Proceedings of the Institute of Acoustics

FURTHER INVESTIGATIONS INTO THE PERFORMANCE OF 'BASS TRAPS'

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1. INTRODUCTION

This paper outlines the continuing research into the performance of an empirically designed passive low frequency absorber for use in rooms, more commonly referred to as a 'bass trap'. In the following sections a description of the experimental procedure will be given, the experimental results will be presented, and finally conclusions will be drawn and future work discussed. Previous work [1] has shown that the large chipboard panels around which the design is centred, are not responsible for any low frequency sound absorption through acoustically induced flexural waves, so investigations have turned to consider other possible mechanisms. Due to the complexity of design, it was deemed sensible to obtain a comprehensive set of experimental results against which future theoretical predictions can be compared.

2. EXPERIMENTAL PROCEDURE

2.1 $^{1}/_{10}$ Scale Model

The experiments were made on a $^{1}/_{10}$ scale, using a duct constructed of concrete paving slabs. The purpose of the experiments was to gauge the affect a side wall of a room covered in 'bass traps' would have on the sound transmission along its length. The model assumes symmetry along the length of the room, thus the model absorber was only placed along one wall of the duct, with the other remaining bare and rigid. Aluminium plates 0.9mm thick were used because their material properties scale up to the properties of the chipboard panels used in the full sized design [2]; they are as height as the duct, and 122m in width. The foam was arbitrarily chosen, its only important characteristic being that it exhibits a non-zero resistance across the frequency range of interest; its absorption coefficient is shown in *Figure 1*. It is desirable for the reflections from

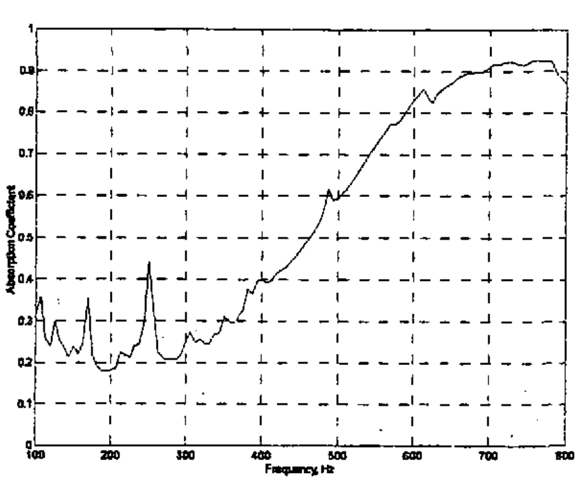

Figure 1

the end of the duct to be significantly attenuated, so as to minimise the inevitable errors in calculating the transfer function between the two microphones, and to that end a 40cm deep absorbent was placed in the end of the duct. As the duct is constructed from 300 x 600mm paving slabs, there are two places along its length where there is a join. A hard drying adhesive grout was used for this purpose, however a small change in acoustic impedance at these points is unavoidable. Evidence for this is seen in the results for transmission as small dips (and peaks in *Figure 1*) at frequencies whose ½ wavelengths correspond to the distance between grouting points. The means of acoustic excitation was via six 75mm direct radiating loudspeakers placed in a common baffle. *Figure 2* illustrates the complete experimental rig described above, in plan view.

