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Respiratory protective devices — Human factors —

Part 8: Ergonomic factors

Appareils de protection respiratoire — Facteurs humains — Partie 8: Facteurs ergonomiques

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Foreword

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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. www.iso.org/directives

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The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, SC15, *Respiratory protective devices*.

ISO/TS 16976 consists of the following parts:

— *Part 1: Metabolic rates and respiratory flow rates*

— *Part 2: Anthropometrics*

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

— *Part 4: Work of breathing and breathing resistance: Physiologically based limits*

The following parts are under preparation:

— *Part 5: Thermal effects*

— *Part 6: Psycho-physiological effects*

— *Part 7: Hearing and speech*

Introduction

This part of ISO/TS 16976 provides guidance for the writers of respiratory protective devices (RPD) performance standards on the specification of ergonomic factors.

Ergonomics involves the application of scientific methods and appropriate data to the design and specification of machines, equipment, environments, systems and the interface with the people using it. The successful use of ergonomics in designing RPD will enhance the acceptability of the RPD and through this will improve the safety, health, performance and effectiveness of the wearer.

RPD is used in situations where a risk to health or safety has been identified. The preferred solution is to reduce the risk to zero and thereby to remove the need for RPD. If this is not possible, the threat should be reduced so that practical RPD can minimize the risk to wearer exposed to that hazard. In some working conditions some RPD may be more comfortable than none and not to be considered as an additional discomfort. Side effects of using RPD can range from discomfort to severe constraint and physical load. The application of ergonomic principles to RPD allows optimization of the balance between protection and usability.

Some aspects of the design and specification of RPD require specialist knowledge of the particular job the RPD is used for and of the particular hazard against which the RPD is to be effective or particular ergonomics issues. Although this part of ISO/TS 16976 covers many aspects, the writers of performance standards should be aware that it cannot be expected to identify all the existing and possible future problem points for which ergonomic factors and test methods will be required in performance standards. It will remain the responsibility of the relevant experts to identify and quantify the hazards in the work place and to foresee the potential ergonomic problems, and thus to ensure that the RPD specified and manufactured is fit for the purposes intended in all respects.

For practical reasons, this part of ISO/TS 16976 presents ergonomics factors separately. However, it should be recognized that the overall acceptability of a RPD will be determined by a combination of these and other factors by the individual wearer.

Together with ISO/TS 16976 Parts 1 to 7, this part of ISO/TS 16976 provides basic human factor data.

Respiratory protective devices — Human factors —

Part 8: Ergonomic factors

1 Scope

ISO/TS 16976 provides information on factors related to human physiology, ergonomics and performance for the preparation of standards for performance requirements, testing and use of respiratory protective devices (RPD).

This part of ISO/TS 16976 gives guidance on the generic ergonomic factors related to RPD.

It specifies for the writers of RPD performance standards principles relating to:

— the biomechanical interaction between RPD and the human body;

— the interaction between RPD and the human senses: vision, hearing, smell, taste and skin contact.

This part of ISO/TS 16976 does not cover requirements related to specific hazards for which RPD are designed.

2 Normative references

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

ISO 16972, *Respiratory protective devices — Terms, definitions, graphical symbols and units of measurement*

3 Terms and definitions

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

4 Ergonomic factors

4.1 General

Harmonized performance standards for RPD should contain ergonomic requirements and test methods, or should make normative reference to other standards to be applied.

Usually, ergonomic assessments of RPD have to be made while people are wearing them or are connected to the external component of the system. Wherever possible, the assessments should be objective, although some aspects can only be assessed subjectively.

Examples of how to make assessments are given in Annex A.

4.2 Integration of performance and ergonomic requirements

The primary purpose of RPD is to provide protection against specific inhalation hazards that cannot be eliminated or adequately reduced by other means. Performance standards should therefore contain performance requirements and test methods to ensure that the products fulfilling the performance

provide the appropriate protection against the identified hazards, and that they are ergonomically suitable for the users.

Performance standards writers should consider the tasks being performed, the equipment being used, the duration of the usage of the RPD, and the environments likely to be encountered. They should ensure as far as possible that the RPD does not create hazards for the users. This may be by incorporating in performance standards requirements and test methods based on this part of ISO/TS 16976.

