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Absorption Corrections for Transmission Loss Measurements

by A.C.C. Warnock and R.E. Halliwell

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RÉSUMÉ

Des mesures de la perte de transmission du son ont été effectuées au moyen de neuf méthodes pour évaluer les effets de l'absorption dans une pièce. Un échantillon de mur a été placé dans cinq positions différentes dans l'ouverture entre deux pièces d'un laboratoire d'acoustique. Quatre niveaux d'absorption ont été utilisés. La méthode classique de décroissance s'est révélée efficace dans tous les cas ainsi qu'une méthode consistant à utiliser une source sonore de puissance connue pour déterminer l'absorption. Une méthode faisant appel au niveau de pression acoustique à proximité de la source et à la moyenne de la pièce (méthode proche/éloignée) ne s'est pas révélée aussi efficace.

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Absorption corrections for transmission loss measurements

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Measurements of sound transmission loss made using nine different methods to estimate the effects of room absorption are reported. A single wall specimen was used in five different positions in the opening of a laboratory sound transmission loss test suite. Four different levels of room absorption were used. The conventional decay method is shown to work well in all cases, as does a method using a sound source with a known power to estimate the room absorption. A method using a sound-pressure level near the source and the room average, the near-far method, did not work as well.

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INTRODUCTION

The measurement of transmission losses for a partition in a building¹ can be considered in two parts: measurement of the noise reduction and a correction for absorption in the receiving room. The first of these quantities can be measured in a straightforward manner with a sound level meter or the equivalent. The preferred method of obtaining the room absorption correction is to measure the decay rate of sound in the receiving room,² but in the past this has presented problems in buildings where sound fields are far from diffuse and decay rates can be very rapid. Decay measurements usually require equipment that is not easy to use in field situations and that in some cases may not even be adequate for the job. Tape recorders have been used to carry data back to laboratories where more powerful instruments can measure rapid decays, or the tape can be replayed at slower speed,³ but this is rather inconvenient. Two steady-state measurement methods have been developed in an attempt to simplify the measurement of the room absorption correction: the reference sound source method¹ and the near-far method.⁴ From a practical point of view these methods offer considerable advantages because the same instruments used to measure noise reduction can be used to measure the room absorption correction. This paper compares measurements of the room absorption done with variants of each of the methods mentioned above, and examines the differences among them. Although instrumentation that will easily measure rapid decays in the field is now available, it is still of considerable interest to look carefully at the different methods of measuring the room absorption correction as some of these methods are still permitted in acoustical standards and not everyone has the latest instrumentation.

I. ROOM DESCRIPTION

The description of the rooms used, the measurement equipment, and the partition under test were reported in a previous paper.⁵ Briefly, a 2.44 × 3.05-m hardboard partition was moved to five different positions in the opening between two reverberation rooms, one a large room with a volume of 250 m³ and the other a small room with a volume of 65 m³. The transmission loss for the panel was measured using different techniques for four different absorptive con-

ditions, A0–A3, in the 65-m³ room. The A0 condition corresponded to the room in its normal condition, i.e., reverberation times around 2 s, while the other three conditions had gradually increasing amounts of absorption added until the reverberation times were about 0.2 s. Some representative times were given in Ref. 5. The combination of five wall positions and four absorption conditions provided a total of 20 room configurations in which the different methods of determining the absorption correction could be tested. One of the main purposes of this study was to investigate how well these different methods of measuring room correction would work in fairly small, highly absorptive rooms, typical of those in furnished buildings. Therefore the measurements described in the following were all made using the 65-m³ room as the receiving room for the transmission loss measurement. The changes in wall position did not seriously alter the receiving room shape but, as will be seen, even these changes were enough to show that some of the methods are not adequate.

II. BACKGROUND TO MEASUREMENT PROCEDURES

In current standards^{1,2} the transmission loss (TL) of a partition is given by the expression

$$TL = L_s - L_r + 10 \log(S_p) - 10 \log A_r, \quad (1)$$

where L_s = mean sound-pressure level in source room, L_r = mean sound-pressure level in receiving room, S_p = area of partition under test, and A_r = total absorption in receiving room.

In our previous paper⁵ we suggested that Eq. (1) is incomplete and should be written as

$$TL = L_s - L_r - W_r + 10 \log(S_p) - 10 \log(4bV/c), \quad (2)$$

where

V = volume of receiving room,

b = energy decay rate in receiving room,

$$A_r = 4bV/c, \quad (3)$$

$$W_r = 10 \log(1 + S_r \lambda / 8V), \quad (4)$$

S_r = surface area of receiving room,

λ = wavelength of sound,

c = speed of sound.

