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Factors Affecting the Sound Insulation Provided by Windows

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1. Introduction

Since the introduction of the Noise Insulation Regulations (1975) there have been a number of field studies into the effectiveness of secondary glazing systems installed under these regulations. Examples of this include work by Utley and Sargent (1), Deag, Fontaine and Pittams(2).

Sargent(1) reported that the sound insulation provided by a secondary glazed window, installed under the Noise Insulation Regulations, is very similar to that provided by a thermal glazed window (ie with a small pane spacing). This was based on a traffic noise spectrum using a dB(A) level difference (D_A) and the comparison was based on a large number of windows.

From the results obtained by Sargent it is reasonable to conclude:

1. The performance of the noise insulation package is very variable;
2. Thermal glazing (with a small pane spacing) produces a similar performance to that provided by secondary glazing systems.

These trends contrast significantly with the D_A values obtained for laboratory measurements as shown in table 1. From table 1 it can be seen that in the field the performance of the thermal glazing is comparable to that provided by the secondary glazing. In the laboratory, however, the thermal glazing provides a performance equivalent to that provided by single glazing.

In an attempt to understand some of these anomalies this work has compared the effects of some modifications to the window/frame. In addition results obtained using different measurement methods are also considered.

Weighting Method	Field Measurements			Laboratory Measurements		
	Single	Thermal	Secondary	Single	Thermal	Secondary
D_A	28.6	33.3	34.3	40.4	40.8	45.2

Table 1: Typical results from field measurements taken by Sargent(1) measured directly in a normal living room (Reverberation time ~ 0.3 s) and laboratory tests covered in this paper normalised to 0.3 seconds.

2. Program of work.

The effects of the factors listed below on the sound insulation were investigated

i. **Experimental Method.** A comparison of idealised field measurements with standard laboratory measurements to see if laboratory measurements are a good indicator of field measurements.

ii. **Coupling.** Work by Vinokur(3) suggests that having a mechanical bridge joining the two leaves of a double partition can effect the sound insulation. When the windows were installed in the transmission suite an isolated reveal liner was installed, which was not connected to the primary frame. By screwing wood bridging pieces between the primary frame and the reveal liner the two panes could be effectively linked.

iii. **Frame type.** This is not usually considered. For this work the same tests have been repeated for three different types of frame. All the frames were to fit in an aperture 1.76m x 1.19 m. Two wooden frames, one with large panes and one with small panes were used. In addition a μPVC frame with similar pane sizes to the large pane wood frame was tested. A simple sliding secondary glazing system was also installed. This used 4 mm glass. Spacings of 150 mm and 300 mm were tested.

iv. **Glazing System.** In order to improve the sound insulation additional panes of glass are often used. These can take the form of thermal glazing units where the inter pane spacing is small (typically 12 mm), or secondary glazing where a second window frame is necessary, (for this the usual spacing is 150 mm). Both systems were tested in this work.

v. **Sealing.** The necessity for sealing has been demonstrated in work by Wooley(4), and is confirmed by Lewis(5) and Bishop(6). The importance of sealing the primary and secondary windows is investigated here.

iv. **Reveal Lining.** The noise insulation regulations (1975) require an absorbent lining for the reveal and the effect of this is investigated here with different cavity widths.

3. Description of the laboratory conditions

All the laboratory tests were undertaken at the Building Research Establishment, using either the Anechoic/Reverberant facilities to simulate ideal outdoor to indoor conditions, or the transmission suite .

The anechoic/reverberant facilities consist of an aperture approximately 5 m x 3 m between the anechoic and reverberant chambers. Within the aperture a brick and lightweight block cavity wall was built, leaving a suitable opening for the installation of the window frame. Parkin (7) gives a full description of the constructional details of this facility. To improve the sound insulation of the wall constructed in the aperture an independent lining of plasterboard was installed on the reverberant side.

The transmission suite consists of two adjacent rooms (volumes 116 m^3 and 130 m^3) The smaller room is isolated from the larger room. There is an aperture (2.7 m x 3.6 m) between the two rooms. Into this on the north side of the separating cavity is built a 225 mm brick wall with a suitably size aperture for the window frame. To reduce flanking a 112 mm brick wall with a matching aperture for the window has been constructed on the south side of the cavity. A loose fitting timber blocking piece has been used to close the cavity between the two walls. Onto this closing piece a liner has been fitted, into which a secondary glazing system may be installed. This liner is isolated from the main structure.

4. Measurement Technique

The sound reduction indices for windows and other partitions may be obtained either by assuming the sound field in the receiving room is diffuse and measuring using microphones, or by the use of intensity techniques. Both methods are outlined below.

For the measurements undertaken within the transmission suite the standard method outlined in BS2750 part 3 / ISO 140 part 3 (8) was used. The sound reduction indices were calculated using the formulae given in this standard (8).

