SOUND TRANSMISSION THROUGH DOUBLE DOORS

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ABSTRACT

This report presents the results of a series of tests to evaluate sound transmission through a double door system (two doors with an airspace between). The main purpose of these tests was to establish that such a system using conventional door panels can provide substantial noise reduction. The secondary goal of the series was to evaluate typical office doors including the effect of minor modifications that could increse the noise reduction provided by the door system.

SOMMAIRE

Ce rapport présente les résultats d'une série d'essais visant à évaluer la transmission du son à travers un système de porte double (deux portes séparées par une lame d'air). Le principal objectif visé était de montrer qu'un pareil système, constitué de panneaux de porte classiques, peut assurer une réduction importante du bruit. L'objectif secondaire consistait à évaluer la performance des portes de bureau types, notamment l'effet de modifications mineures susceptibles de réduire davantage la transmission du bruit à travers les systèmes de portes.

INTRODUCTION

The main purpose of these tests was to establish that a double door system (comprising two conventional doors with an airspace between) can provide sufficient noise reduction for confidential speech privacy - in specific, that they can achieve a sound transmission class (STC) of 45 or higher. An STC of about 45 is required to provide confidential speech privacy in a typical office environment. The secondary goal of the series was to evaluate typical doors including the performance of weatherstripping and other features that could affect the noise reduction provided by the door system in the long or short term.

Because of the large potential benefits (savings for major landlords, or improved office performance for occupants) if an inexpensive alternative to commercial acoustical doors can be developed, an extensive series of tests was performed. In total, thirty three sound transmission tests were run, including five cases that were repeated to test variability of the acoustical performance of weatherstripping. Two types of weatherstripping were tested, and to assess their effectiveness, measurements were also made with the doors sealed. The tests used two types of doors (a solid-core wood door and a hollow metal door) to determine whether their acoustical differences would be significant in this application. Two door frame systems were tested, to show the dependence of the sound transmission on the space between the two doors, and to establish the minimum inter-door spacing that could reliably achieve the target of STC 45. The effect of adding acoustically absorbing material to the space between the two doors was also examined.

DESCRIPTION OF THE MEASUREMENTS

The sound transmission characteristics of the doors were determined in accordance with ASTM Standard E90-85, "Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Elements". The Sound Transmission Class (STC) was calculated from the resulting sound transmission loss data, in accordance with ASTM Standard Classification E413-73.

The transmission loss expresses in decibels what fraction of the sound energy striking a building element is transmitted through it. The higher the transmission loss, the better the noise reduction by the element. The ASTM E90 test method requires measurement of transmission loss in the 16 standard 1/3-octave frequency bands whose centre frequencies range from 125 Hz to 4000 Hz; normal practice in this laboratory includes measurements in additional frequency bands. Although the data for all of these frequency bands are useful for analysis of the factors controlling sound transmission, a single-figure rating is required for convenient comparison of two or more elements.

In keeping with common practice, the rating used here is the Sound Transmission Class (STC). This rating has been shown to correlate well with subjective impressions of the sound insulation provided against sounds such as speech.

The door frame was installed in a partition 2.44 m high x 3.05 m wide in the test frame between two reverberation rooms. This partition was supported by two rows of lightweight 90 mm steel studs; a 25 mm space separated the two rows of studs. Glass fibre batts of nominal 90 mm thickness were placed between the studs in each row. Two layers of 16 mm gypsum wallboard were applied to each face of this partition; the nominal surface density was 23 kg/m^2. The wall details and frame installation are shown in Figs. 1 and 2.

Tests with the door opening blocked showed that the partition had higher transmission loss than the doors at all frequencies (the wall STC was 61). In the following analysis of the test results, sound transmission through the partition may be ignored in most cases, and the double door system (whose area was 2.23 m^2) is treated as the only sound transmission path. In the case of the best door systems, flanking transmission through the surrounding partition slightly reduced the apparent transmission loss at low frequencies. The true transmission losses of the door systems were calculated (using the measured transmission loss of the gypsum board partition) and the corrected data are presented below. Even for the best doors, this systematic distortion of the results did not reduce the STC by more than 2 dB, and for doors whose STC was under 45, the effect of flanking was less than the measurement uncertainty. Overall, the effect of flanking was less serious than the variability associated with how firmly the door was latched, and how the weatherstripping mated with the door surfaces.

