# INTERNATIONAL STANDARD

# ISO 16976-7

First edition

# Respiratory protective devices — Human factors —

## Part 7: Hearing and speech

*Appareils de protection respiratoire — Facteurs humains —*

*Partie 7: Discours et audition*



**PROOF/ÉPREUVE**

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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 procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.



This document was prepared by Technical Committee ISO/TC 94, *Personal safety — Personal protective equipment*, Subcommittee SC 15, *Respiratory protective devices*.

This first edition of ISO 16976-7 cancels and replaces the second edition (ISO/TS 16976-7:2019), which has been technically revised.

The main changes as follows:

— requirements more specified.

A list of all parts in the ISO 16976 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

For an appropriate design, selection and use of respiratory protective devices, basic physiological demands of the user should be considered. The function of a respiratory protective device, the way it is designed and used, and the properties of its material can affect communications: either speech or hearing or both.

This document belongs to a series of documents providing basic physiological and anthropometric data on humans. It contains information about hearing and speech associated with wearing respiratory protective devices.

# Respiratory protective devices — Human factors —

# Part 7:
# Hearing and speech

## 1 Scope

This document contains information related to the interaction between respiratory protective devices and the human body functions of hearing and speech.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 — Estimation of noise-induced hearing loss*

ISO 16972, *Respiratory protective devices — Vocabulary and graphical symbols*

IEC 61672, *Electroacoustics — Sound Level Meters*



## 3 Terms and definitions, and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 1999, ISO 16972 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

### 3.1 Terms and definitions

**3.1.1**
**hearing**
manner in which the brain and central nervous system recognizes and interprets *sounds* (3.1.5)

**3.1.2**
**ototoxicity**
damage to *hearing* (3.1.1) from overexposure to drugs or toxic substances

**3.1.3**
**noise**
unwanted *sound* (3.1.5)

**3.1.4**
**presbycusis**
gradual sensorineural *hearing* (3.1.1) loss due to natural ageing

**3.1.5**
**sound**
form of energy that moves through media in waves of pressure

**3.1.6**
**sound pressure**
local pressure deviation from the ambient atmospheric pressure caused by a *sound* (3.1.5) wave

Note 1 to entry: The sound pressure is measured in pascals (Pa).

**3.1.7**
**RMS sound pressure**
deviation from the ambient atmospheric pressure caused by a sound wave at an instant in time over a given period of time

## 3.2 Abbreviated terms

SPL sound pressure level

NIHL noise induced hearing loss

TWA time-weighted average

STI speech transmission index

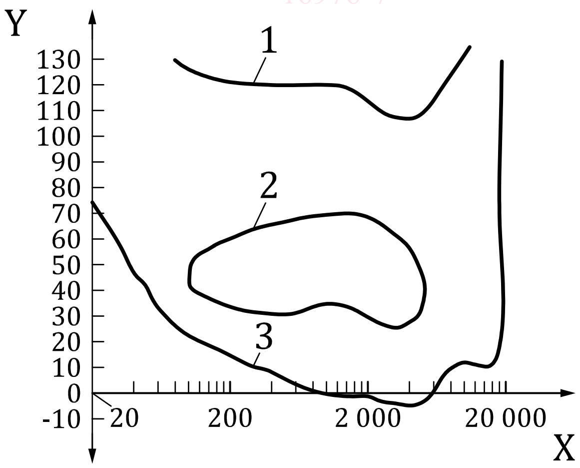
SII speech intelligibility index

RMS root mean square



# 4 Range of hearing and speech

Humans with normal hearing can usually hear sound pressure waves in a frequency range of about 20 Hz to 20 000 Hz, but the ear is most sensitive to frequencies from 500 Hz to around 4 000 Hz and declines dramatically in sensitivity as frequencies drop below 500 Hz. Figure 1 depicts the frequency response and sound pressure level response of human hearing and speech. The frequency range is affected by ageing as explained further in 7.3.




**Key**

X logarithmic sale of frequency in Hz

Y sound pressure level, in dB

1 pain threshold

2 range of speech

3 hearing threshold

**Figure 1 — Range of human hearing and speech**

## 5 Measurement of sound pressure

The measurement of sound pressure is carried out using a sound level meter which shall meet the requirements of IEC 61672.

