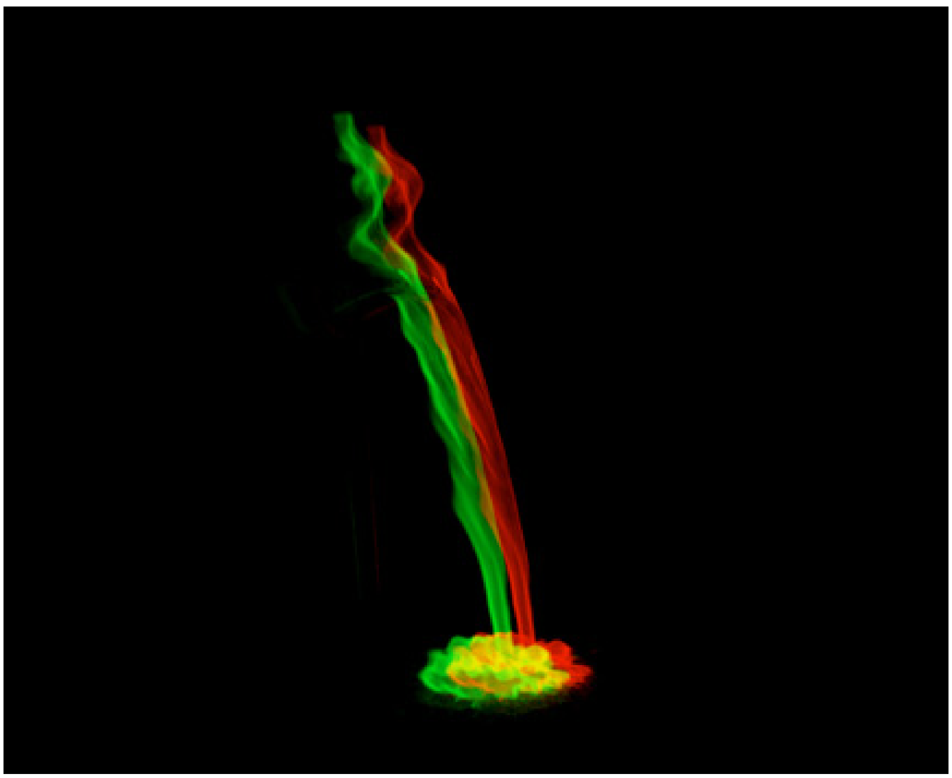
3D Flaming Liquid

Group Gamma Project 3



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Flow Visualization – MCEN 4228

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Intoduction

The intent of this submission was to take the photographs of flaming liquid from our Project 2 submission, and re-realize them in 3D. Splashing flaming liquid seemed like the perfect medium with-which to take advantage of modern 3D imaging. The impact of splashing flaming liquid was very well-realized in the last submission, but the team thought that it would have a greater impact if the viewer had better perspective on the splash. To accomplish 3D imaging of the previous submission, the team was aided by CU professor John Hart, who is an expert of polarized stereo photography. The images produced were quite striking, accomplishing the intent of the 3rd project, as well as providing for some interesting and unexpected fire flow phenomena (see picture xxxx). The images are presented in their red/green form, for more clarity the original left image can be seen in the appendix.

Materials

The materials and method used were the exact same as those used in Group Project 2, which is repeated here for convenience to the reader:

The flammable liquid was a mixture of methanol (99.8% grade) and boric acid. The chemicals were obtained from the chemistry stock room in the Christol Chemistry building on campus. The methanol provides the liquid and the property of flammability; the boric acid powder is added to impart the green color. The idea of using such a mixture was sourced from another previous Flow Visualization submission by David Levine et al. [2], who used crude versions of the chemicals in the form of anti-freeze and roach pesticide. Using the purest forms of the chemicals imparted a much brighter color to the flame than that of Levine, and gave the flames a light, "evergreen" coloration. The 600mL beaker was filled with ~200mL of methanol for each pour (enough methanol to visualize the pour, and develop an end pool of ~2ft in diameter). At first, the team used a 1:3 vol./vol. mixture of boric acid to methanol as suggested by Levine, but found that only a fraction of the added solute (boric acid) dissolves enough to saturate the liquid. With an excess of boric acid in the beaker at all times, we were assured the solvent (methanol) was constantly saturated for each pour, and simply refilled the beaker with fresh methanol before every trial; we found this method to be quite convenient and recommend it to anyone duplicating the experiment. The only lighting used here was the natural illumination provided by the flaming liquid.

Procedure

The procedure is almost exactly the same as that in the previous submission [1]. The procedure is repeated below, with the appropriate modifications:

The flow apparatus involved a lab test stand, beaker, turning rod and multiple cameras exactly 6 feet from the splash zone.

