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Acoustics — Determination of occupational noise exposure — Engineering method

Acoustique — Détermination de l'exposition au bruit en milieu de travail — Méthode d'expertise

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9612 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 9612:1997), which has been technically revised.

Introduction

This International Standard provides a stepwise approach to the determination of occupational noise exposure from noise level measurements. The procedure contains the following major steps: work analysis, selection of measurement strategy, measurements, error handling and uncertainty evaluations, calculations, and presentation of results. This International Standard specifies three different measurement strategies: task-based measurement; job-based measurement; and full-day measurement. This International Standard gives guidance on selecting an appropriate measurement strategy for a particular work situation and purpose of investigation. This International Standard also provides an informative spreadsheet to allow calculation of measurement results and uncertainties. ISO is not responsible for errors that may arise or occur with the use of this spreadsheet.

This International Standard recognizes the use of hand-held sound level meters as well as personal sound exposure meters. The methods specified optimize the effort required for obtaining a given accuracy.

Acoustics — Determination of occupational noise exposure — Engineering method

1 Scope

This International Standard specifies an engineering method for measuring workers' exposure to noise in a working environment and calculating the noise exposure level. This International Standard deals with A-weighted levels but is applicable also to C-weighted levels. Three different strategies for measurement are specified. The method is useful where a determination of noise exposure to engineering grade is required, e.g. for detailed noise exposure studies or epidemiological studies of hearing damage or other adverse effects.

The measuring process requires observation and analysis of the noise exposure conditions so that the quality of the measurements can be controlled. This International Standard provides methods for estimating the uncertainty of the results.

This International Standard is not intended for assessment of masking of oral communication or assessment of infrasound, ultrasound and non-auditory effects of noise. It does not apply to the measurement of the noise exposure of the ear when hearing protectors are worn.

Results of the measurements performed in accordance with this International Standard can provide useful information when defining priorities for noise control measures.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1999, *Acoustics — Determination of occupational noise exposure and estimation of noise-induced hearing impairment*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61252, *Electroacoustics — Specifications for personal sound exposure meters*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
A-weighted time-averaged sound pressure level
$L_{p,\mathrm{A},T}$
A-weighted equivalent continuous sound pressure level
$L_{p,\mathrm{A,eq}T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the A-weighted sound pressure, p_A, during a stated time interval of duration T (starting at t_1 and ending at t_2), to the square of a reference value, p_0, expressed in decibels

$$L_{p,\mathrm{A},T} = L_{p,\mathrm{A,eq}T} = 10 \lg \left[\frac{\frac{1}{T}\int_{t_1}^{t_2} p_\mathrm{A}^2(t)\,\mathrm{d}t}{p_0^2} \right] \text{ dB} \tag{1}$$

where the reference value, p_0, is 20 µPa

NOTE Adapted from ISO/TR 25417:2007 [9].

3.2
A-weighted noise exposure level normalized to an 8 h working day
daily noise exposure level
$L_{\mathrm{EX,8h}}$
〈occupational noise〉 level, in decibels, given by the equation:

$$L_{\mathrm{EX,8h}} = L_{p,\mathrm{A,eq}T_\mathrm{e}} + 10 \lg \left[\frac{T_\mathrm{e}}{T_0} \right] \text{ dB} \tag{2}$$

where

$L_{p,\mathrm{A,eq}T_\mathrm{e}}$ is the A-weighted equivalent continuous sound pressure level for T_e;

T_e is the effective duration, in hours, of the working day;

T_0 is the reference duration, $T_0 = 8$ h

NOTE 1 If the effective duration of the working day, T_e, is equal to 8 h, then $L_{\mathrm{EX,8h}}$ equals $L_{p,\mathrm{A,eq,8h}}$.

NOTE 2 If the average or normalized exposure over a number of days is desired, Equation (3) can be used:

$$\bar{L}_{\mathrm{EX,8h}} = 10 \lg \left[\frac{1}{X} \sum_{x=1}^{X} 10^{0{,}1 \times L_{\mathrm{EX,8h},x}} \right] \text{ dB} \tag{3}$$

The value of X is chosen according to the purpose of the averaging process. For example, $X = 5$ leads to a daily noise exposure level normalized to a nominal week of five 8 h working days.

NOTE 3 This definition differs from that given in ISO/TR 25417:2007 [9].

