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SOUND INSULATION FOR HERMETICALLY-SEALED DOUBLE AND TRIPLE GLAZINGS

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INTRODUCTION

The Danish Acoustical Institute is carrying out a project series concerning optimization of sound insulation for windows. The total project comprises investigations of hermetically-sealed double and triple glazing and frame/sash constructions. Until now, double and triple glazings have been investigated. The influence of glass thicknesses, laminating, glass spacing(s), and gas filling on the sound reduction index has been examined. The results are described in [1] and [2]. The aim of the experiments is to give manufacturers of windows and glazings better possibilities of optimizing the sound insulation in relation to total weight, thickness, and price of the glazing.

FACTORS CONTROLLING SOUND TRANSMISSION THROUGH WINDOWS

Basically the sound insulation of a window depends on glass thicknesses, laminating, glass spacing(s), and cavity filling(s). Moreover, the sound insulation is influenced by the mounting conditions of the glazing, the type of frame and sash, the tightenings, and the size of the window. In addition, the importance of each construction detail is connected with different frequency regions, but the significance is dependent on the other details, too. These confounding effects are especially pronounced for windows. Combined with the fact that test results are laboratory-dependent it is often difficult to obtain useful comparisons between measurement results.

Unfortunately, the theoretical models for walls are not valid for windows. Empirical models modified for windows may be useful in some cases within limited frequency ranges. Due to the large amount of parameters for windows and the above-mentioned confounding effects, it is not possible to obtain full agreement between empirical and experimental data. The problems are especially connected to the frequency ranges around the resonance and coincidence dips which are often quite essential to the total performance of the window.

To obtain information on the importance of some parameters it is necessary to carry out series of measurements, varying the parameters in question. The remaining parameters and measurement conditions should be held as constant as possible. However, the parameters cannot be examined one by one. When planning experiments the mutual influences must be estimated and taken into account. If not done, the applicability of the results may be limited.

DESIGN OF EXPERIMENTAL INVESTIGATIONS

Test specimens

In order to achieve maximum usefulness of the project results, "realistic" test specimens were chosen for the experiments. I.e. the glazings were commercially produced hermetically-sealed double and triple glazings and were not extremely heavy, thick, nor expensive. The total thickness of the glazings was 14 to 44

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mm and the weight 20 to 42 kg/m^2. The glass thicknesses were 4 to 8 mm, laminated glass 8 to 10 mm, spacings 4 to 24 mm. Except for a special test series, the gas filling used for the experiments was SF_6.

The size of the windows was 12M × 12M corresponding to a test opening of 1,21 m × 1,21 m. As this size of facade windows is the most widespread size in Denmark, it is recommended as test size in the Danish Standard DS 1084 for classification of sound insulating windows. Most measurements were performed with glazings mounted in a firm frame (wood), but selected types of glazings were also tested in an openable window (wood).

A sectional view of the windows and their mounting in laboratory are shown on Fig. 1 and 2.

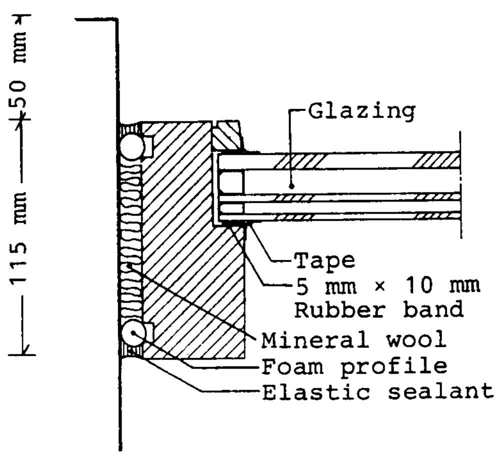

Fig.1 Firm window. Mounting in laboratory. Horizontal and vertical section.

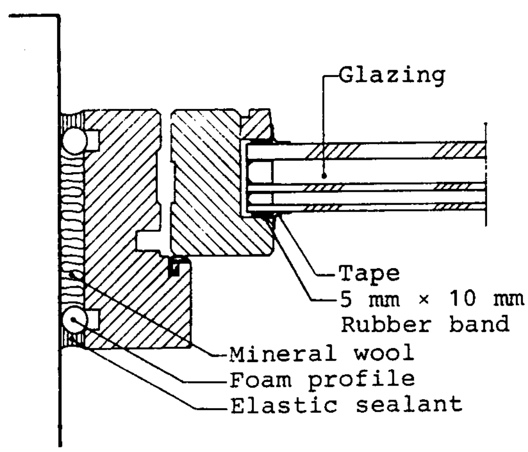

Fig.2 Openable window. Mounting in laboratory. Horizontal section.

