MCEN 4151

FLOW VISUALIZATION

REPORT- IMAGE 2: RISING FLAME

C. Schroeder[1]

MCEN 4151: Flow Visualization

Mechanical Engineering, University of Colorado Boulder.

1- Introduction

The main purpose of this image is to show the behavior of a flame as it rises from its' fuel source. As a second project image, it builds upon my previous study of smoke using a more dynamic subject. When I first tried shooting the flames, I discovered that ambient light in the room made the background appear grey in color. To fix this issue, I decided to not use external lighting for this photo and rely solely on the light from the flame. From the perspective of fluid flow, the colder (dense) air falls to the base of the flame, which in turn displaces the hot air (less dense). This process (known as convection) feeds the fire with oxygen, which combines with the vapors from the lighter fluid to create a flame. The teardrop shape of the flame is due to the upward currents of air created by this density gradient. To control the height of the flame, the carboard was only covered in a few drops of lighter fluid. Initial tests showed that even a small volume of fluid results in a flame of adequate height to photograph. I also experimented using other materials soaked in lighter fluid. These included printer paper, dried leaves, and dryer lint. However, the cardboard yielded the most consistent and regular flame patterns. As a result, cardboard (torn from a typical cardboard box) was selected as the medium to soak with lighter fluid.

2- Experimental Setup

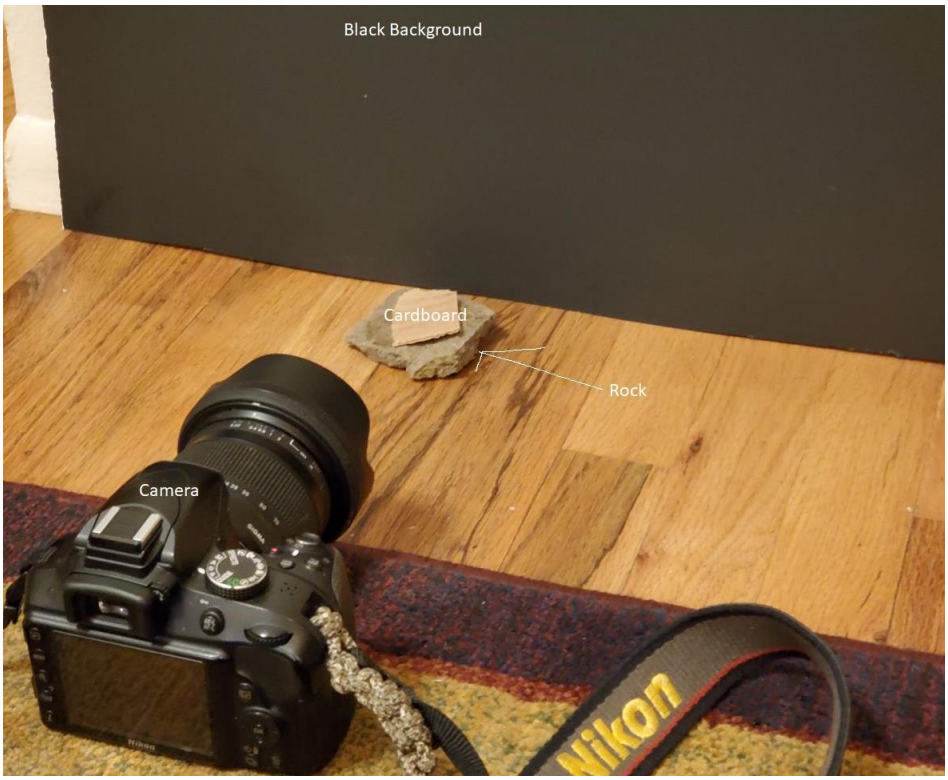

Figure 1: Experimental Setup

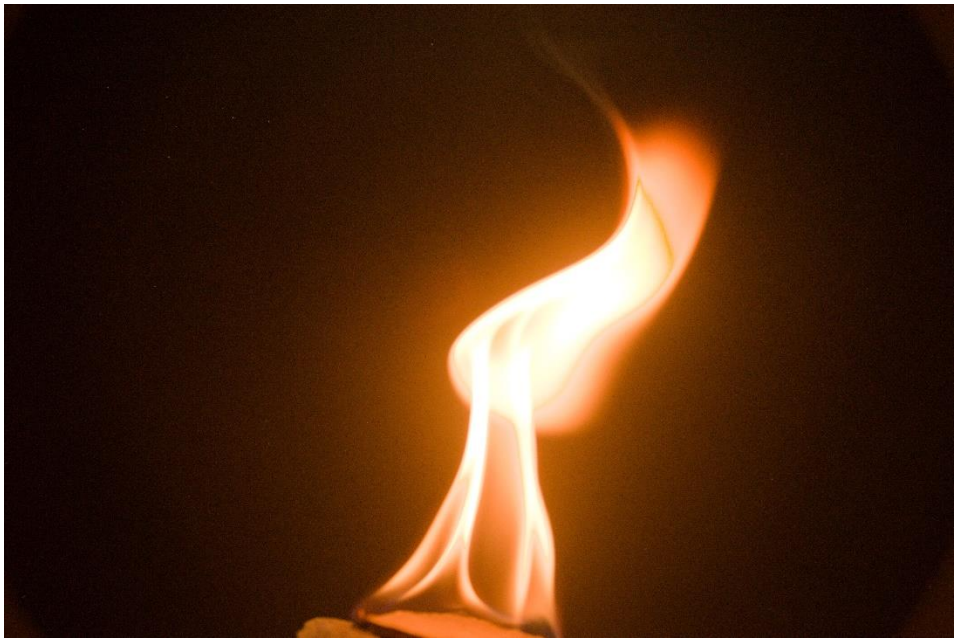

Figure 2: Burning Cardboard

Figure 1 depicts the experimental setup. The flaming cardboard was not lit externally. The black background was a dark piece of posterboard. The camera was mounted on a tripod initially. However, the final image was taken offhand without additional support. As the cardboard/lighter fluid burned, the flame would become smaller in height. (*Figure 2*) shows the burning cardboard on to of the small rock. The photo was only lit by the flame itself. No external light sources were used. The photo was taken in a dark room at night.

Flow Phenomena

The primary flow characteristic exhibited by the flame is convection. As the fuel is burned (and particles released) the heat from the reaction causes the air at the base of the flame to be heated. This air expands when it is heated, and thus becomes lighter than the surrounding air. This causes the air to rise, carrying the particles above the source of the flame. As the cool air comes in from the sides of the flame, it is heated and begins to rise. This forms a convection column above the flame, which can be visualized by the soot/smoke after photons are no longer emitted. Additionally, parallels can be drawn between flame patterns and fluid flows. From the behavior of the flame, it appears that it often experiences laminar flow. However, given the significant differential between the flame temperature and the ambient air (in addition to the quick combustion process occurring) this flow only occurs for a short period of time. This can be partially seen in *Figure 2*.