3.3
nominal day
working day over which it is chosen to determine the noise exposure

NOTE 1 The nominal day is determined from the work analysis and depends on the purpose of the measurements. For example, it may be a typical day representing the work performed over several days or the day with the highest noise exposure. See also 7.3.

NOTE 2 The noise exposure level is normally calculated on a daily basis, but there may be circumstances where the use of weekly or longer periods of noise exposure is considered appropriate.

3.4
C-weighted peak sound pressure level
$L_{p,\mathrm{Cpeak}}$
ten times the logarithm to the base 10 of the ratio of the square of the C-weighted peak sound pressure, p_{Cpeak}, to the square of a reference value, p_0, expressed in decibels

$$L_{p,\mathrm{Cpeak}} = 10 \lg \frac{p_{\mathrm{Cpeak}}^2}{p_0^2} \ \mathrm{dB} \tag{4}$$

where the reference value, p_0, is 20 μPa.

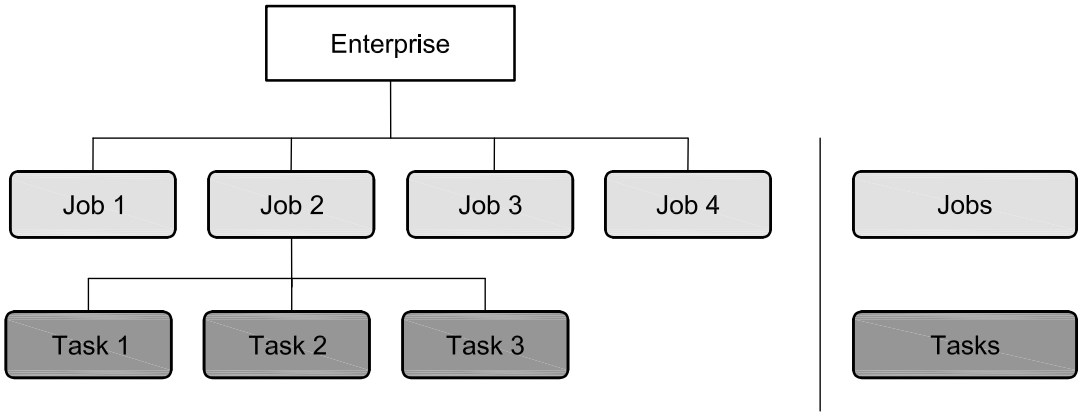
3.5
task
⟨occupational noise⟩ distinct part of a worker's occupational activity

Figure 1 illustrates the hierarchy of jobs and tasks.

3.6
job
⟨occupational noise⟩ overall occupational activity that is carried out by a worker, consisting of all the tasks performed by the worker during the entire working day or shift

NOTE A worker often has a job title that describes his or her job, sometimes complemented with an additional description to ensure clear identification, e.g. "welder - process line A".

Figure 1 illustrates the hierarchy of jobs and tasks.



