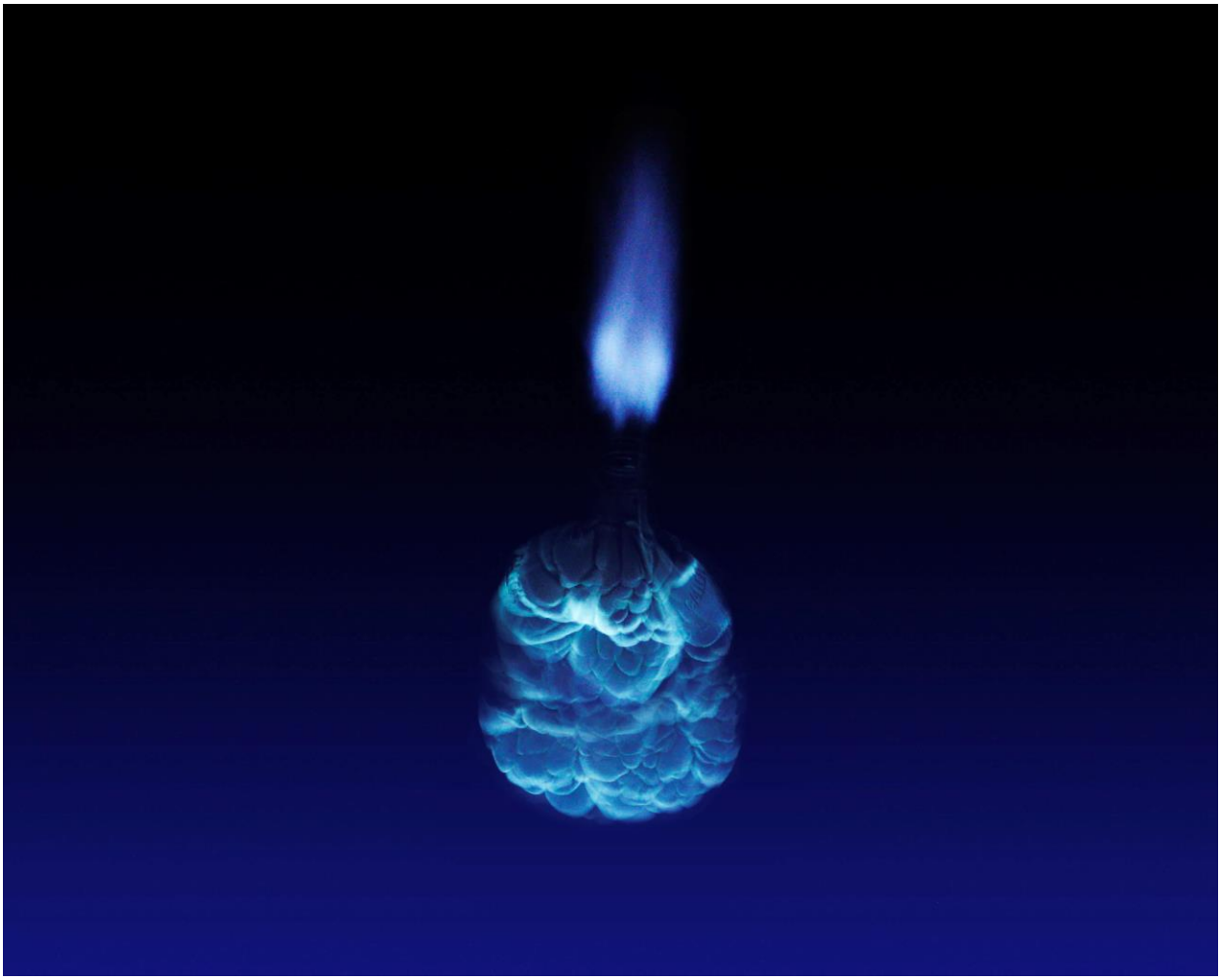
Team 1

Flow Visualization

MCEN 4151



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Fall 2015

Introduction

The purpose of this assignment was to further explore the physics of fluid flow, but this time, each of us were put into teams of four. The purpose of the teamwork aspect was to encourage us to try more difficult experiments and to achieve a more complex fluid phenomena. Also, to have multiple students brainstorm different ideas, which will lead to a wider variety of different experiments. For our experiment, my team and I decided to explore the fluid dynamics behind combustion when it is contained within a large glass jar.

