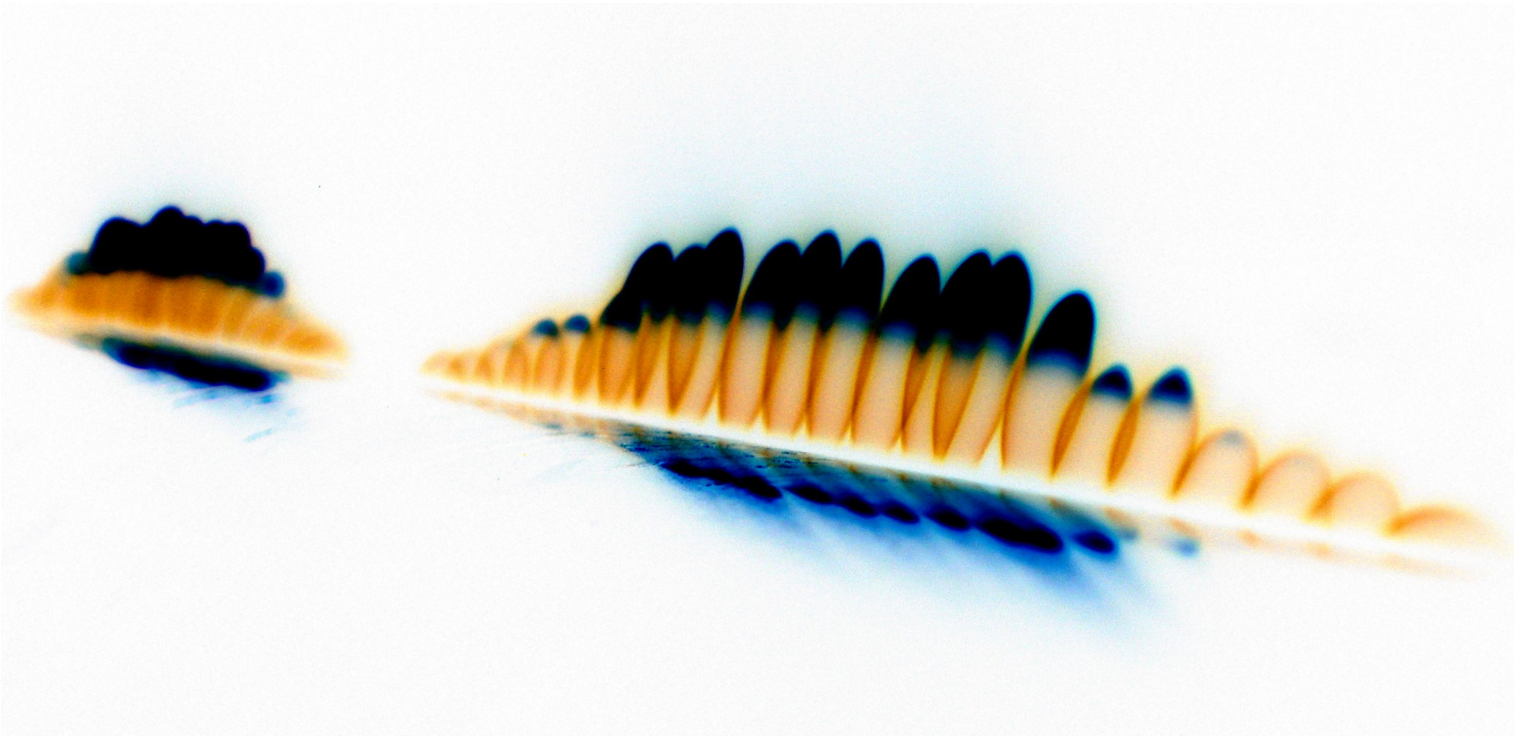
TEAM IMAGE # 3



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For the third and final team photo assignment, my group (Team #2) decided to attempt the construction and operation of a “Ruben Tube”. This idea came from a couple different team members after observing the behavior of a Ruben Tube on an online video on *YouTube.com*.
A Ruben Tube is an impressive way to visualize the effects of sound pressure waves on the flow of a combustible gas and the corresponding flame height out of small orifices drilled into a section of pipe. A simplified diagram of a Rubens Tube is shown in Figure 1.