Key

Job 1 scaffolders
Job 2 welders
Job 3 painters
Job 4 store keepers

Task 1 planning
Task 2 grinding
Task 3 welding

Figure 1 — An example illustrating the hierarchy of jobs and tasks

4 Symbols

c_i	sensitivity coefficient related to each input quantity	—
c_1	sensitivity coefficient associated with job noise level sampling	—
$c_{1a,m}$	sensitivity coefficient associated with noise level sampling of task m	—
$c_{1b,m}$	sensitivity coefficient associated with estimation of duration of task m	dB h^{-1}
c_2	sensitivity coefficient associated with measurement instrumentation	—
c_3	sensitivity coefficient associated with microphone position	—
i	task sample number	—
I	the total number of task samples	—
j	number of observations of task duration	—
J	total number of observations of task duration	—
k	coverage factor related to a confidence interval	—
K_N	denominator as given in C.3.3, Note 2	—
$L_{EX,8h}$	A-weighted noise exposure level normalized to a nominal 8 h working day	dB
$\overline{L}_{EX,8h}$	A-weighted noise exposure level normalized to a nominal 8 h working day averaged over a number of days	dB
$L_{EX,8h,m}$	A-weighted noise exposure level of task m contributing to the daily noise exposure level	dB
$L^*_{p,A,eqT,m}$	estimate of the true A-weighted equivalent continuous sound pressure level for task m	dB
$L_{p,A,T} = L_{p,A,eqT}$	A-weighted equivalent continuous sound pressure level over a period T	dB
$L_{p,A,eqT,m}$	A-weighted equivalent continuous sound pressure level for task m	dB
$\overline{L}_{p,A,eqT,m}$	arithmetic average of a number of samples of the A-weighted equivalent continuous sound pressure levels for task m	dB
$L_{p,A,eqT,n}$	A-weighted equivalent continuous sound pressure level of job sample n	dB
$L_{p,A,eqTe}$	A-weighted equivalent continuous sound pressure level for the effective duration of the working day	dB
$L_{p,Cpeak}$	C-weighted peak sound pressure level	dB
m	task number	—
M	total number of tasks	—
n	job sample number	—
N	total number of job samples	—
n_G	number of workers in a homogenous exposure group	—
p_0	reference value; $p_0 = 2 \times 10^{-5}$ Pa	Pa
p_A	A-weighted sound pressure	Pa
p_{Cpeak}	C-weighted peak sound pressure	Pa
Q_2	correction for measurement instrumentation	dB
Q_3	correction for microphone position	dB
t	duration of measurement as described in Figure 2	h
T	time period over which an average is taken	h
T_0	reference duration; $T_0 = 8$ h	h

T_e	effective duration of the working day	h
T_m	duration of task m	h
$T_{m,j}$	duration of sample j of task m	h
T_n	duration of job sample n	h
U	expanded uncertainty	dB
u	combined standard uncertainty	dB
u_i	standard uncertainty of each input quantity	dB
u_1	standard uncertainty of the energy average of a number of measurements of A-weighted equivalent continuous sound pressure level	dB
u_1^*	estimated standard uncertainty of a number of measurements of A-weighted equivalent continuous sound pressure level	dB
$u_{1a,m}$	standard uncertainty due to noise level sampling of task m	dB
$u_{1b,m}$	standard uncertainty due to the estimation of duration of task m	h
u_2	standard uncertainty due to the instrumentation	dB
$u_{2,m}$	standard uncertainty due to the instrumentation in the task method	dB
u_3	standard uncertainty due to microphone position	dB
x	day number	—
X	total number of days	—

5 Instrumentation

5.1 Sound level meters and personal sound exposure meters

Measurements can be made by using either integrating-averaging sound level meters or personal sound exposure meters.

Sound level meters, including the microphone and associated cables, shall meet the requirements for IEC 61672-1:2002, class 1 or class 2 instrumentation. Class 1 instrumentation is preferred and should be used when measuring at very low temperatures or when the noise is dominated by high frequencies (see also Note 3).

Personal sound exposure meters, including the microphone and cable, shall meet the requirements specified in IEC 61252. Personal sound exposure meters fulfilling the requirements of IEC 61672-1:2002, class 1, are recommended and should be used when measuring at very low temperatures or when the noise is dominated by high frequencies (see also Notes 2 and 4).

NOTE 1 Most sound level meters that meet the requirements of IEC 60651:2001 [10] 1) and IEC 60804:2000 [11] 1) also meet the acoustic requirements of IEC 61672-1:2002.

NOTE 2 “Personal sound exposure meter” is often referred to as “noise dose meter” or “noise dosimeter” (North America).

NOTE 3 For IEC 61672-1:2002, class 1 instruments, the specified tolerance limits are applied for the temperature range from −10 °C to +50 °C. For instrumentation in accordance with IEC 61672-1:2002, class 2, and for personal sound exposure meters in accordance with IEC 61252, the influence of variations in the air temperature on the measured signal level is specified over the range from 0 °C to +40 °C. In order to maintain accuracy when performing measurements outside this temperature range, it can be necessary to use an instrument for which the manufacturer specifies compliance

1) Superseded.

for a wider temperature range. Alternatively, a sound level meter in accordance with IEC 61672-1:2002, class 1, may be selected. In cold conditions, the measuring instrument may be kept warm, e.g. under clothing, such that only the microphone is exposed to low temperatures.

NOTE 4 The choice of the instrumentation influences the uncertainty of the measurements.

