Team First

MCEN 4151

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The image described in this report was the first team assignment in the University of Colorado's Flow Visualization class. The purpose of the team projects are to allow you to develop a more challenging experimental setup from which to capture fluid flow phenomenon. The phenomenon intended to be captured in this image was that of combustion of various salts resulting in different colored flames. Many attempts were made to capture these colored flames, however, the images never quite turned out as they were supposed to.

To create this image, isopropyl alcohol was used as the accelerant. The combustion of isopropyl alcohol results in only the emission of carbon dioxide and water as seen in equation 1. It was due to this "clean" burning effect that the group chose to use isopropyl alcohol. [1]

$$2\ C_3H_7OH + 9\ O_2 \rightarrow 6\ CO_2 + 8\ H_2O$$

Equation 1

The isopropyl alcohol was spread on a large concrete slab and ignited with a cigarette lighter. Water was then poured around the isopropyl alcohol for two reasons: a) the water acted like a mirror for the flame to reflect upon creating an image with depth to it and, b) to further protect the surrounding from the flame a second line of defense. The salts came in $25\ g$ packets labeled "Mystical Fire" and contained a mixture of Cupric Sulfate (CAS # 7758-98-7), Cupric Chloride (CAS # 7447-39-4, and Polyvinyl Chloride (CAS # 9002-86-2) that are intended to be put in a fire, such as one would make camping, and cause the fire to burn different colors. The salts where then sprinkled over the burning isopropyl alcohol thus creating a colored flame.

Combustion flames are the visible, gaseous part of a fire. When a fuel burns, the high heat vaporizes small particles of the fuel which mix with oxygen in the air thus perpetuating the combustion cycle. The visible portion of a flame is actually the incandescence of fine soot that is produced during combustion.[2] The bouncy effects of hot, less dense gases rising and being replaced by cool, denser gases, are the driving cause of flow of a combustion flame. Combustion flames, however, have never before been studied quantitatively until the present day. Thus there are no reliable models for predicting their behavior.

To clearly visualize the beautiful dancing of the flames being produced by the isopropyl alcohol, we decided to conduct our experiment at night. As stated earlier, water was also poured on the ground to reflect the incandescent light being emitted by the flames. The camera was placed only inches above the ground in order to take full advantage of the reflected light. Although the salts added to the flame did change the color of the flame, it was very irregular and thus I decided to take images of only the naturally burning isopropyl alcohol.

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[1] McMurry, John, Robert C. Fay, and Logan McCarty. Chemistry. Upper Saddle River, NJ: Pearson Education, 2004. Print.

[2] http://science.howstuffworks.com/environmental/earth/geophysics/fire1.htm

This photo was taken on a Nikon P7100 10.1 Mega Pixel digital camera. The focal length was $6.0\ mm$ with a sensor size of $7.6x5.7\ mm$ resulting in a $64.7°$ horizontal and $50.8°$ vertical angle of view. This field of view was chosen so that the flame and reflection would fall completely inside the image. The camera was set to a fixed ISO 400 value to minimize image noise. A small F-Stop of f/2.8 was chosen to allow for a greater density of light to hit the camera sensor and to emphasize the flow phenomenon by defocusing the rest of the image, however, due to the speed of flow the camera was focused on the foreground reelection instead of the actual flame. A shutter speed of $1/500\ sec$ was chosen to allow for the maximum quantity of light to reach the camera sensor but allow for the flame to blue slightly and become very smooth looking. Finally, Photoshop was utilized to alter the image by cropping, increasing contrast, decreasing exposer and increasing color saturation. Then the image was inverted, switching the values of every color 180. The original image shown in Figure 1 can be compared to the final.

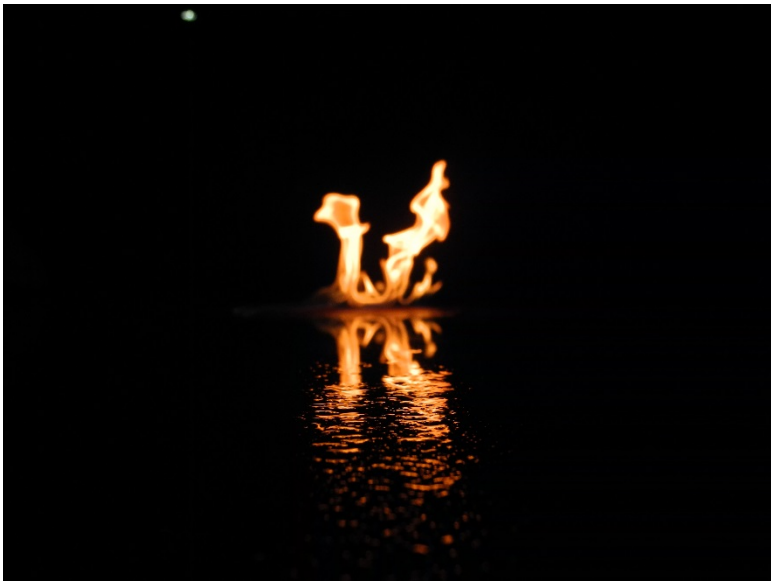

Figure 1 – Original image as captured before Photoshop alteration.

This image reveals both the incredible beauty of combustion flames and the turbulent unpredictability of their nature. The image is well composed from the unique inverted coloring, the focused reflection in the poured water and the image clarity. Although the image is a wonderful expression of a combustion flame, it also speaks to the wild mystery and excitement that one of humans oldest mastered tools can still bring to the present day.