INTERNATIONAL STANDARD

ISO 13732-3

First edition
2005-12-01

Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces —

Part 3: Cold surfaces

Ergonomie des ambiances thermiques — Méthodes d'évaluation de la réponse humaine au contact avec des surfaces —

Partie 3: Surfaces froides

Reference number
ISO 13732-3:2005(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

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

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 13732-3 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

ISO 13732 consists of the following parts, under the general title *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces*:

— *Part 1: Hot surfaces*

— *Part 2: Human contact with surfaces at moderate temperature* [Technical Specification]

— *Part 3: Cold surfaces*

For the purposes of this part of ISO 13732, the CEN annex regarding fulfilment of European Council Directives has been removed.

Contents

Foreword

This document (EN ISO 13732-3:2005) has been prepared by Technical Committee CEN/TC 122 “Ergonomics”, the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 159 “Ergonomics”.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2006, and conflicting national standards shall be withdrawn at the latest by June 2006.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directives.

EN ISO 13732 consists of the following parts, under the general title "Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces"[1]:

— Part 1: Hot surfaces;

— Part 3: Cold surfaces.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1) Part 2: has been published as ISO Technical specification ISO/TS 13732-2:2001 Human contact with surfaces at moderate temperature.

Introduction

This European Standard is a type B standard as stated in EN ISO 12100. The provisions of this document may be supplemented or modified by a type C standard.

NOTE For machines which are covered by the scope of a type C standard and which have been designed and built according to the provisions of that standard, the provisions of that type C standard take precedence over the provisions of this type B standard.

Working with unprotected hands is often inevitable in the cold operation when a precision task is demanded. However the contact of bare skin with cold surfaces reduces skin temperature, causing acute effects such as discomfort, pain, numbness or frostbite. In addition repeated cold exposures with severe cooling of the skin may induce non-freezing cold injury (possible damage of nerves or vessels). Although the existing international standards are at hand for the assessment of the cold hazards involved, no standard concerns the special problems of contacting cold surfaces so far. Assessment of contact cooling is thus considered necessary.

To assess the risk of the cold injury, it is necessary to know the major factors affecting principally hand/finger cooling on cold surfaces. These factors involve:

— properties of the object surface;

— temperature of the cold surface and ambience;

— duration of contact between the skin and the surface;

— characteristics of hand/finger skin and the type and nature of the contact.

In practice, these factors are somewhat interacted and complicated. The type of contact material has an impact on the contact time at various cold temperatures. Thus, the contact time for the critical contact temperature limits on cold surfaces were empirically correlated with the major factors such as thermal penetration coefficient and surface temperature of the material, respectively. The statistically non-linear models (empirical models) based on the database of lower quartile (75 % protected) are able to estimate the finger/hand contact cooling of a large range of individuals on the cold surfaces.

This European Standard is designed to integrate all results obtained from the experimental research with both human fingers and an artificial finger. It outlines a guideline document for the specification of safe time limits of hand/finger contact with various cold surfaces.

1 Scope

This European Standard describes methods for the assessment of the risk of cold injury and other adverse effects when a cold surface is touched by bare hand/finger skin.

This standard provides ergonomics data to establish temperature limit values for cold solid surfaces. The values established can be used in the development of special standards, where surface temperature limit values are required.

The data of this standard will be applicable to all fields where cold solid surfaces cause a risk of acute effects: pain, numbness and frostbite.

The data are not limited to the hands but apply to human skin in general.

The standard is applicable to the healthy skin of adults (females and males). Considerations on the extension of applications are given in Annex B.

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.

EN ISO 12100-1:2003, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology (ISO 12100-1:2003)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100-1:2003 and the following apply.

3.1
touchable surface
surface of a product, which can be touched by a person

3.2
surface temperature
T_s
temperature of a material surface in °C

3.3
critical contact temperature
T_c
contact temperature at which defined skin response criteria are elicited in °C

3.4
contact period
D
duration during which contact of the skin with the surface takes place in s

3.5
thermal inertia
product of density (ρ), thermal conductivity (K) and specific thermal capacity (c) of a material

3.6
contact factor
F_c
thermal penetration coefficient, computed as square root of the thermal inertia

NOTE The mathematical definition is: $F_c = \sqrt{\rho \cdot K \cdot c}$.
where
ρ is the density of a material;
K is the thermal conductivity of a material;
c is the thermal capacity of a material.

3.7
percentile
percentage of population of which specific characteristics fall below or above a given value in a cumulative distribution

[EN ISO 11064-4]

4 Principles for risk assessment

4.1 General

In order to assess the risk of cold injury and other effects, the following steps (4.2 to 4.8) shall be carried out.

4.2 Identification of cold touchable surfaces

All essential information concerning the cold touchable surfaces of the object shall be gathered. This shall include the objects attributes:

a) accessibility of the surface;

b) rough estimation of surface temperatures (above or below 0 °C);

c) material and texture of the cold surface;

d) all operating conditions of the object where contact with the cold surface is needed (including the worst case).

4.3 Task observation and analysis

According to the activities and tasks required, all necessary information concerning the contact with the cold surface shall be collected, by observation or analysis. Particular attention should be paid to possible intentional and unintentional contact with cold surfaces. The type and nature of the contact shall be identified from the task observation and analysis:

a) cold surfaces which are or can be touched;

b) intentional or unintentional touching;

c) frequency of intentional touching;

d) probability of unintentional touching;

e) duration of contact with the cold surface;

f) contacting area;

g) contacting force.

4.4 Classification of contact with a cold surface

4.4.1 General

The type of contact is classified according to the following two categories:

4.4.2 Finger touching

Subjects contact a defined material during a short period (up to 120 s). The contact area is small (only finger pad).

4.4.3 Hand gripping

Subjects grip an object of defined material. Gripping is applied constantly for a longer period (up to 1 200 s).

4.5 Measurement of surface temperature

The surface temperatures shall be measured on those parts of the object where skin contact with the surface can occur.

The measurement shall be carried out under real operating conditions of the object by thermocouples. The accuracy of the instrument shall be ± 0,5 °C in a range from – 25 to + 5 °C and ± 1 °C below – 25 °C (see ISO 7726:2001 and [4]).

NOTE The results of the measurement of the surface temperature can only be compared with the threshold values of Clause 5, if they are realized using the same physical measurement principle which was used for the determination of the threshold values of Clause 5. The application of a different measuring principle, e.g. a radiation thermometer, can lead to other results which are not comparable with the threshold values.

4.6 Period

The contact period of bare skin with a cold surface can be measured or estimated according to values in Table D.1.

4.7 Classification of type of effect on skin during contact

4.7.1 General

Type of effect shall be determined according to the following criteria.

4.7.2 Frostbite

The effect is predicted from a drop in contact temperature to below 0 °C, at which the contacting skin tissue will freeze.

4.7.3 Numbness

The effect is predicted from a drop in contact temperature to around 7 °C, at which sensory receptors of contacting skin will be blocked and numbness will occur.