Where the presence of more than one risk or the need to cover more parts of the body makes it necessary for a wearer to use simultaneously besides an RPD another item of Personal Protective Equipment (PPE), such equipment must be mutually compatible and continue to be effective against the risk or risks in question.

In addition to interactive effects on technical performance, interaction between different forms of PPE including RPD may influence ergonomic aspects. Thus, although the effect of individual items of PPE tested in isolation may not be significant, it will be the combined effect that will determine the overall load and consequent acceptability. For example, both a half-mask respirator and a safety helmet may intrude upon the visual field (glasses). Either in isolation may be acceptable but, when worn together the combined impact may not be. At its most extreme, extensive body coverage by RPD, or wearing several forms of protection may result in sensory and physical isolation.

Ergonomics requirements can be taken into account by determination of performance levels on the basis of a risk assessment.

4.3 Factors to be considered in the determination of the best ergonomic solution

4.3.1 General

RPD is to be worn by an individual for protection against one or more health and safety hazards. This protection is the intended effect of the RPD, but wearing RPD can also result in unintended negative effects, which can interfere with the wearer's normal performance of the risk-related tasks.

Performance standards writers should consider how to specify the best compromises between protection, practicality, and any potentially adverse impact of wearing the RPD. If different solutions apply, equivalent compromises may be possible.

4.3.2 Factors to be considered in specifying the optimum level of protection to be provided

Performance standards writers should consider the following variable aspects of the use of RPD:

— the duration of use of the RPD (some RPD such as escape RPD may be worn for only a few minutes when it is perceived that a hazard is present, but other RPD may be worn for several hours or throughout a working day/shift);

— whether there are different situations in which the RPD is used, that require different amounts of the body to be covered and for various other PPE to be used in addition;

— the reasonable balance between the severity of the hazard, protection, burden and duration.

4.3.3 Factors to be considered in specifying the optimal practicability

The designs of RPD that result from compliance with performance standards should allow, as far as possible, normal pursuit of all activity within the occupational environment. To ensure this is achieved, performance standards should include test procedures and requirements based on the performance of prescribed movements, or should make normative reference to such procedures and requirements. Standards writers should, where relevant, include reference to the fact that where RPD suppliers claim mutually compatible components of PPE, the resulting combination should be tested together. Tests should be selected to represent a range of the normal movements made by wearers of the RPD while using it.

For fire fighter PPE assessment, standard writers should refer to BS 8469.[19]

In any event they should include the following:

— understanding instructions and warnings given by the manufacturers;

— putting on, adjusting, and taking off the RPD and/or PPE;

— general activities, such as moving and communicating;

— activities specific to situations where the RPD is to be used;

— safety of the subjects.

Practical performance tests may impose physiological strains on the test subjects thus requiring stringent controls. To ensure the safety of test subjects:

a) the test subjects should be medically examined and certified fit in accordance with ISO 12894[5];

b) ethical clearance should be obtained in accordance with Reference;[20]

c) the experimentation should be performed in accordance with Reference;[20]

d) there should be physiological monitoring of test subjects;

e) normal safety procedures should be applied, including close supervision by trained, experienced staff, and voluntary withdrawal should be permitted at any time.

Interpretation of the results should take into account the levels of hazard against which the RPD is intended to provide protection, the inevitable burdens such RPD will impose, and the environmental conditions under which it will be used.

Guidance on the choice of movements and the overall conduct of ergonomic assessment of RPD using human subjects is given in Annex A.

For more information, see ISO/TS 16976-1[9], ISO/TS 16976-3[11] and ISO/TS 16976-5[12].

4.3.4 Factors to be considered in the physiological impact of RPD

The following indicators might be considered to determine the physiological impact in relation to the use of RPD:

— heart rate,

— oxygen consumption,

— alveolar gas composition,

— breathing rate,

— body temperature change,

— sweat rate,

— fatigue or strain of muscles.

Examples where indicators might be used include where the mass of the RPD may result in an excessive burden or where the exothermic processes providing breathable air or other factors of RPD may give rise to thermal strain.

More information may be obtained in ISO/TS 16976-1[9] and ISO/TS 16976-3[11].

4.4 Factors to be considered in specifying requirements for the adjustability of RPD and its appropriate fixation to the body

Performance standards writers should consider whether requirements and test methods need to be included to test the adjustments and restraint of RPD. In deciding that need, they should consider the seriousness of the consequences of displacement of the RPD, and the maximum tolerable displacement. The following are examples of aspects that could be considered:

— the information and instructions for fitting and adjusting;

— the information and instructinos for doffing of the RPD;

— the adjustability and the stability of adjustments;

— determining that the RPD has been correctly fitted.