NOTE 5 For personal sound exposure meters, IEC 61252 allows wide tolerances in the frequency characteristics above 4 000 Hz, which can lead to incorrect measurement of high frequency sound such as that from air nozzles. In order to reduce the uncertainty when measuring noise dominated by high frequencies, it may be necessary to use a measuring instrument for which the manufacturer specifies high frequency characteristics within a narrower tolerance range. Alternatively, a sound level meter specified in accordance with IEC 61672-1:2002, class 1, may be selected.

Personal sound exposure meters can have a cut-off level at around 70 dB. It should be checked whether this influences the measurement result.

5.2 Calibrator

The calibrator shall meet the requirements specified in IEC 60942:2003, class 1.

5.3 Periodic verification

The calibration of the sound calibrator and the compliance of the instrumentation system with the requirements of IEC 61672-1, IEC 61252 and other relevant standards shall be verified at intervals in a laboratory making calibrations traceable to appropriate standards.

Unless national regulations dictate otherwise, it is recommended that the sound calibrator and the compliance of the instrumentation system with the requirements of IEC 61672-1 be verified at intervals not exceeding 2 years.

The date for the last periodic verification and the name of the laboratory that performed it shall be recorded and given in the measurement report.

6 Methodology — Chronological steps

6.1 Step 1: Work analysis

The work analysis shall provide sufficient information about the work and the workers under consideration so that an appropriate measurement strategy can be selected and measurements can be planned. Work analysis shall be carried out in accordance with Clause 7.

6.2 Step 2: Selection of the measurement strategy

A measurement strategy shall be selected from task-based measurement, job-based measurement or full-day measurement as specified in Clause 8. More than one measurement strategy may be used, if relevant (see Clause B.6).

6.3 Step 3: Measurements

The basic measurement quantity shall be $L_{p,\mathrm{A,eq}T}$. In addition, $L_{p,\mathrm{Cpeak}}$ shall be measured, if relevant. The measurements shall follow the chosen strategy as specified in one of Clauses 9, 10 or 11 and comply with the requirements of Clause 12.

6.4 Step 4: Error handling and uncertainties

Sources of errors and uncertainties that may influence the result shall be evaluated in accordance with Clauses 13 and 14.

6.5 Step 5: Calculation and presentation of results and uncertainty

Calculate $L_{EX,8h}$ as specified for the selected strategy (see Clauses 9, 10, and 11) and the uncertainty as specified in Annex C. The results and uncertainties can be calculated by using the spreadsheet provided with this International Standard.

The results shall be presented as specified in Clause 15. Annexes D, E, and F provide practical examples for the task-based, job-based, and full-day measurements, respectively.

7 Work analysis

7.1 Introduction

Work analysis is required in all situations. It shall provide the information necessary to:

a) describe the activities of the enterprise and the jobs of the workers under consideration;

b) define homogeneous noise exposure groups (see 7.2), if relevant;

c) determine a nominal day or days for each worker or group;

d) identify tasks which make up the jobs, if relevant;

e) identify possible significant noise events;

f) choose the measurement strategy;

g) establish the measurement plan.

The work shall be analysed with emphasis put on production, process, organization, workers and activities.

The measurements may be performed by using the task-based, job-based or full-day strategy. Whichever strategy is used, it is essential to identify all events which are significant with regard to noise exposure and to make sure that the measurement plan takes them into account. See Annex A for an example of a checklist.

NOTE The order in which the items above are performed can depend on the complexity of the situation on site. The items are strongly connected, and the process can therefore be iterative in complex situations, i.e. increased knowledge about one of the items can result in a new description or redefinition of others.

7.2 Defining homogeneous noise exposure groups

Measurement efforts can be reduced by defining homogeneous noise exposure groups. These are groups of workers that are performing the same job and are expected to have similar noise exposures during the working day. If used, the homogeneous noise exposure group shall be clearly identified and can consist of one or more workers.

NOTE A **homogeneous noise exposure group** is also called **similar noise exposure group** US.

Homogeneous noise exposure groups can be defined in a number of ways. For example, it may be possible to define such groups according to job title, function, work area or profession. Alternatively, the groups can be defined by analysing the work according to production, process or work activity criteria.

In whichever way the groups are defined, they should be verified in consultation with the workers and supervisor, and ultimately by evaluating the measurement results, see 10.4.

