

# INTERNATIONAL STANDARD



# 532

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## Acoustics — Method for calculating loudness level

*Acoustique — Méthode de calcul du niveau d'isosonie*

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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.

Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, Technical Committee ISO/TC 43 has reviewed ISO Recommendation R 532 and found it technically suitable for transformation. International Standard ISO 532 therefore replaces ISO Recommendation R 532-1966 to which it is technically identical.

ISO Recommendation R 532 was approved by the Member Bodies of the following countries :

|                |                |                |
|----------------|----------------|----------------|
| Australia      | Denmark        | Netherlands    |
| Austria        | Finland        | New Zealand    |
| Belgium        | Germany        | Sweden         |
| Brazil         | Greece         | Switzerland    |
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The Member Body of the following country expressed disapproval of the Recommendation on technical grounds :

France

The Member Bodies of the following countries disapproved the transformation of ISO/R 532 into an International Standard :

Canada  
U.S.A.

## Acoustics — Method for calculating loudness level

### 0 INTRODUCTION

It is often desirable to seek a single number that corresponds to the loudness or to the loudness level of a given sound. Such a number can be calculated if there is available a spectrum analysis of the sound obtained by physical measurement. It has to be understood that the calculated number is a statistic, i.e. it conveys less information than the spectrum measurements from which it is derived.

Such analysis is often accomplished in terms of either octave bands or one-third octave bands. Sounds in which the spectra do not have discontinuities as a function of frequency can be represented adequately in terms of octave bands, but sounds which contain such discontinuities may require one-third octave-band analysis if they are to be described adequately.

This International Standard specifies two methods for calculating the loudness or loudness level of a complex

sound, which differ not only in the method of analysis of the sound, but also in the principles of computation. The first, Method A, utilizes physical measurements obtained from spectrum analysis in terms of octave bands. The second, Method B, utilizes spectrum analysis in terms of one-third octave bands.

In addition to the different band widths involved in the basic physical measurements, the two methods differ in other respects, and the results obtained do not always agree. Method B generally gives slightly higher results than those obtained for the same sounds by Method A, the difference being possibly as much as 5 phons; but it would seem to take better into account those variations in sound spectra that occur within narrow ranges of frequency.

The quantities calculated by either method should be designated with specific reference to one or other method using the system of symbols and abbreviations given in table 1.

TABLE 1 — Designations for calculating loudnesses and loudness levels

| Method | Quantity measured          |                            | Band width of analysis | Sound field       |
|--------|----------------------------|----------------------------|------------------------|-------------------|
|        | loudness                   | loudness level             |                        |                   |
| A      | sones (OD)                 | phons (OD)                 | octave                 | diffuse           |
| B      | { sones (GD)<br>sones (GF) | { phons (GD)<br>phons (GF) | 1/3 octave             | { diffuse<br>free |

## SECTION ONE

## METHOD A FOR CALCULATING THE LOUDNESS OF A COMPLEX SOUND THAT HAS BEEN ANALYSED IN TERMS OF OCTAVE BANDS

## 1 GENERAL

This section of this International Standard specifies a procedure, Method A, for calculating the loudness of steady complex sounds for which octave-band analyses are appropriate. (Octave-band analyses may, of course, be reconstructed from more detailed analyses.) The level in each octave band is converted into a loudness index, and the total loudness in sones (OD) is then calculated by means of an empirical formula. The total loudness thus calculated may then be converted into a calculated loudness level in phons (OD) by means of the relation specified in ISO/R 131, *Expression of the physical and subjective magnitudes of sound or noise*.

Method A also yields a graph that provides a valuable guide for the further study of the sound, particularly if the loudness index is plotted as the ordinate (see note to 4.3).

Method A also contains extensions for analyses made in terms of bands of one-third octave and one-half octave. For calculating the loudness of noises that require one-third octave-band analysis, however, Method B is recommended.

This Method A has the advantage of simplicity and is specified for sounds for which octave-band analyses are appropriate. Many noises of practical interest fall in this class.

Since the purpose of this section is to provide a simple and convenient method by which complex sounds of diverse levels and spectra may be ordered on a scale of subjective magnitude, certain simplifying assumptions and linear approximations have been made. The procedure is derived from three relations :

- 1) A loudness function relating loudness in sones to loudness level in phons, which is identical to that in ISO/R 131.
- 2) An empirical set of equal-loudness contours for bands of noise in a diffuse sound field.
- 3) A rule relating the total loudness of a sound to the loudness indices of the frequency bands composing it.