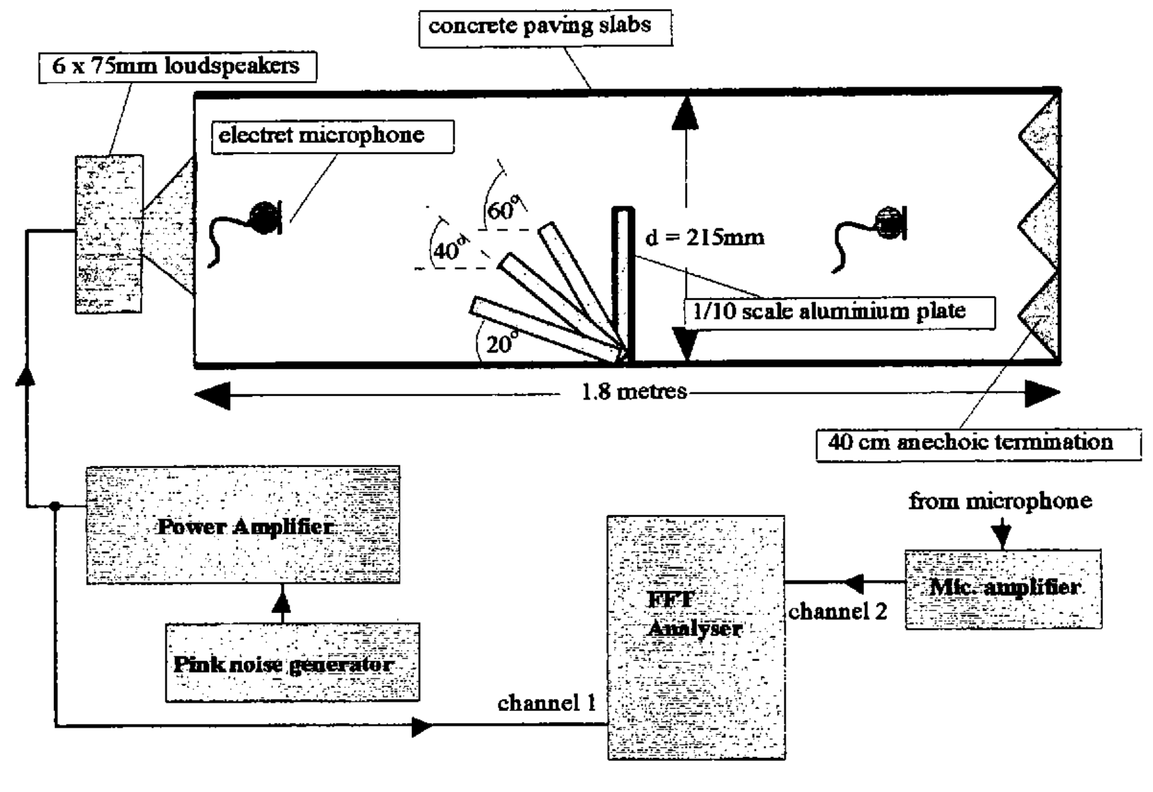

Figure 2

2.2 Experimental Procedure

In order to measure the sound transmission along the duct four measurements has to be taken for each orientation. Two transfer functions (between the input to the loudspeakers and the output of the microphone) are calculated at positions either side of the panels, thus allowing the sound pressure field to be decomposed into the forward and backward going components, of which the forward going one is of interest. Once this is found, the transmission is calculated by dividing the forward going component at the termination end of the duct by the same quantity at the loudspeaker end. A simple microphone stand was fashioned from wire to keep the two electret mics a specified distance apart, a distance determined by the frequency range of interest [3], in this case it was 165mm. Initially the frequency range has been constrained to allow only plane waves to propagate down the duct. The first cut on frequency is at around 570Hz (corresponding to a duct height of 30cm), though the results extend to 800Hz. Two main sets of experiments were performed, firstly without a foam lining, and secondly with a foam lining. The former were very thorough, with transmission measured for different numbers of panels at every combination of four angles (20°, 40°, 60°, and 90°), and four panel separation distances (6, 9, 15, and 21cm). The results from this set of experiments then guided the measurements made for the second set, where the foam lining along the wall was present.

3. SOUND TRANSMISSION ALONG THE DUCT

3.1 Transmission for Rigid Walls

As mentioned in *Section 2,* there are far too many results from the rigid walled experiments to be presented here, however as they show a general trend throughout, it is sufficient to show in *Figure 3* the transmission for 7 panels, spaced 15cm apart, at the four angles.

