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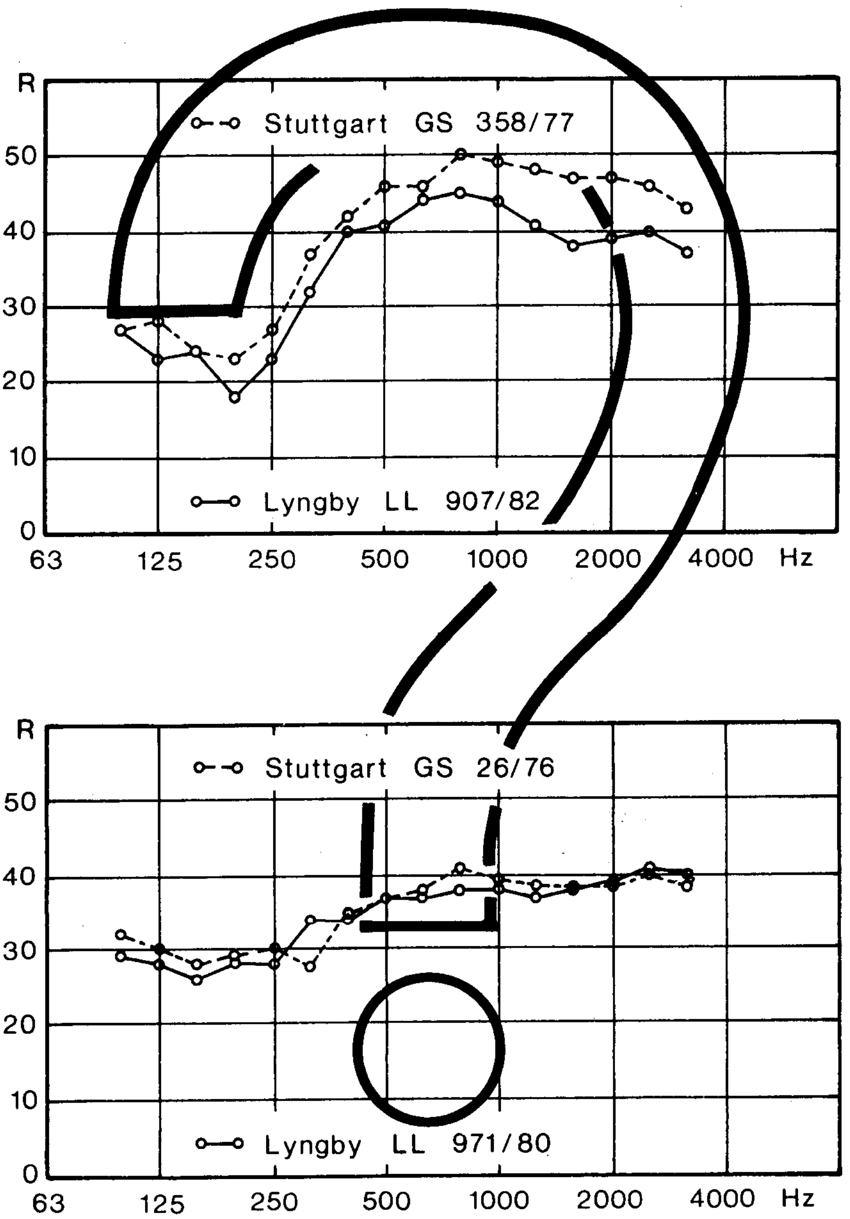
Laboratory Effects on the Measured Sound Reduction Index of Windows and Glazings

Nordtest Project 215-80



Danish Acoustical Laboratory
The Danish Academy of Technical Sciences

Report no. 34 1982

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TECHNICAL REPORT

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Head of Institute: A. C. Nilsson

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Work carried out by: Nic Michelsen & Birgit Rasmussen

Reporters sign.

Summary

This report presents an investigation carried out for Nordtest. The aim has been to give an explanation of differences in sound reduction index of windows or glazings when measurements in different laboratories are compared.

It has been shown that the measurement results slightly depend on the geometry of the test aperture and on the position of the test specimen in the aperture. For a laminated sound insulating pane the differences found with different geometries of the test aperture were rather small. Some additional measurements on an ordinary insulating pane showed a larger spread.

It is concluded that NT ACOU 013 DOORS AND WINDOWS: SOUND REDUCTION INDEX [1] is satisfactory in order to obtain stable results within a single laboratory. The actual way of mounting is shown to influence greatly the sound reduction index of a pane. Thus the mounting of a pane needs to be carried out according to real building practice.

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2. INTRODUCTION

During the latest years measurements of the sound reduction index of windows and panes have become more and more important. The reason is of course the increasing outdoor noise levels and requirements or recommendations introduced by various authorities.

In Denmark it is now possible for a manufacturer of a window to obtain a classification on the sound insulation properties of a window construction according to a Danish Standard [2]. The classification is based on a measurement of the sound reduction index of the window under laboratory conditions. Similar standards for classification of the sound insulation properties of a window might as well be adopted in the other Scandinavian countries. Some years ago a standard of this kind was adopted for doors. Then the acceptance of measurement results from country to country was hardly achieved until a comparative investigation [3] showed a good agreement between four Scandinavian laboratories. As a part of that work the NT ACOU 013 [1] for measurements of the sound reduction index of doors and windows was established.

The background of the present Nordtest-project arises from difficulties in obtaining similar results for identical products if the measurements are made in Scandinavia and compared to German results. The German DIN 52210 [4] has recently been revised, now providing detailed instructions for

a) the wall with the test opening restricted to be made as a double wall of plastered brickwork (ρ = 1800 kg/m^3) or concrete having a total depth of 410 mm ±10 mm,

b) the test opening restricted in dimensions to a width of 1250 mm and a height of 1500 mm,

c) the test opening prescribed to be staggered on the top and the two vertical sides by 60 mm to 65 mm,

d) hinged windows to be mounted in one of two defined positions,

e) panes to be mounted in a defined position using a prescribed way of mounting.

The two positions for mounting of windows according to DIN 52210 [4] are shown in Figure 2.1 whereas in Figure 2.2 the position and way of mounting of a pane is shown.

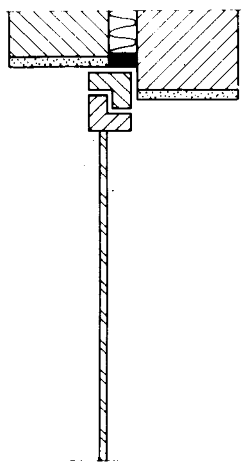


Bild 8. Einbau eines Fensters gegen Anschlag

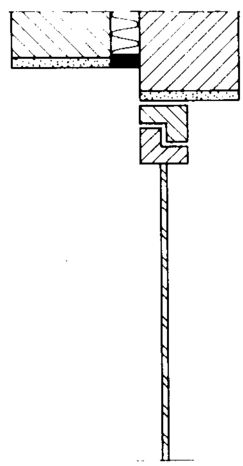


Bild 9. Einbau eines Fensters stumpf

Figure 2.1 Positions for mounting of windows according to DIN 52210 [4]

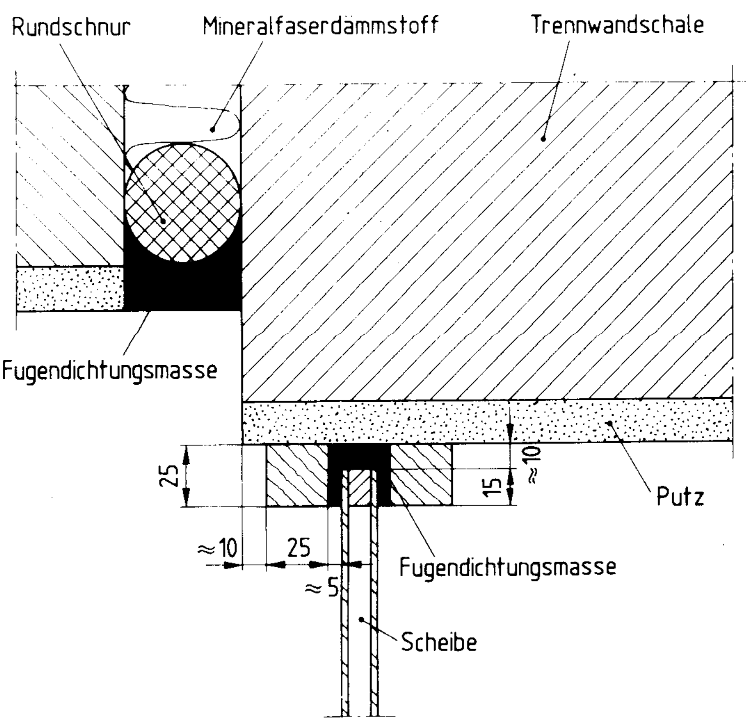


Bild 11. Einbau einer Scheibe stumpf, Einzelheit zu Bild 10

Figure 2.2 Position and way of mounting of panes according to DIN 52210 [4]

It is evident that the restrictions on mounting presented in DIN 52210 [4] are given in order to achieve a better agreement between measurements carried out by different laboratories. However, no technical background for the different restrictions has been presented yet. Thus some doubt about the necessity of such restrictions are quite natural as common laboratory practice in Scandinavia will not meet these restrictions.

For example a staggered test opening is never used in a Scandinavian laboratory.

Due to a discussion of these problems it was decided to investigate the influence of design of the test opening and possible mountings of a window in the test opening as a Nordtest -project. It was decided that one laboratory should carry out measurements under different mounting and boundary conditions in order to examine possible variations within a single laboratory.

3. REPORT ON THE ACTIVITIES OF THE PROJECT GROUP

The members of the project group were:

Kaj Bodlund, Statens Provningsanstalt, Sweden;
Nic Michelsen (convenor), Lydteknisk Laboratorium, Denmark;
Juhani Parmanen, Statens Tekniska Forskningscentral, Finland;
Terje Tengesdal, Akustisk Laboratorium, Norway.

The secretariat was placed at the Danish Acoustical Laboratory (Lydteknisk Laboratorium), which also conducted the measurements.

The project group met in Lyngby on 1st July, 1981. At that time part of the total measurement programme had been carried out. Therefore discussions were both related to general problems and to the results of the investigation carried out so far.

In all the Scandinavian countries it had been observed that very high sound reduction indices of panes were presented by German manufacturers. It was the general opinion that due to differences found comparing Scandinavian and German test results the whole problem of testing windows and/or panes needed further treatment. On the other hand the restrictions presented in DIN 52210 [4] were not felt to be attractive compared with common practice in Scandinavia. Further there was no evidence that the restrictions of DIN 52210 [4] would prevent unrealistic measurement results from particular laboratories.

It was agreed that problems did exist related to the choice of measurement object which could be

- a window with pane,
- a pane mounted in a sort of neutral frame, or
- a pane alone.

It was the general opinion that the test object of interest was the window with pane which should be tested as a whole.

It was not possible to reach any conclusion for measurements on the pane. It was argued that data on panes (alone or in a neutral frame) had been misused as data for actual window constructions. In contrast to this, panes mounted in a fixed wooden frame have been tested in Denmark for several years as well as windows with panes. Experience from the last few years has further demonstrated that the sound reduction of a pane strongly depends on the width of the frame. Thus no simple answer exists to this problem and no general agreement could be found within the project group.

The part of the investigation carried out prior to the meeting was considered and some additional measurements were decided.

By correspondence the project group later reached the following conclusions:

1. Considering the position of the test specimen within the test opening, the existing NT ACOU 013 [1] gives a satisfactory recommendation.

   In this standard it is recommended that the test specimen is mounted with niches at both sides having a ratio in depth of 1:2. Moreover this corresponds to common building practice in Scandinavia.

2. The use of a staggered test opening seems to give no significant advantages compared to ordinary flat test openings. Such staggered test openings might cause problems with increased flanking transmission. Further the mounting of a window with a deep frame would be restricted with respect to the choice of position within the test opening.

3. Measurements on a pane strongly depends on the mounting.

   In case such measurements are carried out, the mounting must be in accordance with actual building practice. The mounting conditions should be properly described in the test reports.*

* This problem has been taken up within ISO and will hopefully be solved in the next edition of ISO 140/III.

4. INTRODUCTION TO THE INVESTIGATION

The measurements have been carried out in the sound transmission rooms (004 and 003) at the Technical University of Denmark. The rooms have been built for measurements of the sound reduction index of walls, but are often used for tests on smaller building components like doors and windows.

In such cases a wall with a high sound reduction index is erected in the test opening. In this wall a test aperture with dimensions suitable for the actual test specimen is left open.