On the basis of these empirical relations, the total loudness of a sound may be calculated with the aid of a table or a chart, together with a linear equation. Subject to certain restrictions specified below, the recommended method may be expected to assess loudness or loudness level with an accuracy that is sufficient for engineering purposes.

## 2 SCOPE AND FIELD OF APPLICATION

This section of this International Standard specifies a method for calculating the loudness experienced by a typical (median) listener under the following conditions :

## 2.1 Diffuse sound field

The sound is assumed to reach the listener's ears from all directions at the same intensity. This condition is approximated in an ordinary room.

## 2.2 Kind of spectrum

The method is designed specifically for the types of broad band spectra most commonly encountered. Errors may arise if it is applied to certain types of line spectra, or to spectra having two or more sharp maxima that are separated by more than an octave. The magnitude of the error that may result from an unusual spectrum can only be determined experimentally.

## 2.3 Steady state

The method is designed for noises that are steady rather than intermittent. Nevertheless, in a diffuse field, many noises of impulsive origin behave effectively as steady noises, because reverberation serves to diminish temporal discontinuities.

## NOTES

- 1 The error that may result with intermittent noises is not necessarily attributable to the calculation procedure. It may also be affected by the averaging characteristics of the meter used to determine the sound pressure levels.
- 2 Since the loudness of a sound depends upon the nature of the enclosure in which it is heard, it is important that comparative evaluations of different noise sources should be based on measurements made in essentially similar enclosures.
- 3 The band levels in the diffuse field should be measured by means of an omni-directional microphone located in the unobstructed sound field at the position of the listener's head.

## 3 DEFINITIONS

For the purposes of this International Standard the following definitions apply (the definitions in 3.1 and 3.4 are common to both methods) :

**3.1 sound pressure level ( $L$ ) :** Sound pressure level in decibels is  $20 \log_{10} (p/p_0)$  dB, where  $p$  is the measured sound pressure and  $p_0$  is a reference sound pressure having the value

$$2 \times 10^{-5} \text{ N/m}^2 = 2 \times 10^{-4} \text{ dyn/cm}^2 \text{ (see ISO/R 131).}$$

**3.2 band pressure level :** Sound pressure level corresponding to the part of the spectrum (octave) under measurement.

**3.3 loudness ( $S$ ) in sones** : Numerical designation of the strength of a sound which is proportional to its subjective magnitude as estimated by normal observers. One sone is the loudness of a sound whose loudness level is 40 phons.

**3.4 loudness-loudness level relation** : Loudness level  $P$  in phons of a sound is related to the loudness  $S$  in sones by the relation :

$$S = 2^{(P - 40)/10}$$

NOTE — When loudness levels are computed from calculated loudness values, the results may differ from those obtained by direct subjective judgement. It is important, therefore, to state whether the values have been calculated or have been measured by other means.

**3.5 loudness index** : Number determined by the geometric mean frequency and the band pressure level of the octave band, according to the curves of figure 1.

## 4 SPECIFICATION

### 4.1 Calculated loudness

The method for calculating loudness is embodied in a table and a formula. For convenience, table 2 is also presented graphically as a chart (figure 1). The table or chart provides a means for converting each band level to a loudness index, and the formula provides a rule for combining the loudness indices to obtain the calculated total loudness.

The procedure is as follows :

- 1) Enter the geometric mean frequency of each band in the table or in the abscissa of figure 1. Then, from the band level (the ordinate in figure 1), determine the loudness index of each band.

- 2) Compute the total loudness in sones (OD)  $S_t$  by means of the formula :

$$S_t = S_m + F (\Sigma S - S_m)$$

where  $S_m$  is the greatest of the loudness indices and  $\Sigma S$  is the sum of the loudness indices of all the bands. For octave bands the value of  $F$  is 0,3.

NOTE — Method A has also been applied to analyses made in terms of one-half octave and one-third octave bands, and may be so used in cases where the sound spectrum would fall under the restrictions of Method A. In such cases the value of  $F$  is as follows :

One-third octave 0,15

One-half octave 0,2

### 4.2 Calculated loudness level

The total loudness may be converted into calculated loudness level in phons (OD) by means of the formula :

$$S_t = 2^{(P - 40)/10}$$

$$\text{or } P = 40 + 10 \log_2 S_t$$

A nomogram giving this relation is included in figure 1.

