Flow Visualization: Team Photo 1

MCEN 4151: Flow Visualization
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Purpose

The motion of fog- and smoke-like fluids can be very interesting when photographed. With proper lighting to accent stream lines, the flow characteristics can be determined. The simplest way to create homemade fog is to use the assistance of dry ice, or solid carbon dioxide. When combined with water, dry ice sublimates vigorously, and the mixture expels a dense fog of water vapor. This photograph utilizes the dry ice and water phenomenon. It was created with the help of three team members: Gaberiel Bershenyi, Jennifer Milliken, and Zachary Brunson.

Flow Apparatus

It is important to select a thick glass container or a container that will not shatter or crack when very cold to house the water and dry ice mixture. This photo used a 6.5 inch cylindrical glass container with a diameter of 3.5 inch. The glass was filled three quarters full of water. Warm water must be used in order to create the fog. Once the water temperature reaches 50 degrees F, it will stop producing fog but continue to bubble until all of the dry ice has sublimated.[1] A medium sized (2" X 2" X 2") cube of dry ice was then dropped into the glass container. At this moment the mixture will start to emit bubbles and fog. The mixture was placed on a table flush up against the edge of a box (roughly the size of a shoe box) covered with an all-black T-shirt. The black box allows a clear visualization of the fog as it travels across the black surface. The figure below describes the layout of the flow apparatus.

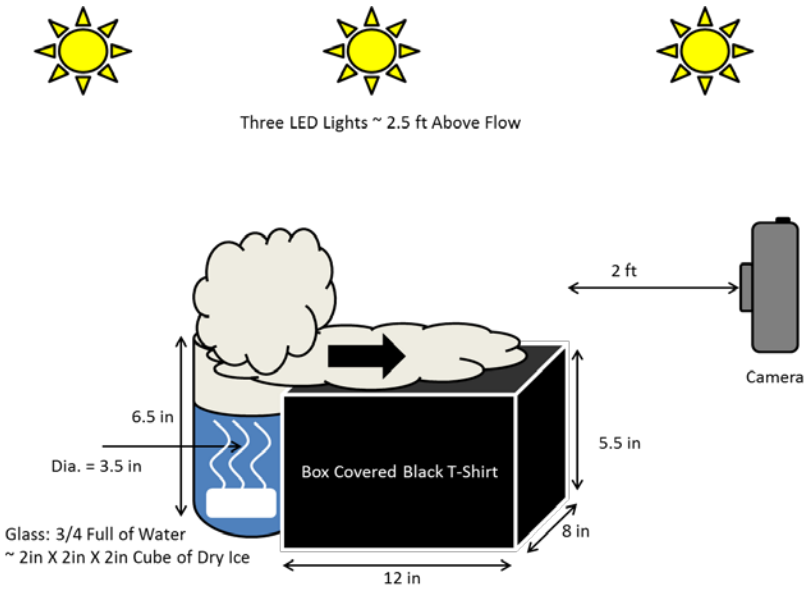

Figure 1: Flow Apparatus

Flow Dynamics

More specifically, when dry ice is dropped into a container of warm water, it sublimates and transforms directly from solid state to gaseous state. In both forms it is completely composed of carbon dioxide. This means that the fog you see is entirely water vapor. The water vapor is present because the extremely cold dry ice produces extremely cold gaseous carbon dioxide. Since the emitted gas is colder than the temperature of the condensation point of water, the surrounding air's humidity is converted to fog.[1]

The fog that is created is denser than air due to its water vapor content, so it will sink. In this apparatus the fog exited the container and fell to the surrounding surface, the black box. The fog then traveled across the box and on to the table. The interesting phenomenon in this image includes both the wave like propagation of the fog across the box and the stream lines created within fog flow.

The Reynolds number can be used to better understand the physics of the presented flow phenomenon. Reynolds number is calculated:[2]

$$Re = \frac{\rho * V * d}{\mu} = \frac{U * D}{v}$$

where U is the velocity of the fog, R is the radius of the water vapor droplets in the fog, and v is the viscosity of the water vapor.