7.3 Determination of a nominal day

A nominal day, including work periods and breaks, shall be determined in consultation with both workers and management. The work shall be studied in order to obtain an overview and understanding of all factors which can influence the noise exposure. See Annex A for more details.

Issues that shall be addressed are:

a) tasks (content and duration) and variation within tasks;

b) main noise sources and noisy work areas;

c) work pattern and any significant noise events, resulting in a change of the noise level;

d) number and duration of breaks, meetings, etc., and whether they should be regarded as a part of the nominal day.

Measurements shall be planned to ensure that all significant noise events are included. For each of the events, it shall be recorded when it occurred, its nature, duration and daily frequency. An example of a checklist to ensure that significant noise events are detected during the work analysis is given in Annex A.

In some cases, the work and consequently the noise exposure, varies from day to day so that there is no typical daily exposure, e.g. for workers who work in different locations or jobs each day. In these cases, the nominal day can be defined from work situations during several days, e.g. 1 week. See also Notes to 3.2 and 3.3.

Any indicators that characterize the work with respect to noise shall be identified, quantified, and reported. Examples of such indicators are: type of production in process; materials; quantities; thickness of workpiece; adjustment; speed; and number of workers involved.

If the purpose of measurements is to estimate the long-term risk of hearing impairment of workers, then the nominal day chosen shall be representative of the average exposure over the period under consideration, in accordance with ISO 1999.

8 Selection of measurement strategies

8.1 General

The selection of an appropriate measurement strategy is influenced by several factors such as the purpose of the measurements, complexity of the work situation, number of workers involved, effective duration of the working day, time available for measurement and analysis, and amount of detailed information required.

8.2 Measurement strategies

Three measurement strategies for the determination of workplace noise exposure are offered by this International Standard. These are:

a) task-based measurement: the work performed during the day is analysed and split up into a number of representative tasks, and for each task separate measurements of sound pressure level are taken (see Clause 9);

b) job-based measurement: a number of random samples of sound pressure level are taken during the performance of particular jobs (see Clause 10);

c) full-day measurement: sound pressure level is measured continuously over complete working days (see Clause 11).

Detailed guidance on the choice of the measurement strategy is given in Annex B.

9 Strategy 1 — Task-based measurement

9.1 Dividing the nominal day into tasks

For the workers or homogenous noise exposure groups under evaluation, the nominal day shall be divided into tasks. Each task shall be defined such that $L_{p,\mathrm{A,eq}T}$ is likely to be repeatable. Care shall be taken to ensure that all relevant noise contributions are included. Detailed information regarding the duration of tasks is particularly important for noise sources with high noise levels.

Identification of the noise sources and tasks that give the highest peak levels is important to obtain a correct determination of both $L_{p,\mathrm{A,eq}T}$ and $L_{p,\mathrm{Cpeak}}$.

9.2 Duration of tasks

The durations of the tasks, T_m, shall be determined. This can be done by:

a) interviewing the workers and the supervisor;

b) observing and measuring durations during noise measurements;

c) gathering information regarding operation of typical noise sources (e.g. work processes, machines, activities at the workplace and in its surroundings).

Optionally, the duration of a task can be regarded as a variable. To determine possible variations in duration, the task can be observed and the duration recorded, for instance, three times. Alternatively, multiple workers and supervisors may be asked to indicate the most reasonable duration range.

If J observations of the task duration $T_{m,j}$ are available, the arithmetic average value of task duration, $\overline{T}_m$, is given by Equation (5):

$$\overline{T}_m = \frac{1}{J}\sum_{j=1}^{J} T_{m,j} \tag{5}$$

The sum of individual durations of tasks, T_m, which make up the nominal day, shall correspond to the effective duration of the working day. The effective duration of the working day, T_e, is given by:

$$T_\mathrm{e} = \sum_{m=1}^{M} \overline{T}_m \tag{6}$$

where

$\overline{T}_m$ is the arithmetic average duration of task m;

m is the number of a task;

M is the total number of tasks.

NOTE Task-based measurements can, for instance, be combined with full-day measurements to verify that all relevant sources are included.

9.3 Measurement of $L_{p,\mathrm{A,eq}T,m}$ for tasks

For each task, the $L_{p,\mathrm{A,eq}T,m}$ representative of the noise exposure of the worker shall be measured in accordance with Clause 12. The measurements shall cover variations in noise level within each task in time, space and working conditions.