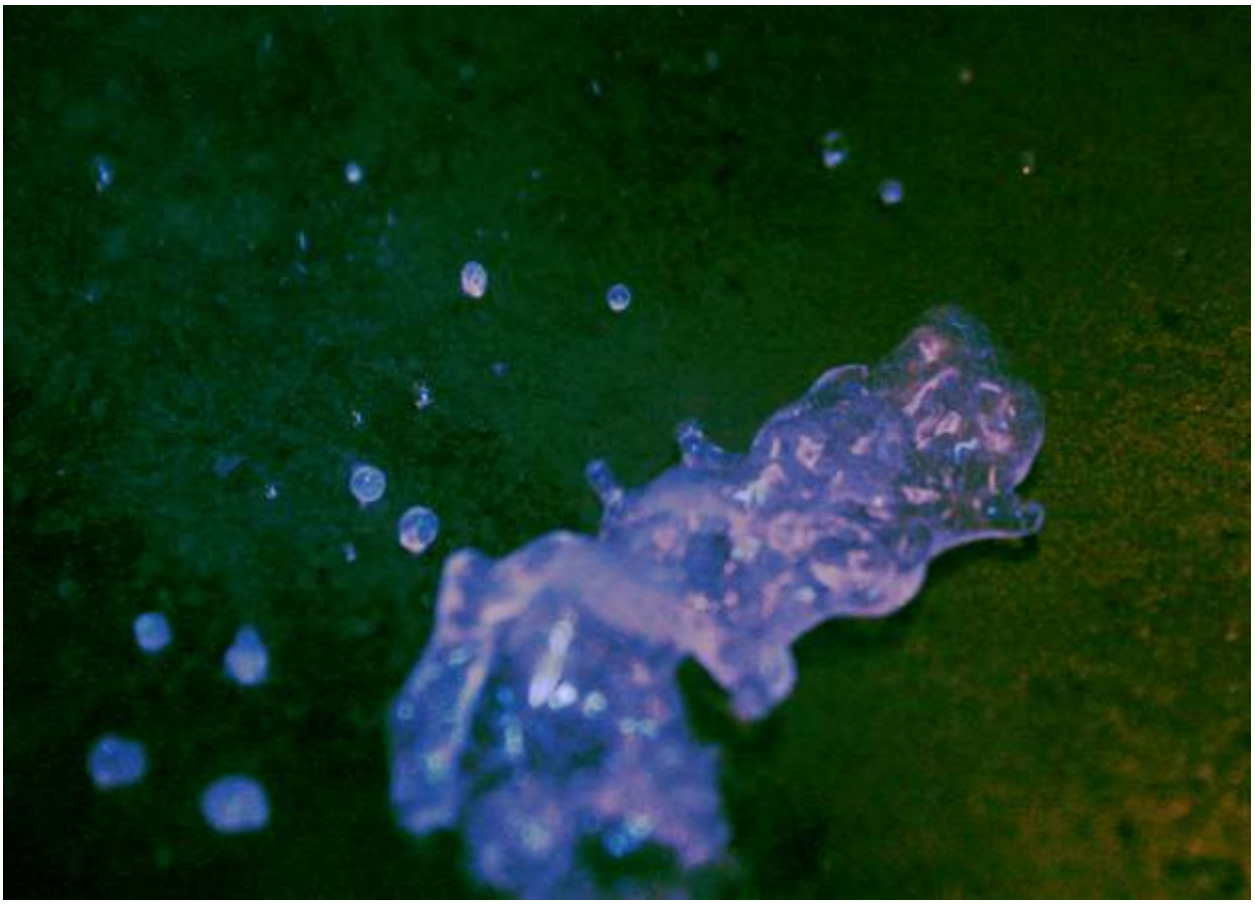
Leidenfrost effect



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MCEN 5228: Flow Visualization

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Introduction

The image above was taken of water on the surface of a hot pan, substantially above 100° C, the evaporation temperature of water. The image was taken for the second group assignment project in the flow visualization course. The intent of the photo was to demonstrate the Leidenfrost effect. The Leidenfrost effect occurs when a liquid, in this case water, comes in contact with a hot pan at a temperature well above the liquids boiling point. If the pan is hot enough a vapor layer will form underneath the liquid on which the liquid will float (1). From the photo above this hovering effect can easily be seen in both the larger liquid splash as well as the smaller droplets. They all appear to be hovering in mid air above the pan's surface. Because of the Leidenfrost effect liquids will boil slower due to the vapor barrier insulating them from the hot surface. Applications of the Leidenfrost effect are found in pan temperature when cooking as well as steam boiler temperatures (2).