The sound pressure level (SPL) is the logarithmic ratio of the sound pressure to a reference sound pressure and is expressed in decibels (dB) by Formula (1):

$$L_p = 20\log_{10}\left(\frac{p_{\mathrm{RMS}}}{p_0}\right) \tag{1}$$

where

| | |
|---|---|
| $L_p$ | is the sound pressure level, in dB, |
| $p_{\mathrm{RMS}}$ | is the root mean square (RMS) sound pressure, in Pa, |
| $p_0$ | is the sound reference pressure, in Pa. |

In air, the reference sound pressure is 20 µPa. That reference is based on the average human threshold of hearing at a frequency of 1 000 Hz.

When measuring sound pressure level as it relates to human perception, weighting factors, as given in IEC 61672, are used to represent human loudness perception at different frequencies. The most common is the A weighted sound measurement which approximates the human loudness perception at 40 phon (40 dB at 1 000 Hz) and is expressed as dBA. Examples of some typical sound levels are:



| | |
|---|---|
| library: | 40 dBA; |
| normal conversation: | 60 dBA; |
| traffic noise: | 80 dBA; |
| metal shop: | 100 dBA; |
| siren: | 120 dBA; |
| jet engine: | 140 dBA. |

A perceived difference in sound level occurs at approximately 3 dB, and a perceived doubling of sound volume occurs with a 10 dB increase in sound pressure level.

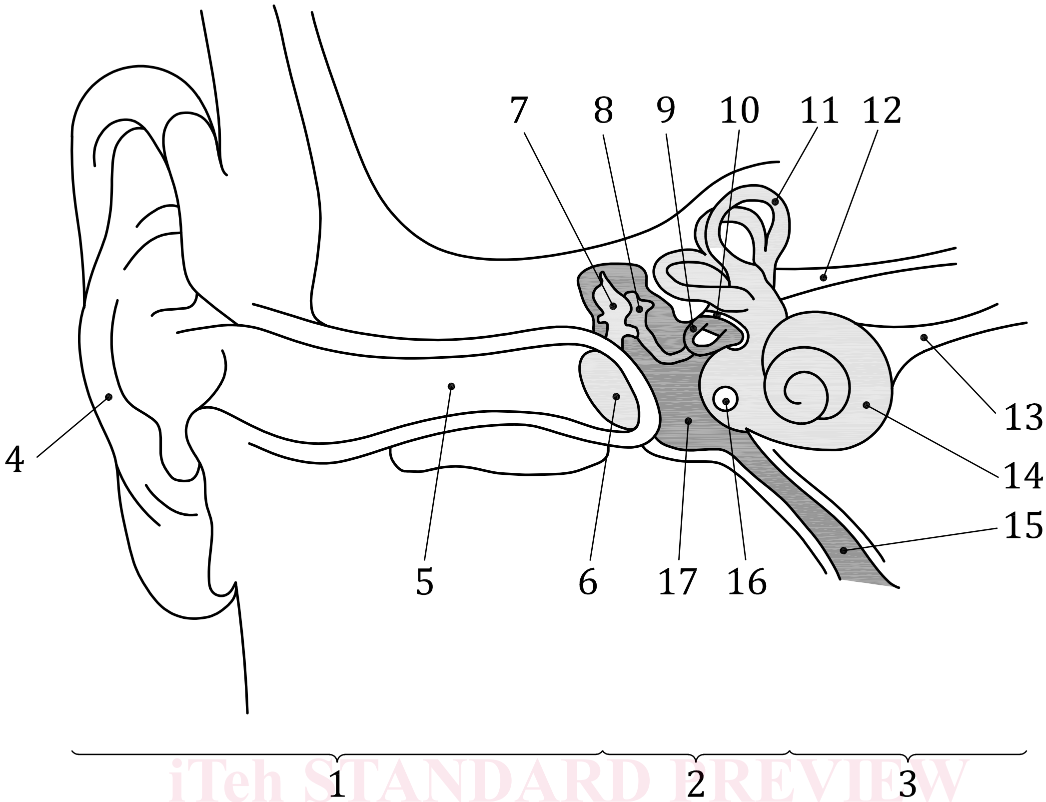
Another sound weighting is the C-weighting, which approximates the human loudness perception at 100 phon.

## 6 Physiology of the ear

### 6.1 General

The human ear is the sense organ that detects sounds and changes the pressure waves into a signal of nerve impulses that is sent to the brain. The ear not only receives and converts sound but also plays a major role in the sense of balance and body position.

