Sacred Heart

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I. Introduction

This report documents the techniques used to create propane gas bubbles and display their flammability, as well as the physics and fluid principles that are involved. It will also describe the photographic techniques used to capture the image. It is very important to consider and to take appropriate safety precautions when imaging or experimenting with fire and flammable gases, these precautions will also be covered.

This project was the second of three team projects for the Flow Visualization Course at the University of Colorado at Boulder in the spring of 2012. The purpose of the assignment was to group together engineers and art students, and combine their disciplines, in order to visually produce a fluid phenomenon and capture it using the photographic technique of their choice.

II. Flow Apparatus

"Fire is the rapid combination of oxygen with fuel in the presence of heat, typically characterized by flame, a body of incandescent gas that contains and sustains the reaction and emits light and heat." [2]. The colors we see in flames are excited electrons rising and then falling. When they fall they give off different photons of light, such as seen in this image. The flames rise because the lighter, hot air inside the flame is less dense that the air surrounding it. As the cool air underneath pushes up, the flames rise.

The mechanical behavior of the flame is largely due to the ambient conditions outside, and the flame is also affected by the wind. The adiabatic burning velocity is difficult to calculate because it is greatly sensitive to perturbations [1]. The velocity of the flame is estimated to be 33 to 41 cm/s [2] and the viscosity is approximately 1. A ratio of internal to viscous forces, or Reynolds number, of the flame is difficult to determine due to sporadic changes, but is estimated to be very high, around 2610 to 1.3e5.

The original image was captured using the set up technique shown in **Figure 1**. The image was taken just after sunset and only the lighting from the flame emission was used. The photographer stood a safe working distance of 3 feet from the flame, to protect himself and the camera from flame and heat.

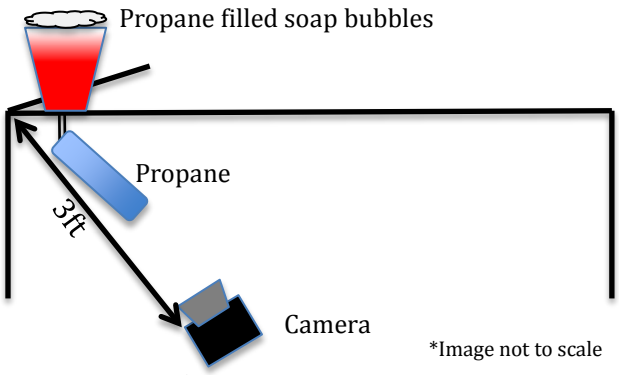

Figure 1: Experiment setup

III. Visualization Technique

Before setting up this experiment several safety precautions were taken. First, it is important to have an assistant on hand to call for help if needed. Next, a non-flammable location was chosen, outdoors, away from any other flammable objects. An ABC fire extinguisher and a bucket of sand were kept near by to extinguish any undesired fire. A safe distance was kept and appropriate PPE, including leather gloves, were used as additional protection

The next step in creating this image is to assemble the flow apparatus, the materials needed are:

- **Clear 2-liter bottle**
- **3/4" silicone tubing- .5 meters**
- **Instant adhesive (Super glue)**

First, the 2- Liter bottle was cut in half horizontally. Then, a ¾" hole was drilled in the center of the cap. The tubing was inserted approximately 1 inch into the cap and sealed into the cap using instant adhesive. The cap was re-secured onto the bottle and the container was then set up on a non-flammable structure, outdoors, and away from any other flammable objects.

