

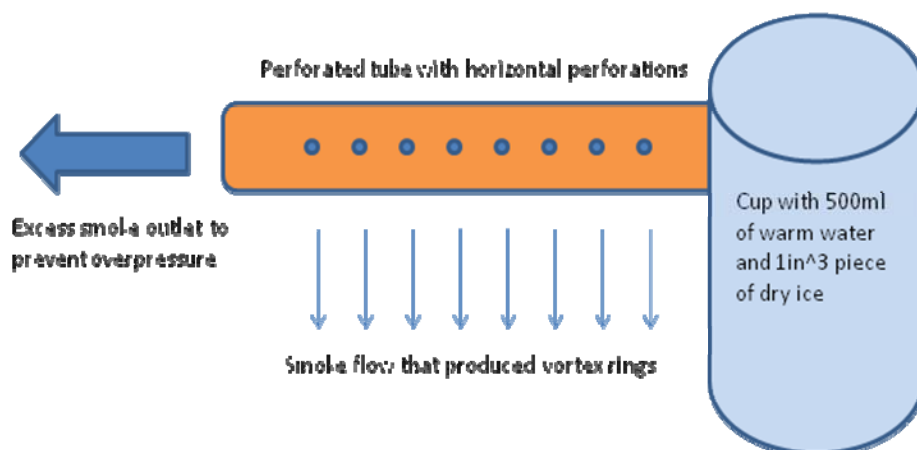
## Introduction

The purpose of this assignment was to introduce the photography of a fluid flow and to institute some introductory techniques. I came up with the idea to incorporate the water vapor produced from dry ice to enable the flow phenomena to become visible to the human eye. This was inspired from the “smoke” that can be seen around a solid piece of dry ice sitting within a room. Now as dry ice vapor as the subject, the next step was to produce a flow phenomena utilizing the visible water vapor within air. This was done by forcing the water vapor through a series of small holes of 2 millimeters in diameter. This produced the following picture (after post processing).



## Experimental Setup

To produce the photo above the dry ice vapor had to be further stimulated in order to increase visible water vapor output which will now be referred to as smoke. This was done by placing a 1 cubic inch piece of dry ice into 500 milliliters of water at 70 degrees Fahrenheit. The warmer water prevented the water from freezing around the piece of dry ice hence encapsulating the dry ice within a thin sheet of ice which would drastically reduce the “smoke” output. Now, this smoke had to be harnessed and channeled into the perforated tube. This was done by sealing one end of the tube with the cup that had the dry ice and warm water. The other end of the tube was left unobstructed to allow the smoke to flow through the tube and also out of the 2mm holes that run the length of the tube horizontally. And illustration of this setup can be seen below:



This setup produced a very interesting and steady flow. The flow begins laminar near the exit hole and then forms vortex rings as the smoke travels farther away from the origin. This set up was extremely repeatable and seemed to produce a steady state flow of smoke and air interaction.

