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A new type of absorber for use by classical musicians in rehearsal rooms

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ABSTRACT
Classical music students practice in small rehearsal rooms for many hours and hence increase their noise exposure to levels above those allowed under the new Control of Noise at Work legislation 2005. A feature of all these rooms is a full length mirror where the musician checks posture and technique. Consequently, the musician plays directly in front of a perfect acoustic reflector. Hence, a new product, the 'Sound Absorbing Mirror' has developed to absorb the sound energy in a localized fashion. The paper reports on how the absorptive mirror was developed, proto-typed, refined and tested.

1. INTRODUCTION
With the enforcement of the Control of Noise At Work Regulations for entertainment noise coming into force from April 2008, the Royal Academy of Music wished for the conservatoire to be in compliance. To this end, a multitude of approaches have been taken to meet the requirements of the regulations. An architectural idea, using noise control techniques, of putting sound absorbent materials as close to the sound source as possible was proposed. It was found, from observation, that music students spend more than 8 hours performing or practicing, and that a great deal of time was spent in front of mirrors in small rooms.

Practice rooms range from effectively a cell, approximately 2.5m square, to rehearsal rooms, approximately 10m by 8m. Each room has one wall with a large full height glass mirror installed, see Figure 1. These mirrors are used to check posture and technique. Of course, mirrors are excellent reflectors both in terms of light and sound, and hence the idea of a sound absorbing mirror.

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A number of types of absorber exist, the most common being the porous absorber. This type of absorber is found in rehearsal and practice rooms, as either carpets or curtains. However, most of the room surfaces are acoustically hard, typically walls, floor, and ceiling. An idea room design would consist of hard surfaces for the walls, giving the feeling of envelopment, and an absorptive floor and ceiling to reduce the overall noise exposure.

Figure 1: A typical rehearsal room at the Royal Academy of Music

2. DEVELOPMENT OF THE SOUND ABSORBING MIRROR

A new lightweight reflective, heat shrunk and adhesive material was found. This material was so light, traditional acoustic theory might not apply. The traditional acoustic theory suggests that a impervious material facing on a porous material will only be acoustically transparent at one frequency or octave band [1].

A. Standing Wave Tube Experiment

Quick initially tests were undertaken using a standing wave tube to demonstrate that the mirrored membrane material was acoustical transparent at the dominant frequencies for classical musical instruments. This was accomplished by applying the Russian material to small samples of porous material, see Figure 2. It was found that the mirrored membrane was effectively acoustically transparent.

Figure 2. Mirrored membrane on a porous sample used in the standing wave tube

B. Small Prototype

The next stage was to build a small frame for the mirror. It was decided to test another type of heat shrunk reflective film, designed for model aircraft wings, to test the manufacturing approach. A small hardwood frame, 1.0m by 0.60m, was constructed and the modelling film applied and heated using a modelling heat dryer, see Figure 3. The airplane reflective material was heavier than the originally tested mirrored material, not perfectly reflective, and sounded like a drum when struck.

Figure 3: Mirrored modelling film membrane on a small frame, result a drum

B. Large Prototype

The third stage was to build a full size, 2m by 1.2m, wooden frame with the original reflective film. A welcomed design fault was introduced- the large frame had no cross struts and hence when the reflective material was heated the heat shrink material pulled the middle in, thus giving a significant portion of the population a good feeling! The downside was the mirrored surface was only near perfect as the reflective material relaxed, it sagged, see figure 4. Directly behind the mirrored surface 30mm of high density porous material was positioned giving a total depth of 37mm, considerably more than the 7mm of a typical large mirror. However, very similar to typical micro perforated acoustic membrane with porous absorber backing. Obviously, the micro perforated membrane is not impervious, but size, weight and depth are similar [2].

C. Alternative Large Prototype

To demonstrate the difference in acoustic performance was due to the thickness of the film. Another full size mirror was built, this time with cross bracing, which used an alternative heat shrunk mirrored membrane. This film was manufactured by Rosco and is used by theatres to replicate mirrors without the dangers of glass on stage

Figure 4: Sound absorbing mirror in the lab and undergoing initial performance testing

3. LABORATORY PERFORMANCE TESTS- SAMPLE

The two prototype 2.5m^2 mirrors were tested in a reverberation chamber following the principles of ISO 354 [3]. Due to the prototype nature of the mirrors 10m^2 of material was not available. A third test was undertaken, that using only the porous material. An interrupted pink noise source with 5 receiver positions and 2 sound source positions was used to establish the absorption coefficient of the bare reverberation chamber before introducing each mirror separately, see Figure 4. A Rion NA-28 was used to take the measurements.