DESCRIPTION OF DOOR SYSTEMS

The wood door was a standard commercial solid-core door with hardboard faces. The door dimensions were 2134 mm high x 914 mm wide x 45 mm thick. Weight of the door was 46.7 kg with hardware. The steel door was a commercial hollow metal door with 18 gauge wipecoat galvanised steel faces and 20 gauge internal steel stiffeners. The door dimensions were 2115 mm high x 905 mm wide x 45 mm thick. Weight of the door was 50.1 kg with hardware.

For the first series of tests, the two doors were mounted on opposite sides of a single door frame of 16-gauge pressed steel with an opening 2135 mm high x 915 mm wide. To reduce sound transmission due to vibration of the door frame itself, two layers of 16 mm gypsum wallboard were fastened inside this frame as shown in Fig. 1, and all visible cracks and holes were plugged with caulking. The space between the surfaces of the two doors was 65 mm. To obtain a larger spacing between the doors, for the second series of tests the doors were mounted in adjoining 16-gauge pressed-steel door frames with door separation of 228 mm, as shown in Figure 2.

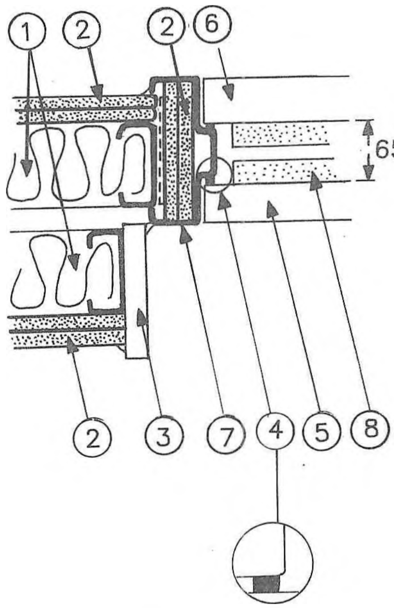

Fig. 1: Cross section sketch showing installation of the single doorframe in the partition. Door separation is 65 mm.

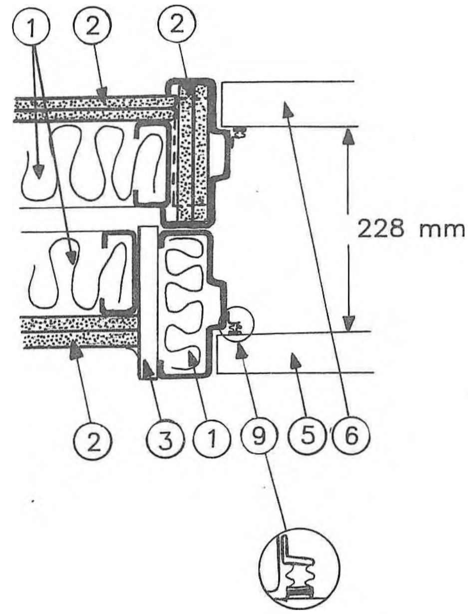

Fig. 2: Cross section sketch showing installation of the double doorframe in the partition. Door separation is 228 mm.

Components are: (1) glass fibre batts between studs and inside doorframe, (2) double layer of 16 mm thick gypsumboard, (3) 16 mm thick plywood, (4) closed-cell foam weatherstrip compressed between door and frame, (5) hollow metal door, (6) solid core wood door, (7) 16 gauge pressed steel doorframe, (8) 25 mm thick open cell polyurethane acoustical foam, (9) magnetic weatherstrip.

Conventional hinges, door handles, latches, and strike plates were installed to permit normal opening and closing of both doors. At the bottom of the door, a plywood threshold gave essentially the same profile as the door frame had at the sides of the door.