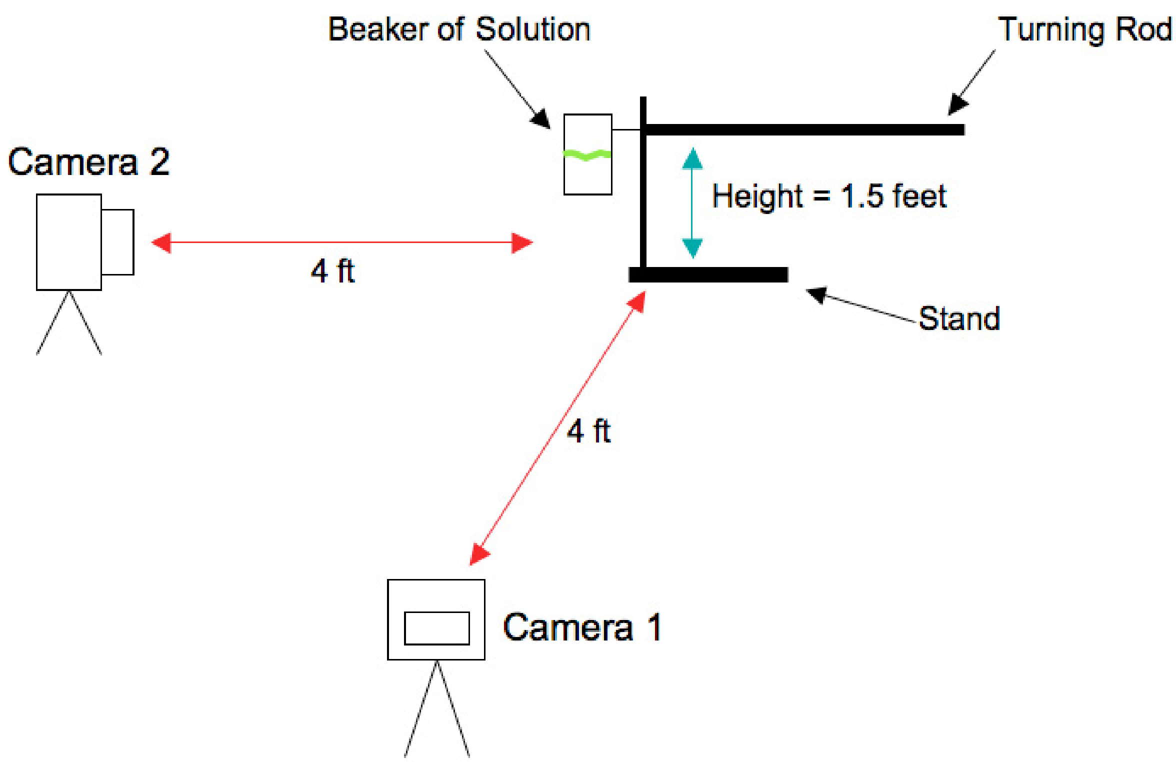

Figure 1. Flow apparatus

We poured the test solution from the beaker and observed the splash pattern and size and then positioned the cameras outside of that area. Most of our images have a width of 2-3 feet with the pool of flames occupying most of that area. The solution was ignited by match held by a Kevlar glove. The photographers were then queued to start shooting images in rapid succession, and the fluid was poured. The pouring of 300 ml of the solution took approximately 3 seconds. The liquid fell ~1.5 feet and accelerated to a maximum velocity of ~9.79 ft/sec. At the base of the pouring liquid, the diameter was 0.5 inches resulting in a Reynolds Number of 5.09×10^{-5}, which means that our flow was completely laminar throughout the pour (Re ~ 0). With exception given to the moment of impact, both the flow out of the beaker as well as the flow over the concrete floor were laminar flows. Below are the characteristic properties of the flow which dictate the Reynolds number [2,3]:

Free-stream velocity: 9.79733333 feet / second
Characteristic Diameter: 0.5 in
Fluid Density: 791.8 kg/m^3
Fluid Dynamic Viscosity: 590000 Pa-s
Reynolds Number = 5.09 x 10^{-5} ***Laminar Flow***

3D Conversion Procedure

The images were made 3 dimensional with the help of John Hart. Two Sony DSC-V3s were mounted together and the lens centers were set 3.75 inches apart and placed on a tripod 6 feet away from the flame. Two Canon EOS Rebel XSs were mounted together and the lens centers were set 4.8 inches apart and placed on a tripod 6 feet away from the flame at a different angle. Both Sony's and both Canon's were hooked up to a triggering mechanism so that both cameras fired at the same time. The distance the images had to be apart was found using the B=N/f, where B is the base distance between the center of the lenses, N is the near distance from the camera to the closest object you want in focus, and f is the focal length. The two images were than loaded into software called StereoPhoto Maker English Edition. This software converted the images into red-green Anaglyph and mirror right images so that they could be viewed in 3-d. The red-green Anaglyph conversion was used because it was recommended by Prof. Hart due to the natural green color of the liquid flame, and the mirror was used so it could be viewed without glasses.