Measurement of sound transmission loss using conventional techniques comprises what is essentially a measure of the sound power being radiated from the partition under test, and the added term, W_r , is the Waterhouse correction, which is required to account for the buildup in sound energy close to the walls of the room and is specified in ANSI S1.31.⁶ As in the previous work,⁵ the A_r term is expanded to make it clear that the important parameter is the rate of energy dissipation in the receiving room, b . If the sound field in the receiving room is diffuse, then according to simple diffuse field theory the decay rate is related to the total absorption in the room by Eq. (3). When the receiving room is very absorptive and the sound field in it is definitely not diffuse, it is not likely that Eq. (3) is still valid but it does not matter if b is measured directly. One of the main purposes of this study was to investigate this statement and to see how well Eq. (2) accounts for changes in room energy decay rate. Both ASTM E90 and E336 limit the amount of sound-absorbing material that can be in the rooms during a sound transmission loss measurement. The data to be presented here suggest that these restrictions are not necessary although they may be preferable in laboratory situations.

A. Decay rate measurements

ASTM E90 requires that the room correction be determined by measuring the decay rate in the room. As detailed in the previous paper,⁵ this was done using a computer-based system and doing a least mean squares fit to the first 25 dB of ensemble-averaged decays. Using the earliest possible part of the decay meant that any problems with decay curvature were minimized. Transmission through the wall from the large room, which becomes visible during the later part of the decays, was not significant.

B. Reference power source measurements

Given a source of known sound power level L_w , the mean sound-pressure level in a room L_{ra} can be related to the room absorption using the relationships given in ANSI S1.31 which can be manipulated to give

$$10 \log A_r = L_w - L_{ra} - W_r + 6.2. \quad (5)$$

The number 6.2 is treated, for convenience, as a constant in the expressions that follow, but it actually depends on atmospheric pressure and air temperature. However, both of these quantities were measured during the experiments and corrections were made in accordance with the equations in ANSI S1.31.⁶ Equation (5) omits the nearfield contributions of the source because users of the standard are required to make measurements far enough away from the source that such contributions are negligible.

The reference power method of determining the room absorption described in ASTM E336 does not include a Waterhouse correction and only states that

$$10 \log A_r = L_w - L_{ra} + 6.2. \quad (6)$$

If this expression is substituted in Eq. (1) then the transmission loss is given by

$$TL = L_s - L_r + 10 \log (S_p) - (L_w - L_{ra} + 6.2). \quad (7)$$

Substitution of Eq. (5) in Eq. (2) gives the same result. Thus although there is apparently an error in Eq. (6), the expression used in E336, there is a compensating error in Eq. (1). The two W terms are cancelled and the final values for transmission loss should be correct even though the Waterhouse correction is omitted twice.

Two different calibrated power sources were used: an ILG reference sound source, which is a centrifugal fan, and a Tracoustics model NS-100 sound source. This latter source is a loudspeaker with associated circuitry designed to meet the requirements of ASTM E597.⁷ It is not sold as a reference sound source but it was included in these investigations to get some idea of the magnitude of the errors that might arise from the use of such a source, even though it is calibrated in a laboratory.

Each of the sources was used in two different configurations in the corner of the room adjacent to the partition under test, and in three positions beside the partition under test. These source configurations are illustrated in Fig. 1. When three source positions were used the room corrections for each position were added together to give a mean correction for this configuration. Thus four reference power measurements of the room absorption were available for each room condition. To calibrate the sources, the sound power of each was measured in accordance with ANSI S1.31 for configurations equivalent to the measurement conditions but with the sources on the other side of the partition in the 250-m³ reverberation room (Fig. 1).

C. Near-far method

This method follows a technique for measuring room corrections described in the AMA-I-II method,⁴ which is used to measure the sound transmission between two rooms having a common ceiling and plenum. The near-far method has been suggested for use in other standards and is presently allowed in ASTM E597 which measures noise reduction between rooms using A-weighted sound pressure levels. In the AMA-I-II near-far method, the sound-pressure level is measured at a reference point close to the source and compared to the mean sound level in the room. The procedure is calibrated by making the same room fairly reverberant and measuring decay rates as well as the near-far level difference. The absorption correction is then given by

$$10 \log (A_r) = 10 \log (A_c) + (D_r - D_c), \quad (8)$$

where A_r = absorption in the receiving room in the test condition, A_c = absorption in the calibration condition,

FIG. 1. Source configurations.