Experimental Setup

The setup for this experiment was very simple. First a cast iron pan was heated on an electric stove stop at medium heat. After heating up for approximately 3 minutes a teaspoon of water was dropped onto the pan every 30 seconds until a desired Leidenfrost effect was observed. Initially the water just quickly evaporated; however, after a couple more minutes the water hitting the pan would burst into a bunch of water beads that hovered above the pans surface. As the pan got hotter the water droplet no longer burst into beads but rather remained one large droplet. The photo above was taken in between these two stages, where only a few water beads formed but the majority of the original drop stayed intact. The lighting used was two 100 watt bulbs above the stove top. An additional 1 watt led headlamp was also used which helps create some glare on the water surface, adding more definition to the surface texture of the water. Below is a diagram of the experimental setup.

Visualization Techniques

To shoot the water droplets on the pan, a digital SLR camera was used, specifically a 12 mega pixel Canon Rebel XSi. Because the water droplets were vibrating at a high frequency a high shutter speed had to be used, 1/800 seconds, to reduce motion blur. Because of this lighting became a factor. Because of the low light source a high ISO of 800 was used. A large aperture, f-stop 4.5 was also used. Because of the large aperture the depth of field was significantly reduced and some parts of the water drop came out blurry. To obtain such a large aperture on the camera a short focal length of 35 mm was needed. Reduced zoom required that the camera be held close to the pan, about 10 inches away at a 45 degree angle.

Leidenfrost Physics

When a surface is heated sufficiently above a liquids boiling point a vapor layer will form between the liquid and the surface on which the liquid will float. The temperature at which this happens is called the Leidenfrost point. The Leidenfrost point for water is somewhere around 160^{o} C; however, this number will vary with surface texture and pressure.

When water initially comes into contact with the hot surface bubbles nucleate at the pans surface and travel freely up through the water. As the surface temperature is increased more nucleation points will form and more bubbles will rise up through the water. As the temperature is further enough bubbles will form and combine together at the bottom of the liquid they will form a vapor layer between the liquid and the surface. At this point no longer is the liquid in contact with the hot surface. At this point heat transfer is slowed drastically because of the vapor layer. The vapor layer in essence acts as insulation between the hot surface and the liquid. At this point the liquid will not slowly evaporate as heat is transferred through the existing vapor layer. The vapor from the evaporating liquid continues to replenish the vapor layer (3).

When the volume of the liquid is small enough surface tension will dominate and the shape of the liquid on top of the vapor layer will be spherical. As the volume is increased however gravity will dominate and the liquid shape will appear more cylindrical in shape (3).

Conclusion

The photo for this project captures the Leidenfrost effect well. However, the imaging techniques could have been improved. More light was needed for the photo. Because of the low light situations a high ISO was used as well as a large aperture. This caused the photo to be someone grainy and out of focus in areas. The photo did seem to be time resolved, and there was very little motion blur.

Works Cited

1. **Protius.** Leidenfrost Effect. *Scienceray.* [Online] January 31, 2010. http://scienceray.com/earth-sciences/leidenfrost-effect/.

2. **Talley.** On properly heating your pan. *Houseboat Eats.* [Online] http://www.houseboateats.com/2009/12/on-properly-heating-your-pan.html.

3. **Walker, Jearl.** Boiling and the Leidenfrost Effect. *University of Oregon .* [Online] http://darkwing.uoregon.edu/~linke/papers/Walker_leidenfrost_essay.pdf.

Image Assessment Form

Flow Visualization

Spring 2010

Name(s) scott schollenberger

Assignment: team 2 Date:

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

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

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

Photographic technique	Your assessment	Comments
Exposure: highlights detailed	Ok	
Exposure: shadows detailed	Good	
Full contrast range	Ok	
Focus	Ok	
Depth of field	X	
Time resolved	Good	
Spatially resolved	Good	
Clean, no spots	Good	

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