4.1 Description of Test Facility

The two rooms (004 and 003) have a width of 6.25 m and a height of 4.95 m. The length of room 004 equals 7.85 m whereas the length of room 003 equals 7.65 m. Between the end walls of the rooms - the thickness of which is 10 cm and 30 cm, respectively - there is an 80 cm thick concrete frame with a test opening, which is 3.68 m wide and 2.69 m high. The remaining walls, ceiling and floor are all made of 30 cm concrete. Both rooms and the concrete frame have their own separate foundations.

Sound diffusing elements of concrete or damped steel plates are placed on two walls and the ceiling in each room. The volumes of the two rooms are about 230 m^3 (004) and 215 m^3 (003), respectively.

In the test opening a 30 cm thick double wall was erected. Each side of the wall consisted of 10 cm lightweight concrete elements (650 kg/m^3), and the 10 cm cavity of the wall was filled with glass wool. After the measurement of the sound reduction index of the wall itself (see Figure 4.4) a 121 cm × 121 cm test opening was cut in the wall. The test opening was 60 cm above the floor and the distances to the sides of the original test opening were 121 cm and 127 cm.

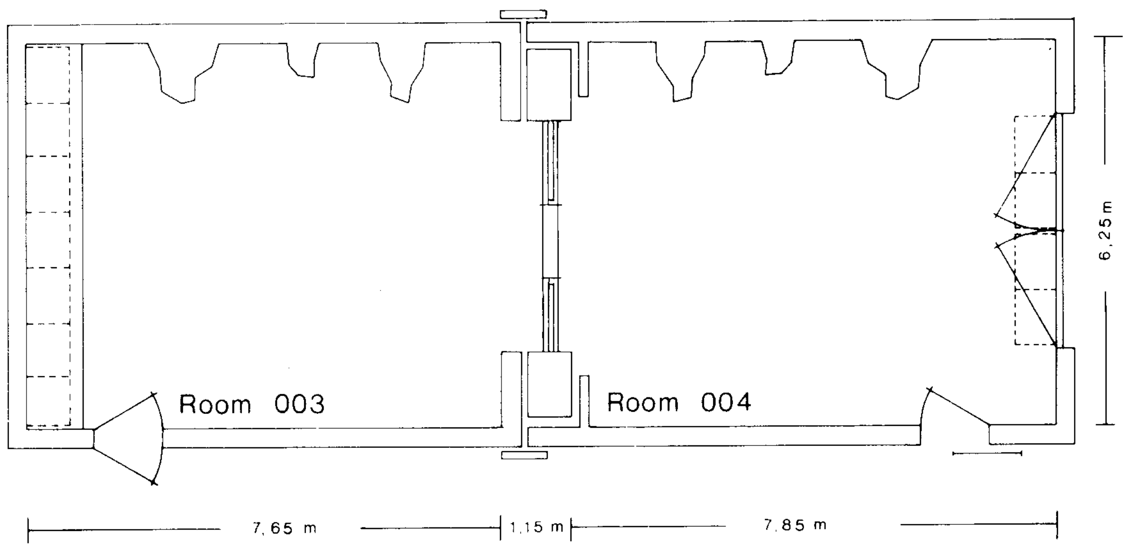


Figure 4.1 Horizontal section of the reverberant rooms at the Technical University of Denmark

The cavity in the wall was covered in the test aperture with a 19 cm × 10 cm lightweight concrete element. The joint between the two parts of the wall was sealed with an elastic material approximately ½ cm deep. Plaster was applied to the inside of the aperture.

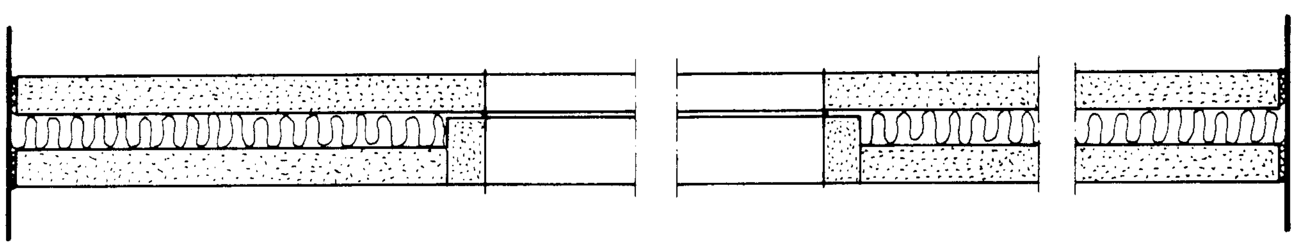


Figure 4.2 Horizontal section of the lightweight concrete wall with test opening

4.2 Description of Measurement Procedure

The measurement were carried out sequentially in 1/3 octave bands from 100 Hz to 6300 Hz. Two rotating microphone systems (16 s./rev., radius approximately 125 cm) were used.

The measurements were performed using the B & K 4417 Building Acoustics Analyzer. An integration time of 32 s. - equal to two revolutions of the rotating microphone system - was used for the sound pressure level measurements. The reverberation time was evaluated over a range of 20 dB using 3 excitations in each of 3 positions equally spaced around the microphone path. Each decay was evaluated separately and the average reverberation time was given as the result. The microphones were calibrated before each measurement and the calibrations controlled after the measurement series had been completed.

The instrumentation used during the measurements is shown in Figure 4.3.

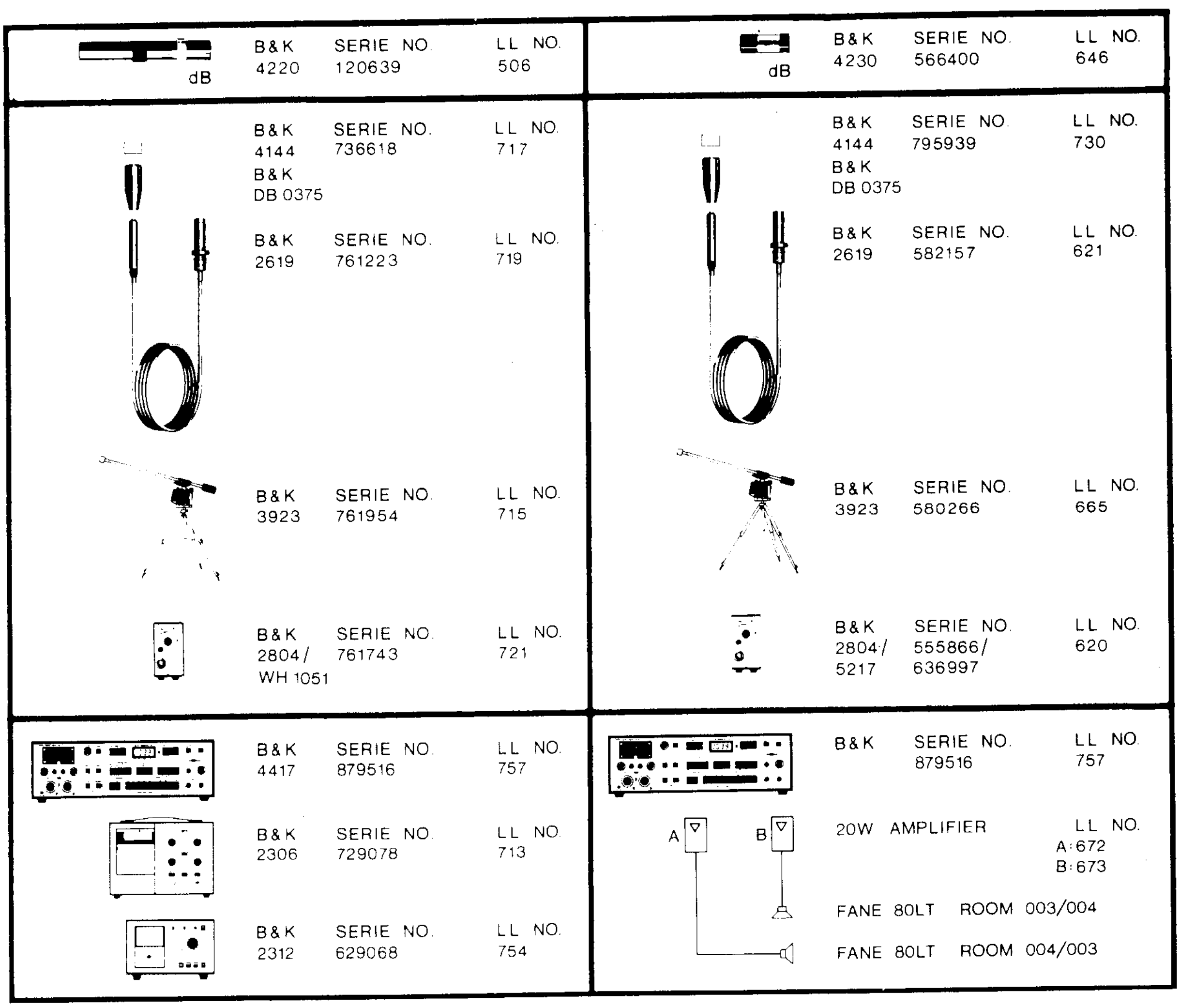


Figure 4.3 Identification of measuring instrumentation

The sound reduction index was determined according to

$$R' = L_s - L_r + 10 \lg \frac{S}{A_r} \qquad (4.1)$$

where

L_s = time and space averaged sound pressure level in the source room

L_r = time and space averaged sound pressure level in the receiving room

S = area of test aperture

A_r = equivalent sound absorption of the receiving room calculated form Sabine's formula ($A_r = \frac{0,16 \cdot V}{T_r}$)

The sound reduction index was measured in both directions without changing the microphone paths. Taking the average value of the two results, any systematic difference between the two measuring directions is ruled out and a higher reliability is obtained for the final result

$$R' = \frac{1}{2} (\overrightarrow{R}' + \overleftarrow{R}') \qquad (4.2)$$

where

$\overrightarrow{R}'$ = apparent sound reduction index in one direction (4.1)

$\overleftarrow{R}'$ = apparent sound reduction index in opposite direction (4.1)

Finally the measurement result was corrected for the possible effect of sound transmission via the wall in which the test specimen was inserted. This was done according to the method in NT ACOU 013 [1]

$$R = R' - 10 \lg \left(1 - \frac{S^* - S}{S} 10^{-0.1(R^* - R')}\right) \qquad (4.3)$$

where

R = sound reduction index of the test specimen after correction for sound transmission via the wall

R' = sound reduction index of the test specimen before correction for sound transmission via the wall

R* = sound reduction index of the wall in which the test specimen is inserted

S = area of the test aperture

S* = area of the wall including the test aperture

In the present investigation the largest correction did not exceed 0.4 dB.

The sound reduction index of the double wall itself is shown in Figure 4.4.

