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**Ergonomics of the thermal environment —
Assessment of the influence of the thermal
environment using subjective judgement scales**

*Ergonomie des ambiances thermiques — Évaluation de l'influence des
ambiances thermiques à l'aide d'échelles de jugements subjectifs*
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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.

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.

International Standard ISO 10551 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

Annexes A, B and C of this International Standard are for information only.

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Introduction

The present International Standard forms part of a series of standards on the assessment of thermal stress and strain in the work environment.

This series is concerned in particular with:

- 1) establishing specifications on methods for measuring and estimating the characteristic physical parameters of climatic environments, thermal properties of clothing and metabolic heat production;
- 2) establishing methods for assessing thermal stress in hot, cold and temperate environments.

This International Standard proposes a set of specifications on direct expert assessment of thermal comfort/discomfort expressed by persons subjected to various degrees of thermal stress during periods spent in various climatic conditions at their workplace. The data provided by this assessment will most probably be used to supplement physical and physiological methods of assessing thermal loads. The methods belong to a psychological approach consisting in gathering, as appropriate, the on-site opinions of persons exposed to the conditions under consideration (diagnosis) and thus may complete data provided by predictive approaches described elsewhere in this series.

The ergonomist who is concerned with the thermal environment of workplaces is able to determine the value of various indices (WCI, PMV and PPD, WBGT) which will predict the average climatic conditions for thermal comfort or the average degree of thermal stress suffered by a worker in a number of general cases. In practice, specific cases often differ from general cases in ways such as spatial heterogeneities, local differences, temporal fluctuations, clothing arrangements, personal characteristics. Thus it becomes necessary to supplement the values proposed in an initial predictive approach by a direct determination of the subjective experience which persons at work have of the climatic environment and of their corresponding personal state, an experience which these persons can judge and express. The approach is diagnostic.

These data are not obtained by means of a questionnaire; it is left to the user to incorporate the scales into a list of more comprehensive or more specific questions (medical survey, list of work stresses), presented in a form (oral, written; individual, collective) adapted to the particular case and to the collective standards (national, professional) in force.

If persons exposed to thermal environments are to be asked about their corresponding experiences or information requested on their cultural attitude in order to obtain the most appropriate subjective judgement scales, favourable relationships should first be established between these persons and the organization responsible, through the persons conducting the ergonomic investigation.

The thermal environments which lend themselves to the application of subjective judgement scales relate to conditions which differ to a moderate degree from thermal neutrality. Under extreme conditions, physical and physiological assessment methods of the thermal load shall be preferred, provided that their results can be used as criteria for a decision. In particular, tolerance limits for thermal load cannot be confidently based on subjective judgements and have to be decided in view of accepted health risk criteria. More specific conditions for applying the judgement scales will be made clear in connection with each of them.

The subjective nature of the data obtained using judgement scales leads some experts to doubt their benefit and prefer "objective", physical or physiological data. The question of the validity of subjective data as regards thermal environments can be viewed in two distinct ways:

a) The first approach corresponds to the following question:

To what extent is the information provided by these data the same as that provided by "objective" data?

The relation which may or may not exist between objective and subjective data will be examined with the aim of substituting collection of the former by that of the latter, which are more easily obtained. This International Standard is not concerned with this approach, however interesting it may be once the relation has been established.

b) The second approach corresponds to the following question:

What is the intrinsic value of the data supplied by these scales?

The opinions held by persons about the thermal environments in which they work have a value in themselves. It is up to the ergonomist whether or not to take them into account. The reputation of these data for lack of reliability does not justify dismissing them out of hand. The aim of this International Standard is precisely to improve their reliability by specifying the appropriate tools to use in collecting them and the requirement for using them.

