TECHNICAL SPECIFICATION

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

Part 1: Principles and methods for assessment of thermal stress

Ergonomie des ambiances thermiques — Évaluation des ambiances thermiques dans les véhicules —

Partie 1: Principes et méthodes d'évaluation de la contrainte thermique

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Foreword

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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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

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An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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ISO/TS 14505-1 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

ISO/TS 14505 consists of the following parts, under the general title *Ergonomics of the thermal environment — Evaluation of thermal environments in vehicles*:

— *Part 1: Principles and methods for assessment of thermal stress* [Technical Specification]

— *Part 2: Determination of equivalent temperature*

— *Part 3: Evaluation of thermal comfort using human subjects*

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 1:
Principles and methods for assessment of thermal stress

1 Scope

This part of ISO 14505 gives guidelines for the assessment of thermal stress inside vehicles used for land, sea and air operation. It offers information about the assessment of hot, cold as well as moderate thermal environments by referring to different methods, as specified in International Standards, and specifying the constraints and necessary adjustments needed for the special case of vehicle climate assessment.

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
cold stress
climatic conditions under which body heat loss is just equal to, or too large for, heat balance at the expense of significant and sometimes uncompensated physiological strain

3.2
equivalent temperature
temperature of a homogenous space, with its 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

3.3
heat stress
climatic conditions under which the body heat loss is just equal to, or too small for, heat balance at the expense of significant and sometimes uncompensated physiological strain (heat storage)

3.4
local equivalent temperature
temperature of a homogenous “room”, with mean radiant temperature equal to air temperature and zero air velocity, in which a defined zone of the human body surface exchanges the same heat loss by convection and radiation as in the actual conditions under assessment

3.5
thermal asymmetry
condition in which opposite parts of the human body are exposed to different climatic conditions

3.6
thermoneutral zone
temperature interval within which the body maintains heat balance exclusively by vasomotor reactions

3.7
vehicle
confined, normally fully enclosed, space of a mobile or stationary unit intended for transportation of or operation by humans

3.8
HVAC-system
heating, ventilating and air-conditioning system of the vehicle and/or cabin

4 Assessment principles

The thermal environment in a vehicle changes as a function of the external climatic conditions and the quality and capacity of the HVAC-system of the cabin. Most vehicles are able to supply heating or cooling of the cabin under adverse external climatic conditions, thus reducing the extreme levels of climatic stress. However, in simple vehicles and during break-down of the HVAC-system, the operator may be subjected to high levels of thermal stress.

The assessment of the thermal conditions in vehicles is based on three types of effect on the operator, illustrated in Figure 1:

a) heat stress (hot climate);

b) thermal discomfort (moderate climate);

c) cold stress (cold climate).

For all three types, an analysis of the actual conditions is made using methods described in existing International standards or similar documents (see Figure 1). The evaluation focuses on the stress on the exposed individual (stress test).

The methods do not provide information on the performance of the vehicle HVAC-system (heating, ventilating and air-conditioning system), as the external conditions are not standardized, but are subject to evaluation in combination with the system. Performance tests require standardized environmental conditions and focus on the evaluation of the performance of the HVAC-system under standardized conditions (see example in Annex B). Recommendations for this kind of test are given in ISO 14505-2.

Subjective assessment of the thermal conditions can be made, both as a result of thermal stress or as part of performance tests (see Figure 1, bottom box). For persons with special needs, assessment can be made by using ISO/TR 14415.