4.7.4 Pain

The effect is predicted from a drop in contact temperature to around 15 °C, at which a subjective sensation of pain at the contacting skin will be experienced.

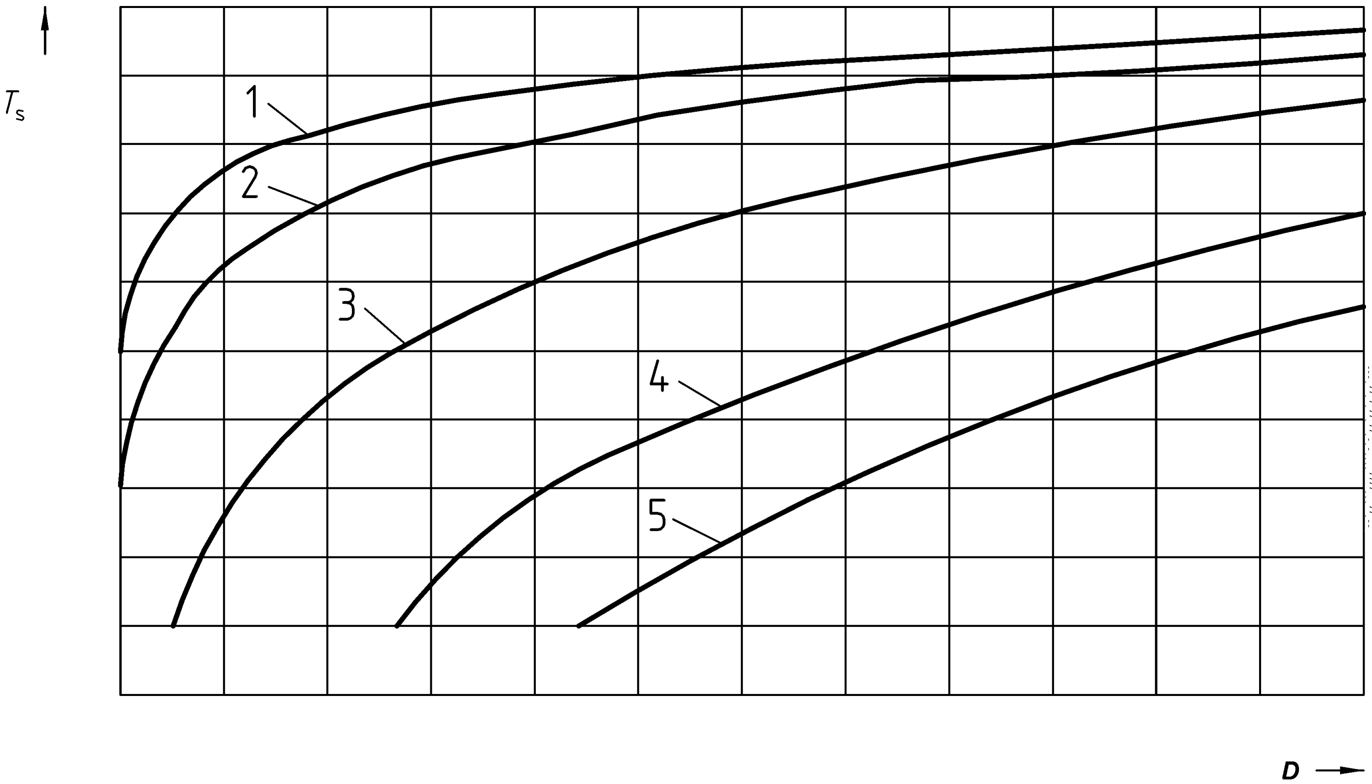
4.8 Risk evaluation

On the basis of this information the data in Clause 5 shall be used for final evaluation to establish if there is a risk for the selected type of effect to occur. An estimate of the risk is made on the basis of surface temperature and contact period specified in 5.2 and 5.3.

5 Threshold data

5.1 General

This Clause provides surface temperature data for cooling thresholds from the ergonomics database. Figure 1 shows the principal relation between material, time and temperature for skin in contact with a cold surface. Below the curve of each material there is a risk of an adverse effect of skin cooling. This figure is presented for guidance only of the temperature/time relationship and the relative effects of different materials. The quantitative information is provided in the subsequent Clauses.



Key

1	Aluminium	3	Stone	5	Wood
2	Steel	4	Nylon		
D	Contact period	T_s	Surface temperature		

Figure 1 — Principal relationship between material, duration and temperature for skin in contact with a cold surface

The thermal properties of the mentioned materials (Aluminium, Steel, Stone, Nylon, and Wood) and other selected materials are given in Annex C.

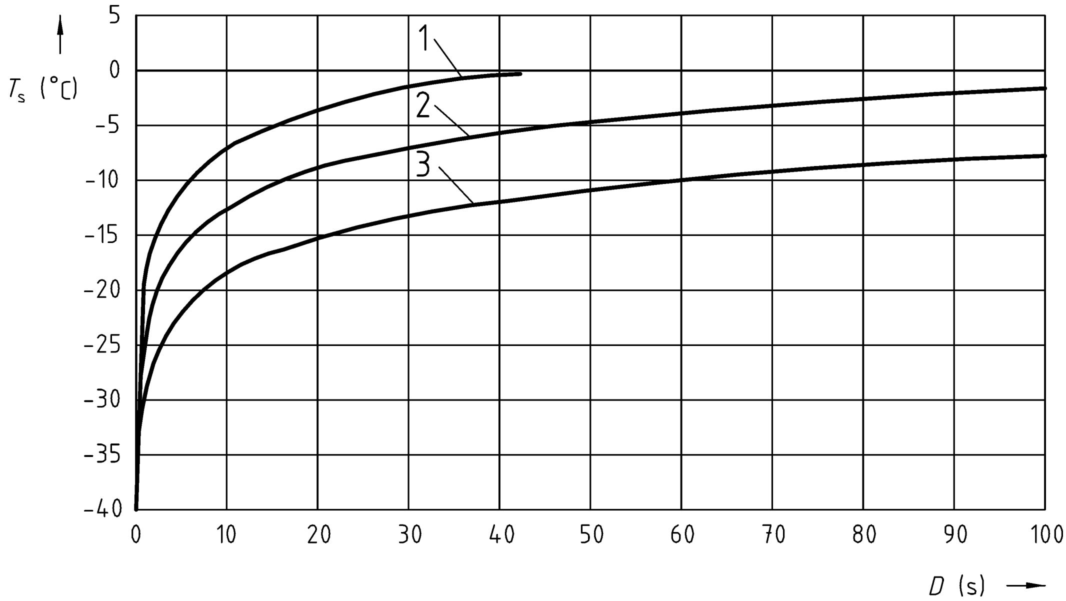
5.2 Finger touching

5.2.1 General

Thresholds for finger skin touching are specified in 5.2.2 (Figures 2 to 4).