D_r = near-far difference in test condition, and D_c = near-far difference in calibration condition.

For general use as a means of estimating the room absorption correction in different rooms, Eq. (8) is not quite correct, again because the Waterhouse effect was not considered. The near-far method assumes that a measurement of the nearfield level L_n can be made close enough to the source that the reverberant field is negligible and

$$L_n = L_w + 10 \log [Q / (4\pi R^2)], \quad (9)$$

where Q = directivity of the source and R = distance of near point from the source. The method then assumes that a far-field measurement L_f can be made in the room such that

$$L_f = L_w - 10 \log A_r + 6.2 - W_r, \quad (10)$$

which is simply Eq. (5) rearranged with L_f replacing L_{ra} . The difference $L_n - L_f$ is given by

$$D = 10 \log [Q / (4\pi R^2)] - 6.2 + 10 \log A_r + W_r. \quad (11)$$

If one assumes that the Q of the source is not significantly affected by the different room conditions, then the first two terms on the right-hand side of this equation are constants and one can write

$$D_c - 10 \log A_c - W_c = D_r - 10 \log A_r - W_r, \quad (12)$$

where the subscript c refers to the calibration condition. From this it is easily seen that Eq. (8) should have been written as

$$10 \log A_r = 10 \log A_c + (D_r - D_c) + (W_c - W_r). \quad (13)$$

When this is substituted in Eq. (2) one gets

$$TL = L_s - L_r + 10 \log S_p - (D_r - D_c) - 10 \log A_c - W_c. \quad (14)$$

Thus if the near-far technique were used to measure the room absorption, and no account of the Waterhouse correction were taken in the measurement, the transmission loss would be in error by the Waterhouse correction for the calibration room.

The two sources and source configurations used for the near-far measurements were the same as those used for the reference sound source method. This again gave four slightly different near-far measurements for comparison. The near microphone for the ILG source was equipped with a wind-screen and was placed on the extension of the axis of rotation of the fan so that the microphone was 50 mm from the fan. The near microphone position for the Tracoustics source was directly in front of the speaker cabinet at a distance of 300 mm, the distance normally used in E597 testing with this particular source.

To calibrate the sources for the near-far measurement, they were placed in a reverberant 120-m³ room. It might have been preferable to have calibrated the sources in the 250-m³ room because the W_c term would have been smaller, but at the time it was thought more appropriate to calibrate them in a room that was about the same size as normal rooms in buildings. In any case, the difference between the W_c corrections for the 250-m³ and 120-m³ rooms are rather small.

There were thus nine methods used to determine the sound transmission loss for each wall position and for each absorption condition in the room. These are identified according to the method used to determine the room correction as follows:

- 0: The decay method,
- 1: ILG reference source—one position
- 2: ILG reference source—three positions,
- 3: Tracoustics reference source—one position,
- 4: Tracoustics reference source—three positions,
- 5: Near-far method—ILG, one position,
- 6: Near-far method—ILG, three positions,
- 7: Near-far method—Tracoustics, one position,
- 8: Near-far method—Tracoustics, three positions.

In all methods the noise reduction was measured in the usual way as the difference between mean room sound-pressure levels. The data sets obtained using method 0 in absorption condition A0 are used in the following as reference conditions with which all comparisons are made.

III. DISCUSSION OF RESULTS

A. Decay rate results—method 0

Table I shows ΔTL , the average differences between the transmission losses measured in the A0 room condition and those measured in the A1, A2, and A3 conditions using the decay rate method. Each entry in the table represents the mean of the differences measured for the five wall positions. This table shows that the decay rate method is only slightly affected by the presence of fairly large amounts of sound absorbing material in the receiving room. The ΔTL values and the standard deviations in the table are both quite small.

One can conclude therefore that measurements of transmission loss using method 0 in fairly absorptive receiving rooms in field situations should work just as well as they did

TABLE I. Mean difference ΔTL between transmission loss values for different room absorption conditions. Standard deviation (s.d.) is about the mean. Reference is A0 TL value.