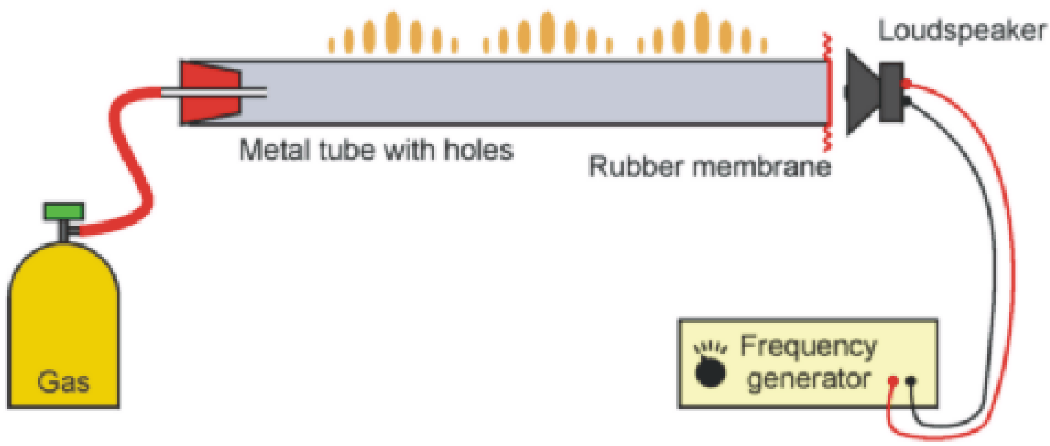

Figure 1: Diagram of the basic setup of a Rubens Tube
(Image from <http://www.fysikbasen.dk/English.php?page=Vis>)

After some initial research, the team was convinced we could build a version of this experiment without having to spend much money. The materials which our team used build our inexpensive version of a Ruben’s Tube are listed below in Figure 2. There are various substitutions and variations of the particular materials used which can be used depending on the availability of materials and funding.

Equipment Name	Description / Use
20 lb Propane Tank	Fuel supply
Propane Regulator and Tubing (gas grill style)	Fuel transfer into main tube
4 inch diameter X 60 inch Copper Pipe	Main pipe section with vent holes
Rubber Swim Cap	Rubber membrane/diaphragm to react with speaker
4 inch diameter speaker	Speaker to generate sound pressure waves
Amplifier	Frequency generator to provide frequencies or music

Figure 2: Table of equipment used by team to construct Rubens Tube

Our version of the Rubens Tube design incorporated the use of a 20 lb. tank of propane typically used for a gas grill, along with the fuel tube and regulator that come with a gas grill setup. For the main ‘tube’ we utilized a 60 inch (5 ft) long section of 4 inch diameter copper pipe. A drill with a 1/16th inch drill bit was used to create a straight line of small holes down the majority of the length of the pipe section. The holes were drilled every ½ inch, giving us around 100 holes for the propane to vent out of, and possible flame locations once the Ruben Tube was lit.

The team met during the evening (after dark to ensure the best flame visualization) so that we could assemble and test the Rubens Tube outdoors such that we were certain to have adequate air circulation. **We would not suggest testing a Rubens Tube design indoors, as the threat of accidental combustion of household materials, as well as the toxic buildup of Carbon Monoxide and Carbon Dioxide would be a threat to the safety of persons and animals present in a the residence.** After assembling all of the components, we opened the valve on the propane tank, and waited for the tube to fill. Surprisingly, it took our main tube around 15 minutes in order to fill with a large enough volume of propane fuel that it would stream out of the 1/16th inch holes drilled in the copper pipe. After a number of failed attempts to get the venting gas to ignite, we finally were able to light the entire length of the Ruben Tube. Initially, the flame height was very small. Once we turned on the amplifier and applied various sound frequencies to the speaker, the flames characteristics changed dramatically. Starting with only a single frequency being transmitted to the speaker at a time, we were able to obtain and observe several representations of the classic “standing wave”, with two periods visible in both my original and submitted images, shown on the cover page and page 4 respectively. A standing wave is named as such due to its constant position. In the case of our Ruben Tube, the standing wave is caused by two opposing waves combining into one standing wave, as shown in Figure 3.

