INTERNATIONAL STANDARD ISO 3742

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Méthodes de laboratoire en salles réverbérantes pour les sources émettant des fréquences discrètes et des bruits à bandes étroites

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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.

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

Australia	Germany	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	India	Spain
Brazil	Ireland	Sweden
Bulgaria	Israel	Switzerland
Canada	Netherlands	Thailand
Czechoslovakia	Norway	Turkey
Denmark	Poland	United Kingdom
France	Portugal	U.S.A.

No Member Body expressed disapproval of the document.

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Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms

0.1 RELATED INTERNATIONAL STANDARDS

This International Standard is one of a series specifying various methods for determining the sound power levels of machines and equipment. These basic documents specify only the acoustical requirements for measurements appropriate for different test environments as shown in table 1.

When applying these basic documents it is necessary to decide which one is most appropriate for the conditions and purposes of the test. The operating and mounting conditions of the machine or equipment to be tested must be in accordance with the general principles stated in the basic documents.

Guidelines for making these decisions are provided in ISO 3740. If no sound test code is specified for a particular machine, the mounting and operating conditions shall be fully described in the test report.

TABLE 1 — **International Standards describing methods for determining the sound power levels of machines and equipment**

International Standard No.*	Classification of method	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
3741	Precision	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third octave or octave bands	A-weighted sound power level
3742				Steady, discrete-frequency or narrow-band		
3743	Engineering	Special reverberation test room		Steady, broad-band, narrow-band, discrete-frequency	A-Weighted and in octave bands	Other weighted sound power levels
3744	Engineering	Outdoors or in large room	No restrictions : limited only by available test environment	Any	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey	No special test environment	No restrictions : limited only by available test environment	Steady, broad-band, narrow-band, discrete-frequency	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels

* See clause 2.

0.2 SYNOPSIS OF ISO 3742

Applicability

Test environment

Prescribed reverberation room which is to be qualified according to a test procedure given in clause 3 of the main part of the standard and in annex A. Additional test room requirements as given in ISO 3741.

Size of noise source

Volume of the source preferably less than 1 % of test room volume.

Character of noise radiated by the source

Steady (as defined in ISO 2204), discrete frequency and/or narrow-band.

Accuracy

Precision (standard deviation for determining sound power levels for the 1 kHz octave band is less than 1,5 dB).

Quantities to be measured

Sound pressure levels in frequency bands on a prescribed path or at several discrete microphone positions.

Quantities to be determined

Sound power levels in frequency bands, A-weighted sound power level (optional).

Quantities which cannot be calculated

Directivity characteristics of the source, temporal pattern of radiated noise for sources emitting non-steady noise.

0.3 INTRODUCTION

This International Standard specifies in detail two laboratory methods for determining the sound power of small sources using a reverberation test room.

The procedure specified in ISO 3741 applies to sources which produce steady, broad-band noise. This International Standard gives additional precautions that must be observed when discrete frequencies or narrow bands of noise are present in the spectrum of the noise radiated by the sound source.

When a source emits narrow-band or discrete-frequency sound, a precise determination of the radiated sound power requires greater effort. The accuracy objectives for characterizing broad-band sound sources (table 2 of ISO 3741) cannot be achieved with a three-meter microphone traverse (or with only three microphones in a fixed array) and with only one source location in the reverberation room. The reasons are as follows :

1) the spaced-time averaged sound pressure along the microphone path (sub-clause 7.1 of ISO 3741), or as determined with an array of three microphones, is not always a good estimate of the spaced-time averaged mean-square pressure throughout the room;

2) the sound power radiated by the source is more strongly influenced by the normal modes of the room and by the position of the source within the room.

When narrow bands of noise or discrete frequencies are emitted by a source, a determination of its sound power level in a reverberation room requires the use of a greater number of source locations and microphone positions (or a greater path length for a moving microphone). The required numbers of locations and positions depend upon the desired accuracy, the spectrum of the radiated noise, and the properties of the test room. These numbers can usually be reduced if one or more diffusers are rotating in the test room during the measurements. Guidelines for the design of suitable rotating diffusers are given in annex B. The use of rotating diffusers considerably reduces the effort required to make measurements on sources that emit discrete-frequency components.

This International Standard, together with the others in this series (see table 1), supersedes ISO/R 495.

1 SCOPE AND FIELD OF APPLICATION

1.1 General

This International Standard specifies the special requirements that are necessary for accurate determinations of the sound power when discrete frequencies or narrow bands of noise are radiated by a source.

