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Indian Standard

MEASUREMENT OF SOUND INSULATION IN BUILDINGS AND OF BUILDING ELEMENTS

PART V FIELD MEASUREMENTS OF AIRBORNE SOUND INSULATION OF FACADE ELEMENTS AND FACADES

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MEASUREMENT OF SOUND INSULATION IN BUILDINGS AND OF BUILDING ELEMENTS

PART V FIELD MEASUREMENTS OF AIRBORNE SOUND INSULATION OF FACADE ELEMENTS AND FACADES

0. FOREWORD

0.1 This Indian Standard (Part V) was adopted by the Indian Standards Institution on 3 December 1981, after the draft finalized by the Acoustics Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The purpose of this standard is:

a) to specify procedures to measure the sound insulation properties of a facade with respect to outside noise such as traffic noise, thus making it possible to ensure that the constructions meet the desired acoustical conditions inside the building; and

b) to prescribe field procedures to determine whether facades have met building specifications and to check where faults occurred in the facade construction.

0.3 This standard covering field measurement of airborne sound insulation of facade elements and facades, is a part of the series of Indian Standards on measurement of sound insulation in buildings and of building elements. Other standards in this series are:

Part I Requirements for laboratories

Part II Statement of precision requirements

Part III Laboratory measurements of airborne sound insulation of building elements

Part IV Field measurements of airborne sound insulation between rooms

Part VI Laboratory measurements of impact sound insulation of floors

Part VII Field measurements of impact sound insulation of floors

Part VIII Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a standard floor

0.4 While preparing this standard, assistance has been derived from ISO/DIS 140/V 'Measurement of sound insulation in buildings and of building elements: Part V Field measurements of airborne sound insulation of facade elements and facades', issued by the International Organization for Standardization.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part V) specifies field methods for measuring the sound insulation properties of facades under particular acoustical conditions and for determining the protection afforded by the facade to the occupants of the building.

2. TERMINOLOGY

2.0 For the purpose of this standard, the terms and definitions given in IS : 1885 (Part III/Sec 8)-1974† shall apply.

3. CONDITIONS OF MEASUREMENT

3.1 The test specimen is located either in an outer wall (for example in the case of a window) or is the outer wall itself (for example a whole facade).

3.2 When determining the existing acoustical conditions, the measurements should preferably be carried out according to **4** with traffic noise (sound from different directions and with varying intensity).

3.3 When testing the sound insulation properties of facades, measurements can alternatively be performed according to **5** with loudspeaker noise (directed sound).

3.4 However, on account of the differences in the nature of the incident sound, the results of both methods cannot be expected to agree fully.

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*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part III Acoustics, Section 8 Architectural acoustics.

4. MEASUREMENT WITH TRAFFIC NOISE

4.1 Principle

4.1.1 If the sound is incident on the test specimen from different directions with varying intensity, as, for example, traffic noise in busy streets, the sound reduction index is obtained from the equivalent sound pressure levels measured as a function of frequency on both sides of the test specimen. This quantity is denoted by R_{tr}:

$$R_{tr} = L_{eq,1} - L_{eq,2} + 10 \log_{10} \frac{S}{A} \text{dB} \qquad \ldots\ldots (1)$$

where

$L_{eq,1}$ is the equivalent sound pressure level 2 m in front of the test specimen including the reflection effect of the test specimen;

$L_{eq,2}$ is the equivalent sound pressure level in the receiving room averaged over the room;

S is the area of the test specimen (*see* Appendix A);

A is the equivalent absorption area in the receiving room.

NOTE — Equation (1) is applicable when the line of traffic is sufficiently long and straight to ensure a fairly uniform distribution of incident sound. When the angle of elevation (observed from the point of least distance between the test specimen and the line of traffic) is more than about 20°, there will be predominance of oblique angles of incidence and the results may differ from those obtained at ground floor level to the extent that the sound reduction index of the test specimen is dependent on the angle of incidence. When the angle of elevation exceeds 50°, equation (1) should not be used.

In cases where it is required to measure the protection afforded by the facade irrespective of its construction and surface area or its position relative to the noise sources, the standardized level difference $D_{nT,tr}$ should be used:

$$D_{nT,tr} = L_{eq,1} - L_{eq,2} + 10 \log_{10} \frac{T}{T_0} \text{dB} \qquad \ldots\ldots (2)$$

where

T is the measured reverberation time in the receiving room;

T_0 is the reference reverberation time, 0·5 second for dwellings.

