
**Acoustics — Recommended practice for
the design of low-noise workplaces
containing machinery —**

Part 3:

Sound propagation and noise prediction in
workrooms

iTeh STANDARD PREVIEW
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*Acoustique — Pratique recommandée pour la conception de locaux de
travail à bruit réduit contenant des machines —*

Partie 3: Propagation du son et prévision du bruit dans les locaux de travail

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example).

ISO/TR 11690-3:1997

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 11690-3, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 11690 consists of the following parts, under the general title *Acoustics* — *Recommended practice for the design of low-noise workplaces containing machinery*:

- *Part 1: Noise control strategies*
- *Part 2: Noise control measures*
- *Part 3: Sound propagation and noise prediction in workrooms*

Introduction

This Technical Report is intended for use by all parties involved in noise reduction in workplaces and design of low-noise workplaces. The objective is:

- to make them aware of what is the current technical consensus regarding sound propagation and noise prediction in workrooms,
- to aid the interaction between them within a common technical framework,
- to promote the understanding of the desired noise control requirements.

This Technical Report provides the connection between the emission of sound sources e.g. machines and the sound pressure level at workstations caused by their operation in a workroom. Therefore, it allows an interchange of information between machine suppliers, who are responsible for noise emission values, and machine users, who require low noise immission values.

A further target is the assessment of the acoustical performance of a workroom.

These tasks are connected by the determination of the sound propagation descriptors of a workroom.

A methodology for noise prediction in workrooms is presented and a structure is given for the classification of prediction methods according to the level of detail of input parameters.

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Acoustics — Recommended practice for the design of low-noise workplaces containing machinery —

Part 3 : Sound propagation and noise prediction in workrooms

1 Scope

In this part of ISO 11690, sound propagation in a room is considered together with the prediction of sound pressure levels and of noise immission at the workplace.

Details of the description of the physical phenomena involved in a noise prediction scheme are strongly dependent on the situation being considered and the way this situation is modelled (input parameters, calculation techniques). This dependency is surveyed and the methodology for noise prediction is described. Recommendations are provided concerning the use of noise prediction as an aid for noise control in workrooms. Examples of use of noise prediction methods are given in annexes A to E.

2 References

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References listed in ISO 11690-1 should also be consulted when using this Technical Report.

3 Definitions

Definitions given in ISO 11690-1 apply to this Technical Report.

4 Basic principles of sound propagation in rooms

4.1 Sound propagation descriptors

A basic element for noise prediction in workrooms is the prediction of the distribution of sound pressure levels caused by an omnidirectional point source. This distribution is influenced by :

- the shape and the volume of the room,
- the absorption of the surfaces,
- the fittings.

The resulting sound level distribution can be considered using a spatial sound distribution curve (see definition 3.4.11 of part 1 and figures 1 and 2 of this Technical Report). The information contained in this curve can be summarized, for a given distance range, by two quantities (see definitions 3.4.12 and 3.4.13 of part 1):

- the rate of spatial decay of sound pressure level per distance doubling (DL2),
- the excess of sound pressure level with respect to a free field (DLf).

The spatial sound distribution curve and these two quantities are used to describe the acoustical characteristics of a room. The sound pressure level caused by a given source is indeed smaller if DLf is low and DL2 is high (see 6.3 of part 2). Annex D shows how the acoustical characteristics of a room can be described from spatial sound distribution curves.

The spatial sound distribution curve is determined on a free path with no obstacle between the source and the receiver. For its measurement, see 8.4 of part 2.

NOTES

1 An International Standard specific to the measurement of spatial sound distribution curves in rooms is in preparation (ISO 14257 presently at the stage of draft).

2 When sound sources (machines) with dimensions too large to be neglected are considered, the sound distribution curve may differ from that of a point source for distances less than the typical dimension of the machine.

