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MEASUREMENT OF ABSORPTION COEFFICIENTS IN A REVERBERATION ROOM

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BRIEF HISTORY

The ISO Recommendation R 354, *Measurement of Absorption Coefficient in a Reverberation Room*, was drawn up by Technical Committee ISO/TC 43, *Acoustics*, the Secretariat of which is held by the British Standards Institution (B.S.I.).

Work on this question by the Technical Committee began in 1955 and led, in 1961, to the adoption of a Draft ISO Recommendation.

In November 1961, this Draft ISO Recommendation (No. 477) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies:

Australia	Germany	New Zealand
Austria	Greece	Portugal
Belgium	India	Switzerland
Brazil	Indonesia	Sweden
Denmark	Ireland	United Kingdom
Finland	Netherlands	U.S.S.R.

Three Member Bodies opposed the approval of the Draft:

France, Japan, U.S.A.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in December 1963, to accept it as an ISO Recommendation.

ISO Recommendation R 354 December 1963

MEASUREMENT OF ABSORPTION COEFFICIENTS IN A REVERBERATION ROOM

INTRODUCTION

With a source of sound operating in an enclosed space, the level to which reverberant sound builds up, and the subsequent decay of reverberant sound when the source is stopped, are governed by the sound-absorbing characteristics of the boundary surfaces or objects in the room. In general, the fraction of the incident sound power which is absorbed at a surface depends upon the angle of incidence. In order to be able to assess the reverberation time of an auditorium or the noise reduction which would be effected by an absorbing treatment in e.g. an office or workshop, a knowledge is required of the absorbing characteristics of the surfaces, normally in the form of a suitable average over all angles of incidence. Since the angular distribution of sound in actual enclosures varies, it is convenient for the purpose of standardization to take as the basis the simplest angular distribution, namely a uniform distribution, since there are no grounds for preferring special directions. This is called *the diffuse state*.

The aim of measurements of the sound absorption of objects, or the absorption coefficients of surfaces in a reverberation room, is to obtain the values appropriate to this condition. In view of the difficulty of obtaining complete diffusion, absorption coefficients determined in a reverberation room may not be so precise as absorption coefficients measured at specific angles of incidence, especially at normal incidence by the tube method. The fact that, owing to diffraction at the edges, the equivalent absorption area of a plane specimen is not directly proportional to its surface area, also contributes to this lack of precision. Nevertheless, measurements under reverberant conditions are necessary, because only in this way can one include the effects of practical mounting conditions, which cannot be simulated in the tube method. Furthermore, it is the only way to determine the absorption of separate objects.

The purpose of this ISO Recommendation is to promote uniformity in the methods and conditions of measurement of absorption coefficients in reverberation rooms, so that values determined by different laboratories should agree as far as possible.

Again, it should be pointed out that to attain the above aims stricter diffuse conditions are required than ordinarily exist in most auditoria, and certain other restrictions, e.g. the volume of the reverberation room, are necessary. As a consequence, the absorption coefficients determined by the method described may not be directly applicable for design calculations in special cases.

It is hoped that these recommendations will not restrict in any way development of new techniques for the measurement of sound absorption. In some respects, the present methods may fall short of the declared aims, and these proposals will possibly be revised as improved methods come into use.

1. SCOPE

This ISO Recommendation describes how a reverberation room should be used to measure, under specified conditions, the sound absorption coefficients of acoustical materials used as wall or ceiling treatments, or the equivalent absorption area of separate objects, such as furniture, persons or space absorbers. The general principle is that the specimen is introduced into the room and the absorption added is computed from measurements of the reverberation time of the room (or the decay rate of the reverberant sound) before and after the introduction of the specimen.

This ISO Recommendation specifies certain features of the size and shape of the room, the size and disposition of the test specimen, the methods of measuring the reverberation time (or the decay rate of the reverberant sound) and of computing the results, the frequencies to be used and the manner in which the results should be stated.

2. EXPLANATION OF TERMS AND PRINCIPLE OF MEASUREMENTS

2.1 Reverberation. For the purpose of this ISO Recommendation, the decay of the sound energy in an enclosure after the source has stopped is called reverberation.