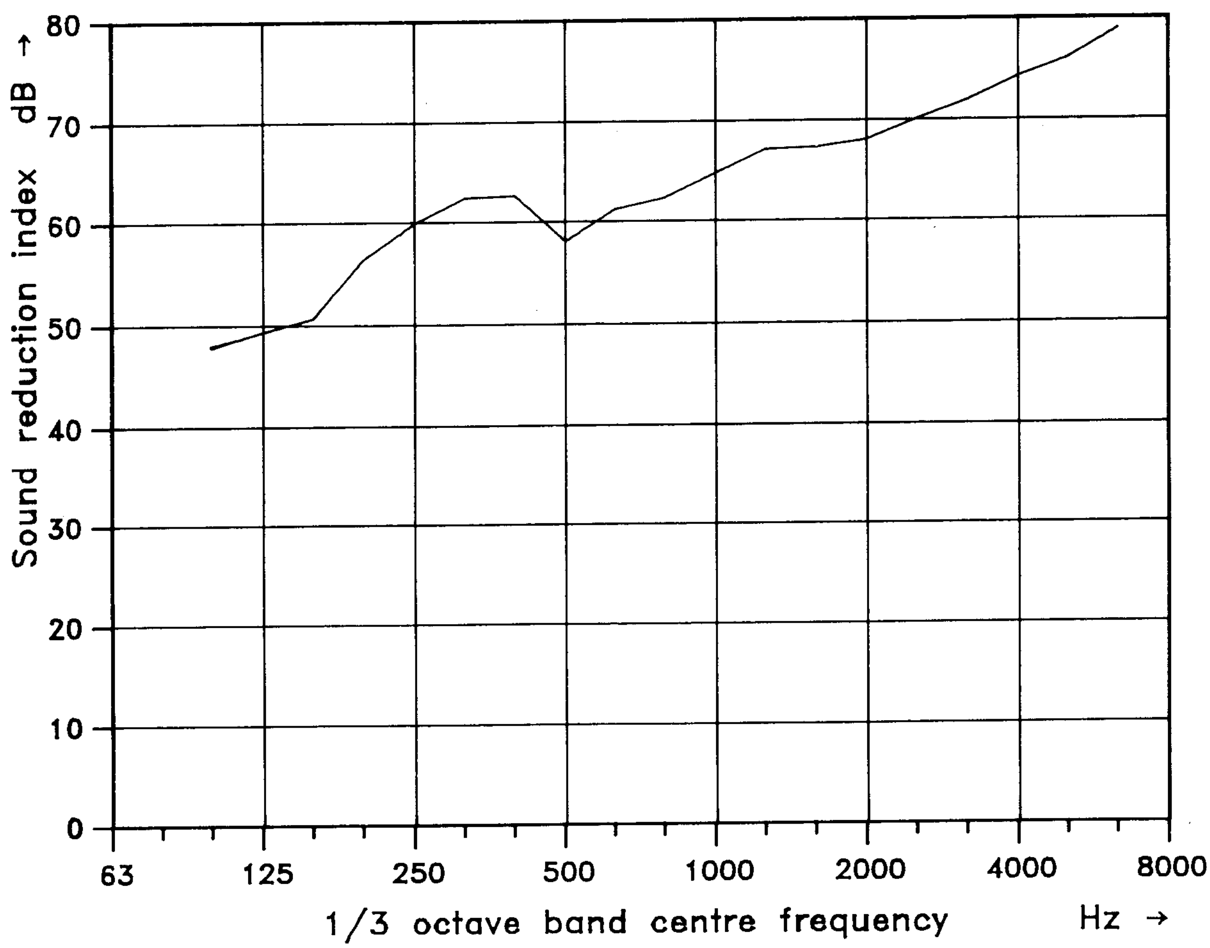


Figure 4.4 Sound reduction index of the double lightweight wall described on p. 8

In order to get an indication of the precision of the measurements of the sound reduction index an estimate of the standard deviation on the sound reduction index is calculated using the equation suggested by Michelsen [5]

$$s(R) \simeq \tfrac{1}{2}\, s(\Delta R') \qquad (4.4)$$

where

- $s(\ )$ = standard deviation on the term within the brackets
- R = sound reduction index of the test specimen
- $\Delta R'$ = difference in sound reduction index between the two measuring directions ($\Delta R' = \vec{R}' - \overleftarrow{R}'$, see equation 4.2)

The estimate of s(R) will, however, only be true if the measurements in the two directions are uncorrelated. This condition can be assumed to be fulfilled since the sound sources are changed.

In Figure 4.5 s(R) is shown based on all the measurements in the present investigation (n = 29).

Further Figure 4.5 shows the average difference between the two measuring directions.

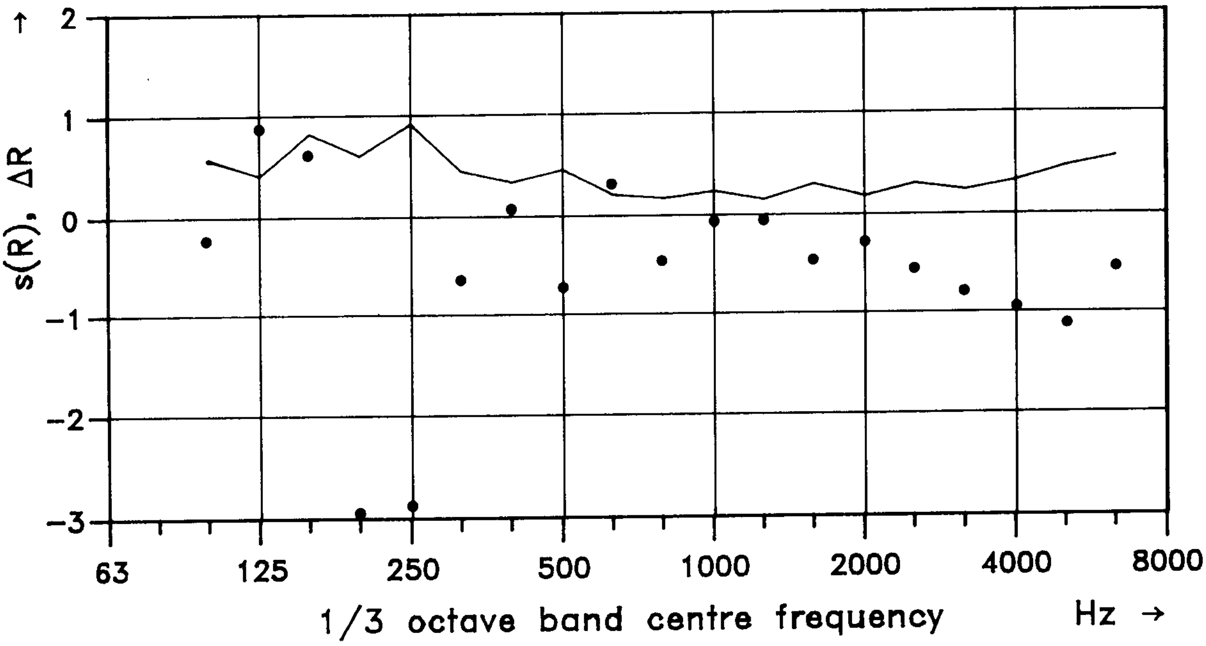


Figure 4.5 Estimate of s(R) calculated from 29 measurements in both directions shown together with the average difference between the two measuring directions

- estimate of s(R)

● average difference in R between the two measuring directions

As can be seen from Figure 4.5 the difference between the results for the two measuring directions is small, of the order of 0.5 dB in the frequency range 315 Hz to 2500 Hz, whereas at the frequencies 200 Hz and 250 Hz some differences exist.

4.3 Description of Test Objects

Two test objects were used in the investigation.

The major part of the measurements were carried out using a 4/4-15-4 sound insulating pane. The pane consisted of a 4 + 4 mm laminated glass and a 4 mm glass. The two glasses were separated by a 15 mm profile of aluminium and were sealed with thiocol. The laminated glass had a 1.14 mm plastic film (polyvinyl butural) embedded in it. The sound insulating pane had a total thickness of 28 mm and a weight of approximately 30 kg/m^2.

The 4-12-4 pane consisted of two 4 mm glasses separated by a 12 mm profile of steel which was sealed with butyl and thiocol.

The panes were generally mounted in wooden frames with a 4 mm × 8 mm porous rubber profile at both sides and from one side topsealed with an elastic sealant.

The wooden frames were mounted in the test aperture using two screws at each side. The joints were filled with mineral wool and from both sides sealed with a soft foam profile and elastic sealant (see Figure 4.6a).

An additional part of the frame were for some measurements screwed on the backside of the window frame with two strips of 4 mm × 8 mm porous rubber profile in the joint (see Figure 4.6b).

For some other measurements an additional frame was mounted reducing the size of the test opening to the lateral size of the airspace within the pane (see Figure 4.6c).

The additional frames were made of 22 mm chipboard and a strip of 4 mm × 8 mm porous rubber profile was mounted in the joint between the window frame and the additional frame.

The joint between the test opening and the additional frame was secured with a ϕ15 mm to ϕ25 mm soft rubber string also acting as fixture for the additional frame. A few blocks with an elastic interlayer were used to secure the position of the additional frame.

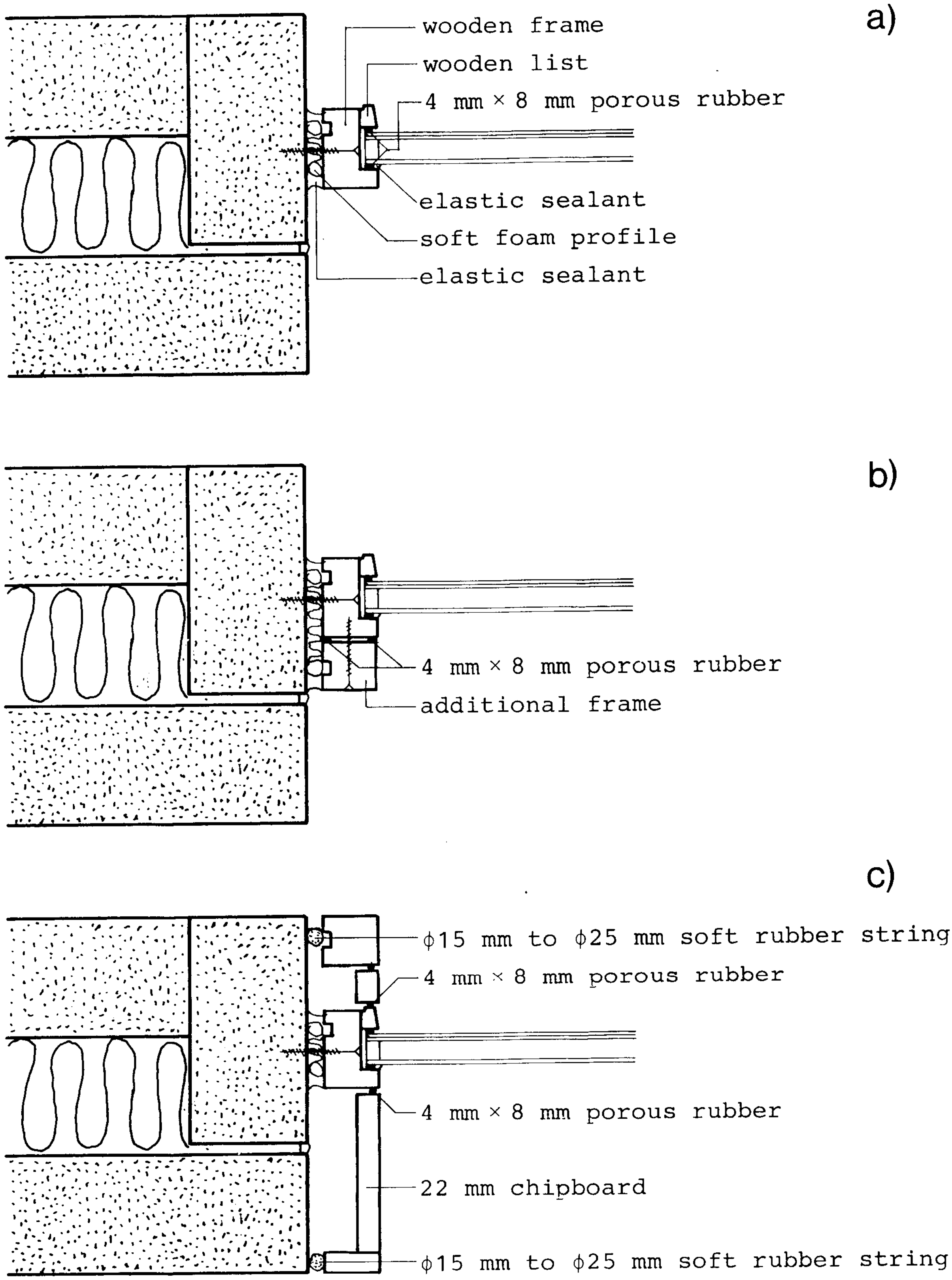


Figure 4.6 Details of mounting of the pane

5. MEASUREMENTS ON A SOUND INSULATING PANE (4/4-15-4)

Three different positions of the frame within the test aperture were used. In each position slight modifications of the geometry of the test aperture were arranged in order to see the effect on the measured sound reduction index. In all cases the sound reduction indices are calculated using the area of the original test aperture (1.21 m × 1.21 m) in the normalization term of equation 4.1. The details of the actual mounting and the geometry of the test opening is presented in the following figures above the diagrams.

5.1 Flat Test Opening, One Niche

The test specimen was mounted in the test aperture with one side flush with the surrounding wall. This way of mounting was recommended by the first draft proposal for NT ACOU 013 [3]. However, this recommendation was later changed. The results and mounting conditions are shown in Figure 5.1.

5.2 Flat Test Opening, Niche Depths approximately 1:2

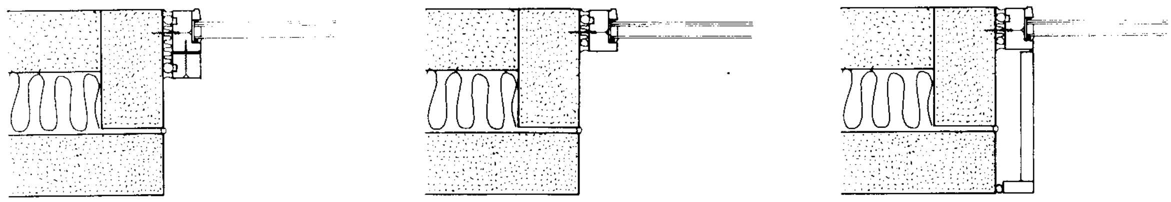
The test specimen was mounted in the test aperture with niche depths approximately equal to 1:2 as recommended in NT ACOU 013 [1]. The distance from the wall to the front of the window frame was equal to 8 cm. Measured to the fronts of the pane the niche depths were approximately 10 cm and 17 cm. The results and mounting conditions are shown in Figure 5.2.

