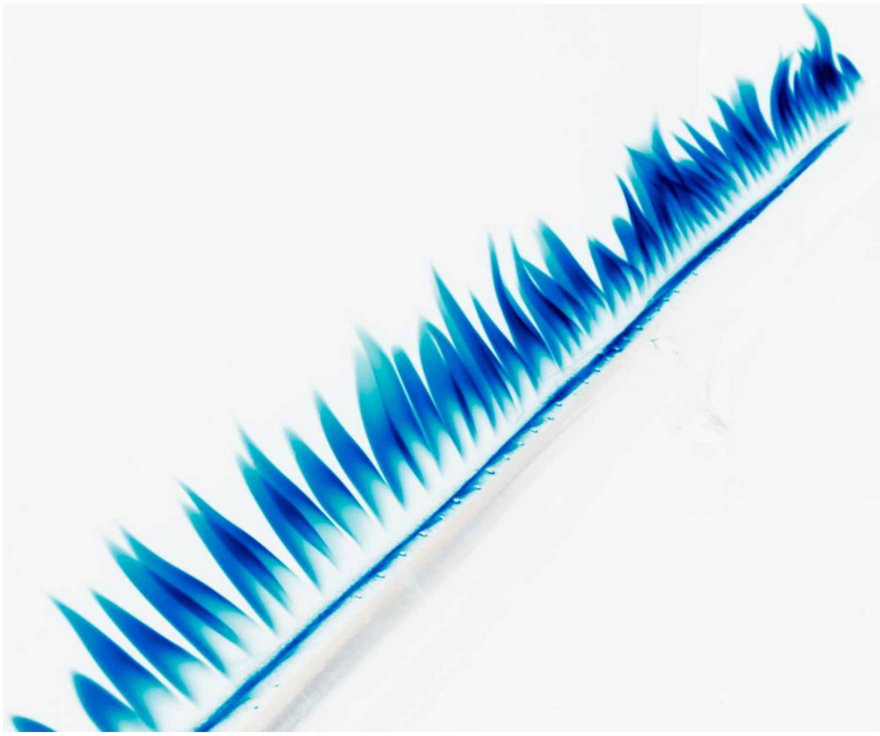
Rocking Fire



Team First Report

MCEN 5151

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Aaron Zetley

Introduction:

In the final image, I worked to present the Ruben's tube ability to capture the wave motion of sound in an intriguing way. Initially, I planned to submit a recording of the flames in slow motion but the DSLR used did not have a high enough audio and/or video frame rate to function effectively for slow motion video. The final image submitted instead shows a visually attractive perspective of the flow apparatus at a singular moment. Using gifs below the final image, the full interaction of the of the flames and sound waves played into the tube can be seen overtime. During this project, I was particularly interested in capturing the flames reaction to the movements of music especially profound powerful sounds like guitar riffs. The final image with its stark contrast and inverted colors reveal the differences in the densities of the flames at different locations along their heights along with each flames' interactions with resonating sounds within the tube, forming their many shapes and curls.

Fluid Apparatus and Flow Description:

The image was captured using a homemade Ruben's tube using material obtained from home depot and built based on the directions of a manual found on online by joshtheengineer (2). In the Rubens tube use for the experiment approximately 100 one sixteenth holes were drilled into the pipe each ¾ in from each other in a straight line along the pipe. The Rubens tube was invented by a German physicist in 1905 named Heinrich Rubens who worked significantly on the formation of quantum theory. (3) The device was intended to demonstrate resonance and standing wave formation through the differences in pressure across the tube.

As a flammable fluid (in this case propane) flows into the tube, a pressure differential is created between the inside the tube and the atmospheric pressure outside. With the pressure differential formed the propane flows evenly out of each small hole in the tube forming with no outside interference or sound a straight line of individual flames. As a sound is played through the tube, the waves form create differences in pressures along each hole forming antinodes and nodes that make up a standing wave. (4) That standing wave's length can then be measured to determine the frequency of sound played through the tube. (4) In the case of the rock song played through the Ruben's tube the dynamic sound prevented the tube from forming a singular wave. Standing waves earlier in testing were found when my voice was played into the tube as can be seen in the image below.

