



BSI Standards Publication

## Respiratory protective devices — Human factors

---

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

## National foreword

This Published Document is the UK implementation of ISO/TS 16976-3:2019.

The UK participation in its preparation was entrusted to Technical Committee PH/4, Respiratory protection.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2019  
Published by BSI Standards Limited 2019

ISBN 978 0 580 51449 4

ICS 13.340.30

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 March 2019.

### Amendments/corrigenda issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|

---

# TECHNICAL SPECIFICATION

**ISO/TS**  
**16976-3**

Second edition  
2019-03-22

---

---

## **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 limitations en oxygène et en gaz  
carbonique dans l'environnement respiratoire*



Reference number  
ISO/TS 16976-3:2019(E)

© ISO 2019



## **COPYRIGHT PROTECTED DOCUMENT**

© ISO 2019, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
Ch. de Blandonnet 8 • CP 401  
CH-1214 Vernier, Geneva, Switzerland  
Tel. +41 22 749 01 11  
Fax +41 22 749 09 47  
[copyright@iso.org](mailto:copyright@iso.org)  
[www.iso.org](http://www.iso.org)

# Contents

Page

|                                                                                                          |           |
|----------------------------------------------------------------------------------------------------------|-----------|
| <b>Foreword</b>                                                                                          | <b>iv</b> |
| <b>Introduction</b>                                                                                      | <b>v</b>  |
| <b>1 Scope</b>                                                                                           | <b>1</b>  |
| <b>2 Normative references</b>                                                                            | <b>1</b>  |
| <b>3 Terms and definitions</b>                                                                           | <b>1</b>  |
| <b>4 Symbols and abbreviated terms</b>                                                                   | <b>5</b>  |
| <b>5 Oxygen and carbon dioxide in the breathing environment: Physiological responses and limitations</b> | <b>5</b>  |
| 5.1 General                                                                                              | 5         |
| 5.2 Oxygen and carbon dioxide gas exchange in the human lung                                             | 6         |
| 5.3 Oxygen and carbon dioxide transport in the blood                                                     | 6         |
| 5.4 Oxygen and carbon dioxide and the control of respiration                                             | 8         |
| 5.5 Hyperoxia: physiological effects                                                                     | 9         |
| 5.6 Hypoxia: physiological effects                                                                       | 10        |
| 5.7 Hypercarbia: Physiological effects                                                                   | 13        |
| 5.8 Relevance to the use of respiratory protective devices (RPD)                                         | 16        |
| 5.9 Interpretation of results                                                                            | 20        |
| 5.10 Significance of results                                                                             | 21        |
| <b>Bibliography</b>                                                                                      | <b>22</b> |

## 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](http://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](http://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](http://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 second edition cancels and replaces the first edition (ISO/TS 16976-3:2011), which has been technically revised. The main changes compared to the previous edition are as follows:

- adding a new [Table 3](#) to give limits for CO<sub>2</sub> when breathing against imposed breathing resistance;
- explanation of the new limits for CO<sub>2</sub> derived from a study.

A list of all parts in the ISO/TS 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](http://www.iso.org/members.html).

## Introduction

Due to the nature of their occupations, millions of workers worldwide should 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.





# 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 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 <http://www.electropedia.org/>

#### 3.1

##### **alveoli**

##### **s. alveolus**

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.