5.3 Flat Test Opening, Identical Niche Depths

The test specimen was mounted in the test aperture with identical niche depths. The distances from the wall to the front of the panes were approximately 13½ cm. The results and mounting conditions are shown in Figure 5.3.

5.4 Staggered Test Opening, Identical Niche Depths

Without changing the position of the test specimen the test aperture was staggered by 6.5 cm as suggested in DIN 52210 [4]. This was done at both sides of the test opening and on the top and bottom. In [4] for some reason or other (perhaps normal building practice in Germany) the bottom of the test



M 5.11 ——— M 5.12 ---- M 5.13 —·—

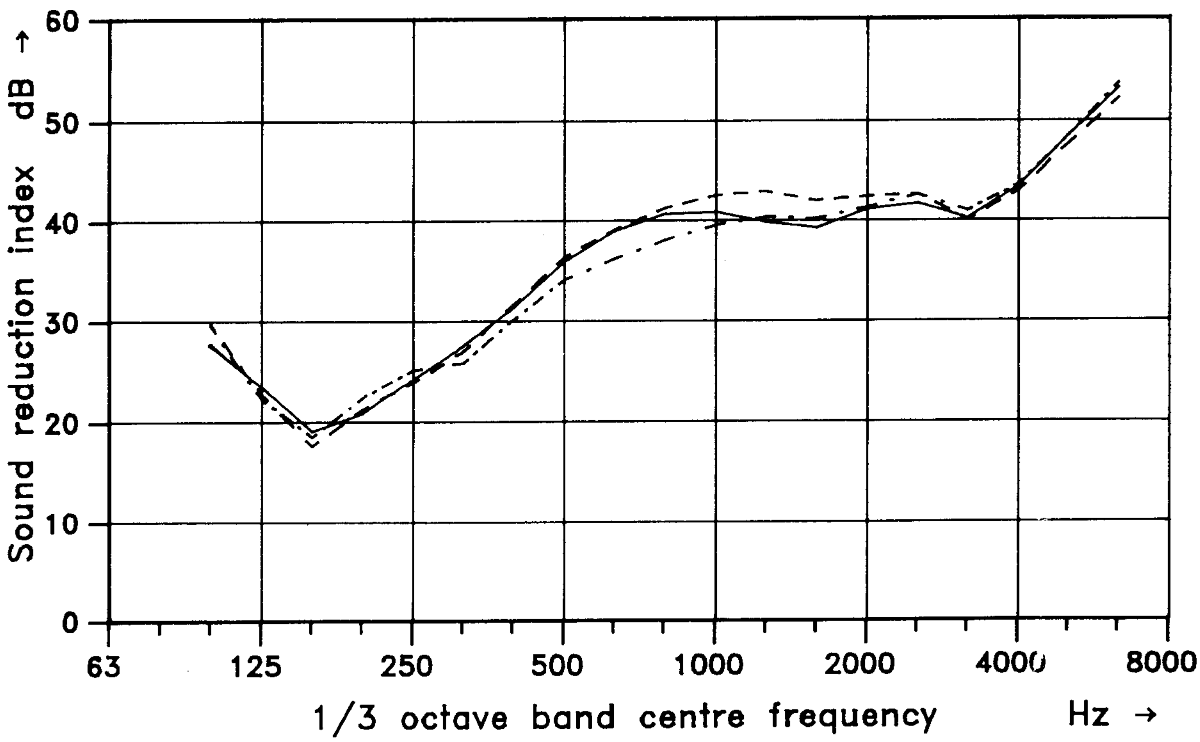


Figure 5.1 Sound reduction index of a 4/4-15-4 sound insulating pane mounted flush with one side of the test wall

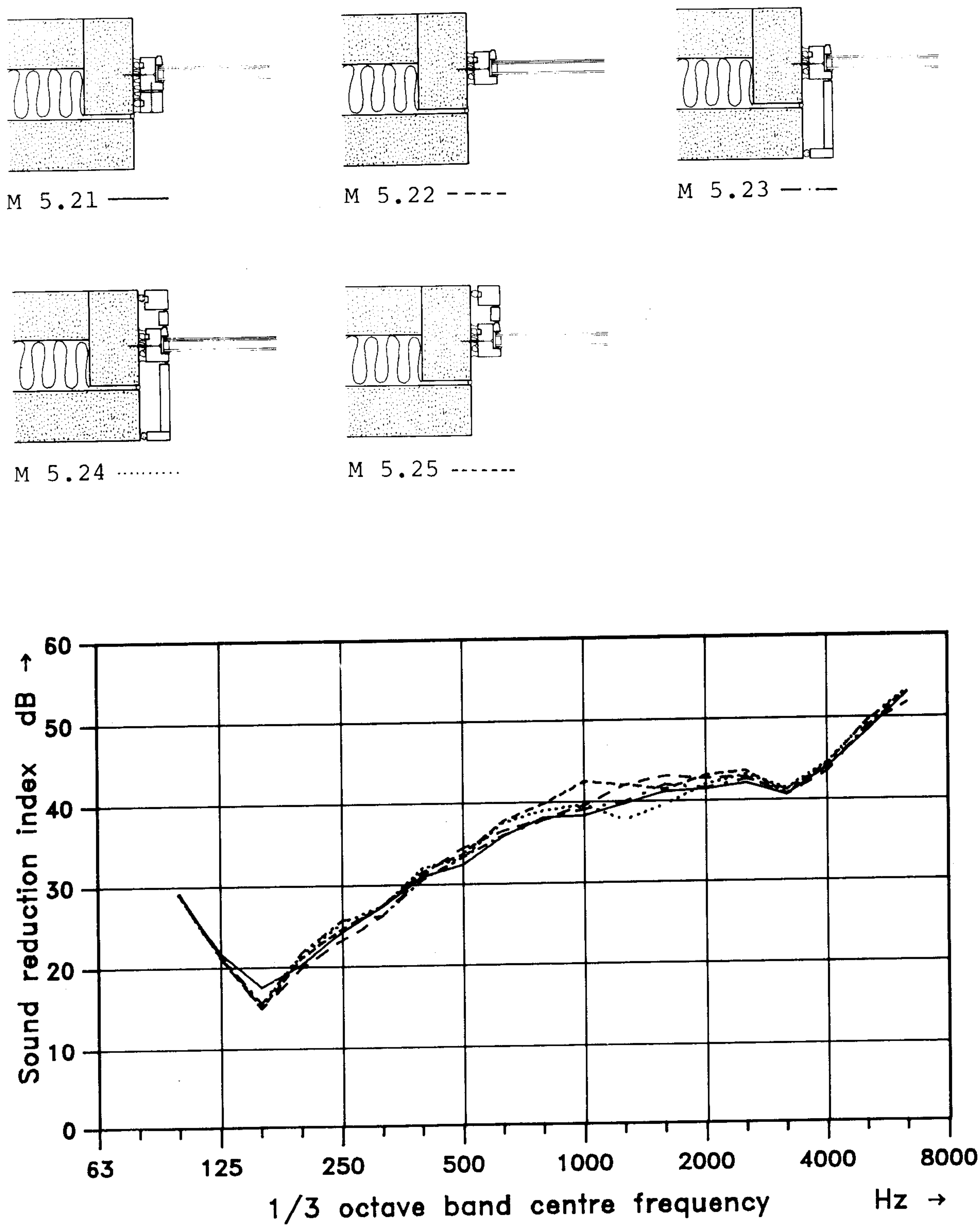


Figure 5.2 Sound reduction index of a 4/4-15-4 sound insulating pane mounted with niche depths having a ratio of 1:2 (10 cm and 17 cm)

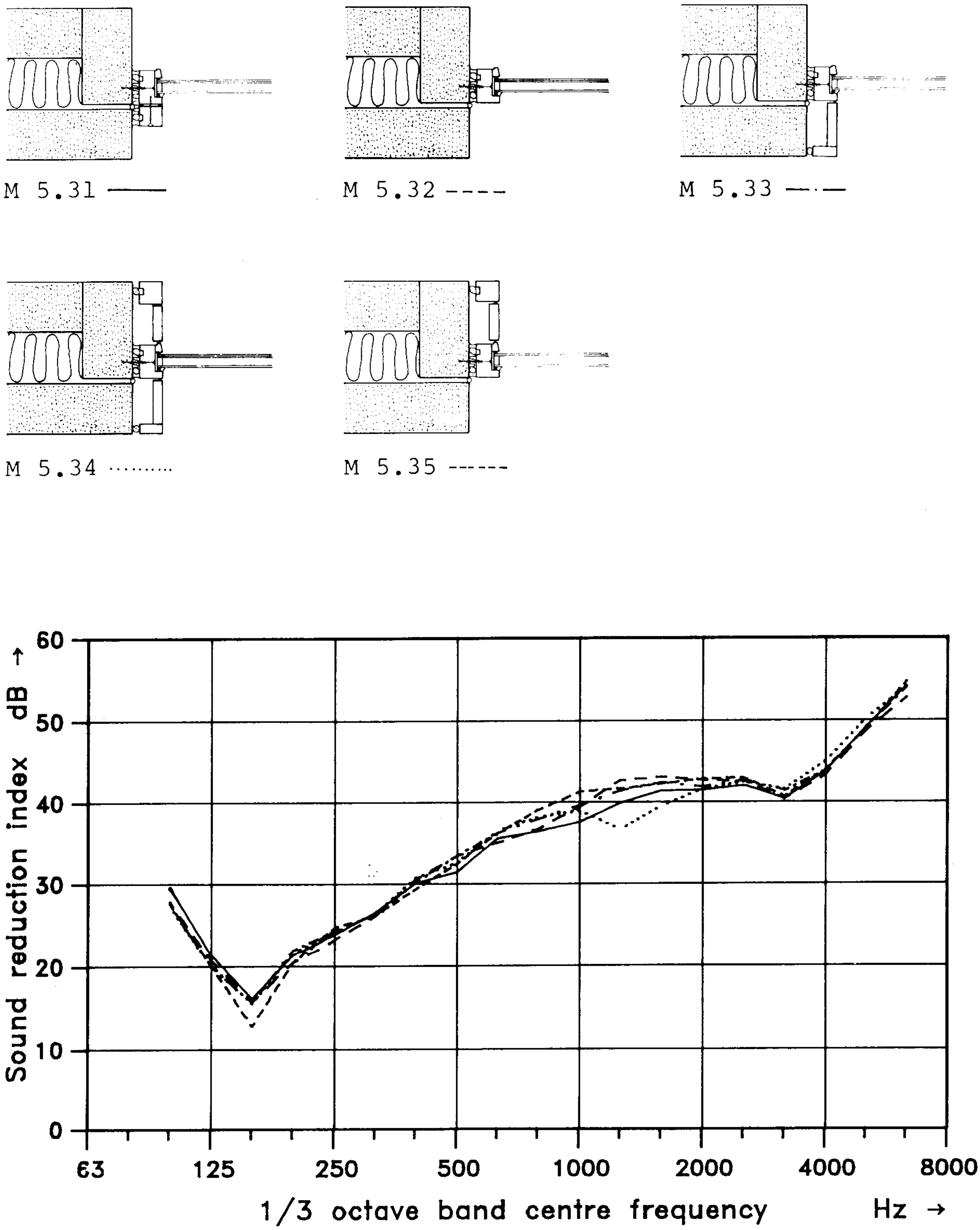
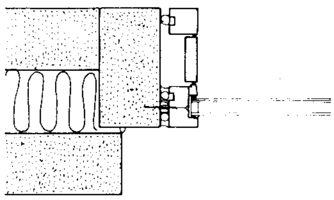
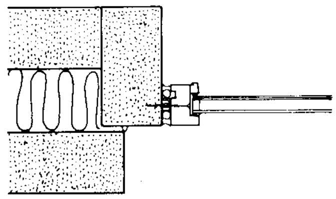