Freq. (Hz)	ΔTL				s.d.			
	A1	A2	A3	Mean	A1	A2	A3	Mean
63	0.6	1.3	2.2	1.4	1.0	1.4	1.6	1.5
80	-0.1	0.7	1.1	0.6	0.5	0.6	0.7	0.8
100	0.3	0.2	-0.0	0.1	0.5	0.4	0.4	0.4
125	-0.0	-0.0	-0.2	-0.1	0.4	0.6	0.3	0.4
160	-0.1	-0.1	-0.1	-0.1	0.4	0.3	0.5	0.4
200	-0.1	-0.1	-0.5	-0.2	0.6	0.7	0.8	0.7
250	0.4	0.5	0.6	0.5	0.3	0.2	0.3	0.3
315	0.2	0.3	0.7	0.4	0.3	0.4	0.6	0.5
400	0.2	0.7	0.9	0.6	0.1	0.2	0.3	0.4
500	0.3	0.9	1.3	0.8	0.2	0.2	0.3	0.5
630	0.3	0.7	0.7	0.6	0.2	0.1	0.3	0.3
800	0.3	0.6	0.7	0.5	0.1	0.1	0.5	0.3
1000	0.3	0.6	0.7	0.5	0.1	0.2	0.4	0.3
1250	0.3	0.5	0.7	0.5	0.1	0.2	0.3	0.3
1600	0.4	0.7	1.0	0.7	0.1	0.2	0.3	0.3
2000	0.4	0.8	0.9	0.7	0.1	0.1	0.4	0.3
2500	0.5	0.7	0.8	0.7	0.2	0.2	0.6	0.4
3150	0.4	0.7	0.5	0.5	0.2	0.2	1.0	0.6
4000	0.4	0.6	0.5	0.5	0.2	0.3	1.1	0.6
5000	0.4	0.6	0.4	0.4	0.2	0.3	0.9	0.5
6300	0.4	0.5	0.5	0.5	0.3	0.4	0.8	0.5

here. One can also conclude that the restrictions in the standards^{1,2} on the amount of sound absorbing material allowable in the receiving room are unnecessarily stringent.

B. Reference sound source results—methods 1–4

Table II and III give the ΔTL values for methods 1–4 where the reference sound sources were used to get the room corrections. The mean and the standard deviation are calculated from the five sets of differences from the five wall positions. Examination of these tables shows that using room corrections obtained from the ILG source in the corner consistently produces transmission loss values in the four or five low-frequency bands around 160 Hz that are about 1.5 dB too low with respect to the decay rate TL values. Table IV, which gives the mean ΔTL for all absorptive conditions, supports this conclusion.

Method 2, with the ILG source in three positions against the partition under test, seems to be slightly better than method 1 and the transmission loss values at low frequencies are not noticeably reduced with respect to the reference conditions except at 80 Hz where the measurements may not be valid.

In contrast, the data obtained from method 3 with the Tracoustics loudspeaker source in the corner are not noticeably different from those obtained from method 4 where it is placed against the partition under test. One obvious difference between these two sources is size. The Tracoustics source is several times larger than the ILG source and does not fit into the corner of the room so well. On the other hand, this source was more sensitive to the addition of sound absorbing material in the receiving room, and lower transmis-

TABLE II. Reference power transmission loss measurements. Methods 1–4 ΔTL , mean differences from reference TL values for absorption conditions A0–A1.

Freq.	Absorption condition A0 ΔTL				Absorption condition A1 ΔTL			
	1	2	3	4	1	2	3	4
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	1.2	0.6	2.0	1.1	-0.2	0.1	2.2	2.5
80	0.8	-2.6	-1.0	6.9	-0.3	-2.8	-0.8	6.1
100	2.0	0.4	-1.7	0.5	1.8	0.8	-0.4	1.3
125	2.1	0.8	0.1	-0.8	1.6	0.9	0.9	-0.4
160	1.3	-1.3	-0.9	-0.5	1.4	-0.5	-0.1	-0.0
200	0.4	0.2	-0.7	1.1	1.1	0.6	0.3	1.6
250	0.1	0.3	-0.3	-0.1	0.9	0.9	1.5	0.8
315	-0.9	0.2	0.3	0.4	-0.5	0.7	2.0	1.4
400	-0.8	-0.0	-0.1	-0.2	0.1	0.4	1.6	1.0
500	-1.4	0.3	-1.2	-0.4	-0.7	0.6	1.1	1.1
630	-0.6	-0.4	-0.5	-0.5	0.1	0.0	1.6	0.9
800	-0.4	-0.3	-0.7	-0.3	0.6	0.0	0.9	0.7
1000	-0.7	-0.4	-0.6	-0.5	0.1	0.1	0.7	-0.0
1250	-0.7	-0.5	-0.9	-0.5	0.1	-0.3	0.5	0.2
1600	-0.4	-0.4	-0.9	-0.6	0.5	0.0	0.3	-0.0
2000	-0.3	-0.5	-0.0	-0.1	0.5	-0.1	1.0	0.2
2500	-0.3	-0.4	-0.4	-0.4	0.4	0.0	0.5	0.2
3150	-0.0	-0.0	0.0	-0.0	0.5	0.2	1.0	0.6
4000	0.2	0.2	-0.1	-0.2	0.6	0.4	0.9	0.3
5000	0.4	0.4	0.4	0.5	0.7	0.6	1.3	1.1
6300	0.6	0.7	0.7	0.7	0.8	0.9	1.7	1.2