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4.2 Rooms with diffuse sound fields

If diffuse sound field conditions are met (see definitions 3.4.8 and 3.4.9 of part 1), at a certain distance from the source, sound pressure levels are nearly constant and independent of receiver position, as shown in figure 1.

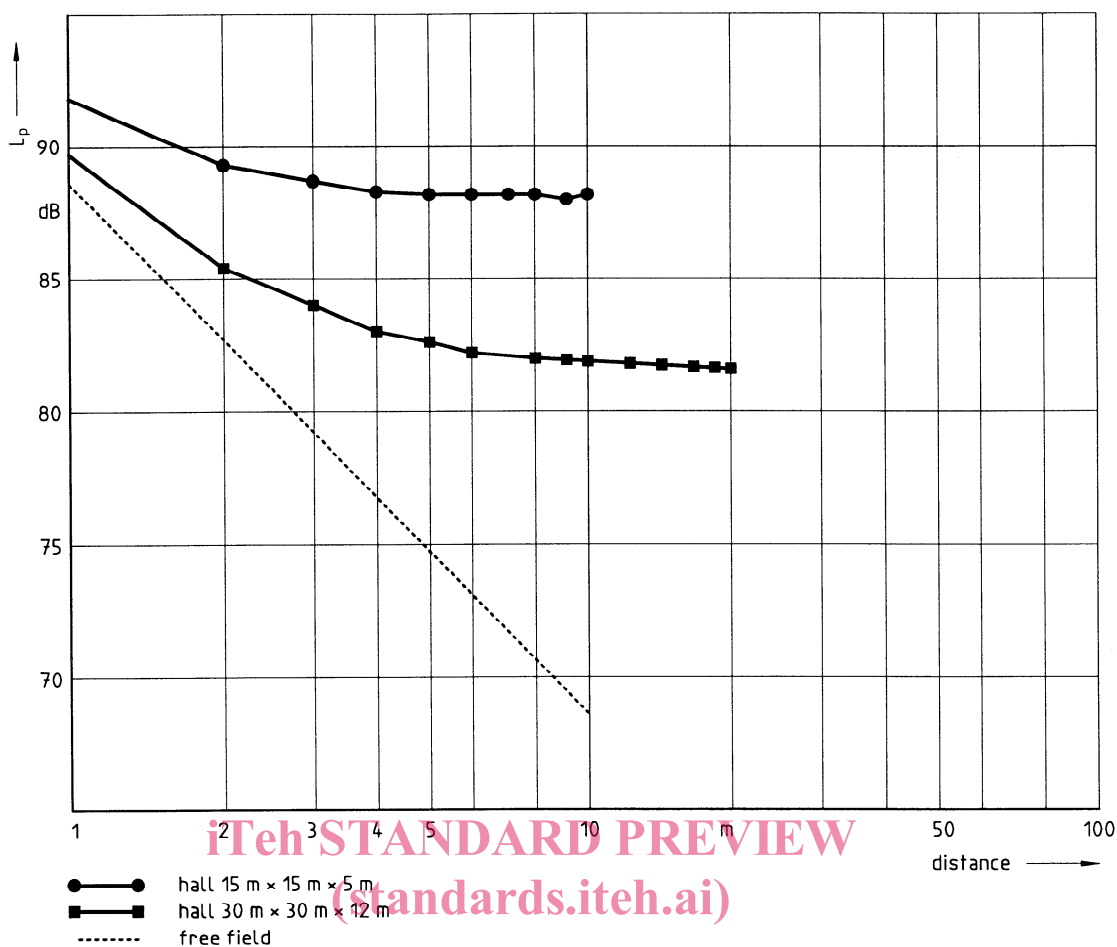


Figure 1 : Examples of spatial sound distribution curves for an omnidirectional point source and two rooms with different sizes, equal absorption coefficients and diffuse field. The dotted curve is the spatial sound distribution curve under total free field conditions. L_p denotes the sound pressure level at a given point when the sound power level of the source is 100 dB.