For some of the tests with each door frame system, weatherstrip was installed to reduce sound transmission around the four edges of each door. With the single frame (65 mm between the doors) two types of weatherstrip were tested: closed cell foam and a magnetic type similar to refrigerator door gaskets. Only the magnetic weatherstrip was tested with the larger (228 mm) space between the doors. Typical location of the foam or magnetic weatherstrip are shown in the expanded details in Figures 1 and 2. Self-adhesive metal strips (to mate with the magnetic weatherstrip) were applied to the face of the wood door. With each spacing between the doors, acoustically absorbing material was mounted on the face of one or both of the doors for some of the tests. The location of the absorbing material is illustrated in Figure 1. The material used was 25 mm thick open cell polyurethane acoustical foam; in some cases with the larger space between the doors, a double layer was used.

MAJOR TEST RESULTS

It was clearly established that a simple double door system, using two conventional doors with typical gaps at the perimeter and no special acoustical treatment, will not give an STC as high as 45. With quite simple modifications, however, an STC appreciably above STC 45 is attainable. A summary of the test results is presented in the following table. This is followed by a brief discussion of the acoustical effect of various modifications to the door system.

Table 1: Typical Sound Transmission Class (STC) values for door systems tested.

	No Seal	Weatherstrip	Fully Sealed
Wood door	22	26 - 30	31
Steel door	17	28 - 32	35
Both (no absorption)			
65 mm separation	29	39 - 41	47
228 mm separation	34	49 - 50	52
Both (with absorption)			
65 mm separation	41	43 - 45	49
228 mm separation	43	51 - 53	54

To examine the significance of leakage around the doors and compare the acoustical potential of the two types of doors, each door was tested by itself with several treatments to reduce leakage between the door and the frame. The results for the wood door are shown in Figure 3; those for the steel door are in Figure 4. Adding weatherstrip at all four edges of the door gives substantial acoustical improvement. The magnetic weatherstrip provided much better high frequency transmission loss than the foam seals, but gave only slightly higher STC values.

To compare the wood door's potential noise reduction with that of the metal door, both were tested with the cracks between door and frame sealed by weatherstrip at one face, and at the other face with an impervious tape (the heavy solid curves at the top in Figures 3 and 4). Previous studies of sound transmission have shown that for small cracks this provides similar performance to caulking the openings. The metal door had the higher STC but with typical weatherstripping, sound leaks around the door panel would largely eliminate this difference. Without any seals at the perimeter (bottom curves in Figures 3 and 4), the wood door provided more noise reduction than the metal door because the cracks between the wood door and frame were about 1/3 the width of those around the metal door. The test results for "double doors" are for one wood and one steel door, but use of two wood or two metal doors would not greatly affect the performance.

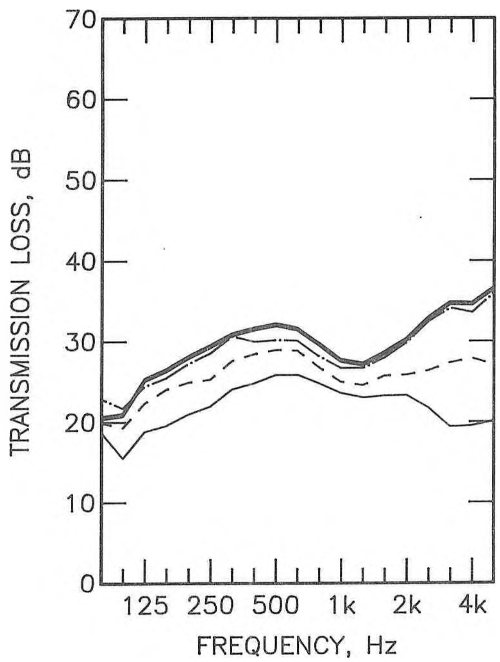

Fig. 3: Transmission Loss of wood door:
(———) no seals, STC 22;
(– – –) foam weatherstrip, STC 26;
(—·—) magnetic weatherstrip, STC 30;
(▬▬▬) fully sealed, STC 31.