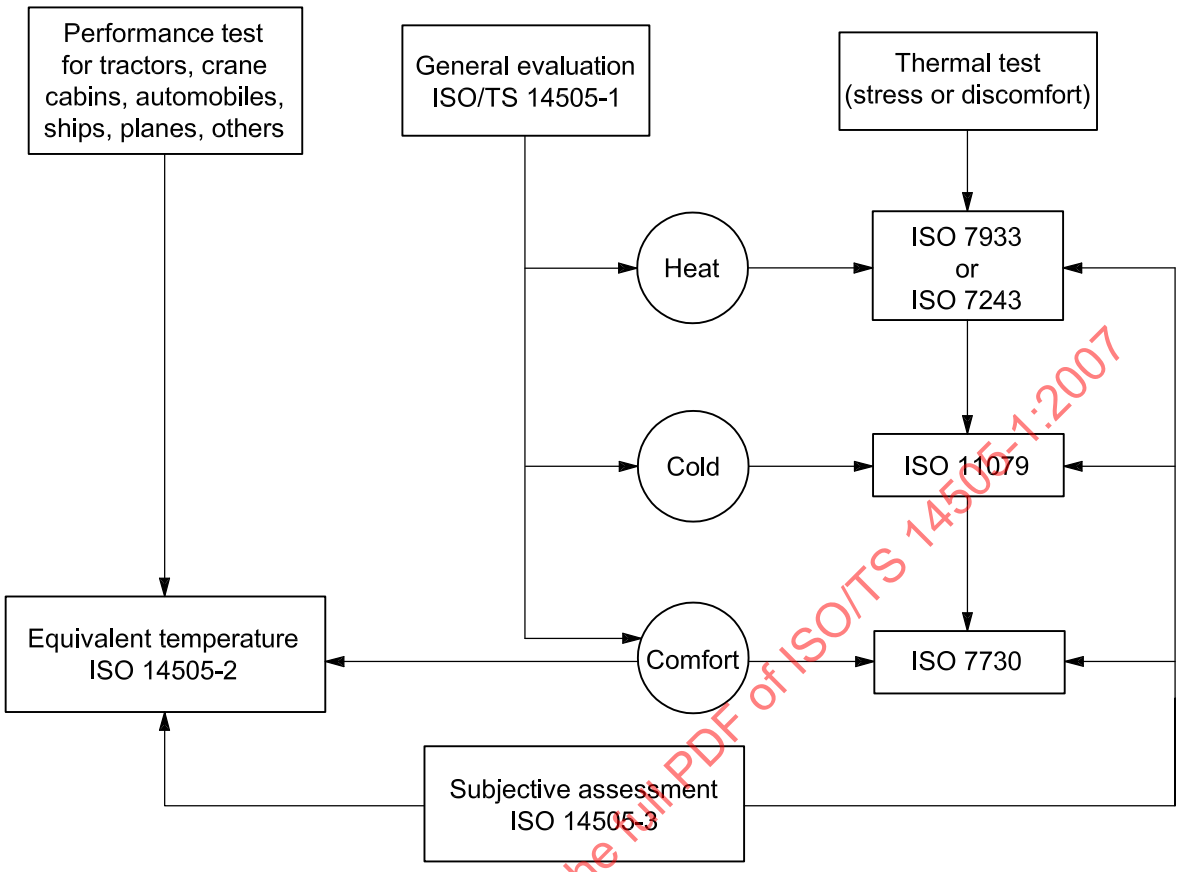

Figure 1 — Schematic illustration of principles for climate evaluation using International Standards

5 Methods for measurement of in-vehicle climate

5.1 General

This clause provides information on suggested methods for use in various types of thermal stress in vehicles under driving conditions. Additional information for the actual assessment is given in Annex A and examples in Annex B.

5.2 Thermal comfort

5.2.1 General

The achievement of thermally comfortable conditions in a vehicle cabin is the aim of the HVAC-system. Most systems are able to create more or less comfortable climates after an initial stabilization period. Whole body heat balance can be relatively easily maintained under thermoneutral conditions, whereas severe local discomfort can still occur due to the local climatic conditions.

The assessment principle is based on the measurement and analysis of the conditions for heat balance in the thermoneutral range and the associated thermal sensation.

Two methods are available, in ISO 7730 and ISO 14505-2.

5.2.2 Whole body evaluation using PMV and PPD indices

Recommendations for an overall whole body assessment is given in ISO 7730. Based on measurements of air temperature, mean radiant temperature, humidity and air velocity, as well as estimations of metabolic rate and clothing thermal insulation, the PMV and PPD indices can be calculated. The value of PMV indicates the level of thermal neutrality assumed to be perceived by drivers for the conditions under examination.

The local thermal criteria in this part of ISO 14505 are not recommended for use with vehicles.

5.2.3 Detailed evaluation using equivalent temperature

Recommendations for the detailed assessment are given in ISO 14505-2. The equivalent temperature provides a unified, physical measure of the climatic effects on human body heat exchange. By definition, the equivalent temperature is restricted to effects on dry heat exchange. On the basis of the actual value and the variation in equivalent temperature, conditions for heat balance in, or close to, the thermoneutral zone can be evaluated. As people's thermal sensation is primarily influenced by general and local changes and variations in skin heat flux, a significant correlation between thermal sensation votes and equivalent temperature has been found.

The climate is assessed in terms of a *whole body 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*).

As many problems and complaints regarding vehicle climate refer to thermal asymmetries, the local equivalent temperature is particularly suitable for evaluation.

Equivalent temperature can be determined by different methods:

a) heated sensors at discrete locations;

b) full-scale sized thermal manikins.

5.3 Heat stress

5.3.1 General

When conditions of thermal comfort cannot be maintained in a vehicle in hot climatic conditions, heat stress of the operator can develop. Heat stress puts a physiological strain on the operator that eventually cannot be tolerated. Intolerable heat stress may develop into heat injuries.

Recommendations for the assessment are given in ISO 7243 or ISO 7933. Contact with hot surfaces is recommended to be assessed using ISO 13732-3.

The assessment in both cases is based on the evaluation of whole body effects and whole body heat balance. However, due to the presence of considerable asymmetric climatic conditions, special care needs to be taken to assure a representative measure of the total climate in the vehicle.

When WBGT (wet bulb globe temperature) is used, the activity class should be selected according to Annex A.

5.3.2 Solar radiation

Solar radiation comprises one of the most important sources of heat load on the vehicle compartment. The final effect results from factors such as glazing area, insulation of compartment walls, size of compartment, and surface colour of vehicle. Most important is the direct radiation that hits the driver through the glass, as large quantities of heat can be absorbed locally by clothing and underlying skin. The radiated area can be small when the sun is at it zenith, or great in modern vehicles with large front windows when the sun stands lower.

