

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

ICS 13.180

National foreword

This British Standard is the UK implementation of EN ISO 11079:2007. It supersedes DD ENV ISO 11079:1999 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PH/9, Applied ergonomics, to Subcommittee PH/9/1, Thermal environments.

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

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Ergonomie der thermischen Umgebung - Bestimmung und Interpretation der Kältebelastung bei Verwendung der erforderlichen Isolation der Bekleidung (IREQ) und lokalen Kühlwirkungen (ISO 11079:2007)

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Foreword

This document (EN ISO 11079:2007) has been prepared by Technical Committee ISO/TC 159 "Ergonomics" in collaboration with Technical Committee CEN/TC 122 "Ergonomics" the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by June 2008, and conflicting national standards shall be withdrawn at the latest by June 2008.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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Endorsement notice

The text of ISO 11079:2007 has been approved by CEN as a EN ISO 11079:2007 without any modification.

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

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interprétation de la contrainte liée au froid en utilisant l'isolement
thermique requis du vêtement (IREQ) et les effets du refroidissement
local*



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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 11079 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

This first edition of ISO 11079 cancels and replaces the ISO/TR 11079:1993, of which it constitutes a technical revision.

Introduction

Wind chill is commonly encountered in cold climates, but it is low temperatures that first of all endanger body heat balance. By proper adjustment of clothing, human beings can often control and regulate body heat loss, to balance a change in the ambient climate. The method presented here is based therefore on the evaluation of the clothing insulation required to maintain the thermal balance of the body in equilibrium. The heat balance equation used takes into account the most recent scientific findings concerning heat exchanges at the surface of the skin as well as the clothing.

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

1 Scope

This International Standard specifies methods and strategies for assessing the thermal stress associated with exposure to cold environments. These methods apply to continuous, intermittent as well as occasional exposure and type of work, indoors and outdoors. They are not applicable to specific effects associated with certain meteorological phenomena (e.g. precipitation), which are assessed by other methods.

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 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

ISO 8996, *Ergonomics of the thermal environment — Determination of metabolic rate*

ISO 9237, *Textiles — Determination of permeability of fabrics to air*

ISO 9920, *Ergonomics of the thermal environment — Estimation of thermal insulation and water vapour resistance of a clothing ensemble*

ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

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

ISO 15831, *Clothing — Physiological effects — Measurement of thermal insulation by means of a thermal manikin*

EN 511, *Protective gloves against cold*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 13731 and the following terms, definitions and symbols apply.

3.1 Terms and definitions

3.1.1

cold stress

climatic conditions under which the body heat exchange is just equal to or too large for heat balance at the expense of significant and sometimes uncompensable physiological strain (heat debt)

3.1.2

heat stress

climatic conditions under which the body heat exchange is just equal to or too small for heat balance at the expense of significant and sometimes uncompensable physiological strain (heat storage)

3.1.3

IREQ

required clothing insulation for the preservation of body heat balance at defined levels of physiological strain

3.1.4

thermoneutral zone

temperature interval within which the body maintains heat balance exclusively by vasomotor reactions

3.1.5

wind chill temperature

temperature related to the cooling effect on a local skin segment

3.2 Symbols

A_{Du}	Dubois body surface area, m^2
ap	air permeability, $l \cdot m^{-2} \cdot s^{-1}$
C	convective heat flow (exchange), $W \cdot m^{-2}$
c_e	water latent heat of vaporization, $J \cdot kg^{-1}$
c_p	specific heat of dry air at constant pressure, $J \cdot kg^{-1} \cdot K^{-1}$
C_{res}	respiratory convective heat flow (loss), $W \cdot m^{-2}$
D_{lim}	duration limited exposure, h
D_{rec}	recovery time, h
E	evaporative heat flow (exchange) at the skin, $W \cdot m^{-2}$
E_{res}	respiratory evaporative heat flow (loss), $W \cdot m^{-2}$
f_{cl}	clothing area factor, dimensionless
h_c	convective heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$
h_r	radiative heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$
I_a	boundary layer thermal insulation, $m^2 \cdot K \cdot W^{-1}$
$I_{a,r}$	resultant boundary layer thermal insulation, $m^2 \cdot K \cdot W^{-1}$

