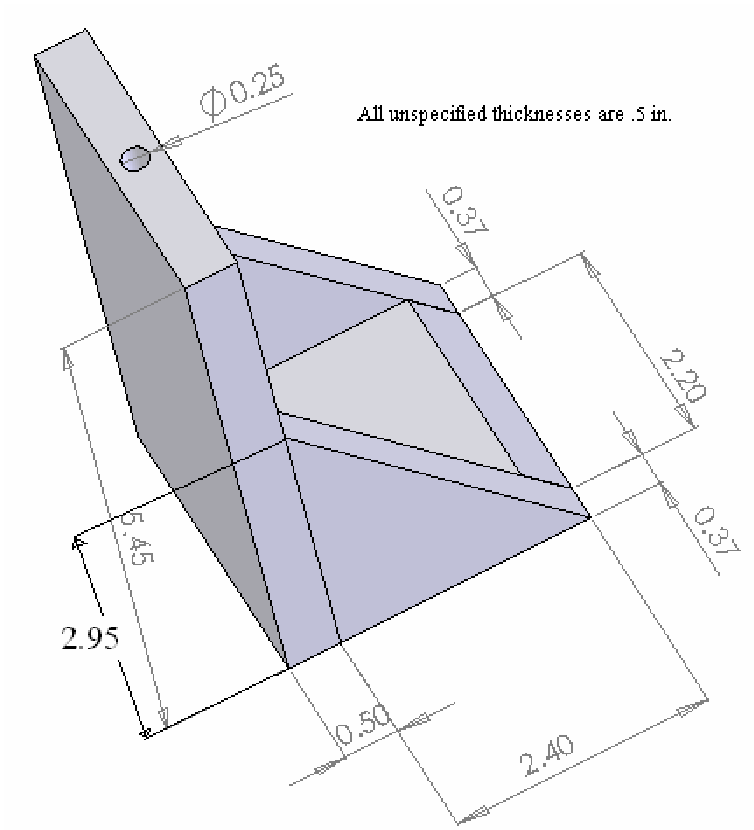
The hook was used with two newly designed obstacles for the flume. The first one can be described as a polycarbonate straight wall and the dye is injected in the top, perpendicular to the direction of the water flow. The second obstacle is an acrylic wavy object with two holes in it. The holes are used one at a time for inserting the dye in different areas of the flow so that different behaviors of the flow can be seen.

The last part of our project was to take pictures of the dye in the flow using our new obstacles. Before this could be done we first needed to do other things. We needed to fix the syringe pump and obtain a background. We already had a syringe pump in the lab but a part was missing, a box with gear racks for used for pushing the syringe at a constant speed, inserting the dye at a constant flow rate. So we built a new one; the box is a little loose in the gears of the syringe pump but it still works perfectly.

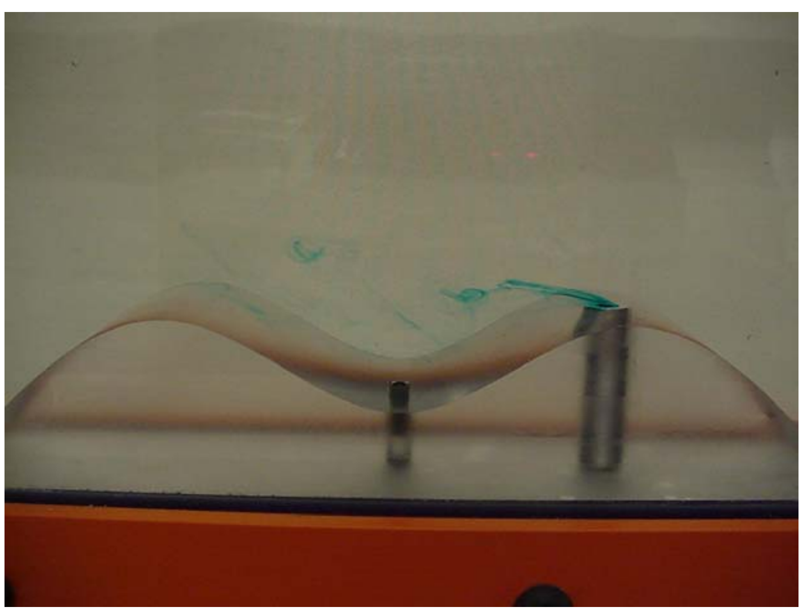
For the background the specifications were the following: slightly translucent, easily storable and water resistant. We were able to complete all this specifications by buying a shower curtain.

After the syringe pump was fixed and the curtain was obtained we were able to take the pictures. We took some pictures using the two obstacles with a digital camera from the ITLL. The best pictures were taken in the range of 4 to 5 inches from the glass wall of the flume. For later work, more obstacles can be designed and the weather stripping can be perfected.

APPENDIX

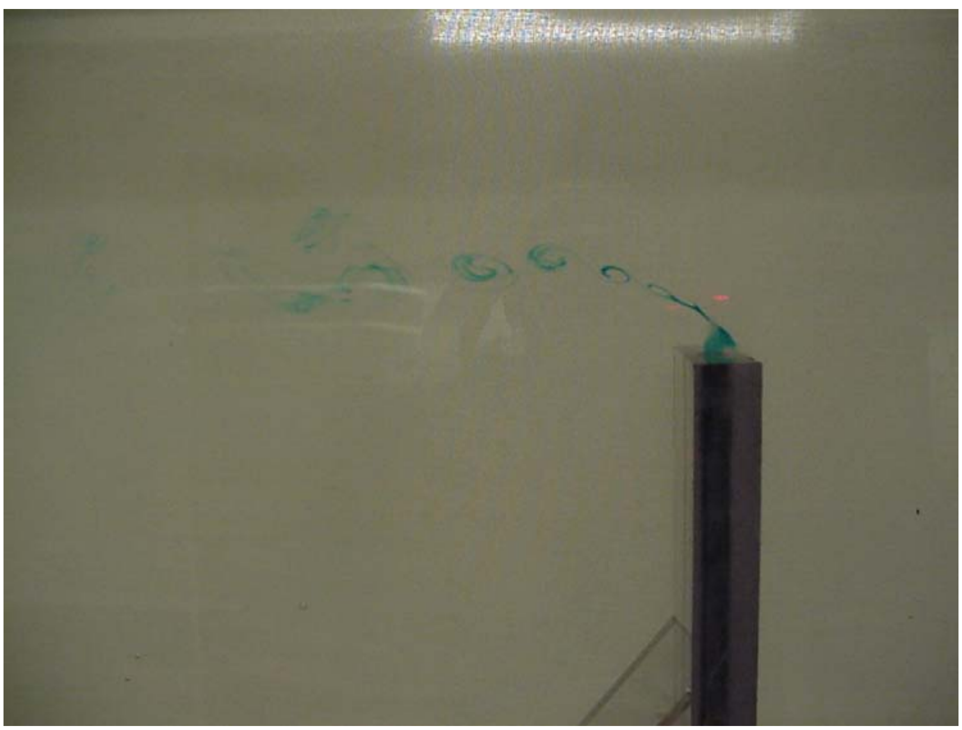


A1: Dimensions for wall obstacle



A2: Photo of dye released from back hole in wavy obstacle.


A3: Photo of dye released from center hole


A4: Photo of dye released from wall

REFERENCES:

1. <http://ITLL.colorado.edu/modules>