In accordance with the test principles in ISO 140 (1978) the test specimens were mounted with ordinary mounting materials as far as it was practicable. Small and unessential changes (tightening with tape) were used taking into consideration a quick and safe accomplishment of the test series.

For several reasons the number of test specimens had to be limited as much as possible. When choosing glass thicknesses, lamination, spacings and fillings individually, there is an enormous number of different glazings. For double- and triple-glazed windows the number are more than 100 and 1000, respectively. Totally, 36 types of glazings (with gas filling) were ordered to the main parts of the three test series. The time interval between successive test series was approx. one year. Some duplicates were ordered to check the consistency of the production or simply to make it possible to carry out the measurement programme. Test specimens with atmospheric air in one or both cavities were obtained by a puncture and subsequent sealing. The full measurement programmes for the test series are found in [1] and [2].

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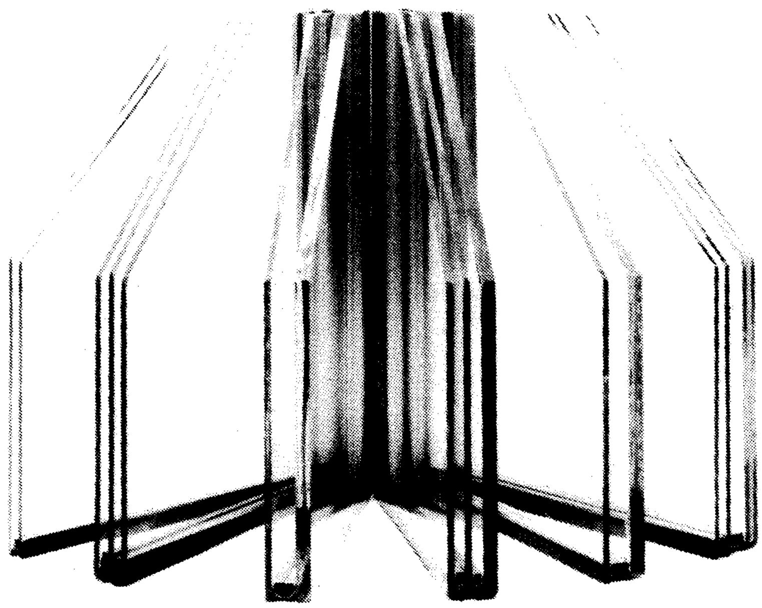


Fig. 3

Samples of different hermetically-sealed double- and triple-glazed units.

At the design of the experiments special importance was attached to examining glazings with small spacings (6-9 mm) and glazings with gas filling. Further it was considered essential to examine the effect of different fillings in the two cavities of triple-glazed units.

A few selected measurement results are presented graphically on Fig. 4-8. The glazings are identified by means of a "code" which specifies the glass thicknesses and spacings in the indicated order. The letters behind specify the fillings: G = gas filling (SF_6) and L = atmospheric air. E.g. 8-12-4-6-4 GL is the code for a triple glazing consisting of 8+4+4 mm glass and with 12 and 6 mm cavities with gas filling and air, respectively. The code 4/2/4 describes a laminate consisting of 4+4 mm glass with a 2 mm thick intermediate layer of laminating material. The "F" before the glazing code means that the result is found with the glazing mounted in the firm window.

Test facility and measurement procedure

The measurements are carried out in the transmission rooms no. 003 and 004 at the Technical University of Denmark. A detailed description of the rooms and the wall with test opening are found in [1] and [2] (in Danish). The rooms with a slightly changed wall is described in [3] and [4]. The test method, the measurement procedure, and the instrumentation are described in all 4 references.

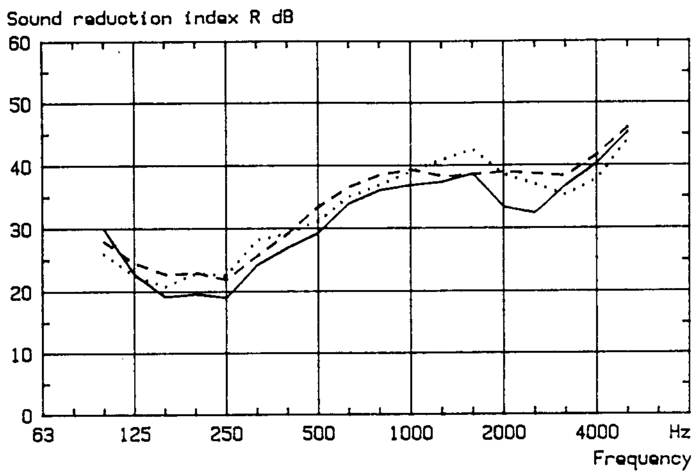
Precision of measurement results

A useful comparison between the experimental results presumes that the measurement procedure, the test facility, and the products are "well-defined" as described in [2]. It has been checked that the consistency of products and between test series is satisfactory. The checks are described in [2]. Confidence of test results are described more generally in [3] and [4].

