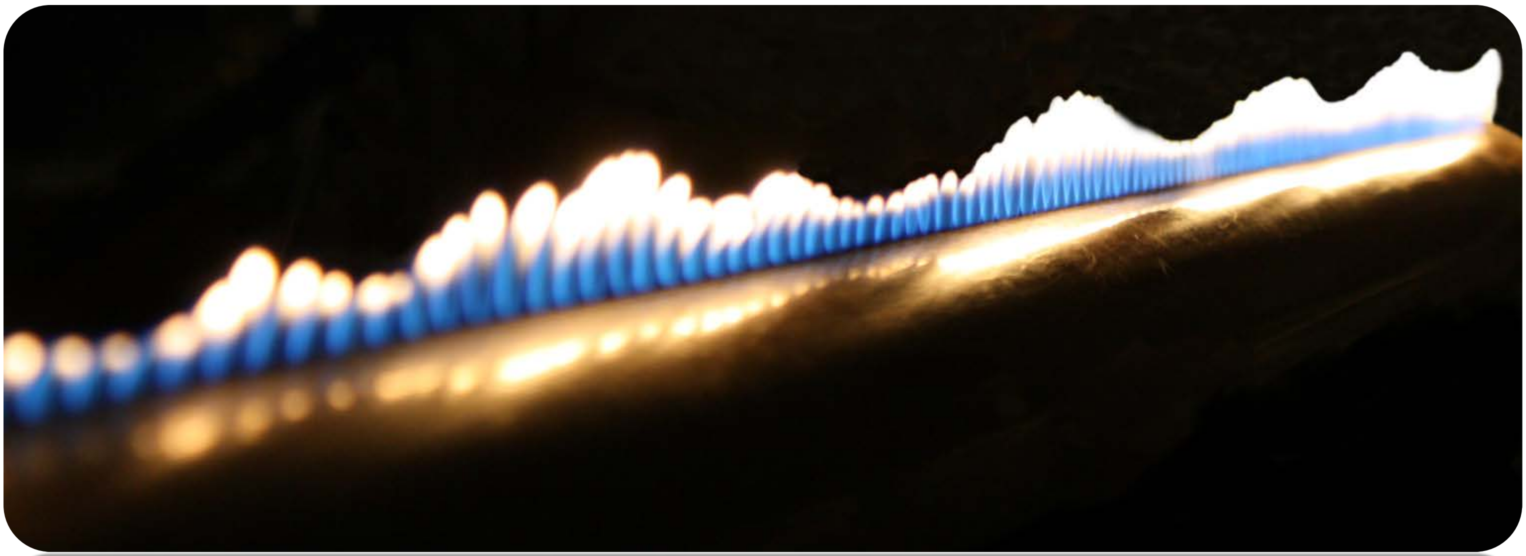
Flow Visualization
MCEN 4151

Spring 2013



Team Project III

Jeremy Parsons

University of Colorado at Boulder

Introduction:

The image shown on the previous page is a one of the images taken by Team 3 during our Ruben's Tube imaging experimentation. Credit for the original photograph must be shared with Daniel Ming, Anna Gilgur and Jonathan Fritts. A special thank must be given to Michael Thomason and the physics department for their aid and resources in the experimentation setup. Each group member participated in the experimentation process aided in the capture of the final images presented. The purpose of this image is to demonstrate to the viewer how the Ruben's Tube experiment is a unique way of understanding the science behind converting compressional sound waves into a longitudinal output as well as aiding in understanding the relationship between frequency and wavelength in sound waves. The intent of our images was to capture this unique phenomenon in order to convey the physics of the waves in an interesting and aesthetically appealing manner by using the fire.

Reuben's Tube Physics:

The premise behind the Ruben's Tube is that it serves as a unique means of explaining wave phenomena in a visual manner. We used a waveform generator to create the initial sinusoidal waves that were fed into the amplifier/speaker system. This was a convenient means of producing the first longitudinal waves because it added a degree of control to the experiment. The waveform generator allowed us to change the amplitude, frequency and waveform freely without the use of any analog components. The signal went through an amplifier and into the speaker where it is converted in to a compressional, sound wave. Since the time averaged pressure is equal at all points of the tube, it is not straightforward to explain the different flame heights. The flame height is proportional to the gas flow as shown in the figure. Based on Bernoulli's Principle, the gas flow is proportional to the square root of the pressure difference between the inside and outside of the tube [1]. Based on this argument, the flame height depends non-linearly on the local, time-dependent pressure. The time average of the flow is reduced at the points with oscillating pressure and thus flames are lower. This is illustrated in Figure 1 to the right. Thus the end result is that one can view the steady-state nodes and antinodes of the specific wavelength in question. Even more uniquely the wavelength can be measured in between one's fingers by measuring distance between the nodes at the crests of the flames. By serving as means of physical means of manipulating the waveforms

