Mary Rahjes
Team First Image/Video
MCEN 5151: Flow Visualization
October 14, 2019

I. Introduction

For our first team assignment, my team decided that we wanted to work with fire. We thought of many different experiments, with a range of fluids and physics phenomenon, that we could photograph. After testing out different setups, I decided to record a video of isopropyl alcohol burning on a concrete floor. The video captures the constant transition between turbulent and laminar flow of the flame as it burns. Although our entire team was working on our individual assignments in the same area and at relatively the same time, I would like to acknowledge Jennifer Kracha specifically as a contributor, as she was the team member who provided the isopropyl alcohol for us to use.

II. Photograph Setup

The setup for this picture was done in a concrete alcove after sunset, roughly 8:00PM. This isolated the flames from any plants or other items that could pose a potential risk to accidental ignition. This location also allowed for an unsteady flow of air from the wind, which added to the flickering of the flame as it burned through the isopropyl alcohol fuel. Below is a diagram of how the camera and fire were placed in regards to the concrete walls around it.

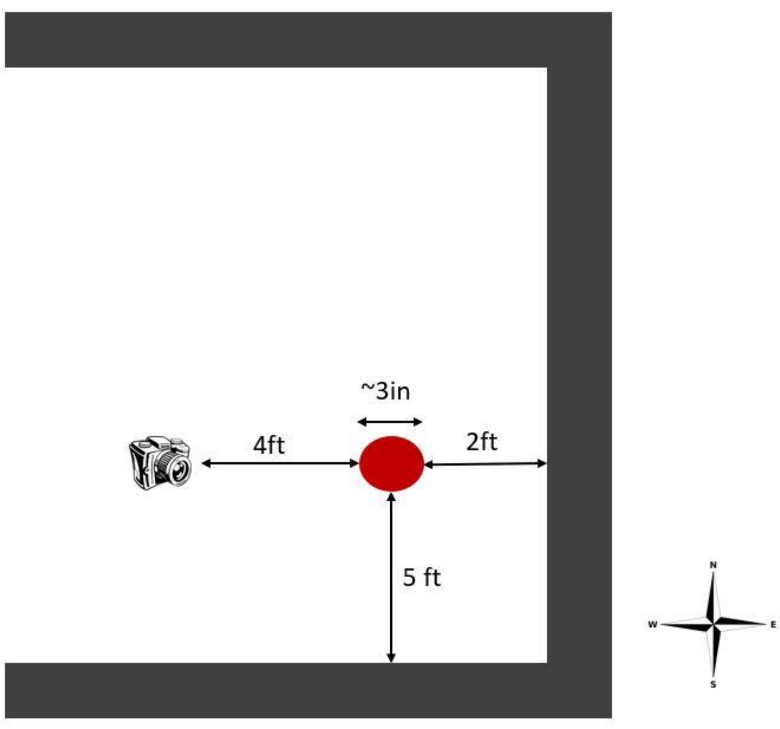

Figure 1: Diagram of experiment setup

III. Fluid Dynamics

The fire that I was able to capture in my video is known as a diffusion flame, or a pool flame. It can be seen in the video that the flame seems to separate into two or more distinct sections. This separation of the flame is commonly referred to as "flickering". This can be seen especially well at the beginning of the video, but is also noticeable when the flame is smaller towards the end of the video. Flickering in a flame is caused by toroidal vortices that form at the edge of the flame and the air around it [1]. A diagram of this effect can be seen in Figure 2 below.