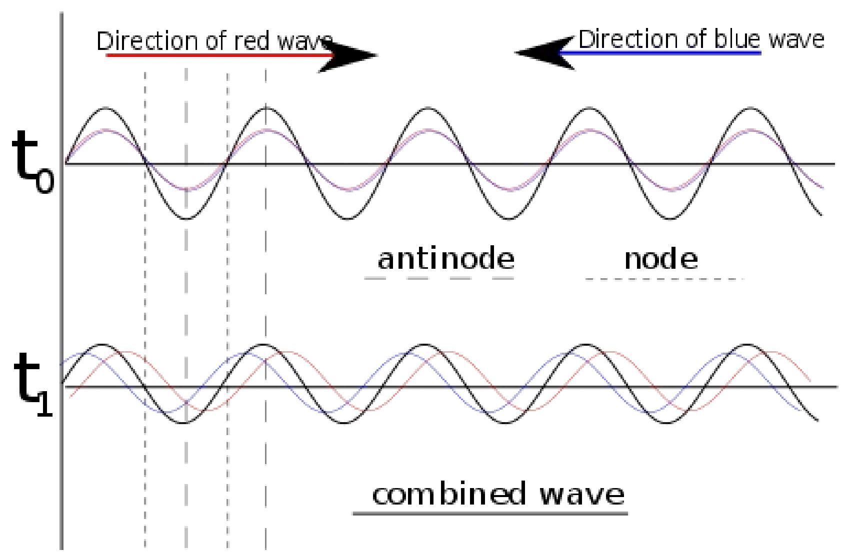

Figure 3: Two opposing waves combine to form a standing wave - in this case, the waves are sound waves generated by the speaker at one end of the Ruben Tube.
(Image from <http://en.wikipedia.org/wiki/File:Standingwaves.svg>)

My understanding is that the standing wave causes areas of localized high and low pressures within the main tube, such that the areas of local low pressure are formed at the troughs of the waves, sucking in air through the holes present in the trough region of the wave. The areas of local high pressure force the fuel-air mixture out of the holes present in the peak region of the wave, thus resulting in greater flame height corresponding to the height of the periodic wave.

One of the facets of the original image that I wanted to really emphasize in my edited image was the differences in vertical flame color. The bottom of the flame, shown as blue in the original image and as orange in the edited version, is the cleanest burning section of the flames, also known as the 'pre-mixed combustion' region. In this portion of the flame, the propane fuel and oxygen present in the air have mixed in the correct proportions to provide a very-nearly complete combustion of all of the fuel-air mixture. The top section of the flames, appearing as orange in the original image and as blue in the edited version, represent a region where the fuel-air mixture is no longer in the optimum proportions to provide clean combustion of the gases. This results in blackbody emission of soot (carbon) particles that were not completely consumed in the combustion reaction.

This image was captured outdoors at night on April 12, 2011 at 7:59pm MST, and is the third image in a sequential set of 3 photographs taken in succession to capture different stages of the initial test of the Ruben Tube. The approximate field of view of the original image is 2 feet across by 1 foot high, with a distance from lens to the center standing wave of approximately 2 feet. The digital camera used is a Canon PowerShot SD 500, with an F-stop of f/4.9, image focal length of 23.1 mm, and shutter speed of 1/13 sec. The flash was not needed to provide lighting, as the light provided by the flames was adequate for acceptable photographic conditions. The original image's dimensions are 3072 x 2304 pixels, vs. the edited image's size of 2428 x 1180 pixels. Extensive editing was performed using Adobe Photoshop CS5, and included cropping, color inversion using the "Negative Preset" and curve adjustment of this setting within the Photoshop software. The original image is shown as Figure 4 on page 4.

I was generally pleased with the original image that I captured, but I fell in love with the edited interpretation that I managed to obtain using Adobe Photoshop. When I initially viewed the original set of images captured of the flame behavior, I was not too optimistic of the final quality that I would be able to obtain during the editing process. However, much to my delight, my use of the color inversion (negative) tool in Photoshop brought out texture, color, and reflective lighting details on the surface of the copper pipe section that did not immediately catch my attention upon my initial review of the image set. As my final image for this Flow Visualization course, I am very pleased with the uniqueness of the device that our team built and the resulting imagery that I was able to capture from the Ruben Tube apparatus.