Image #1 by Tim Jarrell

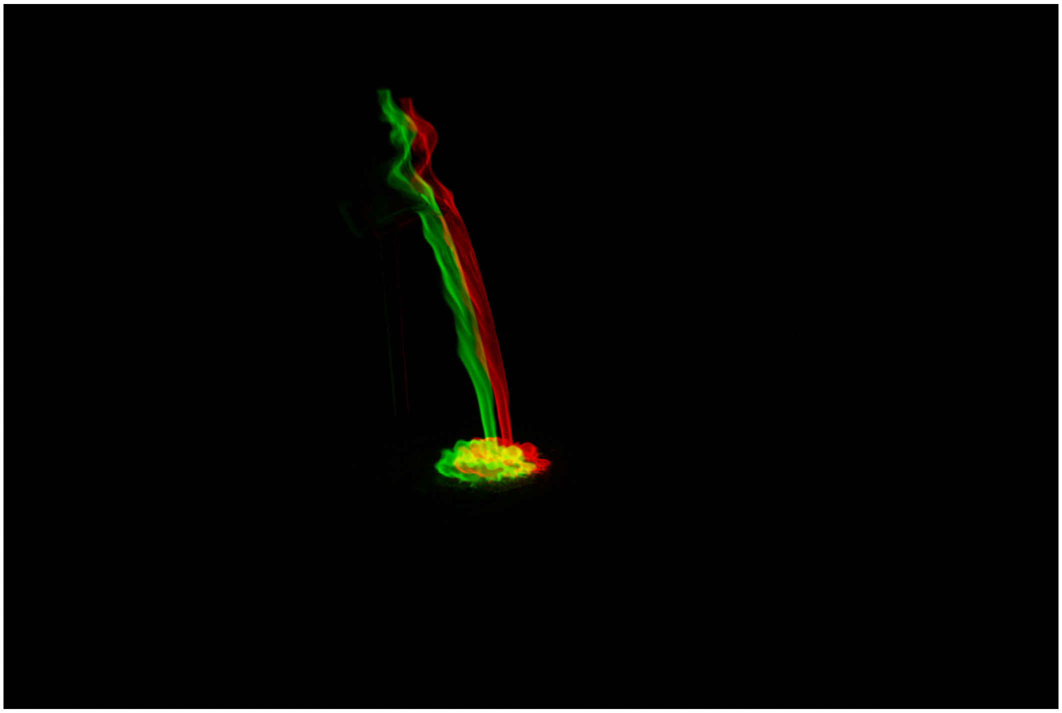

Figure 2. Image by Tim Jarrell

- The field of view: 4 ft
- Distance to object: 6 ft
- Focal length 24 mm, aperture f/5.6, exposure of 1/160 sec, ISO of 1600
- Camera: Canon EOS Rebel XS
- Format: Digital, original image size: 2816 pixels, height 1880 pixels.
- The only changes made to the original images were the red-green 3D application and the back-to-back mirror affect.

"My image reveals the impact affect of the boric acid directly after contact with the ground. The image was taken directly after the pour was started which was approximately 1/3 of a second after the pour started. The impact on the ground was very symmetric and dynamic. The smooth flow of the liquid surrounded by the flaming gas interface and the flame propagating from the top of the beaker had a great feel and texture. The contraction of the liquid and flame is very apparent and becomes even more so at the ground. What I most enjoy about this image is the simplicity to the flame pour and its dramatic impact with the ground. Since this was the second time we were using the boric acid pouring flame we just made it into 3D to really show off how the flame impacts the ground."

