Stephen Lepke

Flow Visualization
Get Wet Project

-Professor Hertzberg

2/1/2010

"Fire Ball"

Flames capture the imagination, as they dance in the wind. A flame is produced after an exothermic reaction (releases heat) called combustion. The flame needs fuel and oxygen to continue to burn, and in return carbon dioxide, water and energy are released. There are a variety of fuel sources, but most are hydrocarbons or organic compounds in either the solid, liquid, or gas phase. In this particular shot, the flame is burning off of the flames emitted from rubbing alcohol as it evaporates into the atmosphere. The picture was taken for the Flow Visualization Class for Professor Hertzberg at the University of Colorado at Boulder, and all protective measures were taken to ensure safety making the images.

In order create the image; rubbing alcohol (C_3H_8O) was poured into a blue glass bowl. The artist saturated three tennis balls in the rubbing alcohol in the bowl and then took a variety of shots with the balls on fire, on top of ice. These three balls were arranged in various patterns to capture different view-points of the burning tennis balls. The image captured showed combustion with non-linear movement of flames with the light reflecting off of the ice.

As seen in Figure 1, the camera was placed about 6 inches above the ground on top of a flat object, and was about 3 feet away from the tennis balls. The artist did not use any backdrop because he wanted to try and use the reflectivity of the ice in the shot. The light from the flame was enough to illuminate a decently clear picture and also allow reflectivity off the ice. There was also some interesting light bending phenomena from the light emitted around the tennis balls. The tops of the flames have some motion blur due to a slow shutter speed. However, this lighting was enough to clearly capture the blue flames on the tennis ball's surface.

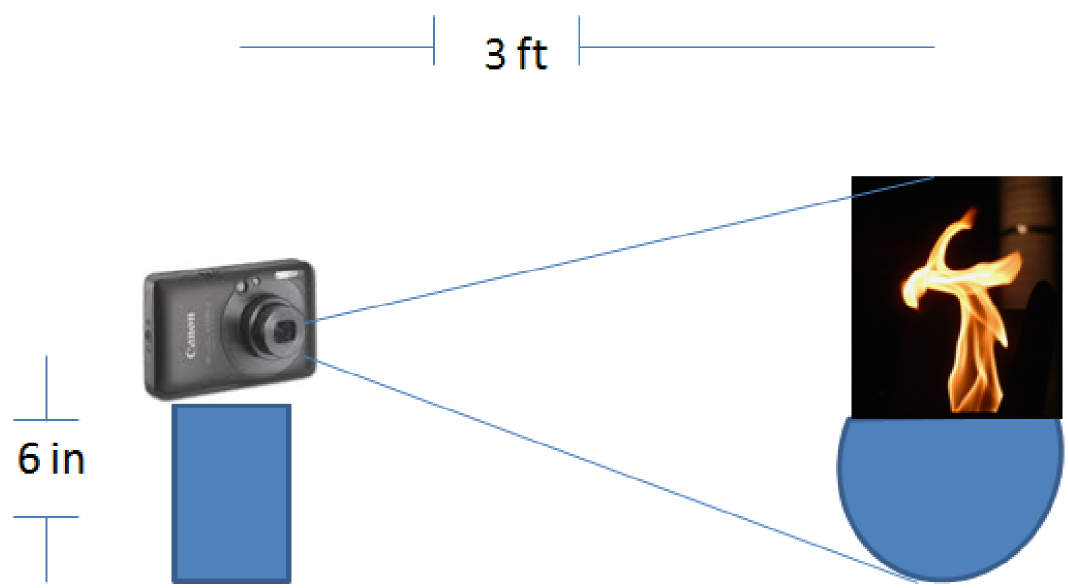

Figure 1: Camera & Picture Setup

When the alcohol is burned, it releases heat, light, water, and carbon dioxide. There is an optimal amount of mixing between the air and the fuel (alcohol vapor) and the flame that drives the flame's size, intensity, and color. The release of light is caused by electrons in the alcohol atoms being excited by the introduction of heat, and so they increase their energy level. However, the electrons are in an unstable state, and so they release energy by moving down to their original energy state, and in doing so they release photons (Lee). These photons vary due to the temperature of the flame and/or fuel being used. In this picture, the flames were both blue and red, indicating that certain parts of the flame (blue) were hotter than others (red). The blue light is also indicative of blue radicals being released as the flame combusts the alcohol. This is confirmed Dragojlovic's research, where he writes about fuel material driving flame color during combustion. One can also see the black body radiation of the flame. This radiation is the thermal radiation (or heat) given off by a flame to its surroundings. Its named is derived the observation that a perfect thermal radiating object would expel all of its energy in thermal form if only the object was not giving off any light and only absorbed it; thus it looks black.

Flames are hard to capture on camera because they move quickly. The flame moves in an unpredictable motion because it is being driven by a multitude of other fluids such as wind. Additionally, the alcohol is evaporating at different rates over the entire liquid surface, thus having different amount of fuel for the flame's combustion. Since flames have virtually no inertia, the small amount of force exerted by the surrounding air easily moves adjusts the motion of the flame. The flame's length scale can be calculated via the Reynold's number (RE=velocity*length/kinematic viscosity). This turns out to be RE= (1 m/s)*(.3 m)/(18.2 *10^-5 m^3/s)= 1648. This RE indicates a laminar flow, which can be seen by the image. The camera details can be shown in Table 1 below. The ISO is 200.

Table 1: Image Details

More Info:

Dimensions:	3264 × 1888
Device make:	Canon
Device model:	Canon PowerShot SD850 IS
Color space:	RGB
Color profile:	sRGB IEC61966-2.1
Focal length:	5.8
Alpha channel:	No
Red eye:	No
F number:	2.8
Exposure time:	1/4

In my opinion, this picture demonstrates the unique and beautiful flow of flames. It shows how beautiful it can move easily and beautiful among and on top of objects. Not only does the picture show the beauty of a flame's agility, but also its intensity and potential destructive power. I particularly like this picture a lot because of the contrast and dichotomy presented between the blue flame on the near surface of the tennis ball, and the orange flame that is birthed as the flame grows in stature.

References:
http://en.wikipedia.org/wiki/Combustion

http://upload.wikimedia.org/wikipedia/commons/1/16/Australia_Cairns_Flame.jpg

LEE A, LAW CK. "An Experiment Investigation on the Vaporization and Combustion of Methanol and Ethanol Droplets". COMBUSTION SCIENCE AND TECHNOLOGY, vol. 86, 1992. Pages 253-265.

Dragojlovic, Veliko. "Flame Tests Using Improvised Alcohol Burners". *J. Chem. Educ.*, 1999, 76 (7), p 929.

http://en.wikipedia.org/wiki/Black_body

Before and After Shots

After

Before