Majestic Fire

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Flow Visualization – Spring 2014

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I. INTRODUCTION

This report documents the flow visualization technique to take a picture color changing fire. By using different types of salt to change the color composition of fire the image was taken while reflecting the fire over the surface of water. The combustion process causes energizing of certain electrons in the metal. The following report identifies the interesting aspects of combustion of salts and relates it to the visualization techniques.

II. FLOW APPARATUS

The simple chemical reaction between oxygen and ethanol, or even wood, if ignited will cause a combustion reaction. Naturally, fire produces light, this is known as incandescence. [1] The color of a flame can identify what temperature it is burning. The hottest part of a flame glows blue whereas the less hot parts glow orange and then yellow.

Interesting enough ethanol will catch fire if it is heated to about 26°C and wood will only catch fire at about 232°C[2] after all the water has evaporated from the wood. When burning the ethanol on the cement ground the temperature at which the ethanol needs to be in order to burn is relatively much lower than the temperature that wood would need to burn.

The Mystical Fire salts had a compound called copper (II) chloride. When the copper ions are heated they become excited and move to higher energy levels. The electrons are not stable in the higher energy levels and thus return back to their ground state. When the electrons return back to the ground state they emit light, a photon, to release the energy gained from being excited[3]. This is seen as the blue and green flames in the image.

Initially, the Mystical Fire salts were poured onto the ground where the ethanol was being ignited. Unfortunately the yellow and oranges that would be seen with a normal fire were all that could be seen and the effect of the salts was not visible. Then so small mulch chips were set on fire and the salts were poured on top of the mulch chips and now small glimpses of green and blue could be seen. This could mean that in order excite the electrons of copper (II) chloride the fire the burning temperature has to be higher than when just using ethanol.

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[1] Harris, Tom. "How Fire Works." *HowStuffWorks*. HowStuffWorks.com, 14 May 2002. Web. 01 March 2014.
[2] "Wood Combustion - FlameWorks - High Efficiency Hearth." *Wood Combustion - FlameWorks - High Efficiency Hearth*. N.p., n.d. Web. 01 March 2014.
[3] Harris, Tom. "How Fire Works." *HowStuffWorks*. HowStuffWorks.com, 14 May 2002. Web. 01 March 2014.

The reflection of the fire is a result of Fresnel conditions[4]. Fresnel equations describe how electromagnetic waves are reflected at an interface. The light from the fire goes from air with a medium of index, 1, to water with a medium of index 1.33. If the surface is smooth and the angle of incidence is 90° that gives and angle of transmission of 48.75° resulting in a reflection coefficient of:

$$r_{||} = \left(\frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)}\right)^2 = 1$$

The one represents the fractional intensity of the reflection meaning the fire is being reflected 100%.

III. VISUALIZATION TECHNIQUE

In order to capture the image using fire some precautions were put in place. A large cement bunker was located where nothing surrounding it was flammable. Then a small amount of ethanol was sprayed toward the center of the cement slab and water was poured around the ethanol. The ethanol was lit on fire using a large stove lighter. Once the fire was burning the mulch chips were thrown into the fire. Finally, the Mystical Fire salts were added. The water had a tendency to evaporate quickly so having an additional person pouring water around the fire allowed for the thin layer of water to reflect the flame.

Figure 1: Mystical Fire Set-Up

[4] "Fresnel's Equations." *Fresnell's Equations: Reflection and Transmission*. Georgia State University, n.d. Web. 01 Mar. 2014.

The image was captured at night with very little light surrounding. There were a few lights in the distance which allowed for the image to be captured without using a flash. Although there was grass and a few bushes in the distance the limited light allowed for the bright fire to eliminate any of the distracting elements in the background. The image was taken perpendicular to the ground while being as close to the ground as possible without getting the camera wet from the puddle. This allowed the reflection of the flame to be captured as if the flame were floating on water.

IV. PHOTOGRAPHIC TECHNIQUE

The mystical fire image was captured using a Canon EOS Rebel T1i was used with a Canon EF-S 18-55mm f/3.5-5.6 IS lens. Even though there was limited light the bright fire allowed for the image to be taken at surprisingly fast speeds and low aperture. This image was captured at f5.6 with a shutter speed of 1/250 of a second. With an ISO value of 400 the image was able to remain crisp without getting too grainy.

The final image was no post processed. The colors came out well and the focus successful. The image was cropped to a size of 2300 x 4426 pixels.

V. IMAGE ANALYSIS

The image reveals the amazing reflective capabilities of water as well as the photon emission of excited electrons. The crispness of the refection of the fire on the water demonstrates medium of index of water compared to air and how this directly affects the Fresnel reflection intensity. Initially the goal was to find a flammable substance that floated on the surface of water but this proved to be harder that it seemed. If the reflection touched the bottom of the actual fire it would make this image stronger. Additionally it would be nice to have more green and blue colors within the image rather than the normal flame colors of fire; this could be achieved by burning a hotter fire with more salts.

Image Assessment Form
Flow Visualization
Spring 2013

Name(s) Danielle Metzner, Cameron Misegadis, Nicole Lubinski, Kyle Thatcher
Assignment: Team photo 1 Date: March 1, 2014
Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	+	
Effective	+	
Impact	✓	
Interesting	+	
Beautiful	+	
Dramatic	+	
Feel/texture	+	
No distracting elements	+	
Framing/cropping enhances image	✓	

Flow	Your assessment	Comments
Clearly illustrates phenomena	+	
Flow is understandable	✓	
Physics revealed	+	
Details visible	+	
Flow is reproducible	+	
Flow is controlled	✓	
Creative flow or technique	+	
Publishable quality	✓	

Photographic/video technique	Your assessment	Comments
Exposure: highlights detailed	+	
Exposure: shadows detailed	+	
Full contrast range	+	
Focus	+	
Depth of field	+	
Time resolved	N/A	
Spatially resolved	✓	
Photoshop/ post-processing enhances intent	N/A	
Photoshop/ post-processing does not decrease important information	N/A	

Report		Your assessment	Comments
Collaborators acknowledged		+	
Describes intent	Artistic	+	
	Scientific	✓	
Describes fluid phenomena		+	
Estimates appropriate scales	Reynolds number etc.	✓	
Calculation of time resolution etc.	How far did flow move during exposure?	N/A	
References:	Web level	+	
	Refereed journal level	N/A	
Clearly written		+	
Information is organized		+	
Good spelling and grammar		+	
Professional language (publishable)			
Provides information needed for reproducing flow	Fluid data, flow rates	✓	
	geometry	+	
	timing	+	
Provides information needed for reproducing vis technique	Method	+	
	dilution	N/A	
	injection speed	N/A	
	settings	+	
lighting type	(strobe/tungsten, watts, number)	+	
	light position, distance	+	
Provides information for reproducing image	Camera type and model	+	
	Camera-subject distance	+	
	Field of view	+	
	Focal length	+	
	aperture	+	
	shutter speed	+	
	Frame rate, playback rate	N/A	
	ISO setting	+	
	# pixels (width X ht)	+	
	Photoshop and post-processing techniques	N/A	
	"before" Photoshop image	N/A	