

# **Ergonomics of the thermal environment — Guide to design and evaluation of working practices for cold indoor environments**

ICS 13.180

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# Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee PH/9, Applied ergonomics, to Subcommittee PH/9/1, Thermal environments, upon which the following bodies were represented:

- British Occupational Hygiene Society
- British Textile Technology Group
- Cold Storage and Distribution Federation
- Consumer Policy Committee of BSI
- Health and Safety Executive
- Home Office
- Institute of Occupational Medicine
- Institution of Fire Engineers
- Ministry of Defence
- Transport and General Workers Union
- Coopted members

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## Foreword

The British Standard has been prepared by Subcommittee PH/9/1.

Annexes A, B and C are informative.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 13 and a back cover.

## 1 Scope

This British Standard gives guidance on ways in which cold stress or discomfort in cold indoor environments can be evaluated and cold strain reduced. It describes the human responses (physiological and behavioural) to the cold, together with the influence of different working practices on these. The risks from cold environments are also described.

This British Standard applies to those indoor environments which are either cold by design or by virtue of a designed process. It does not apply to outdoor work or those environments which, although largely enclosed, are cold by virtue of exposure to the external climate (e.g. unenclosed loading bays, tyre fitting bays, farm out-buildings).

For the purposes of this British Standard, cold environments are taken to be those with an air temperature of 12 °C or less.

**NOTE** The lower limit of application of this British Standard has not been rigorously defined. In survey work, temperatures down to -40 °C were encountered, with one application at a lower temperature. At temperatures below -40 °C, hazards not considered in this document, for example to the respiratory tract, are known to exist.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS EN 511, *Specification for protective gloves against cold*.

BS EN 27726, *Thermal environments — Instruments and methods for measuring physical quantities*.

BS ISO 9920, *Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble*.

## 3 Terms, definitions and symbols

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

### 3.1 Terms and definitions

#### 3.1.1

##### **contact period**

time during which contact with the surface takes place

#### 3.1.2

##### **thermal inertia**

product of the density, thermal conductivity and specific thermal capacity of the surface

#### 3.1.3

##### **material properties**

chemical/physical composition of the material and the characteristics (rough, smooth) and shape of the surface

#### 3.1.4

##### **air temperature**

temperature of the air surrounding the human body

#### 3.1.5

##### **absolute humidity**

mass of water vapour contained in a given mass of air

#### 3.1.6

##### **mean radiant temperature**

uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the workplace

#### 3.1.7

##### **metabolic rate**

rate of transformation of chemical energy into heat and mechanical work by aerobic and anaerobic metabolic activities within an organism

#### 3.1.8

##### **cold stress index**

mechanism by which appropriate factors are integrated into a single number, which indicates the likely resulting cold strain

## 3.2 Symbols

$DLE_{neut}$  duration limited exposure for neutral criteria

$DLE_{min}$  duration limited exposure for minimal criteria

$IREQ_{neut}$  neutral required clothing insulation

$IREQ_{min}$  minimal required clothing insulation

$t_a$  air temperature

$t_{ch}$  chilling temperature

$t_r$  mean radiant temperature

$t_s$  temperature of surrounding surfaces

$WCI$  wind chill index

**NOTE** The majority of the symbols in this British Standard guide have been taken from ISO/TR 11079.

## 4 Human responses to cold

### 4.1 Physiological responses

The human body is not generally well-equipped physiologically to cope with cold environments. The two principal responses are:

- a) to increase heat production, partly by muscular activity such as shivering and partly by secreting hormones to increase the basal metabolic rate of the body;
- b) to reduce heat loss by constricting the blood vessels of the skin (cutaneous vasoconstriction).

In response to these changes the oxygen uptake by the body will increase and cardiac output rise.

If cold exposure continues, or if it is sufficiently severe, then cooling of the hands, feet, ears and face may result in their blood vessels dilating intermittently (cold vasodilation).

### 4.2 Behavioural responses

The initial, tangible impact is one of subjective discomfort, either of the whole body or localized to specific areas of the body. Even where reasonable levels of insulation are provided, exposed peripheral sites such as hands and feet are particularly susceptible to local discomfort. Cold may distract workers and alter behaviour, which may have consequences for safety and productivity.

## 5 The assessment of cold environments

### 5.1 General

Cold strain arises from an imbalance in the heat exchange between the body and its surrounding environment.

In assessing the likelihood of such strain occurring it is necessary to consider:

- a) the external (thermal environment) parameters which influence heat exchange;
- b) the internal (metabolic) heat production, which is related to physical activity;
- c) the boundary between a) and b), principally influenced by clothing insulation.

The individual elements of a) to c) are described in 5.2 to 5.4.

### 5.2 Environment

#### 5.2.1 Introduction

The four environmental parameters that are physiologically relevant are:

- a) air temperature (see 5.2.2);
- b) humidity (see 5.2.3);
- c) air velocity (see 5.2.4);
- d) radiant temperature (see 5.2.5).

The instruments and methods for their measurement are described in BS EN 27726. The principle is to quantify the environment where people are located.

#### 5.2.2 Air temperature

In cold conditions, the air temperature is one of the most influential factors in determining the degree of cold stress experienced.

#### 5.2.3 Humidity

Measures such as the relative humidity or the saturation level define the amount of water vapour in the air in relation to the maximum amount that it can contain at a given temperature.

In cold conditions the water vapour capacity of the air is low and humidity therefore has a minimal effect on physiological heat balance although it may affect thermal comfort.

#### 5.2.4 Air velocity

The air velocity is a quantity defined by its magnitude and direction. In practice, it is the magnitude (air speed) which is often used.

In cold conditions the air velocity may have a marked effect on heat exchange, causing wind-chill and general heat loss by removing the warmed boundary layer from the surface of the body. In addition, fluctuations in air velocity or turbulent flow promote subjective discomfort (draughts).

#### 5.2.5 Radiant temperature asymmetry

Where the radiant temperature is likely to be highly asymmetric, such as proximity to surfaces at a substantially lower surface temperature than the surrounding air, or where heat radiating devices are used, it may be appropriate to measure this asymmetry.

### 5.3 Activity level

The level of activity will determine metabolic rate and therefore metabolic heat production. Methods for the determination of metabolic heat production are described in BS EN 28996 which provides for three different levels of determination of increasing accuracy.

NOTE Annex A provides a table of examples of values based on the simplest of these approaches described in BS EN 28996, with examples related to work in cold conditions.

### 5.4 Clothing insulation

Methods for the estimation of the thermal characteristics (resistance to dry heat loss and evaporative heat loss) for a clothing ensemble are given in BS ISO 9920.

The insulating value of an item of clothing or a clothing ensemble is conveniently cited using the clo unit ( $1 \text{ clo} = 0.155 \text{ m}^2 \cdot ^\circ\text{C} \cdot \text{W}^{-1}$ ).

NOTE Annex B provides examples of insulation values of clothing used in cold conditions.

An estimation of the required level of insulation can be determined from ISO/TR 11079, which describes the *IREQ* index (see 5.5.2). This index utilizes the parameters given in 5.2.1 to estimate the level of insulation required for a given set of environmental and metabolic conditions to maintain the body in a state of thermal equilibrium at acceptable levels of body and skin temperature.