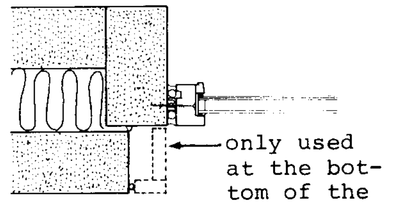
Figure 5.3 Sound reduction index of a 4/4-15-4 sound insulating pane mounted with equal niche depths, approximately 13½ cm



M 5.41 ------



M 5.42 ----



M 5.43 —··—

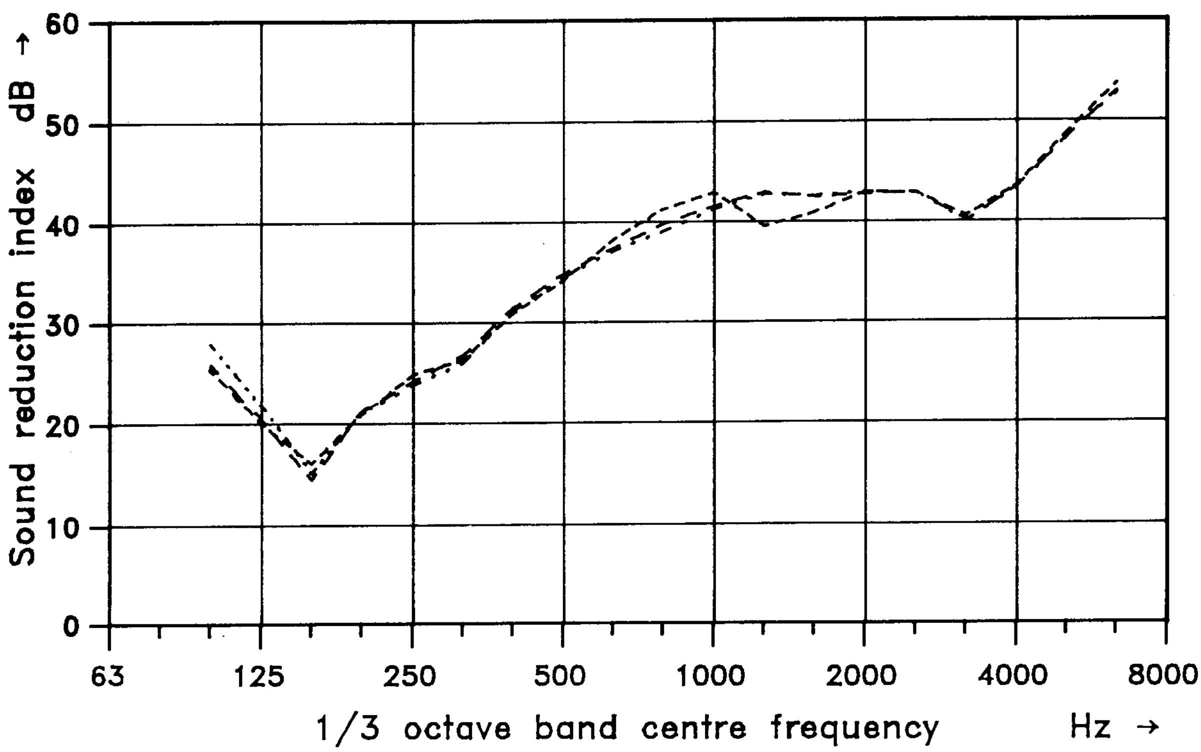


Figure 5.4 Sound reduction index of a 4/4-15-4 sound insulating pane mounted in a test aperture with one niche staggered by 6.5 cm. The niche depths were identical, equal to approximately 13.5 cm

aperture is not staggered. For this reason a measurement with bottom of the test aperture unstaggered using an additional frame was carried out. The results and mounting conditions are shown in Figure 5.4.

5.5 Effects of Test Opening

In Figure 5.5 all the previous measurements are shown together using the same signatures as used before.

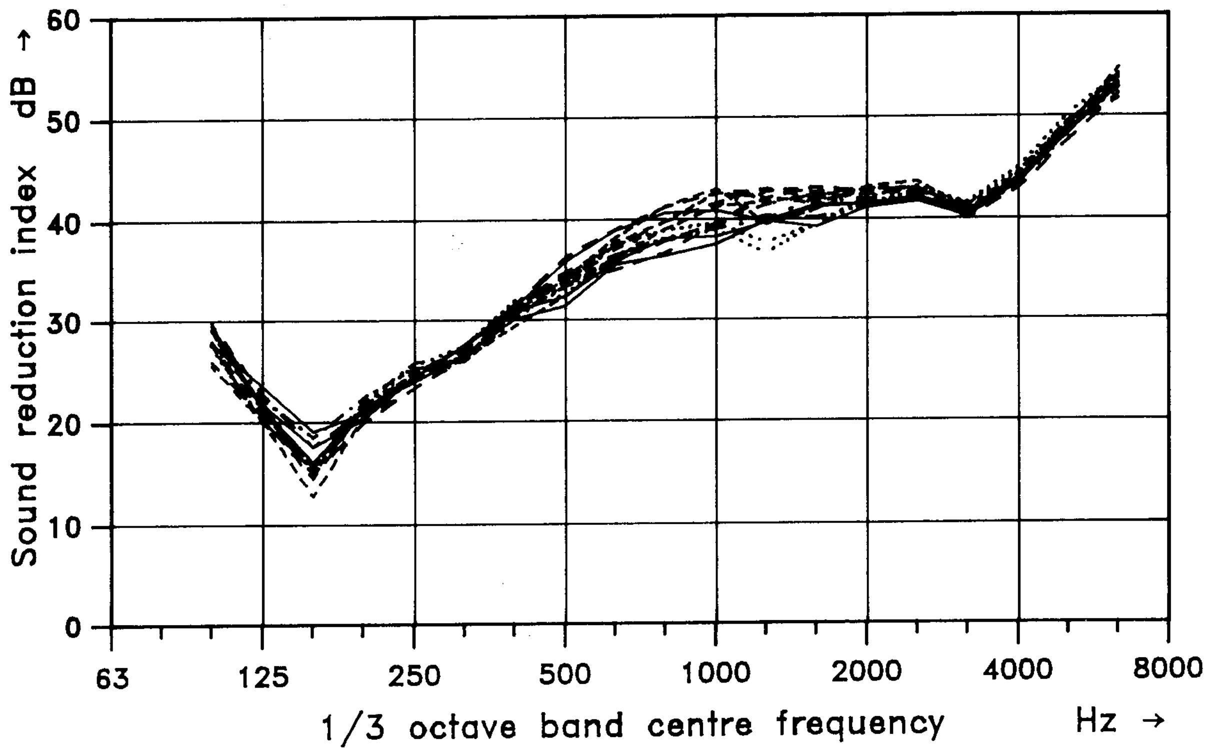
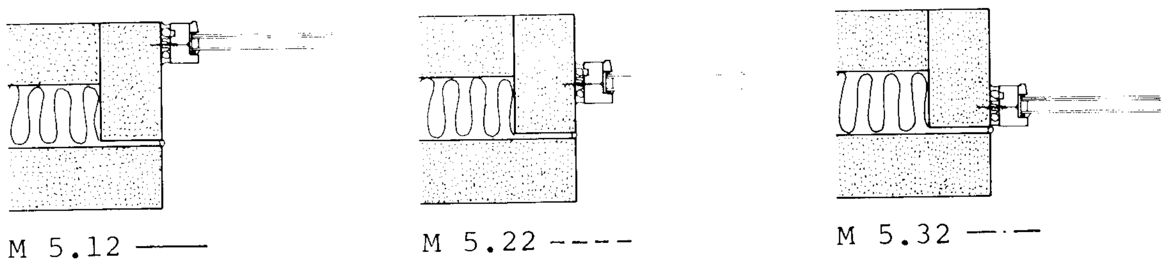


Figure 5.5 Sound reduction index of a 4/4-15-4 sound insulating pane measured in 3 different positions with varying geometry of the test opening

As can be seen rather small differences between the different situations are found except for the frequency range 500 Hz to 1600 Hz. Within this range the major difference occurs due to two different mechanisms.

In the position where the test specimen is mounted flush with one side of the wall an increase of the sound reduction index of approximately 3 dB is found compared to the two other positions with niches at both sides of the test object. A comparison of results with the pane mounted in the wooden frame is shown in Figure 5.6.



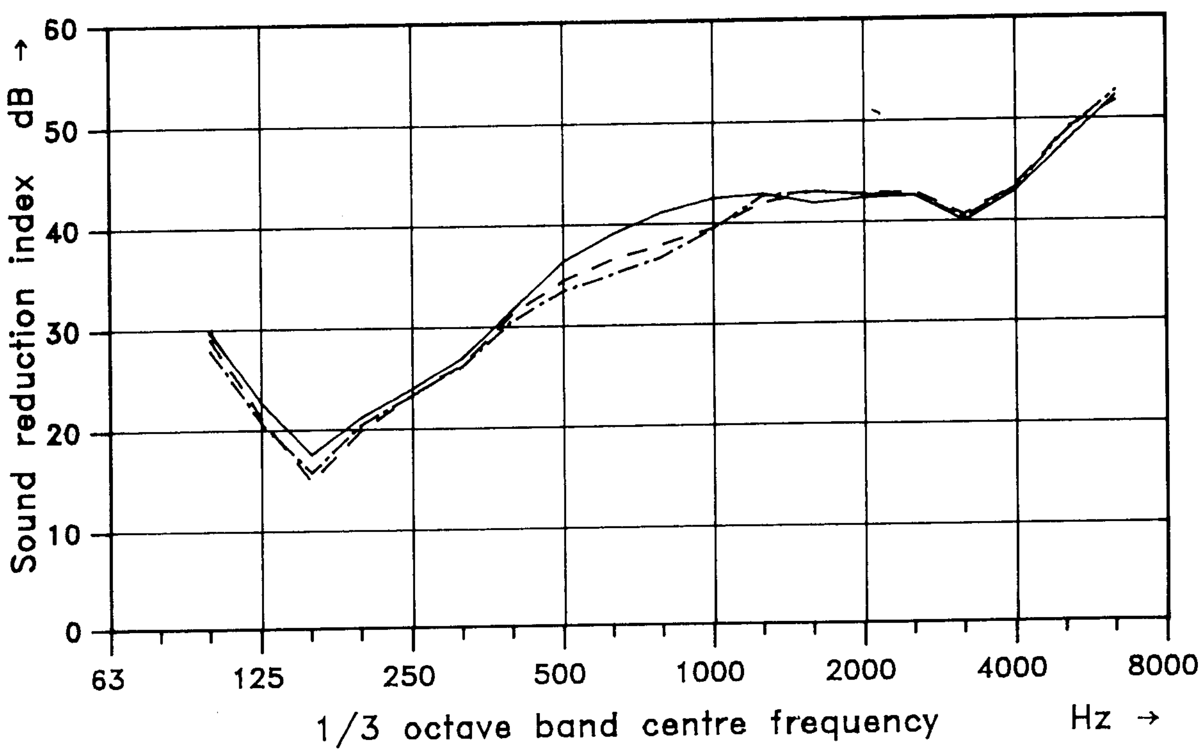


Figure 5.6 Sound reduction index of a 4/4-15-4 sound insulating pane mounted in a wooden frame in 3 different positions

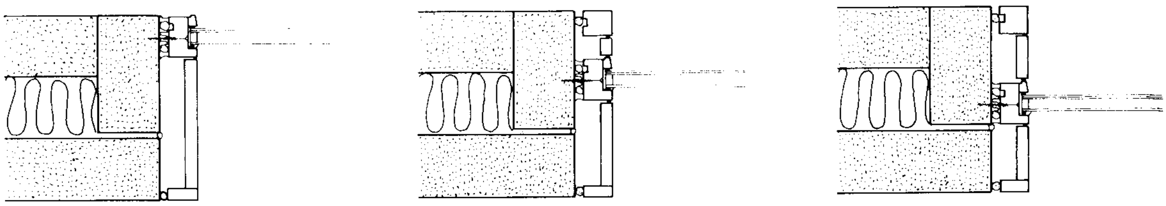
This agrees with the findings of Michelsen [5], where it is shown that the sound reduction index might increase by 3 dB if measured between two rooms, one of which with a cross section equal to the test object and the other with a wider cross section. In this situation the niches act as wave-guides being important below the frequency of coincidence (1600 Hz for the laminated glass). At lower frequencies (below 500 Hz) the depths of the niches are too small compared to the wave-length of the airborne sound. Consequently the position of the test specimen flush with one side of the wall should be expected to give an increase in the sound reduction index as large as 3 dB in the midfrequency range.