The sound pressure level of the diffuse field depends only on the total sound power level of all sources in the room and on the equivalent absorption area A . In rooms with a diffuse sound field, there is a direct connection between the reverberation time and the expected spatial sound distribution curve. It is therefore also possible to qualify such rooms by their reverberation time. In this case, noise prediction is relatively simple.

4.3 Rooms with uniform sound propagation

In many workrooms, diffuse sound field conditions cannot be assumed e.g. because the height of the room is less than one third of the length (flat rooms). In such rooms, even far from the source, the sound field depends on the position being considered and is characterized by a spatial sound distribution curve.

In many workrooms, it can be assumed that the absorption and the fitting density are similar in different parts of the room (this includes a room with an absorbing ceiling and a reflecting floor). In this case, a single spatial sound distribution curve along a free path (not close to walls or fittings) represents the sound propagation and the acoustical quality of the room.

As an example, figure 2 shows two typical spatial sound distribution curves in a flat room containing fittings.

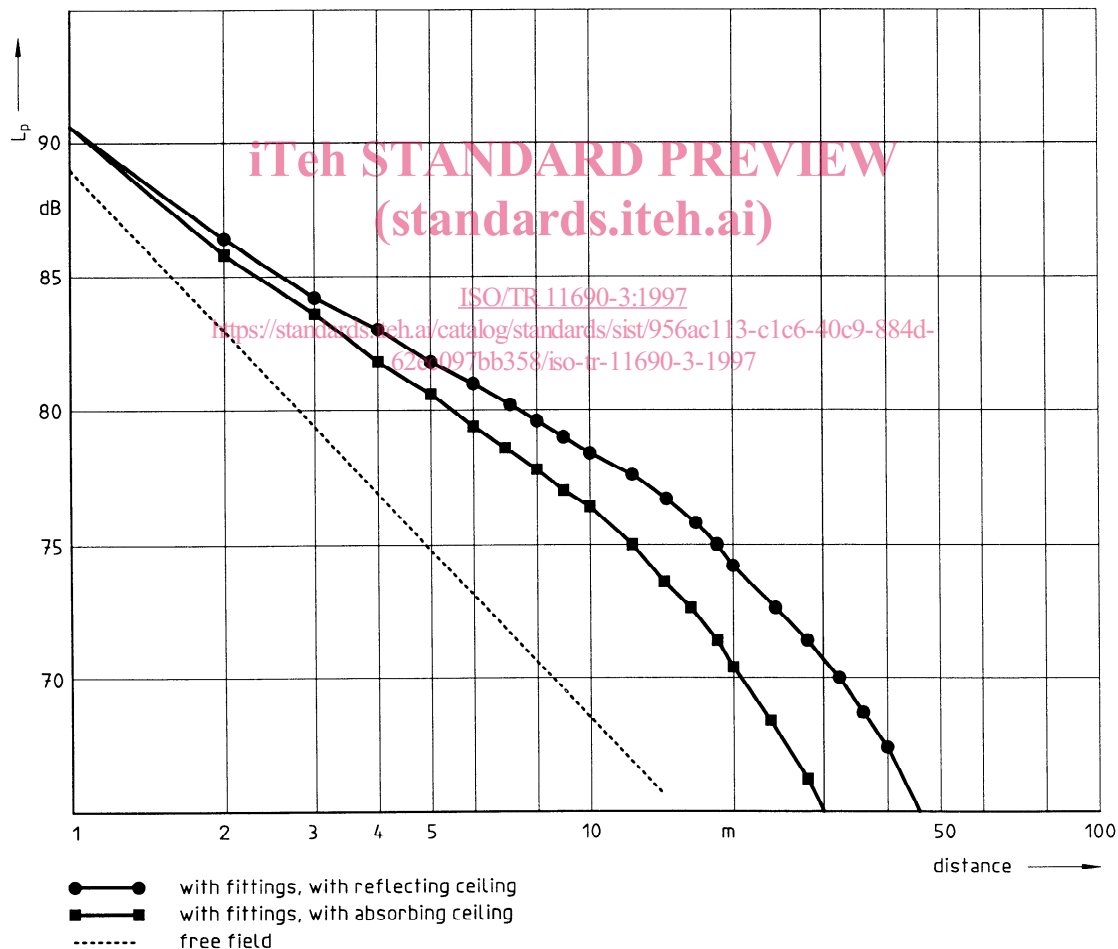


Figure 2 : Examples of typical spatial sound distribution curves for the same flat and fitted room, with and without sound absorbing ceiling. The dotted curve is the spatial sound distribution curve under total free field conditions. L_p denotes the sound pressure level at a given point when the sound power level of the source is 100 dB.

It is often useful to split the spatial sound distribution curve into three sections depending on the distance from the source (see 3.4.11 of part 1). The first section corresponds to the region near the source. In this region, the sound field is dominated by the direct field. The rate of spatial decay per distance doubling, DL_2 , is in most cases approximately 5 dB to 6 dB. Increasing the number of fittings in the vicinity of the source tends to increase the sound pressure level close to the source and to reduce it far from the source.

The second section of this curve corresponds to a middle region. In this region, DL_2 lies in the range 2 dB to 5 dB and DL_f in the range 2 dB to 10 dB.

In the far region (third part), scattering effects of fittings are important. The absorption of the walls, the density and the absorption of fittings have a dominant influence on the sound propagation far away from the source. Therefore, in this region, DL_2 may be greater than 6 dB and DL_f may be negative.

4.4 Rooms with non uniform sound propagation