4.2 Equipment

4.2.1 The equipment shall be suitable for meeting the requirements of **4.4**.

4.3 Test Arrangement

4.3.1 For the test arrangement to be used in the field, it is not possible to standardize the area of the test specimen and the volume and shape of the receiving room.

4.4 Test Procedure and Evaluation

4.4.1 *Generation of Sound Field*

4.4.1.1 For sound excitation, the existing traffic noise, incident on the test specimen, is used.

4.4.2 *Measurement of the Equivalent Sound Pressure Levels*

4.4.2.1 The equivalent sound pressure level L_{eq} is defined by the formula:

$$L_{eq} = 10 \log_{10} \frac{\frac{1}{T_i}\int_0^{T_i} p^2(t)dt}{p_o^2} \text{ dB} \quad \ldots\ldots (3)$$

where

$p(t)$ is the time-varient sound pressure;

$p_o = 20\ \mu Pa$ is the reference sound pressure;

T_i is the integrating time.

4.4.2.2 L_{eq} can be determined by an appropriate integrating device or (as an approximation) by a noise distribution analysis according to IS : 9989-1981*.

4.4.2.3 On account of the possible fluctuations of the traffic noise, the equivalent sound pressure levels $L_{eq,1}$ and $L_{eq,2}$ shall be measured simultaneously on both sides of the specimen, for example, by recording the sound signals with a two-track magnetic tape machine and by evaluating both signals within the same time intervals.

NOTE — When determining the difference of average sound pressure levels from simultaneous measurements, it is unimportant whether the actual readings are expressed in terms of L_{eq}, L_{50} or L_{10}. (L_{50} and L_{10} are the sound pressure levels exceeded in 50% and 10% of the observation time respectively.) In some cases one of each of these will be measured for other reasons and it will not be necessary to measure all three but only that which is the most convenient at the time. When specifically measuring sound insulation and not noise disturbance, it is preferable to use L_{eq}.

4.4.2.4 For determining the equivalent sound pressure level $L_{eq,1}$, the microphone should be placed about 2 m in front of the test specimen.

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*Assessment of noise with respect to community response.

4.4.2.5 Alternatively, the microphone may be placed as close as possible (less than 2 cm) to the outer face of the test specimen with the axis parallel to it. In this case 3 dB are subtracted from the value of R_{tr} or $D_{nT,tr}$ calculated according to equations (1) and (2) respectively.

NOTE 1 — When the microphone is placed as close as possible to the test specimen, several difficulties may arise:

a) the level measurements will depend critically on the position of the microphone with respect to the outer face of the test specimen;

b) insufficiently large impedance of the test specimen (compliance of the window pane, absorption of facade material) may cause error of unknown magnitude;

c) different microphone sensitivity and directivity on both sides of the test specimen.

NOTE 2 — If there is a balcony in front of the test specimen, the measurement with traffic noise cannot be applied for determining the sound reduction index of the test specimen.

However, the combined protection afforded, including the balcony, could be determined by placing the microphone 2 m in front of the balcony and by using equation (2).

4.4.2.6 The sound pressure level in the receiving room should be an average over space and time. This average may be obtained by using a number of fixed microphone positions or a number of stationary positions of a remotely controlled movable microphone. The microphone positions shall be out of the near field of the test specimen.

4.4.3 *Frequency Range of Measurements*

4.4.3.1 The sound pressure level should be measured using third-octave or octave band filters. The discrimination characteristics of the filters should be in accordance with IS : 6964-1973*.

4.4.3.2 Third-octave band filters having at least the following centre frequencies should be used:

100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 150 Hz.

If octave band filters are used, as a minimum the series beginning with centre frequency 125 Hz and ending at 2 000 Hz should be used.

NOTE 1 — Use of lower frequency is dependent on the distribution of natural frequency.

NOTE 2 — The minimum reverberation times for the empty room are adjusted to a volume of 180m³. For other volumes, these times should be multiplied by the factors $(V/180)^{\frac{1}{3}}$ (V being the volume of the room expressed in cubic metres) except at high frequencies, where the air absorption is the predominant factor influencing the decay rate.

