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Flow Visualization
Team Report # 3
4/30/12

The original intention for this image was to burn a piece of copper wire, copper pipe, or any scrap piece of copper I could find at the hardware store with a Bernzomatic® butane torch and produce a green flame. However, after trying to burn a piece of copper pipe and bracket purchased from Home Depot all I could produce was a burnt orange flame with very little green. I thought maybe if a thinner and smaller piece of copper could manipulate the copper easier and allow more surface area be hit by the flame. I looked for a copper wire that could easily be manipulated and flattened out and I found that ArtisticWire® makes a copper wire for jewelry making. I found that it is sold at Hobby Lobby and picked up a spool of it and happy in how easy it was to flatten and manipulate the metal. Using this new item I burned it again with Bernzomatic® butane torch and again was disappointed in see a mostly burnt orange flame been produced. After all this disappointment my intentions for the project changed and I decided to capture an image of the mostly orange flame the burning of the copper wire produced and hoped through Photoshop manipulation the green flame can be brought out. I found by flattening the end of the wire and curling it up I could produce a bigger flame with slightly more visible green coloring and I used this method to capture the image seen in Figure 4.

The apparatus used to capture this image as previously mentioned is the Artistic Wire® copper wire generally used for jewelry making. The tip of the copper wire was flattened and curled and to create a base the copper wire was manipulated. The wire was then placed onto a flame retardant black blanket outside on the cement patio and the Bernzomatic® torch was angled next to it so the flame could directly hit the curled up portion of the wire. An image of this bent up piece of wire and placement of the torch can be seen in Figure 1 and in Figure 2 the wire alone can be seen.

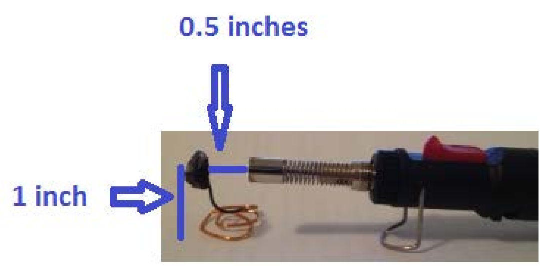

Figure 1

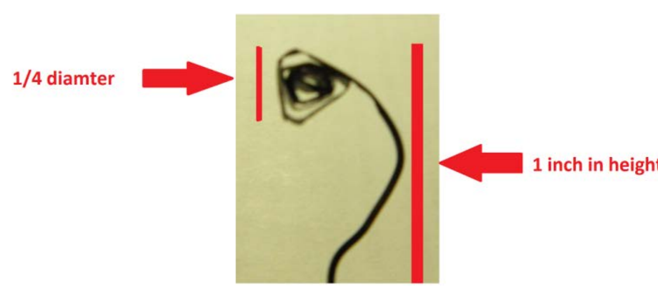

Figure 2

The reason why an orange and green flame can be seen when the copper wire is heated is because the heat cause the electrons in the metal into an excited state. The electrons will leave the excited state and the energy is re-emitted in the form of photons. The frequency and wavelength the emission of photons will produce a different color of light. The main portion of the flame is orange had has a wavelength between 600-650nm, meaning it takes that distance from the start of the cycle to the end of the cycle. Where the characteristic wavelength for green light is between 500-550 nm meaning more energy is required to increase the speed of the cycle.[1] While doing this research I found that blue flame, which has a characteristic wavelength of 400-450 nm, has a flame temperature approximately 2,500°F while orange flames are approximately 1,600°F. Since the properties of copper has melting point, ignition point, of 1984°F explains why the flame would appear to be green. The electrons that make up copper get excited at this temperature and begin to release photons.[2][3]

The problem is that this experiment was carried out using the light blue portion of the butane flame which is not the hottest portion. If the copper was placed into the hotter portion of the flame then the electrons would have gained more energy from the heat and when releasing this energy creating photons it would have enough energy to create the characteristic wavelength for green light. Since it wasn't for this image, the electrons were not able to absorb as much energy from the heat and when the photons were released they only had enough energy to create the characteristic wavelength for orange light.[4]

For the calculation portion of this paper I am going to calculate the Reynolds number for both the orange and blue butane flame. The orange flame was traveling at a velocity of 1.33 inches per second. This velocity was estimated from a video of the flame taken in which it traveled 0.4 inches in 0.3 seconds. The diameter of this flame was approximately held at 0.5 inches during the extent of the combustion. Since the flame was in the air, I am going to use the viscosity of air to determine the fluids flow type. Approximating the air temperature to be at 1500°F the viscosity of air would be 9.5×10^{-7} lb s/ ft[2]. Therefore the Reynolds number is found and means the flame is experiencing a turbulent flow:

$$Re = \frac{Velocity * diamter}{viscosity} = 4873$$

Now for the calculation of the Reynolds Number for the butane flame which is going to be similar in the process of the orange flame. The butane blue flame was estimated to be at a velocity of 2.5 inches per second. It took the flame to travel about ¾ of an inch approximately 0.3 seconds. The diameter of this flame is approximately 0.25 inches. The viscosity of this flame will be the same as the previous for simplicity sake and none of the tables I found with viscosity reached a temperature of 2000°F.