I_{cl}	basic clothing insulation, $m^2 \cdot K \cdot W^{-1}$
$I_{cl,r}$	resultant clothing insulation, $m^2 \cdot K \cdot W^{-1}$
I_T	basic total insulation, $m^2 \cdot K \cdot W^{-1}$
$I_{T,r}$	resultant total insulation, $m^2 \cdot K \cdot W^{-1}$
i_m	moisture permeability index, dimensionless
I_{REQ}	required clothing insulation, $m^2 \cdot K \cdot W^{-1}$
$I_{REQ_{min}}$	minimal required clothing insulation, $m^2 \cdot K \cdot W^{-1}$
$I_{REQ_{neutral}}$	neutral required clothing insulation, $m^2 \cdot K \cdot W^{-1}$
K	conductive heat flow (exchange), $W \cdot m^{-2}$
M	metabolic rate, $W \cdot m^{-2}$
p_a	water vapour partial pressure, kPa
p_{ex}	saturated water vapour pressure at expired air temperature, kPa
p_{sk}	water vapour pressure at skin temperature, kPa
$p_{sk,s}$	saturated water vapour pressure at the skin surface, kPa
Q	body heat gain or loss, $kJ \cdot m^{-2}$
Q_{lim}	limit value for Q , $kJ \cdot m^{-2}$
R	radiative heat flow (exchange), $W \cdot m^{-2}$
$R_{e,T}$	total evaporative resistance of clothing and boundary air layer, $m^2 \cdot kPa \cdot W^{-1}$
S	body heat storage rate, $W \cdot m^{-2}$
t_a	air temperature, $^{\circ}C$
t_{cl}	clothing surface temperature, $^{\circ}C$
t_{ex}	expired air temperature, $^{\circ}C$
t_o	operative temperature, $^{\circ}C$
t_r	radiant temperature
t_{sk}	local skin temperature, $^{\circ}C$
$\bar{t}_{sk}$	mean skin temperature, $^{\circ}C$
t_{WC}	wind chill temperature, $^{\circ}C$
V	respiratory ventilation rate, $kg \text{ air} \cdot s^{-1}$
v_{10}	wind speed measured 10 m above ground level, $m \cdot s^{-1}$
v_a	air velocity, $m \cdot s^{-1}$
v_w	walking speed, $m \cdot s^{-1}$
W	effective mechanical power, $W \cdot m^{-2}$
w	skin wettedness, dimensionless

W_a	humidity ratio of inhaled air, kg water/kg dry air
W_{ex}	humidity ratio of exhaled air, kg water/kg dry air
σ	Stefan-Boltzmann constant
ε_{cl}	emissivity of clothing surface, dimensionless

4 Principles of methods for evaluation

Cold stress is evaluated in terms of both general cooling of the body and local cooling of particular parts of the body (e.g. extremities and face). The following types of cold stress are identified.

a) General cooling

For general cooling, an analytical method is presented in Clause 5 for the evaluation and interpretation of the thermal stress. It is based on a calculation of the body heat exchange, the required clothing insulation (IREQ) for the maintenance of thermal equilibrium and the insulation provided by clothing ensemble in use or anticipated to be used.

b) Local cooling

- 1) convective cooling (wind chill)
- 2) conductive cooling
- 3) extremity cooling
- 4) airway cooling

For local cooling, methods are proposed in Clause 6. Criteria and limit values are also given in Clause 6 and Annex B.

In the following sections, the main steps of evaluation are described.

5 General cooling

5.1 Overview

A general equation for body heat balance is defined. In this equation clothing thermal properties, body heat production and physical characteristics of the environment are the determinant factors. The equation is solved for the required clothing insulation (IREQ) for maintained heat balance under specified criteria of physiological strain. IREQ is subsequently compared with the protection (insulation) offered by the worker's clothing. If worn insulation is less than required, a duration limited exposure (D_{lim}) is calculated on the basis of acceptable levels of body cooling. Detailed formulas, coefficients and criteria are proposed in Annexes A and B.

The method involves the following steps, outlined schematically in Figure 1:

- measurements of the thermal parameters of the environment;
- determination of activity level (metabolic rate);
- calculation of IREQ;
- comparison of IREQ with resultant insulation provided by clothing in use;
- evaluation of the conditions for thermal balance and calculation of the recommended maximal exposure time (D_{lim}).