In contrast to this the comparison in Figure 5.7, where for all positions in the test opening extra panels are mounted reducing the size of the test opening to that of the lateral size of the airspace within the pane, shows that the effect of position within the test opening disappears. This certainly contradicts the argumentation in relation to Figure 5.6.

The major reason for this discrepancy is related to the influence of the frame in which the pane is mounted. This frame is of importance for the sound transmission above the mass-spring-mass resonance frequency and below the frequency of coincidence. In Section 6.2 this mechanism for the sound transmission is treated separately.

The use of a staggered test opening seems to have some influence if the test opening at one side of the pane equals the lateral dimensions of the airspace within the pane, see Figure 5.8. If the pane is mounted in a window frame, the effect of the staggered test opening is slightly reduced as shown in Figure 5.9.

Considering all results, the effects of varying the geometry of the test opening has been rather small. If the weighted sound reduction index R_w is calculated according to ISO/DIS 717/3 [6], the spread is rather inconsiderable. In this comparison the R_w-values were found to vary between 35.4 dB and 37.2 dB.



M 5.13 ——— M 5.24 ---- M 5.34 —·—

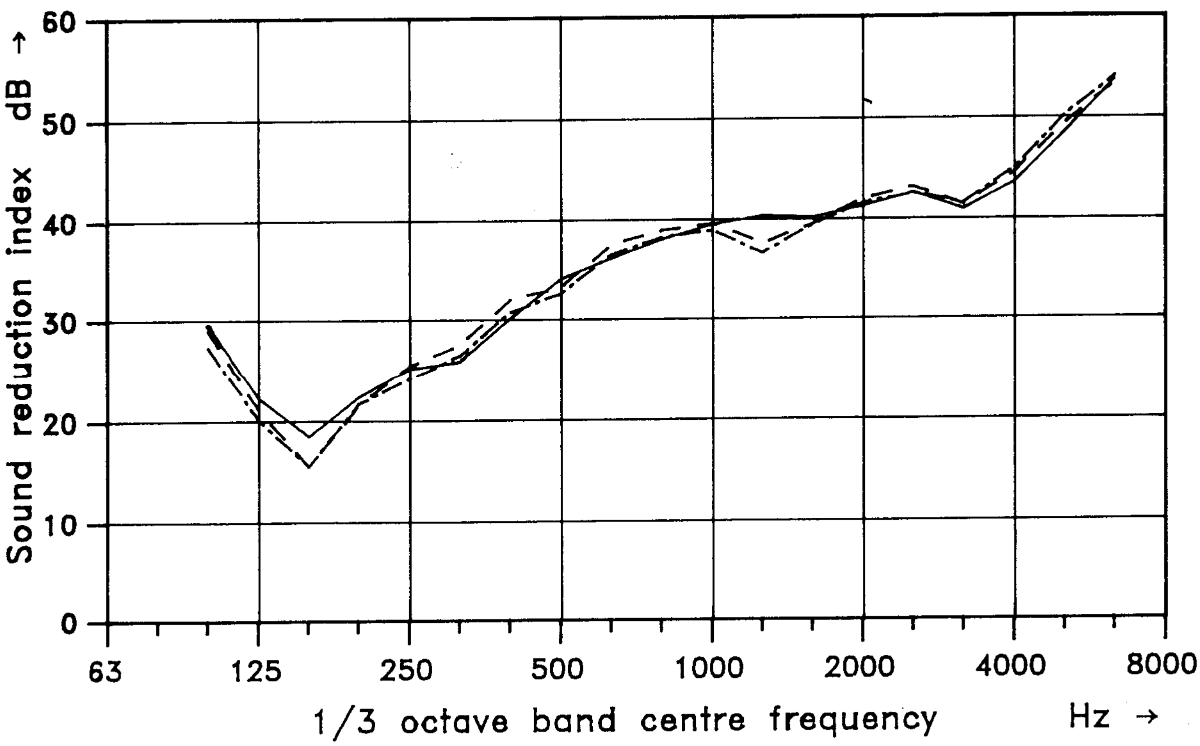
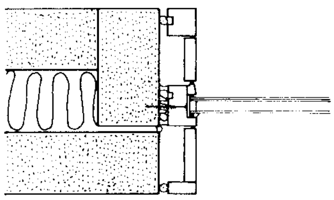
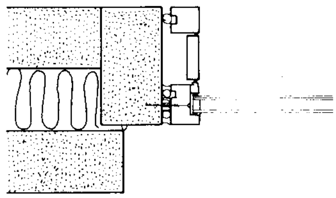


Figure 5.7 Sound reduction index of a 4/4-15-4 sound insulating pane mounted in 3 different positions in the test opening, the size of which equals the lateral size of the air-space within the pane



M 5.34 ....



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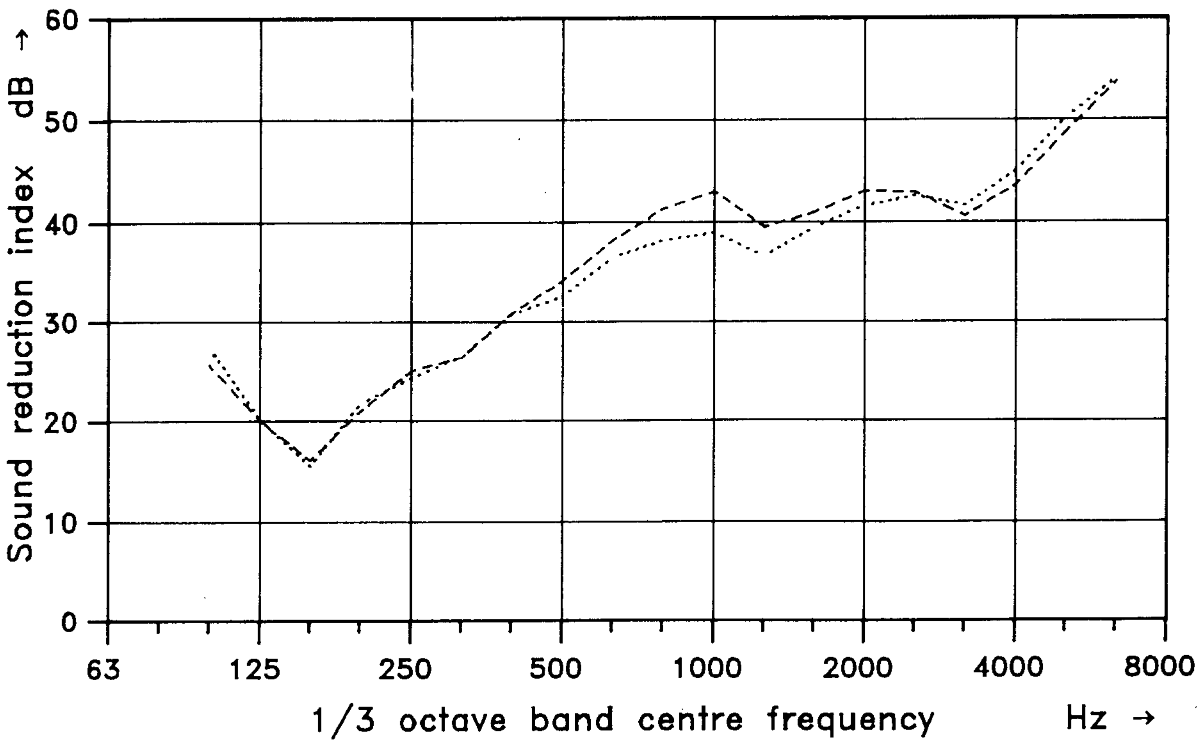
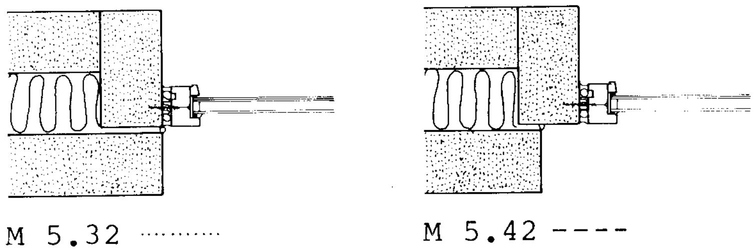


Figure 5.8 Sound reduction index of a 4/4-15-4 sound insulating pane measured in a test opening with dimensions equal to the lateral size of the airspace within the pane and with one niche staggered by 12.5 cm



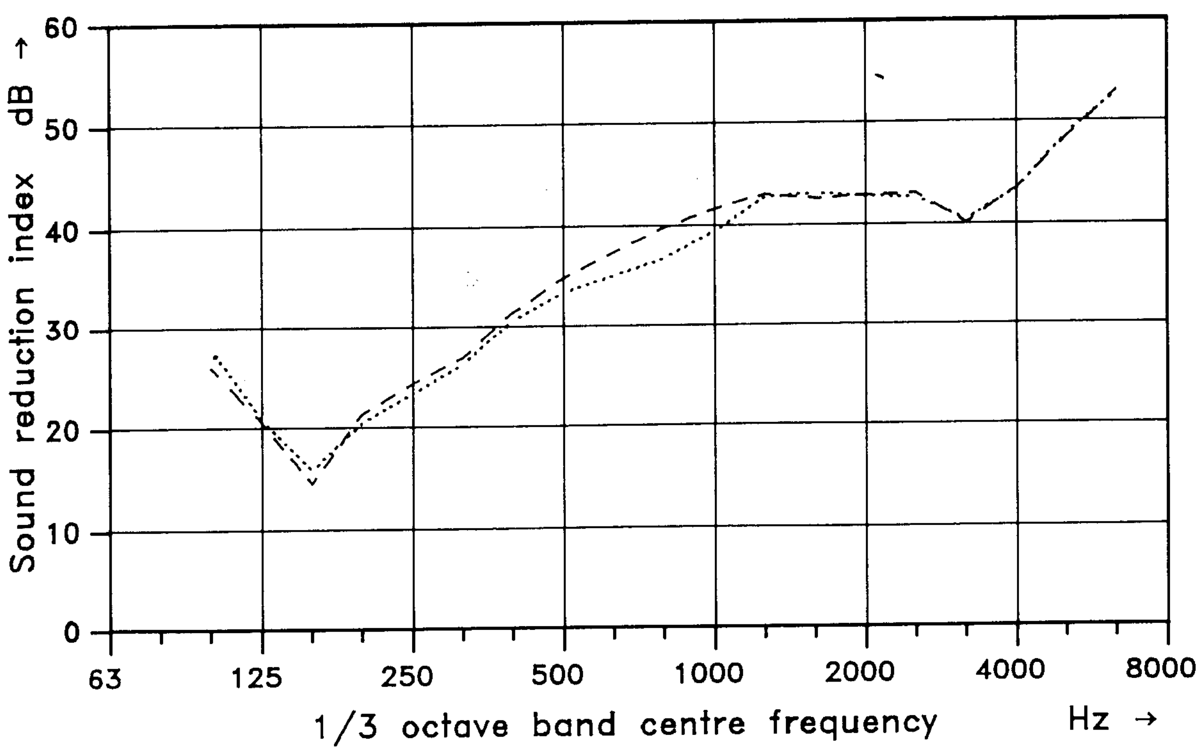


Figure 5.9 Sound reduction index of a 4/4-15-4 sound insulating pane mounted in a window frame and measured in a flat test opening versus a test opening with one niche staggered by 6.5 cm

6. MEASUREMENTS ON A PANE (4-12-4)

Only one position in the test opening with niche depths having a ratio of 1:2 was used in this investigation. The addtional frames used in this part of the investigation were made of 5 cm solid wood. Only a limited number of tests were conducted. The purpose of these tests was to examine if the rather small differences between the measured results reported in Section 5 were due to the choice of a pane with one glass laminated.

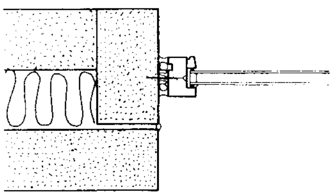
6.1 Flat Test Opening, Niche Depths approximately 1:2

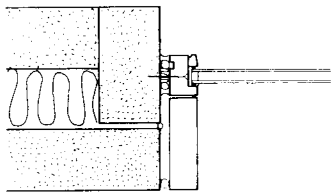
The test specimen was mounted in the test opening with niche depths approximately equal to 1:2 as recommended in NT ACOU 013 [1]. The distance from the wall to the front of the window frame was equal to 8 cm and measured to the fronts of the pane the niche depths were approximately 11 cm and 17 cm. The results and mounting conditions are shown in Figure 6.1. Comparing Figure 6.1 with Figure 5.2 it is seen that the test object itself has an apparent influence on the differences obtained using different geometries of the test opening. Again this has to do with the coupling of the lateral modes in the airspace within the pane to the modes in the niches. However, it is noted that decoupling only at one side of the pane gives rather small changes of the sound reduction index (6.12 and 6.13) whereas decoupling at both sides of the pane raises the sound reduction index from 250 Hz to 2000 Hz. This decoupling effect is further treated in Section 6.2.

