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TESTS OF A ROBUST ACOUSTIC ABSORBER MATERIAL FOR APPLICATION IN AN INDUSTRIAL HYGIENIC ENVIRONMENT

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1. INTRODUCTION

The tests described were undertaken during a study of control of glass container handling noise on conveyor lines and associated equipment [1].

With many lines already existing and equipment being developed primarily to satisfy functionality, the preferable approach of noise control at source by avoidance of container impacts is rarely possible to satisfy current needs. Application of traditional passive measures such as line covers and equipment enclosures is thus of interest.

Although the screening effect of these measures can be adequate to reduce the prominence of noise 'hot-spots' at attended locations, and thus in many cases meet a 90 dB(A) L_{eq} noise limit, the reduction in 'reverberant' noise level will be negligible for covers with the large openings necessary for product access unless sound power can also be dissipated. High general noise levels are often a cause of poor working environment in areas of low acoustic absorption as found in many factories, due to the subjective sensation of being 'surrounded by noise'. This aspect of added absorption is not addressed in this paper, but the author was interested to note recently that Scandinavian workplace noise standards require the surfaces of factory buildings to have a minimum effective absorption coefficient of 0.2 (over the octave band frequency range of 0.5k to 4 kHz) to avoid extreme conditions. The frequency range of most concern in the application reported here is the 2 kHz and 4 kHz octave bands (see Figure 1).

2. CURRENT COVERS FOR HYGIENIC APPLICATIONS

Products, usually in the form of washable tiles, have appeared on the market to allow treatment for the factory space to be achieved even under hygienic requirements. These could also be fitted inside larger machinery enclosures, but particularly for the case of line covers, which would typically be required to have widths of about 150 mm to 300 mm, the standard sizes of such ceiling tiles, and the rather fragile surface of most, does not lend them to this application.

Neither have the acoustic line covers fitted with film-faced fibre or foam linings been very widely adopted successfully in the bottling industry, not only due to cost but also due to fragility of the surface and the need for absolute confidence in the sealing of the lining to avoid the risk of contamination.

3. REQUIREMENTS OF AN ACOUSTIC ABSORBER SYSTEM FOR LINE COVERS

The ideal absorber system for a hygienic application would meet the following criteria:

- give adequate acoustic absorption in the required frequency range (2k and 4 kHz octave bands)
- be reliably and easily cleanable
- be transparent (to allow unrestricted observation of flow/blockage)
- be robust in service and cleaning and not shed fibres etc
- not fail by becoming unhygienic
- be easily repaired/replaced when unserviceable
- be lightweight to minimise support
- be economically viable (and low cost!)
- not introduce additional hazards (e.g. be unflammable and non-toxic).

At present, we believe that no available materials or system satisfy all these criteria. Transparency is a major difficulty. Foil absorbers [2], made up of areas of thin plastic sheet (rather of the appearance as if moulded over a large segmented chocolate bar), do offer some transparency and are used in these applications, but in our experience they have not been greeted with enthusiasm by factory management for close-fitting application because of their apparent fragility.

It was therefore decided to investigate the performance and configuration of a non-transparent but robust material with a view to obtaining acceptable performance whilst minimising visual impediment by configuration.

Active noise control measures were not considered appropriate because of the unattractive ratio of wavelength/enclosure dimension, and within the scope of the project there was inadequate opportunity to consider this further.

4. MATERIALS AND CONFIGURATION TESTED

The robust material selected was a rigid sheet form of microporous high density polyethylene (supplier's grade F) used for fluid filtration and also moulded to silencers for pneumatic relief venting. This material is inherently free from detachable fibres, although edges should be deburred during fabrication. It is claimed to be a hygienic material suitable for food and medical applications.

From the range of available thickness, values of 1.5 mm and 4.7 mm were tested. The absorption coefficient values provided by the supplier show optimum performance at high frequencies, as required in this application (Figure 2).

