Design, Characterization and Testing of a Custom Air Horn

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Abstract

Construction and testing of an air horn can provide educational insight into how certain design decisions can influence resulting acoustic properties. Using readily available materials such as PVC pipe and tin sheeting, one can construct an air horn capable of producing sound waves in the 100+ decibel range and frequencies between 150 and 400 Hz. Upon completion of a prototype, many experimental opportunities are available. The degradation of sound intensity over a distance can be tested by use of a sound level meter. Due to the unidirectional behavior of the sound waves from the horn, samples from different distances and angles from the source can provide more understanding of how sound propagates as a wave in an open environment, as opposed to it being a simple directional wave.

Theory of Operation

The sound produced by an air horn is caused by a rapid pressure change in the main chamber. Compressed air enters through the inlet, but is initially contained within the main chamber. The pressure is applied to all of the surfaces within the chamber (Figure 1), however the external walls of the main body are much thicker and can withstand much higher pressures than that of the diaphragm. This results in the diaphragm flexing away from the chamber and allowing the pressurized air to flow into the outlet pipe in its attempt to reach equilibrium (Figure 2). When this occurs, the pressure in the main chamber is reduced back to its original state and the diaphragm snaps back to its original position as well, resulting in a loud "slap" against the end of the outlet pipe. This process repeats itself hundreds of times per second, resulting in what seems like a pure tone from the horn.

Upon completion of the testing, changes to the initial construction design can be implemented to investigate the relationship between the new model's performance and the prototype's. The air horn provides many opportunities for experimentation and testing. For example, frequencies and sound intensity can be altered by making design adjustments such as: diaphragm size, diaphragm material, housing material, bell size, nozzle length, etc. With a better understanding of the inner workings of these sound sources, one could use this design as a blueprint to expand the concept to either much larger or much lower frequency ranges which have applications in many different fields of study.