*Specification for octave, half-octave and third-octave band filters for analyses of sound and vibrations.

4.4.4 *Measurement and Evaluation of the Equivalent Absorption Area*

4.4.4.1 The correction term of equation (1) containing the equivalent absorption area may preferably be evaluated from the reverberation time measured according to IS : 8225-1976* and evaluated using Sebine's formula:

$$A = \frac{0{\cdot}163\ V}{T} \qquad \ldots\ldots(4)$$

where

A is the equivalent absorption area, in square metres;

V is the receiving room volume, in cubic metres;

T is the reverberation time, in seconds.

An alternative method of taking the equivalent absorption area into account is to measure the average sound pressure level produced by a sufficiently stable sound source the power output of which is known.

4.4.5 *Measurement Procedure*

4.4.5.1 The necessary criteria which affect the repeatability of the measurements are shown below:

a) On the outside,

   i) traffic noise source(s); and

   ii) position of the microphone relative to the test specimen.

b) On the inside,

   i) minimum distance between microphone and room boundaries, especially test specimen, with regard to the near fields;

   ii) number of microphone positions;

   iii) averaging time of the levels; and

   iv) method for determining the equivalent absorption area, which involves a number of repeated readings in each position.

An example of typical test conditions is given in Appendix B.

4.5 Precision

4.5.1 It is required that the measurement procedure should give satisfactory repeatability. For the instrumentation and, in specific cases,

*Method of measurement of absorption coefficients in a reverberation room.

for the complete measuring conditions, this can be determined with the method shown in IS : 9901 (Part III)-1981*.

4.5.2 It is recommended that different organizations in the same country periodically perform comparison measurements on the same test object to check the repeatability and the reproducibility of their test procedures.

4.6 Expression of Results

4.6.1 For the statement of the airborne sound insulation of the test specimen, the sound reduction index $R\varphi$ should be given at all frequencies of measurement in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for a 10 : 1 frequency ratio should be equal to the length for 10 dB, 25 dB, or 50 dB on the ordinate scale.

4.7 Test Report

4.7.1 The test report should state:

a) name of organization that has performed the measurements;

b) date of test;

c) description of test specimen, if possible with sectional drawing and details of mounting;

d) indication of traffic situation and the equivalent sound pressure level $L_{eq,1}$;

e) a suitable plan of the building, showing the position of the test specimen in relation to the traffic flow;

f) volume and equivalent absorption area of the receiving room;

g) method applied for determining the equivalent sound pressure level including the time intervals used and, in the case of a noise distribution analysis, the class width used;

h) either sound reduction index $R\varphi$ of test specimen or the standardized sound level difference $D_{nT,tr}$ as a function of frequency whichever is appropriate;

j) the area S used for evaluation of $R\varphi$;

k) brief description of details of procedure and equipment (*see* **4.4.5**).

*Measurement of sound insulation in buildings and of building elements: Part III Laboratory measurements of airborne sound insulation of building elements.

5. MEASUREMENT WITH LOUDSPEAKER NOISE

5.1 Principle

5.1.1 The loudspeaker is located outside the building at an appropriate distance from the test specimen. The sound is incident on the test specimen mainly from one direction only.

5.1.2 The sound reduction index determined by this method is called $R\varphi$ and is given by the following equation:

$$R\varphi = L_1' - L_2 + 10 \log_{10} \frac{4S \cos\varphi}{A} \text{ dB} \qquad \ldots\ldots (5)$$

where

- L''_1 is the average sound pressure level immediately in front of the test specimen without the reflecting effect of the test specimen (*see* **4.4.2**);
- φ is the angle of incidence (angle between the loudspeaker axis directed at the centre of the test specimen and the normal to the surface of the test specimen);
- L_2 is the average sound pressure level in the receiving room;
- S is the area of the test specimen (*see* Appendix A);
- A is the equivalent absorption area in the receiving room.

5.2 The equipment shall be suitable for meeting the requirements of **5.4.**

5.3 Test Arrangement

5.3.1 For the test arrangement to be used in the field, it is not possible to standardize the area of the test specimen and the volume and shape of the receiving room.

