Flow Visualization: Bowl of Fire

MCEN 4151 - Flow Visualization

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Figure 1

Context

This image was taken with the intent to capture the unique flow of fire. I was intrigued by how flames would look captured up close by a camera, and thought that I would be able to capture some cool patterns. All the photos I took were in a pitch black room in order to emphasize the flame as the object for the image. I first experimented with candles and then moved on to isopropyl alcohol as the fuel. For my final image, I chose to light isopropyl alcohol in a bowl in order to contain the flame and capture an interesting pattern.

Experimental Setup

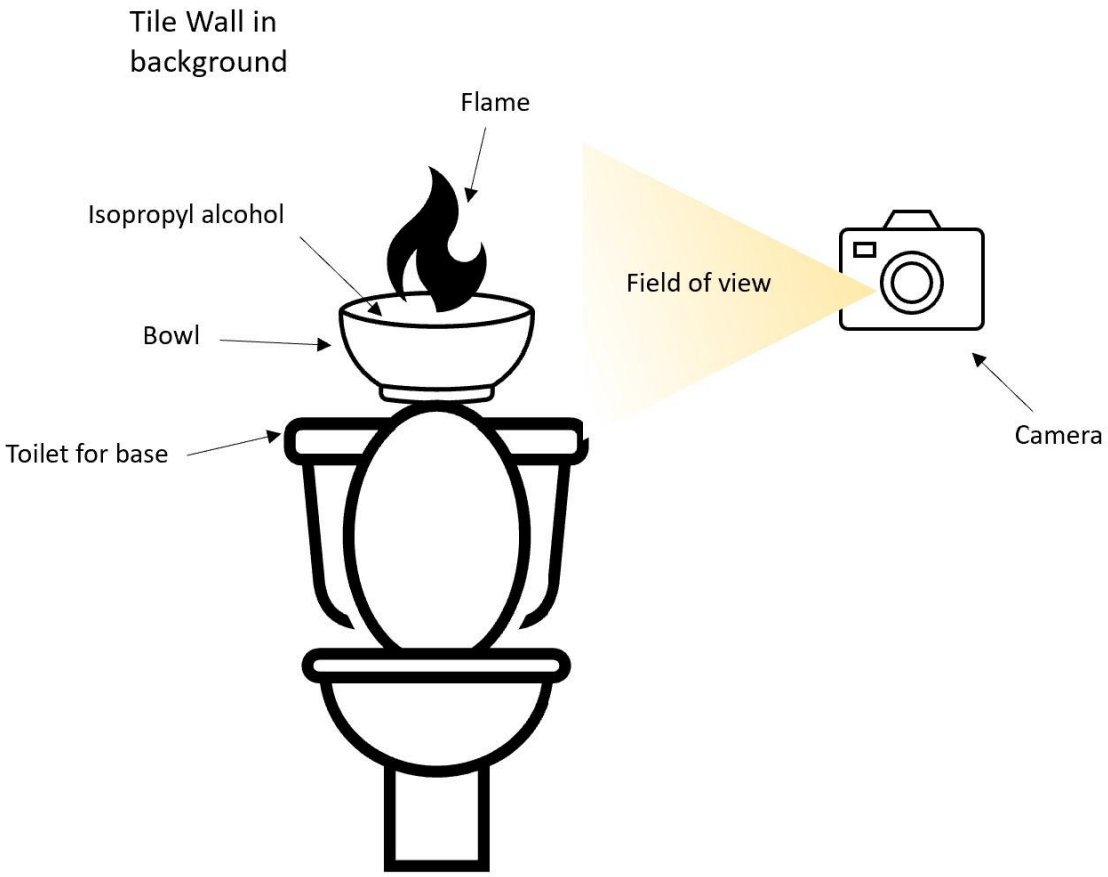

Figure 2: Sketch of photograph setup

Figure 2 illustrates the setup of the photograph I took shown in figure 1. I took the photo in my bathroom with the door shut and with the light off. I chose my bathroom because my bathroom has a tile background and I wanted to capture a reflection of the flames for visual appeal. I placed a bowl on the top of my toilet tank as that was the most accessible spot, and then I poured a few fluid ounces of isopropyl alcohol in the bowl, coating the entire inner surface. I then used a lighter with a long handle to light the

isopropyl alcohol inside the bowl. It immediately lit and cast a bright orange light across the bathroom. I then proceeded to take many photos, changing the focal length and distance to the flame. Choosing my final photo came down to my preference of the particular shape of the flame and the lighting.