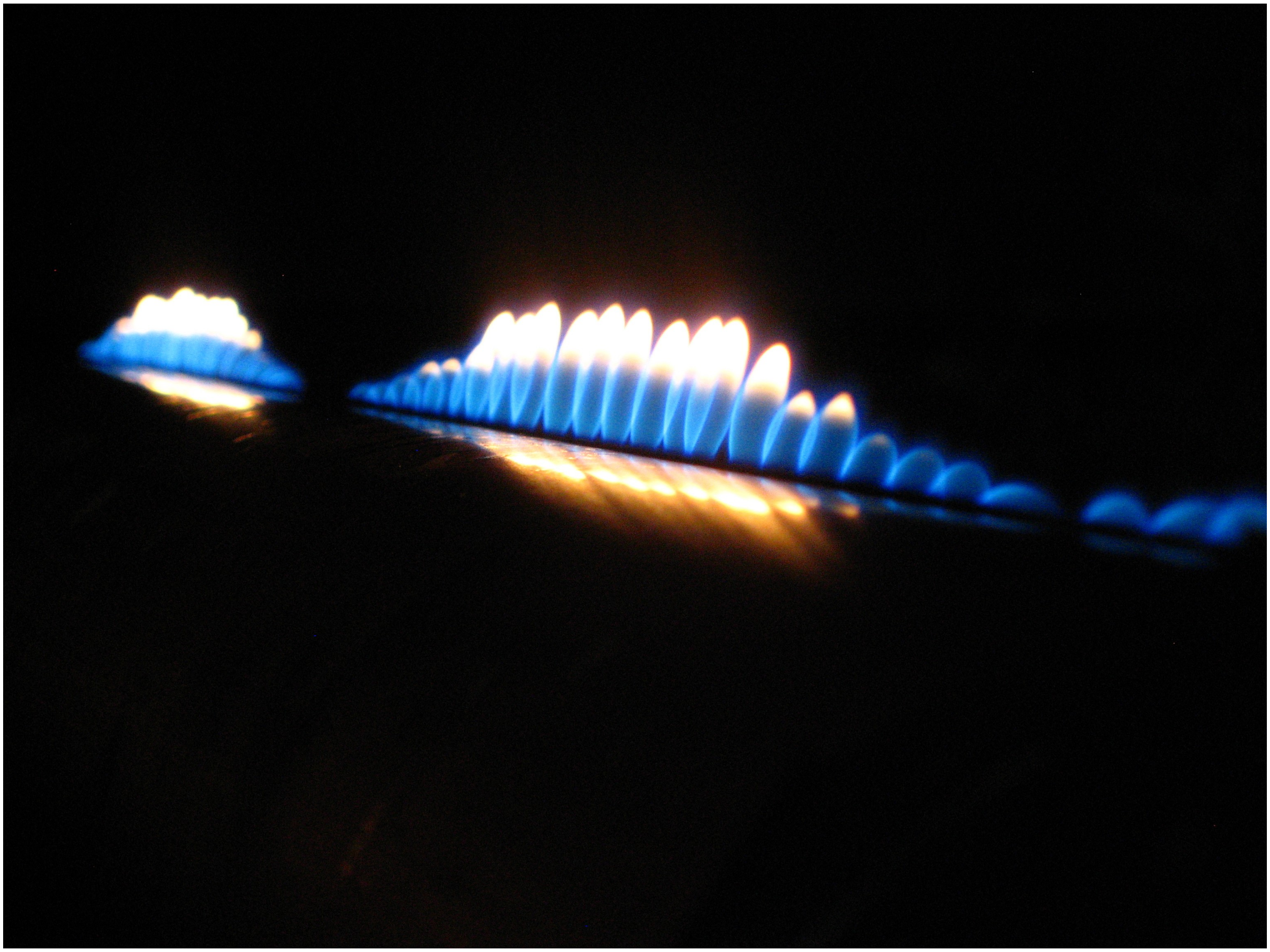

Figure 4: Original, unedited image taken on 12 Apr 2011.

References

"Combustion Research - Premixed Combustion." *University of Queensland - Australia; School of Mechanical and Mining Engineering*. Web. 4 May 2011. <http://www.mech.uq.edu.au/combustion/premixed.htm>.

Hertzberg, Jean. "Get Wet Image Critique." Flow Visualization Class Lecture. University of Colorado at Boulder, Boulder, CO. 4 Feb. 2011. Lecture.

"The Ruben Flame Tube." *FYSIKbasen*. 22 Sept. 2008. Web. 06 May 2011. <http://www.fysikbasen.dk/English.php?page=Vis>.