Image #2 by Lucy Dean

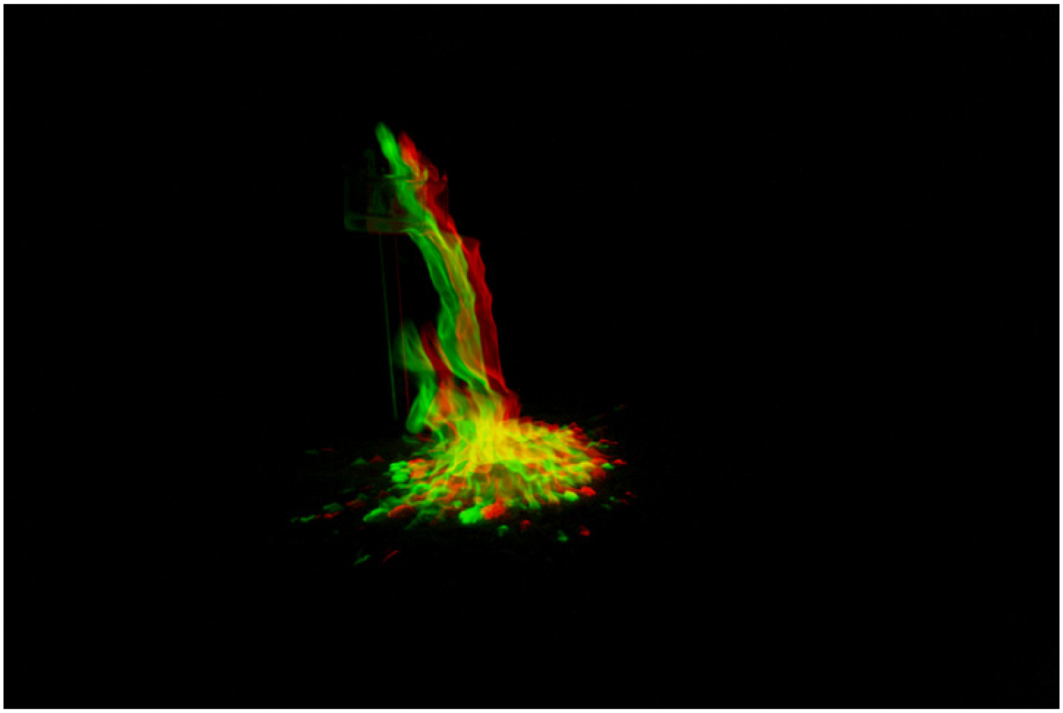

Figure 3. Image by Lucy Dean

- Field of view 2 x 4 feet
- Distance from object to lens 6 feet
- Focal Length 24 mm
- Distance between lens 4.8 inches
- Canon EOS Rebel XS
- Digital, Original and final Image width 2816 pixels, height 1880 pixels. Taken with a Canon Rebel XS.
- Aperture f 5.6, shutter speed 1/160s, ISO setting 1600
- Nothing was done to the image in Photoshop.

"The image shows a great splash. There is also an interesting spiral effect on the falling flame. I think the image is very captivating in 3-D. I like how it feels like the splash is coming at you. I would like to improve