Introduction to thermal comfort standards

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Abstract
The aim of this paper is to describe existing ISO standards and current activity concerned with thermal comfort. It describes how an ISO standard is produced from a new work item proposal (NP) to publication as an international standard (ISO). A framework is provided for the assessment of ISO standards and their revisions. Standards should be valid, reliable, useable, and with sufficient scope for practical application. The existing thermal comfort standard (ISO 7730) is considered in terms of these criteria as well as ISO 8996 (metabolic rate) and ISO 9920 (clothing). The consequences of inaccuracy in estimation of metabolic rate and clothing insulation show that 'reasonable estimates' can provide a range of thermal sensation predictions. The work of ISO/TC 159 SC5, 'Ergonomics of the physical environment', is presented in Appendix 1. Descriptions of ISO 7726 (instruments), ISO 10551 (subjective measures), ISO TS 13732 Part 2 (contact with surfaces at moderate temperature), ISO 14505 (vehicles), and ISO 14515 (people with special requirements) are described in Appendix 2.

Keywords: Standards, thermal comfort

Introduction
There are a number of national organizations whose standards have international influence and some make a contribution to the creation of knowledge of thermal comfort and the application of that knowledge. For a standard to be truly international however requires a co-ordination of countries and a process of common consent. The International Standards Organization (ISO) was set up in 1947 and has over 130 member countries. Its principles of a single representative organization from each country and a democratic system of voting support the notion of a democratic process of globalization and a fairly operating world market in a world economy. It is interesting that one of the major issues concerning thermal comfort is the apparent conflict between a so called 'western' approach, which attempts to 'seal' a building and control the internal environment to constant levels of air temperature appropriate to western behaviour and clothing, and an adaptive approach where people can adapt to a wider range of conditions that complement their culture and in hot (or even cold) climates are less energy demanding. The issue is more complex, however it demonstrates the advantage of international consensus over national trends and interests. That is, an international organization with democratic processes will allow a broad international perspective to be considered.

The aim of this paper is to provide an introduction to ISO standards concerned with thermal comfort. The standards are described in the context of the ISO system for standards production, existing ISO standards concerned with people in thermal environments, current thinking about future standards, and decisions that need to be made to bring thermal comfort standards into the 21st century. The paper is an introductory paper to the Conference and, in particular, provides background to the proposed revision of ISO 7730, which is described by Dr Bjarne Olesen later in this conference session.

How is an ISO standard produced?

ISO standards are produced by experts from participating countries (P - members) according to agreed rules and a system of voting. There is a six-stage process from the initial idea for a standard to its final publication. This is shown in Table 1.

Table 1: Six-stage process to the production of an International Standard (ISO)

Stage	Process	Document
1	New work item proposal (TC, SC, WG, national, regional, organization, individual)	New Proposal (NP) (Enquiry/Voting)
2	Building expert consensus (WG)	Working Document (WD)
3	Consensus building across countries (TC, SC, WG)	Committee Draft (CD) (Enquiry/Voting)
4	Integration of comments and preparation of Draft International Standard (WG)	Draft International Standard (DIS) (Enquiry/Voting)
5	Integration of editorial comments and preparation of Final Draft International Standard (WG)	Final Draft International Standard (FDIS) (Enquiry and Yes/No vote)
6	Preparation of International Standard (Secretariat)	International Standard (ISO)

Key:
WG = Working Group ISO/TC 159 SC5 WG1 *Ergonomics of the Thermal Environment*
Convener: Dr Bjarne Olesen, Denmark
SC = Sub-Committee ISO/TC 159 SC5 *Ergonomics of the Physical Environment*
Chairman: Professor Ken Parsons, UK; Secretariat BSI: Dr Sina Talal
TC = Technical Committee ISO/TC 159 *Ergonomics*
Chairman: Wolfgang Schultetus, Germany; Secretariat DIN: Norbert Breutmann