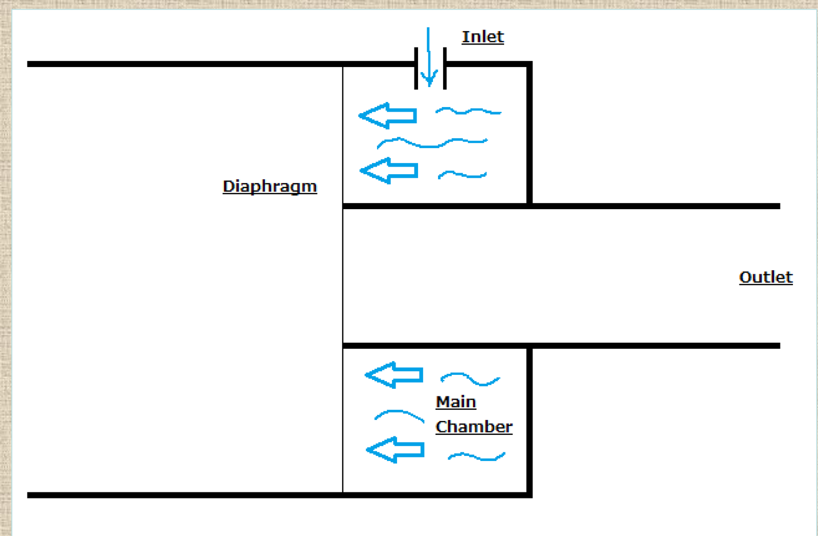


Figure 1

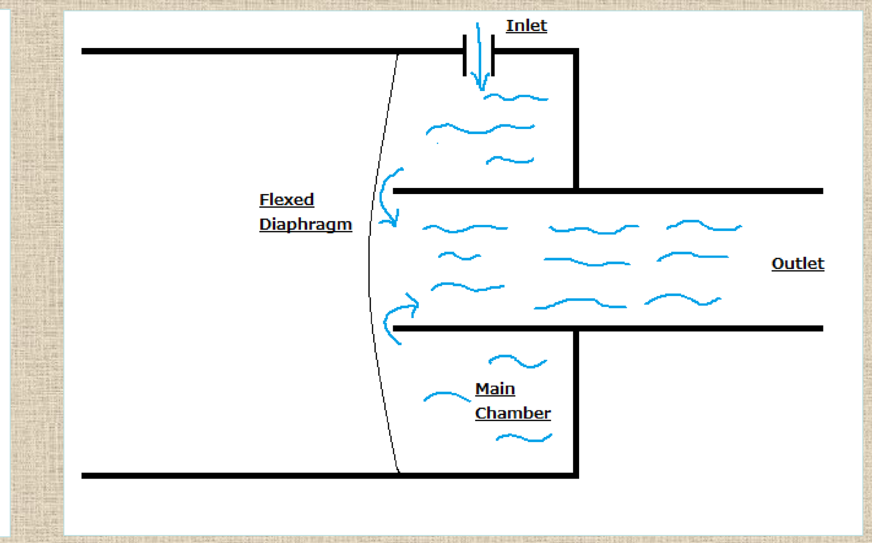
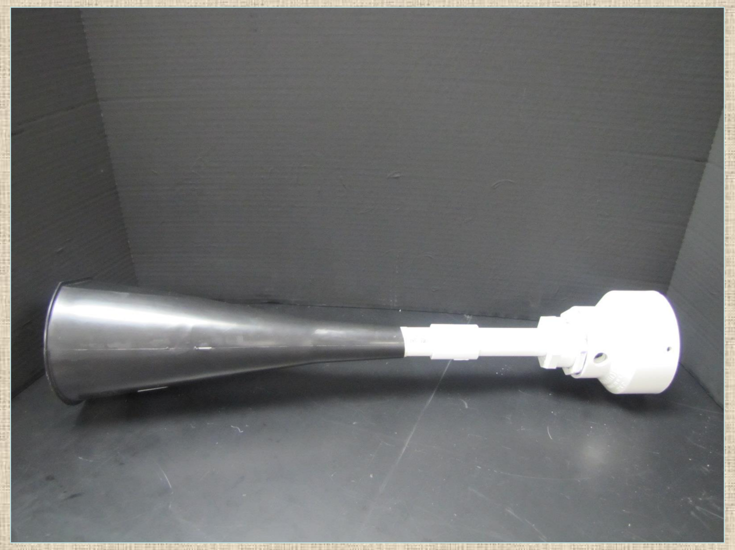