The performance calculations using the Sabine formula with air absorption compensation was used to predict the diffuse field absorption coefficients for the three materials, see Figure 5

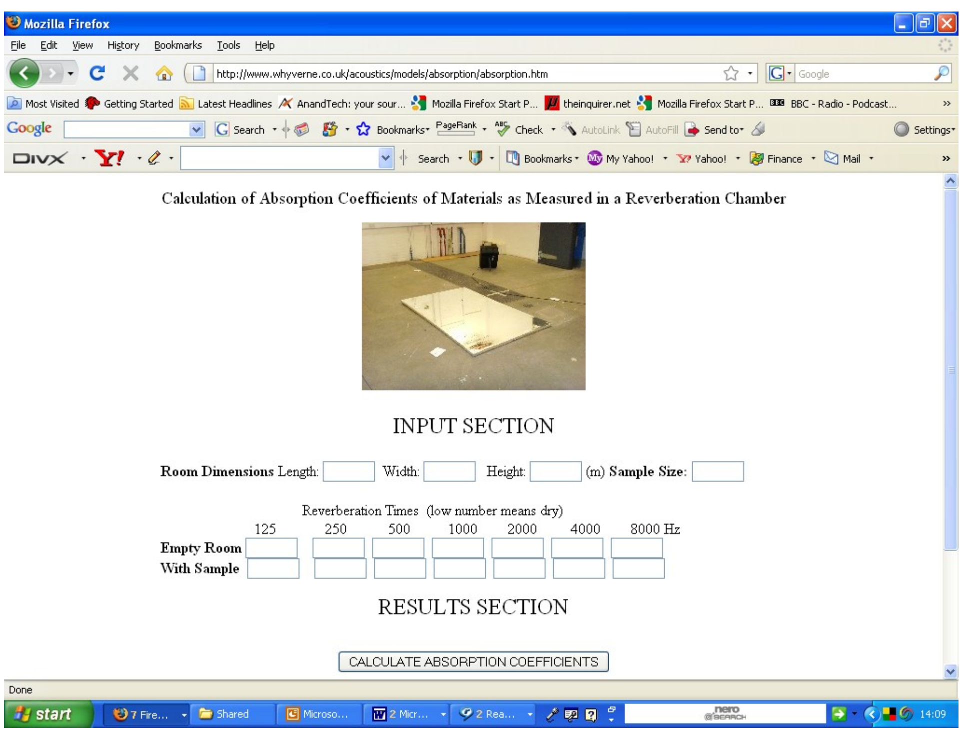

Figure 5: http://www.whyverne.co.uk/acoustics/models/absorption/absorption.htm

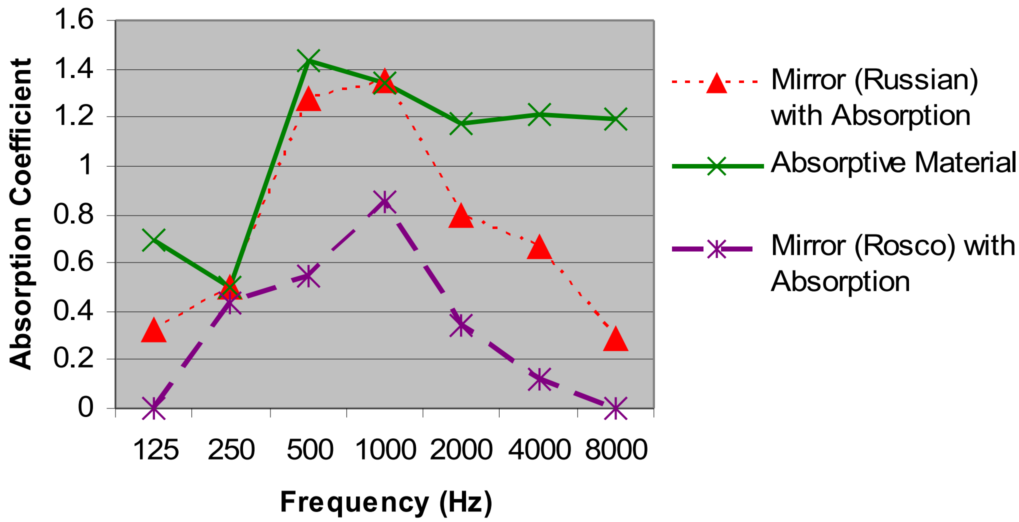

Figure 6: The Sabine absorption coefficients for 3 small samples of materials

The bare absorptive material had the best performance with excellent mid and high frequency performance. By way of comparison both the mirrors performance fell away at higher frequencies. However, the Russian film appears to be acoustically transparent at 250 Hz to 1 kHz, where as the Rosco film was not, but did show peak performance at 1 kHz, as expected from traditional acoustic theory. In terms of Noise Reduction Coefficient, an arithmetic average of 250 to 2kHz, the results were 0.55, 0.95, 1.10, for the Rosco Mirror, the Russian Mirror and the porous absorption. Obviously, with such a small sample size these values are only a guide.