TABLE III. Reference power transmission loss measurements. Mean differences from reference TL values for absorption conditions A2 and A3.

Freq.	Absorption condition A2 ΔTL				Absorption condition A3 ΔTL			
	1	2	3	4	1	2	3	4
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	0.4	0.9	2.3	-0.4	0.9	1.6	2.4	2.9
80	1.0	-2.2	0.4	6.8	0.9	-2.1	0.7	7.0
100	2.1	0.7	-0.6	0.9	1.7	0.5	-0.8	0.4
125	1.1	0.8	-0.3	-1.0	0.6	0.4	-0.5	-1.2
160	1.3	-0.5	-0.4	-0.2	0.9	-0.7	-1.2	-0.4
200	1.0	0.7	-0.4	1.8	1.2	0.6	-0.4	1.7
250	1.1	1.0	1.4	1.2	1.1	0.9	1.2	1.3
315	-0.4	0.8	1.2	1.5	0.1	0.7	1.9	1.7
400	0.3	0.3	1.7	1.3	0.5	0.3	2.3	1.4
500	-0.6	0.5	1.7	1.3	-0.3	0.7	1.9	1.1
630	0.1	-0.1	2.0	1.1	-0.0	-0.0	1.8	1.2
800	0.6	-0.3	0.5	0.6	0.5	-0.1	1.0	0.9
1000	0.1	0.0	0.2	-0.2	-0.2	0.1	0.3	-0.2
1250	0.2	-0.3	0.1	0.3	0.0	-0.4	-0.1	0.4
1600	0.6	-0.0	-0.1	-0.2	0.6	-0.0	0.1	0.0
2000	0.7	-0.1	0.6	0.3	0.8	-0.2	1.0	0.2
2500	0.3	-0.0	-0.2	0.1	0.3	-0.1	-0.2	0.0
3150	0.3	0.2	0.5	0.6	0.1	-0.1	0.5	0.6
4000	0.4	0.4	0.6	0.3	0.1	0.0	0.4	0.4
5000	0.6	0.5	1.2	1.1	0.2	0.2	1.3	1.2
6300	0.5	0.7	1.2	1.3	0.4	0.6	1.6	1.5

sion loss values resulted from its use in room conditions A1, A2, and A3. The data for this source exhibited more variance than those for the ILG.

The Tracoustics source is not sold as a reference sound source so it is perhaps not surprising that it did not function too well in these experiments. It would have been conven-

TABLE IV. Reference power transmission loss measurements. Mean differences from reference TL values for mean of absorption conditions A0, A1, A2, and A3. Standard deviation (s.d.) is about the mean.

Freq.	ΔTL				s.d.			
	1	2	3	4	1	2	3	4
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	0.6	0.8	2.2	1.5	1.8	1.9	0.8	3.6
80	0.6	-2.4	-0.2	6.7	1.7	1.9	1.4	1.6
100	1.9	0.6	-0.9	0.8	0.9	0.6	0.9	1.3
125	1.3	0.7	0.1	-0.9	1.2	0.8	0.9	0.7
160	1.2	-0.7	-0.7	-0.3	0.7	0.8	0.9	0.7
200	0.9	0.5	-0.3	1.6	0.7	0.7	0.9	0.4
250	0.8	0.8	0.9	0.8	0.7	0.9	1.0	0.8
315	-0.5	0.6	1.3	1.2	0.6	1.0	1.0	1.1
400	0.0	0.3	1.4	0.9	0.6	0.5	1.1	1.0
500	-0.7	0.5	0.9	0.8	0.7	0.8	1.4	0.9
630	-0.1	-0.1	1.2	0.7	0.5	0.5	1.1	1.0
800	0.3	-0.2	0.4	0.5	0.6	0.5	0.8	0.7
1000	-0.2	-0.0	0.1	-0.2	0.5	0.5	0.8	0.6
1250	-0.1	-0.4	-0.1	0.1	0.6	0.5	0.8	0.7
1600	0.3	-0.1	-0.2	-0.2	0.6	0.6	0.7	0.6
2000	0.4	-0.2	0.6	0.2	0.6	0.5	0.6	0.4
2500	0.2	-0.1	-0.1	-0.0	0.5	0.5	0.7	0.8
3150	0.2	0.1	0.5	0.4	0.6	0.6	0.7	0.6
4000	0.3	0.2	0.5	0.2	0.6	0.6	0.8	0.8
5000	0.4	0.4	1.1	1.0	0.6	0.6	0.7	0.6
6300	0.6	0.7	1.3	1.2	0.5	0.7	0.7	0.7