5.2.2 Thresholds for finger contacting cold surfaces

The freezing (frostbite) threshold values of finger touching three cold surfaces (aluminium, steel and stone) are shown in Figure 2.

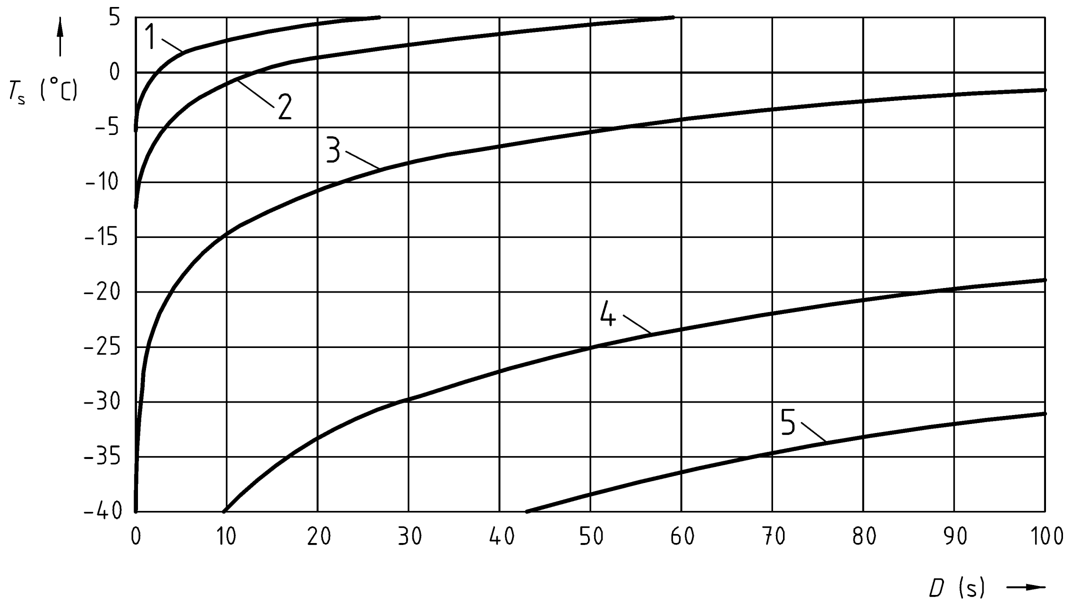


Key

1 Aluminium
2 Steel
3 Stone

Figure 2 — Frostbite threshold as function of contact period (finger touching)

The numbness thresholds for finger touching the five materials are indicated in Figure 3.

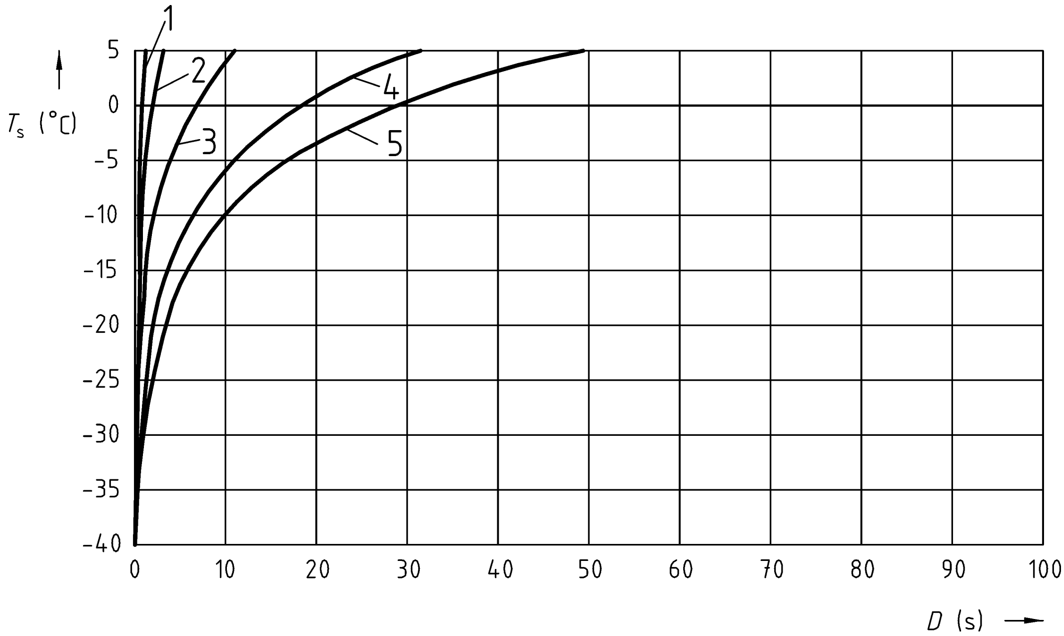


Key

1 Aluminium
2 Steel
3 Stone
4 Nylon
5 Wood

Figure 3 — Numbness threshold as function of contact period (finger touching)

The pain thresholds for finger touching different materials are indicated in Figure 4.



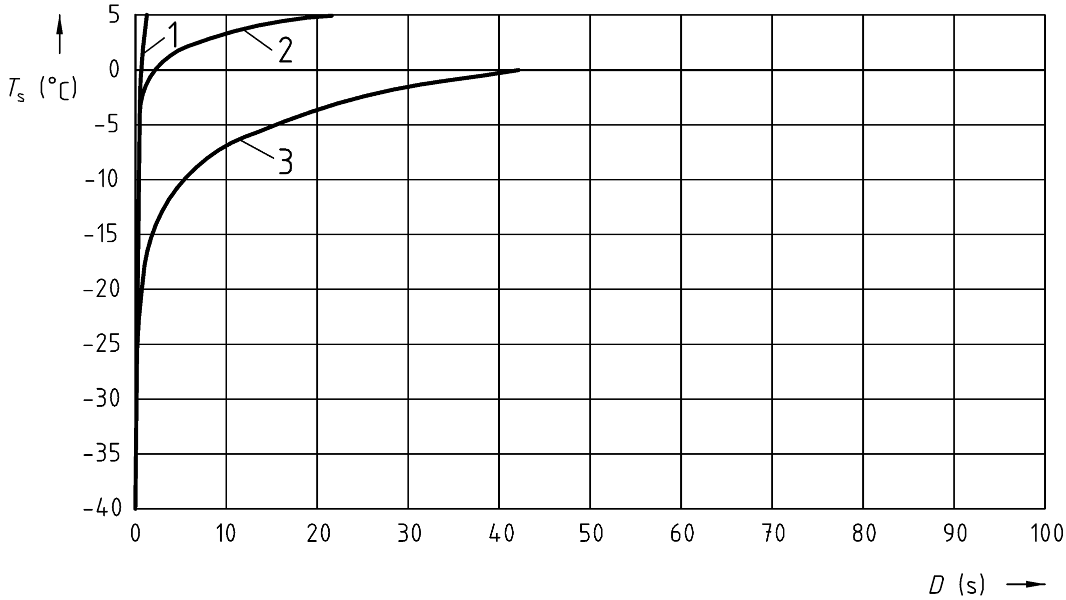
Key

1 Aluminium
2 Steel
3 Stone
4 Nylon
5 Wood

Figure 4 — Pain threshold as function of contact period (finger touching)