In some situations, the room shape, absorption and fitting density differ from one part of the room to the other to such an extent that it is not possible to describe the sound propagation in the room with a single spatial sound distribution curve. In such situations, it may be necessary to describe the sound field in a way which takes into account the above factors. Fittings can also be considered individually.

5 Noise prediction in workrooms

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Noise prediction in workrooms (see 9 of part 1) is an aid in making decisions regarding noise control measures. It allows calculation of the sound pressure level at any point and determination of sound propagation descriptors. It is therefore possible to compare these values with specified values or limits and to compare various solutions of a noise control programme. Although several noise prediction methods are available, all of them are based on a common procedure. This procedure is summarized in the flow chart shown in figure 3 and is outlined in the next clause.

6 Methodology for noise prediction in workrooms

Noise prediction in workrooms should follow five steps described below.

6.1 Objectives - Values to be achieved

At an early stage of a noise prediction scheme, acoustical descriptors must be chosen and target values defined by the parties involved, taking account of the various constraints associated with the project. Such descriptors can be sound pressure levels at workstations, immission and/or exposure data, spatial sound

distribution curves, rates of spatial decay per distance doubling, excesses of sound pressure level, reverberation times etc.

6.2. Collection of input data

The level of detail of input parameters should be in accordance with the desired or possible value of the accuracy of the results. Different levels of detail in the description of the input parameters are shown in tables 1 to 3. The sound field that can be assumed in the room, the degree of knowledge of the input parameters and the acoustical description of the room are key factors for the selection of the prediction method.

6.2.1 Empty room description

The empty room is the space limited by the room surfaces such as the boundaries of the workroom (ceiling, floor, walls) and large internal surfaces which limit the space in it (screens, partitions, enclosures, cabins, etc.).

Prediction methods need the characteristics of the hall surfaces, such as their geometry (position, dimension, shape etc.), their absorption and reflection properties. Due to their complexity in real workrooms, room surfaces often need to be partitioned into sub-elements with different acoustical properties.

Absorption coefficients are also important parameters whose values affect the result of the prediction. Any prediction method should specify clearly the procedure to be used for estimating these parameters.

Table 1 shows several possible degrees of complexity in the description of the workroom.