U was estimated to be roughly 1 ft/sec (0.3048 m/s) using a ruler and stopwatch (the fog traveled across the 12 inch box in about a second). The diameter of a water vapor particle within the fog was about 10 µm based on the average diameter fog equipment produces.[3] The viscosity of the water is about 1.0 X 10^-6 m^2/s.[4]

$$Re = \frac{0.3048\frac{m}{s} * .0001m}{1.0x10^{-6}\frac{m^2}{s}} = 3$$

This Reynolds number describes a fluid in laminar flow which makes sense with the fog system. The flow in the image is very parallel in motion in the direction of travel and appears laminar.

The laminar flow is accented by the streaks in the fog. The best hypothesis for these streaks is that they are caused by the drag created from fibers of fabric in the black cloth. The wave like propagation of fog across the surface could be explained by variable size plumes of vapor emissions. The inconsistency of the dry ice sublimation and water vapor condensation would cause varying amounts of emissions released over time.

Visualization Technique

The Image was created with the help of Gaberiel Bershenyi, Jennifer Milliken, and Zachary Brunson. The flow apparatus was placed in a mostly dark room and lit using LED lights. The camera can be at any angle or distance from the fog. For this image the camera was looking directly at the black box with the container of water and dry ice hidden behind. The lens was about an arm's length from the surface of flow. The lighting was about 2.5 feet above the flow and staggered as shown in Figure 2. No flash is needed. The most crucial part of the photograph is to have effective lighting. Using black back drops and black surfaces allows for minimal distraction of the fog and better visualization. By using larger chunks of dry ice and warmer water, more fog can be produced which may be favorable and easier to photograph.

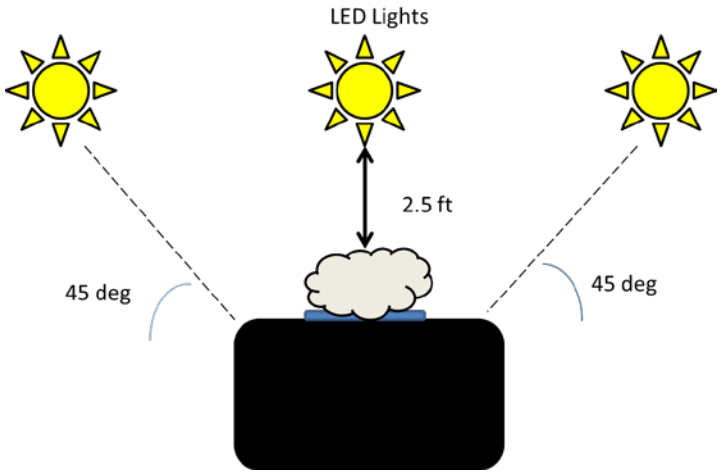

Figure 2: Visualization Layout from Camera Perspective

Photographic Technique

The photographer of the image was Jennifer Milliken. The camera used was a Canon EOS Rebel T3 (12.2 megapixels).[5] No flash was needed because LEDs were used for illumination. The original photograph is 12.2 megapixels (4272 X 2848). The ISO was set at 1600 to increase sensitivity and ensure a clean image with the limited light in the photograph. The shutter speed was set to 1/80 of a second which captured a quick shot of the fast moving flow while allowing an appropriate time for light to enter. Aperture was F4 which allowed an effective volume of light to enter the lens.[6]

I did all of the post processing utilizing Photoshop. Very little modifications were needed. The image was slightly cropped to better align the plume in the center. The contrast curve was adjusted slightly to distinguish

the blacks and whites as well as black out the background. Lastly, the image was converted to gray scale to eliminate any of the brown tint within the white fog.