5.4 Test Procedure and Evaluation

5.4.1 *Generation of Sound Field*

5.4.1.1 The kind of loudspeaker arrangement and its distance to the test specimen should be so chosen that the test specimen is excited as uniformly as possible. The loudspeaker should be placed as near as possible to the ground, preferably on the ground.

5.4.1.2 The local differences of sound pressure level over the surface of the test specimen should not exceed 5 dB.

5.4.1.3 The measurements shall be made at an angle of incidence of 45°. Other angles in the series 0°, 15°, 30°, 60° and 75° may be added.

5.4.2 *Measurement of the Average Sound Pressure Levels*

5.4.2.1 The average sound pressure level L''_1 is obtained from the sound radiation of the loudspeaker in the free field. The microphone should be placed at the same distance from the source as the surface of the test specimen. The sound pressure level should be averaged over an area corresponding to the surface of the test specimen. Except for the reflecting influence of the test specimen, this measurement should be carried out under the same acoustical conditions as during the actual measurements on the test specimen. It can be considered as calibration of the loudspeaker.

NOTE — If there is a balcony in front of the test specimen, the measurement shall not yield the reduction index of the test specimen alone but rather the combined sound protection offered by the test specimen and the balcony under the given angle of incidence.

5.4.2.2 The sound radiation of the loudspeaker should not change between calibration and measurement of sound insulation.

NOTE — This may be checked by placing the microphone at a distance of about 1 m from the loudspeaker on the axis of radiation or by measuring the loudspeaker current.

5.4.2.3 The sound pressure level in the receiving room should be an average over space and time. This average may be obtained by using a number of fixed microphone positions or a continuously moving microphone with an integration of p^2. The microphone positions shall be out of the near field of test specimen.

NOTE — An alternative method which may be advantageous in some cases is described in Appendix C.

5.4.3 *Frequency Range of Measurements* — Provision of **4.4.3** shall apply.

5.4.4 *Measurement and Evaluation of the Equivalent Absorption Area*

5.4.4.1 Concerning the correction term of equation (5) containing the equivalent absorption area, provision of **4.4.4** shall apply.

5.4.5 *Measurement Procedure*

5.4.5.1 Each organization should determine a normal test procedure which complies with this standard.

5.4.5.2 The necessary criteria which affect the repeatability of the measurements are shown below:

a) On the outside,

i) position of the loudspeaker relative to the test specimen;

ii) directivity of the loudspeaker;

iii) angle of incidence;

iv) calibration of loudspeaker.

b) On the inside,

i) minimum distance between microphone and room boundaries, especially test specimen, with regard to near fields;

ii) number of microphone positions or, in the case of a moving microphone, the microphone path;

iii) averaging time of the level;

iv) method for determining the equivalent absorption area, which involves a number of repeated readings in each position.

An example of typical test conditions is given in Appendix D.

5.5 Precision — Provision of **4.5** shall apply.

5.6 Expression of Results

5.6.1 For the statement of the airborne sound insulation of the test specimen, the sound reduction index $R\varphi$ should be given at all frequencies of measurement in tabular form and/or in the form of a curve. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the length for a 10 : 1 frequency ratio should be equal to the length for 10 dB, 25 dB or 50 dB on the ordinate scale.

The angle of incidence should be indicated, for example R_{45}.

5.7 Test Report

5.7.1 The test report should state:

a) name of the organization that has performed the measurements;

b) date of test;

c) description of test specimen, if possible with sectional drawing and details of mounting;

d) a suitable plan of the building, showing the position of the test specimen;

e) volume and equivalent absorption area of the receiving room;

f) kind of loudspeaker arrangement, the angle φ of sound incidence as well as the position of the loudspeaker relative to the test specimen that is the height of the test specimen, the distance of the loudspeaker from the facade and the lateral displacement or the angle of elevation ϕ and the angle of azimuth β (*see* Appendix E);

g) type of noise and filters used;

h) sound reduction index $R\varphi$ of the test specimen as a function of frequency;

j) the area S used for the evaluation of $R\varphi$;

k) brief description of details of procedure and equipment (*see* **5.4.5**).

APPENDIX A

(*Clauses* 4.1.1 *and* 5.1.2)

AREAS OF TEST SPECIMEN

A-1. When determining the sound reduction index of a facade, S in equations (1) and (5) is the area of the whole facade as viewed from within the receiving room.

