# Passive Noise Control in Prenatal Incubators

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**Abstract**

Incubators in the NICU are known to produce high Sound Pressure Levels (SPL) that can have detrimental effects on infants. Due to certain machine requirements such as the ventilator pump, fan and environmental noise, the sound level that is perceived by the developing newborn can cause both short and long term hearing loss as well as psychological damage. To help eliminate these effects on premature babies, a modern incubator was used with replicated sound levels from actual equipment and analyzed. To help reduce noise levels, a variety of sound absorbing materials covered in sound transparent fabric used as the baby mattress, were tested along with variations in the experimental set up. Microphones were set up both inside and outside the incubator to allow for maximum coverage of sound. The most successful runs at reducing SPL were used as the main focus for further/additional research. By taking into account all noise contributors to the inside of the incubator, these machines will be more sufficiently designed to allow for a quieter environment for the developing infants.

## 1.) Introduction

Infants in the neonatal intensive care unit are constantly surrounded by high SPLs. Sources of these sounds can be due to the ventilator pump, the fan for the incubator and additional outside and background noises. There are guidelines stating that a pressure level above 45 dBA can be harmful to the baby's ears and can affect their growth and development. The main goal and purpose of this project is to understand how noise is produced, decide how noise reduction can be accomplished, and finally, to apply these new passive noise treatments to incubators that will in the end, minimize the sound that the baby will hear.

The structure of the project is as follows:

- Measure and analyze SPL from Intensive Care Unit
- Investigate and experiment with how foams affect sound perceived at the baby's ears

## 2.) Incubator Noise Study *In Situ*

The hospital data was collected from the Neonatal Intensive Care Unit at the Children's Hospital of the King's Daughter's in Norfolk, VA. An isolated room that occupied one incubator with all the necessity running equipment was where the apparatus was set up.

<u>Basic Incubator Appearance/Function</u>

Inside the incubators, a tube is inserted into the baby's mouth from a ventilator pump which provides respiratory support such as oxygen or positive airway pressure. This is monitored by a set of equipment that has multiple settings of which vary depending on the infant's condition. This incubator had the pump located on the outside back end supported by a plexiglass shaped design which helps decrease the noise that the infant hears inside. The incubator has a fan that circulates warm air and operates the whole time the baby is in the incubator. Seen below in figure 1 is the setup in the hospital room.

**Figure 1:** *Instrumented baby inside incubator with artificial lungs.*

<u>Test Setup</u>

A baby doll about the size of a premature newborn was used for the representation of an actual baby. Quarter inch microphones in the baby's ears will approximate acoustic diffraction around the baby while half inch microphones were used for the internal and external references. The internal microphone was always located facing the baby's left ear, while the external microphone was near the pump and fan.

Two ventilator pump pressures and frequencies were used as a base for these experiments. The low pressure was taken at 24 Pascal with a rate of 420 Hz while the high pressure was at 50 Pascal with 500 Hz. During all test performances, the fan for the incubator plus all other equipment is running to help reenact the actual environment. Measurements were taken for 60 seconds and the top of the incubator was closed for all tests. A set of artificial lungs was attached to the tube in order to realistically show the acoustical termination of the oxygen tube.

Test Results

Figure 2 seen below shows an example of an A–weighted broadband spectrum at the baby left and right ears, for both the low and high pressure.