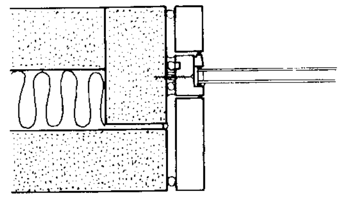
6.2 Effect of Frame Width, Niche Depth approximately 1:2

In order to examine the effect of decoupling of the lateral modes in the airspace within the pane from the modes in the niches at both sides of the pane a test series was run with frame widths of 2.5 cm, 5.5 cm, 10.5 cm, and 15.5 cm. Typically the frame width of a hinged window should be some 12 to 15 cm.

The first measurement was carried out with the pane mounted between two 25 mm × 25 mm pieces of wood, whereas the three next measurements were carried out with the pane mounted in a wood-


M 6.11 ----


M 6.12 —·—


M 6.13 ....

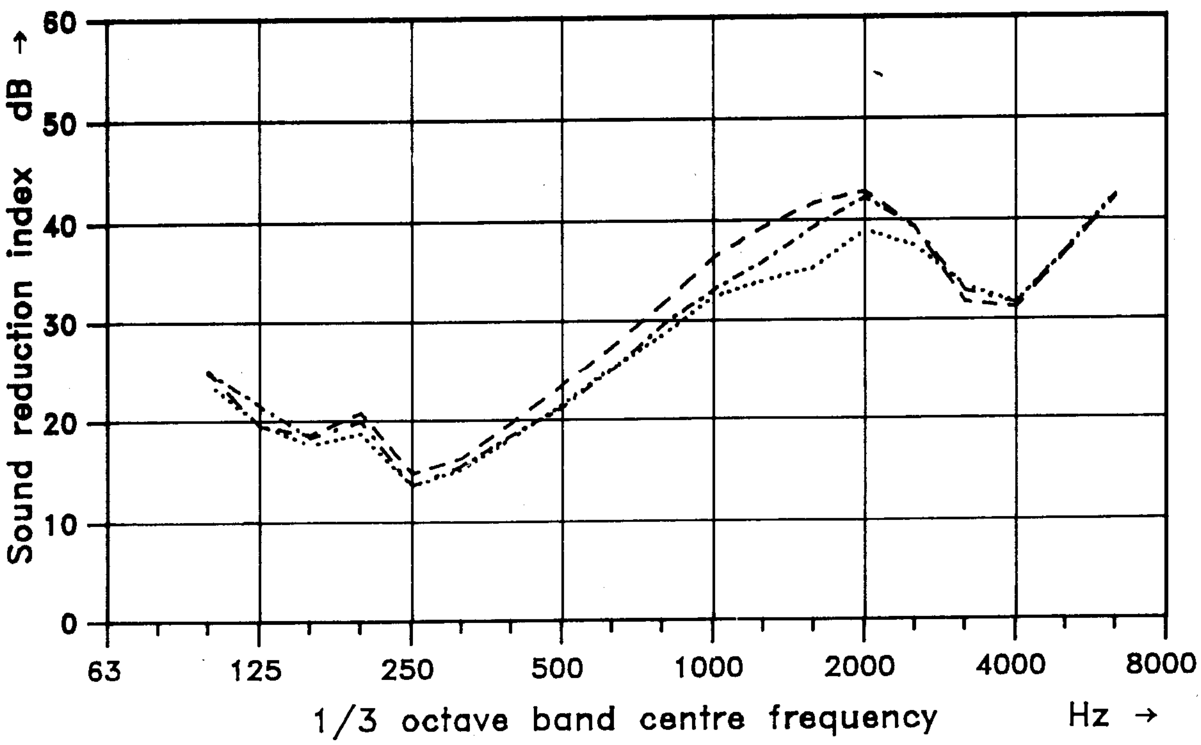


Figure 6.1 Sound reduction index of a 4-12-4 pane mounted with niche depths having a ratio of approximately 1:2 (11 cm and 17 cm)

en frame which were made wider and wider from measurement to measurement.

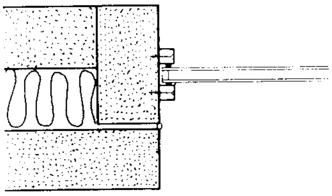
Details of the mountings are shown in Figure 6.2 together with the measurement results. All sound reduction indices were calculated using the area of the test aperture according to equation 4.1. Further it was checked that sound transmission via the wooden frame was negligible. Considering only the change in dimensions of the pane one would expect a 2 dB higher result for measurement 6.24 compared to measurement 6.21.

As can be seen from Figure 6.2 the actual dimensions of the pane compared with dimensions of the test aperture are very important for the measured sound reduction index in the region above the resonance frequency (mass-spring-mass). This explains the surprising fact that a higher sound reduction index is often found when the same pane is mounted in a hinged frame compared with a measurement on the pane mounted in an unhinged (and slimmer) frame or without a frame at all.

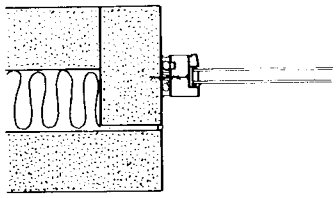
This phenomenon was first reported by Gösele and Lakatos [7] and was later observed by Michelsen and Rasmussen [8]. Gösele and Lakatos [7] argued that the phenomenon was connected with the increase in sound pressure level in the niche corners. As mentioned before the cause of this phenomenon is instead believed to be the decoupling of the lateral modes in the airspace within the pane from the modes in the niches at both sides of the pane. It is obvious that test results can be misinterpreted if the boundary conditions are not considered.

6.3 Effects of Mounting with a Resilient Sealing Material

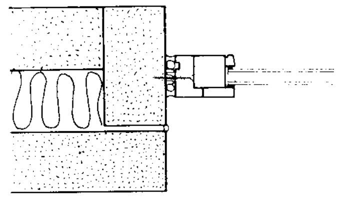
In DIN 52210 [4] it is also prescribed that the pane has to be mounted with a cavity in the perimeter of the pane filled with a resilient sealing material. In order to examine the effects of different mounting conditions a series of tests was run on the 4-12-4 pane installed as shown in Figure 6.2 (M6.21). First the sound reduction index was measured with the pane sealed with a 4 mm × 8 mm porous rubber profile at both sides (M6.31). Later, at one side an elastic sealant was added on



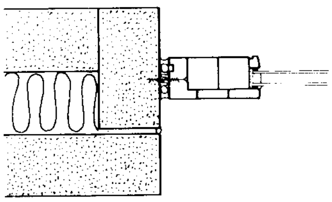
M 6.21 ———



M 6.22 ----



M 6.23 ------



M 6.24 ··········

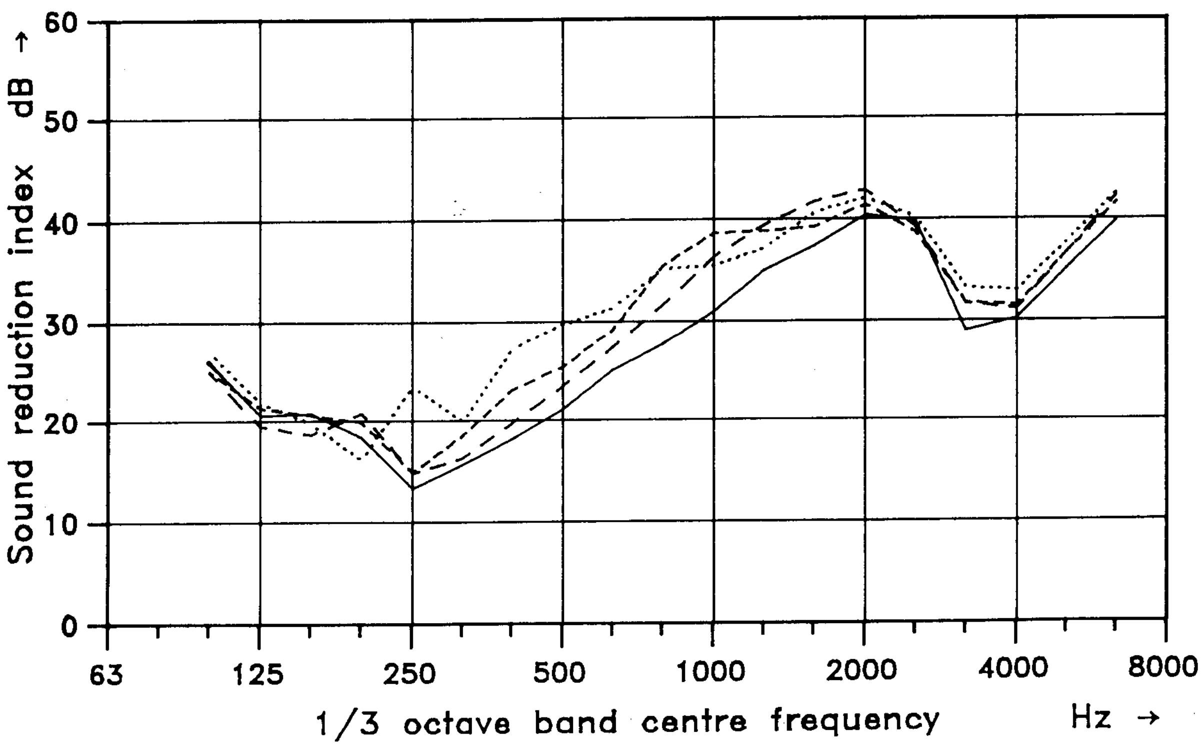
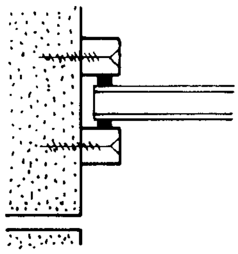
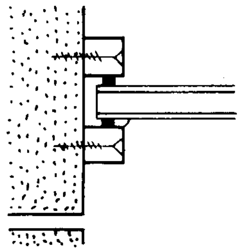


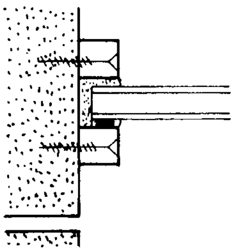
Figure 6.2 Sound reduction index of a 4-12-4 pane mounted in frames of varying width and with niche depths approximately equal to 1:2



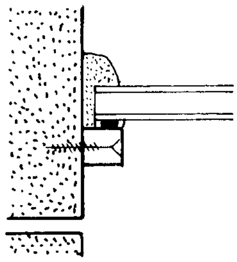
M 6.31 —··—



M 6.32 ———



M 6.33 – – –



M 6.34 -----

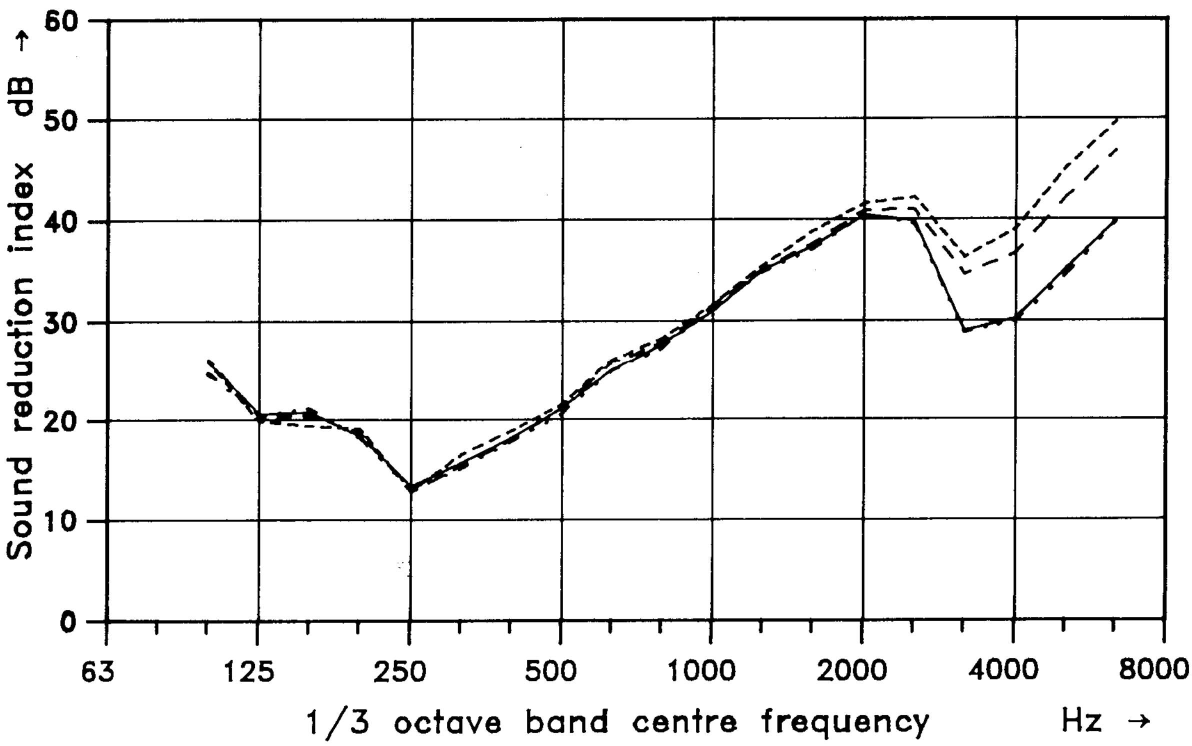


Figure 6.3 Sound reduction index of a 4-12-4 pane mounted without and with resilient sealing material in the cavity along the perimeter of the pane, depth of niches approximately equal to 1:2

top of the rubber profile (M6.32). No effect of the elastic top sealant could be noted on the measured sound reduction indices. The next two measurements were made with a resilient sealing material (Bostik 800) filling the cavity along the perimeter of the pane. The first one (M6.33) was performed with wooden pieces mounted at both sides of the pane and the second (M6.34) with additional resilient material instead of the wooden pieces at one side of the pane.