some of the contrast in the image; however I don't have enough confidence in my ability to match the two images well. It was a true experience to work with Prof. John Hart taking these images. He had a lot of great insight to offer and was extremely helpful."

Image #3 by Joe Duggan

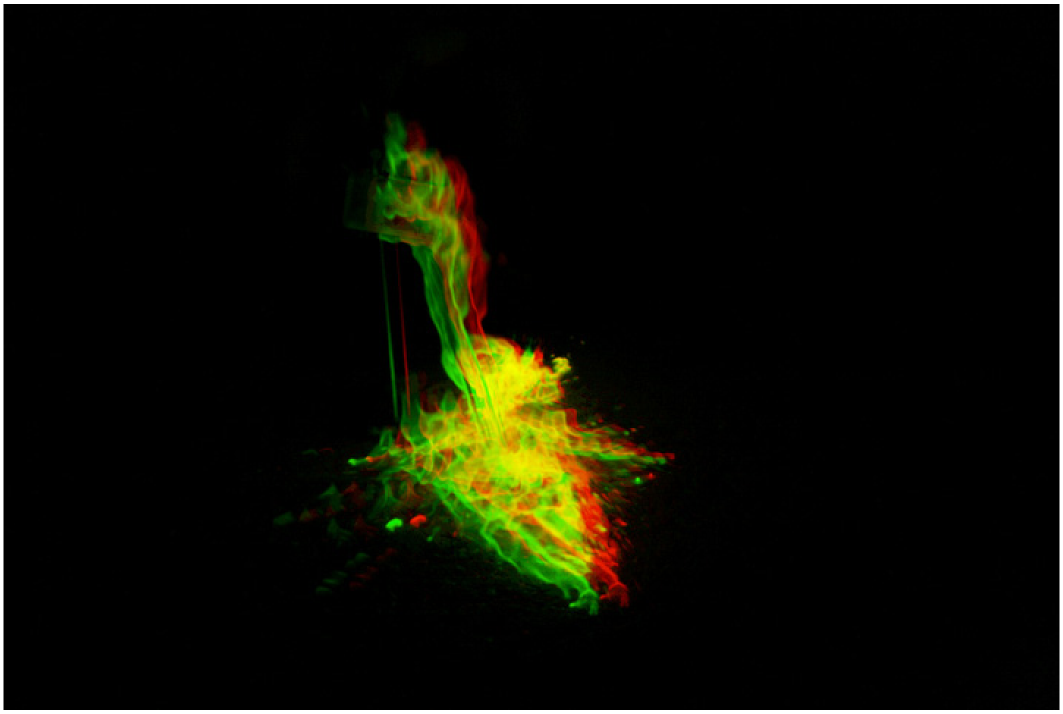

Figure 4. Image by Joe Duggan

- The field of view: 3.5 ft
- Distance to object: 6 ft
- Focal length 24 mm, aperture f/5.6, exposure of 1/160 sec, ISO of 1600
- Camera: Canon EOS Rebel XT
- Format: Digital, original image size: 2816 pixels, height 1880 pixels.
- There were no changes made to the photo using image-editing software.

