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Acoustics — Measurement of reverberation time in auditoria

Acoustique — Mesurage de la durée de réverbération des auditoriums

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3382 was drawn up by Technical Committee ISO/TC 43, *Acoustics*, and circulated to the Member Bodies in March 1974.

It has been approved by the Member Bodies of the following countries :

Australia	Germany	Sweden
Belgium	Hungary	Switzerland
Brazil	India	Thailand
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Czechoslovakia	Norway	U.S.A.
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Finland	South Africa, Rep. of	
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The Member Body of the following country expressed disapproval of the document on technical grounds :

Canada

Acoustics — Measurement of reverberation time in auditoria

0 INTRODUCTION

The general evaluation of sound decay in an auditorium in its working condition depends on many parameters, for example the properties of the source. However, the reverberation time is the physical value which is commonly used to describe the acoustical behaviour of auditoria of all kinds.

At present, several methods exist for the measurement of reverberation time and there are some new ideas in this field.

Each of these methods may give a different result for the same auditorium. The reasons for such differences lie in the different types of signal employed as well as the methods of recording the decay of sound. The general standardization of all possible methods of measurement of reverberation time, therefore, seems to be premature. It is necessary and important, however, to approach this standardization by steps.

The first step is to standardize a widely used method so that it is possible to compare the data obtained by this one method.

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies a method for the measurement of reverberation time in auditoria by describing the state of occupancy of an auditorium for which the reverberation time is required, the measurement procedure, the apparatus necessary, and the method of evaluating the data and of presenting the test report.

2 REFERENCES

ISO 266, *Acoustics — Preferred frequencies for measurements.*

ISO/R 354, *Measurement of absorption coefficients in a reverberation room.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

3 DEFINITIONS

For the purposes of this International Standard, the following definitions apply.

reverberation time T : The time that would be required for the sound pressure level to decrease by 60 dB after the source has stopped (see ISO/R 354).

NOTE — This definition is based on the assumption that in the ideal case the dependence of sound pressure level upon time is a straight-line relationship and that the background level is sufficiently low.

states of occupancy: There are at least three significant values for the reverberation time of auditoria, which depend on different states of occupancy:

a) **empty state**: The auditorium prepared for a performance and ready for receiving performers and public, but without these persons present.

b) **studio state**: The auditorium occupied by the performers only (without public), for example at rehearsals or during sound recordings. The number of performers and other persons, such as technicians, shall correspond to the usual number.

c) **occupied state**: The auditorium with the performers and the public. The number of persons shall correspond to the usual number.

NOTES

1 An accurate description of the state of occupancy of the auditorium is of decisive importance in assessing the results obtained by measuring the reverberation time.

2 The auditorium may be regarded as "occupied" when 80 to 100 % of the auditorium seats are occupied. The presence of a choir would constitute an extraordinary occupancy, above the normal value. Furthermore, the number of members of the orchestra shall correspond to the usual number.

3 In theatres, a distinction shall be made between "safety curtain up" and "safety curtain down" and between "orchestra pit open" and "orchestra pit closed", as also between "orchestra seated on the stage" with and without concert enclosure. In all these cases, measurement may be useful. If the safety curtain is up, the amount of furnishing of the stage is of importance and shall be described.

4 MEASUREMENT PROCEDURES

4.1 Empty state

4.1.1 Sound source

The sound should preferably be generated by loudspeakers which should be as non-directional as possible.

For the sound signal, preferably a noise limited by filters with a band-width not greater than one octave or less than 1/3 octave should be used.

The sound source shall produce a sound pressure level at least 40 dB above the background level in the corresponding frequency band. It shall be placed near to the real sound source (stage, podium, pulpit, etc.) but several positions are also permitted, for example orchestra pit, stage and choir.

NOTE — In churches and concert-halls, an organ may be used as the sound source. In order to excite as many eigentones as possible, all semitones in each corresponding frequency range shall be played.

In auditoria where the reverberation times are long (for example more than 1,5 s below 1 000 Hz), measurement may also be made by means of impulses from pistol shots and from other sources that are not themselves reverberant.

When using an impulse, care shall be taken that there are sufficiently high sound pressure levels at both low and very high frequencies. Therefore, it is advisable that, before the measurement is made in the auditorium, a frequency analysis of the impulse should be carried out in the laboratory, for example in a reverberation room. The sound source may be considered to be adequate only if, in all frequency bands, a sound pressure level 40 dB above the auditorium background level can be expected in the auditorium.

4.1.2 Recording the reverberation

4.1.2.1 APPARATUS

The recording apparatus shall consist of a microphone as non-directional as possible, an amplifier, and a recording system.

The apparatus shall be provided with 1/3 or octave band filters. Octave band filters may be sufficient if 1/3 octave bands of noise are radiated. The specification for the filters is that given in IEC Publication 225.

The recording system may consist of a level recorder, a cathode ray tube with a logarithmic amplifier or other adequate equipment with which it is 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. The time-scale of the recording system shall be adjusted so that the decay curves have a slope of about 45°.

If the sound decay is initially recorded on magnetic tape, the linear frequency characteristics of the tape recorder should cover the frequency range of interest of this International Standard, and its dynamic range should be at least 40 dB. Care shall be taken that the recording level allows an adequate signal to noise ratio.

The speed of the magnetic tape and the paper speed of the level recorder shall be checked. The tape speed shall be the same for both recording and playback.