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Ergonomics of the thermal environment — Assessment of the influence of the thermal environment using subjective judgement scales

1 Scope

This standard covers the construction and use of judgement scales (scales of thermal perception, thermal comfort, thermal preference, acceptability expression form and tolerance scale) for use in providing reliable and comparative data on the subjective aspects of thermal comfort or thermal stress.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

- ISO 7243:1989, *Hot environments — Estimation of the heat stress on working man, based on the WBGT-index (wet belt globe temperature).*
- ISO 7726:1985, *Thermal environments — Instruments and methods for measuring basic physical quantities.*
- ISO 7730:1994, *Moderate thermal environments — Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.*
- ISO 7933:1989, *Hot environments — Analytical determination and interpretation of thermal stress, using calculation of required sweat rate.*
- ISO 8996:1990, *Ergonomics of the thermal environment — Estimation of metabolic heat production.*
- ISO 9886:1992, *Evaluation of the thermal strain by physiological measurements.*
- ISO 9920:1994, *Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble.*
- ISO/TR 11079:1993, *Evaluation of cold environments — Determination of required clothing insulation (IREQ).*

3 Symbols

- I_{cl} thermal resistance (insulation) of the clothing, in square metres degrees Celsius per watt or in clo (1 clo = 0,155 m² · °C/W);
- Met heat produced by the metabolism, in watts per square metre;
- PMV predicted mean vote (see ISO 7730);

PPD	predicted percentage of dissatisfied (see ISO 7730);
WBGT	wet bulb globe temperature (see ISO 7243);
WCI	wind chill index (see ISO/TR 11079).

4 Subjective judgement scales for thermal environments: Principles of scale construction and conditions of use

There are a number of subjective judgement scales for thermal environments. They differ in whether emphasis is placed on some aspect of judgement: perceptual or affective (evaluative and preferential), global (encompassing the whole environment or organism) or localized, present or past, instantaneous or extended over a period of time. They also differ as to the object of judgement: environment or person, the whole or its component parts (temperature, humidity, air movement; thermal state of the body, skin wetness, respiration), permanent or temporary situation, temperate or extreme conditions.

This International Standard recommends subjective judgement scales based on the thermal state of the body. In the case of steady climatic conditions, with sedentary working people ($60 \text{ W/m}^2 \leq \text{Met} \leq 70 \text{ W/m}^2$) clothed in a normal manner ($(0,5 \pm 0,2) \text{ clo} < I_{cl} \leq (1,0 \pm 0,2) \text{ clo}$) and after a stay of at least 30 min, the global judgement people make about their own thermal state and the global judgement they make about the ambient temperature are typically in agreement. At the workplace, these situations are of particular importance (in terms of frequency, of priority given to their treatment). In general, judgements made by people about their personal thermal state are more relevant to ergonomists than judgements made about their thermal surroundings.

In the case of varying climatic or clothing factors, as well as in the case of variation in physical activity (transient conditions), agreement between both kinds of judgement does not necessarily occur. The same is true in the case of steady climatic conditions associated with people with a level of physical activity higher than the level corresponding to sedentary working ($\text{Met} > 70 \text{ W/m}^2$), or with people clad in less ($I_{cl} < 0,5 \text{ clo}$) or more ($I_{cl} > 1,0 \text{ clo}$) clothing than customary.

In each of these cases, it is more important from the point of view of ergonomic practice to know how the workers feel themselves than to know how they judge the local climate. Thus the present International Standard retains judgements that workers make about their own thermal state as a whole. It distinguishes between perception, present affective assessment (comfort/discomfort) and future preference.

This International Standard also uses the same scales, with appropriate modification, for temperate environments and for more intensely hot or cold environments.

NOTE 1 This International Standard also suggests supplementing the perceptual, evaluative and preferential judgement scales by a statement of acceptability and a scale of tolerance of thermal environments.

In most instances, the exposure to given climatic conditions lasts for several hours. Therefore, it is useful to gather the persons' opinions throughout, by repeating the expression of the judgements at regular intervals (e.g. 30 min), using exactly the same scales.

NOTE 2 The procedure of obtaining synthetic judgements by hypothetically integrating spot impressions over an extended period of time should be avoided.