EXPERIMENTAL RESULTS

In [1] and [2] R_w-values (ISO 717/3-1982) are found in tabular form. Besides there are presented a large number of comparisons of sound reduction index curves, which illustrate the influence of the examined parameters one by one and some examples of mutual influences are also found. Below the diagrams the R_w-value is found corresponding to each curve. Decimal values are mentioned, too, even if the R_w-value is defined as an integer value. This implies an easier assessment of the significance of the differences. A few selected diagrams are presented below, showing some of the experimental results.

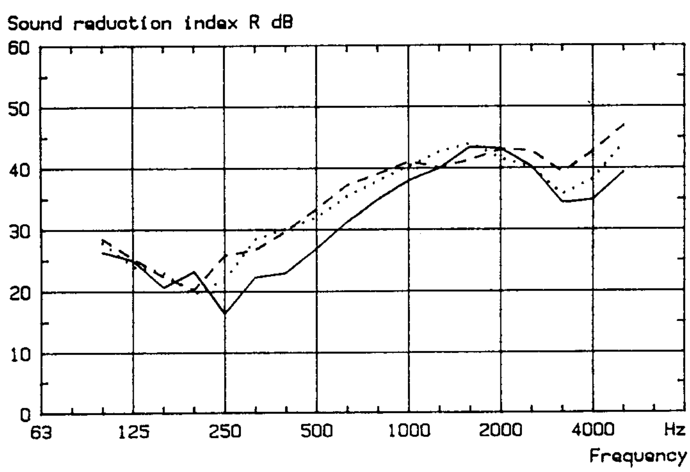
Fig.4 illustrates that asymmetry of glass thicknesses improves the sound reduction index in the whole frequency range and not only in the coincidence region. Fig. 4 and 5 show that a small asymmetry has a great effect, whereas the effect of a further change in glass thickness can be relatively small.



···············	F 6-12-4 L	R_w = 35 dB Δ_{max} = 5,4 dB ;	R_w(dec) = 35,4 dB
- - - - - - -	F 8-12-4 L	R_w = 35 dB Δ_{max} = 6,1 dB ;	R_w(dec) = 35,9 dB
————	F 6-12-6 L	R_w = 32 dB Δ_{max} = 6,0 dB ;	R_w(dec) = 32,8 dB

Fig.4

Sound reduction index curve for a symmetric double glazing (weight 30 kg/m^2) compared with curves for two asymmetric glazings (weight 25 kg/m^2 and 30 kg/m^2, respectively).

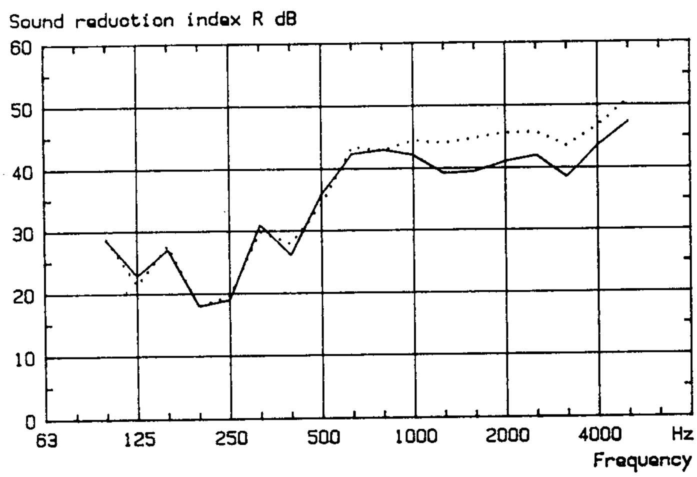


————	F 4-6-4-6-4 LL	Rw = 32 dB Δmax = 8.6 dB ;	Rw(dec) = 32.2 dB
············	F 6-6-4-6-4 LL	Rw = 36 dB Δmax = 7.0 dB ;	Rw(dec) = 36.0 dB
- - - - - -	F 8-6-4-6-4 LL	Rw = 37 dB Δmax = 6.7 dB ;	Rw(dec) = 37.0 dB

Fig.5

Comparison of sound reduction index for 3 triple-glazed units with different thicknesses of one of the outer glasses.