1.2 Field of application

This International Standard applies to sources which radiate discrete frequencies or narrow bands of noise. The spectrum of the source may or may not include broad-band components upon which the prominent discrete frequencies or narrow bands of noise are superposed. These methods may be found to be complex and time-consuming for measurements on sources which primarily radiate discrete frequencies below 200 Hz. For such sources, measurements in a free field as described in ISO 3745 may be more appropriate.

1.3 Measurement uncertainty

Measurements made in accordance with this International Standard tend to result in standard deviations which are equal to or less than those given in table 2. The standard deviations take into account the cumulative effects of all causes of uncertainty.

TABLE 2 — **Uncertainty in determining sound power levels of discrete-frequency sound sources in reverberation rooms**

Octave band centre frequencies	One-third octave band centre frequencies	Standard deviation
Hz	Hz	dB
125	100 to 160	3,0
250	200 to 315	2,0
500 to 4 000	400 to 5 000	1,5
8 000	6 300 to 10 000	3,0

1.4 Principal requirements

To meet the accuracy objectives of table 2, additional microphone positions and source locations are usually required as determined in clause 4. First, however, a determination may be made concerning the presence and significance of discrete-frequency components or narrow bands of noise in the spectrum of the sound emitted by the source (clause 3).

Alternatively, it may be assumed that the spectrum of the sound emitted by the machine or equipment under test does contain significant discrete-frequency components. In this case either the precautions described in clause 4 should be followed or the test set-up should be qualified as described in annex A.

If the room qualifies according to the requirements of annex A, additional source locations are not required. Qualification of the test set-up according to annex A is usually possible only when a rotating diffuser and additional microphone positions are used in the room.

1.5 Other requirements

All other requirements for determining the sound power emitted by discrete-frequency and narrow-band sound sources are the same as for broad-band sources described in ISO 3741.

2 REFERENCES

ISO/R 266, *Preferred frequencies for acoustical measurements.*

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

ISO/R 1680, *Test code for the measurement of the airborne noise emitted by rotating electrical machinery.*

ISO 2204, *Guide to the measurement of airborne acoustical noise and evaluation of its effects on man.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*[1]

ISO 3741, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms.*

ISO 3743, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms.*[2]

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*[2]

ISO 3745, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*[2]

ISO 3746, *Acoustics — Determination of sound power levels of noise sources — Survey method.*[1]

IEC Publication 50 (08), *International electrotechnical vocabulary — Electro-acoustics.*

IEC Publication 179, *Precision sound level meters.*

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

3 DETERMINATION OF THE SIGNIFICANCE OF DISCRETE-FREQUENCY COMPONENTS AND NARROW BANDS OF NOISE

3.1 General

When a discrete-frequency component is present in the spectrum of a source, the spatial variations in the sound pressure level usually exhibit maxima separated by minima having an average spacing of approximately 0,8 λ where λ is the wavelength corresponding to the frequency of the sound.

3.2 Qualitative procedure

The presence of a significant discrete-frequency component can often be detected by a simple listening test. If such a component is audible, the measurements described in 3.3 may be omitted. In this case, either the provisions of the bottom row of table 3 shall be applied or, alternatively, the test set-up shall be qualified as described in annex A.

Discrete-frequency components may be present in the spectrum even when these components are not audible. A conclusion that no discrete-frequency components are present can only be reached by performing the test described in 3.3.

3.3 Estimate of standard deviation

An estimate of the standard deviation of the sound pressure levels produced by the source under test in the room is obtained as follows :

3.3.1 Select an array of six fixed microphones (or six microphone positions) spaced at least $\lambda/2$ apart, where λ is the wavelength of the sound corresponding to the lowest frequency of the frequency band of interest. Locate the source at a single position in the test room.

1) In preparation.

2) At present at the stage of draft.

Obtain the time-averaged sound pressure level L_i at each microphone position according to the techniques described in ISO 3741. Instead of a fixed array, a single microphone may be sequentially positioned at six points equally spaced along a path the length of which is calculated from equation (2) with $N_m = 6$.

The time-averaged sound pressure level is determined at each point.

3.3.2 For each one-third octave or octave band within the frequency range of interest, calculate the standard deviation from the following equation :

$$s = [n-1]^{-1/2} \left[\sum_{i=1}^{n} (L_i - L_m)^2 \right]^{1/2} \qquad \dots (1)$$

where

s is the standard deviation of space/time-averaged sound pressure levels in the room, L_i, in decibels;

L_m is the arithmetic mean value of the sound pressure levels L_1 to L_6, in decibels;

$n = 6$.

