TECHNICAL SPECIFICATION

ISO/TS 16976-5

First edition
2013-11-01

Respiratory protective devices — Human factors —

Part 5: Thermal effects

Dispositifs de protection respiratoire — Facteurs humains — Partie 5: Effets thermiques

Reference number
ISO/TS 16976-5:2013(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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. 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. 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 15, *Respiratory protective devices*.

ISO/TS 16976 consists of the following parts, under the general title *Respiratory protective devices — Human factors*:

— *Part 1: Metabolic rates and respiratory flow rates* [Technical Specification]

— *Part 2: Anthropometrics* [Technical Specification]

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

— *Part 4: Work of breathing and breathing resistance: Physiologically based limits* [Technical Specification]

— *Part 5: Thermal effects* [Technical Specification]

— *Part 7: Hearing and speech* [Technical Specification]

— *Part 8: Ergonomic factors* [Technical Specification]

The following parts are under preparation:

— *Part 6: Psycho-physiological effects* [Technical Specification]

Introduction

For an appropriate design, selection and use of respiratory protective devices, basic physiological demands of the user must be considered. The function of a respiratory protective device, the way it is designed and used and the properties of its material may have a thermal effect on the human body.

This part of ISO/TS 16976 belongs to a series of documents providing basic physiological and anthropometric data on humans. It contains information about thermal effects associated with wearing respiratory protective devices

Respiratory protective devices — Human factors —

Part 5: Thermal effects

1 Scope

This part of ISO 16976 is one of a series of Technical Specifications that provide information on factors related to human anthropometry, physiology, ergonomics and performance for the preparation of standards for design, testing and use of respiratory protective devices. It contains information related to thermal effects of respiratory protective devices on the human body, in particular:

— temperatures of surfaces associated with discomfort sensation and harmful effects on human tissues;

— thermal effects of breathing gas temperatures on lung airways and tissues;

— effects of breathing gas temperature and humidity on respiratory heat exchange;

— effects of respiratory protective devices on overall body heat exchange.

The information represents data for adult healthy men and women in the age 20–60 years.

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 7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

ISO 7933, *Ergonomics of the thermal environment — Analytical determination and interpretation of heat stress using calculation of the predicted heat strain*

ISO 11079, *Ergonomics of the thermal environment — Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects*

ISO 13732-1, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces*

ISO 13732-3, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 3: Cold surfaces*

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

ISO/TS 16976-1, *Respiratory protective devices — Human factors — Part 1: Metabolic rates and respiratory flow rates*

ISO/TS 16976-3, *Respiratory protective devices — Human factors — Part 3: Physiological responses and limitations of oxygen and limitations of carbon dioxide in the breathing environment*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

3.1.1
clo
unit for the expression of the thermal insulation of clothing

Note 1 to entry: 1 clo is equal to 0,155 m^2 °C/W.

3.1.2
insulation required
IREQ
cold stress index as determined according to ISO 11079

3.1.3
metabolic rate
physiological energy utilization per unit of time

3.1.4
predicted heat strain
PHS
heat stress index as determined according to ISO 7933

3.2 Symbols and abbreviated terms

PPE personal protective equipment

RPD respiratory protective device

PMV predicted mean vote

PPD predicted percentage dissatisfied

T_s surface temperature: temperature of the surface contacted by skin

T_a ambient temperature: temperature of the air surrounding the body or inhaled

T_c contact temperature: temperature of the interface between skin and contacted surface

T_r rectal temperature: temperature of the core body

4 Local thermal effects

4.1 General

The effects of heat and cold described hereafter will vary according to individual sensitivity.

Notice should be taken of the assessment scales given in ISO 8996.[1]

4.2 Effects on skin contact by the RPD

Heat transfer by conduction takes place via the hands when handling the equipment and via face, head and torso during the actual use of the equipment.

Parts of RPD are, by their very nature, in more or less direct contact with naked human skin for example in the face. In contact areas heat exchange will be affected. The magnitude of this effect is dependent on contact pressure, structure of surfaces, size of contact area, mass of material in contact, thermal conditions and thermal properties of materials in contact.

Materials used in RPD are mostly made of materials with low conductive heat transfer properties. Exceptions are metal parts, in particular, if they are not insulated.

In extreme hot or cold environments the ambient conditions may heat or cool the RPD or parts of it, thereby increasing the risk of a thermal effect on the skin.

A risk assessment of contact cooling or heating of the bare skin shall be based on

ISO 13732-1, for hot surfaces, and

ISO 13732-3, for cold surfaces.

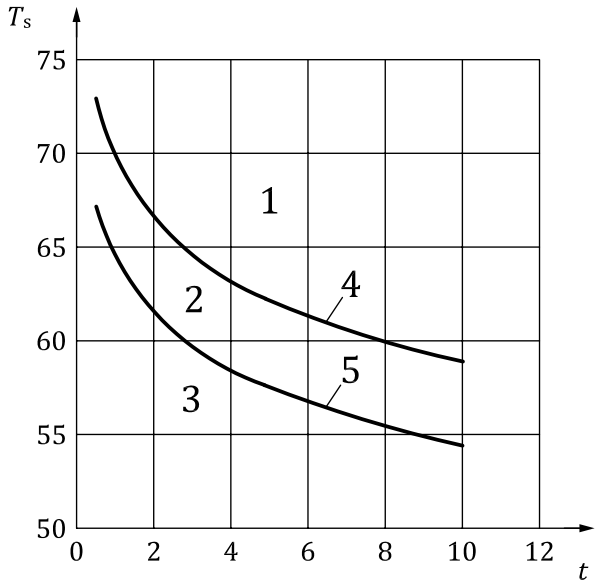
Exposure values and criteria used in the figures below are based on hand or body skin surface contacts. Face skin is likely to be more sensitive in particular to discomfort and more conservative values should be used.