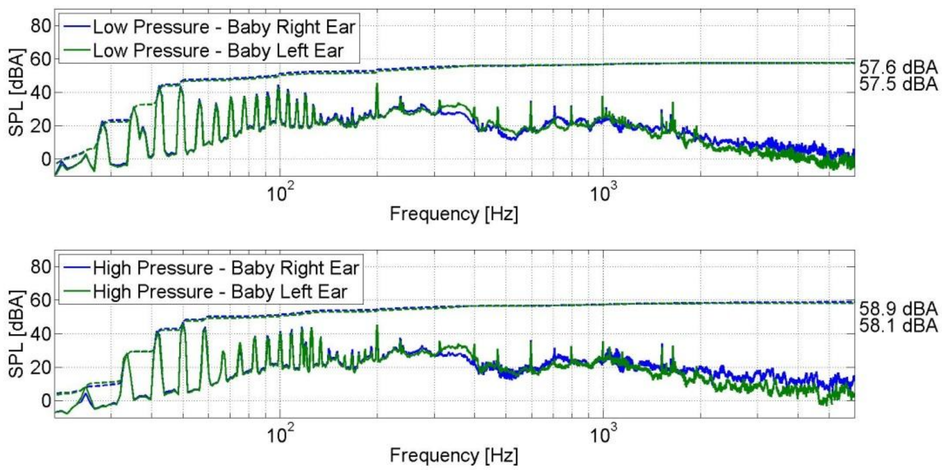


**Figure 2**: *Broadband SPL (solid line) and cumulative SPL (dotted line) at the baby's left and right ears for the low (top graph) and high pressure (bottom graph).*

The first few tones up to around 140 Hz are separated by a constant frequency spacing of 7.1 Hz for the low pressure case and 8 Hz for high pressure. This frequency spacing coincides with the pulsation frequency of the ventilator pump for each case meaning that these tones are radiating from the ventilator pump itself and the oxygen supply tube. These tones have dBA levels ranging from 20 to 45 dBA, reaching a maximum at 50 Hz. Individual tones starting around 200 Hz in increments of 100 Hz are representative of fan tones. Broadband fan noise due to air flow also contributes to the spectrum. The dotted curve on each graph represents the cumulative SPL for the entire frequency range, reaching levels on the order of 58 dBA at each ear.

## 3.) Study of Passive Acoustic Treatment in Incubator

The objective of this study is to find a comparative measure of the noise reduction using different mattresses. The current experiment involves exciting the incubator in one angle of incidence with a speaker in an anechoic chamber. The noise will be compared inside and outside at two positions, baby right and left ears, using the transfer function. The future experiment will be to create a diffuse sound field around the incubator with a speaker in the reverberation chamber. This will allow for multiple angles of incidence.

Sound – absorbing poroelastic materials that include melamine, polyimide and polyurethane will be tested to help reduce SPLs inside the incubator. An acoustically – transparent and waterproof mattress

See figure 3 below for the schematic of both the anechoic chamber and reverberation chamber.

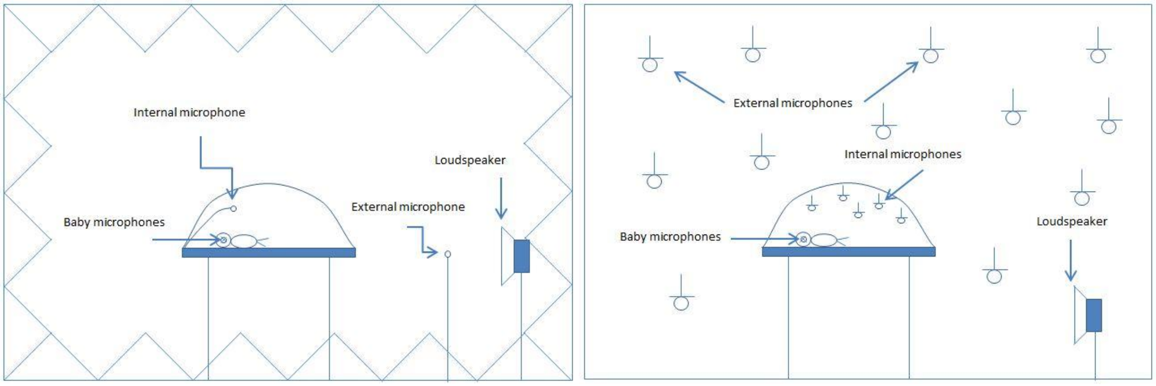


**Figure 3:** *Anechoic chamber setup (left), and multiple microphones in reverberation chamber for future research (right).*