When writing a test, consideration should be given to the static and dynamic forces that might be exerted on the RPD in normal wear, and during the circumstances in which it is intended to provide protection and how these may be represented in test methods.

4.5 Factors to be considered in specifying requirements to ensure that RPD does not irritate or cause discomfort

RPD shall not irritate or cause discomfort which may later lead to injuries for the users who may come into contact with it. Factors to be taken into account include:

— whether the RPD will be in contact with the skin and how sensitive this particular area of skin is to the effects of rubbing and pressure;

— for how long the RPD will normally be in contact with the skin;

— whether the type of RPD may have sharp or hard edges or points;

— whether the bulk, hardness and position of adjustment and closure mechanisms may have a negative impact on the user;

— whether chemical composition of the material used and its by-products may affect the body;

— whether any materials likely to be used in contact with the skin are known to produce allergic reactions in a proportion of the population;

— whether any closure mechanism, or other feature, may become caught up with scalp, facial or body hair;

— whether the outer surface of the RPD could harm other people;

— whether simple visual and manual examination of the RPD is adequate for an assessment, or whether specific test methods need to be developed for assessing the hardness, roughness or other features of the RPD.

4.6 Factors to be considered in specifying requirements to take into account the anthropometric factors of RPD

In determining appropriate anthropometric factors of the intended RPD wearer group to be specified in the RPD performance standards, the following shall be considered:

— the body part(s) it will be in contact with or cover;

— the physical activities expected to be performed during its use.

The body part(s) the RPD will be in contact with will serve to identify those parts for which anthropometric data are needed. If the RPD crosses or covers a body joint, then more anthropometric dimensions should be specified based on different joint positions.

The physical activity expected to be performed during the use of RPD may alter body dimensions. This should be taken into account in specifying anthropometric dimensions in a RPD performance standard. Excessively close fitting or otherwise poorly dimensioned RPD may prevent or hinder the performance of necessary activities.

Loose fitting or bulky RPD may restrict access to working areas or may present a potential safety hazard by snagging on projections or other features of the environment.

The intended user group will need to be defined to ensure that appropriate dimensions are specified to encompass that population. Variations in size may be accommodated by means of adequate adjustment systems or the provision of size ranges as appropriate.

Because different body dimensions are not necessarily closely correlated, standards writers should consider the need to specify more than one essential anthropometric dimension in order to ensure satisfactory fit for the intended user group.

Performance standards writers should address at least the topics related to anthropometric factors detailed in ISO/TS 16976-2[10] and in ISO 15537[6].

4.7 Factors to be considered in specifying requirements to take into account the biomechanical factors of RPD

4.7.1 General

In determining appropriate biomechanical effects to be specified in the RPD performance standards, the following should be considered:

— the static distribution of mass, the dynamic or inertial forces and consequent load on the human body when using different types of RPD and/or combinations of RPD and PPE,

— optimization of the influence of biomechanical effects of RPD on workload and/or task performance.

RPD can have adverse effects on the body by increasing muscle strain or energy consumption through increased passive loading or by altering the dynamic loading. For example, additional mass on the head produces forces in the neck that have to be countered by the neck muscles.

The mass of RPD and its distribution have to be considered in relation to the specific body part or parts likely to be affected.

Heavy masses on the body or body parts increase energy consumption, especially when walking or running.

Care should be taken when applying the principles in this section of this document to RPD intended to be worn under water or in situations involving unusual accelerative forces.

4.7.2 Mass distribution

Peripheral parts of the body are more susceptible to added mass than the trunk, because of the increased moment. Hence, an additional weight is best worn on the trunk and as close as possible to the body centre of gravity and as symmetrical as possible. This means that the waist is the body location where such a weight is best carried. However, this is often not practical because RPD is normally made to be worn on specific body parts in order to protect against a specific risk.

4.7.3 Restriction and prevention of movements

Heavy, close fitting, stiff or bulky material can excessively impede the bending of joints and restrict working positions and movements. Materials and products that resist movement elastically and require a continuous muscular effort acting against the elastic recoil to maintain a particular joint position can cause fatigue and injury.