For comparison, examples of commercial faced and unfaced acoustic-grade foam 25 mm thick were also tested. Typical absorption characteristics for these materials are shown superimposed on Figure 2. Representative values from measurements with the faced foam are difficult to achieve because of their sensitivity to film tension which can occur when loading an impedance tube sample holder. Values are often not quoted by suppliers for the film-faced materials.

It is clear that the absorption performance of the latter is degraded at high frequencies, just where it is most needed in this application. A similar trend is shown by the foil absorbers [2].

5. MODEL ENCLOSURE/COVER TESTS

A series of tests was undertaken in the laboratory and on a conveyor loop to give some acoustic performance data on both lined and unlined covers, to develop cover performance guidelines and to test an unconventional lining material. The test programme is summarised in Table 1 and the results are summarised in Table 2.

All results are expressed as Insertion Loss (IL) or as change in Insertion Loss, where

IL (dB) = (noise level without the enclosure cover) − (noise level with the enclosure cover); both measurements at the <u>same</u> location.

Sound pressure levels were measured for the octave bands with centre frequencies between 0.5k and 4 kHz, and for the overall 'A' weighted spectrum.

The model enclosure overall dimensions and materials, together with the measurement locations, are shown in Figures 3 and 4.

5.1 Laboratory Tests

In the laboratory tests, a small fixed source was used in the centre of the covered area so that all aspects were under control and preliminary selection of lining parameters could be made in preparation for the more realistic line tests. A spectrum shape typical of glass contact noise was used for the laboratory test source.

5.1.1 Unlined Enclosure. With no lining, but with in-feed and discharge openings, the Insertion Loss varied from 3 dB(A) for the reflected field laboratory test to 1-11 dB(A) for the direct field tests and 2-5 dB(A) for the line tests. The range of values given for the direct field and conveyor line tests is as given by the two measurement locations, the lower value referring to the 45° location which is not shielded from the end opening.

Even the unlined cover shows some loss in the reflected field because the internal surfaces of the cover absorb some energy and air absorption also acts along the multiple-reflection paths inside the enclosure at very high frequencies. With solid ends, the maximum attenuation was scarcely increased (although there may have been some influence of the source output when driving into a sealed chamber).

5.1.2 Lined Enclosure.

a. Lining Materials Tested. The materials were tested as flat sheets. The faced-foam material was tested in the direct-field (anechoic chamber) tests, fitted to one surface of the enclosure side-wall. The extra insertion loss compared with the unlined cover was 2-3 dB(A), which was 1 dB(A) less than given by replacing the faced-foam with the thinner (1.5 mm thick) microporous sheet, installed with a 25 mm air gap. This difference is due to the superior absorption coefficient of the microporous sheet in the 2 kHz and 4 kHz octave bands. Thus there is no acoustic disadvantage in using the microporous sheet, neither does it occupy more space in the cover than a faced-foam slab, so no further tests were undertaken with the faced foam.

In addition to its use as a lining, the microporous sheet was tested as a cover wall sheet, both as an end panel with an aperture for container access and as a side wall. However, even when double thickness was used (9 mm thick), its insulation effect was negligible and thus the material is only suitable as an absorbent lining.

b. Additional Lining Configurations with the Microporous Sheet. The benefit of the lining of microporous material was doubled when the roof was also lined; but lining a third surface gave little extra benefit. It would also have caused unacceptable visibility problems since only the ends remained transparent.

Although the benefit of the second surface being lined was directly proportional to the extra area of lining, the distribution of the lining is likely to have some secondary effect. To line one side in a pair of opposite sides and then line one side of another pair of opposite sides (e.g. rear wall and roof) is likely to be more effective than distributing the same total area over both sides of one opposite pair (e.g. front and rear wall, leaving roof unlined). This applies to a parallel-sided cover. If the cover has an angled or pitched roof or has a curved cross-section, the effect of distribution will be reduced. The lined enclosure retained a very small benefit when the hinged side was open (1-2 dB(A)).

c. Lining Material Thickness. It was found that the 4.7 mm thick microporous sheet gave 3 dB(A) less insertion loss than the 1.5 mm thick sheets, due to inferior high frequency absorption. On the conveyor test, the insertion loss of the cover measured at 45° was reduced by 3 dB(A), from 6 dB(A) to 3 dB(A) and the reflection-field (reverberant chamber) test showed a reduction from 8 dB(A) to 5 dB(A).