The tests sampled included:

- No mattress
- Incubator with and without plexiglass enclosure
- Original mattress with thickness of 1″ with and without covering
- Melamine with thicknesses of 2″ and 4″ thicknesses, with and without Tyvek
- Polyimide with thicknesses of 1″, 2″ and 3″ thicknesses, with and without Tyvek
- Polyurethane with thicknesses of 1″, 2″, 3″ and 4″ thicknesses, with and without Tyvek

<u>Test Results</u>

In figure 4 below, the broadband transfer function and the 1/3rd octave transfer function between the baby right ear microphone and external microphone is displayed.

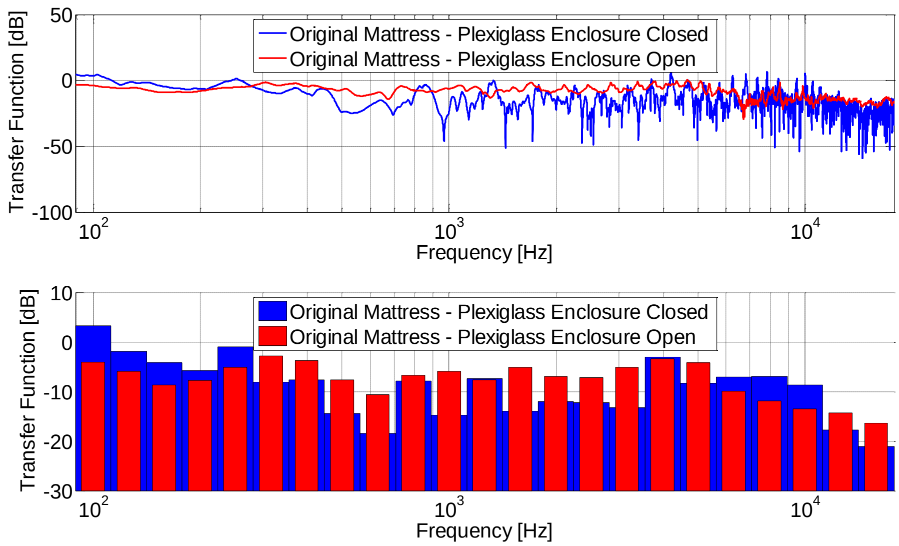


**Figure 4:** *Broadband (top graph) transfer function and 1/3rd octave (bottom graph) transfer function between baby right ear microphone and external microphone with (blue) and without (red) plexiglass enclosure.*

It is seen that when the plexiglass is open, the dB level doesn't fluctuate nearly as much as it does when the plexiglass is closed. The peaks reveal the modal nature of the volume of air enclosed in the incubator.

At frequency values up to 300 Hz, the plexiglass does not attenuate noise level but at frequencies greater than 300 Hz, sound decreases in the incubator.

Figure 5 below compares the original mattress to a two inch thickness of melamine.