4.3 Hot surfaces

ISO 13732-1 provides comprehensive information about the risk of bare skin contacting different types of materials at different temperatures. Figure 1 shows surface temperatures of polished metal that may cause skin burns. This condition appears to be the most severe case, but other metals such as steel and copper maybe as harmful at similar or slightly higher temperatures. Other materials like plastic, glass and ceramics require considerably higher temperature to cause harm to bare skin.

For long contact duration (10 min and longer) the burn threshold doesn't depend on the type of material.

For these materials the zone 3 "safe surface" in Figure 1 moves up to the line 4, i.e. upper limit



Key

t contact duration, in s

T_S surface temperature, in °C

1 Zone 1 indicates a high risk of skin burn

2 Zone 2 indicates a possible risk of skin burn

3 Zone 3 indicates safe surface temperatures

4 upper limit

5 lower limit

Figure 1 — Surface temperature of uncoated, polished metallic surfaces with similar heat conductivity properties that may cause skin burns within 10 s

RPD is likely to be used for short duration timed in minutes and longer duration timed in hours. Table 1 indicates burn thresholds for contact periods of 1 min and longer for different materials (modified from ISO 13732-1). Values apply for contact areas that are less than 10 % of the body surface, so they should apply for most RPD.

Table 1 — Burn threshold for contact periods of 1 min and longer

Material	1 min °C	10 min °C	8 h and longer °C
Uncoated metal	51	48	43
Coated metal	51	48	43
Ceramics, glass and stone materials	56	48	43
Plastics	60	48	43
Wood	60	48	43

4.4 Cold surfaces

ISO 13732-3 provides detailed information about the assessment of cooling effects on skin in contact with various types of cold surfaces. Information is given about five types of materials: aluminium, steel, stone, plastic and wood. For each of the materials three criteria for cooling are applied.

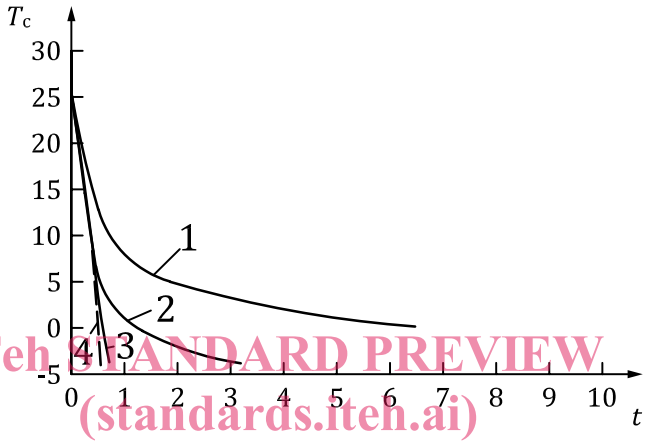
As with a hot surface, contact with a small skin surface area with cold, metallic goods may rapidly cool the skin and eventually result in local frostbite. Figure 2 shows cooling curves obtained with the finger tip touching surfaces of steel and aluminium at temperature of −20°C, −30°C, −40 °C and −50 °C. The contact temperature (T_c), which is likely to be very close to the skin surface temperature drops to below 0°C within few seconds when touching the metal surfaces.[3] The risk of developing local frostbite is highly probable.

Studies[3] have shown that

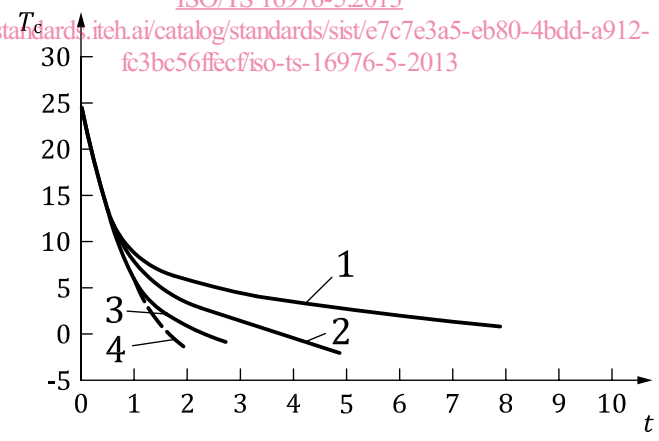
— cooling to a skin temperature of 0 °C is associated with an imminent risk of tissue freezing "frostbite"

— Cooling to a skin temperature of −7 °C is associated with the gradual development of numbness

— Cooling to a skin temperature of −15 °C is associated with the experience of pain



a) Steel



b) Aluminium

Key

t contact duration, in s

T_c contact temperature, in °C

1 – 20 °C

2 – 30 °C

3 – 40 °C

4 – 50 °C (estimated value shown, no published data available)

Figure 2 — Change in *Tc* of finger in contact with metallic surfaces at temperatures of −20 °C, −30 °C, −40 °C and −50 °(estimated)