## Safety

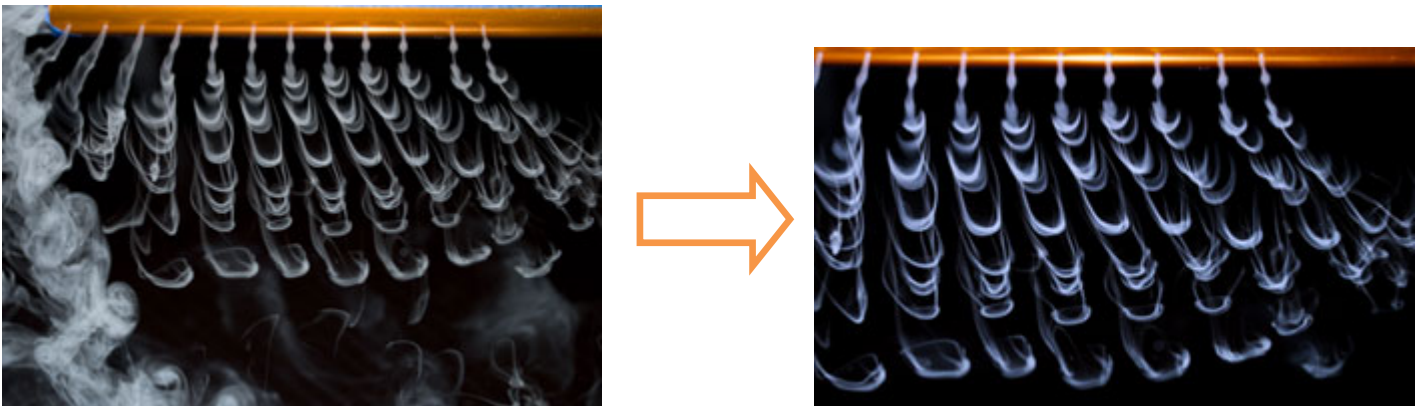
When working with dry ice one must work in a large and open area with plenty of air. This is because when dry ice sublimates it produces CO<sub>2</sub> gas that may displace oxygen and cause death or injury. Another danger with dry ice is forcing it within an enclosed area. This can produce enormous pressures that can produce deadly explosions. During the course of this experiment this and all other safety precautions were taken.

## Photography and Post Processing

Once the experiment was properly setup a Nikon D60 SLR digital camera was used to capture the image. The smoke was flowing parallel to the floor and the camera and strobe was placed about 6 inches above the phenomena and the lens was looking downward perpendicular to the floor. The parameters of the camera when the image was taken are shown below:

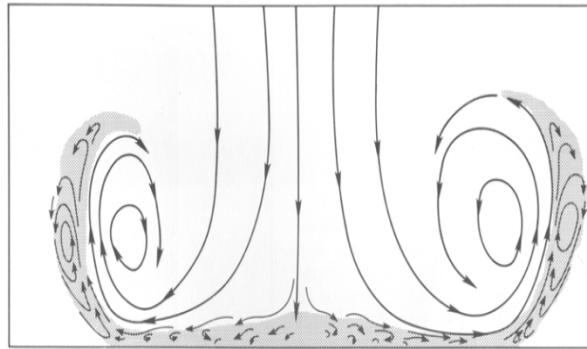
Date Time	1/31/2010 - 3:38:19 AM
Shutter Speed	1/125
F-Stop	f/5.3
Aperture Value	f/5.3
ISO	100
Focal Length	42mm

After the photo was taken there was some post processing to touch up the image and enhance its visual impact. This consisted of removing some distracting smoke that was not a part of the main flow phenomena. Then the contrast and brightness was also altered in order to bring out the smoke a little bit more. Finally the photo was cropped to my liking. I intentionally left the source (orange perforated tube) in the picture because I felt the color and source of the smoke positively enhanced the photo. A before and after photo can be seen below:



## Physics

This setup produces some very interesting and pleasing flow phenomena. Now due to the nature of the smoke stream when exiting the origin I estimate that the Reynolds number is relatively low and within the laminar region. Then, after about 1-2 inches or travel the smoke streams begin forming vortex rings. This is due to the moving smoke stream being injected into stationary fluid (air). In laymen terms this causes the external layers of the stream to peel back onto itself thus forming the rings while the center most stream drives the creation of the vortex ring. An example image of this is seen below:



(<http://www-frd.fsl.noaa.gov/~caracena/micro/MBVoring.htm>)

As you can see when comparing this image to the photograph the rings look very similar and are photographed from the same point of view.

## Sources

Vortex Rings

[http://en.wikipedia.org/wiki/Vortex\\_ring#cite\\_ref-1](http://en.wikipedia.org/wiki/Vortex_ring#cite_ref-1)

Reynolds Number

[http://en.wikipedia.org/wiki/Reynolds\\_number](http://en.wikipedia.org/wiki/Reynolds_number)