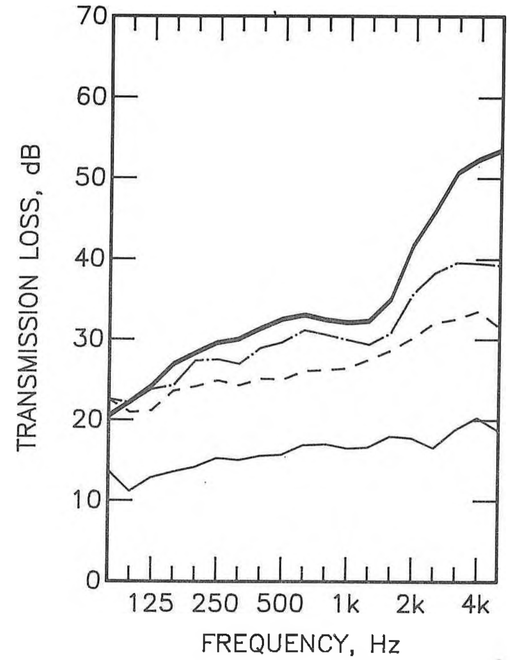

Fig. 4: Transmission Loss of metal door:
(———) no seals, STC 17;
(– – –) foam weatherstrip, STC 28;
(—·—) magnetic weatherstrip, STC 32;
(▬▬▬) fully sealed, STC 35.

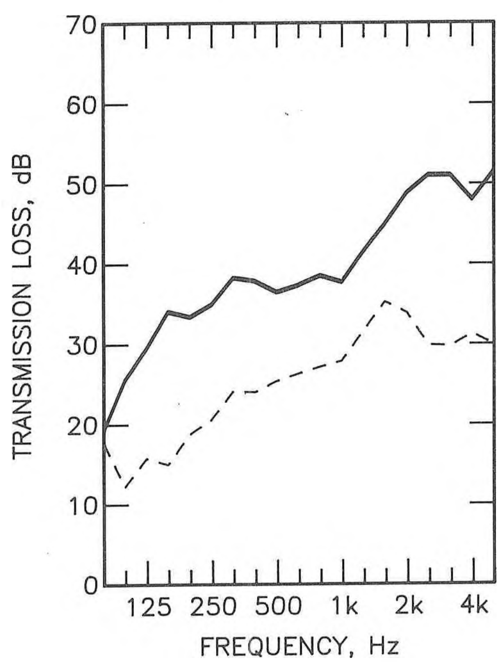

Fig. 5: Sound Transmission Loss for double door with 65 mm airspace:
(– – –) no seals, STC 29;
(———) magnetic weatherstrip, STC 41.

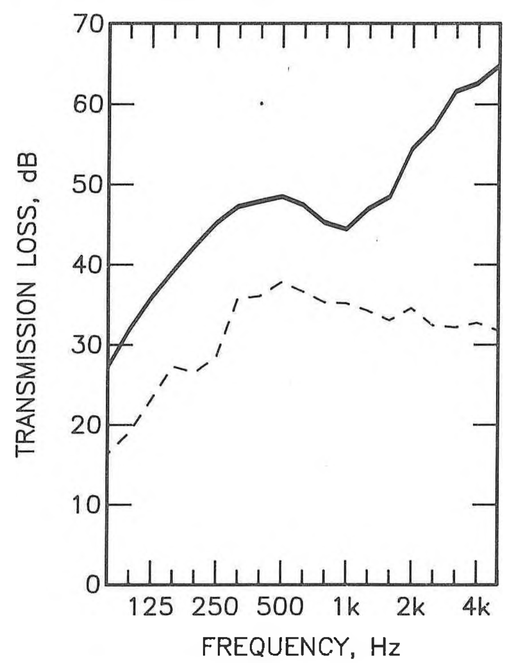

Fig. 6: Sound Transmission Loss for double door with 228 mm airspace:
(– – –) no seals, STC 34;
(———) magnetic weatherstrip, STC 49.

Test results with both doors closed are given in Figure 5 (for the 65 mm separation) and Figure 6 (for the 228 mm separation). The dashed curves (for the case with no treatment at the perimeter of the doors) show that simple double door systems of this type do not provide high STC. Even with the larger spacing, the STC was only 34. Without seals, most of the sound energy goes around the doors rather than through them. Reducing the sound energy going around the edges of the doors, by adding weatherstrip at the perimeter, gave much higher transmission loss as shown by the solid curves in Figures 5 and 6. With the larger spacing, the STC of the weatherstripped doors was well above the design target of 45.

