Jonathan Cook

Image Project #3

Flame Rising from a Bowl of Isopropyl Alcohol

Image Taken on November 13, 2015 at 3:55pm

For the final project of the semester, I chose to submit an image that I took on my own while at home in my kitchen. While I did not initially plan to perform this experiment, I felt compelled to capture some images when I saw the size and intensity of the flame that was created. The setup consisted of a bowl of 99% isopropyl alcohol in a kitchen bowl. The alcohol was lit on fire using a grill lighter. The blue colors in the flame are an effect of post-processing intended to add clarity and artistic effect, the original flame color was yellow.

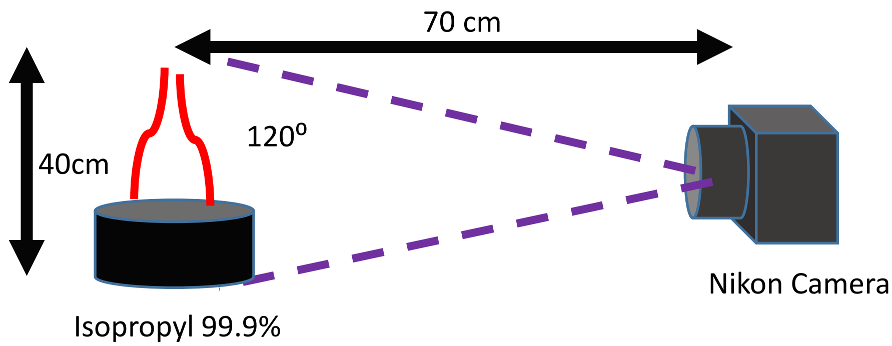

Figure 1: Illustration of Experimental Setup

The kitchen bowl has a square shape of approximately 10cm by 10cm with rounded edges. The bowl is 4.8cm deep and was about half full with the alcohol solution. The flame rose as high as 35cm from the top of the bowl. The flame itself was changing constantly in height and shape, a normal effect in flame that is indicative of the turbulent air-flow it causes as it rises. Ambient air temperature was about 22°C (72°F), and isopropyl alcohol burns at a temperature of about 750°C (399°F) [2]. This difference in temperature and density results in a pressure instability and the hot gas rises through the air. A rough estimation for the Reynold's number can be made knowing the density and dynamic viscosity of the ambient air and assuming the flame has the same values. Of course it does not, but for the sake of the problem we will assume that they are equivalent. The dynamic viscosity (μ) of air at 27°C is 1.846×10^{-5} kg/(m*s). The density of air (ρ) at that temperature is 1.177 kg/m^3 [1]. The characteristic diameter (D) will be chosen as the diameter of the bowl: 10 cm. Finally an estimate for the speed at which the flames rise was made at 1 m/s. Using Reynold's equation $R = {\rho * D * V}/{\mu}$, we find that R = 6376 confirming that the flow is in fact turbulent [3].

The chemical formula for isopropyl alcohol is C_3H_8O [2]. The balanced stoichiometric equation for the combustion of isopropyl alcohol therefore is $2C_3H_8O + 9O_2 = 6CO_2 + 8H_2O$. If the solution was premixed with oxygen then 100% of the fuel would be burned off and the flame color would be a soft blue. However, oxygen cannot be supplied to the reaction at a fast enough rate to burn the fuel in a clean way. This causes excess alcohol particles to glow a bright yellow color as they are lifted up into the flame without being burned off.

The isopropyl alcohol that was used is a standard solution that can be purchased at any grocery or hardware store. It was poured into a kitchen bowl and ignited with a long-stemmed grill lighter. The rest of the lights in the room were turned off and a solid black fabric was held directly behind the flame to remove any background information and maximize contrast. No flash or external light source was used; the flame emitted all of the light that was used in the image.

In order to capture the image the camera was held approximately 70 centimeters from the flame. The camera used was a Nikon Coolpix P520 with a focal length of 4mm. I set the shutter speed to 1/1000 seconds and the camera auto-adjusted the aperture to f/3. The short shutter speed was selected to capture a crisp image of the quickly moving flames, and the large aperture was necessary to gather enough light during the very short exposure. The sensitivity was also turned up very high due to the low light from the flame, and was set at ISO-1600. The result of this high sensitivity was a fairly grainy raw image. The dimensions of the raw image are 4896 pixels in width by 3672 pixels in height. The final image was cropped in order to highlight the flame as the subject and the only useful information.