A thermal comfort standard is proposed (by a working group, committee or other) and supported by a document that explains the requirement, the rationale and the scope of the proposed standard. The sub-committee (ISO/TC 159 SC5) then considers the proposal and submits it for international voting. On acceptance and an indication that sufficient (≥ 5) member countries will participate in the work, the sub-committee allocates the work to a working group (ISO/TC 159 SC5 WG1). The working group identifies a project leader who develops working documents with advice and comments from the international experts under the guidance and co-ordination of the convener. A proposal to revise a standard would also be considered as a new proposal. All standards are reviewed every five years and, in the case of ISO 7730, it was considered that significant developments had taken place since its adoption and that a revision was required. The work was allocated by ISO/TC 159 SC5 to its working group on thermal environments (ISO/TC 159 SC5 WG1) with Dr Bjarne Olesen as project leader. Working documents have been produced and discussed at meetings in Paris, Yokohama, Barcelona, Copenhagen and London. The document is now proposed as a Committee Draft (ISO CD 7730). It is important at this stage to have full international discussion about technical content so that the draft standard can be modified to allow consensus (approval of two thirds of the P members voting).

The Committee Draft (ISO CD 7730) is circulated to member countries who will circulate it within their country and provide comments and a vote. Five months is allowed for voting, providing a deadline of around July 2001 for ISO CD 7730. If accepted, the working group (ISO/TC 159 SC5 WG1) will respond to comments and revise the document accordingly. It is likely that this will take place during the working group meeting in Naples, September 2001. A Draft International Standard (ISO DIS 7730) will then be produced, circulated for voting and comments, and revised to form a Final Draft International Standard (ISO FDIS 7730). This will be subjected to a Yes/No vote and, if accepted, published as ISO 7730, probably in 2003.

ISO Standards: Ergonomics of the Physical Environment

The following describes the current ISO Ergonomics standards and activity concerned with thermal comfort. For more detail on Ergonomics and standardization the reader is referred to a Special Issue of the journal, Applied Ergonomics – Vol. 26, No 4, August 1995.

International Standards in Ergonomics have been developed since 1974 when ISO/TC 159 was established at the request of the International Ergonomics Association (IEA). Sub-committee ISO/TC 159 SC5 *Ergonomics of the Physical Environment* was established at the same time and is responsible for over 30 work items which are requests, by international voting, to produce a standard. The sub-committee has three working groups that develop the standards. These are concerned with thermal environments, lighting and danger signals and communication in noisy environments. Countries involved are Australia, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, Netherlands, Poland, Slovakia, Sweden, Thailand, UK, and USA. Some countries are more active than others, with some taking an observer role. A list of published standards and current work is provided in Appendix 1.

Standards concerned with thermal comfort are produced by ISO/TC 159 SC5 WG1. The main thermal comfort standard is ISO 7730 which is based upon the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) thermal comfort indices (Fanger, 1970). It also provides methods for the assessment of local discomfort caused by draughts, asymmetric radiation and temperature gradients. Other thermal comfort standards include a technical specification, thermal comfort for people with special requirements (ISO TS 14415), responses on contact with surfaces at moderate temperature (ISO 13732, Part 2), and thermal comfort in vehicles (ISO 14505, Parts 1 to 4). Standards that support thermal comfort assessment include ISO 7726 (measuring instruments), ISO 8996 (estimate of metabolic heat production), ISO 9920 (estimation of clothing properties), and ISO 10551 (subjective assessment methods).

Present position and future options for ISO thermal comfort standards

ISO thermal comfort standards should provide the best internationally agreed methods and data available. They can be judged on a number of criteria as discussed by Parsons (in Delleman *et al*, 2000). ISO standards should be **valid**, **reliable** and **useable** with sufficient **scope** for practical application.

- **Validity** is concerned with whether the assessment method or prediction accurately represents the phenomenon of interest. For example, does an index that predicts thermal comfort accurately predict the thermal comfort perceived by people?
- **Reliability** is concerned with whether a standard used to assess thermal comfort would give the same prediction if repeatedly used to assess exactly the same conditions. If a procedure is ambiguous or non-specific (where to measure, what to measure, when to measure, etc.), it will reduce reliability. Note that reliability does not imply validity but validity *does* imply reliability.
- **Usability** is concerned with whether the users of a standard can use it correctly. A standard may be valid and reliable but if it is not presented such that the users can use it, it will be limited in its application.