Radiation effects can be estimated on the basis of shielded and unshielded globe temperature measurements or by measurements of the radiant flux. Measurements should be weighted according to their percentage of the total body surface. In most cases the radiated area will be less than 20 %.

5.3.3 Air velocity

High air velocities are common in vehicles and can vary over the body surface. They are caused either by open windows during driving or by the HVAC-system. The result in both cases normally is a local cooling of the affected parts of the body. Measurements of air velocities should be done in representative spots representing areas exposed and weighted according to their percentage of the total body surface. In most cases, this value will be less than 20 %, as large parts of the body are protected by the seat.

5.3.4 Evaporative heat exchange

The water vapour pressure in general is the same over the whole vehicle compartment. Accordingly, one measure should be sufficient for the assessment. It is expected, though, that radiated areas and areas with high convection allow more evaporative heat exchange. This effect is difficult to determine. It is recommended that the effect be neglected, as it works on the positive side (reduces heat stress).

5.4 Cold stress

When the heating system fails or is insufficient under cold climatic conditions, there is a progressive risk of whole body cooling as well as local cooling of body parts. Initially, discomfort arises, but with time and further cooling more pronounced physiological strain and, eventually, cold injuries can occur.

Recommendations for assessment of cold stress are given in ISO 11079. Cold stress is assessed by analysing the conditions for heat balance. The cooling load is calculated by comparing required clothing thermal insulation (IRW) with the available thermal insulation provided by clothing. When protection is insufficient, body cooling will inevitably occur and a time is calculated for recommended exposure.

Significant local cooling may arise from cold surfaces, such as windows, or from a cold seat. Recommendations for assessment of contact with cold surfaces are given in ISO 13732-3.

5.5 Metabolic rate and clothing

When vehicle climate is assed by using ISO 7243, ISO 7730, ISO 7933 or ISO 11079, appropriate values for metabolic rate and clothing thermal characteristics should be selected (Annex A).

6 Assessment by means of subjects

The climatic conditions in a vehicle under defined conditions can be evaluated by means of human subjects. This method provides information about the group mean assessment and the individual variation. Methods for subjective assessment of the thermal environment are described in ISO 14505-3.

Annex A
(informative)

Measurement or estimation of metabolism and clothing characteristics

A.1 Measurement or estimation of metabolism

Heat production of the driver depends on his physical activity (see Table A.1). In most driving tasks, the physical activity is low. More details on metabolic rates during physical activity are provided in ISO 8996.

Table A.1 — Values for metabolic heat production during vehicle driving

Activity	Metabolic rate W/m^2
Automobile driving on paved roads	70
Driving on rugged roads	80
Off-road driving	90

A.2 Estimation of clothing characteristics

ISO 9920 provides examples of thermal characteristics of clothing ensembles. Values are affected due to the compression effects of the seated position. The insulative effect of a driver's seat should be added. Examples of such effects are also given in ISO 9920. Ventilated seats reduce resultant thermal insulation by 10 % to 20 % and the insulation values need to be lowered accordingly. Evaporative resistance of the ensemble must be considered in the assessment of heat stress.

Annex B
(informative)

Examples of thermal stress assessment

B.1 Assessment of thermal stress

B.1.1 General

The example assessments given in this annex are based on a truck driving on a highway in regular traffic conditions. All assessments are carried out under actual driving conditions.

B.1.2 Assessment of thermal comfort

B.1.2.1 General

Thermal comfort can be evaluated in terms of overall whole body effects and in terms of local effects.

B.1.2.2 Overall assessment

Thermal conditions are determined and analysed according to ISO 7730.

B.1.2.3 Detailed assessment

Measurements of equivalent temperature are carried out for whole body as well as local thermal effects according to ISO 14505-2.

B.1.3 Heat stress assessment

Assessment of heat stress in a vehicle is carried out according to ISO 7243. Only whole body assessment is made. Detailed assessment is carried out according to ISO 7933 (analytical evaluation). Measurements are taken during driving of the vehicle under the actual climatic conditions. Results give information about the level of heat stress and needs for preventive action.

B.1.4 Cold stress assessment

Assessment of cold stress in a vehicle is carried out in a similar manner to the example of B.1.3. Only whole body assessment is required. Measurements are carried out according to ISO 11079 (analytical evaluation). Measurements are taken during driving of the vehicle under the actual climatic conditions. Results give information about the level of cold stress and needs for preventive action such as improved cold protective clothing or heating capacity of the HVAC-system.

B.2 Performance testing of vehicle HVAC-systems

For detailed evaluation of the performance of the HVAC-system of a vehicle, tests are carried out in a climatic chamber/wind tunnel with defined, pre-set climatic conditions. Conditions are usually one summer and one winter condition. Measurements are carried out according to ISO 14505-2. For relevant, repeatable and valid tests, the detailed test conditions need to be specified in specific application standards.