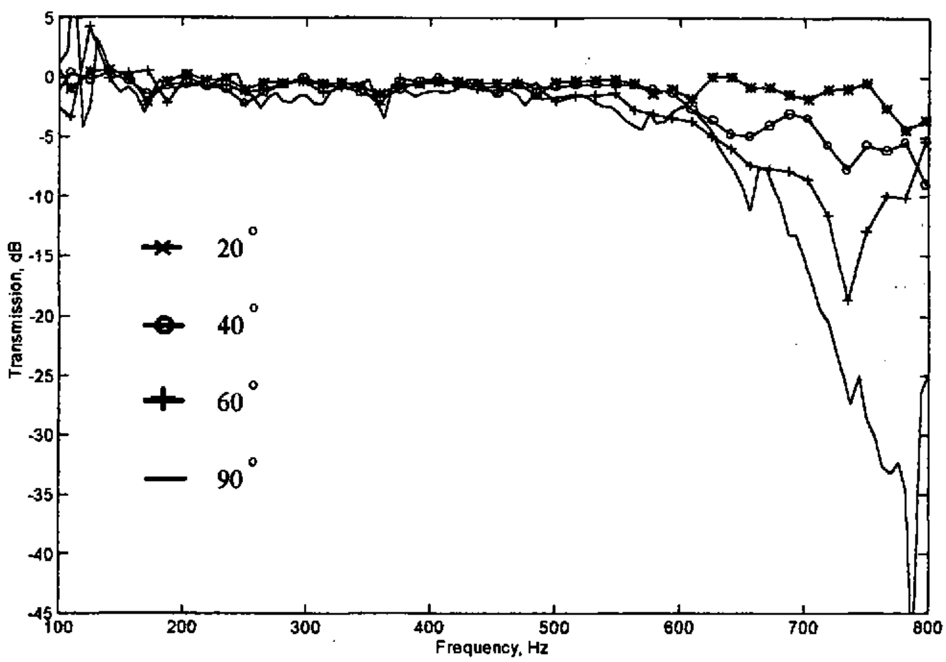

Figure 3

It is clear from *Figure 3* that when the panels are at shallow angles to the duct wall, the transmission loss (TL) is negligible, even with a spacing typically five times greater than that used in the full scale design. The appearance of a stop band is most evident at the more obtuse angles, though whether or not this is due to the panels protruding a greater distance into the duct will require more experimentation. *Figure 3* certainly indicates that the presence of a non-rigid back wall is of paramount importance in the performance of this design. The other rigid walled experiments showed that the stop band became evident at a lower frequency for a larger spacing, and achieved larger values of TL for a greater number of panels. The angular dependence for the other results are as in *Figure 3*.

3.2 Transmission with Wall Lined

Once that the purely reactive case had been investigated, the same experiments were made with one wall lined with 26mm of foam covered with double-sided sticky tape (necessary in order to fix the panels in position).

3.2.1 Angular Dependency

Figure 4 shows the transmission for three angles, with the other variables are held constant at 14 panels and 6cm spacing.