The magnitude of s depends upon the properties of the sound field in the test room. These properties are influenced by the characteristics of the room as well as the characteristics of the source (i.e. directivity and spectrum of emitted sound). In theory, a standard deviation of 5,56 dB corresponds to a spectral component of zero bandwidth, i.e. a discrete tone.

4 NUMBER OF MICROPHONE POSITIONS AND SOURCE LOCATIONS

4.1 General

Because equation (1) gives only an estimate of the true standard deviation, this International Standard uses three broad ranges of values for s to determine the number of microphone positions (or path length) and the number of source locations required to achieve the estimated accuracy. Detailed knowledge of the spectrum of the source is not necessary for carrying out the measurements. Irregularities in the sound field are taken into account in so far as they influence the estimate of the standard deviation s.

4.2 Computational procedures

The value of s calculated according to 3.3.2 is used with tables 3 and 4 to determine the recommended microphone path length and the number of source locations. The number of microphone positions is determined from table 4. If a continuous microphone traverse is used, the length of the traverse should be at least

$$l = N_m (\lambda/2) \qquad \dots (2)$$

where λ is as defined in 3.3.1, and N_m is the number of microphone positions.

The required number of source locations depends on the reverberation time and volume of the room, and on the frequency. For discrete-frequency tones, the recommended number of source locations, N_s, should be computed from

$$N_s \geqslant K \left[0{,}79 \left(\frac{T}{V} \right) \left(\frac{1\,000}{f} \right)^2 + \frac{1}{N_m} \right] \qquad \dots (3)$$

where

T is the reverberation time of the room, in seconds;

V is the volume of the room, in cubic metres;

f is the frequency, in hertz, of the discrete tone or the centre frequency of the band in which a discrete-frequency or narrow-band noise component is found;

K is a constant given in table 4;

N_m is the number of microphone positions for the narrow-band or discrete-frequency tone (see table 4).

TABLE 3 – Procedures to be followed in the measurement of discrete-frequency components or narrow bands of noise

Standard deviation, s dB	Procedure	Number of microphone positions, N_m (or microphone path length, l)	Number of source locations, N_s
$s \leqslant 1{,}5$	Broad-band procedure adequate	$N_m = 3$ or l computed from equation (2) for a continuous path	$N_s = 1$
$1{,}5 < s \leqslant 3$	Assume that a narrow band of noise is present	N_m determined from table 4 or l computed from equation (2) for a continuous path	Use half the number of source locations computed from equation (3)
$s > 3$	Assume that a discrete tone is present	N_m determined from table 4 or l computed from equation (2) for a continuous path	Compute N_s from equation (3)

The value of N_s shall be rounded to the nearest higher integer.

The minimum distance between any two source positions shall be $r_{min} = \lambda/2$, where λ is as defined in 3.3.1. The source positions should not be symmetric with respect to the axes of the test room.

After the minimum number of microphone positions (or appropriate microphone path length) and the recommended number of source locations have been selected, the procedures of 7.2 of ISO 3741 shall be followed to obtain values of L_p, the mean band pressure levels in the room in the one-third octave or octave bands of interest.

The sound power emitted by the source is then calculated using the procedures of clause 8 of ISO 3741.

TABLE 4 — **Number of microphone positions required and constant K for determining number of source locations**

Octave band (and one-third octave band) centre frequencies	**Number of microphone positions (N_m) if $1,5 < s \leqslant 3$ dB**	**Number of microphone positions (N_m) if $s > 3$ dB**	**Constant K for determining number of source locations**
125 (100, 125, 160)	3	6	5
250 (200, 250, 315)	6	12	10
500 (400, 500, 630)	12	24	20
1 000 (800, 1 000, 1 250) and up	15	30	25

ANNEX A

ALTERNATIVE QUALIFICATION PROCEDURE FOR THE MEASUREMENT OF DISCRETE-FREQUENCY COMPONENTS

A.1 INTRODUCTION

The procedure described in this annex may be used to estimate the uncertainty of measuring discrete-frequency sounds in a given reverberation room using a given microphone array or path. If the standard deviations do not exceed the values given in table 6 over the frequency range of interest, the test facility (consisting of the room, the instrumentation, and the microphone array or path) is considered to be satisfactory for testing a source whose spectrum contains significant discrete-frequency components. No additional evaluations (such as clause 4) are then necessary for any particular sound source.