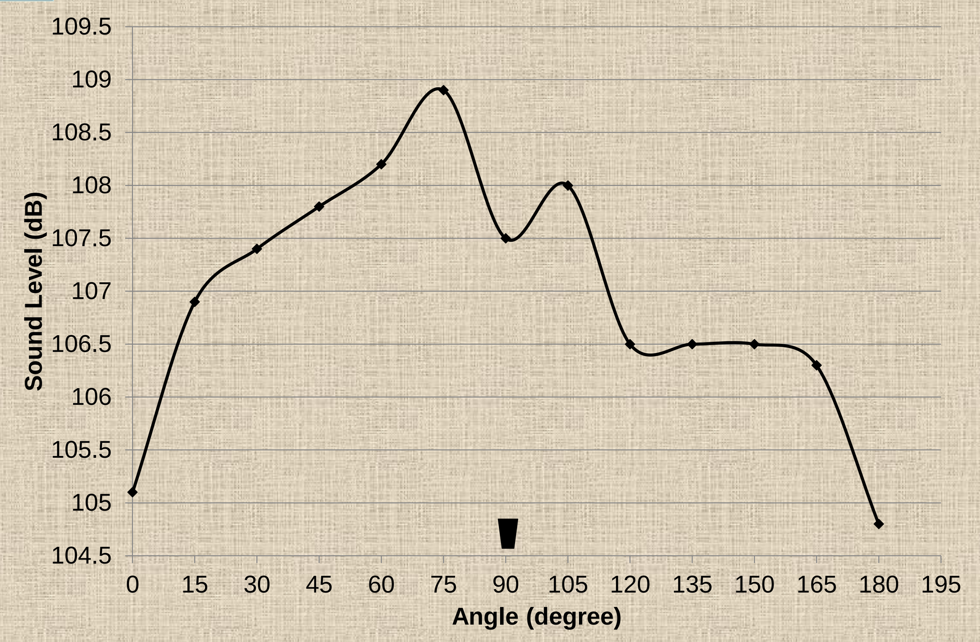
Figure 2

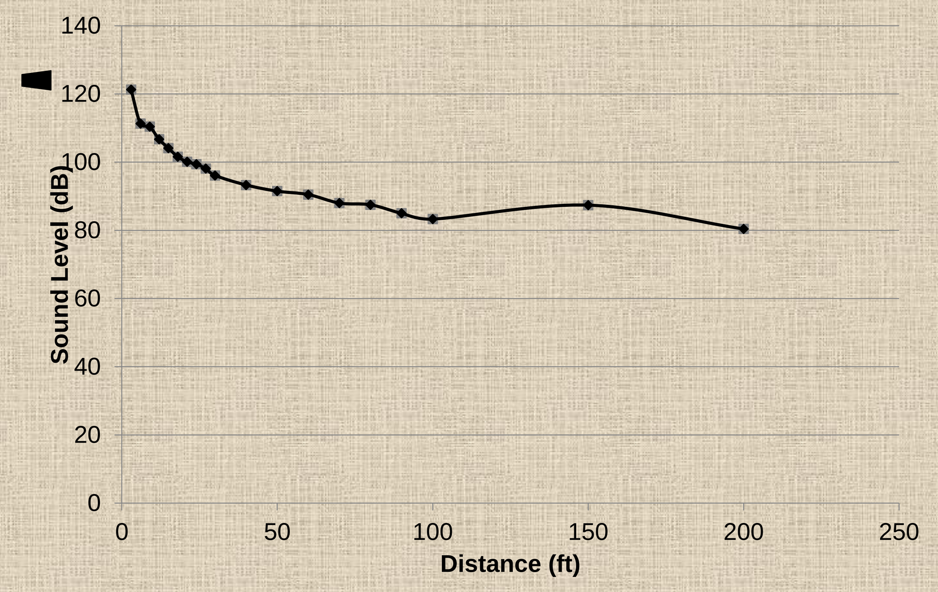
First Prototype (v1.0)



The first prototype was built with a PVC frame with a design found online.[1] This gave us a cheap, reliable starting point to work from. We could analyze exactly how the sound was produced due to pressure changes within the chamber and how the material and thickness of the diaphragm had potential to alter sound quality.

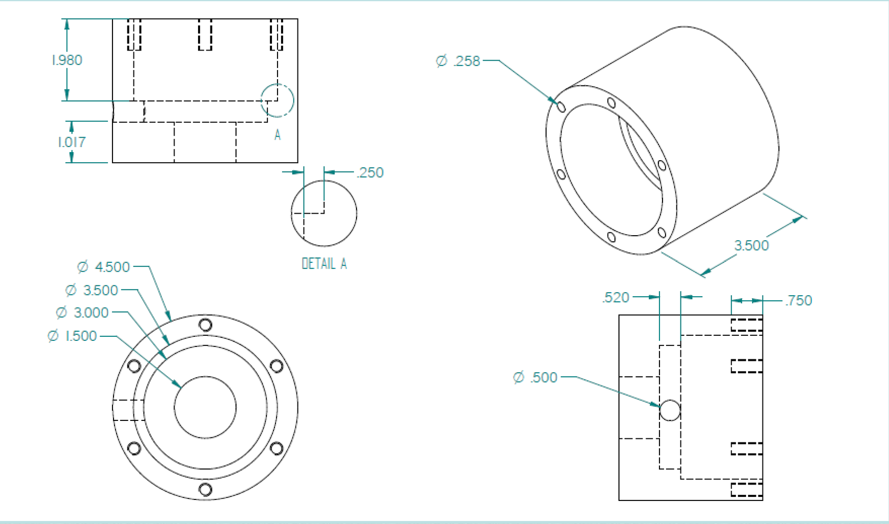
The change in sound level in relation to the angle to the source can be seen to the right. This test was performed at a controlled distance from the horn with 90 degrees representing in line with the horn. The asymmetrical nature of the graph comes from the bell not being a perfect circle.