As shown in Figure 2, the ear is usually described in three sections: the outer ear (key 1), middle ear (key 2) and inner ear (key 3).






**Key**

1 outer ear
2 middle ear
3 inner ear
4 pinna
5 external auditory channel
6 tympanic membrane
7 malleus
8 incus
9 stapes
10 oval window
11 semi-circular canals
12 vestibular nerve
13 cochlear nerve
14 cochlea
15 Eustachian tube
16 round window
17 tympanic cavity

**Figure 2 — Physiological ear terms**

## 6.2 Outer ear

The outer ear is the most external portion of the ear. The outer ear includes the pinna (also called auricle), the ear canal, and the very most superficial layer of the ear drum (also called the tympanic membrane). In humans, the only visible portion of the ear is the outer ear. The outer ear does help get sound (and imposes filtering), but the ear canal is very important. Unless the canal is open, hearing will be damped. Ear wax (cerumen) is produced by glands in the skin of the outer portion of the ear canal. The outer ear ends at the most superficial layer of the tympanic membrane.

The pinna helps direct sound through the ear canal to the tympanic membrane (eardrum).

## 6.3 Middle ear

The middle ear, an air-filled cavity behind the ear drum (tympanic membrane), includes the three ear bones or ossicles: the malleus (or hammer), incus (or anvil), and stapes (or stirrup). The opening of the Eustachian tube is also within the middle ear. The three bones are arranged so that movement of the tympanic membrane causes movement of the malleus, which causes movement of the incus, which causes movement of the stapes. When the stapes footplate pushes on the oval window, it causes movement of fluid within the cochlea (a portion of the inner ear).

In humans the middle ear (like the ear canal) is normally filled with air. Unlike the open ear canal, however, the air of the middle ear is not in direct contact with the atmosphere outside the body. The Eustachian tube connects from the chamber of the middle ear to the back of the pharynx.

The arrangement of the tympanic membrane and ossicles works to efficiently couple the sound from the opening of the ear canal to the cochlea. There are several simple mechanisms that combine to increase the sound pressure.

— The first is the “hydraulic principle”. The surface area of the tympanic membrane is many times that of the stapes footplate. Sound energy strikes the tympanic membrane and is concentrated to the smaller footplate.

— A second mechanism is the “lever principle”. The dimensions of the articulating ear ossicles lead to an increase in the force applied to the stapes footplate compared with that applied to the malleus.

— A third mechanism channels the sound pressure to one end of the cochlea and protects the other end from being struck by sound waves. In humans, this is called “round window protection”.

### 6.4 Inner ear

The inner ear includes both the organ of hearing (the cochlea) and a sense organ that is attuned to the effects of both gravity and motion (labyrinth or vestibular apparatus). The balance portion of the inner ear consists of three semi-circular canals and the vestibule. When sound strikes the ear drum, the movement is transferred to the footplate of the stapes, which presses into one of the fluid-filled ducts of the cochlea. The fluid inside this duct is moved, flowing against the receptor cells of the cochlear nerve, which fire. These stimulate the spiral ganglion, which sends information through the auditory portion of the eighth cranial nerve to the brain.



## 7 Hearing loss

### 7.1 Conductive hearing loss

Abnormalities such as impacted ear wax (occlusion of the external ear canal), fixed or missing ossicles, or holes in the tympanic membrane generally produce conductive hearing loss. Conductive hearing loss may also result from middle ear inflammation causing fluid build-up in the normally air-filled space. In some cases, conductive hearing loss is reversible.

### 7.2 Ototoxicity

A number of drugs in clinical use and some substances at the workplace (e.g. styrol) are considered “ototoxic” and have the potential to cause damage to hearing as a side effect, especially in combination with noise exposure. Hearing loss caused by ototoxic drugs can be reversible or permanent.

### 7.3 Presbycusis

Hearing loss caused by natural aging affects the higher frequencies making word recognition difficult, see Clause 8. It is permanent.

### 7.4 Noise induced hearing loss (NIHL)

NIHL is caused by exposure to sound levels or durations that damage the hair cells of the cochlea. Initially, the noise exposure may cause a temporary threshold shift, that is, a decrease in hearing sensitivity that typically returns to its former level within a few minutes to a few hours. Repeated exposures lead to a permanent threshold shift, which is an irreversible sensorineural hearing loss. Hearing loss has causes