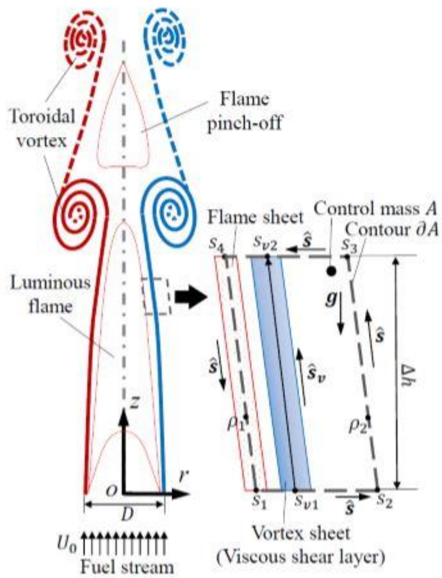

Figure 2: Schematic of toroidal vortex in a diffusion flame [1]

It is possible to calculate the frequency of the flickering using the following equation, where f_p is the flickering of a pool flame, g is the gravitational constant, and D is the diameter of the base of the flame [1].

$$f_p = 0.48\sqrt{g/_D} \qquad (1)$$

In this case, $g = 9.8\,{}^{m}/_{s^2}$ and $D = 3in = 0.0762m$. Plugging these values into the equation, we get the following:

$$f_p = 0.48\sqrt{9.8/_{0.0762}} = 5.44Hz$$

This means that the flame flickers about five times per second. This number will increase as the fuel burns out, as the diameter of the flame will shrink until it is gone.

It is important to note, however, that this equation is not entirely accurate to the situation I was able to capture in my video. In the specific experiments referenced, the researches were working with controlled, laminar flames. The flames they observed had a continuous fuel source and did not burn out over time. Another difference was that my experiment took place outside, where it was subjected to the uneven airflow from the winds. This could have affected the frequency at which the flame flickered. Despite these differences, though, I feel that the principals of flickering still apply, and that the calculations are accurate enough to show the physics phenomenon taking place.

IV. Visualization Technique

Since I knew I would be working with fire, I tried to find an area that was sufficiently dark in order to maximize the effect of the flame. To do this, I waited until after sunset to start work, and found a secluded area with very little outside light. Other than this, though, there were no other techniques used to capture the flow more clearly.

V. Photographic Technique

This video was taken on a Nikon D3500 camera, and was shot at 60 frames per second.

For post processing, I felt that the only necessary changes that needed to be made were editing the length of the video. It took the isopropyl alcohol around 2-3 minutes to burn completely, and I believed that the most impactful parts of the video could be seen within the first minute or so. With this edited section, the audience would still be able to see the switching from turbulent to laminar and back again while the fuel burned out, without having to watch an overly long video.

After the edited section was chosen, I added music to the video. I did this because music can add a depth and emotion to a video that the image itself can't. Depending on what music a person chooses, they can completely change the tone of the situation. My music choice came from a royalty free music website, https://www.bensound.com. I chose this site over others because of the ability to choose music based on the style, which allowed me to find the right feel for my video before having even selected a specific piece. The song I used was listed under the cinematic section, and is titled Adventure. This song was dramatic, yet uplifting and somewhat subtle. The expected music choice for a video involving fire would be heavy, dark, brooding, etc. This song is more upbeat and completely changes the way the fire is viewed by the audience, turning into something happy and light.

Privileges for the song can be found in the figure below, which prompts the user anytime they choose to download or purchase rights from the website. I used the song with the "Free Creative Commons License".

Figure 3: Right to use from https://www.bensound.com

VI. Results

Originally when I started this assignment, I wasn't sure what flow I wanted to capture. All I knew was that I wanted to work with fire, and through the trials and errors of experimentation, found an incredibly interesting fluids phenomenon. I believe that the video captures the flickering phenomenon well, even with minimal post processing or special setup beforehand. If I were to do this experiment over, I would like to try different camera specs, though. Perhaps the use of a high-speed camera would help the flickering stand out even clearer than when it was captured at 60fps. That way the audience could clearly see the breaking points between the two sections of flame, and how it changes as the fuel burns out or the wind changes speed and direction.

VII. References

[1] Xi Xia and Peng Zhang. "A Vortex-Dynamical Scaling Theory for Flickering Buoyant Diffusion Flames."