Although the thicker material is more expensive, it is attractive in being more self-supporting in flat sheet form. However, the loss in performance could be too high for this application. A compromise is suggested, at 2.5 mm thickness. Although this will not be very self-supporting, it will be better than the 1.5 mm material whilst remaining flexible enough to be bent into a curved shape or around a supporting feature. Cover design is discussed below.

A further advantage of a thinner material is that it will hold less liquid when being cleaned and may therefore drain more quickly.

5.2 Works Trial

The line tests were undertaken on a training school facility, handling 300 ml bottles with a parallel transfer as the noise source. The insertion loss values given are corrected for background noise contributed by sources on the line other than the enclosed bottle contact area, such as conveyor drives and the conveyors belts themselves. The insertion loss of the cover for the total noise was 3-5 dB(A), rather than 6-9 dB(A) for the covered source alone.

6. CONCLUSIONS

6.1 Acoustic Performance

- The cover lining of microporous sheet gave slightly higher insertion loss when spaced 25 mm from the cover wall, than did the faced foam occupying the same thickness space,
- no sealing or special feature was needed for installing with the air-gap,
- 1.6 mm thickness of microporous sheet gave better performance in the tests than 4.7 mm (due to 4 kHz absorption) but an intermediate thickness might be preferred as more self-supporting,
- lining two surfaces gave 4 dB(A) extra insertion loss over the unlined cover in the workshop conveyor loop test,
- the transmission loss of the microporous sheet is too low for its use as a cover wall material; it can only be used as an internal lining.

6.2 Cleaning Procedure

The manufacturers advised that soap and hot water, acetone or propanol solvents, or caustic cleaning solutions can be used without detriment to the microporous material. The sheeting is not provided with a facing paper sheet; this would be ideal to protect it during fabrication. It would be appropriate to cut and drill the lining sheets in a cleaner area, such as a carpenter's shop, than a fabrication/fitters area.

The intention is that if the lining sheets are clean when installed, they would be maintained by wiping with a clean cloth or removed and cleaned in a bath of one of the cleaning liquids mentioned above.

However, having soiled the surface during fabrication of a trial cover, in practice an industrial user found that cleanliness could not be restored by wiping the surface and so did not pursue its application further. Therefore, experience in maintaining a clean cover in service may yet remain to be obtained and the importance of avoiding dirt during fabrication is emphasised. Suppliers of these materials need to be able to demonstrate the cleanability to the acceptance of the end user.

ACKNOWLEDGEMENT

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REFERENCES

[1] J.N. Pinder: Final Report Part 3. Noise Control of Cold-End Equipment and Container Handling. *HSE Contract No. 2566/S45.22,* July 1992 (ISVR-CS ref R08 3964/C1).

[2] L.L. Beranek, I.L. Ver (Eds.): Noise and Vibration Control Engineering, Principles and Applications (Ch. 8), *John Wiley & Sons Inc.,* 1992, ISBN 0-471-61751-2.