ient, however, if such a simple source had worked well enough for field sound transmission loss measurements.

C. Near-far results—methods 5–8

Tables V and VI give the ΔTL values for methods 5–8, the near-far techniques. Again each table contains the mean of five wall positions for a single room absorption condition. The means for all absorption conditions and wall positions are given in Table VII.

Examination of these tables shows that for the ILG source in the corner position there is a systematic ΔTL of about -2 dB, that is, the measured transmission losses using this method to obtain the room correction would be about 2 dB higher than those from the reference decay rate method. The three-position arrangement also shows this systematic difference.

Methods 7 and 8, using the Tracoustics source in the near-far configurations, give much more erratic results than the other methods. No clear trends are visible and the variance for this source tends to be larger than that for the ILG source.

Neither the ILG nor the Tracoustic represents a true point source, and thus there could be some question as to the validity of the near measurement. However, this method is allowed in ASTM E597 and will probably be used by acousticians in the field; for this reason it was included in the study.

IV. DISCUSSION OF RESULTS

Part of the reason for doing this work was to investigate the variance introduced into the standard methods of mea-

TABLE V. Near-far transmission loss measurements. Mean differences and standard deviations from reference TL values for absorption condition A0 and A1.

Freq.	Absorption condition A0 ΔTL				Absorption condition A1 ΔTL			
	5	6	7	8	5	6	7	8
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	1.1	1.6	2.1	7.1	-0.4	1.4	2.0	7.9
80	-3.2	0.9	-0.2	3.0	-4.6	0.7	-1.5	1.5
100	-0.1	-1.1	-0.3	0.5	-0.1	-0.6	-0.5	-0.0
125	-1.5	-2.5	-0.6	-1.2	-2.3	-2.2	-1.9	-2.1
160	-2.1	-1.2	-1.9	-5.4	-2.1	0.0	-3.1	-5.9
200	-2.7	-2.0	-0.2	-2.3	-2.6	-1.5	-0.5	-2.6
250	-2.4	-0.2	-1.8	0.1	-2.0	0.9	-0.9	0.4
315	-2.5	-1.7	-1.3	-1.1	-2.3	-1.1	-0.4	-1.2
400	-2.3	-1.7	-1.6	-1.8	-1.7	-1.4	-0.5	-1.4
500	-2.0	-1.2	-1.6	-1.4	-2.0	-0.9	0.4	-0.6
630	-1.4	-1.8	-1.7	-0.1	-1.1	-1.6	-1.2	-0.2
800	-0.9	-0.8	-1.5	1.3	-0.4	-0.6	-2.5	0.6
1000	-0.9	-1.2	0.3	-0.6	-0.8	-1.1	1.4	-0.8
1250	-1.5	-1.2	0.5	0.2	-1.1	-1.3	1.4	0.3
1600	-2.0	-1.1	0.0	-0.1	-1.5	-1.3	1.1	-0.1
2000	-2.4	-2.0	-0.3	-0.6	-2.1	-2.0	0.4	-0.5
2500	-2.3	-3.4	-1.0	-1.5	-2.2	-3.8	0.1	-1.0
3150	-1.7	-1.8	-0.2	0.6	-1.6	-2.1	0.9	1.2
4000	-1.5	-1.0	-0.4	-1.0	-1.7	-1.2	0.4	-0.7
5000	-1.9	-2.5	-0.7	-0.9	-1.6	-2.6	0.0	-0.4
6300	-2.0	-1.6	-1.1	-0.8	-2.0	-1.5	-0.3	-0.4

TABLE VI. Near-far transmission loss measurements. Mean differences and standard deviations from reference TL values for absorption conditions A2 and A3.