For the measurements using the anechoic/reverberant chamber the method detailed in the committee draft ISO 140 Part 5 (9) was used. This requires placing the source at a minimum distance of 5 m from the partition and at an angle of 45° to the test partition. The source levels were measured by microphones mounted directly on the surface of the window pane. The receiving room levels were measured by using several microphones throughout the reverberant chamber, or by following the procedure outlined in annex E of (9), using an intensity measuring system. Here the sound intensity probe is used to obtain the sound intensity entering the receiving room via the panel. An advantage of this method is that a diffuse sound field in the receiving room is not necessary. In many cases it is essential to add absorbent to the receiving room to improve the accuracy of the measurements. The second advantage is that the method only considers the sound entering the receiving room via the panel under test, hence any reduction in the sound insulation by flanking transmission is reduced. Against this must be set the complexity and increased expense of the equipment.

Work by Emmanuel (10) has compared the results obtained by using an intensity method with those results obtained using more traditional methods. The results compare well, and so the intensity method has been considered acceptable for use in this study.

This work has used all of these methods. For the measurements in the anechoic chamber the intensity method was chosen because of the relatively poor sound insulation provided by the wall in which the windows were mounted. When the measurements were undertaken in the transmission suite the standard method was perfectly adequate, though some measurements were undertaken using the intensity method for comparison purposes. Again the sound reduction indices have been calculated using the formula given in the draft standard (10).

5. Results and discussion

A selection of the results have been presented as figures 1 - 10. From the results the following findings appear:

i. Experimental method. The draft ISO 140 (9) details a method of measuring with a 45° angle of incidence that should give field results that are comparable with laboratory (transmission suite) results. This supposition is based upon work by Eisenberg(11). It can be seen that for the single (4 mm) glazing (fig 1) this comparison of transmission suite (random incidence) with directional (45°) does work. The single figure R_w obtained for both methods is 30 dB. However when the 6-12-6 thermal glazed window (fig 2) is considered the comparison is not as good. This gave an R_w of 34 dB when tested using the idealised field conditions and 32 dB when tested using the transmission suite, although the shape of the sound reduction index curves are similar.

Another anomaly comes to light when we consider the anechoic and reverberant chamber measurements. One of the tests undertaken was to reverse the direction of measurement. This is similar to attempting to measure the sound insulation of a window by having the source inside the building and measuring the sound exiting via the window using an intensity probe. The results compare well for thermal glazing (fig 3), however when an additional pane in the form of secondary glazing is added there is a marked difference. This was not found when the measurement direction in the transmission suite was reversed (fig 4) both with and without the second pane. This suggests that the difference is a consequence of the measurement method, not a property of the window.

ii. Coupling. It is well known that having a mechanical bridge joining the two leaves of a double partition can effect the sound insulation, but the size of the effect for windows has not been investigated.The secondary windows were installed in the transmission suite on an isolated reveal lining. This was done using foam to isolate the lining from the reveal. The secondary glazing was then attached to this lining. By screwing wood bridging pieces between the primary frame and the reveal liner the two panes were effectively linked. The degradation in the sound insulation across the frequency range can clearly be seen (fig 5). Here the R_w decreased from 52 dB to 50 dB. When the primary window was 4 mm glass and the spacing only 150 mm the R_w was reduced from 42 dB to 41 dB.

iii. Frame type. The performance of the μPVC frame was very similar to that provided by the well sealed wood frame with the 6-12-6 thermal glazing. The R_w was 36 as opposed to 34 for the wood frame. This slight difference is probably due to the poorer sealing of the wood frame. As would be expected from theory the small pane wood frame give a marginally better performance at the lower frequencies as illustrated in fig 6.

iv. Sealing. The necessity for sealing is well known and has been demonstrated in work by Wooley(4), and others (Lewis(5) and Bishop(6)). This work confirms that good sealing is essential. A 2 or 3 dB improvement to the single figure ratings was achieved by use of an additional foam seal round the openable panes for the already sealed wood frame to compensate for slight warping. This degradation is still apparent for secondary glazing where the secondary pane seals well but the primary pane is not fully sealed (fig 7). The failure of sealing is generally indicated by the presence of dips in the insulation curve between 800 Hz and 2 kHz. Burgess(12) has proposed that these dips in the insulation curve are caused by the cavity enclosed by the opening part of the frame acting as a resonator.