In most cases, for a given frequency or frequency band, this decay takes place approximately exponentially with time after the first reflections. If this is so, the process of reverberation may be characterized quantitatively in either of the two following manners:

(*a*) by the decay rate *d*, i.e. the rate of decay of the measured sound pressure level with time in decibels per second (see clause 2.2 below),

(*b*) by the reverberation time *T*, i.e. the time in seconds required for the measured sound pressure level to decrease by 60 dB.

$$T = \frac{60}{d} \tag{1}$$

2.2 The decay rate *d* is given by two additive parts:

(1) the first is due to the dissipation of sound energy during the propagation in air, and may be characterized by the energy attenuation coefficient *m*

$$d_a = (10/1\text{n } 10)\ c \cdot m = 4.34\ c \cdot m \tag{2a}$$

where *c* is the velocity of sound in air;

(2) the second depends on the absorption of sound energy at the partial reflections at the boundaries of the room and the objects in it.
This part defines the equivalent absorption area *A* of the room, according to the following formula:

$$d_b = [10/(4\ 1\text{n } 10)]\ c \cdot A/V = 1.086\ c \cdot A/V \tag{2b}$$

where *V* is the volume of the room.

2.2.1 *The equivalent absorption area A* may be evaluated from the measured decay rate or the measured reverberation time, according to the equations:

$$d = d_a + d_b = 1.086\ c\ (4\ m + A/V) = 60/T \tag{2c}$$

giving $$A = \left(0.92\ \frac{d}{c} - 4\ m\right) V \quad \text{ou} \quad A = \left(\frac{55.3}{cT} - 4\ m\right) V \tag{2d}$$

If the equivalent absorption area of the empty reverberation room is increased by the additional absorption area ΔA of objects brought into the room, ΔA may be evaluated from the difference of the reverberation decay rates d_2 after, and d_1 before, the introduction of the objects, according to the formula:

$$\Delta A = (0.92\ \frac{V}{c}\ (d_2 - d_1) \quad = (55.3\ \frac{V}{c}\ \left(\frac{1}{T_2} - \frac{1}{T_1}\right) \tag{3a}$$

if the temperature and humidity, which influence the energy attenuation coefficient m, have not been altered substantially between the two measurements. Otherwise, for high frequencies, additional terms have to be taken into account:

$$\Delta A = \left[\frac{0.92}{c}\ (d_2 - d_1)\ - 4\ \ (m_2 - m_1)\right]\ V \tag{3b}$$

Furthermore, it is assumed that the introduction of the additional objects does not alter the equivalent absorption area of the empty room by an appreciable amount due to the covering of part of the walls, floors, etc.

2.3 **Absorption coefficient.** In the case of a plane absorber mounted on the floor, wall or ceiling of the room, ΔA may be divided by the surface area S of the specimen under test, and a specific quantity, the absorption coefficient, may be so evaluated:

$$\alpha_S = \Delta A/S \tag{4}$$

In the case of a poor absorber (e.g. plaster), it may be necessary to consider that ΔA is actually the difference between the equivalent absorption area of the material under test and that of the portion of wall or floor covered. The formula (4) has then to be amended to:

$$\alpha_S = \Delta A/S + \alpha_{S1} \tag{5}$$

where α_{S1} is the absorption coefficient of the wall or floor covered. It should be mentioned, however, that this quantity can be measured only very crudely by the evaluation of the decay rate d_1 or the reverberation time T_1 of the empty room (see Appendix, clause A.2.3).

3. MEASUREMENT ARRANGEMENTS

3.1 Room

3.1.1 The volume of the reverberation room should be larger than 180 m³. It is further recommended, in the case of new constructions, that the volume should be as close to 200 m³ as possible (see Appendix, clause A.3.1.1).

3.1.2 The shape of the room should be such that

$$l_{max} < 1.9\ V^{1/3},$$

where l_{max} is the length of the greatest straight line which can fit within the boundary of the room (e.g. in a rectangular room, it is the major diagonal).

3.1.3 The room should be such that the decaying sound field is sufficiently diffuse (see Appendix, clause A.3.1.3). Natural frequencies in the low-frequency region should be as uniformly spaced as possible.

3.1.4 The reverberation times of the empty room should exceed the values of:

	5.0	5.0	5.0	4.5	3.5	2.0	seconds
at	125	250	500	1000	2000	4000	Hz (c/s)

(see Appendix, clauses A.3.1.1 and A.3.1.4).