4. LABORATORY PERFORMANCE TEST - LARGE

Three further mirrors were constructed using the Russian film. This was significantly expedited by the use of the Bakery School's ovens! A second set of mirrors were also produced with a small aesthetic redesign to demonstrate reproducibility. Figure 7 shows the measurements repeated in accordance with ISO 354 using identical equipment.

Figure 7: Large sample size mirror and porous absorption material under testing

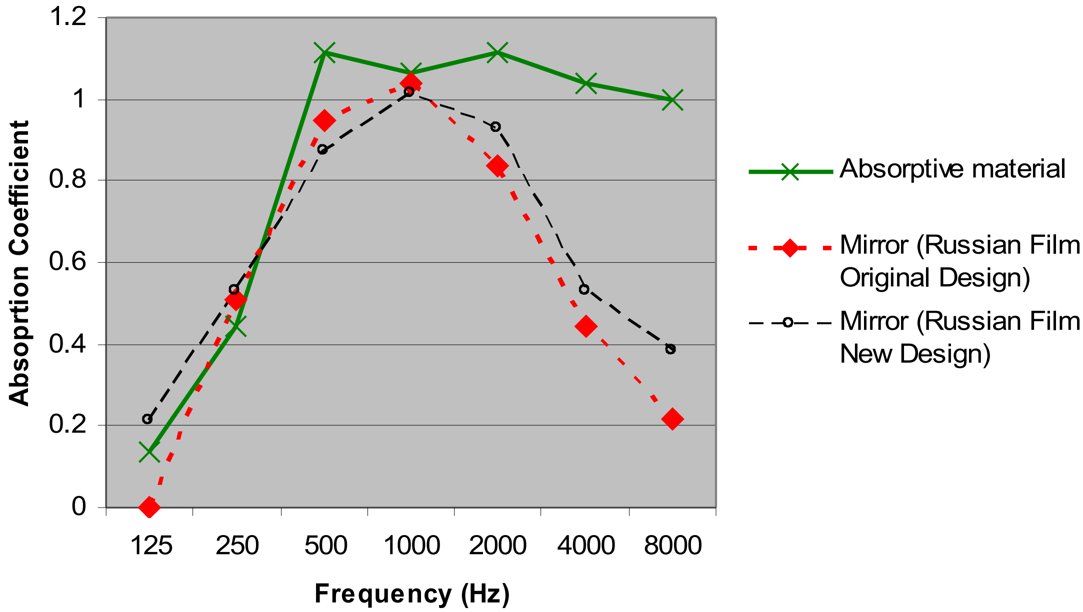

Figure 8: Absorption coefficients for the porous absorber and 2 sound absorbing mirrors

Figure 8 shows similar results as for the small samples in figure 6, but the calculated absorption coefficients are lower, as expected. The bare porous material had the best acoustic performance, an NRC of 0.95. However, the sound absorbing mirror's performance was 0.85. The mirror is an effective absorber between 250 and 4 kHz, mechanical resistance increases at 8 kHz reducing the predicted absorption coefficient to less than 0.5. The aesthetic frameless redesign introduced an additional 3mm air gap, which provides the extra high frequency acoustic absorption. The equivalent micro-perforated membrane under tension with 40mm of porous absorption has an NRC of 0.80.

5. CONCLUSIONS

The sound absorbing mirror has been designed, prototyped, tested and then developed to provide musicians localized absorption in small rehearsal rooms. The mirror's sound absorbing performance is nearly that of the bare porous absorber, and hence provides an impervious barrier which is nearly acoustically transparency. Traditional acoustic theory does not allow an impervious facing layer to provide such acoustic performance; at best a facing material can only be designed to be transparent for one octave band, as found for mirror using the heavier film. The use an extremely light film under tension over a traditional porous absorber is the reason for the improved performance.

Outside the area of mirrors, the new design provides an opportunity to be used outside of the entertainment industry for example, food preparation, hospitals, or in enclosures, anywhere that an impervious barrier ease the problem of cleaning or architectural aesthetics.

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