

Ergonomics of the thermal environment — Evaluation of thermal environments in vehicles —

Part 2: Determination of equivalent temperature

ICS 13.180; 43.020

National foreword

This British Standard is the UK implementation of EN ISO 14505-2:2006. It is identical with ISO 14505-2:2006, incorporating corrigendum August 2007.

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 subcommittee can be obtained on request to its secretary.

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Foreword

This document (EN ISO 14505-2:2006) 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of an identical text or by endorsement, at the latest by June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

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Endorsement notice

The text of ISO 14505-2:2006 has been approved by CEN as EN ISO 14505-2:2006 without any modifications.

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Introduction

The interaction of convective, radiative and conductive heat exchange in a vehicle compartment is very complex. External thermal loads in combination with the internal heating and ventilation system of the vehicle create a local climate that can vary considerably in space and time. Asymmetric thermal conditions arise and these are often the main cause of complaints of thermal discomfort. In vehicles without or having a poor heating, ventilating and air-conditioning system (HVAC-system), thermal stress is determined largely by the impact of the ambient climatic conditions on the vehicle compartment. Subjective evaluation is integrative, as the individual combines into one reaction the combined effect of several thermal stimuli. However, it is not sufficiently detailed or accurate for repeated use. Technical measurements provide detailed and accurate information, but require integration in order to predict the thermal effects on humans. Since several climatic factors play a role for the final heat exchange of a person, an integrated measure of these factors, representing their relative importance, is required.

Ergonomics of the thermal environment — Evaluation of thermal environments in vehicles —

Part 2: Determination of equivalent temperature

1 Scope

This part of ISO 14505 provides guidelines for the assessment of the thermal conditions inside a vehicle compartment. It can also be applied to other confined spaces with asymmetric climatic conditions. It is primarily intended for assessment of thermal conditions, when deviations from thermal neutrality are relatively small. Appropriate methodology as given in this part of ISO 14505 can be chosen for inclusion in specific performance standards for testing of HVAC-systems for vehicles and similar confined spaces.

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

3 Terms and definitions

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

3.1 equivalent temperature

t_{eq}
temperature of a homogenous space, with mean radiant temperature equal to air temperature and zero air velocity, in which a person exchanges the same heat loss by convection and radiation as in the actual conditions under assessment

3.2 whole body equivalent temperature

$t_{eq,whole}$
temperature of an imaginary enclosure with the same temperature in air and on surrounding surfaces and with air velocity equal to zero in which a full-scale, human shaped, heated sensor will exchange the same dry heat by radiation and convection as in the actual non-uniform environment

3.3 segmental equivalent temperature

$t_{eq,segment}$
uniform temperature of an imaginary enclosure with the same temperature in air and on surrounding surfaces and with air velocity equal to zero in which one or more selected zones of a thermal manikin will exchange the same dry heat by radiation and convection as in the actual non-uniform environment

3.4

directional equivalent temperature

$t_{eq,direct}$

uniform temperature of an imaginary enclosure with the same temperature in air and on surrounding surfaces and with air velocity equal to zero in which a small flat heated surface will exchange the same dry heat by radiation and convection as in the actual non-uniform environment

3.5

omnidirectional equivalent temperature

$t_{eq,omni}$

uniform temperature of an imaginary enclosure with the same temperature in air and on surrounding surfaces and with air velocity equal to zero in which a heated ellipsoid will exchange the same dry heat by radiation and convection as in the actual non-uniform environment

3.6

segment

part of a human-shaped sensor, normally corresponding to a real body-part, consisting of one or several whole zones, for which a segmental equivalent temperature, $t_{eq, segment}$, is presented

3.7

zone

physical partition of a manikin, which is independently regulated and within which the surface temperature and heat exchange is measured

3.8

HVAC-system

heating, ventilating and air-conditioning system of the vehicle and/or cabin

4 Assessment principles

The assessment principle is based on the measurement of the equivalent temperature. The equivalent temperature provides a unified, physical measure of the climatic effects on the human dry heat exchange. On the basis of the actual value for, and the variation in, equivalent temperature, it is possible to predict the conditions for heat balance under conditions in or close to the thermoneutral zone. People's thermal sensation is primarily influenced by general and local levels and variations in skin surface heat flux. Values for the equivalent temperature of a defined environment have been found to be closely related to how people perceive thermal conditions when exposed to the same environment. This can be used for the interpretation of the t_{eq} value and assessment of the quality of the environment.

The climate is assessed in terms of a *total equivalent temperature*, which describes the level of *thermal neutrality*.

The climate is also assessed for local effects on defined parts of the human body surface. The *local equivalent temperatures* determine to what extent the actual body parts fall within the range of acceptable levels of heat loss (*local discomfort*).

4.1 General description of equivalent temperature

The equivalent temperature is a pure physical quantity, that in a physically sound way integrates the independent effects of convection and radiation on human body heat exchange. This relationship is best described for the overall (whole body) heat exchange. There is limited experience with relations between local dry heat exchange and local equivalent temperature. The standardized definition of t_{eq} applies only for the whole body. Therefore, the definition has to be modified for the purposes of this part of ISO 14505. t_{eq} does not take into account human perception and sensation or other the subjective aspects. However, empirical studies show that t_{eq} values are well related to the subjective perception of the thermal effect.

4.2 General determination principle of equivalent temperature

Determination of t_{eq} is based on equations for convective and radiative heat transfer for clothed persons. Heat exchange by conduction is assumed to be small and accounted for by radiation and convection.

$$R = h_r (t_{sk} - \bar{t}_r) \quad (1)$$

$$C = h_c (t_{sk} - t_a) \quad (2)$$

where

R is heat exchange by radiation, in watts per square metre (W/m^2);

C is heat exchange by convection, in watts per square metre (W/m^2);

h_r is the radiation heat transfer coefficient, in watts per square metre degree Celsius [$W/(m^2\text{°C})$];

h_c is the convection heat transfer coefficient, in watts per square metre degree Celsius [$W/(m^2\text{°C})$];

t_{sk} is the skin temperature, in degrees Celsius ($^{\circ}\text{C}$);

$\bar{t}_r$ is the mean radiant temperature, in degrees Celsius ($^{\circ}\text{C}$);

t_a is the ambient air temperature, in degrees Celsius ($^{\circ}\text{C}$).

In practice the equivalent temperature is determined and defined by

$$t_{eq} = t_s - \frac{Q}{h_{cal}} \quad (3)$$

where

t_s is the surface temperature;

t_{eq} is the temperature of the standard environment;

Q is the measured convective and radiative heat loss during the actual conditions,

$$Q = R + C \quad (4)$$

h_{cal} is the combined heat transfer coefficient, determined during calibration in a standard environment.

The standard environment comprises homogenous, uniform thermal conditions with $t_a = \bar{t}_r$ and air velocity, v_a , $< 0,1$ m/s. A suitable calibration procedure is described in Annex C.