The influence of laminated glass is illustrated on Fig.6. An increase in the sound reduction index is obtained at the high frequencies. However, due to deep resonance dips (caused by gas filling in small cavities) for this specific glazing R_w is not improved by the lamination. With more optimized fillings (air in one cavity) the R_w-value will be increased by 2 dB, compare results for 8-6-4-6-4 GL (R_w = 38 dB) and 4/2/4-6-4-6-4 GL (R_w = 40 dB, see Fig.8).

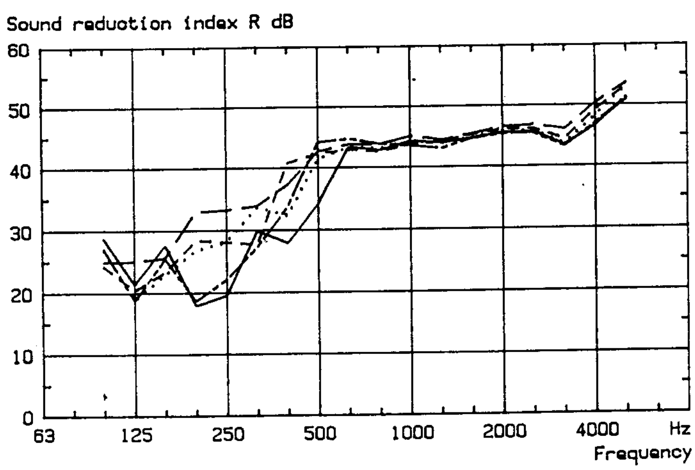


———— F 8-6-4-6-4 GG Rw = 36 dB Δmax =10.0 dB ; Rw(dec) = 36.1 dB
············ F 4/2/4-6-4-6-4 GG Rw = 36 dB Δmax = 9.4 dB ; Rw(dec) = 36.7 dB

Fig.6

Comparison of sound reduction index for an "ordinary" triple glazing and a corresponding glazing with one glass laminated.

On Fig.7 it is shown that changes in glass spacings can influence the sound reduction index considerably at some frequencies. The glazings are gasfilled, and the significance of spacings is much less pronounced with atmospheric air in one or both cavities.



———— F 4/2/4-6-4-6-4 GG Rw = 36 dB Δmax = 9.4 dB ; Rw(dec) = 36.7 dB
—·—·—· F 4/2/4-9-4-9-4 GG Rw = 38 dB Δmax = 9.3 dB ; Rw(dec) = 38.1 dB
············ F 4/2/4-12-4-6-4 GG Rw = 40 dB Δmax = 6.6 dB ; Rw(dec) = 40.7 dB
– – – – – – F 4/2/4-12-4-12-4 GG Rw = 41 dB Δmax = 9.3 dB ; Rw(dec) = 41.3 dB
—— —— —— F 4/2/4-20-4-6-4 GG Rw = 43 dB Δmax = 5.0 dB ; Rw(dec) = 43.3 dB

Fig.7

Comparison of sound reduction index curves for triple-glazed units with different combinations of spacings, but all with identical glass combination and gas filling.

Gas filling influences the sound insulation. However, the use of gas filling in sealed glazings was originally promoted due to the influence on the heat insulation.

For some types of glazings the choice of gas filling is important to the sound insulation as illustrated on Fig.8. A better sound insulation is obtained with gas filling in one cavity than with gas filling or air in both cavities. It is assumed that the main reason for this phenomenon is mismatch of modes in the two cavities due to different sound velocities for SF_6 and atmospheric air. It should be noticed that the order of glass thicknesses, spacings, and fillings are not unimportant. As an instructive example it could be mentioned that for the glazing 4-12-4-6-4 with fillings GG, GL, LG, and LL the measured R_w-values are 32, 35, 32, and 32 dB, respectively.

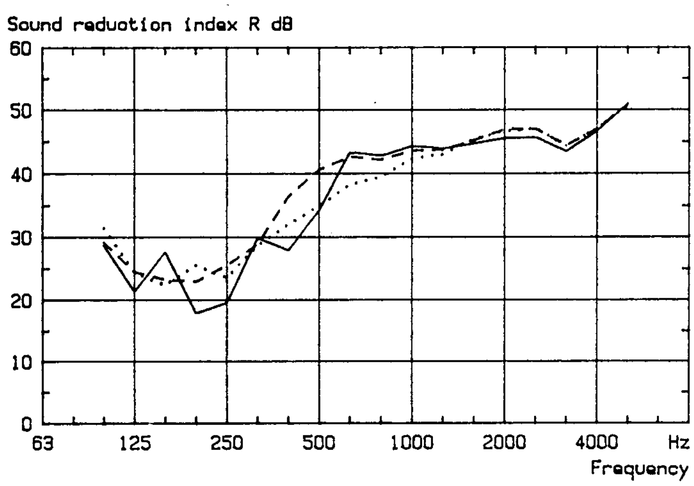


Fig.8

Comparison of sound reduction index for a triple glazing 4/2/4-6-4-6-4 with different combinations of cavity fillings.