Freq.	Absorption condition A2 ΔTL				Absorption condition A3 ΔTL			
	5	6	7	8	5	6	7	8
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	0.3	2.8	1.9	4.7	0.1	3.2	2.2	8.2
80	-3.5	1.7	-0.5	2.3	-3.5	1.4	-0.4	2.2
100	-0.2	-0.5	-0.9	-0.7	-0.7	-0.7	-1.1	-1.3
125	-3.0	-2.1	-2.7	-2.5	-3.8	-2.5	-3.2	-2.6
160	-2.6	-0.1	-2.5	-6.5	-3.3	-0.3	-3.3	-6.5
200	-2.9	-1.5	-0.5	-2.7	-2.7	-1.3	-1.2	-2.6
250	-1.8	0.6	-0.8	0.9	-2.0	0.8	-1.3	0.8
315	-2.5	-1.2	-1.7	-1.0	-2.1	-0.9	-1.2	-0.9
400	-1.8	-1.5	-1.8	-0.8	-1.8	-1.3	-0.9	-0.8
500	-2.4	-1.2	0.9	-0.6	-2.0	-1.0	1.3	-0.6
630	-1.2	-1.9	-0.2	-0.1	-1.6	-1.8	0.1	-0.3
800	-0.7	-1.3	-3.4	0.1	-0.8	-1.1	-3.4	0.1
1000	-1.1	-1.4	0.7	-1.4	-1.3	-1.4	0.6	-1.3
1250	-1.1	-1.3	0.6	-0.1	-1.4	-1.4	0.5	0.1
1600	-1.4	-1.2	0.4	-0.2	-1.5	-1.3	0.6	-0.1
2000	-2.3	-2.0	-0.3	-0.7	-2.1	-2.4	0.4	-0.8
2500	-2.4	-3.6	-0.9	-1.2	-2.3	-4.2	-0.7	-1.2
3150	-2.0	-2.1	0.0	0.9	-2.1	-2.7	0.1	1.0
4000	-1.8	-1.3	-0.1	-0.8	-2.3	-1.5	-0.2	-0.7
5000	-1.9	-2.6	-0.3	-0.6	-2.2	-3.1	-0.0	-0.6
6300	-2.5	-1.7	-1.0	-0.5	-2.6	-1.8	-0.3	-0.2

suring transmission loss in field situations by allowing the use of two different methods of correcting for the room absorption. The results show that the near-far techniques used are not good enough to be permitted in standard measure-

TABLE VII. Near-far transmission loss measurements. Mean differences and standard deviations from reference TL values for mean of all absorption conditions A0, A1, A2, and A3. Standard deviation (s.d.) is about the mean.

Freq.	ΔTL				s.d.			
	5	6	7	8	5	6	7	8
	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos	ILG Corner	ILG 3-Pos	TRAC Corner	TRAC 3-Pos
63	0.3	2.3	2.1	7.0	2.1	2.3	1.1	3.7
80	-3.7	1.2	-0.7	2.2	1.8	2.1	1.4	2.8
100	-0.2	-0.7	-0.7	-0.4	1.1	0.7	1.2	1.3
125	-2.7	-2.3	-2.1	-2.1	1.2	1.0	1.4	0.9
160	-2.5	-0.4	-2.7	-6.1	0.9	1.0	1.0	0.9
200	-2.7	-1.6	-0.6	-2.5	0.5	0.9	0.8	0.7
250	-2.1	0.5	-1.2	0.6	0.6	1.0	0.9	1.6
315	-2.4	-1.2	-1.1	-1.1	0.5	1.1	1.2	1.0
400	-1.9	-1.5	-1.2	-1.2	0.4	0.8	1.3	1.0
500	-2.1	-1.1	0.3	-0.8	0.4	0.9	1.3	1.2
630	-1.3	-1.8	-0.7	-0.2	0.4	0.7	1.2	0.9
800	-0.7	-1.0	-2.7	0.5	0.5	0.5	1.4	2.0
1000	-1.0	-1.3	0.8	-1.0	0.5	0.6	0.8	0.8
1250	-1.3	-1.3	0.7	0.1	0.5	0.6	0.7	0.9
1600	-1.6	-1.2	0.5	-0.1	0.4	0.6	0.7	0.8
2000	-2.2	-2.1	0.1	-0.6	0.4	0.6	0.7	0.8
2500	-2.3	-3.8	-0.6	-1.2	0.4	0.7	0.7	0.6
3150	-1.8	-2.2	0.2	0.9	0.7	0.7	0.8	0.8
4000	-1.8	-1.2	-0.1	-0.8	0.6	0.8	0.8	0.7
5000	-1.9	-2.7	-0.3	-0.6	0.6	0.7	0.7	0.7
6300	-2.3	-1.6	-0.7	-0.5	0.6	0.7	0.7	0.6

TABLE VIII. Mean ΔTL and standard deviation for methods 0, 1, and 2 for absorption conditions A0, A1, A2, and A3.