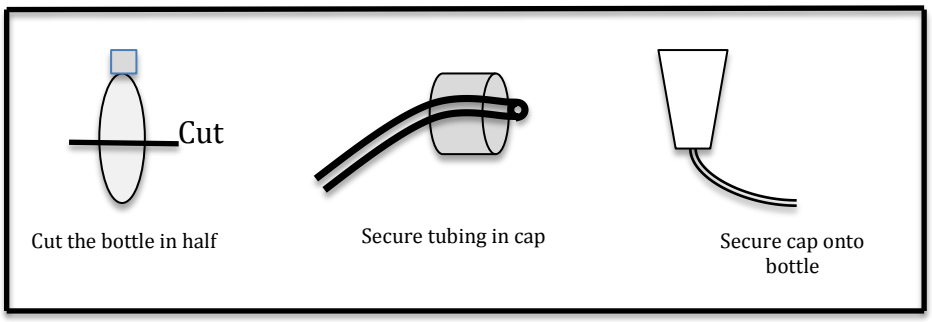

Figure 1. Container construction

For this experiment a combination of water and soap was mixed together using 1 liter of water and 25ml of dish soap. 10 drops of red food coloring, or propylene glycol, was then added in for aesthetic purposes. With the bottle secured, the propane bottle and regulator were attached to the distal end of the tubing and the container was filled with the liquid made earlier.

As the gas is slowly turned on, the lighter gas enters the bottom of the apparatus and it rises through the liquid. The gas rises to the top of the liquid where it is trapped inside soap bubbles it formed on the way up. These bubbles gather around the top of the liquid and can be ignited. Once a small amount of bubbles were formed they were ignited and produced the captured image.

IV. Photographic Technique

An 18.1-mega pixel DSLR camera was used and captured a RAW image of 5184 x 3456 pixels. The camera was a Canon EOS Rebel T2i body, housing the high resolution CMOS sensor, with a Canon EFS 18-55mm f/3.5-5.6 IS II lens [3]. The field of view is calculated to be 64inches by 45inches. The camera was focused manually and custom exposure settings were used including shutter speed, aperture, and ISO. A relatively fast shutter speed of 1/160s and an aperture value of f/3.5 were chosen to quickly capture the moving flow, minimizing distortion that maybe caused when photographing moving objects. An ISO of 400 was used to compliment the shutter and aperture values also due to the low light level that was provided. The camera's focal length was 18.0mm. The RAW image can be found in **Figure 3**.

Figure 3: RAW Image

Post processing was done using Adobe Photoshop CS5 and adjustments were performed to enhance subtle qualities and produce the final image. An adjustment to the tonal curves **(Figure 4)** was used to darken the background and bring the viewers attention to the flame and the glowing liquid below, this emphasized shading and color qualities by brightening light colors and deepening the darks. A small amount of cropping at the bottom of the image was also performed.

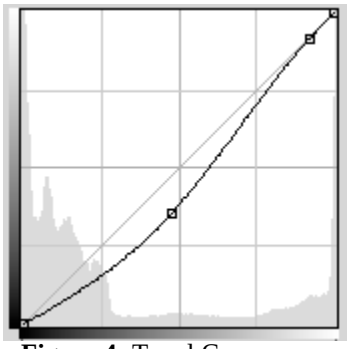

Figure 4: Tonal Curves

V. Image Analysis

The final image effectively reveals the fascinating combustion of propane bubbles and the physics involved in a unique and intriguing way. Intent was achieved and I feel this image would make a great piece of art, if it was printed and framed. The illuminated and vibrant red fluid, with flame reaching out, resembles, a famous religious symbol, the sacred heart. I really enjoy the colors and the shape of the flows, as they are very vibrant and seem to pop out right out of the photo. I would like to make some more adjustments in post processing to remove some glare in container and highlight some of the flame shape.

References

[1] Bosschaart, K. "The Laminar Burning Velocity of Flames Propagating in Mixtures of Hydrocarbons and Air Measured with the Heat Flux Method." *Combustion and Flame* 136.3 (2004): 261-69. Print.

[2] Bruno Renou, et al. "Measurement Of Laminar Burning Velocity And Markstein Length Relative To Fresh Gases Using A New Postprocessing Procedure: Application To Laminar Spherical Flames For Methane, Ethanol And Isooctane/Air Mixtures." *Combustion & Flame* 159.2 (2012): 577-590. *Academic Search Premier*. Print.

[3] Canon U.S.A. "Consumer & Home Office." EOS Rebel T2i EF-S 18-55IS II Kit. Web. Accessed 16 Feb. 2012. <http://usa.canon.com/cusa/consumer/products/cameras/slr_cameras/eos_rebel_t2i_ef_s_18_55is_ii_kit>.