Group Project 2: Fire!

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MCEN 4228: Flow Visualization

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Introduction

The goal of this project was to capture the abstract motion of combustion. The flame was to be the only object visible in the image. This was accomplished by carefully controlling the experimental setup and camera settings.

Experimental Setup

A pool of Kingsford brand charcoal lighter fluid was ignited using a stick lighter. A piece of cardboard was placed near the center of the pool in order to maintain a flame through the experiment. With the cardboard there was no need to re-ignite the fluid; more fluid could simply be sprayed onto the flaming cardboard.

Lighter fluid was added from a distance of 1-2 feet. Images were photographed from a distance of 5 feet. The experimentation also included the use of a WD-40 spray can to visualize rapid combustion of an aerosol spray. These images were not chosen in the end due to the similarity to images from previous iterations of this course.

The experimental set-up can be seen below in Figure 1.

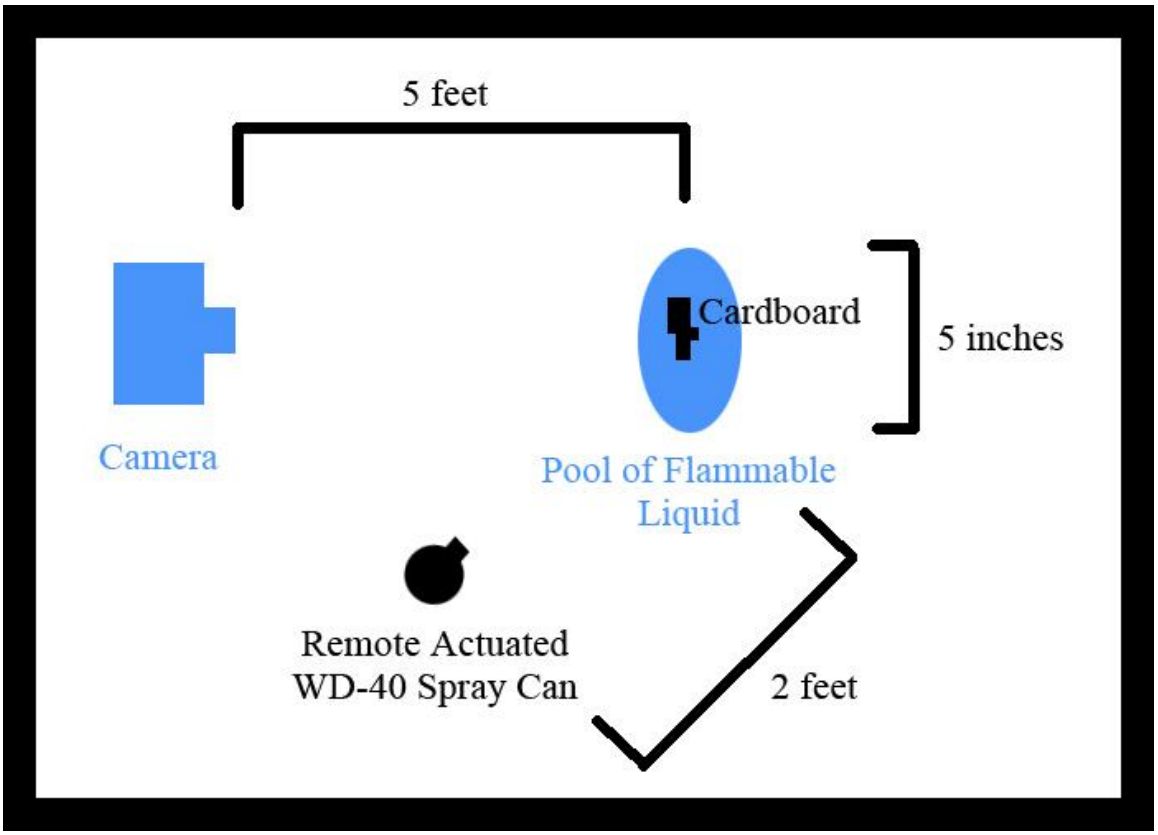

Figure 1: Experimental Setup

Physical Information

The correct name for the charcoal lighter fluid is Petroleum Naphtha. The specific gravity of this fluid is approximately .776 at 60C [1]. Specific gravity is a measure of a materials density relative to the density of water. That is to say that water has a specific gravity of 1 [2]. Thus the density of the Naphtha can be calculated by multiplying .776 by the density of water, yielding a density of ~776 kg/m^3 or .776 g/cm^3.