Table 1 - Absorption and shape of the room

Level of detail of the description	Absorption and shape of the room
1	The room is characterized by its volume and by the mean absorption coefficient of its surfaces.
2	Box-like shape. Each surface is characterized by a single absorption coefficient.
3	Box-like shape. Sub-division of the room surfaces into elements of different absorption coefficients.
4	Actual room shape. Distribution of absorption and reflection properties of the room surfaces.

6.2.2 Description of room fittings

By fittings, it is meant any part of the lay-out of the hall which affects sound propagation. Fittings are machines, stocked goods, screens, pillars, ducts, partitions, cabins, etc. Fittings may either be introduced in the prediction model as a whole or subdivided into smaller parts with different acoustical properties.

Table 2 shows several possible levels of detail in the description of the room fittings.

NOTE 3 Fittings may be described by their density, q , which is defined as follows

$$q = S / 4 V \text{ in m}^{-1}$$

where S is the total surface area of fittings, in m^2 and V is the volume, in m^3 , of the room or the zone where fittings are located.

Table 2 - Room fittings

Level of detail of the description	Description of room fittings
1	Fittings are not taken into account.
2	Fittings are represented for the total room by one mean value for their density and one mean value for their absorption.
3	Fittings are represented for different parts of the room by one mean value for their density and one meanvalue for their absorption.
4	Actual shape and location of fittings are taken into account. Shielding by and reflection from these individual obstacles are taken into account.

NOTE: Levels 2, 3 and 4 in table 2 are not mutually exclusive.

6.2.3 Sources

Noise sources considered are machines, equipment and any noisy activity.

Noise emission can be characterized by the following descriptors (see ISO 3740 series, ISO 9614, ISO 11200 series, ISO 4871) :

- sound power level : A-weighted, in octave bands or third-octave bands,
- emission sound pressure level at workstation: A-weighted, in octave bands or in third-octave bands,
- time variation of emission, peak value etc.
- directivity or sound pressure level distribution on the measuring surface,
- distribution of noise sources on the machine structure,
- dimensions of the source.

Table 3 shows several possible levels of detail in the description of sources.

Table 3 - Sources
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Level of detail of the description	Source description
1	Omnidirectional point sources
2	Point sources with a directivity pattern
3	Complex sources

For all the levels of detail in table 3, the sound power level and the emission sound pressure level at workstations are normally used. For levels of detail 2 and 3, the individual sound pressure level on the measuring surface and the directivity should also be known. The modelling of complex sources - level 3 in table 3 - requires the knowledge of the number, position and sound power level of all the elementary sources. Sound power level and emission sound pressure level at workstations are the main source descriptors. They can be measured either in laboratories or in-situ (see ISO 3740 series, ISO 9614 and ISO 11200 series) or found in noise emission declarations (see ISO 4871). Operating and mounting conditions strongly affect the noise emission from machines. The type and rate of the process must therefore also be taken into account.

NOTE 4: The description of the source should be of a high level of detail when the direct sound in the vicinity of the source is more important than the reflected sound.

6.2.4 Reference data

Reference data are collected either from previously studied similar workrooms or from the workroom itself if it already exists. The reference data can be parameters such as absorption coefficients, sound emissions of sources and/or data such as sound pressure levels, noise maps, spatial sound distribution curves, etc. The knowledge of these quantities helps the noise specialist to choose the most appropriate prediction method.

6.3 Choice of the prediction method

Table 4 presents two important categories of prediction methods.

Table 4 - Categories of prediction methods

Category	Prediction methods	
1	Diffuse field	
2a	Geometrical	Rooms that can be approximated by one mean absorption coefficient for each wall and one mean density for the fittings.
2b	Geometrical	Rooms that can be approximated by one mean absorption coefficient for each room surface and one mean density for the fittings in each zone of the room.
2c	Geometrical	Rooms for which individual distribution of absorption and fittings has to be considered.

Recommendations regarding the use of the different prediction methods are given in annex E. Some basic literature on sound propagation in rooms and indoor noise prediction methods is given in annex F.