“Space Cannon” Experiment

Antonio L Gueretta

Department of Mechanical Engineering, University of Colorado Boulder,
1111 Engineering Drive, Boulder CO 80309

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1. Introduction

The purpose of this assignment was to capture a fluid phenomenon in an artistic fashion in a team setting for the second time. This assignment was submitted to the Flow Visualization course, MCEN 5151, led by Professor Jean Hertzberg. The experiment was carried out with the assistance of Jason Fontillas. The goal of this experiment was to observe and capture the interactions with dry ice, water, bubbles, and ink coloring. For the submitted image only dry ice and water were used.

2. Discussion of Flow

Dry ice is commonly thought of as extremely cold frozen water. It is actually frozen carbon dioxide. As the dry ice is submerged in water it undergoes a process known as sublimation. Sublimation is the rapid transition from a solid phase to a gas phase, skipping the transition to a liquid [1]. For this experiment a dry ice chip was submerged in water and as the gaseus carbon dioxide left the solid carbon dioxide chip it then rose to the surface of the water. Surface tension would contain the gas forming a “bubble” of carbon dioxide.

The pressure would increase as more and more gas was added to the bubble until the pressure would increase above the atmospheric pressure. At this instant the bubble would pop and a white cloud of gas would be released at once. When this happens, there is the possibility for vortex rings to form. These vortex rings are also related to how a mushroom cloud forms as seen in the image. There are laminar (smooth) or turbulent (chaotic) vortex rings [2]. To understand what type of vortex rings are present in this image the Reynolds number can be approximated to understand if the flow is laminar or turbulent. The Reynolds number (Re) is a ratio between the Inertia Forces and the Viscous Forces and can be expressed using *Equation 1*,

$$Re = \frac{\rho V l}{\mu}$$

where ρ is the density of the fluid, V is the velocity of the fluid, l is the characteristic length scale of the fluid, and μ is the bulk dynamic viscosity [3]. The respective quantities for this experiment can be seen in *Table 1*.

Table 1. Properties and measurements of flow for the gaseous carbon dioxide plume

Density (kg/m^3) [4]	1.902
Velocity (m/s)	15.685
Length Scale D (m)	0.035
Viscosity (Pa*s)[5]	1.37×10^{-5}

The velocity and length of the carbon dioxide plume were approximated through image analysis of sequential pictures taken before and after the presented image. The FOV of six inches was used along with the measurement tool in Photoshop to find the change in distance (approx. 0.063 m) and the diameter of the carbon dioxide mushroom cloud head. The pictures analyzed were taken .004 seconds from each other. By using *Equation 1* and the data in *Table 1* the Reynolds Number was approximated to be 76,000 which for values greater than 4000 results in a turbulent flow. It can now be supported that the chaotic plume in the image is turbulent.

3. Visualization Technique

For this experiment a one-inch by two-inch chip of dry ice was completely submerged in about four inches of water. The water and dry ice was contained in a glass container measuring 2x4x4 inches (WxLxH). A black laptop sleeve was used as a backdrop to the image. A headlamp was used to light the experiment from the bottom and a maximum of 350 lumens from the headlamp was used. The light source was placed inside a separate glass container to eliminate fluid from reaching the light source. See *Figure 1* and *Figure 2* for views of the setup. *Figure 3* shows the actual setup of the experiment.