The qualification procedure described below makes use of the fact that irregularities in the frequency response of a reverberation room for a given source position and microphone array or path are indicative of the uncertainties in the coupling of the source to the reverberant field as well as uncertainties in the space/time-averaging procedure.

A.2 INSTRUMENTATION

In addition to the instrumentation and microphone array or path specified in ISO 3741, the following items are required for the qualification test :

A.2.1 a high quality loudspeaker of 200 mm diameter or less with an airtight back enclosure;

A.2.2 an oscillator, a frequency counter, an amplifier, and a voltmeter.

A.3 LOUDSPEAKER TEST

Locate the loudspeaker on the floor of a semi-anechoic room. Place the microphone at a distance of 10 to 20 mm in front of the speaker face. Using the indicating device and frequency analyser (see ISO 3741), record the sound pressure level at constant loudspeaker input voltage over the frequency range for which qualification is desired. In each one-third octave band, take measurements to the nearest half decibel at the frequencies shown in table 5.

NOTES

1 The loudspeaker is suitable only if measurements at adjacent frequencies do not differ by more than 1 dB.

2 The loudspeaker input voltage for this test should be low enough to prevent distortion (i.e. excessive voice coil and diaphragm excursions, particularly at low frequencies), but high enough to prevent interference from background noise (both acoustical and electrical) during this test, as well as during the following test.

A.4 ROOM TEST

Place the loudspeaker at the location(s) where the equipment is to be tested (see ISO 3741). The microphone shall be traversing or the array should be sampled in the same manner as it is for sound pressure level readings (see ISO 3741). If a revolving or oscillating sound diffuser is used, the diffuser shall be in operation.

Record the space/time-averaged sound pressure level at the frequencies listed in table 5. The loudspeaker input voltage shall be the same as for the loudspeaker test (see A.3. above).

NOTE — If an array of fixed microphone positions is used, the array may either be scanned and the mean-square sound pressure level obtained automatically (see ISO 3741) or the mean-square values for the individual microphone positions may be obtained by computation.

Frequency variations shall not exceed ± 0,1 Hz during each set of measurements.

A.5 COMPUTATIONAL PROCEDURE

A.5.1 Correct the room levels taken under clause A.4 to remove the influence of the loudspeaker characteristic by subtracting, at each frequency, the loudspeaker level taken under clause A.3.

A.5.2 For each one-third octave band, calculate the arithmetic mean of the room levels corrected as in A.5.1 and compute the standard deviation of the difference between the corrected room levels and the mean level :

$$s = (n-1)^{-1/2}\left[\sum_{i=1}^{n} (L_i - L_m)^2\right]^{1/2}$$

where

s is the standard deviation, in decibels;

L_i is the room sound pressure levels corrected according to A.5.1, in decibels;

L_m is the arithmetic mean of room sound pressure levels corrected according to A.5.1, in decibels;

n is the number of measurements in the one-third octave band (table 5).

TABLE 5 — **Test frequencies (or periods) for qualification of facility for measuring sounds containing significant discrete-frequency components**

