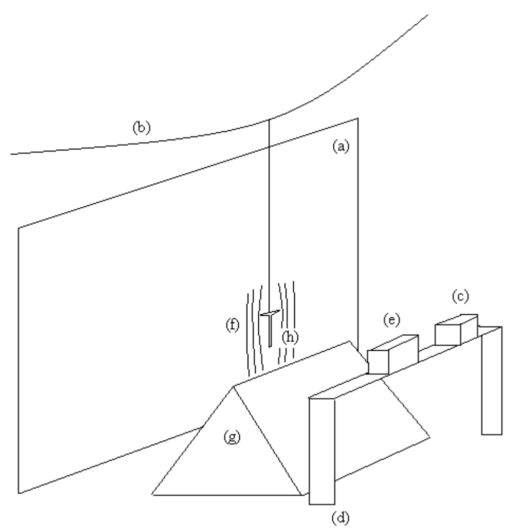
Owen Hnath
351-336
9.25.07
Image Assignment 1: Get Wet

The following report concerns my first individual image assignment: *get wet*. My image concept was to visualize low-velocity air flow around a steel automotive valve. More specifically, I was interested in demonstrating the feasibility of visualizing this specific phenomenon so that I might perform a more advanced study of different face angles and compound valve angles as my final project.

The flow apparatus I created was designed to generate discrete stream lines within the moving fluid. These streamlines were produced in a plane using a plastic cardboard containing an array of rectangular channels measuring 0.125x.200”. A rectangle of this cardboard was cut 4.5” wide by 4” long and inserted vertically into the peak of pyramid (g) (12” tall 14” square base). The 1.65” diameter valve (h) was suspended with its stem .5” above the surface of the cardboard. The valve was suspended using a telescoping magnet from an overhead cable (b), and positioned such that it's symmetry plane was coincident with the plane of streamlines (f). The camera and light source were placed on a rigid table (d) 12” from the valve. The field of view of the camera (e) was parallel to the streamline plane and just below the plane defined by the upper surface of the valve. The light source (c) was positioned at roughly a 35 angle with its focus on the center of the valve face. Finally, the entire apparatus was placed in a darkened garage at night, with non-reflective cloth backdrop (a) 24” behind the pyramid.



Based off video I took of the setup in use, I estimate the average flow velocity at .75~.9 ft/s. Assuming typical properties for atmospheric air at 5,000 ft this would give a Reynolds number of:

$$R_e = \frac{\rho Vl}{\mu} = \frac{2.048E-3(.75)(4.125/12)}{3.637E-7} = 1452$$

This indicates that the flow I am looking is influenced predominantly by inertial forces, and very little by viscous forces. This applies everywhere but the boundary layer along the valve stem and the wake area beyond, where viscous interaction occurs between the flow and the metal.

From our lecture on spatial resolution I know that turbulent flow requires roughly a 5 order of magnitude difference between the minimum and maximum features within the flow. In the case of these images, my minimum feature height was appx .025" and my max at least 1.5." With a camera containing 1712 pixels in the vertical axis and a field of view of 6x4" that leaves me with 10.7 pixels for my smallest feature and 642 for my largest a ratio of only 60. At the same time, with my assumed velocity a particle will travel 1.5" while the camera shutter is open. This would qualify as very poor temporal resolution with the end result being a great deal of unintended motion blur in my images

The flow visualization method I selected was soot from burning paper. The soot provided light scattering particles, and the heat from the fire inside the pyramid provided a relatively homogeneous velocity gradient as the hot air rose out of the pyramid. The light source was a 4.5V Maglite; peak candlepower 22,000 average lumens 76.8, bulb temperature unknown. The light was focused on the valve face at an oblique angle to the streamline plane

Field of view: appx. 6x4"

Distance from object to lens: 12"

Lens focal length: 5.8mm, F-Stop 2.8

Camera used: digital, pixel dimensions 2288x1712, Nikon Coolpix 4100, resolution 300x300".

Exposure: aperture value 3.0, shutter speed (exposure time) 1/6 sec, ISO rating 50, exposure bias value 0.0

Photoshop processing: Images were cropped to show only relevant information, and grouped to show timeseries of decaying velocity.

This image series shows boundary layer formation, pressure gradients resultant from areas of differing fluid velocities, and areas of localized vorticity. It does not show any of these phenomena particularly well. I shot video of several of my experiments which clearly reveal the physics involved, but was unable to reproduce those dynamic motions in a timeseries. Lighting was my primary issue in this image series. I experimented with several sources of varying color, direction and intensity but found none that would produce all the image aspects I wanted. I am very pleased with the soot streamlines I was able to generate, and believe that they could be a useful technique with improved lighting. If I was to pursue this idea further, my first objective would be to obtain a source of light that would better illuminate the soot, without lighting the surrounding apparatus allowing me to increase my shutter speed and reduce motion blur. The second objective would be to create an environment with less ambient air currents since my visualization method was easily influenced by external airflow.