Flow Phenomenon

Fire "is the rapid oxidation of a material (the fuel) in the exothermic chemical process of combustion, releasing heat, light, and various reaction products" (Glossary of Wildland Fire Terminology). Oxidation is the loss of electrons and happens slowly over time under normal conditions. With heat present, oxidation happens much faster and thus can create a chemical reaction like fire. In my experiment, I used isopropyl alcohol as fuel. Isopropyl alcohol when in presence of oxygen gas and enough heat will react to produce carbon dioxide gas and water in the form of steam.

$$C3H7OH + O2 \rightarrow CO2 + H2O$$

Fire is hot and bright because the conversion "of the weak double bond in molecular oxygen, O2, to the stronger bonds in the combustion products carbon dioxide and water releases energy" (Schmidt-Rohr, K 2015). Basically when chemical bonds are broken and formed during a combustion reaction, thermal energy is released as a byproduct. Light is incandescent meaning the hotter the temperature, the brighter the light produced. Isopropyl alcohol has an ignition temperature of 750 degrees fahrenheit however judging by the color of the flame I photographed, I would estimate that the temp is somewhere around 2000 degrees fahrenheit. "Deep red fire is about 600-800° Celsius (1112-1800° Fahrenheit), orange-yellow is around 1100° Celsius (2012° Fahrenheit), and a white flame is hotter still, ranging from 1300-1500 Celsius (2400-2700° Fahrenheit)" (Helmenstine 2020). The shape of the flame is largely due to convection. Convection causes hotter and therefore less dense fluid to rise, and colder, more dense air to sink. This is why flames flow upwards. The surrounding air movement causes the abstract and random movement of the flames. The shape of the bowl I used likely also affected the flow of the flames.

Visualization Technique

I used a tile wall as my background and the result is that I was able to capture a reflection of the flame. I offset the camera enough so that I captured a majority of the reflection while maintaining the real flame as the focus. The fuel I used for the flame was Walgreens brand 91% isopropyl alcohol. For lighting, the room I took the photo in was close to pitch black. A little bit of light came from under the door however this was negligible. I did not use any camera flash. The only light source was from the flame, which was very bright and illuminated the surrounding walls to create an appealing warm glow.

Photographic Technique

The photo was shot with a Canon EOS 40D with a Sigma 18-50 mm f/2.8-4.5 lens. The camera settings I used were f2.8 aperture, 38mm, shutter speed of 1/200 seconds, ISO 400, and AWB. These settings were automatic because I shot in sports mode. I chose sports mode because I wanted a relatively fast shutter speed so that the flames would not be blurry. The size of the field of view is a couple square feet. The distance from the lens to the object is almost exactly three feet. I didn't do any cropping so the original

and final images are 3888 by 2592 pixels (width by height). I did some post processing on my photo which included increased saturation, black level and exposure. These were increased just a little bit in order to deepen the colors and make the photo look better in my opinion. Below are both the original and final images for comparison.

Figure 3: Original Photo

Figure 1: Edited Photo

Final Thoughts

My final image reveals a visually interesting flame rising out of a bowl with a clear reflection of the flame in the background. The flame casts an orange glow over the background that I really enjoy and also creates a natural vignette. The colors and vignette were enhanced by the post processing that I did. I really like how the shape of the flame turned out. I think it is quite abstract with how the majority of the flame is connected and branches off in unique ways. I really like the reflection that I captured as well and believe it adds an interesting element. If I were to improve the image I would change the color of the flame to be darker. There are a few spots where the flame is white and would be seen in more detail if it were darker. I would do this by altering the aperture and shutter speed to let in a little less light in the image. That being said, I am happy with my image and captured what I intended.

Work Cited

"Glossary of Wildland Fire Terminology" (PDF). National Wildfire Coordinating Group. November 2009. Retrieved 2008-12-18.

Schmidt-Rohr, K (2015). "Why Combustions Are Always Exothermic, Yielding About 418 kJ per Mole of O_2". *J. Chem. Educ*. **92** (12): 2094–99. Bibcode:2015JChEd..92.2094S. doi:10.1021/acs.jchemed.5b00333.

Anne Marie Helmenstine, Ph.D. “Why Fire Is Hot (and How Hot It Is).” *ThoughtCo*, ThoughtCo, 21 Nov. 2020, https://www.thoughtco.com/why-is-fire-hot-607320.