By repeatedly applying the same scales, the evolution with time of the thermal comfort or strain experienced in constant conditions may be assessed and an integrated judgement obtained over the whole time of exposure by appropriate computation of the data (e.g. overall mean). In the case of transient conditions, the same repeated judgement collection applies to seasonal or other contextual (time of day, task demand, management style), variations in thermal comfort or strain experienced by the same persons in otherwise constant climatic conditions.

Basic difficulties are encountered in any area which involves the use of language. In this regard, bias and variability in the data can result from inconsistencies and inappropriateness of accompanying instructions. Therefore, it becomes crucial to standardize preparatory instructions which explain the study, as well as the wording of the judgement scales. Of special importance is the terminology used to denote the degrees on the judgement scales. This International Standard specifies the structure of the scales, with annex A providing suggestions regarding wording selection in the various languages.

NOTE 3 International usage and acceptance of the scales in this International Standard will result in the fixing of suitable wording of the degrees on the scales in various languages.

Other judgement scales are in use concerning the thermal state of various parts of the body (e.g. head, torso, hands, feet), the total thermal environment or various components of it (e.g. temperature, humidity or air movement), other aspects of the thermal experience of the person (e.g. wetting of the skin) or evaluations conducted over a certain period of time, including periods during which climatic conditions have not been measured. Other scales, e.g. a bipolar affective evaluation scale, have been structured differently on the model of thermal perception; such a scale is useful for taking into account thermal pleasure and is more sensitive than the unipolar discomfort scale in the region of thermal conditions near to thermal neutrality.

This International Standard is limited to the five scales described in clauses 5 and 6. The gathering of subjective judgement should first be concerned with localized thermal sensations (parts of the body) and with wetting of the skin in constant conditions, given the current interest and application of these data. The second concern should be for data gathered under transient conditions, which are extremely important but are not yet sufficiently well known.

5 Perceptual, evaluation and preferential judgement scales

5.1 Instructions for using the judgement scales

The three judgement scales shall be applied in the following order: perceptual scale, evaluative scale, scale of preference. The combination of possible replies provides all the required information.

The following introductory questions shall be posed:

- before applying the perceptual scale: "How are you feeling (at this precise moment)?" (followed by the replies from the scale);
- after the response given on the perceptual scale, and immediately before applying the evaluative scale: "Do you find this...?" (followed by the replies from the scale);
- after the response given on the evaluative scale, and immediately before the application of the preference scale: "Please state how you would prefer to be now" (followed by the replies from the scale).

A 7-degree scale shall be applied in the case of environments judged to be temperate (close to thermal neutrality or slightly hot or cold); a 9-degree scale shall be applied in the case of environments judged to be more intensely hot or cold. A practical limit between the two categories of environment is suggested at $PMV = \pm 2$.

NOTE 4 It is recommended that the full scales be presented, even in cases of surroundings located only in the cold or in the warmth. The wording of all the degrees of a scale provides a frame of reference useful to those asked to verbalize their instantaneous thermal experience.

5.2 Scale of perception of the personal thermal state

5.2.1 Structure of the scale

A symmetrical 7-degree two-pole scale, which can be extended to 9 degrees, comprising a central indifference point and two times 3 (or 4) degrees of increasing intensity.

	Degrees (- 4) - 3 - 2 - 1 of intensity	Point 0 of indifference	Degrees + 1 + 2 + 3 (+ 4) of intensity	
Pole A				Pole B

5.2.2 Wording of the degrees

The poles A and B are either end of the scale from A = COLD to B = HOT. The central point of indifference corresponds to the ABSENCE OF HOT AND COLD.

The wording of the degrees will depend on the vocabulary choices in each language. The selection of the terms shall be carried out carefully and tested beforehand on a representative number of persons who are native speakers of the given language.

The following wordings shall be taken as an illustration:

- for languages which have several (at least two) distinct terms to denote different degrees of intensity for HOT and COLD, these terms will be used along the lines of English or Russian wording;
- for languages which do not have two terms for denoting different degrees of intensity for each of the poles, a single term will be used for each pole and its intensity modulated by the use of adverbs along the lines of French or Spanish wording.