Even higher transmission loss was obtained by adding acoustically absorbing material to the cavity between the two doors. The change in transmission loss from adding 25 mm of acoustical foam on the face of each door is shown in Figure 7 for both interdoor spacings. In both cases, adding absorptive material increased the transmission loss noticeably, especially near the midfrequency dip (around 1kHz for the 228 mm spacing, and slightly lower for the smaller spacing). The transmission loss was not affected strongly by the amount of absorption added, after the initial 25 mm thickness. Overall, adding absorption typically increased the STC by 2 or 3. This effect is appreciably less than that observed when absorption is added to cavity walls. With the doors sealed, the increase due to added absorption was even smaller and was confined to a small frequency region, as shown in Figure 8. Subsequent measurements of acoustic intensity showed that the change in radiated sound energy was localised near the crack at the door perimeter. It seems reasonable to argue that the absorption in the cavity is effective primarily in reducing the effect of the leaks around the door.

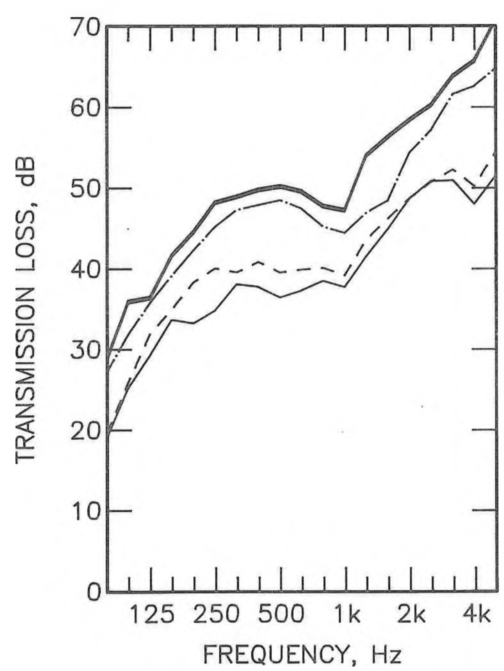

Fig. 7: Sound Transmission Loss for double door with magnetic weatherstrip
65 mm interdoor space:
(———) no absorption, STC 41;
(— — —) with absorption, STC 44;
228 mm interdoor space:
(—·—) no absorption, STC 49;
(▬▬▬) with absorption, STC 52

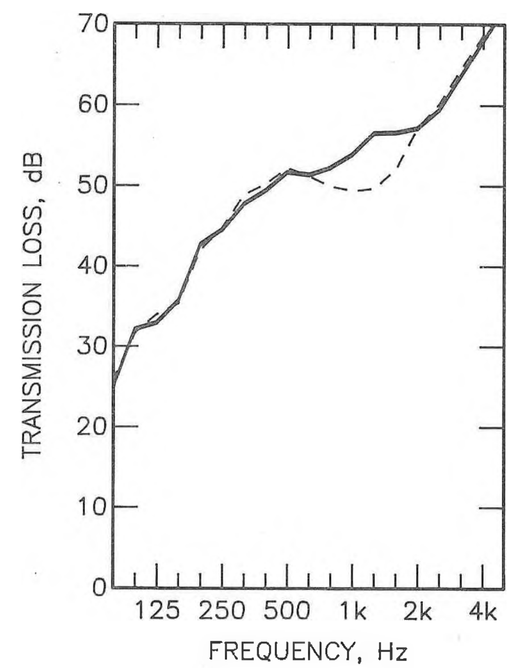

Fig. 8: Sound Transmission Loss for double door with 228 mm airspace and both doors sealed :
(— — —) no absorption, STC 52;
(———) with 25 mm absorption on each door face, STC 54.

The negligible effect of absorption at most frequencies suggests that airborne sound transmission through the inter-door cavity is not dominant when the doors are sealed. The most likely alternative is vibration transmission through the steel doorframe. In these tests, only minor efforts were made to control this transmission path, but eliminating structural coupling would presumably be worthwhile if STC values appreciably above 50 are desired.