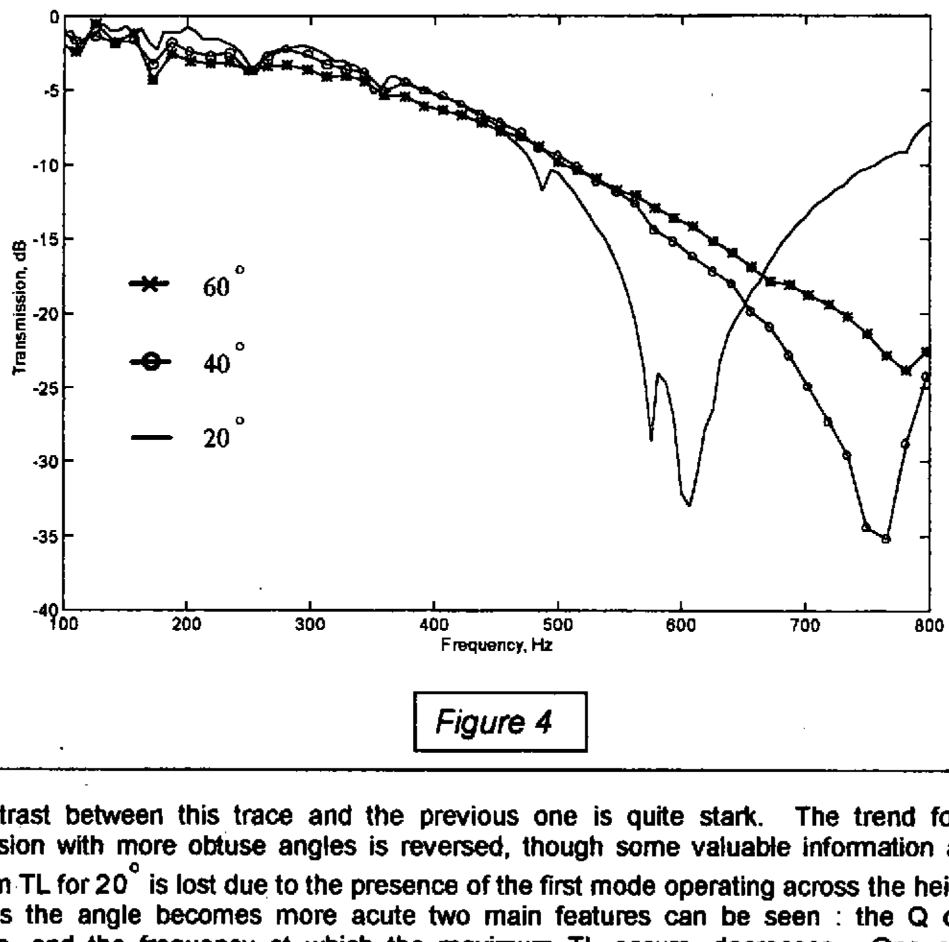

Figure 4

The contrast between this trace and the previous one is quite stark. The trend for greater transmission with more obtuse angles is reversed, though some valuable information about the maximum TL for 20° is lost due to the presence of the first mode operating across the height of the duct. As the angle becomes more acute two main features can be seen : the Q of the TL increases, and the frequency at which the maximum TL occurs, decreases. One could also speculate that the TL also increases (this is certainly the case between 60° and 40°). As a check, the transmission for the liner by itself, and the panels in a rigid duct were plotted, and showed that the performance in *Figure 4* is significantly better than the sum of its parts.

3.2.2 Spatial Dependency

Figure 5 illustrates how the transmission changes as a function of the distance between the panels; as before, the other variables are held constant (9 panels at 20°).

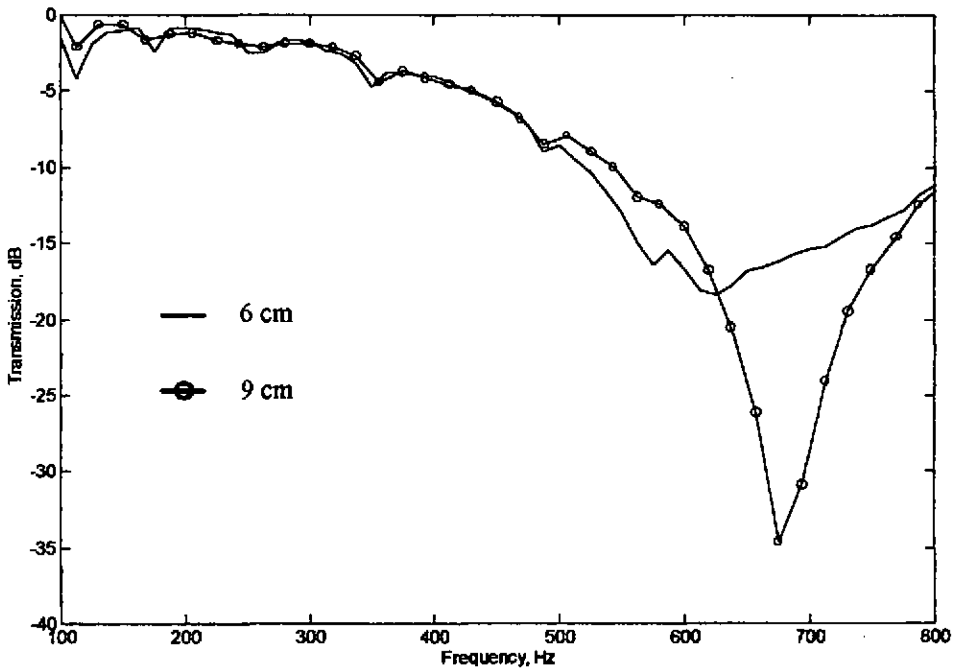

Figure 5

The level of maximum TL for the two traces is not surprising, as the panels occupy 50% more of the duct when 9cm apart, than when 6cm apart. However, it is surprising to note that the frequency at which the TL_{max} occurs is lower when the panels are closer together – this is another trend reversal from the hard walled case.

3.2.3 Dependence on Number of Panels

Although this next dependency might seem a trivial one to consider, it is important that nothing is assumed, and everything tested. *Figure 6* shows the transmission for 9 and 14 panels, 6cm apart, and at 40° to the wall. As one would expect, the TL is greater when more panels are present. However, the other results for this dependency (not shown here) are quite different. At 60° the performance for 9 panels improves, whilst the opposite is true for 14 panels – the two meet half-way and are almost identical.