"I chose this image mostly because of it's resemblance to the previous submission, of which the details I very much liked. The real intent of this last project was to capture what we as a group had already witnessed in the 2D images, but now in 3D; this truly captured the awesome effect of splashing flaming liquid. Attributes highlighted here that were also present in the previous submission are clear liquid flow from the beaker, visible liquid rebounding splash from the concrete, good flame pluming, and lastly an image with enough depth to provide for an enjoyable 3D conversion. I am quite happy with this image as it was the only one out of the batch that resembled my first submission, allowing me to follow through with my original intent of the 3D re-invisioning."

Image #4 by Melissa Lucht

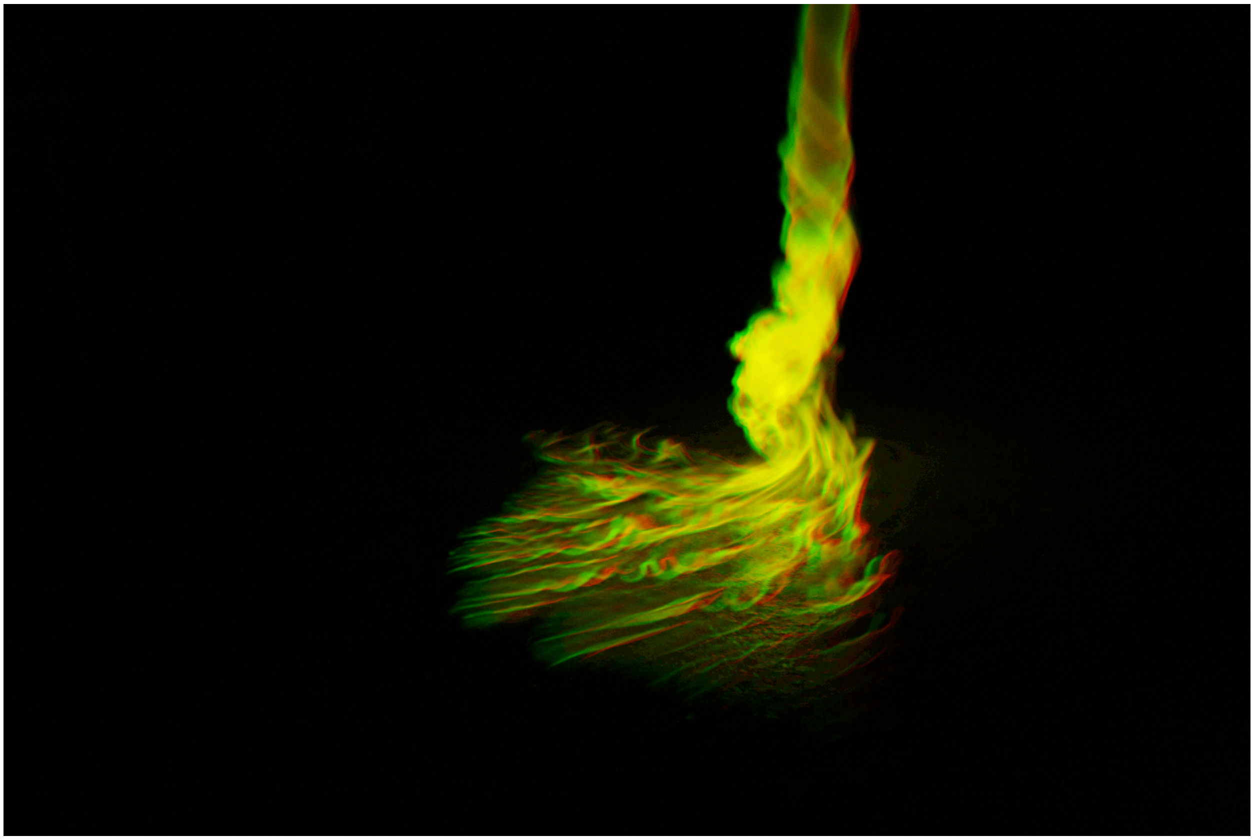

Figure 5. Image by Melissa Lucht

- The field of view: 4ft
- Distance to object to lens: 6ft
- Focal length 24 mm, aperture f/5.6, exposure of 1/160 sec, ISO of 1600
- Camera: Canon EOS Rebel XT
- Format: Digital, original and final image size: 2816 pixels, height 1880 pixels.
- No changes were made to the photograph in photoshop.

“ This image reveals the flame making a vortex tornado. The liquid flame had been poured onto the concrete and the group was waiting for the flame to go out. When all of the sudden this vortex formed and shot seven feet in the air. It lasted for about thirty seconds and then disappeared. I was lucky enough to capture it quick enough. I liked this image the best out of all of our images because of the shape of the vortex and all the little details one can see. I like how you can see the spiral and how it is twisting and forming this flaming vortex. I wish I was able to get the entire vortex, but the camera was set in a specific place and it happened to fast to move the camera. I am very pleased with how the entire project turned out. The 3-D effect makes the image pop out at you and shows how intense the boric acid flame was. Big thanks to Prof. Hart and all his help."

The project was again a complete success. Not only did it provide us with images that exactly mirrored our intent, it also gave us (again) images that we weren't expected at all (flame vortices). The other images included in this submission also show great flame effects, but did not meet the idea of liquid flow visualization as well as did the pictures submitted (they would have been fine for maybe a combustion project). And just as the first submission, we are proud of the fact that the colors and effects in the image are completely true to the original materials instead of being edited-in.

Works Cited

[1] Duggan , J. R. *Flaming Liquid: Group Project 2.* University of Colorado - Boulder, Mechanical Engineering.

[2] Wallace Racing. (n.d.). *Free Fall Calculator.* Retrieved April 8, 2009, from Wallace Racing: http://www.wallaceracing.com/free-fall-math.php

[3] eFunda. (n.d.). *Reynolds Number Calculator*. Retrieved April 7, 2009, from eFunda engineering fundamentals: http://www.efunda.com/formulae/fluids/calc_reynolds.cfm#calc