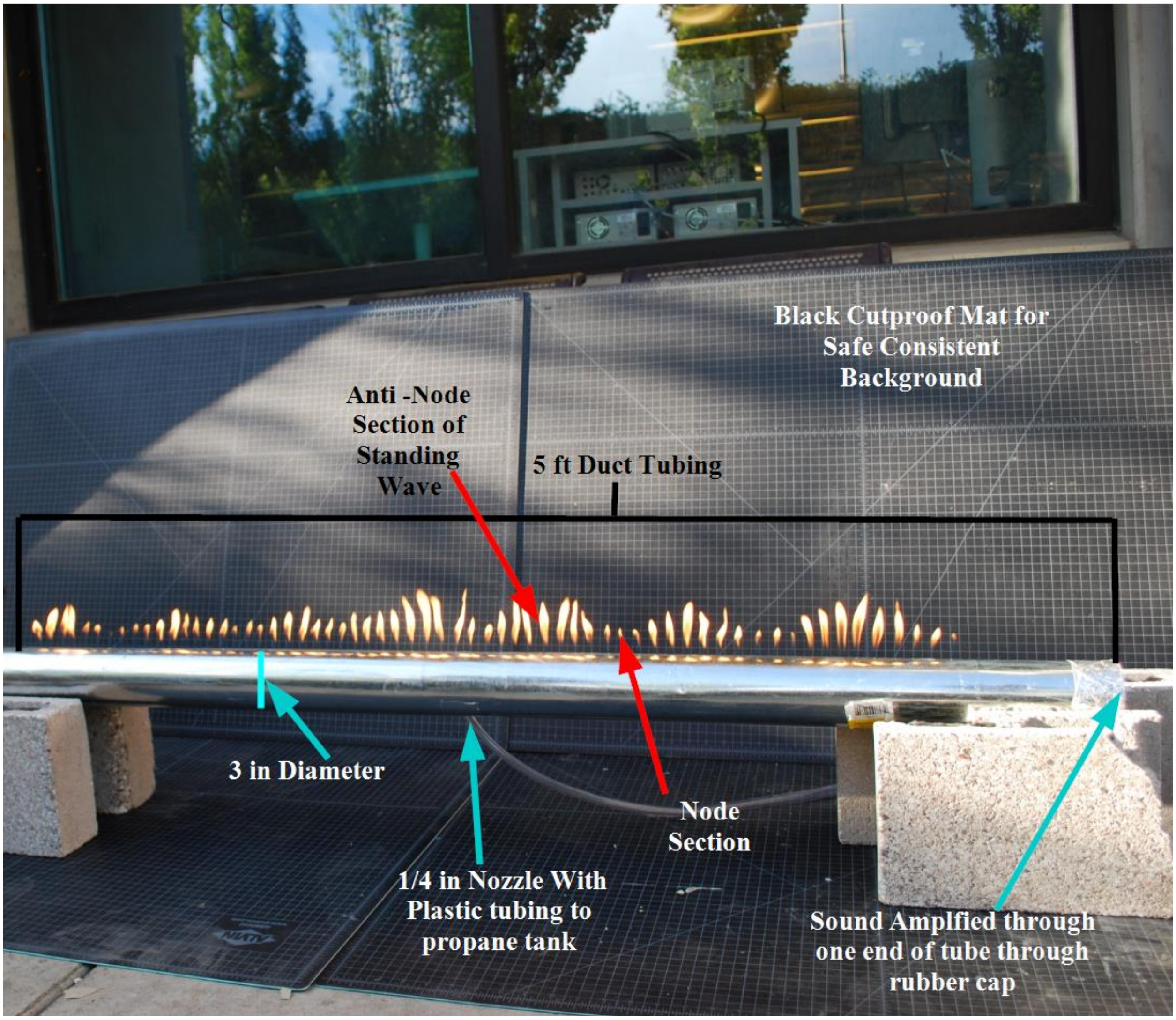

Image of setup taken by teammate Robbie Giannella

Flow Calculation:

Calculating Wave Frequency:

Wave Frequency can be calculated by way of the equation below:

$$f = \frac{v}{\lambda}$$

In this equation frequency (f) can be calculated by the relationship of the wavelength (λ) of a sound in propane and the speed of sound in propane. The wave length in the image was approximated by pixel size to be 0.242 meters. With the speed of sound in propane at room temperature to be 258 m/s we get the following wavelength.