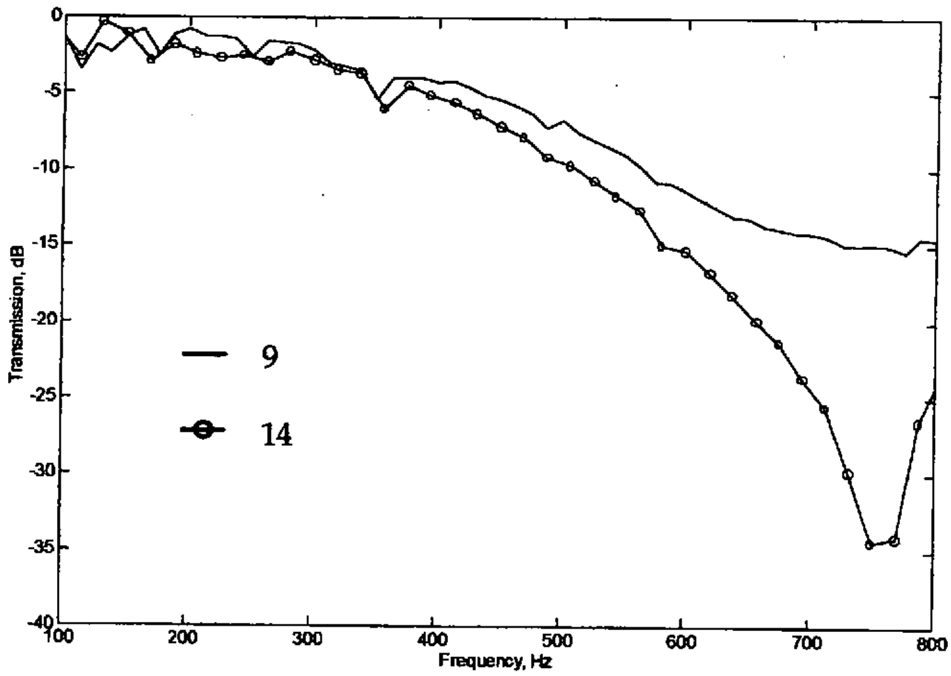

Figure 6

3.2.4 Normalised Distance Dependency

The next two plots illustrate a very important dependency, one where the same length of the duct has panels present, but the number and separation are varied. These results have major implications in real life situations, as if ¼ of the number of panels spaced four times the distance apart exhibit a similar performance, then significant savings can be made in terms of material and labour, both of which heavily influence the overall cost. *Figure 7* show the results at 60° for three arrangements, each occupying 48cm of the duct – 5 panels spaced 12cm apart, 9 at 6cm, and 17 at 3cm. This plot clearly shows that with the panels at this angle, the maximum difference in transmission is only 6dB, though 12 more panels are necessary; the intermediate spacing has a performance that lies between the two. The slight increase in performance is certainly outweighed by the amount of material needed, it does appear to be a law of diminishing returns.

In the case, however, where the panels are at 20° there is far greater difference, and two clear effects are seen. *Figure 8* illustrates two arrangements, both of which occupy 72cm – 9 panels spaced 9cm apart, and 17 at 4.5cm. With more panels closer together the TL_{max} is greater, and the frequency at which it occurs is lower. This result would confirm earlier deductions that more panels yields a greater TL_{max}, and that the resonant frequency decreases in line with smaller spacing.