A-2. If the sound reduction index of only a part of the facade (for example a window) is to be determined, S is the area of that part of the facade as seen from within the receiving room. In the case of a window or a door, S is the area of the free opening in which the element (including a possible frame and sealing) is mounted. In both cases it shall be proved that the sound transmission through the rest of the facade is negligible.

The area S used shall be stated in the test report.

APPENDIX B

(*Clause* 4.4.5.1)

EXAMPLE OF TEST PROCEDURE FOR MEASUREMENTS WITH TRAFFIC NOISE

An example of a test procedure which will normally be expected to give satisfactory repeatability is given below for cases where the room volume exceeds 25 m^3 and the distance between the traffic noise sources and the test specimen is not less than 6 m.

The traffic noise sources shall have a uniform distribution of sound incidence and sufficient sound power as a function of frequency for the measuring situation and the likely sound insulation of the test specimen. The microphone shall be placed about 2 m in front of the test specimen.

Six microphone positions randomly distributed throughout the room are taken, using an averaging time of 5 seconds in each frequency band at each position. No microphone position shall be nearer than 0·5 m to the room boundaries or 1 m to the test specimen.

In the case of single vehicles passing the test specimen, for each of the six microphone positions the level difference is determined separately for each passing on the basis of a filtered tape loop analysis resulting in equivalent sound pressure levels for each frequency band. The averaging time shall be chosen according to the duration of the passing.

The equivalent absorption area should be determined from readings taken using three microphone positions with two reverberation time analyses at each position.

APPENDIX C

[*Clause* 5.4.2.3 (Note)]

OPEN-CLOSED METHOD

In field measurements, difficulties in determining the sound pressure level outside of the building may arise, for example, due to weather conditions (wind, rain) or due to shadow effects of balconies.

In such cases it would be advantageous to determine the sound reduction index of a specimen such as a window or door by measurements in the receiving room only with the test specimen open and closed. This so-called open-closed method is feasible if the test specimen is openable and if the sound reduction index of the outer wall is considerably higher than that of the test specimen.

The sound reduction index determined by this method using loudspeaker noise is called $R_{\varphi OC}$ and given by the following equation:

$$R_{\varphi OC} = L_{2\,\text{open}} - L_{2\,\text{closed}} + 10 \log_{10} \frac{T_{\text{closed}}}{T_{\text{open}}} \text{ dB} \qquad \ldots\ldots (6)$$

where

T_{closed} and T_{open} are the reverberation times measured in the room with the test specimen closed and open.

The correction term

$$10 \log_{10} \frac{T_{\text{closed}}}{T_{\text{open}}} \text{ dB}$$

takes into account that the equivalent absorption area in the receiving room is changed when the test specimen is opened.

If this influence is to be evaluated from the average sound pressure level produced by a standard source, the correction term should be replaced by

$$10 \log_{10} \frac{A_{\text{open}}}{A_{\text{closed}}} \text{ dB}$$

where

A_{open} and A_{closed} are the equivalent absorption areas of the room with the test specimen is open and closed.

If only a part of the test specimen (not less than one-third of the full area S of the test specimen) is openable, a further correction term

$$10 \log_{10} \frac{S}{S_{\text{open}}} \text{ dB}$$

shall be added to equation (6), where S_{open} is the area of the part of test specimen which can be opened.

APPENDIX D

[*Clause* 5.4.5.2 (b)]

EXAMPLE OF TEST PROCEDURE FOR MEASUREMENTS WITH LOUDSPEAKER NOISE

An example of a test procedure which will normally be expected to give satisfactory repeatability in cases where the room volume exceeds 25 m^3 is given below.

For a test specimen at ground floor level, the loudspeaker is placed on the ground at an angle of incidence of 45°, the axis of the loudspeaker being directed to the centre of the test specimen.

The loudspeaker is placed at an adequate distance to ensure uniform sound level over the surface of the test specimen.

Six microphone positions randomly distributed throughout the room are taken, using an averaging time of 5 seconds in each frequency band at each position. No microphone position should be nearer than 0·5 m to the room boundaries or 1 m to the test specimen.

As an alternative, the sound field sampling procedure can be carried out using a rotating microphone device having a sweep radius of 0·7 m. In this case the plane of the traverse is inclined in relation to the room boundaries and the device should have an averaging time equal to the traverse time which should be a minimum of 30 seconds.