Appendix

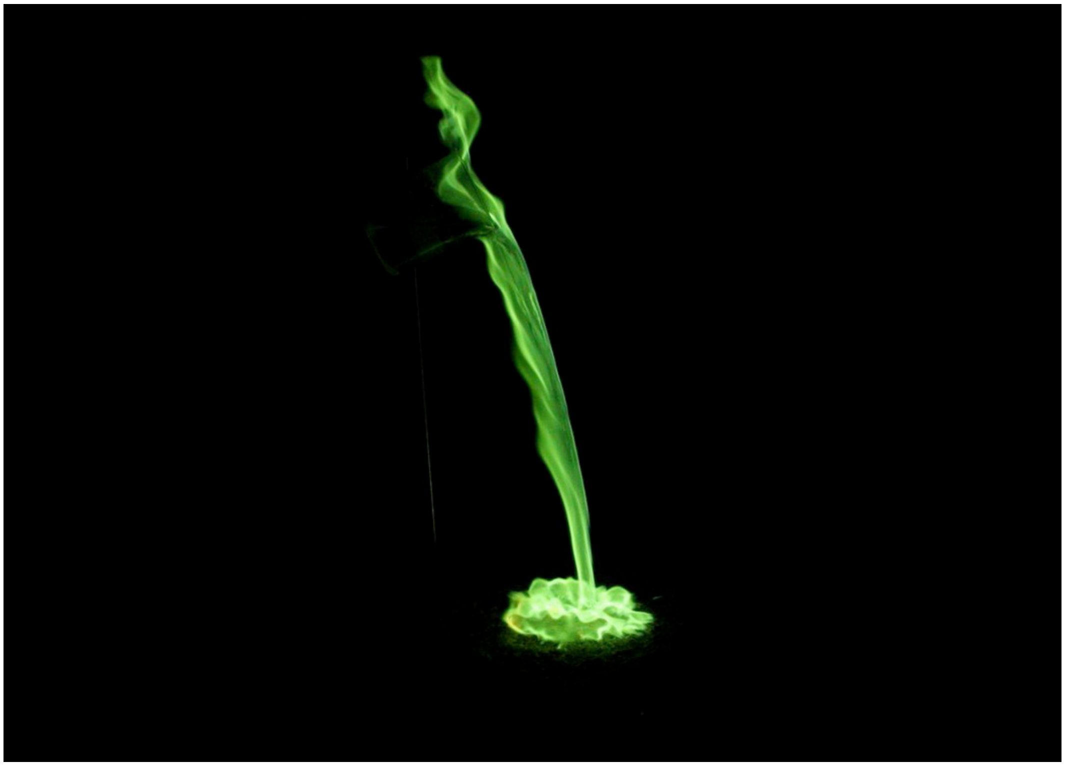

Figure 6. Tim Jarrel Original

Figure 7. Lucy Dean Original

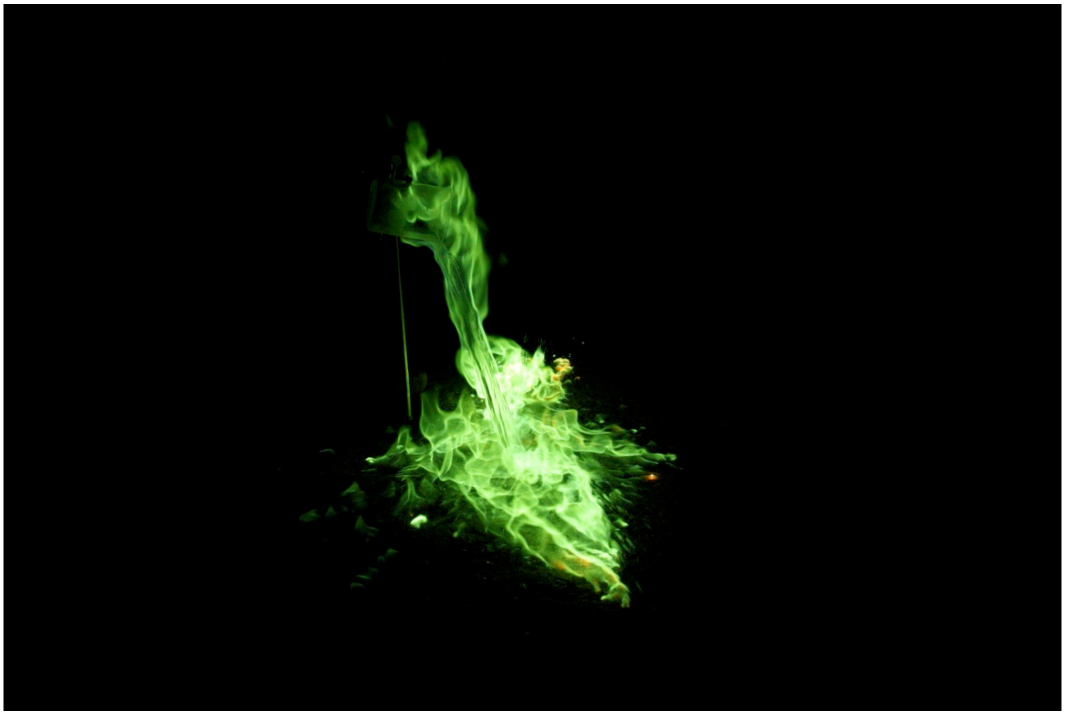

Figure 8. Joe Duggan Original