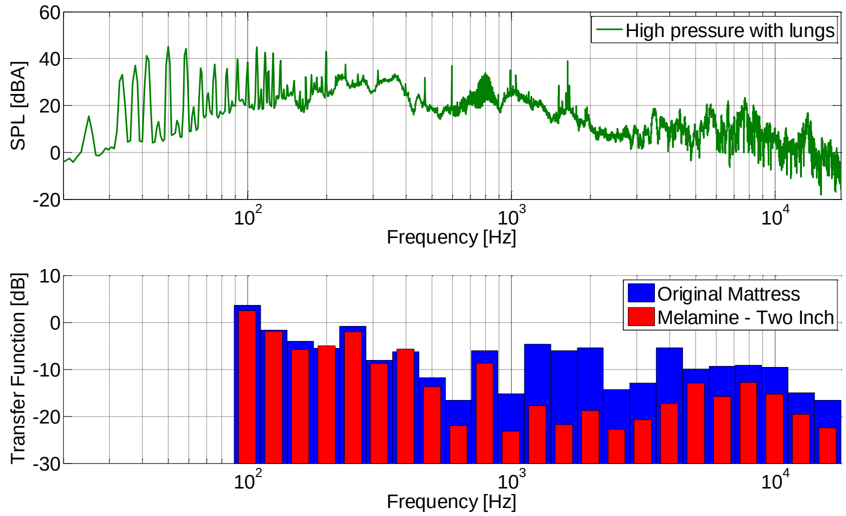


**Figure 5:** *Broadband SPL at baby's left ear (top graph) and 1/3rd octave transfer function (bottom graph) between baby's left ear microphone and external microphone for the original mattress and two inch melamine foam.*

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It can be seen that melamine significantly helps reduce noise compared to the original mattress starting around 500 Hz and ranging from 5 – 15 dB in difference. At tones of 600 Hz and 1800 Hz the melamine foam could reduce these SPLs to a quieter level.

Figure 6 below shows two curves that compare thicknesses of one inch of polyurethane with and without Tyvek.

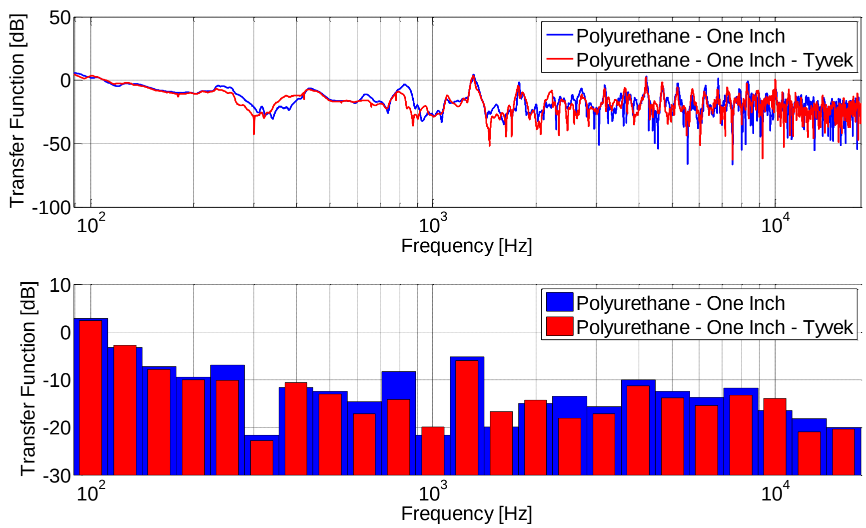


**Figure 6:** *Broadband (top graph) transfer function and 1/3rd octave (bottom graph) transfer function between internal microphone and external microphone polyurethane with (blue) and without Tyvek (red).*

The second graph, showing the transfer function in 1/3 octave, shows that the Tyvek appears to not make much of a difference for a one inch thickness at frequencies from 100 Hz to 700 Hz. Between 2500 Hz and 3000 Hz Tyvek helped reduce noise by 3 dB and in the higher frequency range, doesn't appear to cause any change in noise reduction. This demonstrates that it does not matter if Tyvek will cover the foam since it will not affect its noise reduction.

## 4.) Conclusion and Future Work

In summary, data was collected at the hospital and anechoic chamber with a variety of foam that will help in forming a mattress set for noise reduction. The acoustically transparent Tyvek had a positive effect on the foam and helped reduce noise inside the incubator. For the current work that was performed there was a maximum of four microphones that were used to collect data. The next focus will be putting the incubator in the reverberation chamber with multiple microphones hanging from all directions throughout the chamber and the incubator. The combination of all of these microphones will allow an estimate of acoustic power inside and outside the incubator and will provide a more accurate reading of the sound that is heard throughout the incubator's environment. Another test that could be proposed would include using a Helmholtz resonator and placing it at some location on the incubator. If trying to get attenuate a certain tone, this is of good use since the resonator is tuned at one frequency. Possible locations for this could be under the air mattress once it is elevated, or underneath the incubator.

## 5.) Acknowledgements

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