Freq. (Hz)	ΔTL	Standard deviation
63	0.9	1.8
80	-0.5	2.2
100	0.9	1.0
125	0.7	1.0
160	0.2	1.1
200	0.5	0.8
250	0.7	0.7
315	0.2	0.9
400	0.3	0.6
500	0.2	1.0
630	0.1	0.5
800	0.2	0.6
1000	0.1	0.5
1250	-0.0	0.6
1600	0.3	0.6
2000	0.3	0.6
2500	0.2	0.6
3150	0.2	0.6
4000	0.3	0.6
5000	0.4	0.6
6300	0.6	0.6

ments. All of the measurements made using methods 0-2 are, however, valid according to present field standards. Thus to investigate the variance introduced by these two methods, Table VIII shows the standard deviation of the transmission losses about the A0 decay rate measurements. Each wall position provides four absorption conditions for methods 0, 1, and 2. With the method 0-room A0 condition as the reference in each case, one has 11 sets of differences for each wall position. Thus 55 sets of differences were used to calculate the standard deviation for each frequency band.

This uncertainty contributed to the transmission loss measurement by the use of the decay rate method is negligible. The spatial variance of the energy decay rate may be quite large on a percentage basis but when the $10 \log A_r$ term is calculated, the uncertainty is insignificant relative to the spatial variance of the measured sound pressure levels. When a reference sound source is used to estimate the room absorption correction, two sets of sound-pressure levels are measured in the receiving room and the variance of the levels in each case must be combined with an unavoidable increase in the uncertainty. If the spatial variance of the sound-pressure level is approximately the same in both the source and receiving rooms, then the uncertainty in method 1 will be 1.2 times that for method 0. The uncertainty in method 2, where three ILG positions were used, is somewhat less than that for method 1. The exact amount will in general depend on the number of source positions and microphones used.

V. CONCLUSIONS

The data obtained verify that the use of the sound decay rate as a means of removing the effects of room absorption from a measurement of transmission loss is a reliable tech-

nique. This is already the required method in ASTM E90 but is only one of two permissible methods in methods E336 and E1007.⁸ The restrictions on the permitted room absorption in the field measurement standards could be relaxed significantly at least for the receiving room.

The reference sound source method, the other permissible method in E336 and E1007, shows only small, apparently random differences from the decay rate method with the exception of the low-frequency region discussed above. This is only true for the ILG source. The only suggestion that could be made to improve the field measurement standards would be to require that reference power sources be placed in front of the partition being measured rather than in a corner.

The data presented do not support the use of ordinary loudspeakers as reference sources even when they are calibrated in a reverberation room. It would have been interesting to have included a reference sound source made from a loudspeaker as part of this study but one was not available.

The systematic differences and the larger scatter in the data for the near-far measurements indicate that this technique should not be introduced as a permissible technique in field measurement standards. The method is currently permitted in ASTM E597 but in that case A-weighted sound level measurements are made. The method may work in that case.

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¹ASTM E-336-84, "Standard Test Method for Measurement of Airborne Sound Insulation in Buildings" (American Society for Testing and Materials, Philadelphia, PA, 1984).

²ASTM E90-83, "Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions" (American Society for Testing and Materials, Philadelphia, PA, 1983).

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⁴AMA 1-II-1967, "Method of Test, Standard Specification for Ceiling Sound Transmission Test by Two Room Method" (Acoustical Board Products Assoc., Park Ridge, IL, 1967).

⁵R. E. Halliwell and A. C. C. Warnock, "Sound Transmission Loss: Comparison of Conventional Techniques With Sound Intensity Techniques," *J. Acoust. Soc. Am.* **77**, 2094-2103 (1985).

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⁷ASTM E597-81, "Standard Practice for Determining a Single-Number Rating of Airborne Sound Isolation for Use in Multiunit Building Specifications" (American Society for Testing and Materials, Philadelphia, PA, 1981).

⁸ASTM E1007-84, "Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures" (American Society for Testing and Materials, Philadelphia, PA, 1984).

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