	Centre frequencies of one-third octave bands, Hz																					
	100	125	160	200	250	315	400	500	630	800	1 000	1 250	1 600	2 000	2 500	3 150	4 000	5 000	6 300	8 000	10 000	
Period of test frequency, ms			7,08			3,54	2,76															Test frequency, Hz
			7,02	5,60	4,48	3,51	2,74					1 130	1 410		2 260							
	11,10	8,88	6,96	5,55	4,44	3,48	2,72	2,22	564	712		1 140	1 425		2 280	2 820	3 560		5 640	7 120		
	11,00	8,80	6,90	5,50	4,40	3,45	2,70	2,20	570	720	900	1 150	1 440	1 800	2 300	2 850	3 600	4 500	5 700	7 200	9 000	
	10,90	8,72	6,84	5,45	4,36	3,42	2,68	2,18	576	728	910	1 160	1 455	1 820	2 320	2 880	3 640	4 550	5 760	7 280	9 100	
	10,80	8,64	6,78	5,40	4,32	3,39	2,66	2,16	582	736	920	1 170	1 470	1 840	2 340	2 910	3 680	4 600	5 820	7 360	9 200	
	10,70	8,56	6,72	5,35	4,28	3,36	2,64	2,14	588	744	930	1 180	1 485	1 860	2 360	2 940	3 720	4 650	5 880	7 440	9 300	
	10,60	8,48	6,66	5,30	4,24	3,33	2,62	2,12	594	752	940	1 190	1 500	1 880	2 380	2 970	3 760	4 700	5 940	7 520	9 400	
	10,50	8,40	6,60	5,25	4,20	3,30	2,60	2,10	600	760	950	1 200	1 515	1 900	2 400	3 000	3 800	4 750	6 000	7 600	9 500	
	10,40	8,32	6,54	5,20	4,16	3,27	2,58	2,08	606	768	960	1 210	1 530	1 920	2 420	3 030	3 840	4 800	6 060	7 680	9 600	
	10,30	8,24	6,48	5,15	4,12	3,24	2,56	2,06	612	776	970	1 220	1 545	1 940	2 440	3 060	3 880	4 850	6 120	7 760	9 700	
	10,20	8,16	6,42	5,10	4,08	3,21	2,54	2,04	618	784	980	1 230	1 560	1 960	2 460	3 090	3 920	4 900	6 180	7 840	9 800	
	10,10	8,08	6,36	5,05	4,04	3,18	2,52	2,02	624	792	990	1 240	1 575	1 980	2 480	3 120	3 960	4 950	6 240	7 920	9 900	
	10,00	8,00	6,30	5,00	4,00	3,15	2,50	2,00	630	800	1 000	1 250	1 590	2 000	2 500	3 150	4 000	5 000	6 300	8 000	10 000	
	9,90	7,92	6,24	4,95	3,96	3,12	2,48	1,98	636	808	1 010	1 260	1 605	2 020	2 520	3 180	4 040	5 050	6 360	8 080	10 100	
	9,80	7,84	6,18	4,90	3,92	3,09	2,46	1,96	642	816	1 020	1 270	1 620	2 040	2 540	3 210	4 080	5 100	6 420	8 160	10 200	
	9,70	7,76	6,12	4,85	3,88	3,06	2,44	1,94	648	824	1 030	1 280	1 635	2 060	2 560	3 240	4 120	5 150	6 480	8 240	10 300	
	9,60	7,68	6,06	4,80	3,84	3,03	2,42	1,92	654	832	1 040	1 290	1 650	2 080	2 580	3 270	4 160	5 200	6 540	8 320	10 400	
	9,50	7,60	6,00	4,75	3,80	3,00	2,40	1,90	660	840	1 050	1 300	1 665	2 100	2 600	3 300	4 200	5 250	6 600	8 400	10 500	
	9,40	7,52	5,94	4,70	3,76	2,97	2,38	1,88	666	848	1 060	1 310	1 680	2 120	2 620	3 330	4 240	5 300	6 660	8 480	10 600	
	9,30	7,44	5,88	4,65	3,72	2,94	2,36	1,86	672	856	1 070	1 320	1 695	2 140	2 640	3 360	4 280	5 350	6 720	8 560	10 700	
	9,20	7,36	5,82	4,60	3,68	2,91	2,34	1,84	678	864	1 080	1 330	1 710	2 160	2 660	3 390	4 320	5 400	6 780	8 640	10 800	
	9,10	7,28	5,76	4,55	3,64	2,88	2,32	1,82	684	872	1 090	1 340	1 725	2 180	2 680	3 420	4 360	5 450	6 840	8 720	10 900	
	9,00	7,20	5,70	4,50	3,60	2,85	2,30	1,80	690	880	1 100	1 350	1 740	2 200	2 700	3 450	4 400	5 500	6 900	8 800	11 000	
		7,12	5,64		3,56	2,82	2,28		696	888	1 110	1 360	1 755	2 220	2 720	3 480	4 440	5 550	6 960	8 880	11 100	
									702			1 370	1 770		2 740	3 510	4 480	5 600	7 020			
									708			1 380	1 785		2 760	3 540			7 080			
												1 390			2 780							
Increment	0,10 ms	0,08 ms	0,06 ms	0,05 ms	0,04 ms	0,03 ms	0,02 ms	0,02 ms	6 Hz	8 Hz	10 Hz	10 Hz	15 Hz	20 Hz	20 Hz	30 Hz	40 Hz	50 Hz	60 Hz	80 Hz	100 Hz	
Tolerance of increment	± 0,03	± 0,03	± 0,02	± 0,02	± 0,01	± 0,01	± 0,005	± 0,005	± 2	± 3	± 3	± 3	± 5	± 5	± 5	± 10	± 10	± 20	± 20	± 30	± 30	
n	22	23	25	23	24	25	25	22	25	23	22	27	26	22	27	25	24	23	25	23	22	