iv. Glazing System. As would be expected the use of multiple panes improves the sound insulation. As mentioned earlier when tests are undertaken in the field there often appears to be little difference between the insulation provided by thermal glazing compared to that provided by the secondary glazing system. The results obtained in both the anechoic chamber (fig 9) and the transmission suite (fig 8) do not support this. The secondary glazing provides a considerable improvement over the thermal glazing. A possible explanation for this is that in these experiments both the primary and secondary windows were well sealed, whereas in the field, the secondary glazing generally utilises the original (and often poorly sealed) primary window frame which degrades the performance. Figure 7 illustrates the effect on the insulation provided by secondary glazing when any additional primary sealing is removed. Many original windows will have even less sealing than this. When thermal glazing is installed a new and far better sealing frame is installed as well as the new glass, so optimum performance is achieved. The results also demonstrate the effect of the pane spacing for secondary glazing systems. The large spacing giving an improvement at the lower frequencies.

vi. Reveal Lining. The results (fig 10) show that the use of a reveal liner gives a 2 or 3 dB improvement at higher frequencies. Each line is calculated from the measurements taken with the specified pane spacing both with and without the tile lining, so it is a demonstration of the effect of the liner at that spacing. This effect appears to be increased when the spacing is larger and the area of absorbent can be greater.

6. Conclusions.

This work shows that there are several factors than can effect the performance of a window, some of which affect all windows.

The most significant factor appears to be sealing. Poor sealing will usually cause a reduction in the sound insulation of the order of 3 dB. The effects of poor sealing are apparent as a large dip in the insulation curve at frequencies above 800 Hz. This poor performance is still apparent when other improvements such as the addition of a secondary pane are undertaken.

Other effects are only apparent when the insulation provided by the window is very good. For example the effect of coupling can only be seen when the performance of the secondary windows is already very good.

All this suggests that the detailing of the installation is as important as the improvement measures themselves.

7. References

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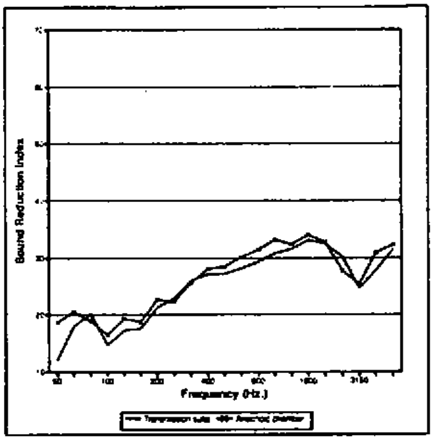

Figure 1. Comparison of test methods. Large pane wood frame fitted with 4 mm glass

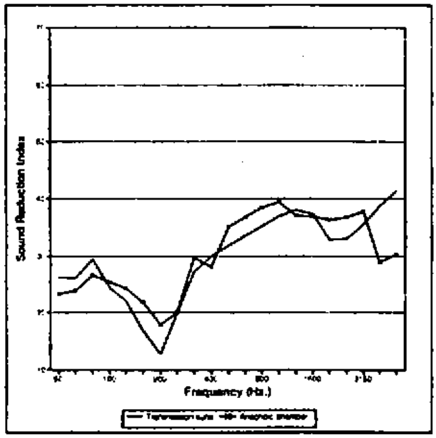

Figure 2. Comparison of test methods. Large pane wood frame fitted with 6-12-6 glass

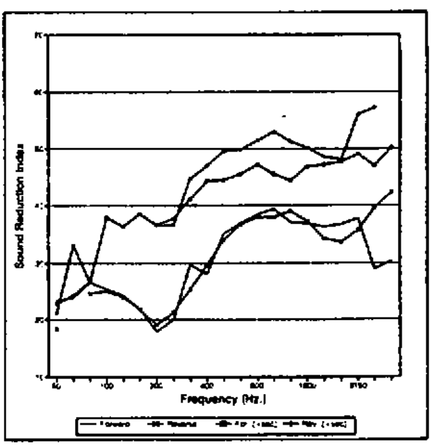

Figure 3. Direction of measurement test (forward and reverse directions).Large pane wood frame in the anechoic chamber. Fitted with 6-12-6 glass. With and without the secondary pane

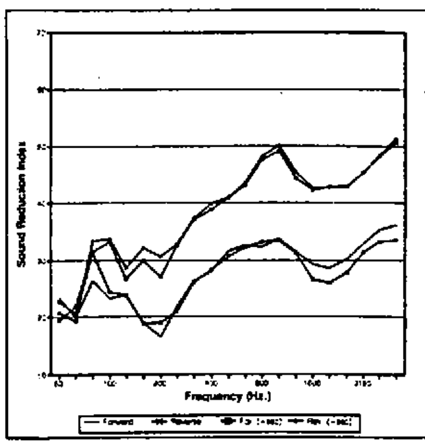

Figure 4. Direction of measurement test (forward and reverse directions). Large pane wood frame in the transmission suite. Fitted with 6-12-6 glass.
With and without the secondary pane