The data for the weatherstripped double door systems show some benefit from the addition of absorption, but do not present a compelling case for its use. Without weatherstripping, however, the effect of added absorption is much more obvious. Figure 9 illustrates the increase in transmission loss from adding absorption with a 65 mm inter-door space. The corresponding data for the larger spacing are given in Figure 10. From a practical point of view, not only does adding acoustical absorption to the face of one (or preferrably both) of the doors increase the noise reduction, but also it limits the deterioration in acoustical privacy that would occur if the weatherstripping were damaged or badly installed.

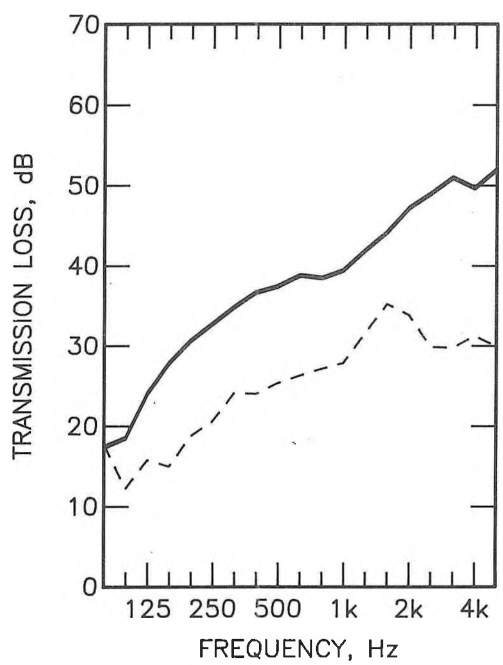

Fig. 9: Sound Transmission Loss for double door with 65 mm airspace and no weatherstripping:
(– – –) no absorption, STC 29;
(———) with 25 mm absorption on each door face, STC 41.

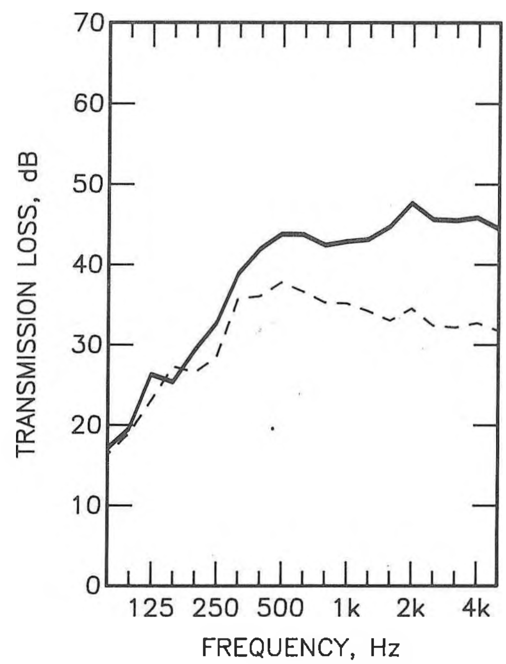

Fig. 10: Sound Transmission Loss for double door with 228 mm airspace and no weatherstripping:
(– – –) no absorption, STC 34;
(———) with 25 mm absorption on each door face, STC 43.

CONCLUSIONS

1. Double door systems using conventional door panels without weatherstripping or other acoustical modifications will not provide an STC much over 30, and thus do not give effective speech privacy.

2. Use of weatherstripping at all four edges of the door gives substantial acoustical improvement. These tests suggest that magnetic weatherstrip is slightly superior to compressed foam gaskets, with the added benefits of permitting much easier opening and closing of the door, and a good record for longevity in residential applications. However, the acoustical advantage of the magnetic weatherstrip is slight, and other types of weatherstripping could provide adequate noise reduction performance for typical applications.

3. Adding acoustical absorption to the face of one (or preferrably both) of the doors increases the noise reduction still further, and drastically lessens the deterioration in acoustical privacy that would occur if the weatherstripping were damaged or badly installed.

4. With weatherstripping on both doors, and acoustical absorption between the doors, a space of approximately 75 to 100 mm (3 to 4 inches) is required between the doors to reliably achieve the target of STC 45 used here as the indicator of acceptable speech privacy.

5. Design of a retrofit system to be added to existing conventional single doors seems to be a feasible (and apparently less expensive) alternative to replacement with commercial acoustical doors. Insensitivity to perfection of the weatherstrip should be much improved relative to typical acoustical doors.

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