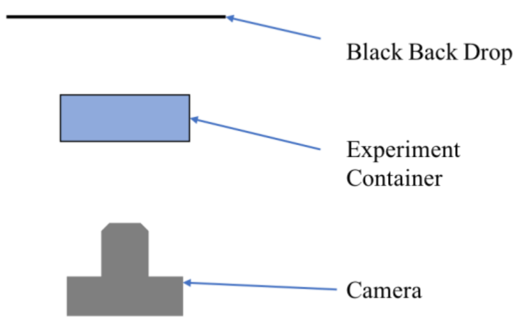

Figure 1. Top View of Setup

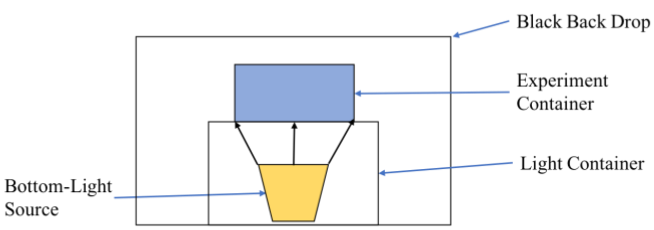

Figure 2. Front View of Setup

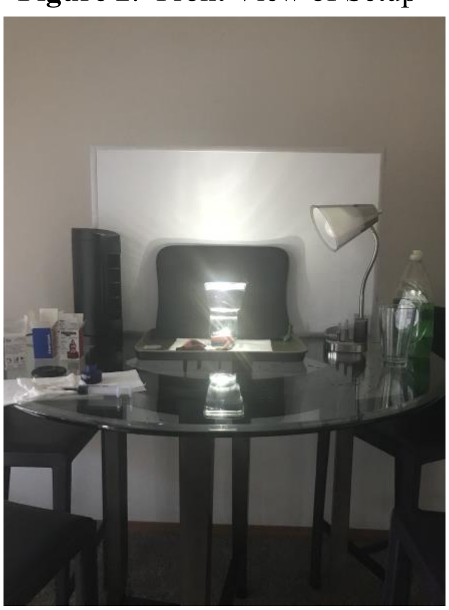

Figure 3. Actual Setup

4. Photographic Technique

A Canon Rebel T3i EOS 600D DSLR camera was used for photographing the dry ice and water interaction. An 55-200 mm lens was used and zoomed in to achieve a FOV of approximately six inches. The distance from the camera and the glass experiment container was approximately three feet normal to the front face of the container. The raw image is 5184 x 3456 (HxW) pixels, *Figure 4*.

Figure 4. Raw Unedited Image

The final edited image is 1300 x 1112 (HxW) pixels, *Figure 5*.

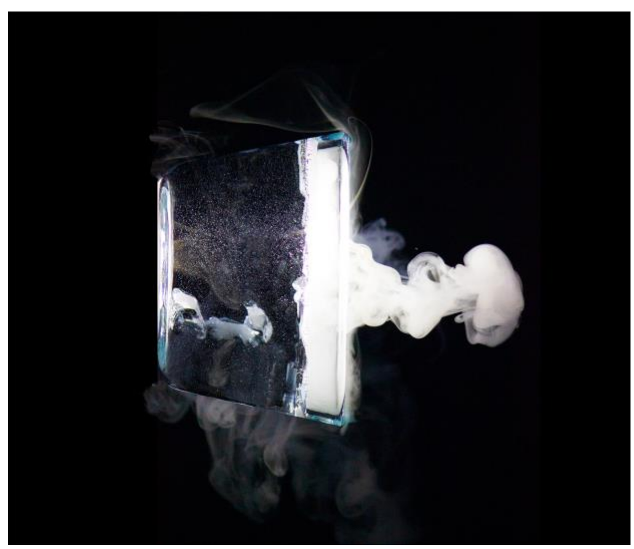

Figure 5. Final Edited Image

The camera settings were as follows: ISO: 3200, Shutter Speed: 1/500, Aperture: f/5, Focal Length: 109 mm.

The edits were done use Adobe Photoshop CC 2019. The curves function was used twice in photoshop to adjust the image as a whole and then to further adjust the "clear" water below the white gas build up. The spot healing tool was also used to remove the glare on the glass walls from the original image. The image was then rotated clockwise 90 degrees and additional background added to the image to create a more centered aspect to the image. The pattern and spot healing tools were used to add additional fog around the bottom parts of the glass container to create a more natural feel to the image in a subtle artistic way. The curves function edit for the entire image can be seen below in *Figure 6*.

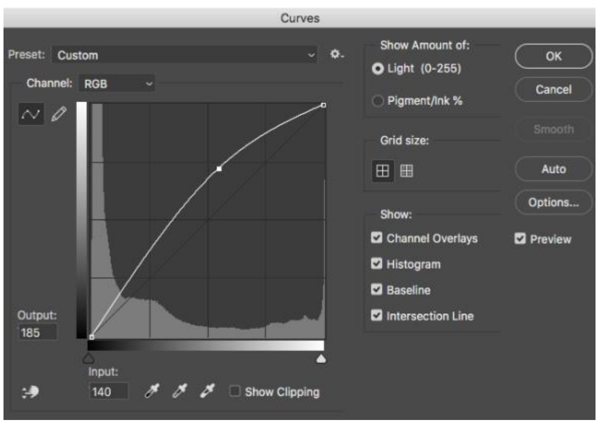

Figure 6. Edit Curves Layer in PS 2019

5. Discussion

I believe that the final image is one of my best works for this class. The experiment was simple, and I honestly lucked out by capturing the white plume cloud exploding from the surface of the water. I believe that the edits successfully enhanced the fluid physics of the image and did so in an artistic fashion.

References:

[1] U.S. Department of the Interior, 2019, "Frozon carbon dioxide (dry ice) sublimates directly into a vapor" https://www.usgs.gov/media/images/frozen-carbon-dioxide-dry-ice-sublimates-directly-a-vapor

[2] Ari Glezer, Department of Aerospace and Mechanical Engineering, The University of Arizona, Tuscon, Arizona, 1988, "The formation of vortex rings"

[3] National Aeronautics and Space Administration, 2014, "Reynolds Number" https://www.grc.nasa.gov/WWW/BGH/reynolds.html

[4] Engineering ToolBox, (2018). *Carbon dioxide - Density and Specific Weight*. [online] Available at: https://www.engineeringtoolbox.com/carbon-dioxide-density-specific-weight-temperature-pressure-d_2018.html

[5] Engineering ToolBox, (2014). *Gases - Dynamic Viscosity*. [online] Available at: https://www.engineeringtoolbox.com/gases-absolute-dynamic-viscosity-d_1888.html