INTERNATIONAL STANDARD

ISO 16976-3

First edition
2022-10

Respiratory protective devices — Human factors —

Part 3: Physiological responses and limitations of oxygen and limitations of carbon dioxide in the breathing environment

Appareils de protection respiratoire — Facteurs humains —

Partie 3: Réponses physiologiques et limites en oxygène et en dioxyde de carbone dans l'environnement respiratoire



Reference number
ISO 16976-3:2022(E)

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Published in Switzerland

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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).

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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 16976-3 cancels and replaces ISO/TS 16976-3:2019, which has been technically revised.

The main changes are as follows:

— the document has been editorially revised.

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.

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Introduction

Due to the nature of their occupations, millions of workers worldwide wear respiratory protective devices (RPD). RPD vary considerably, from filtering devices, supplied breathable gas devices, and underwater breathing apparatus (UBA), to escape respirators used in emergency situations (self-contained self-rescuer or SCSR). Many of these devices protect against airborne contaminants without supplying air or other breathing gas mixtures to the user. Therefore, the user might be protected from particulates or other airborne toxins but still be exposed to an ambient gas mixture that differs significantly from that which is normally found at sea level. RPD that supply breathing air to the user, such as an SCBA or UBA, can malfunction or not adequately remove carbon dioxide from the breathing space, thus exposing the user to an altered breathing gas environment. In special cases, RPD intentionally expose the wearer to breathing gas mixtures that significantly differ from the normal atmospheric gas mixture of approximately 79 % nitrogen and 21 % oxygen with additional trace gases. These special circumstances occur in aviation, commercial and military diving, and in clinical settings.

Breathing gas mixtures that differ from normal atmospheric can have significant effects on most physiological systems. Many of the physiological responses to exposure to high or low levels of either oxygen or carbon dioxide can have a profound effect on the ability to work safely, to escape from a dangerous situation, and to make clear judgements about the environmental dangers. In addition, alteration of the breathing gas environment can, if severe enough, be dangerous or even fatal. Therefore, monitoring and controlling the breathing gas, and limiting user exposure to variations in the concentration or partial pressure of oxygen and carbon dioxide, is crucial to the safety and health of the worker.

This document discusses the gas composition of the Earth's atmosphere; the basic physiology of metabolism as the origin of carbon dioxide in the body, respiratory physiology and the transport of oxygen to the cells and tissues of the body; and the subsequent transport of carbon dioxide from the tissues to the lungs for removal from the body. Following the basic physiology of respiration, this document addresses the physiological responses to altered breathing environments (hyperoxia, hypoxia) and to the effects of excess carbon dioxide in the blood (hypercarbia). Examples are given from the relevant biomedical literature.

Finally, it deals with the impact of altered partial pressures/concentrations of oxygen and carbon dioxide on respirator use. The content of this Document is intended to serve as the basis for advancing research and development of RPD with the aim of minimizing the changes in the breathing environment, thus minimizing the physiological impact of RPD use on the wearer. If this can be accomplished, the health and safety of all workers recommended by their occupation to wear RPD will be enhanced.

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Respiratory protective devices — Human factors —

Part 3: Physiological responses and limitations of oxygen and limitations of carbon dioxide in the breathing environment

1 Scope

This document gives:

— a description of the composition of the Earth's atmosphere;

— a description of the physiology of human respiration;

— a survey of the current biomedical literature on the effects of carbon dioxide and oxygen on human physiology;

— examples of environmental circumstances where the partial pressure of oxygen or carbon dioxide can vary from that found at sea level.

This document identifies oxygen and carbon dioxide concentration limit values and the length of time within which they would not be expected to impose physiological distress. To adequately illustrate the effects on human physiology, this document addresses both high altitude exposures where low partial pressures are encountered and underwater diving, which involves conditions with high partial pressures. The use of respirators and various work rates during which RPD can be worn are also included.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology 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
alveoli
terminal air sacs of the lungs in which respiratory gas exchange occurs between the alveolar air and the pulmonary capillary

Note 1 to entry: The alveoli are the anatomical and functional unit of the lungs.

Note 2 to entry: Actual ambient temperature and atmospheric pressure; saturated water pressure.

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3.2
body temperature pressure saturated
BTPS
standard condition for the expression of ventilation parameters

EXAMPLE Body temperature (37 °C), atmospheric pressure (1 013,25 hPa) and water vapour pressure (6,27 kPa) in saturated air.

Note 1 to entry: It is the atmospheric pressure at the test location that should be used whenever BTPS conditions are specified.

3.3
carbaminohaemoglobin
$HbCO_2$
haemoglobin that has bound carbon dioxide at the tissue site for transport to the lungs

3.4
dead space
<anatomical> conducting regions of the pulmonary airways that do not contain *alveoli* (3.1) and, therefore, where no gas exchange occurs

Note 1 to entry: These areas include the nose, mouth, trachea, large bronchia, and the lower branching airways. This volume is typically 150 ml in a male of average size.

3.5
dead space
<physiological> sum of all anatomical *dead spaces* (3.4) as well as under-perfused (reduced blood flow) *alveoli* (3.1) which are not participating in gas exchange

Note 1 to entry: The volume of the physiological dead space can vary with the degree of ventilation. Thus, the physiological dead space is the fraction of the tidal volume that does not participate in gas exchange in the lungs.

3.6
dyspnoea
sense of air hunger, difficult or laboured breathing, or a sense of breathlessness

3.7
end-tidal carbon dioxide
volume fraction of carbon dioxide in the breath at the mouth at the end of exhalation

Note 1 to entry: End-tidal carbon dioxide corresponds closely to alveolar carbon dioxide.

3.8
haemoglobin
Hb
specific molecules contained within all red blood cells that bind oxygen or carbon dioxide under normal physiological states and transport either oxygen or carbon dioxide to or from the tissues of the body

3.9
hypercarbia
hypercapnia
excess amount of carbon dioxide in the blood

3.10
hyperoxia
volume fraction or partial pressure of oxygen in the breathing environment greater than that which is found in the Earth's atmosphere at sea level, which contributes to an excess of oxygen in the body

Note 1 to entry: This can occur when a person is under hyperbaric conditions (i.e. diving), subjected to breathing gas mixtures with an elevated oxygen fraction, or during certain medical procedures

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