Methodology

These image(s) were captured at night, in the confines of a garage with proper ventilation. The materials involved were as follows: a one gallon glass jar with removable cap, 16 FL OZ. of 70% isopropyl alcohol (rubbing alcohol), and a pack of matches. Setting up the experiment is quite simple. First, we filled the gallon jar with enough rubbing alcohol to have a one centimeter puddle at the bottom. Next, we tightly screwed on the cap and shook the jar so the alcohol coated the edges of the jar and became mixed with the air inside. When working with combustion, it is important to be extremely safe, so I would highly recommend wearing protection such as safety glasses and gloves/oven mitts to avoid injury. Then, with the shaken jar, we moved to a well ventilated open area in a garage and removed the jar's cap. We placed the jar on a small stool, then dimmed the lights. With one of us controlling the camera, the other struck the match and held it directly above the mouth of the jar (figure 1). This then caused the vapor exiting the mouth of the jar to ignite a spread downward through rest of the jar. The reaction is quite fast, only a few seconds, so timing is crucial. Multiple trials were performed in order to obtain better results.

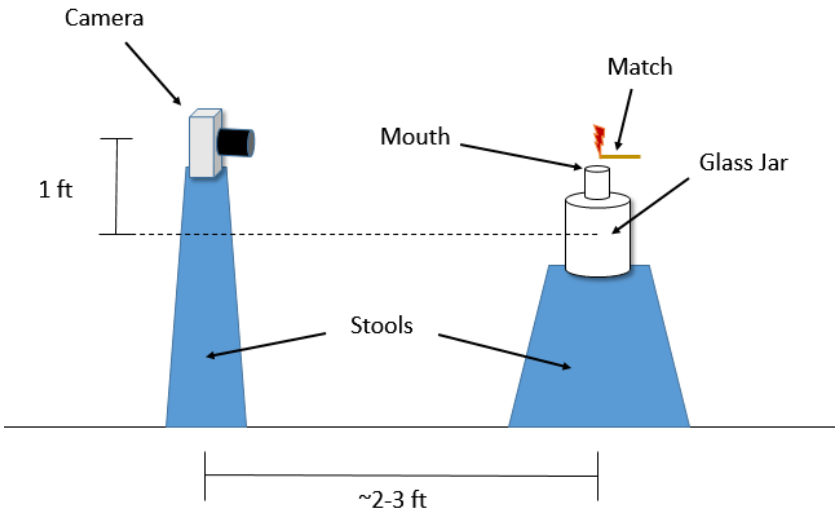

Figure 1: Schematic of set

Analysis

My final image is actually a composite of three different images at different points throughout the reaction (figure 2). I chose to make a composition because one image alone was not enough to capture the beauty of this experiment.

Once the mouth of the jar is lit, a small flame tends to burn like a candle for approximately one second. Then the flame front begins to deflagrate and spread to the remaining fuel throughout the bottle. The jet coming out of the top of the jar is always present during the reaction regardless of where the burning layer is. This is due to the products left within the jar after the burning layer has passed. Before the ignition process, the air-fuel ratio is very low, meaning that there is a very rich mixture. As this mixture burns up all the oxygen within the jar, the products from this reaction are still very rich and hot. When these products exit the jar and are exposed to a plethora of oxygen, the remaining rich mixture burns off resulting in a jet [1].

Reactions like this can also generate acoustic energy from the burning fuel layer [2]. The sound emitted is a "whoosh" whose frequency and volume vary depending on a number of factors like jar geometry, gas velocity, and the type of fuel [2].

In our case, we found that ignition process did seem to be slightly different each time but the noise was more or less the same. We also found that the resulting air within the jar did not contain enough oxygen to spark the reaction again. After each reaction had finished we needed to blow oxygen back into the jar, via straw, in order to perform the experiment again.

Figure 2: The 3 different images use to make the composite (cropped)

Technique

For this shot we use my teammates Canon EOS Digital Rebel XSi. To focus on the jar, we first used the autofocus setting with the lights on. Then once we were focused on the jar we turned the setting off, followed by the lights. As long as the person holding the camera did not move the jar would stay in focus. We chose to shoot with an ISO-1600, F-stop 4.5, 1/30 sec shutter speed, and a 27mm focal length.

As for post processing, I did not crop the base image (4272 x 2848) which was the far right image shown in figure 2. Besides the composite, I played with the curves to make the flame stand out, added a blue gradient, and added a final sharpening filter.

Conclusion

I am very pleased with how all of our images turned out considering we didn't have a tripod. We did try and shoot the jar in the same location each time but figure 2 shows that we were slightly off each time. I personally think this experiment would look very neat if it was shot with a slow motion camera, although lighting may become an issue. I believe this image is a great example of the chaotic nature of combustion and fluid phenomena associated with it. If I were to do this experiment again I would definitely use a tripod and try capturing the reaction in a video.

References

[1] "Simulations of flame acceleration and deflagration-to-detonation transitions in methane–air systems." D.A. Kessler *, V.N. Gamezo, E.S. Oran Web. 11/3/2015. http://www.dtic.mil/dtic/tr/fulltext/u2/a520957.pdf

[2] "Acoustic energy generation by the burning fuel layer." IOP Conf. Series: Materials Science and Engineering Web. 11/2/2015. http://iopscience.iop.org/article/10.1088/1757-899X/86/1/012008/pdf