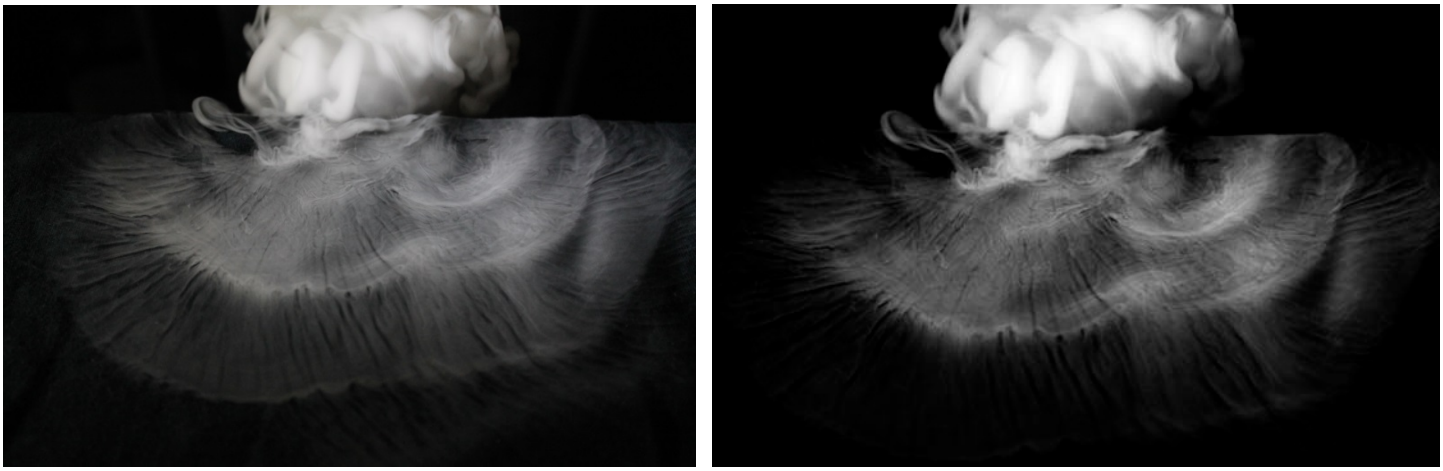

Figure 3: Before (left) and After (right) of Image

Conclusion

The team tried many different attempts and scenarios which all used dry ice. We were all able to develop an image that was very different from each other. We did this by using different mixtures to drop the dry ice in as well as different fluid colors, containers, and lighting. I chose the presented image because it is very easy to see the laminar flow and the black and white aspect eliminates any distractions from the flow. I think the final image is very clean, detailed and successful in displaying flow phenomenon.

References

[1] "Dry Ice Fog and Special Effects." Dry Ice Information - all about dry ice. N.p., n.d. Web. 14 Mar. 2013. <http://www.dryiceinfo.com/fog.htm>.

[2] "Reynolds Number ." Engineering ToolBox. N.p., n.d. Web. 14 Mar. 2013. <http://www.engineeringtoolbox.com/reynolds-number-d_237.html>.

[3] "Mist and Fog Equipment for Propagation | UMass Amherst Greenhouse Crops and Floriculture Program." University of Massachusetts Amherst | Center for Agriculture. N.p., n.d. Web. 14 Mar. 2013. <http://extension.umass.edu/floriculture/fact-sheets/mist-and-fog-equipment-propagation>.

[4] " Water - Dynamic and Kinematic Viscosity ." *Engineering ToolBox* . N.p., n.d. Web. 12 Feb. 2013. <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html>.

[5] "Canon U.S.A. : Consumer & Home Office : EOS Rebel T3 18-55mm IS II Kit." Canon U.S.A., Inc.. N.p., n.d. Web. 14 Mar. 2013.<http://www.usa.canon.com/cusa/consumer/products/cameras/slr_cameras/eos_rebel_t3_18_55mm_is_ii_kit>.

[6] "Exposure | Understanding Exposure - ISO, Aperture and Shutter Speed Explained." ExposureGuide - Photography Tips, Techniques and News. N.p., n.d. Web. 14 Mar. 2013. <http://www.exposureguide.com/exposure.htm>.