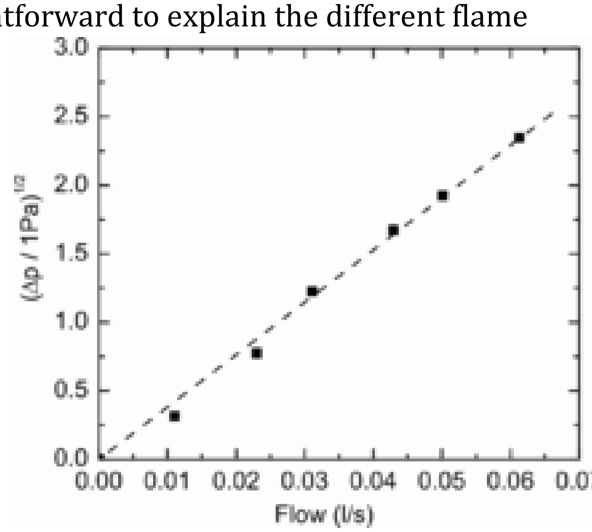


Figure 1 - Linear trend between flow and square root of pressure difference

the Ruben's Tube serves as a very functional learning tool aiding in the instruction of wave physics as well as creating very appealing images.

Image:

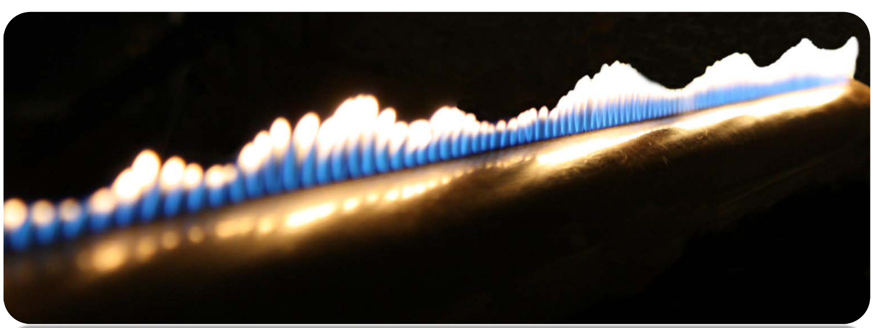
This image was taken on April 17, 2013 inside the Physics Department's module laboratory. The setup consisted of the tube itself, which was seven feet long, sitting on a slate counter in the lab. The lighting and background for this particular setup proved difficult as isolating just the flames was difficult so we had to use particular angles and soft lighting to isolate the flames and keep as much in focus as possible. I elected to use this particular image because I found that I particularly enjoyed how this clearly shows the profile of the wave. I also liked how the image is focused most sharply in the middle while becoming soft focused on the periphery of the image. Overall this image showed the intent of the experiment the best while really capturing the beauty of the flames.

Photographic Technique:

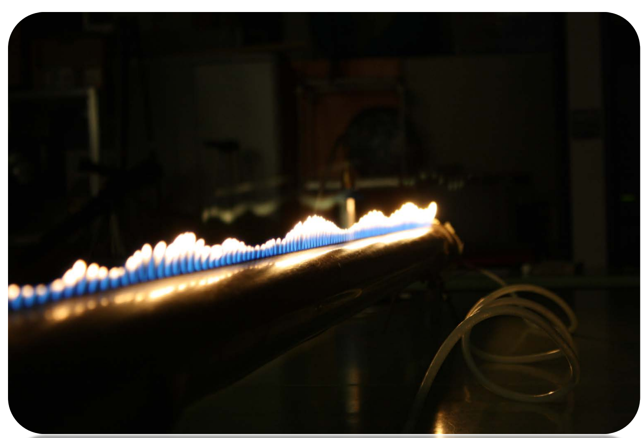
The following is the settings used to capture the image.

- Camera: Cannon Rebel XT Digital
- Lens: Cannon 150mm Macroscopic Lens
- Image size: Original – 3456x2304 pixels and Edited – 2670x960 pixels
- Exposure Settings: ISO-400, F/-4.5
- Exposure Time – 1/120 second
- Editing- Cropping, color balance and foreground editing were done in Photoshop CS6

Original Image



Edited Image



The original and edited images are shown above. The edited image was cropped in all four directions to isolate the flame on the top surface of the tube. The clone stamp tool and spot healing tool were used to remove the distracting elements in the foreground that could not be removed simply via cropping the image. There was no color or contrast editing preformed on the final image, all the colors and contrast are innate.

Commentary:

I enjoy this image very much because it really demonstrates the unique physical behavior of the waves by presenting it in such a beautiful manner. The Ruben's Tube experiment was on our mind the entire semester but proved challenging so finally attain a setup that was functional yet safe enough to execute comfortably. In this regard I must once again offer thank to Michael Thomason and the Physics Department for their cooperation in the process of making our final experiment a real success.

Citations:

1) . N.p.. Web. 30 Apr 2013. <http://en.wikipedia.org/wiki/Rubens'_tube>.