The equivalent absorption area should be determined from readings taken using three microphone positions with two reverberation time analyses at each position.

APPENDIX E

[*Clause* 5.7.1 (f)]

POSITION OF LOUDSPEAKER

The position of the loudspeaker, placed on the ground at Q (*see* Fig. 1), relative to the test specimen is determined by the height h of the test specimen, the distance d of the loudspeaker from the facade and the lateral displacement b.

The angle φ of sound incidence is then given by formula

$$\cos\varphi = \frac{d}{\sqrt{h^2 + d^2 + b^2}}$$

In situ, for a desired angle of incidence the necessary distance for a given height and lateral displacement may be obtained from the formula

$$d = \cot\varphi \sqrt{h^2 + b^2}$$

Conversely, for a given height and distance the lateral displacement is given by the formula

$$b = \sqrt{d^2\, tg^2\, \varphi - h^2}$$

NOTE — Alternatively, the position of the loudspeaker relative to the test specimen can be described by the angle of elevation ϕ and the angle of azimuth β:

$$\cos\phi = \frac{\sqrt{b^2 + d^2}}{\sqrt{h^2 + d^2 + b^2}} \qquad \cos\beta = \frac{d}{\sqrt{d^2 + b^2}}$$

Then, the angle of incidence is given by the formula

$$\cos\varphi = \cos\phi \cos\beta$$

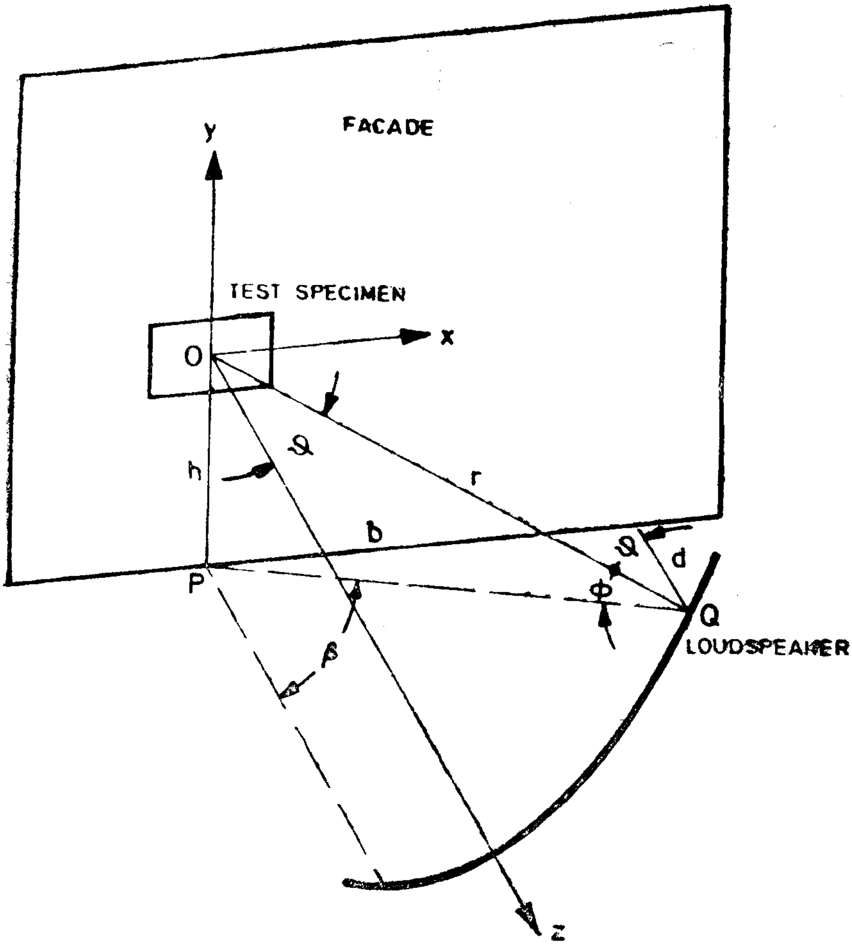

FIG. 1 POSITION OF LOUDSPEAKER RELATIVE TO TEST SPECIMEN

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	1 N = 1 $kg.m/s^2$
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2