It might be useful to compare the sound insulation for double- and triple-glazed windows. Generally considered the experimental results show that triple glazings are heavier than double glazings with the same sound insulation. As regards the total thickness the results are more equal. However, without a well-defined basis of a comparison no general answer could be given. In some cases triple-glazed windows are preferred due to better heat insulation. Sometimes the dividing of the spacing into two smaller spacings can be utilized to an improvement of sound insulation, depending on the actual type of glazing. For example it might be profitable with different fillings in the two cavities.

It should be mentioned that in some literature the upper resonance frequency of a triple glazing is considered unimportant. However, if both cavities are small and gasfilled, it is found that both resonance dips are pronounced. Obviously, this is the case for the curves on Fig.6.

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CONCLUSIONS

The experimental conclusions indicated below should be evaluated in the light of ordinary glazings being symmetric. In Denmark typical glass spacings in double- and triple-glazed windows are 6 to 16 mm and 6 to 9 mm, respectively.

Based on R_w (ISO 717/3-1982) as a measure of the sound insulating property of a window, the following main results have been achieved from the experiments with double- and triple-glazed windows (the gas used is SF_6). The sound insulation is improved by:

- Asymmetry in glass thicknesses
- Using laminated glass
- Increasing the glass spacings - this applies especially to glazings with gas-filled cavities
- Gas filling in a double glazing with a spacing of more than 12 mm
- Gas filling in one of the two cavities in a triple glazing

The last-mentioned result is particularly interesting because it is a rather simple way of improving the sound insulation. Gas filling in both cavities of a triple glazing causes only in a few cases an increase in sound insulation. With small spacings (6 to 9 mm) the sound insulation of a double or triple glazing is reduced by the gas filling. The experiments have been carried out using SF_6, which is the type of gas mostly used. The results cannot be applied right away when using other types of gas with substantially different acoustic properties.

The exact influence of one single change of design can neither be predicted generally - the significance of a detail is, unfortunately, dependent on the overall construction of the window - nor is there a simple connection between the sound insulation and the total thickness or weight of the glazing.

The experiments showed that an optimization of glazing details often results in a 3 to 5 dB higher sound insulation (R_w-value), alternatively a lower weight, thickness or price. The results from Fig.8 can be considered as an example of optimization. The thickness and weight is the same for all three glazings. The price differences are small, but in fact the most expensive glazing is the poorest one with R_w = 36 dB. If "forgetting" the gas filling in one cavity, the R_w-value is improved with 4 dB!

Generally, the best sound insulation is obtained for an asymmetric construction. For a triple glazing this means asymmetry as regards glass thicknesses, interpane spacings, and interpane fillings. Qualitatively indicated, a good and economic "design" of a 3-layer window is achieved by the following order of glasses and spacings:

- Thick glass or laminated glass, if necessary
- Large spacing with gas filling
- Thin glass
- Small spacing with atmospheric air
- Thin glass

Regarding the gas filling pure SF_6 or a gas mixture with SF_6 as the main constituent is assumed.

A specific requirement as regards the sound insulation of a window can perhaps only be met by changing several design details. However, there is an upper limit to the obtainable sound insulation. This limit depends not only on the glazing, but also on the frame/sash type and tightenings. If an R_w-value of more than approx. 38 dB is required for an openable window, it will normally be necessary with two effective tightenings in the joint between frame and sash.

The importance of each construction detail is connected with different frequency ranges, and different changes cannot replace one another right away. In practice, the effect of glass thicknesses is primarily connected to frequencies below 1000 Hz and above 2000 Hz, lamination to the frequency range above 1000 Hz, spacing to the frequency range below 800 Hz and gas filling to frequencies below 1000 Hz.

The importance of the frame/sash construction depends on a number of factors which are not yet completely examined. However, some aspects are indicated in [2] and [5]. It has been established that the effect may be favourable in one frequency range (below approx. 1000 Hz) and unfavourable at other frequencies. When using a glazing with a high sound insulation, the sound reduction index of the total construction can be reduced by sound transmission through the frame and sash material, primarily in the frequency range of 500-2000 Hz. This was also found for some of the windows in the present investigation. Further it is well known that leaks are of special importance at frequencies above approx. 500 Hz. The problems connected to frame/sash construction are being examined more closely in a project which will be finished by the end of 1986.

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