5.2.3 Thresholds for different materials

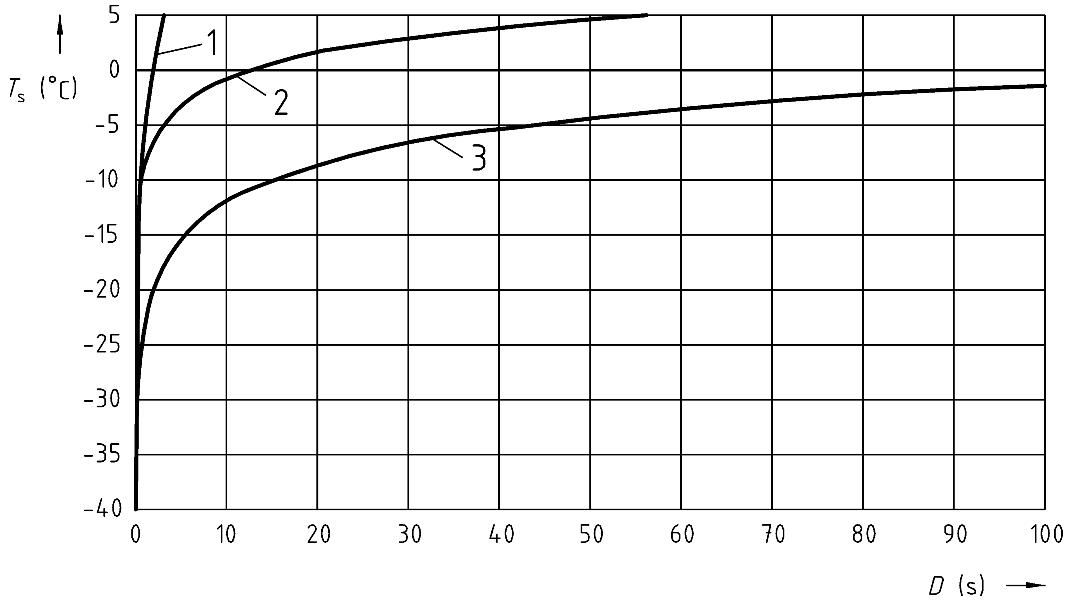
Figures 5 to 6 show the three criteria thresholds for contact with metals (aluminium and steel).



Key

1 Pain
2 Numbness
3 Frostbite

Figure 5 — Threshold curves for contact with an aluminium surface (finger touching)

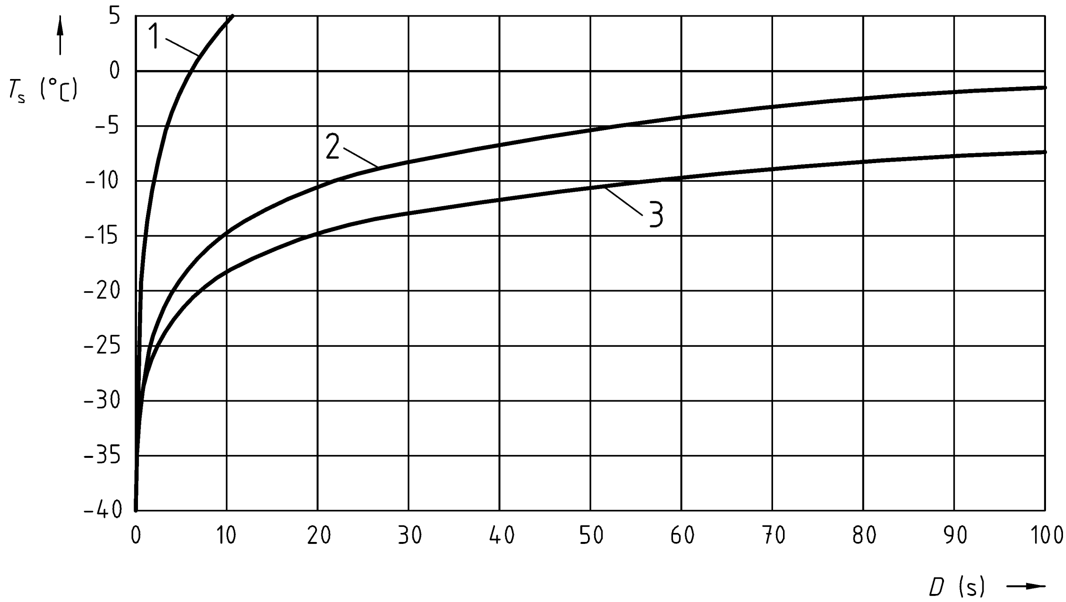


Key

1 Pain
2 Numbness
3 Frostbite

Figure 6 — Threshold curves for contact with a steel surface (finger touching)

The cooling thresholds for contact with stone are shown in Figure 7. The data was predicted from the model of finger touching database.

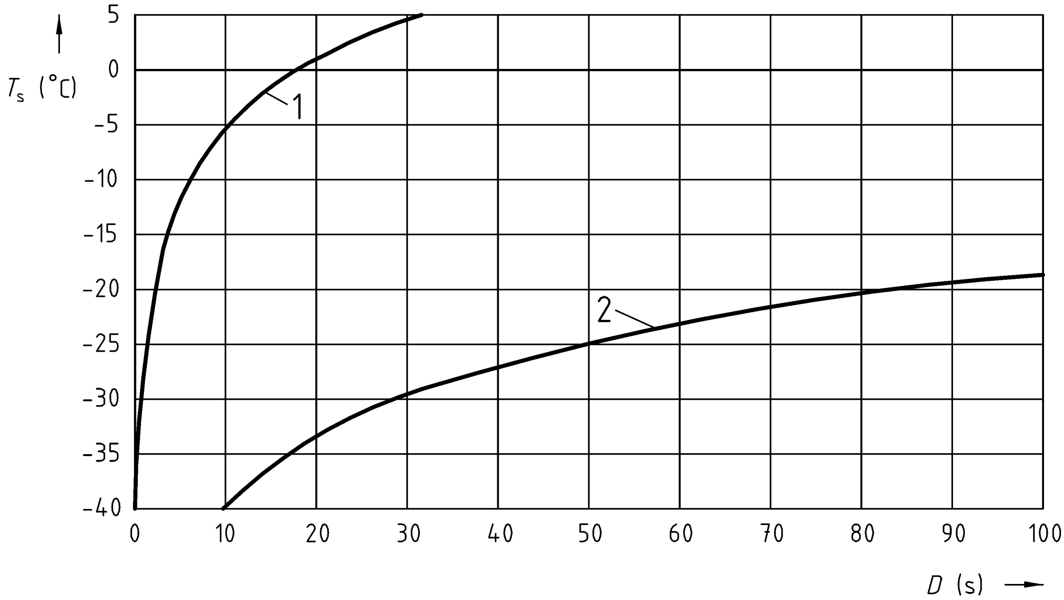


Key

1 Pain
2 Numbness
3 Frostbite

Figure 7 — Threshold curves for contact with a stone surface (finger touching)

