IV 2 Report

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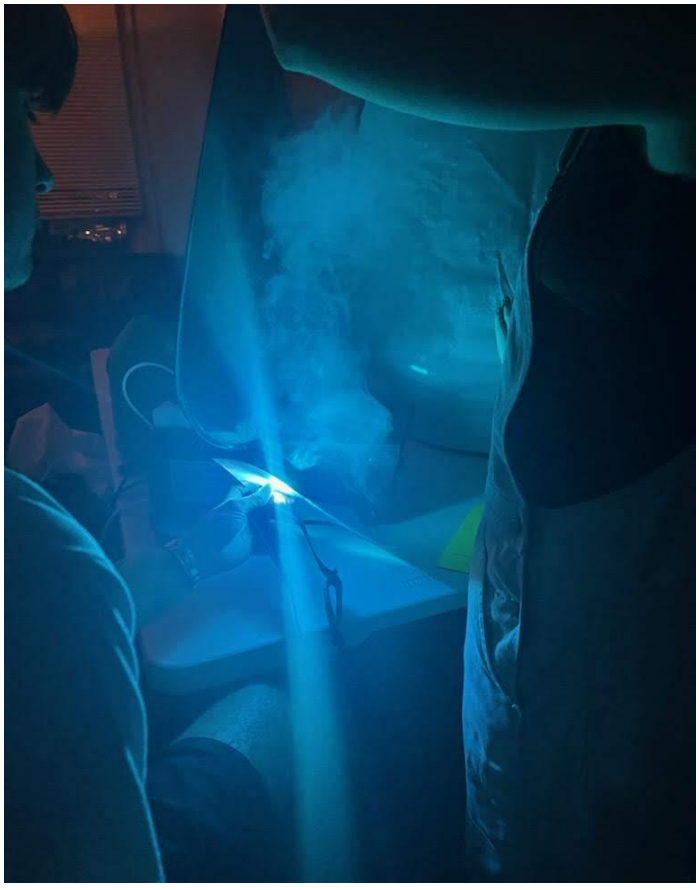
I. Purpose of Experiment

The goal of this project was to capture fog movement in ambient (without wind or drafts) air. Along with that, we also wanted to experiment with different colors in the fog to make the final result more eye-catching. The different colored lights might also help highlight things that wouldn't be able to be seen otherwise, like different depths and levels in the fog plume.

II. Setup

For this set up we used a fog machine, car sun shields, two headlamps (LED lights behind a light diffusing plastic), and 2 colors plastic films. We opened the top of the fog machine to let the fog billow out and up. We framed the fog with the car sun shields to help make the background a flat black color. We took the photos in a completely dark room, so when we turned on the headlamps and shone the light beam into the fog, it was very visible. We then put the colored films over the head lamps to make light red and blue. We held the blue headlamp on one side and the red headlamp on the other.



To take the photo, I held the camera about 5 to 6 inches away from the fog. I also set my focus manually, before the fog, using my teammate's hand as something to focus on. We would then activate the fog machine for about 2 seconds and then wait about 2-4 seconds before starting to take photos. This allows time for the fog to start flowing more naturally.

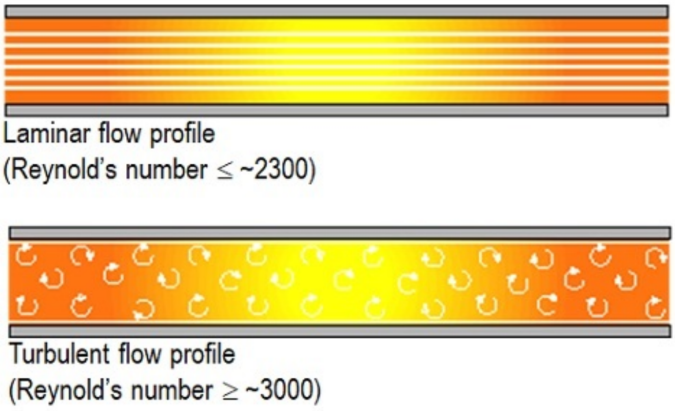
III. Fluid Mechanics

In this image, we can see that the fog is experiencing turbulent flow. Turbulent flow is used to describe when the Reynolds number of the flow of a fluid is above 2300. Laminar flow is when the Reynolds number is below 2300 [1]. To calculate the Reynolds number, we use the equation:

$$Re = \frac{\rho V d}{\mu} \quad \text{Eq. 1}$$

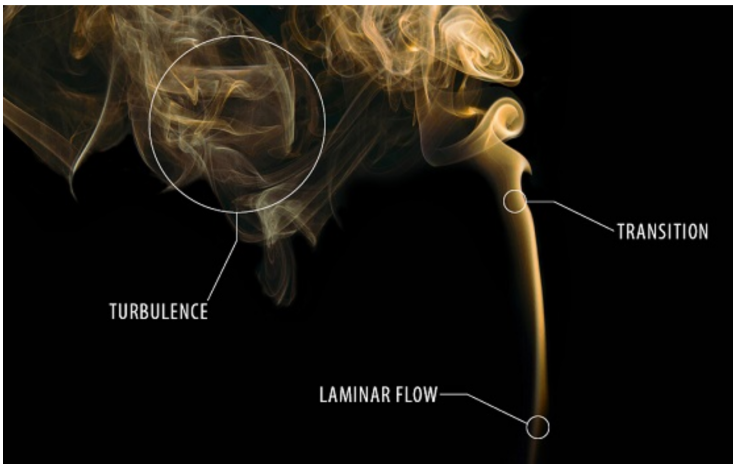
Where ρ is the density of the fluid (kg/m^3), V is velocity of the fluid (m/s), d is diameter that the fluid is traveling through (m), μ is the dynamic viscosity of the fluid (kg/ms), and *Re* is the Reynolds number. When calculated, the units of the input variables cancel out so that the Reynolds number is a unitless number [2].

Another way to determine what kind of flow is occurring, is just by looking at it. Laminar flow is the smooth linear flow of a fluid where each fluid particle is flowing down a straight path. Turbulent flow is when the fluid particles are bumping into each other (or the walls of a pipe) and swirling and moving in all directions.



Laminar vs. Turbulent flow in a pipe [3]

In fog or smoke, this difference is very noticeable. Since the fluid is very visible to the naked eye, it is easy to see the difference between laminar and turbulent. Laminar is the streamlined flow that trails up in a thin ribbon, whereas turbulence resembles more of a fluffy cumulus cloud with vortices. One place that this is very noticeable is when a candle is blown out. When a candle is first blown out, the first few inches of smoke coming off the top of the wick are often in laminar flow. However, once the smoke reaches a bit higher and starts to experience things like air currents in the room or drag, the smoke starts to become turbulent.



Laminar vs. Turbulent vs. Transitional flow in smoke [3]

In the case of the fog machine, most of the fog seen is already in turbulent flow. This is because *d*, the diameter of where the fluid exits, is very big since the fog is exiting out of the top flap of the fog machine (about 6 inches across). As we can see in eq. 1, as *d* increases, *Re* also increases. There are a few areas that are either temporarily experiencing laminar flow, or are in a transitional stage where the fog is transitioning from a laminar to turbulent flow.

IV. Photographic and Visualization Techniques

The photo was taken with a Canon EOS M50. When taking the photo, the settings that I chose were; ISO:2000, F-Stop:f/4, Shutter Speed:1/1600s, Focal Length:17mm. I chose a short exposure since the fog was moving fairly quickly and I wanted to minimize movement blur. I also used a smaller aperture since I wanted a larger depth of field because I was so close to the subject of my photo. To compensate for the loss of light in a short exposure and small aperture, I turned up the ISO which resulted in more graininess in the final photo.

This photo was taken about 4-6 seconds after activating the fog machine. This image captures an area that is about 4 inches across and the camera was held about 5-6 inches away.

When editing this photo I mainly used the rgb curve and the denoise function. I adjusted the rgb curve a very minor amount to highlight more of the fog in the darker areas of the photo. I then used the denoise to get rid of some of the grains and noise that appeared. The original and edited photo size is 6024x4020 pixels as I didn't have anything in the photo that I wanted to crop out.

This image is time-resolved since there is no motion blur that is able to be seen. However, I believe that this image is not sufficiently spatially resolved. There is a loss of spatial resolution due to mainly ISO noise. The ISO had to be greatly increased to make up for the very dark environment, but as a result, the image became a bit grainy.

Original Photo

Edited photo

V. Image Remarks

I am happy with how this photo turned out. I like the color gradient that I got and how in the middle I was able to get a nice dusty lavender color where the red and blue combine. I also like all the swirls and other flowy designs that appeared in the smoke. I enjoy how the photo is in focus so that the paths of the fog particles are very clear and able to be traced. I think there are lots of fun designs hidden within this photo.

If I had more time with this project, I would have liked to have made a photoset or video of several different images of the fog, that way I would be able to catch some of the actual movement of the fog. If I were to develop this idea further I would also like to experiment with fog and lasers, specifically laser planes. Using a laser plane would display just a thin slice of the fog and would highlight even more designs and swirls.

References

[1] “The Engineering Toolbox: Reynolds Number.” Accessed October 10, 2022. https://www.engineeringtoolbox.com/reynolds-number-d_237.html

[2] “Princeton University: Transition and Turbulence.” Accessed October 10, 2022. https://www.princeton.edu/~asmits/Bicycle_web/transition.html

[3] “Bronkhorst: What is the difference between laminar flow and turbulent flow?” Accessed October 10, 2022. https://www.bronkhorst.com/en-gb/blog/what-is-the-difference-between-laminar-flow-and-turbulent-flow-en/