Table A.1 gives examples for each case.

5.3 Evaluative scale

5.3.1 Structure of the scale

A 4-degree one-pole scale, which can be extended to 5 degrees, with a point of origin indicating the absence of the effect, and 3 (or 4) degrees of increasing intensity of the effect.

Point of	Degrees of	
0	1 2 3 (4)	Unique pole
origin	intensity	

5.3.2 Wording of the points

The unique pole devoted to the evaluation of the thermal load denotes a negative effect: DISPLEASURE, DISSATISFACTION or DISCOMFORT. Its intensity can be modulated by adverbs. COMFORT, located at the point of origin, and ABSENCE OF DISCOMFORT, are also classed as positive evaluations (pleasure, satisfaction).

NOTE 5 Table A.2 gives an example.

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5.4 Thermal preference scale

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5.4.1 Structure of the scale

A symmetrical 7-degree bipolar scale comprising a central point of indecision and two times 3 degrees of increasing intensity.

	Degrees	Point	Degrees	
Pole A	- 3 - 2 - 1	0	+ 1 + 2 + 3	Pole B
	of intensity	of indecision	of intensity	

5.4.2 Wording of the degrees

Poles A and B are at either end of the scale from A = COOLER to B = WARMER. The central point of indecision corresponds to the ABSENCE OF CHANGE.

The degrees shall be worded using for each pole a comparative term which can be modulated in intensity by means of adverbs. It is possible to reduce the three degrees of each of the poles to a single degree worded by means of an unmodulated comparative term.

NOTE 6 Table A.3 gives an example.

6 Personal acceptability statement and tolerance scale

6.1 General

In addition to the previous judgements, information shall be obtained indicating how the workers personally feel toward their thermal situation.

This assessment would be in terms of rejection or acceptance on a personal level, complemented in any case by a relative judgement of the degree of personal tolerance. Rejection or acceptance is expressed on a personal level, i.e. out of context, the judgement being based purely on personal preference. The expression of rejection on a personal level (unacceptability) is therefore not incompatible with actual acceptance, which takes into account other contextual motivations (instructions, job requirement, short duration of exposure, remuneration).

In contrast to the three preceding scales, the personal acceptability statement and the tolerance scale consist of judgements made about the thermal surroundings (local climate).

6.2 Instructions for using the judgement expression forms

The acceptability statement form and tolerance scale shall be applied after the perception and assessment scales described above, and shall be in the following order: acceptability statement form, then tolerance scale.

The following introductory questions shall be posed:

- before application of the acceptability statement form:
 - (a) in explicit terms: "How do you judge this environment (local climate) on a personal level?"
 - (b) with the initial statement: "Taking into account only your personal preference ..."
 - 1) either: "... would you rather accept this environment (local climate) than reject it?"
 - 2) or: "... would you rather reject this environment (local climate) than accept it?"

— before the application of the tolerance scale:

"Is it ...?"

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6.3 Description of the forms of judgement expression

6.3.1 Structure of the forms of judgement expression

The form of the personal acceptability statement will be a binary structure of the type:

PERSONAL ACCEPTANCE (GENERALLY ACCEPTABLE) — PERSONAL REJECTION (GENERALLY UNACCEPTABLE).

The personal tolerance scale will have a unipolar 5-degree structure, the single pole expressing DIFFICULTY IN TOLERATING, with a point of origin indicating no difficulty in tolerating and with 4 degrees of increasing difficulty in tolerating, the 4th degree expressing intolerable.

Point	Degrees	
0	1, 2, 3, 4	Unique pole
of origin	of intensity	

6.3.2 Wording of degrees

The wording of the two categories on the personal acceptability statement form may consist of:

- (a) either a clarification of the judgement of the person questioned:

Categories	Wording	Response
ACCEPTABLE	Environment (local climate) acceptable rather than unacceptable
UNACCEPTABLE	Environment (local climate) unacceptable rather than acceptable