As can be seen from Figure 6.3 the effect of the resilient material in the perimeter of the pane is large above the frequency of coincidence (3000 Hz). However, this way of mounting a pane is not accepted by the manufacturers of panes in Scandinavia as experience shows that the lifetime of panes is reduced. Despite the positive effect such mounting conditions could not be accepted for tests in a laboratory.

7. DISCUSSION

The measurements described in Section 5 have shown that for a typical sound insulating pane (4/4-15-4) the effect of the geometry of the test opening is small. Considering the position of the test specimen in the test opening some influence is noticed comparing the results obtained for a niche at one side as opposed to niches at both sides.

The use of a staggered test opening showed a rather small influence on the measured results. In Section 6, where a few measurements were carried out for a common insulating pane (4-12-4), the effect of a staggered test opening was again shown to be of minor importance (M6.12 & M6.13, Figure 6.11).

Larger effects were related to the way of mounting considering the frame widths (Figure 6.2) and the sealing material (Figure 6.3).

It is thus concluded that although differences in results obtained in different laboratories have been observed, no reasonable explanation for these differences can be given with respect to the geometry of the test opening.

It has therefore been natural to compare measurement results obtained in different laboratories in order to see which type of test specimens are likely to yield different results. As most of the test results which could not be reproduced in Scandinavia were measured in Stuttgart, the comparisons have been made with this particular German laboratory.

In [7] a measurement on a 4-12-4 pane is reported and also the way of mounting is shown. The pane occupies the full test opening and is mounted with putty. A comparison with M6.32 is shown in Figure 7.1. As can be seen the agreement between the results obtained is quite satisfactory.

In contrast to this Figure 7.2 shows a comparison of measurements on two identical gas-filled panes with a significant difference in results. It must be noted that the way of mounting was not identical. At the Danish Acoustical Laboratory the pane was installed in a 6 cm wide wooden frame with PVC gaskets.

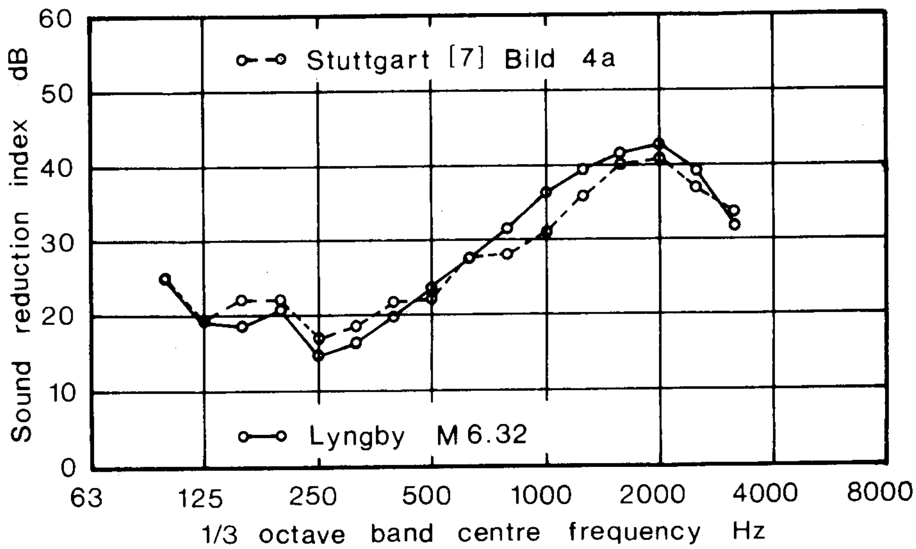


Figure 7.1 Comparison of measurement results on a 4-12-4 pane occupying the full test opening

The way of mounting in Stuttgart is not shown on the diagram of the test report, but based on another test report (GS 24-76) it is seen that panes occupy the full test opening and are layered in putty.

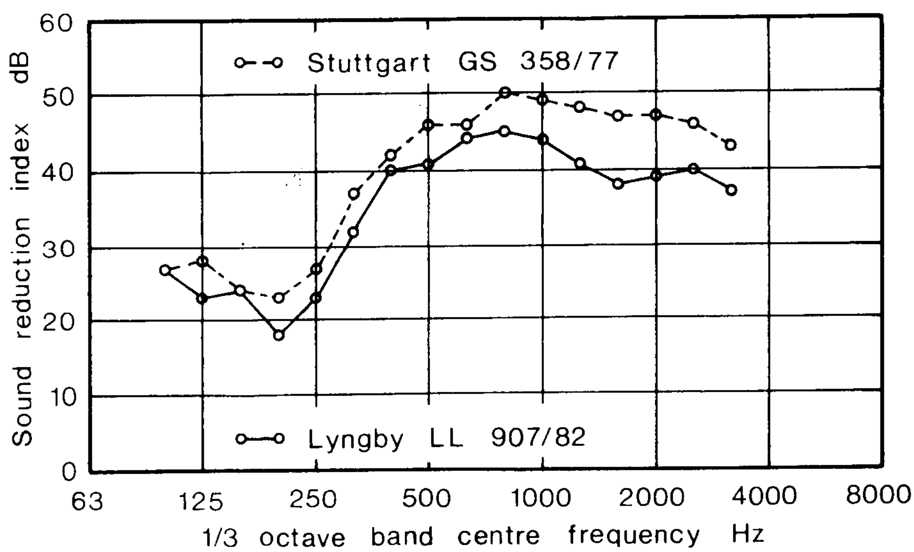


Figure 7.2 Comparison of measurement results on identical gas-filled 8-12-4 panes (80% SF_6 & 20% Ar)

As can bee seen from Figure 7.2 differences of 5-10 dB are found above the resonance frequency for the double construction. A possible explanation for the differences in results could be the different mounting conditions which in Stuttgart might increase the energy losses of the glasses. In order to check the validity of this explanation the measurement was repeated in Lyngby, mounting the pane with a large quantity of Bostik 800. As can be seen from Figure 7.3 the sound reduction index is improved above 1000 Hz, but no effect is noted below this frequency.

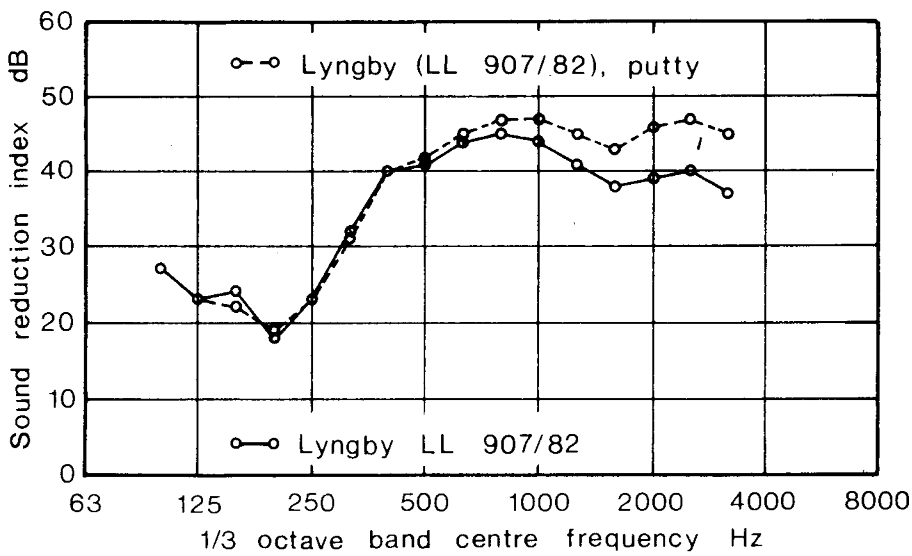


Figure 7.3 Effect of varying the sealing conditions for a 8-12-4 pane filled with 80% SF_6 and 20% Ar

In Figure 7.4 measurements on two window constructions are finally compared. Both windows are made with frame and sash of plastic profiles and equipped with a 8-12-4 pane. As can be seen from Figure 7.4 the agreement in measurement results are quite satisfactory.

Based on these few examples it seems that comparable results might be found for air-filled panes either tested separately or mounted in a window construction. In contrast to this the comparison of the gas-filled panes shows large differences. This is believed to be a general tendency and was in fact the reason why all German test results on windows or glazings only were questioned by the Scandinavian laboratories.

Although not proved by the measurements shown in Figure 7.3 it is believed that the sealing conditions for the pane are very

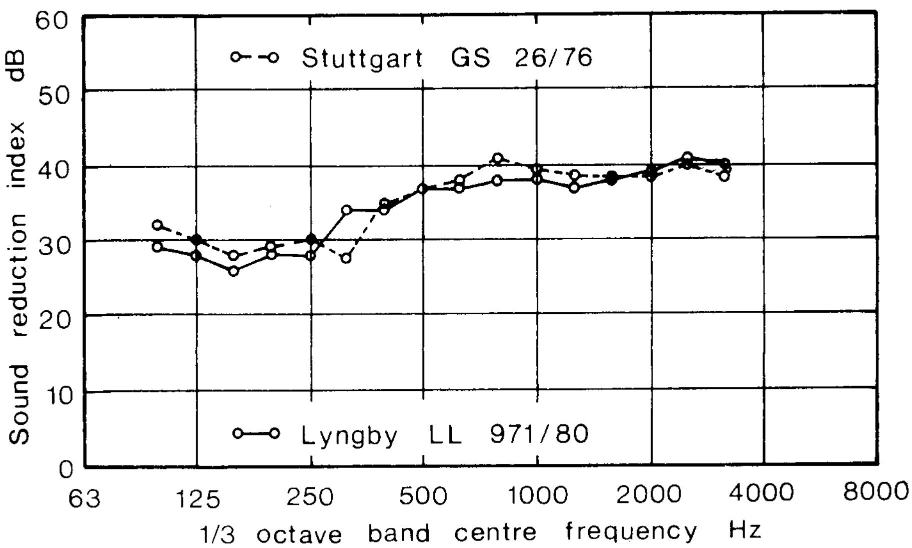


Figure 7.4 Comparison of measurement results on a window construction equipped with a 8-12-4 pane

important, and that differences observed between laboratories mostly are due to different mounting conditions.

In all cases it is hazardous to perform tests in a laboratory with sealing conditions which differ from normal conditions used in buildings. At least in Scandinavia it is not recommended by the manufacturers of insulating panes to use putty for the mounting.

It is finally concluded that test conditions for measurements on panes need to be internationally agreed on, both with regard to the way of mounting and with regard to the way of mounting the pane. The mounting of a pane in a frame makes the test result strongly dependent on the width of the frame. There seems to be no possible solution to this problem. For the practical use of the data it is very unsatisfactory that data on panes and data on window constructions cannot be compared directly. The use of a staggered test opening does not solve this problem unless the mounting of the window construction is in accordance with the left drawing in Figure 2.1. As this installation differs from practice in several countries, too low results for the window constructions would be obtained. For this reason the staggered test opening is not preferable to the ordinary flat test opening.

8. REFERENCES

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