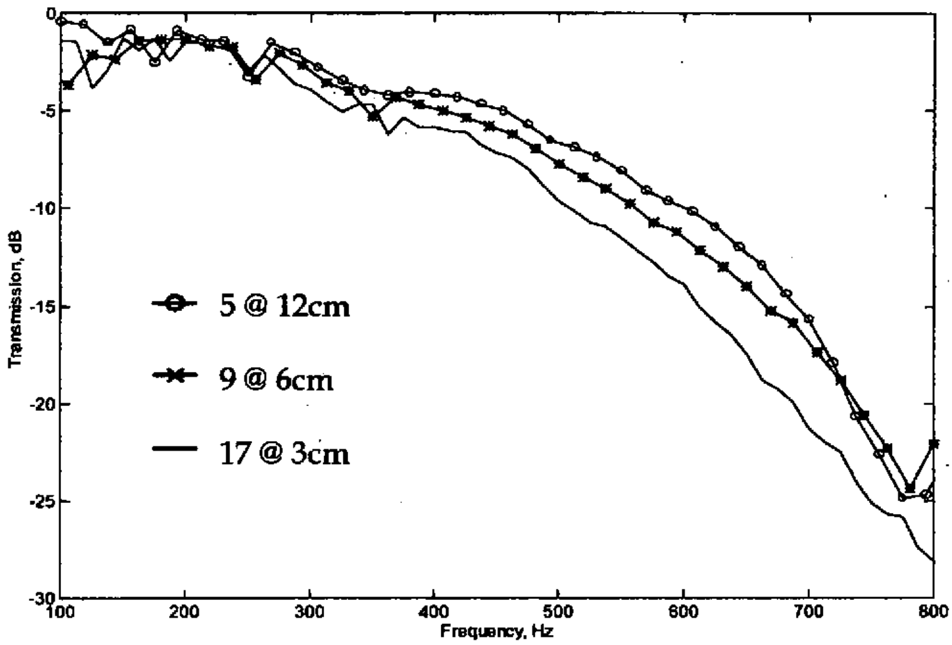

Figure 7

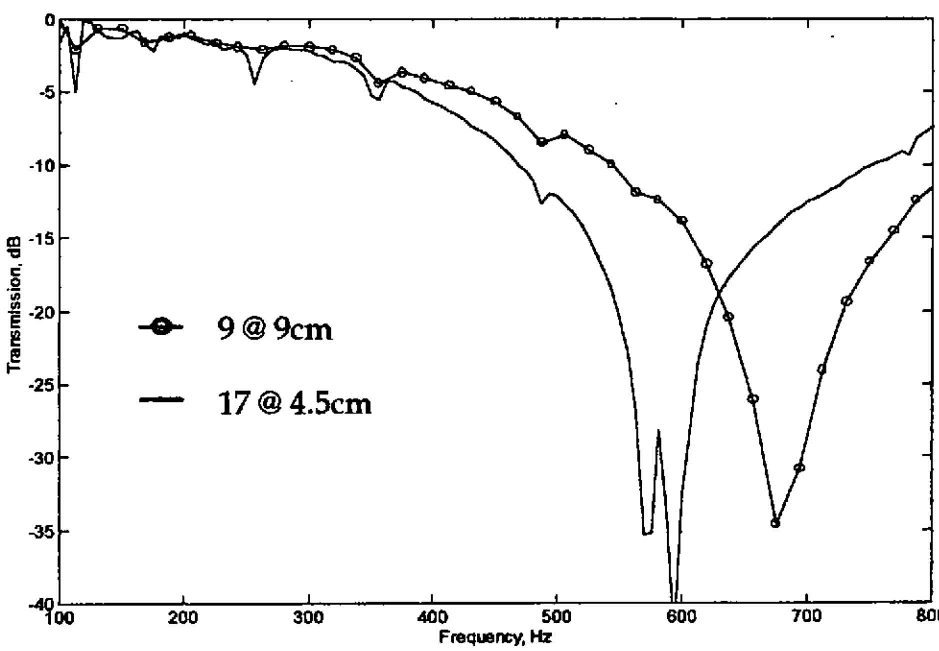

Figure 8

4. CONCLUSION

The experiments outlined in this paper have used a concrete duct as a $^{1}/_{10}$ scale model of half a room to investigate the way in which different arrangements of the 'bass trap' design affect the sound transmission. The purely reactive case, where no wall lining was present, provided results which were not altogether surprising. The TL only became significant in the frequency range of interest when the panels were at obtuse angles, though whether or not that is simply a result of the distance to which the panels protrude into the duct will require further work. The spacing between the panels is also an important factor, as it controls the frequency at which the roll-off in transmission occurs. The number of panels determines the level of TL, though it is highly dependent on the previous two conditions.
By contrast, when an absorbent lining is placed between the panels and the wall, one obtains very different results. Unlike the reactive case, as the spacing between the panels decreases, the frequency of maximum TL decreases; the same result is noted as the angle becomes more acute. Other results for increasingly shallow angles are a higher Q and probable increase in TL. A common result between the two sets of experiments is the increase in TL for greater numbers of panels.
Despite some very interesting results, little more is known as to exactly what mechanisms are responsible for certain performance characteristics, it is thus imperative that a reliable theoretical model is formulated. When that is done, and found to be in agreement with experiment, the 'bass trap' design can be applied more intelligently, rather than through trial and error.

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[3] Bobén, H., & Åbom, M., 1986: 'Influence of Errors on the Two-Microphone Method for Measuring Acoustic Properties of Ducts', *Journal of the Acoustic Society of America,* Vol. 79, No. 2, (February), pp. 546-548.