The velocity of the flame is approximated to be 35cm/s. This was approximated by dividing the height of the flame (35cm) by the approximate time from ignition to full flame height (1s). The viscosity of Naphtha was found to be .97 cP. In order to calculate Reynold's number we define our characteristic length as the diameter of the pool (13cm). Thus we can calculate Reynold's number:

$$Re = \frac{\rho V D}{\mu} = \frac{(.776)(35)(13)}{.97} = 364$$

This shows a very laminar flow. It is likely, however, that the flow becomes turbulent as it interacts with the wind. The wind speed was not recorded during this experiment.

Photographic Technique

This image was captured at night (11pm). This allowed for near total darkness, allowing the flame to be fully captured. The flame was the only source of light. A very small aperture and high ISO combination was used to capture the flame without any added environmental reflection.

Photographic Information:

Camera: Canon EOS Rebel XSi
Shutter Speed: 1/640 s
Aperture: f/36
ISO: 1600
Focal Length: 55mm
Original Image Dimensions (X-Y): 2848px-4272px
Final Image Dimensions (X-Y):

In order to develop a time resolution for this image one must consider the motion blur. If the speed of the flame is assumed to be 35cm/s and the shutter speed was 1/640s, the flame should have moved .055cm. The field of view (FOV) height was approximately 50 cm which correlates to an image dimensions of 4273px. The motion blur is thus calculated as:

$$blur = \frac{(velocity)(shutter\ speed)}{FOV\ height} * image\ height = \frac{(35)\left(\frac{1}{640}\right)}{50} * 4273 = 4.7px$$

Since pixels are the indivisible unit of image information the motion blur is rounded to 5px. This small motion blur is barely noticeable in the image, though flames naturally appear "blurred" in photography.

Post-Processing

The image was modified slightly using Adobe Photoshop CS4. The image was first cropped. A large, soft, black brush was then used to remove a few distracting elements from the image. A color layer was then used to color part of the image blue. This was done to add a visually interesting and abstract aspect to the image. It is important, however, to recognize that the blue coloration is purely a result of post-processing. The original image and submitted image can be seen side by side in Figure 2.

Figure 2: Comparison of image before and after editing

Non-Submitted Images

There were several visually interesting images that I did not submit. Below you fill find a few of these images.

Figure 3: This image has the identical set up as the submitted image, but reminds me of a Koi fish.

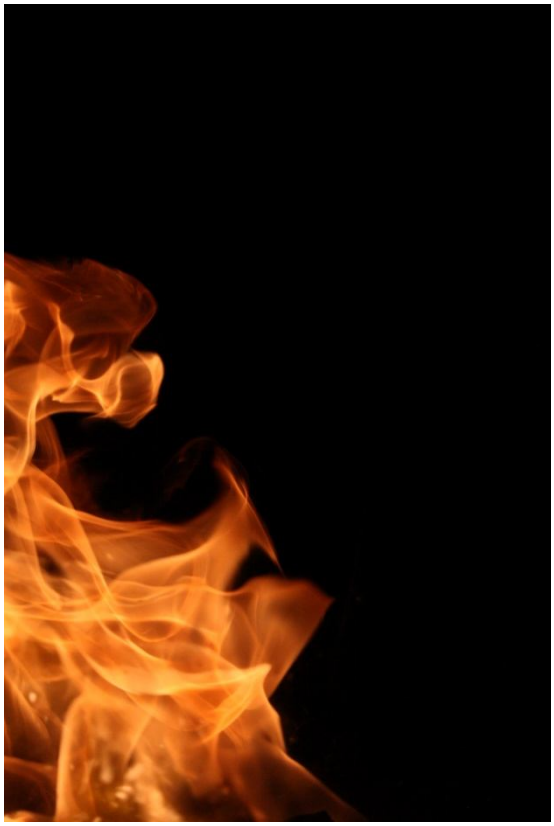

Figure 4: This flame is the result of the ignition of a WD-40 spray stream. More information on this phenomena can be found at:
http://www.colorado.edu/MCEN/flowvis/galleries/2007/assignment3/Miller.pdf

References:

1. http://www.fsafood.com/msds/vault/002/002354.pdf

2. http://www.engineeringtoolbox.com/density-specific-weight-gravity-d_290.html

3. http://www.arb.ca.gov/db/solvents/solvent_pages/Hydrocarbon-HTML/vmp-ii.htm

4. Unsteady Combustion. Culick, Heitor, Whitelaw. Kluwer Academic Publishers. The Netherlands. © 1996

5. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2B-4B3MMNF-1&_user=918210&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000047944&_version=1&_urlVersion=0&_userid=918210&md5=318c0df1c38ee3e24bfc7aef83f5cc6b