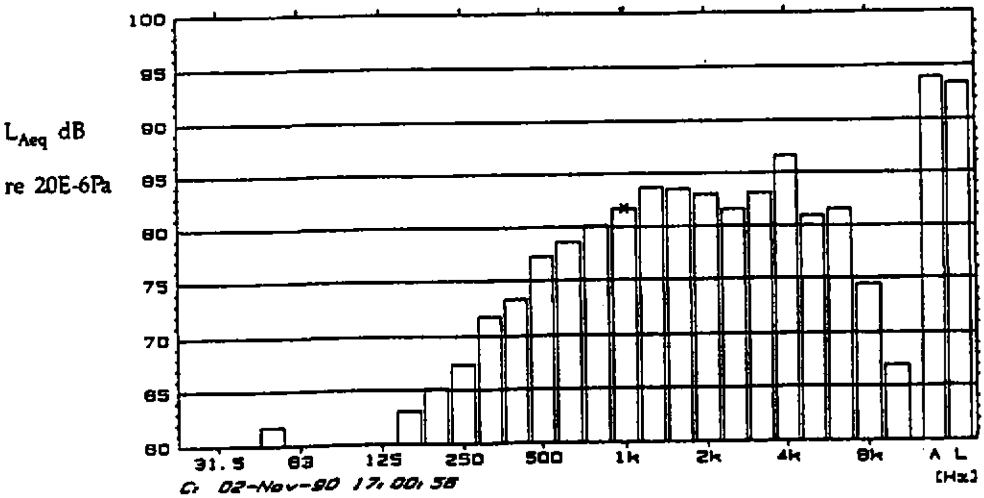


Figure 1 Typical spectrum of general noise level in works due to glass container handling

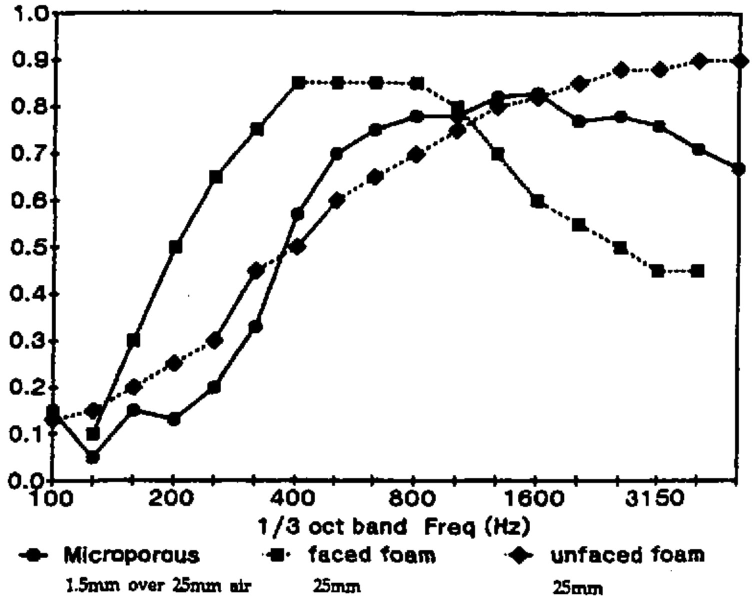


Figure 2 Acoustic coefficient of tested linings.
Random incidence values estimated from normal incidence test

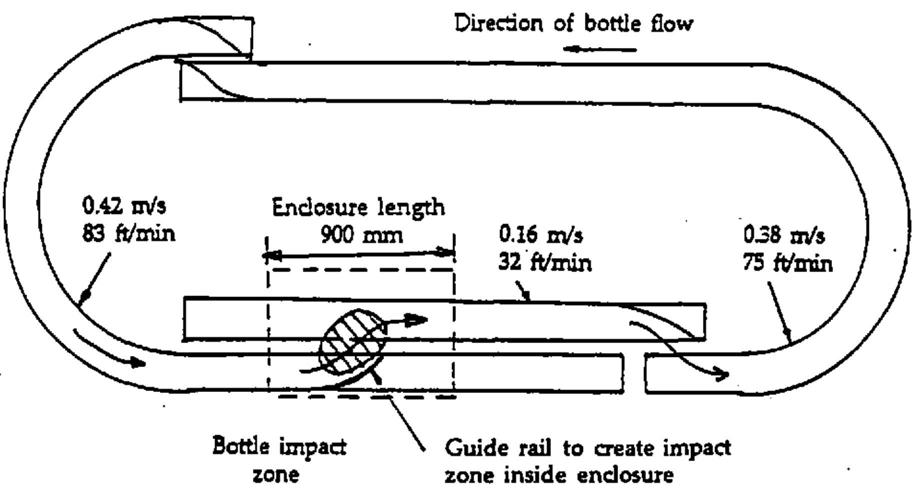
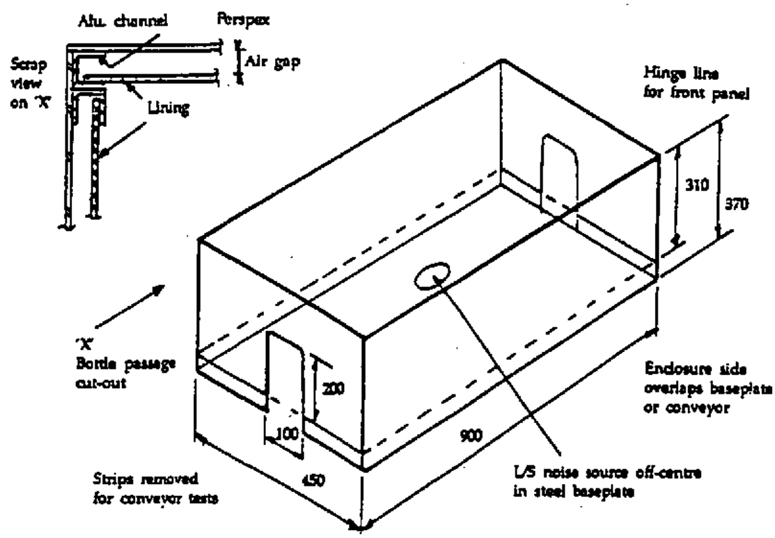