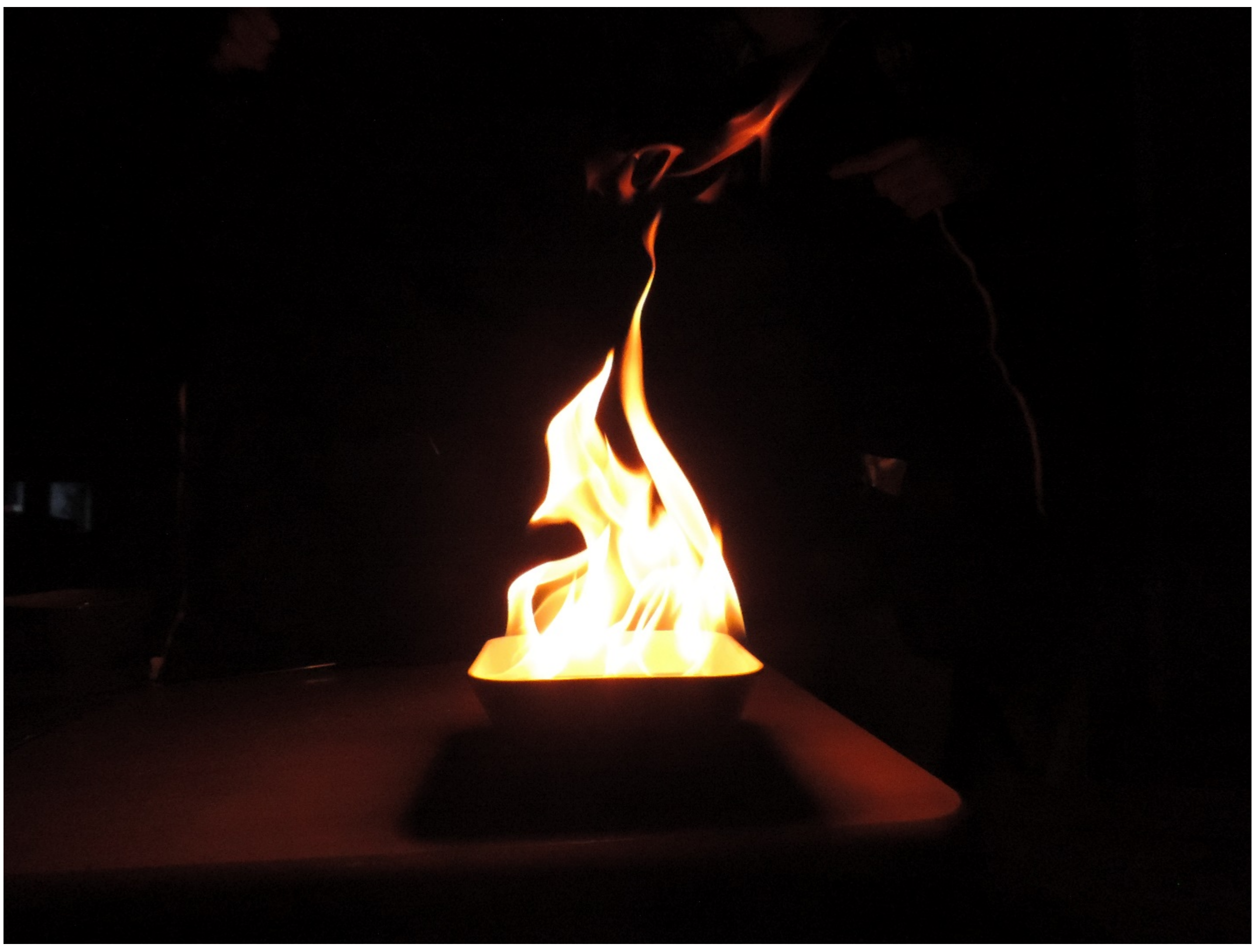

Figure 2: Raw, Unedited Image

All post-processing of the image was performed using the free, open-source software GIMP. The first change that was made to the image was cropping it so that the flame was framed as the subject and the only useful information of the image. The final pixel dimensions are 1586 pixels in width by 2494 pixels in height. The field of view of the final image is approximately 15cm by 40cm. The color tool Curves was used to darken the background to a solid black. It also appeared to reduce much of the grainy effect caused by the high sensitivity. Next, the color channels were altered slightly in Curves to improve contrast and intensity of the colors in the flame. Finally, I found that by drastically altering the hue of the image to a blue scheme, I was able to bring a new effect to the image that highlighted different details in the flame as well as created an interesting artistic effect. I felt as though the color change added an overall dramatic effect without compromising any of the physical flow information in the image.

References:

[1] “Dry Air Properties.” Accessed December 18, 2015. http://www.engineeringtoolbox.com/dry-air-properties-d_973.html.

[2] “Isopropanol.pdf.” Accessed December 15, 2015. http://education.jlab.org/frost/msds/isopropanol.pdf.

[3] “Reynolds Number.” Accessed December 18, 2015. http://www.engineeringtoolbox.com/reynolds-number-d_237.html.