3- Visualization Technique

The flame contrasts relatively well against the black background. To recreate the image, it's important to find a balance between shutter speed and ISO (in addition to aperture). To accomplish this, I took several "test shots" in which captured flames at varying distances and focal lengths. Flash was not used on the photo, as it would have decreased the contrast between the background and the flame. The lighter fluid applied to the cardboard consisted of a Naphtha blend, which burned brightly.

4- Photographic Technique

The photo was shot using manual settings on a Nikon D3300 with a Sigma 17-70 mm HSM Macro lens. For a balance between focal length and aperture, this photo was shot at a 26mm focal length and F3.2. These were paired with a relatively fast shutter speed of 1/800 sec (to capture the moving flame without significant blur), and an ISO of 450 (adjusted down for reduced noise). The manual focus setting was used for capturing this image. In the end, these settings were a compromise due to the consistent flicker of the flame. I did a fair amount of post processing on this image. I applied a hot/dead pixel average, brought down the highlights in addition to the overall exposure of the image. I also worked with the color curve, to accentuate flow within the flame. The photo was also cropped down slightly so the flame would be centered in the image. All editing was done in an open-source program called RawTherapee. *Figure 3* (below) shows the image before editing. *Figure 4* (below) shows the image after editing.

Figure 3: Before Editing

Figure 4: After Editing

5- Meaning

This image reveals the currents within flames that are largely overlooked in our daily experiences with flames. Outside of a large bonfire, it is difficult to visualize flames without the help of photographic mediums. As the flame rises, it slowly fades to a point. It reminds me that some things are always changing and evolving. In less than a tenth of a second, the flame depicted in this report had a completely different profile but was still representative of the convection phenomena occurring. Here are a couple questions I'd like to pose to the reader: Do you think the flame looks unrealistic in this photograph? From an editing perspective, the exposure of the image was brought down significantly, which could alter perception of the flame. Additionally, I would like to know if there are any more post processing techniques to reduce the brightness of the flame without significantly effecting the clarity of the image (to show the source of the flame in better detail). Overall, I am proud of this image, and I think it has taught me about the power of post processing to better visualize fluid flow.