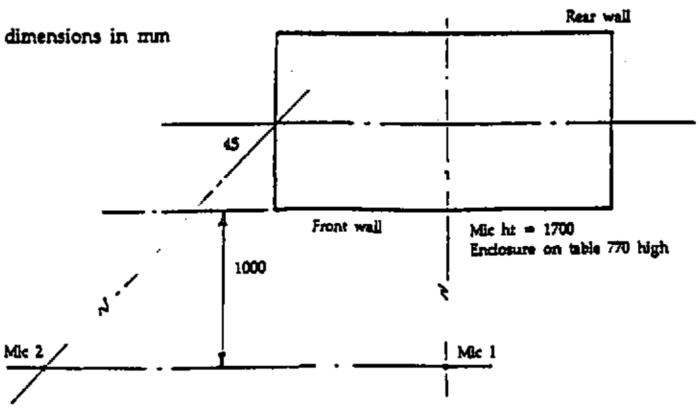
Figure 3 Line loop layout

TESTS OF A ROBUST ACOUSTIC ABSORBER MATERIAL



Model Cover

All dimensions in mm



Plan View showing Microphone Locations for Anechoic Chamber and Line Test

Figure 4

Table 1 Summary of model cover tests programme

Purpose	Environment	Aims: To determine Insertion Loss as stated
1) Measure direct field IL	Anechoic chamber	A. Unlined 1. Fully sealed, cover wall material (anechoic only) 2. With end-wall openings 3. Effect of side-panel open (anechoic only)
2) Measure reflected field IL of cover	Reverberation chamber	B. Lined 1. Faced foam (anechoic only) and microporous sheet 2. Increasing lined area 3. Air gap depth behind lining panel 4. Thickness of microporous lining material 5 Lining as wall material (anechoic only)
Measure with real source; on conveyor	Line loop tests	Microporous sheet lining only 1. Unlined 2. Increasing lining area 3. Thickness of lining material

Table 2 Model enclosure test results: summary of main results
IL dB(A) = No enclosure - Test enclosure

Environment	Direct field		Reflected field	Conveyor loop	
Test Condition Mic (Fig 4):	1	2	(Remote)	1	2
Unlined:	11	1	3	5	2
1. Lined:					
Faced-foam (24 mm, 1 side)	13	4	-	-	-
2. Microporous:					
2.1 25 mm airgap	14	5	7	8	3
1.5 mm, 1 side	18	10	11	9	6
1.5 mm, 1 side + top	-	-	13	9	6
1.5 mm, 2 sides + top	15	7	7	8	3
4.7 mm, 1 side + top					
2.2 No airgap	14	6	-	-	-
1.5 mm, 1 side + top	16	7	-	-	-
4.7 mm, 1 side + top					