Team 3 Image Report

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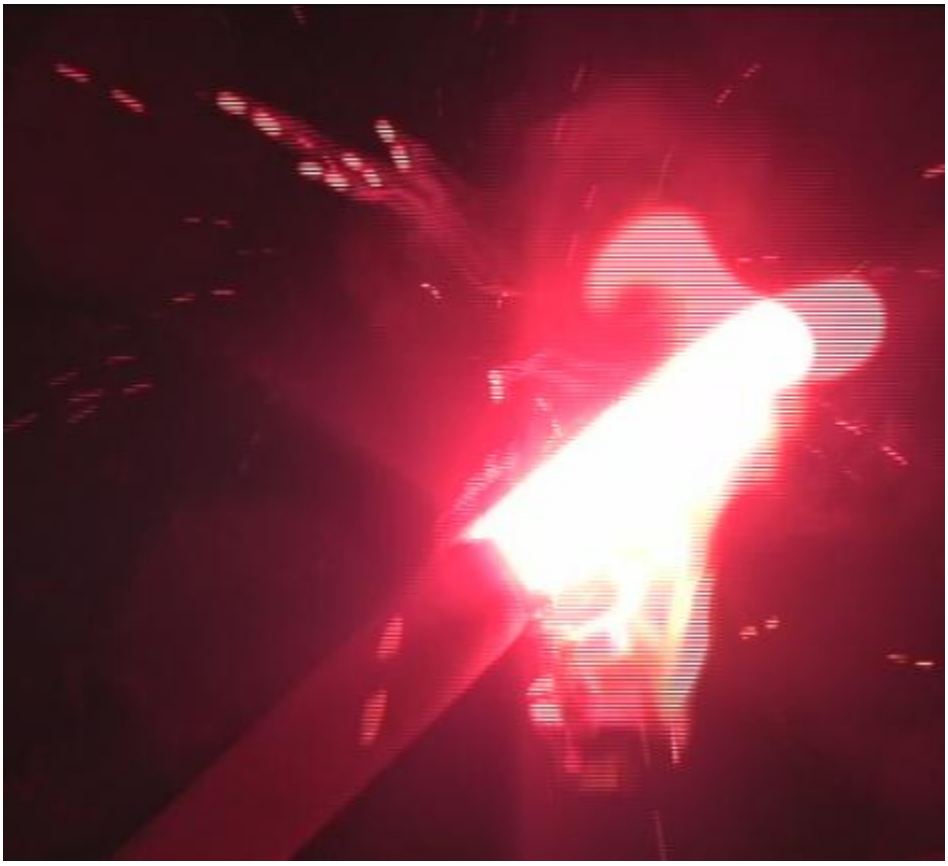

The purpose of this image was to utilize the flow visualization techniques developed over the semester to create a final capstone piece. This image is a result of brainstorming done by Team 9 based on previous image experience. The image, or rather collection of images in the movie form, shows the visual and audial dynamics of a standard road flare in various phases from immediately after ignition to extinguishing by suffocation. The movie was filmed of two different road flares to create a wide variety of shots and burn types. After reviewing the clips, this compilation was created to become the final product.

The setup of this flow visualization experiment involved a ten gallon glass fish tank filled with about 3 inches of water and standard road flare fixed to a mount. An HD camcorder mounted on a tripod was used to film the sequence. The flare was ignited and held close to the camera as it burned through its initial stages. Once the flare was hot enough it was held above the surface of the water and then submerged to extinguish it. A diagram of the experimental set up is shown in figure 1.

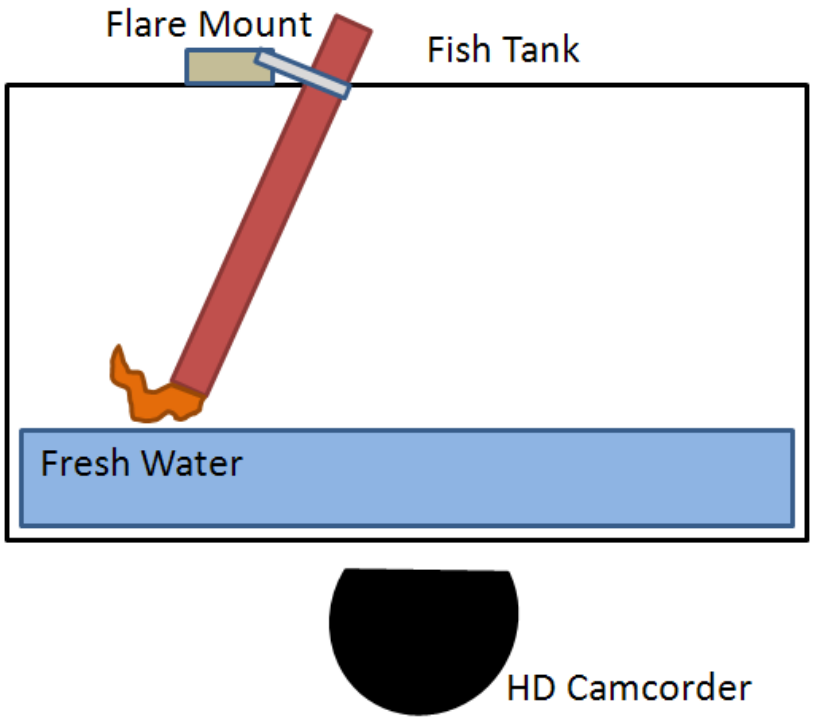

Figure 1: Setup diagram

The flow of interest in this movie is the superheated gas jet being exhausted as the result of a chemical reaction in the flare. The flare ignites at 375 ^{o}F and can continue to burn at up to 3,000 ^{o}F which emits an easily visible bright light[1], hence why they are used in traffic and rescue operations. The flare in this movie burns through three stages; jet flow immediately after ignition, steady burn, and termination by submerging under water.