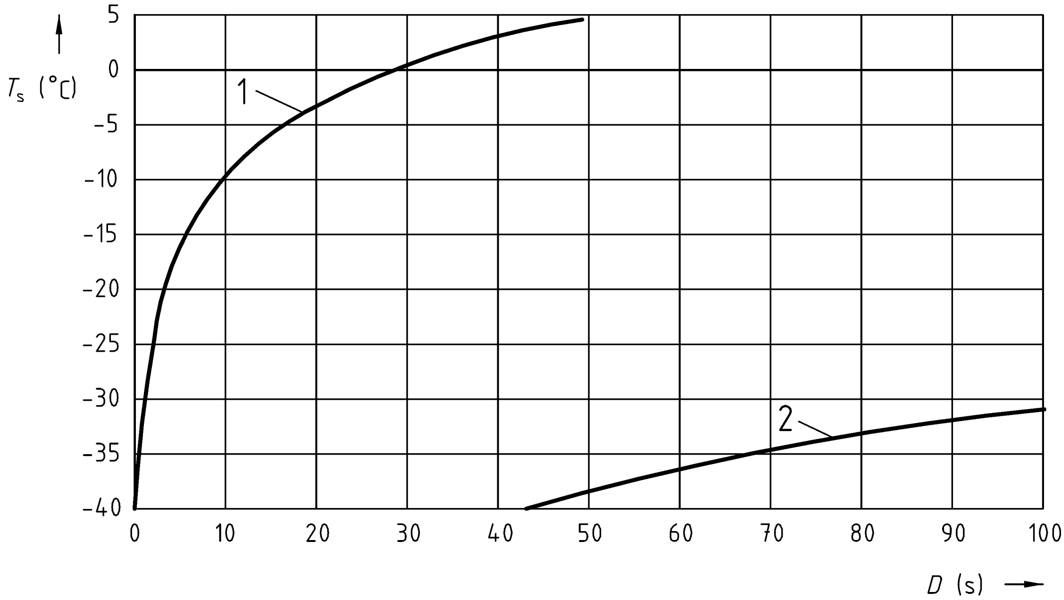
The pain and numbness thresholds for the case of contact with nylon or wood are shown in the Figures 8 to 9. The data did not show any occurrence of freezing for the case of finger touching nylon or wood.



Key

1 Pain
2 Numbness

Figure 8 — Threshold curves for contact with a nylon surface (finger touching)



Key

1 Pain
2 Numbness

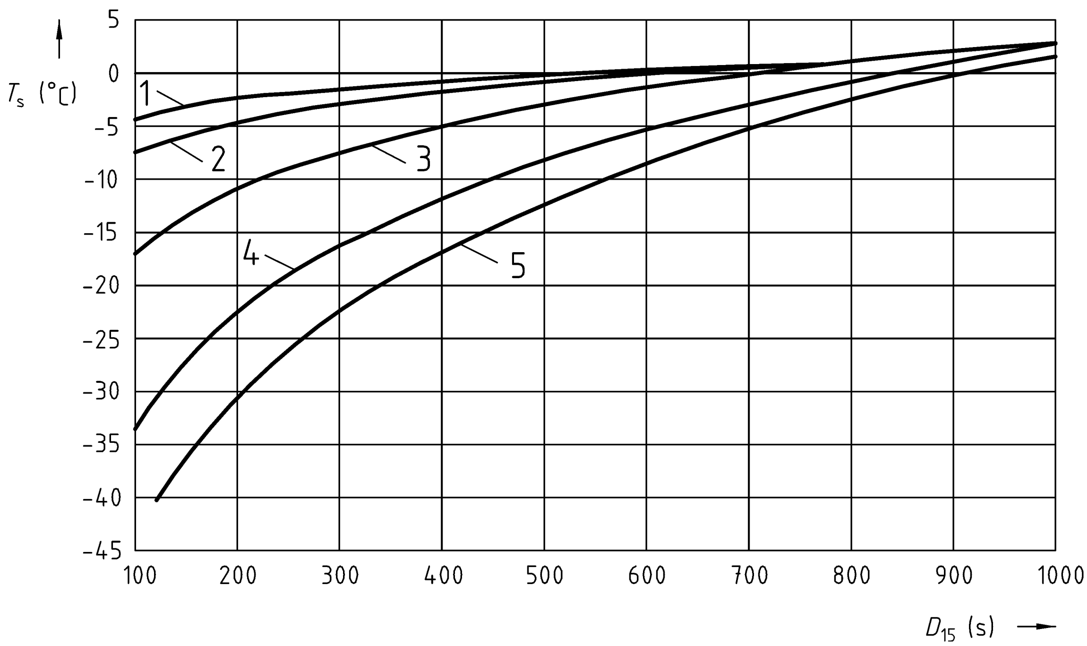
Figure 9 — Threshold curves for contact with a wood surface (finger touching)

5.3 Hand gripping

The pain thresholds for hand gripping different materials are shown in Figure 10. The limit values are based on the actually reported perception of pain by subjects.

A difference is observed between the touching and gripping curves due to different types of contact. The pain thresholds during gripping the material can be lower than that for touching (see Annex A). The main reasons for this are:

- freedom for small adjustments of the hand grip allowed for better control of the response reaction;
- size and mass of rods gripped were smaller than of blocks touched;
- contact area of the hand grip was larger than for the finger touch;
- during hand gripping blood flow is less obstructed than with finger touching;
- at very low air temperatures radiative or convective heat loss may contribute to pain sensation.



Key

1	Aluminium	3	Stone	5	Wood
2	Steel	4	Nylon		

D_{15} Time to reach a contact temperature (at the skin of the hand) of 15 ºC

Figure 10 — Pain thresholds as function of gripping duration for five materials

6 Risk assessment

6.1 General

Due to large individual variations, the risk level is calculated for the 25 percentile (see EN ISO 11064-4) responses. The threshold values should be interpreted as safe for ¾ of the exposed population. For the remaining ¼ of a minute risk of an adverse cooling effect may still exist. This remaining group comprises people with increased susceptibility to cooling (see Annex B).

The curves and the suggested risk interpretation therefore, should only serve as guidance for evaluation and selection of limit values or additional action to minimize the risk.

6.2 Surface temperature higher than thresholds

If the measured surface temperature is higher than the thresholds for defined contact period (up to 10 °C), there is no risk for the defined effects to occur.

6.3 Surface temperature lower than or equal to thresholds

If the measured surface temperature is below or equal to the thresholds for defined contact period, there is a risk of pain, numbness or frostbite of the skin to occur.