There are, of course, other criteria for assessing measurement methods (e.g. sensitivity - the standard needs to be able to distinguish between conditions of interest where a practical difference exists), however the three criteria above will be considered in this paper. Thermal comfort standards can therefore be judged in terms of the above criteria, as can revisions of standards. Criticisms and future options for standards can also be considered in terms of these criteria.

ISO 7730 Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort

This standard describes the PMV (Predicted Mean Vote) and PPD (Predicted Percentage Dissatisfied) indices and specifies acceptable conditions for thermal comfort. The PMV predicts the mean value of the votes of a large group of people on the ISO thermal sensation scale (+3 = hot; +2 = warm; +1 = slightly warm; 0 = neutral; -1 = slightly cool; -2 = cool; -3 = cold). The PPD predicts the percentage of a large group of people likely to feel 'too warm' or 'too cool'. The indices are exactly as described by Fanger (1970). A draft rating index is provided in the standard as an equation involving air temperature, air velocity and turbulence intensity. It is applicable to mainly sedentary people wearing light clothing with a whole-body thermal sensation close to neutral. Recommended thermal comfort requirements are provided in Annex D of the standard (informative – not a formal part of the standard). This includes optimum operative temperature; vertical air temperature gradient; mean air velocity; floor temperature; and relative humidity.

ISO 7730: Validity

The PMV/PPD indices have been extensively investigated throughout the world and mostly in terms of validity. Does the PMV accurately predict the Actual Mean Vote (AMV) of people? Empirical research has led to mixed results and discussion of interpretation. Laboratory studies have often supported the validity of ISO 7730 whereas field studies have not. However, the interpretation of results often involves discussion of the sensitivity of the method to estimates of variables such as metabolic heat and clothing insulation which are difficult to estimate and, in practical situations (along with the other parameters), often vary. Other issues are concerned with the sensitivity of the method. How well can the method distinguish between comfort conditions? How well does it need to? If we achieve statistical significance between

AMV and PMV of 0.1 of a scale value, does this have practical significance? Practical significance will depend upon context, but what difference between AMV and PMV would encourage standards makers to revise the standard on the grounds of validity?

ISO 7730 has been criticised because of its lack of theoretical validity. The PMV/PPD indices were established in 1970. Since then there have been improvements to the human heat balance equation. There are also dynamic models of human thermoregulation that offer more accurate representations of physiological measures such as mean skin temperature and sweat rate. The prediction of sensation away from neutrality (towards warm or cool) is based upon the principle of thermal load. This has been criticised (Humphreys and Nicol, 1996). A more valid approach may be to predict deviation from neutrality using predictions of body state, such as skin temperature, sweat rate, or skin wettedness (Gagge *et al*., 1971). The question for the standards maker is do these limitations have practical significance?

Related to the validity of ISO 7730 is the validity of ISO 8996 – metabolic rate – and ISO 9920 – clothing. The estimation of metabolic heat production and clothing insulation (two parameters to which the PMV is particularly sensitive) and other properties are difficult, especially when considering practical, dynamic contexts. This raises the question as to whether a valid rational thermal index or model is possible. Why continue to improve the heat balance equation or develop thermal models when the complexity of 'reality' will undermine any improvement? The adaptive model of thermal comfort has questioned validity and this is also related to scope. The question of validity is related to how well the methods in the standard (PMV, etc.) relate to the actual thermal comfort responses of people. If people change their thermal comfort response with prevailing outside climatic conditions (for exactly the same clothing, activity and indoor climate) the standard will not respond to this and it will have reduced validity. If different populations and cultures differ in thermal comfort responses (to identical clothing, activity and indoor climate) then the standard will have reduced validity for some populations. If the standard does not include those populations in its scope (e.g. people from Africa, Asia, etc.) then the standard may be valid but should it be accepted as a universal international standard?

