Team Assignment #2

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MCEN 4151/ ARTF5200

Team Assignment 1

Purpose

The image was taken to satisfy the requirements for the second team photo assignment for the Flow Visualization class at CU-Boulder. The image was selected based on two criteria: artistic value and adequate display of fluid physics. The team considered multiple different options for the assignment, all of which involved combustion. The team had originally hoped to capture an image a plume of flame propelling a bottle or other object. The initial ideas did not work either for technical reasons or due to safety concerns. The fluid phenomenon that the team decided to capture was colored flames, particularly green flame. There is not a a significant green coloration to the flame in the selected image, but it was used nonetheless due to the presence of a ring of fire, which is a phenomenon that is difficult to capture on film. The ring occurred by chance and the setup was not designed to create one.

Image Setup

The setup for the project was to capture a green flame. In order to create the conditions necessary to do this, the team setup a safe combustion environment under a fume hood. All flammable materials other than those used in the experiment were removed from the hood, and the cameras were placed outside the hood. The glass on the hood had to be left open a small distance to allow the camera to focus and capture a clear image. A fire extinguisher was kept on hand at all times. The team used rubbing alcohol as the fuel to achieve combustion. The rubbing alcohol was poured over top a root killer designed for drains that can be found at hardware and garden stores. The root killer is 99% copper sulfate, and when burned creates the desired green flame. The root killer and the alcohol were poured on top of an inverted metal dog bowl. The lip of the bowl ensured that the flammable mix did not run and spread to a larger than desired area.

There are two physics phenomena that can be seen in the image. The first is the desired green color that is visible near the base of the flame. This is caused by the combustion reaction of the copper sulfate. The reason that the copper sulfate burns green is due the energy levels of the electrons in the matter. When the substance is heated, the electrons jump to higher energy levels. The colors is seen once these electrons fall back down to their original energy levels. As the electrons fall, they release energy in the form of a photon. The color depends on the wavelength of the photon that is released [1]. The image contains very little green because the fire has been burning for very little time and the electrons have not been able to fall to their original energy levels.

The second physics phenomenon that is visible in the image is the ring of fire. The ring is caused by fluid physics as a result of the interactions between the air and the source. It is formed because the hot air within the combustion zone forms a rapidly rising mass [2]. As the mass rises it displaces the cooler surrounding air which falls around the sides of the hot mass. The fire forms a ring rather with a hollow center rather than a solid circle because the fire needs both fuel and air to combust. The fuel and air at the center of the source is quickly consumed, causing the most intense heat to be at the outer edge where the most fresh air is available for combustion. As the system stabilizes the cool air can fall down through the center of the ring, and combustion will occur more evenly across the area.

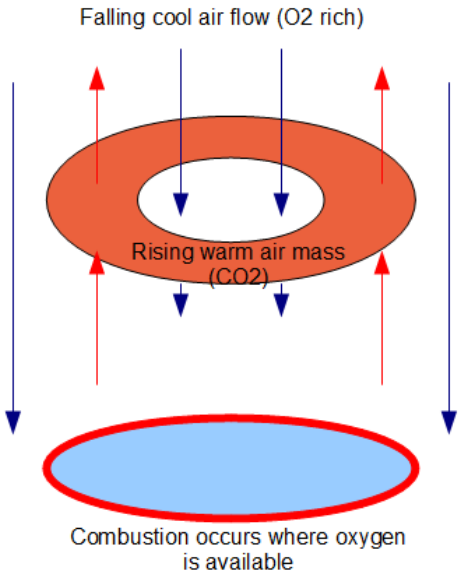

Figure 1

Figure 1 below shows a simple illustration of the effect.

The ring is offset in the image because there is a cross flow within the fume hood that was more prevalent at higher elevations within the hood, which caused the ring to rotate and translate as it rose, but the breeze was not strong enough to disturb the phenomenon at the source. It is extraordinarily difficult to find detailed information on the phenomenon, as most searches will return results related to the Johnny Cash song of the same name, and even amongst scientific journals and articles the topic that is most common is the Pacific Ring of Fire. Due to this fact, much of the conclusions about this effect were determined using research on smoke rings and combining it with knowledge of combustion methods.

Photographic Technique

Photographing the image proved to be difficult, although the setup was relatively easy. The camera was placed on a stable surface, and the shutter was activated by hand at the appropriate time. The camera was outside of the fume hood, looking in through a small opening where the glass was left open. The opening had to be small to eliminate risks of accidental fire, therefore the angles that could be used to capture the image were limited. There was no external light source used for the photographs, and the room was kept as dark as possible. All lighting in the image is the result of the fire itself. Due to the use of this lighting method it proved difficult to achieve the proper exposure, although after experimentation the team was able to determine a range of camera settings that provided acceptable results. The image was slightly overexposed because the initial burst that was captured in this image is brighter than the fire after it has been burning for an extended period of time. This corrected in editing, where brightness was reduced. A focus was placed on reducing the brightness of the reds so that the relatively dim green colors were not lost. All editing was done using the curves function in GIMP. The image was also cropped to eliminate black space.

A Canon Eos Rebel T2i was used to capture the image. The shutter time was $1/42^{nd}$ of a second. The team used manual focus for a number of the images that were captured, but the image used was

captured using auto-focus; it would not be possible to manually focus a camera quick enough to capture the phenomenon. The focal length was 50mm. The aperture of the image was F/5.7. A high ISO of 1600 was used, due to the necessity of a quick shutter speed to prevent motion blur combined with the low light available to capture the image.

Conclusion

The image was originally intended to capture a green flame, and green is visible in the flame in the image. However, a far more unique phenomenon was captured by accident, and a relatively clear image was achieved. Online research would lead one to believe that it is extraordinarily rare to capture an image of a ring of fire, as no existing images could be found online. The overexposed nature of the image makes it difficult to see some of the more intricate details of the fire ring, however the bright ring compared to the dark background is highly visible, and it is immediately clear to an observer what subject of the image is. Additionally, the high contrast of the image is very aesthetically pleasing, and the focus is sharp with minimal noise. The image achieved the original goal, and provided an additional interesting phenomenon to examine.

References

1. "The Color of Fire." *Physics Forum*. http://www.physicsforums.com/archive/index.php/t-67973.html
2. "Smoke Ring." *Wikipedia*. http://en.wikipedia.org/wiki/Smoke_ring