6.4 Further risk parameter

The risk becomes higher:

— when the measured surface temperature is far below the cooling threshold;

— the longer the contact period exceeds the cooling threshold;

— the smaller the chance is for quick withdrawal;

— the more accessible the cold surface is;

— the higher the probability is for unintended touching;

— the more frequent the contact is likely to occur;

— when less previous knowledge of the contact material is to be expected.

If a risk is detected, measured shall be taken to minimize that risk.

NOTE In addition, national regulations may require the application of protective measures. The particular measures to be applied depend on the operational context. Examples of protective measures are given in Annex E.

7 Principles for establishing limit values

The information provided in this standard can help to establish:

— limit values of surface temperature, or

— contact periods for use in product standards or for other purposes, or

— contact periods and measures to minimize the risk for use.

A procedure for the determination of surface temperature limit values requires information about:

— materials to be used;

— types of contact (touching or gripping);

— contact periods;

— types of effect (frostbite, numbness or pain).

A procedure for the determination of contact period limit values requires information about:

— materials to be used;

— surface temperatures;

— types of contact (touching, numbness or pain).

In the Figures 2 to 10 the relations between type of material, temperature and contact period for defined effects are given. A limit value can be selected from the corresponding figure based on effect and material. Examples are given in Annex D.

8 Principles for measures to minimize the risk

The following shall be considered to minimize the risk of contact with cold surface:

— risk assessment according to Clause 6;

— types of operations where the contact is required (seldom, often or frequently);

— possibility of surface treatment of the contact area (e.g. painting, plastic coating);

— possibility of protection of area which can be unintentionally touched;

— liquids at temperatures below 0 °C shall not come in contact with skin because of the imminent risk of skin freezing and development of frostbite. Similarly e.g. solid carbon dioxide gives rise to a risk of frostbite.

Annex A
(informative)

Scientific background

A.1 General

The contact cooling threshold values specified in 5 are based on the scientific research carried out by Cold surfaces research group [4]. Firstly, depending on criteria applied, safe contact temperatures have been investigated for the given materials under cold exposure conditions. Secondly, safe contact time has been determined for the given combinations of type of material and their surface temperature. The results have been compiled in a database that can serve as a basis for the development of an ergonomics database in this standard. The details of the database are presented as follows [4]:

A.2 Database

A.2.1 General

The database, which contains experimental data of finger touching and hand gripping the cold surfaces with human subjects, was compiled based on the pooled data obtained from all experiments run by five laboratories in the project. The five partners used a common methodology [6, 7, 8, 9, 11, 12 and 13]. Experiments on various materials (wood, nylon, stone, steel and aluminium) at surface temperature (T_S, -40 °C to +5 °C) were performed. Each individual curve of the finger skin-surface contact temperature (T_C) versus contact time in the cold was subsequently plotted from all the records. The contact time of critical contact temperature (T_C = 15 °C, 7 °C and 0 °C) for each cooling curve was obtained by inter or extrapolations [5 and 9].

Two databases on touching and gripping experiments were established according to the experimental results. Both include the essential information from each test:

— characteristics of the subject: age, weight, height, hand surface, hand volume, contact area;

— experimental set-up: surface temperature of the material (T_S), exposure hand into a cold box or whole body in a cold climatic chamber;

— parameters such as duration of the resting period in the climatic room, skin temperature before contacting, temperature, pain and numbness sensation were determined before each test;

— parameters such as criteria used to stop the test (risk of frostbite, pain or time limit reached), duration of the test, skin temperature, temperature, pain and numbness sensation were determined after each test;

— parameters like time, the temperature, the pain and the numbness sensations were recorded during each test;

— characterisation and evolution of the skin temperature with time (to reach a contact temperature of 15 °C, 7 °C and 0 °C);

— Characterisation of the material: thermal conductivity, specific heat, density and contact factor.

In addition, the contact time to reach the critical temperature had a large variation among individuals [4 and 14]. The individual variation should be considered when the contact time for the critical temperature is determined. To avoid the complexity caused by individuals and secure the manual or finger protection on the cold touchable surfaces, the contact time for the critical T_C was determined by using the statistical results of the lower quartile. In addition, graphs for threshold lines are only given between –40 °C and +5 °C, because this was the range of experimental conditions. Mathematical extrapolations beyond these temperatures are not validated.

A.2.2 Database for touching

The number of touching experiments are 1657 tests for 24 exposure conditions. The results showed that for most of the experiments with wood and nylon, the limit duration of 120 s could be reached. For steel and aluminium, this time limits could also be reached at certain surface temperatures. The 120 s were chosen as a longest time for which people would maintain physical contact with a cold surface. In most practical situations people would probably release the contact long before that.

From the evolution of the contact temperature with time, the time to reach a temperature of 15 °C (pain threshold *t (15 ºC)*) was either interpolated or extrapolated. The times to reach 7 °C (numbness threshold *t (7 °C)*) and 0 °C (freezing threshold *t (0 °C)*) were also extrapolated.

A.2.3 Database for gripping

The database for gripping includes 584 tests for 21 exposure conditions. The fifth material (stone) was also involved for the studies in addition to wood, nylon, steel and aluminium. The experiments of hands in cold air (exposure to cold but without gripping) were conducted to obtain the reference values.

The inter and extrapolation of the duration to different temperatures were only possible for 15 °C. For most of the cases, the contact temperatures at the end of the tests were higher than 15 °C (15,9 °C ± 5,2 °C).

A.3 Empirical modelling

A non-linear regression analysis was used to empirically predict the duration as a function of the surface temperature (T_S) and the contact factor (F_C) of the material for various critical contact temperature limits.

The non-linear model obtained has the following form:

$$Time = (A / Fc^{B}) \cdot \exp(C \cdot Fc^{D} \cdot Ts)$$

where *A, B, C* and *D* were constants, which can be estimated by the non-regression iterative procedure. The model provides specific equations for each material and effect. In some cases the equation was simplified when one or more of the coefficients did not significantly contribute to the prediction. Values for the constants in the equation were obtained for combinations of materials and contact temperatures. Each prediction model was used with following restrictions:

— predictions for touching experiments were limited to 100 s;

— separate equations were used for the three different contact temperatures;

— no valid prediction could be derived for wood and nylon at *t(0 °C)*.

These extrapolations for all the materials give plausible results. The predicted values are lower than the observed values, suggesting a certain degree of safety. However, in the cases of finger touching wood and nylon, the extrapolated values for *t(0 °C)* are much lower than the values for *t(7 °C)*. The expression for the prediction of *t(0°C)* cannot be used for these non-metallic materials.

In a large portion of the cases in the gripping experiments, the subjects spontaneously interrupted before 20 min, due to experience of pain, and at skin temperatures lower than 15 °C. For this reason an additional regression equation was derived for surface temperature and spontaneous duration of exposure. All data points were used to derive this model for gripping duration. The regression correlated well with the temperature prediction model and was subsequently used for the derivation of the temperature limit values (Figure 10). Gripping experiments lasted for longer exposure times, therefore data are given for exposures between 100 s and 1 000 s.