$$f = \frac{258\, m/s}{0.242\, m} = 1066\, Hz$$

Looking at the actual flow phenomenon of the tube we can calculate the Reynolds number of the fluid flow through the small holes in the tubes through the Reynolds equation below:

$$Re = \frac{\rho\, u\, L}{\mu}$$

In this case ρ is the density of fluid, u the velocity of the fluid through the small holes, L the diameter of the fluid, and μ dynamic viscosity of the fluid. Assuming even flow rate through each hole and with the assumption that the propane remains at a temperature around 20 C, the following values are known: μ dynamic viscosity = 8.02 X10^-6 Pa/s (5), L diameter equals the diameter of hole = 0.0015875 meters squared , ρ density = 1.841 kg/m^3. The velocity of fluid was assumed to be the max flow rate possible out of the a propane gas regulator of 1.5 kg/ h (6). Using the known values for Reynolds equation above the value was converted to meters per second through the small hole as so:

$$1.5\,\frac{kg}{h} * \frac{1}{3} = 0.5\,\frac{kg}{h} * \frac{1}{1.81}\frac{m^3}{kg} * \frac{h}{3600\ s} * \frac{1}{0.0015875\ m^2} = 0.145\,\frac{m}{s}$$

With the following all the individual values known the Reynolds number was determine as

$$Re = \frac{1.841\,\frac{kg}{m^3} * 0.145\,\frac{m}{s} * 0.0015875\ m^2}{8.02 * 10^{-6}\,\frac{Pa}{s}} = 52.84$$

As the Reynolds number is below 2000 the flow is laminar as can be visually seen in the final image above.

Visual Technique

This image was taken using a Ruben’s Tube Apparatus set up outside of the ITL Laboratory. The apparatus was built, assembled, and tested by Team 6. The Rubens tube was built using common parts from home depot and its fuel sourced provided by a regulated propane gas tank. The Reubens Tube was setup on two concrete blocks to keep the tube stable and remain away from any flammable material. Black background mats where place below and behind the tube to insure a consistent black background. To gain an understanding of effect of sound waves through the Ruben’s tube I took both video and photographs to capture the flame movement at different frequencies and signals. I used my Nikon d5500 DSLR camera set on a tripod to ensure balance during recording video and set a small aperture f16 to get a consistent background. When taking this image, I found this shooting angle above the Tube an intriguing view of the tube. Photographed about 2 feet the tube the viewer can see the full length of the flame along with clear movement of all the individual flames. This image was taken while a rock song (Chaghaybou) by the Tuareg North African band Tinariwen was being played through a large speaker.

Original Photo

Photographic Technique:

The image was taken at a distinct angle so the field of view of the image is slightly contorted. I would think the image was taken within a field of view of approximately 3 feet by 4. The Rubens tube itself is approximately 5 feet long with a diameter of 3 inches. The imaged was captured with a Nikon D5500 DSLR Camera (Digital) with a 18-140mm lens. The exposure time was 1/125 sec with a f stop of f/16.0 and a focal length of 45 mm. The image was taken around 2 feet away from the tube to avoid burning the camera and the two insure sharpness in full field of view of the image. To darken the image and insure the highest clarity the image was shot at ISO 100. The image with a pixel size of 6000 X 4000 was not cropped but edited both in lightroom and photoshop. In lightroom slight changes in exposure, contrast, sharpness, and levels were performed in lightroom. The edits were performed to better view the overall color and sharpness of the flame helping the viewer to understand the flame movement of instant photographed. In photoshop the image's colors were inverted to give an intriguing and more unique perspective of the flame movement. These in actions were done in both lightroom and photoshop using the original Raw type file image. On the flowvis website submission two gifs were also added to give the user a better understanding of the true movement of the flame over time. These gifs were generated from videos taken by the DSLR.

Self Reflection and Future Projects

I really enjoyed working the Rubens tube and seeing the interaction of resonance, frequency and tone in different sound outputs effect the flame outputs. I enjoyed how the image visually captured profound sounds that we could not see otherwise. I would like to thank my team members Robbie Giannela, Max Armstrong, Evan Blake, and Byron Pullatasig for their assistance on this project. I am curious to learn more about how sounds like my voice vs sounds like a electric guitar had dynamically different outputs and why my voice could produce a clear sound wave vs the single pluck of a guitar. If the experiment was conducted again I would like to shot the Ruben's tube with a camera capable of a much faster frame rate to capture clear video of the flames in slow motion. I would also like to see if certain sound how different sound frequencies on the Ruben's tube flame levels were visually different than the waves created by the inputted sound waves and how the shape, distance, and material affected the flames' shape.

References:

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