No overloading shall be allowed in any stage of the measuring apparatus. When impulsive noise sources are used, peak level indicating devices are necessary for checking the overloading.

NOTE — When magnetic tape recordings are employed, it may be found to be helpful if a relatively long recording is made to enable

the background noise level to be clearly seen. When these recordings are replayed, more satisfactory records may be obtained, especially if using pistol shots as a sound source, if the direction of the tape is reversed.

4.1.2.2 EVALUATION

The record of the decay shall be evaluated over a range of at least 30 dB; in the case of a steady-state sound field, this range shall extend from 5 to 35 dB below the initial level. In this range a straight line shall be fitted as closely as possible to the decay curve. The slope of this straight line determines the reverberation time.

NOTE — Where the decay characteristic takes the form of a broken curve consisting of two straight lines, each extending over a range of at least 20 dB, the reverberation times corresponding to the upper and lower limits shall be stated.

Records which show a significant curvature shall be excluded from evaluation.

4.1.2.3 NUMBER OF RECORDS

The reverberation time shall be measured at not less than three microphone positions, with at least two records at each position. In large (more than 1 000 m³) or complex (for example coupled) auditoria, more measurements will be necessary. The microphone may occupy any convenient position in the auditorium. The microphone shall not, however, be placed so close to the source as to be in its direct sound field. In large auditoria it shall be about 10 to 15 m from the sound source.

4.1.3 Frequency range of measurements

The reverberation time shall be measured at least within the frequency range from 125 to 4 000 Hz at intervals of 1/3 octave, even if the sound source is fed with 1/3 octave band noise and one octave band filters are used in the receiving apparatus or vice versa.

4.2 Studio state and occupied state

4.2.1 Sound source

The sound source should preferably be the same as in 4.1.1, but since, in these states, one cannot always expect the audience to endure a measurement by means of filtered noise at sixteen frequencies, unfiltered noise may be used; this noise signal shall be 40 dB above the auditorium background level in all frequency bands. A noise signal having equal energy per octave (pink noise) may be found to be suitable.

Furthermore, the orchestra may be used as a sound source. Fortissimo passages of musical compositions followed by adequately long pauses are suitable. Care shall be taken that disturbances do not arise from instruments with self-reverberation (for example undamped kettle drum, double bass especially with open strings, cymbal, piano, etc.) or from applause.

NOTE — It is possible to damp the instruments referred to immediately after the musical break but breaks provided by woodwind and brass only are preferable.

4.2.2 Recording the reverberation

4.2.2.1 APPARATUS

The requirements are those of 4.1.2.1. For the playback of sound recordings, the reverberation shall be analysed with 1/3 octave filters.

4.2.2.2 EVALUATION

As in 4.1.2.2.

4.2.2.3 NUMBER OF RECORDS

The microphone shall be set up in at least two positions in the auditorium chosen in accordance with the use of the auditorium, for example in the stalls and on the balconies. The microphone shall be set up at least 1 m above the heads of the audience and, in large auditoria, shall be about 10 to 15 m from the sound source or from the edge of the platform.

If steady sound sources are used, at least two records shall be taken at each position; for impulses (pistol shots, etc.), at least four records shall be taken at each position; for musical breaks, at least six records shall be taken at each position.

4.2.3 Frequency range of measurement

As for 4.1.3.

5 STATEMENT OF RESULTS

5.1 Tables and curves

The average of the evaluated reverberation times for each frequency of measurement shall be plotted at 1/3 octave intervals in the form of a graph. Moreover, the reverberation times shall be stated in a table with the results underlined for the preferred octave series 125, 250, . . . , 4 000 Hz (see ISO 266).

If, however, there are pronounced differences between the reverberation times (for example more than 10 %) in various parts of the auditorium (for example below balconies), the average value for each part of the auditorium shall be evaluated and presented separately.

In the case of graphs, the points shall be connected by straight lines. The abscissa shall present frequency on a logarithmic scale. The ordinate may present the reverberation time on a logarithmic scale such that a

doubling of the reverberation time corresponds to two octaves on the abscissa. Alternatively, the ordinate may present a linear time-scale such that one second corresponds to one decade along the abscissa. A distance of 5 cm per decade is preferred.

5.2 Test report

The test report shall state that the measurements were made in conformity with this International Standard. It shall include :

- a) the name of the auditorium tested;
- b) the plan and longitudinal section of the auditorium, with scale;
- c) the volume of the auditorium;

NOTE — If the auditorium is not completely enclosed, an explanation shall be given of how the stated volume is defined.

- d) the number and type of seats (for example whether upholstered or not); if upholstered : thickness and kind of upholstery, kind of covering material (porous or non-porous, seats raised or lowered);

- e) a description of the shape and material of the walls and the ceiling;

- f) the state (empty, studio or occupied) of the auditorium;

- g) the condition of variable equipment such as curtains;

- h) for theatres, whether the safety curtain or decorative curtains were up or down;

- i) a description of the stage furnishing, including any concert enclosure, etc;

- j) the temperature and relative humidity in the auditorium;

- k) the type and position of sound sources employed;

- l) a description of the sound signal, in particular whether steady or impulsive (in the case of musical breaks, the composition and, if possible, bar number shall be given);

- m) the microphone positions, preferably shown on a plan and longitudinal section;

- n) the description of measuring apparatus and, in particular, whether tape recorders were employed;

- o) the date of measurement and name of the measuring organization.

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