Annex B
(informative)

Extension of application

B.1 Wider population

It is needed to consider that the reaction time to cold is different between a wider population (i.e. children, elderly and disabled persons). Due to the properties of the hand skin, elderly have usually a longer reaction time compared to the younger. Information about the thermal properties of the materials (see Annex C) will give guidance for this purpose.

B.2 Other materials

For materials not specified in the figures, threshold values can in some cases be interpolated from the figures in Clause 5. Information about the thermal properties of the materials (see Annex C) will give guidance for this purpose.

B.3 Coating and texture of the surfaces

The thresholds presented in the Figures 2 to 4 are valid for smooth surfaces of non-coated materials. The texture of the surface will affect the nature of the contact. For coated or rough surfaces, lower values than those given may apply. The given thresholds therefore, protect also for the case of contacting with coated or rough metals but will allow lower values.

NOTE At current there are no values on the influence of coating and texture of surfaces available.

B.4 Liquids and other substances

Fluids below 0 °C may comprise an acute risk of frostbite when spilled on skin. Examples of such fluids are gasoline, petrolether and nitrogen. Similarly e.g. solid carbon dioxide gives rise to a risk of frostbite.

Annex C
(informative)

Thermal properties of selected materials

Table C.1 shows the thermal properties of selected materials. Thermal properties and additional information on materials can be found in prEN ISO 13732-1.

Table C.1 — Thermal properties of selected material

Material	Thermal conductivity K [a] W / m K	Specific thermal capacity c 10^3 J / kg K	Density ρ 10^3 kg / m^3	Thermal inertia 10^6 J² / s m^4 K^2	Contact factor F_C 10^3 J / s$^{0.5}$ m^2 K
Human skin	0,55	4,61	0,90	2,28	1,51
Aluminium [b]	180	0,90	2,77	449	21,2
Brasses	85,5	0,38	8,90	287	16,9
Steel [b]	14,8	0,46	7,75	52,9	7,27
Concrete	2,43	0,92	2,47	5,52	2,35
Marble	2,30	0,88	2,70	5,47	2,34
Stone [b]	2,07	0,75	2,80	4,35	2,08
Glass [c]	0,88	0,67	2,60	1,53	1,24
Brick	0,63	0,84	1,70	0,90	0,95
Nylon [b]	0,34	1,48	1,20	0,61	0,78
Wood [b]	0,22	2,20	0,56	0,27	0,52

[a] For the terms and symbols see Clause 3.

[b] These materials were used in the experimental studies and their properties were measured.

[c] Ordinary glass.

NOTE Slight variation in material properties might be expected. For highly accurate applications the measured properties of the actual material should be used.

Annex D
(informative)

Examples of cold risk assessment

D.1 The problem

Work with bare hands occurs in various cold conditions when some manual precision tasks are required. It is often in conjunction with operations of machinery and tools, handling goods or fine repair or assembly work. Indoor cold exposure is common in combination with storing and distribution of chilled or frozen food (e.g. food processing industry). Intentionally or accidentally, a person may then contact a cold surface and suffer from a serious local cooling. Two types of contact exposure can be identified:

a) Touching a cold surface with a fingertip for short period, usually for seconds.

b) Gripping cold materials with the hand, usually from seconds to minutes and often intermittent.

Contacting a cold surface is often intentional but can also by unintentional, for example by accident. In the second case the contact is often short (a few seconds) and normally interrupted by behavioural action. The conscious response, however, takes longer time with unintentional contact. Accordingly, an extra safety margin should be added for the case of such contacts. This recommendation applies particularly to contact with metals.

D.2 Procedure

D.2.1 General

A procedure for the risk assessment and determination of a temperature limit value requires information about the following factors:

D.2.2 Material

Material in use is determined and their thermal properties identified. Examples are given in Table C.1. If material is not found an approximation can be done by selection of the nearest similar material or by interpolation between materials.

D.2.3 Temperature

Temperature of the material surface is measured or estimated on the basis of exposure conditions. It is likely that equipment stored and used in a cold environment adopt the same temperatures as the environment.

D.2.4 Type of contact

Contact conditions are determined (touching or gripping).

D.2.5 Time of contact

Time of contact is determined or estimated on the basis of observations or other relevant information. Example of contact times are given in Table D.1.

Table D.1 — Examples of contact period

<table>
<tr><th rowspan="2">Contact period up to</th><th colspan="2">Examples for touching a cold surface</th></tr>
<tr><th>intentional</th><th>unintentional</th></tr>
<tr><td>1 s</td><td>-</td><td>Touching of a cold surface and quick removal following pain sensation</td></tr>
<tr><td>3 s</td><td>Activation of a switch, pressing a button or removing a small spare part with fingertips</td><td>Touching of a cold surface for extended reaction time</td></tr>
<tr><td>10 s</td><td>Prolonged activation of a switch, slight adjustment of a handle, hand wheel or valve or handling spare parts with fingers and hands</td><td>Falling against a cold surface with slow recovery</td></tr>
<tr><td>100 s</td><td>Work with a hand wheel, handle, valve or screw bolt-nut etc. with fingers gripping and hands</td><td rowspan="2">After slipping and falling accidents on cold surfaces, victim is unable to get up</td></tr>
<tr><td>20 min or longer</td><td>Use of hand tool, control elements, handles etc. with hand gripping</td></tr>
</table>

D.2.6 Criterion for assessment

Applicable evaluation criterion is selected (frostbite, numbness or pain).

D.2.7 Determination of temperature or time limit

In the Figures 1 to 10 the relations between type of material, temperature and contact time for defined effect are given. According to specified values above a limit value is selected from the corresponding figure based on criteria, material and time.

D.3 Examples

EXAMPLE 1 Cold store container

Carts with containers made of stainless steel are used in a food industry for transportation of frozen products from the freeze house at –25 °C to a processing hall at a temperature of +5 °C. The temperature of the container may well be around –25 °C in special use conditions.

For the protection of the bare hand from cold injury (frostbite) during short contacts (≤ 20 s) with the cart (pulling or pushing) a temperature limit value of –8 °C needs setting.

This is interpreted as:

— need for control of surface temperature (impractical);

— need for insulating coating of touch zones of the cart;

— need for use of protective gloves (see EN 511), when cart is frequently used in the freeze room.

EXAMPLE 2 Pneumatic tool

A pneumatic tool is used for periods of 5 min to 10 min. The expansion of air in the pneumatic system cools the gripping surface to low temperatures, also at normal room climate the handle temperature may approach 0 °C.

Pain sensation may be experienced within few seconds of gripping (<10 s for aluminium and ~60 s for stainless steel).

For protective purposes the equipment should be insulated and/or the user should be advised to use gloves.