Moreover, the curve of the reverberation time as a function of the frequency should not be irregular at low frequencies.

3.2 Plane absorbers under test

3.2.1 The material under test should cover a single area S between 10 and 12 m².

3.2.2 This area should be of rectangular form, and the ratio of breadth to length should lie between 0.7 and 1, and it should be placed so that no part of the specimen is closer than 1 m from any edge of the boundary of the room.

3.2.3 The mounting of the material under test should preferably be in accordance with the relevant material specifications.
The edges of the test specimen should be enclosed by reflecting surfaces, not wider than 1 cm and equal in thickness to the specimen.

3.3 Generation of the sound field

The sound should be generated by loudspeakers in the reverberation room. The loudspeakers should give as diffuse a sound field as possible. A white noise limited by $^1/_3$ octave or at most $^1/_2$ octave filters, or a warble tone, should be used. The frequency deviation of the warble tone should be at least $\pm$ 10 per cent of the mean frequency, at a modulation frequency of about 6 Hz (c/s), except that for frequencies above 500 Hz (c/s) a frequency deviation of $\pm$ 50 Hz (c/s) is sufficient.

3.4 Recording the reverberation

3.4.1 The receiving apparatus should consist of one or several microphones as non-directional as possible, the necessary amplifiers, possibly a mixer, and a recording system.
The recording system may be a level recorder, a cathode ray tube with a logarithmic amplifier or any other adequate equipment with which it would be possible to verify the straightness of the slope (level versus time).
The recording system should be suitable for handling decay rates of at least 300 dB/s. It is recommended that octave filters should be included in the recording system if warble tones are used, and $^1/_3$ or $^1/_2$ octave filters if filtered white noise is used. The specification for the filters is the same as in ISO Recommendation R 140, *Field and Laboratory Measurements of Airborne and Impact Sound Transmission*.

3.4.2 *Evaluation of the reverberation time.* The record of the decay rate given either by a curve or by single points only, should be approximated by a straight line in the region from 5 to at least 35 dB below the stationary level. The slope of this straight line represents the decay rate in decibels per second and determines the reverberation time.
Records which show a monotonic curvature should be excluded from evaluation.

3.4.3 *Number of records.* Each evaluation of a decay rate or reverberation time for a given frequency band should be based on at least 6 records, except in cases where experience shows that a smaller number of records is sufficient (see Appendix, clause A.3.4.3 for suitable conditions).

3.5 Frequency range of measurements

The measurements should be carried out at least at the following mean frequencies at octave intervals:

125 250 500 1000 2000 4000 Hz (c/s)

If measurements at other mean frequencies are desired, these should preferably be chosen from the $^1/_3$ octave series:

100 125 160 200 .... 4000 Hz (c/s)

4. STATEMENT OF RESULTS

4.1 Tables and curves

The equivalent absorption area of the objects under test or the absorption coefficient, evaluated from the decay rates or the reverberation times according to formula (3) or (4), should be stated, for the frequencies mentioned in clause 3.5, either in the form of a table, or in the form of a curve or graph.

In the first case, the table should give the results for the octave series of frequencies from 125 to 4000 Hz (c/s).

In the graphical presentation, the points of measurements should be connected by straight lines, the abscissa giving the frequency on a logarithmic scale and the ordinate showing the equivalent absorption areas or absorption coefficient linearly. In the latter case, the ratio of the ordinate distance from $\alpha_S = 0$ to $\alpha_S = 1.0$ to the abscissa distance corresponding to 5 octaves should be 2:3

4.2 Complementary data:

The report of the measurement should in addition indicate:

(*a*) the type of sound used;
(*b*) the dimensions of the reverberation room, particularly its volume V and its total surface area S_1 (walls, floor and ceiling);
(*c*) the approximate reverberation times of the empty room;
(*d*) the shape of the room, its diffuse treatment, and the disposition of microphones and loudspeakers;
(*e*) the description of the specimen under test and its mounting, preferably by drawings;
(*f*) the number of absorbing objects or the area of the material under test and their position in the reverberation room (see also Appendix, clause A.2.3);
(*g*) any minor deviations from the prescribed procedure, when these are deemed unavoidable, together with the reasons for the deviations.