The graph on the left shows a drop in the sound level as the microphone gets increasingly farther from the source. The leveling off of the sound level most likely due to the sound waves reflecting off of the hard, flat ground and being picked up by the microphone.

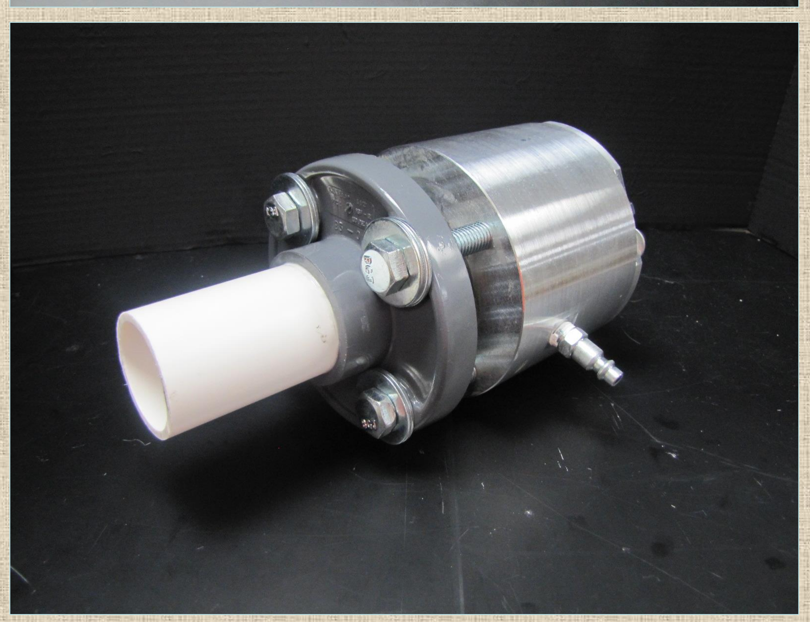
Design and Manufacturing



To facilitate all of the variable tests we wanted to perform, we needed to completely redesign and rebuild the horn from the ground up. We used the Solid Edge ST4 cad program to facilitate the design process. This gave us the ability to dynamically change the specifications as either design problems arose or we decided to add/remove an adjustable variable. We decided on an aluminum main body for a solid build that could support both the air pressure and the stress of constant handling and transportation.

Second Prototype (v2.0)

After many weeks of design and many more in the metal shop creating it, the new prototype was complete. This version gives us the ability to change and test many different variables that we could not with the other one. The ability to switch out and replace the diaphragm freely gives us many more widths, materials, and combinations thereof to test. The new pressure plate will give us a way to quantitatively monitor the pressure on the diaphragm during all of the tests, helping to assure the data is a reliable and accurate as possible. The four bolts running through the flange near the outlet pipe not only provide us with measureable pressure on the diaphragm, but also a means to adjust the pressure independently on the four cardinal sides of the outlet pipe. This assures that the pipe is flush evenly with the diaphragm and there is no small opening through which the air can escape, resulting in a failure to produce the desired sound.



This design is currently being tested with both an aluminum and polycarbonate diaphragm with an aim to identify the characteristics of the resulting sound from each and how they differ. From there we will experiment with different widths and pressure to determine the optimum combination to produce a clear tone that can be easily analyzed.

Reference

1. "Dozerboy" Miller for the initial design
   - http://www.ebay.com/itm/Train-Locomotive-Railroad-PVC-Air-Horn-Builders-Booklet30784746695?pt=LH_DefaultDomain_0&hash=item1e7360dcc7

Acknowledgments

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