EXAMPLE 3 Maintaining and repairing in the cold

Maintenance of telecommunication mast during winter is inevitable. The telecommunication masts are constructed of steel and the height is normally 50 m to 350 m. During maintaining or repairing in the winter, the environmental temperature on the mast is lower than –10 °C or sometimes even lower than –30 °C with chill wind. The tools for the maintenance are quickly cooled down at a low environmental temperature. Two aspects of cold stress risk have been observed:

a) Intentional touching a cold object: Maintainer's bare hands contact some cold objects below –15 °C when manual precision task is required, e.g., changing a small connector by unscrew bolt-nut. This occurrence may cause a risk of cold injury of hand skin, especially if the operator ignores the risk. To protect the hand from frostbite cold injury, a contact period of 5 s (touching steel at –15 °C, Figure 6 in 5.2.3) needs setting.

b) Unintentional contact with cold surfaces: After picking a small object with bare hands at –15 °C, the operator unintentionally uses a cold hand tool (spanner) made of steel without wearing glove.

A painful perception occurs within 0,5 s and a numbness feeling becomes at once, which results in a loss of finger tactile sensitivity. The loss of finger performance reduces working efficiency and causes a possible risk of accident. To prevent such a possible accident, a temperature limit value of the tool needs setting above 0 °C for unintentionally touching a cold steel for short than 3 s (Figure 6 and Table D.1). In interpretation of this, the following protective measures should be taken by:

— insulating the tool (e.g. fibre coating or electric heating the tool box);

— using cooling thresholds as warning signs to show the operator;

— designing ergonomically protective clothes (e.g. cover tool pockets, double layer gloves).

EXAMPLE 4 Slicing meat by machine

Cold hazards are common in food processing industry, where the most common product and environmental temperature is between - 5 °C and 5 °C. Reports of cold hazards in hands and especially fingers are most common. To protect bare hands from this occupational non-freezing cold injury, the contact period with cold meat at –5 °C should be limited to be shorter than 20 min (Figure 10). The cold contact with the machine made of stainless steel should not be more than 45 s for the prevention of finger frostbite cold injury, 5 s for prevention of numbness and 2 s for the prevention of pain sensation (Figure 6). It means that the protective measures should be performed by:

— use of a protective glove to against both wet and cold;

— documentation of the work pause time through organisation;

— coating of the handle of cutting machine with a higher insulation material.

EXAMPLE 5 Limit value in product standard

Medical electrical equipment are likely to be used in different thermal conditions. In order to prevent frostbite of the operator the following information is recommended for use at low temperatures. By selecting the temperatures at or close to the upper end of each time interval the limit values will be overprotective at the lower end.

Table D.2 — Equipment of stainless steel

Contact period s	**Lowest temperature for touching** °C
< 1	-20
1-10	-7
> 10	-2

Annex E
(informative)

Protective measures

Taking the criteria given in Clause 5 into consideration, the following measures can be taken either singly or in combination.

- Engineering measures:
  - insulation of the object (e.g. fibre coating, cork, wood);
  - structure of a surface (e.g. roughening, use of ribs etc.);
  - an insulated/or a heated tool box (e.g. electric heating);
  - warming of work spot, handles and tools (e.g. warm air blowers);
  - improving the operating process.
- Organisational measurements:
  - technical documentation, instructions, training;
  - planning of the work considering the weather conditions in advance;
  - screening of personal symptoms (white spots on the skin, pain, numbness, etc.);
  - warning signs of cold objects (visual and acoustic alarm signals);
  - guards for touchable cold surfaces (barrier, screen).
- Personal protective measures:
  - individual personal protective equipment (sufficient clothing and hand wear);
  - double gloving (keep on thin inner glove when the outer glove or mitten restrict performance);
  - ergonomically designed working clothes (e.g. tool pockets inside of the outer clothes which can keep the tools warm and allow easy to take out/put in).

Bibliography

[1] EN 511:1994, *Protective gloves against cold.*

[2] EN 563:1994[2)], *Safety of machinery — Temperatures of touchable surfaces — Ergonomics data to establish temperature limit values for hot surfaces.*

[3] EN 13202:2000[2)], *Ergonomics of the thermal environment — Temperatures of touchable hot surfaces — Guidance for establishing surface temperature limit values in production standards with the aid of EN 563.*

[4] Holmér I., Geng Q. and Cold Surfaces Research Group (2000) *Temperature Limit Values For Cold Touchable Surfaces- final report of EU Project SMT4-CT97-2149*. Accepted by European Commission DG XII SMT

[5] Holmér, I., Geng, Q. and the Cold Surfaces Research Group. Temperature limit values for cold toushable surfaces. Arbete och Hälsa 2003:7, National Institute for Working Life, Stockholm, Sweden, 2003 (Final report to EC)

[6] Geng Q., Karlsson E., Kuklane K. and Holmér I. (1999) Change in the Skin-surface Interface Temperature of Finger Touching on Cold Surfaces. *Proceedings of10th Year Anniversary Ergonomics Conference*, Luleå, Sweden. 124-129

[7] Geng Q., Holmér I. and Cold Surfaces Research Group (2000) Finger Contact Cooling on Cold Surfaces: effect of pressure. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 – August 4, 2000, 181-184

[8] Geng Q., Holmér I. and Cold Surfaces Research Group (2001) Change in the Contact Temperature of Finger Touching Cold Surfaces. *International Journal of Industrial Ergonomics,* 27(6)

[9] Hartog E. den, Havenith G. and Cold Surface Research Group (2000) Modelling of Fingertip Cooling during Contact with Cold Materials. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 –August 4, 2000, pp 197-200

[10] Holmér I., Geng Q. Q., Malchaire J. and ColdSurf research group (2000) Database For Touchable Cold Surfaces. Accepted by *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 – August 4, 2000, 201-204

[11] Jay O., Havenith G. and Cold Surface Research Group (2000) The Effects of Gender on Temperature Limit Values for Cold Touchable Surfaces. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 –August 4, 2000, 185-188

[12] Piette A., Malchaire J. and Cold Surface Research Group (2000) Duration Limit after Cold Grip Exposure with Several Materials. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 – August 4, 2000, 193-196

[13] Powell S., Havenith G. and Cold Surface Research Group (2000) The Effects of Contact Cooling on Manual Dexterity and Cooling of the Hand. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany July 30 –August 4, 2000, pp 205-208

[14] Rissanen S., Rintamäki H. and Cold Surface Research Group (2000) Individual Variation during Slow and Rapid Contact Cooling. *Proceedings of 9th ICEE Ruhr 2000*, Ruhr-Univerisity Bochum, Germany, July 30 – August 4, 2000, pp 189-191

---

2) EN 13202:2000 and EN 563:1994 will be merged and published as EN ISO 13732-1:2006

[15] EN ISO 7726:2001, *Ergonomics of the thermal environment — Instruments for measuring physical quantities (ISO 7726:1998).*

[16] EN ISO 11064-4, *Ergonomic design of control centres - Part 4: Layout and dimensions of workstations (ISO 11064-4:2004).*

[17] EN ISO 12100-2, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles (ISO 12100-2:2003)*

[18] prEN ISO 13732-1, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces (ISO/DIS 13732-1:2004).*

ICS 13.180

Price based on 21 pages