The flare is ignited by passing an abrasive surface against the flammable outer coating of the flare head. This lighting process is similar to striking a match. Once the surface is ignited it quickly burns through a small region that allows hot gases combusting inside the flare to escape. This rapid discharge of hot gas through a small opening causes a turbulent jet flow. As seen in the movie, this type of flame jet looks and sounds remarkably similar to a rocket engine on a very small scale. The jet widens as it exits and decays showing the spreading of the flame. In this process the gases in the jet also cool and no longer radiate light past two inches of the jet exit. This

is why the jet seems very short. The portion of the jet that is emitting light follows the pattern of a standard experimental turbulent jet as seen in figure 2. The noise that is heard is caused by periodic expansion and contraction of the turbulent fluid which gives rise to a sound wave.[2]

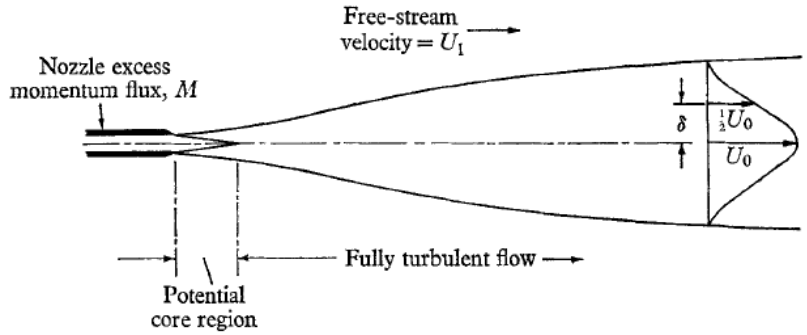

Figure 2: Schematic representation of a jet spreading into a moving airstream[3]

As the initial jet phase wears off, the flare starts burning deeper and burns off the initial volatile outer surface. These lower layers are designed to burn slower and burn evenly as opposed to the initial fast burning point jet. In part of the video the flames start shooting out from the side of the flare and finally burst off the head. As this phase burns it begins dropping small bits of the flare material. This is what is seen falling into the water and causing the deep gurgling sound. The flare bits are very hot and immediately vaporize the water around them when they hit the surface. These bubbles of steam rise up to the surface, and in one case a group of very tiny bubbles can be seen forming into a rising vortex ring.

To extinguish the flame, the entire burning section of the flare is submerged in water. Some flares are capable of burning underwater, but unfortunately the flares used in this experiment either required air or were too old to have this property. The flame can be seen trying last for a little bit as a small glow. The second extinguishing sequence shows a large flare bit being burst off the side. The bubbles rising are both the gas from the flare escaping and steam from the water boiling on contact.

The visualization technique used in this experiment was boundary visualization by light emitting particles. The hot soot from burning Strontium Nitrate radiates a bright light in the at lower color wavelengths generating a red tinted flame. The road flares were 30 Min Red Fusee flares manufactured by Gateway Safety Products based in Trinidad, Colorado. The flares used in this experiment were set to expire in September of 2006, so it was impressive that they still lit after so long. The shots were taken outside at night in nearly complete darkness. Safety protocols such as leather gloves, supervision, and the availability of fire extinguisher were closely followed. A black poster board backdrop was set behind the fish tank to eliminate any distracting elements. No external light sources were used in the filming of this movie.

This is a macro shot movie with the widest portion of the jet at about 1 inch. The head of the flare is approximately 6 inches from the lens of the camcorder. A Canon VIXIA HF S200 8.59 MegaPixel Digital Camcorder was used to take the shot creating an original movie sized at 3264 by 1840 pixels. The shutter speed was set to the maximum value of 2000 frames per second. The clips were edited in Adobe Premiere. The best shots were isolated and edited together. One shot was intentionally left blurry to give a cool distant star feel. The final termination shot is slowed down 50% to clearly show the extinguishing of the flame under water.

This movie nicely demonstrates the processes occurring when a road flare is lit. The sounds that accompany it really enhance the piece and make it enjoyable to watch. There are countless other flow

phenomenons occurring in this piece that haven't been covered in this paper. The original intent was to see an actual road flare flame burning underwater, but unfortunately these road flares were not capable of that. In future experiments, different types of road flares could be used to see if the underwater flame is possible.

REFERENCES:

[1]National Wildlife Coordinating Group. The New Generation Fire Shelter. National Association of State Foresters. NFES 2710. March 2003.

[2]Howe, M. S. "Contributions to the theory of aerodynamic sound, with application to excess jet noise and theory of the flute." Journal of Fluid Mechanics. Vol 71. pp 625-673 (1975)

[3]L. J. S. Bradbury & J. Riley. "The spread of a turbulent plane jet issuing into a parallel moving airstream." Journal of Fluid Mechanics. Vol 27. pp 381-394 (1965)