Vis 4 Report
Flow Visualization
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I. Introduction

The goal of this visualization was to film the ignition of a small puddle of liquid camp fuel when it came into contact with a lighter with a Phantom Miro C110 high speed camera. In doing so, we were able to visualize the formation of the flame with a clarity not possible with a camera filming at normal speeds. We can use this to analyze the different parts of the flame in question, thereby giving us a greater understanding of the combustion process. The full video can be found here.

II. Testing Setup and Materials

The test apparatus consisted of the high-speed camera sitting on a tripod about 4-5 feet away from the subject looking almost straight at it. The subject was a glass pyrex container filled almost to the top with water sitting on top of a table. A thin layer of liquid camp stove fuel was then carefully deposited on top of the water by pouring it gently over a spoon submerged in the water. We then began the high-speed recording as we slowly approached the container with a lighter, eventually causing the camp fuel to combust. If repeating this experiment, be sure to have all individuals near the fire wear eye and hand PPE and make sure there is a fire extinguisher on hand at all times.

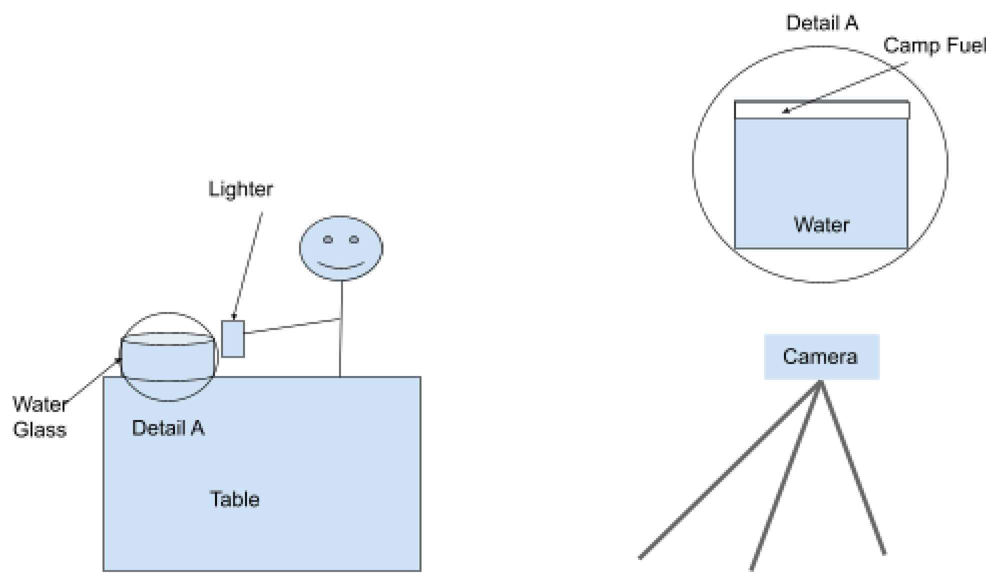

Figure 1: Experimental Setup

Ideally, the subject would be in a completely dark space so that the light from the flame would contrast more visibly with the darkness around it and be easier to see. Thankfully, the large light requirement of the high-speed camera balanced out the natural light present, resulting in a clear image of the flame.

III. Physics Analysis

The primary physics concept illustrated in this video is that of a simple combustion reaction that gives off energy in the form of light and heat. Combustion occurs when a substance (the fuel) is heated to an ignition temperature (in this case by the lighter), and the reaction has enough oxygen present to begin the reaction. The reaction will then continue until it either runs out of fuel or it runs out of oxygen (Science Learning Hub). In the ideal case, the combustion reaction will produce a minimum of three things: CO_2, H_2O, and energy in the form of light and/or heat. This is called complete combustion, and it occurs only when the reaction has enough oxygen present to fully turn all of the carbon and hydrogen molecules into water and carbon dioxide molecules. It is possible to tell if a reaction is undergoing complete combustion because the fire will appear blue, not orange and yellow (Science Learning Hub). As the fire present in the video is orange, we can tell that this is not a complete combustion reaction. This means that the reaction is also producing some waste products that are a combination of carbon monoxide and carbon molecules. These byproducts are what make up the smoke that we are used to seeing in most natural fires. According to MSR, their fuels are made up of a combination of propane and isobutane, meaning that one possible chemical equation of this reaction is the following (MSR Team):

$$C_3H_8 + C_4H_{10} + O_2 \Rightarrow CO_2 + H_2O + CO + C + energy.$$

Without more advanced equipment, it is difficult to say exactly what proportion of the output of the reaction was smoke byproducts. However, due to the minimal amount of smoke present in the video, we can estimate that we were operating at close to complete combustion. This makes sense as complete combustion is the most efficient way of producing energy, and any liquid fuel worth buying should strive to be as energy efficient as possible.

IV. Photographic Technique and Post-Processing

This video was taken by a Phantom Miro C110. The known camera specifications are shown in Table 2 below. Other specifications, such as the ISO, were automatically set by the camera program and not present in the metadata and are therefore unknown.

Table 2: Camera Specifications

Specification	Value
FPS	1200
Resolution	1024 x 768

The camera was about 4-5 feet away from the container. The container was lit using only a small amount of natural indirect sunlight from outside. This was to ensure that the flame would be easy to see. The video was processed in Minitool Movie Maker, although very few adjustments were made to the video itself. The primary reason for any post-processing at all was to add sound effects to the video in order to enhance the entertainment value of the visualization.

Unfortunately, some parts of the original video file were corrupted in the retrieval process. This resulted in the very start of the flame formation process being overwritten with visual static, rendering it unusable. Luckily, the majority of the formation process was unharmed, allowing me to use it for this visualization.

V. Conclusion

I am overall very happy with how this video and image turned out. I think that, while the focus and lighting were tricky, the image came out clear and clean which I am happy about. I was also satisfied with how well you could see the flame progress across the top of the water and go from the formation stage to the stable flame stage. If I were to perform this experiment again, I would try to reduce the amount of light even more to get an even clearer picture. I would also check to make sure the video files were not corrupt before dismantling the experimental setup.

VI. References

MSR Team. “The Ins and Outs of Canister Fuels - The Summit Register.” *MSR*, 24 March 2022, https://www.msrgear.com/blog/ins-outs-canister-fuels/. Accessed 16 November 2022.

Science Learning Hub. “What is fire? — Science Learning Hub.” *Science Learning Hub*, 19 November 2009, https://www.sciencelearn.org.nz/resources/747-what-is-fire. Accessed 16 November 2022.