### 4.3 Table of loudness index

In table 2 values of the loudness index are tabulated for the frequency of 1 000 Hz. Values at other frequencies can be obtained by means of the following rules. The value of the loudness index is constant on the contour having a slope of  $-3$  dB/octave. Above 9 000 Hz the contour has a slope of  $12$  dB/octave. Below a certain frequency the contour has a slope of  $-6$  dB/octave. The frequency at which this change of slope occurs lies on a line having a slope of  $-21$  dB/octave. This line passes through the point determined by 1 000 Hz and 10 dB band pressure level.

NOTE — The chart of figure 1 shows one means of presenting the relation between loudness index, band pressure level and frequency. Here the loudness index is the parameter of the family. For certain purposes, it may be convenient to prepare charts for the band pressure level as a parameter, and the loudness index as an ordinate.

TABLE 2 – Loudness index at 1 000 Hz

| Band pressure level<br>dB | Loudness index | Band pressure level<br>dB | Loudness index | Band pressure level<br>dB | Loudness index |
|---------------------------|----------------|---------------------------|----------------|---------------------------|----------------|
| 15                        |                | 50                        | 2,68           | 85                        | 23,0           |
| 16                        |                | 51                        | 2,84           | 86                        | 24,7           |
| 17                        |                | 52                        | 3,0            | 87                        | 26,5           |
| 18                        | 0,10           | 53                        | 3,2            | 88                        | 28,5           |
| 19                        | 0,14           | 54                        | 3,4            | 89                        | 30,5           |
| 20                        | 0,18           | 55                        | 3,6            | 90                        | 33,0           |
| 21                        | 0,22           | 56                        | 3,8            | 91                        | 35,3           |
| 22                        | 0,26           | 57                        | 4,1            | 92                        | 38,0           |
| 23                        | 0,30           | 58                        | 4,3            | 93                        | 41,0           |
| 24                        | 0,35           | 59                        | 4,6            | 94                        | 44,0           |
| 25                        | 0,40           | 60                        | 4,9            | 95                        | 48             |
| 26                        | 0,45           | 61                        | 5,2            | 96                        | 52             |
| 27                        | 0,50           | 62                        | 5,5            | 97                        | 56             |
| 28                        | 0,55           | 63                        | 5,8            | 98                        | 61             |
| 29                        | 0,61           | 64                        | 6,2            | 99                        | 66             |
| 30                        | 0,67           | 65                        | 6,6            | 100                       | 71             |
| 31                        | 0,73           | 66                        | 7,0            | 101                       | 77             |
| 32                        | 0,80           | 67                        | 7,4            | 102                       | 83             |
| 33                        | 0,87           | 68                        | 7,8            | 103                       | 90             |
| 34                        | 0,94           | 69                        | 8,3            | 104                       | 97             |
| 35                        | 1,02           | 70                        | 8,8            | 105                       | 105            |
| 36                        | 1,10           | 71                        | 9,3            | 106                       | 113            |
| 37                        | 1,18           | 72                        | 9,9            | 107                       | 121            |
| 38                        | 1,27           | 73                        | 10,5           | 108                       | 130            |
| 39                        | 1,35           | 74                        | 11,1           | 109                       | 139            |
| 40                        | 1,44           | 75                        | 11,8           | 110                       | 149            |
| 41                        | 1,54           | 76                        | 12,6           | 111                       | 160            |
| 42                        | 1,64           | 77                        | 13,5           | 112                       | 171            |
| 43                        | 1,75           | 78                        | 14,4           | 113                       | 184            |
| 44                        | 1,87           | 79                        | 15,3           | 114                       | 197            |
| 45                        | 1,99           | 80                        | 16,4           | 115                       | 211            |
| 46                        | 2,11           | 81                        | 17,5           | 116                       | 226            |
| 47                        | 2,24           | 82                        | 18,7           | 117                       | 242            |
| 48                        | 2,38           | 83                        | 20,0           | 118                       | 260            |
| 49                        | 2,53           | 84                        | 21,4           | 119                       | 278            |
|                           |                |                           |                | 120                       | 298            |