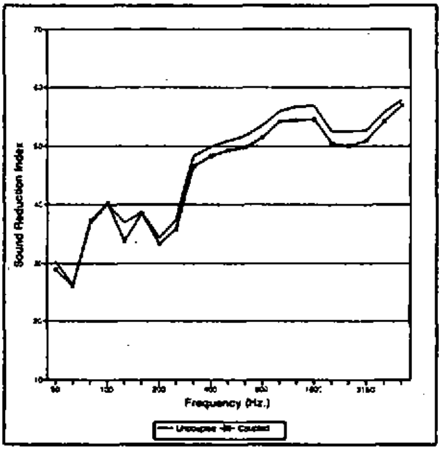

Figure 5. Effect of coupling. Large pane wood frame fitted with 6-12-6 glass and 300 mm secondary

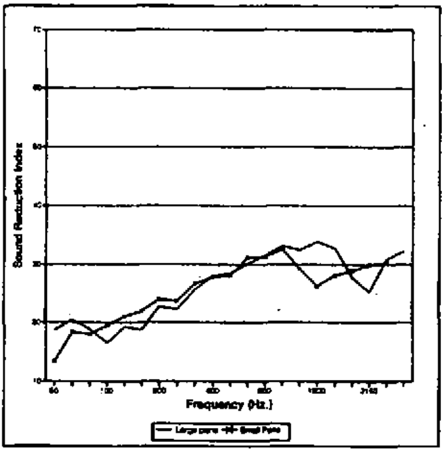

Figure 6. Effect of pane size. Wood frames fitted with 4mm glass in the anechoic chamber.

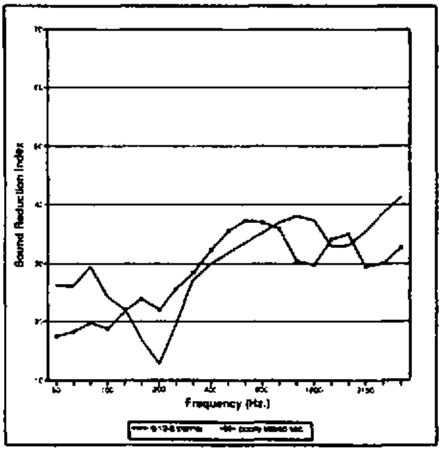

Figure 7. Comparison of insulation provided by a well sealed thermal window with a secondary glazed window with poor sealing.

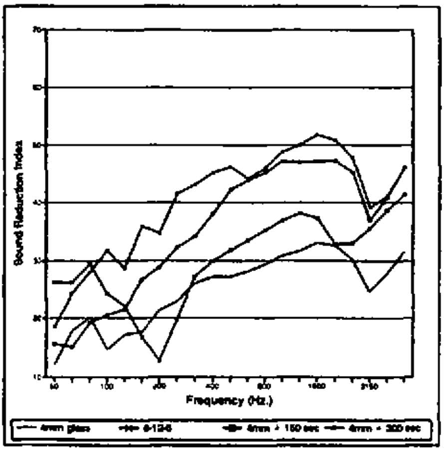

Figure 8. Effect of different window types. Large pane wood frame, tested in the transmission suite.

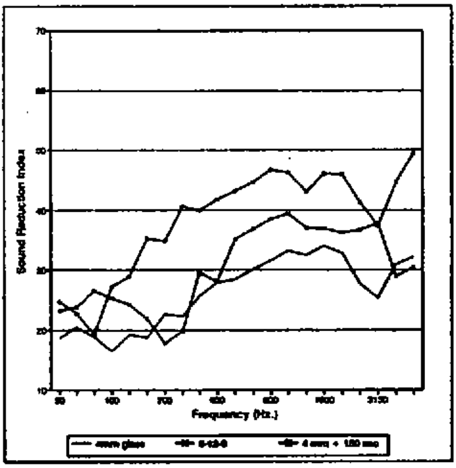

Figure 9. Effect of different window types. Large pane wood frame tested in the anechoic chamber

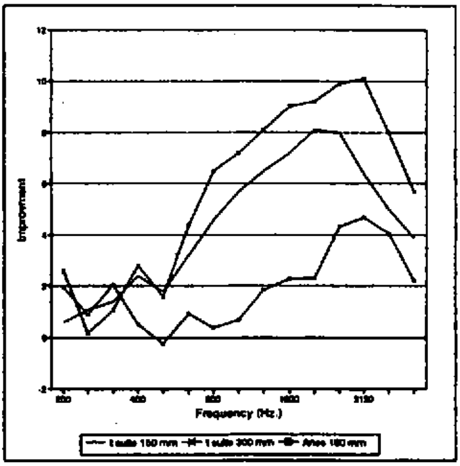

Figure 10. Improvements offered by a reveal liner. Large pane wood frame with 4 mm glass.