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1 "UV-Visible Spectroscopy." *Object Moved*. Web. 04 May 2012. <http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Spectrpy/UV-Vis/spectrum.htm>.

2 Marion, Marie C., Edourard Garbowski, and Michel Primet. "Catalytic Properties of Copper Oxide Supported on Zinc Aluminate in Methane Combustion." *Journal of the Chemical Society, Faraday Transactions* 87 (1991): 1795-800. Print.

3 Treviño, Linda Klebe., and Katherine A. Nelson. *Managing Business Ethics: Straight Talk about How to Do It Right*. Hoboken, NJ: Wiley, 2007. Print.

4 "Visible Light Waves." *301 Moved Permanently*. Web. 04 May 2012. <http://science.hq.nasa.gov/kids/imagers/ems/visible.html>.

$$Re = \frac{Velocity * diamter}{viscosity} = 4568$$

As I expected the butane torch flame is also experiencing a turbulent flow.

The image seen in Figure 4 had external light sources and was taken in complete darkness except only light that was available was the flight coming from the blue flame of the butane torch and the light from the burning of the copper wire. The camera was placed 3 inches from the two flames and the camera had no tilt and was kept perfectly vertical.

The size of view the photo was taken in was 2 inches by 1.5 inches or an area of 3 in^2. The cameras lens was 3 inches from the center of this photo. The camera I used is a Pentax Optio WS80 digital camera with a focal length of 6.2 mm. This picture had a shutter speed value of 1/4 of a second and a Aperture Value of 3.852. The ISO setting used was 800. Using Photoshop the image was cropped to only include the two flames, the contrast was increased by 100, and the brightness was reduced by 100. The contrast was used to darken the background of the image and the brightness was reduced to allow the flame to be more clearly seen without the glow. The overall final image did come out a bit grainy in the edges of the flames but the brilliant contrast between the blue flame and orange flame creates a very unique image. The original and final images can be seen below:

<u>Original Image:</u>

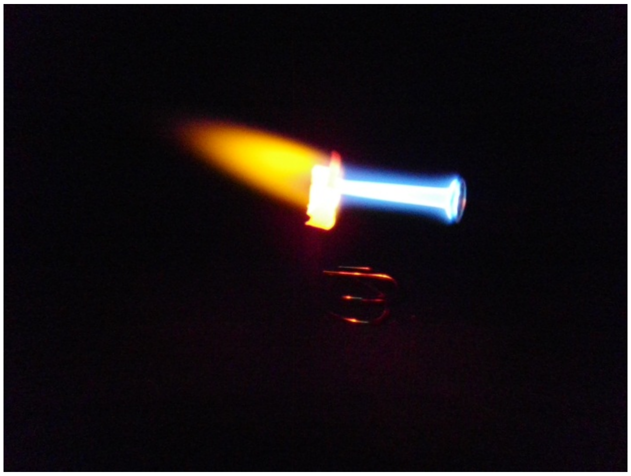

Figure 3

Width: 3648 pixels
Height: 2736 Pixels

<u>Final Image</u>:

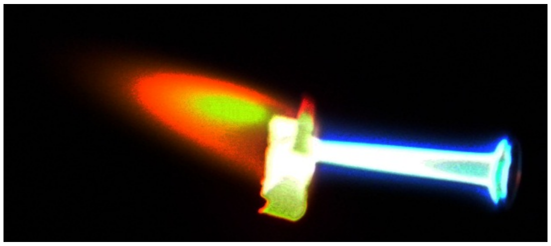

Figure 4

Width: 1938 pixels
Height: 846 pixels

The image reveals the difference in the light emission spectrum of orange and blue light. I really enjoy how it goes from a brilliant blue to such a distinct orange. I also like how the copper coil can be seen glowing as the electrons it contains get into an excited state and then release its photons to produce light. If I had to do this again I would place the copper coil closer to the hottest part of the butane flame and probably use a Bunsen burner. It seems those flames are easier to control and more consistent. The butane torch I used would sputter and change in length constantly and also tended to run out of fuel rather quickly. To further develop this idea I would want to carry it out in a proper lab like the ones in the chemical engineering wing. I wouldn't have to deal with wind and again have a more consistent flame.

Marion, Marie C., Edourard Garbowski, and Michel Primet. "Catalytic Properties of Copper Oxide Supported on Zinc Aluminate in Methane Combustion." *Journal of the Chemical Society, Faraday Transactions* 87 (1991): 1795-800. Print.