Flow Visualization
Team Project #2

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The basis for this image was taken from something I had seen online. Oxidation of the tungsten filament from a light bulb lets off a plume of smoke. This plume has a nice laminar flow that goes into turbulence. I wanted to capture all of this on film from beginning to end. I feel like this was accomplished through the series of images attached.

The apparatus used was a simple table lamp and broken 40W light bulbs. Right as I was taking the pictures, I would turn the lamp on, and let the filament burn out. Figure 1 shows the exposed filament and basic set-up. Any table lamp will do. 40W Soft White bulbs from GE were used. Tungsten is known as having the highest melting point of all non-alloy metals, and works well as the resistive element in an incandescent light bulb. However, it is very brittle and oxidizes very quickly. Therefore light bulbs are surrounded in a vacuum to prevent that. I carefully broke the bulbs in order to oxidize the tungsten.

These images were taken in quick succession with approximately 0.29 seconds between each image (this is due to camera constraints). Measuring the height of the plume, and using the time measurement, it is determined that the velocity of the smoke is 0.3018 m/sec. Using this value and the approximating the material properties of the smoke to that of the air, we get a Reynolds number of 1850. We would expect a number greater than 2000 because we are starting to see transition into turbulent flow. However, up to that point the flow is laminar.

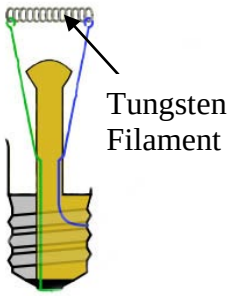

Figure 1: Broken 40W Light Bulb[1]

At the top of the plume in the middle image a toroidal vortex is being formed. This vortex is where the fluid folds back on itself, and then pushes the ring forward or upwards. This ring enlarges and then dissipates. The formation of the toroidal vortex is shown in Figure 2.

[1] http://en.wikipedia.org/wiki/Incandescent_light_bulb

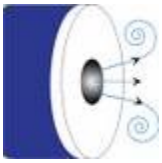

Figure 2: Toroidal Vortex[2]

The smoke was created by rapid oxidation of heated tungsten metal from a light bulb filament. 40W light bulbs were used because they burned off slower than higher wattage bulbs. The room had no significant airflow during shoots, and was as dark as possible. For lighting there were two external 100W incandescent lamps aimed from the lower left and right up at the target. Also a Nikon Speedlight SB-20 was used on the camera. It was in wide mode, had diffused filter, and on full power.

The image covers an area of 26 x 17 cm, and the bulb was 37 cm from the lens. Each image had the exact same settings on the camera with a shutter speed of 1/80th of a second, an aperture value of 4.5, and an ISO speed of 100. A Canon Rebel XSi digital camera with a EF-S18-55mm f/3.5-5.6 IS lens was used. The focal length was set at 33 mm. The original image size for each image is 4272 x 2848 pixels. The final image size is 4272 x 7120 pixels. The photo style set by the camera is neutral. There was no manipulation done in Photoshop other than combining the multiple images into one.

The image shows the overall life cycle of tungsten oxidation. One of the coolest things is the vortex being formed in the middle image. If you look closely you can see the smoke circling back in. This leads to the fourth image, from the left, which has the full ring rising up. It really demonstrates the toroidal vortex being formed by the smoke. The only thing that I believe is lacking is in the fourth and fifth images that they don't show the entirety of the flow. Also by using a high speed camera the flow could be better visualized.

[2] http://en.wikipedia.org/wiki/Incandescent_light_bulb