ISO 7730: Reliability

Defining the PMV/PPD in an international standard provides the major advantage of ensuring that when it is calculated anywhere in the world the same result will be obtained. However, if two assessments were made of identical conditions, by different users, or the same user on a different occasion, identical outcomes may not be achieved. Methods for estimating metabolic rate (ISO 8996), clothing insulation (ISO 9920), and environmental parameters (ISO 7726) will influence reliability as will ambiguities in the standard about where and when to assess the environment.

ISO 7730: Usability

It is not clear who the users of ISO 7730 are intended to be and this clouds a discussion of usability. However it is probably reasonable to assume that those involved in environmental design and assessment, building services, engineering and ergonomics would be users. The PMV/PPD indices provide clear predictions of likely discomfort and dissatisfaction. It could be argued however that exactly how to measure or estimate input parameters for the model are technical and not exact.

Examples, in an annex to the standard, of how it can be used would aid usability. Usability testing where groups of users were observed using the standard and feedback provided would also improve the usability of the standard.

ISO 7730: Scope

The scope of a standard is concerned with to what it does and does not apply. ISO 7730 can be considered in terms of to whom it applies and over what range of environmental conditions. The PMV/PPD index was developed using North American and European people. The standard notes that deviations may occur due to ethnic and national-geographic deviations and for people who are sick or disabled. It applies to healthy men and women. Children are not considered. The standard applies to indoor environments where steady state thermal comfort or moderate deviations from comfort occur. This allows for interpretation and judgement. Does the standard apply to environments where conditions vary? Can the PMV index be used as an adaptive model as it can account for changes in clothing, activity, posture and environmental conditions? The draught rating model is limited in scope to a narrow range of conditions and for people in thermal neutrality. People who are hot or cold may respond differently from the predictions of the draught rating model.

ISO 8996 Ergonomics – Determination of metabolic heat production

This standard describes six methods for estimating metabolic heat production, an essential requirement in the use of ISO 7730 and the assessment of thermal comfort. The methods are divided into three levels according to accuracy. Level I provides tables of estimates of metabolic rate (assumed identical to metabolic heat production) for kinds of activity and occupation. This is 'rough information where the risk of error is great'. Level II presents tables of estimated metabolic rate based upon group assessment, specific activities, and measurement of heart rate. This is 'High error risk – accuracy ± 15%'. The most accurate measure (± 5%) is a method of estimating metabolic rate by analysis of expired 'air' from the lungs (indirect calorimetry). The principle is that energy is produced from burning food in oxygen. Comparison of the oxygen content of expired air (collected in a Douglas bag or other method – a typical value will be around 16% to 18%) with that of inspired air (20%) provides the rate of oxygen used by the body. With adjustments for type of combustion (from CO_2 output) temperature and pressure, the metabolic rate can be derived from the calorific value of food. The units are presented as Watts per square metre of the body surface of a standard person (70 Kg, 1.8 m^2 male; 60 Kg, 1.6 m^2 female). For an activity, such as walking up hill, the weight of the person will be important and adjustments may need to be made.

The **validity** of ISO 8996 is, in principle, high as oxygen consumption clearly relates to energy production. However, there are limitations. How metabolic rate relates to heat production for a given activity is not clear. Heart rate is affected by a number of factors (including psychological) as well as metabolic rate. The accuracy presented is an estimate and is not justified. The use and calibration of instrumentation in indirect calorimetry is important and the estimation of metabolic heat production from tables is applicable to the context and population measured in the production of the tables. This will reduce **reliability**. There are also limitations to **scope** (e.g. to which populations does the standard apply?) and **usability** (who are the intended users and can they use it as intended?). Despite the limitations, ISO 8996 probably provides the best available methods and data. The importance of the estimate of metabolic rate can be demonstrated in an example calculation of the PMV for conditions: air temperature (t_a) = mean radiant temperature (t_r) = 24 °C; partial vapour pressure (Pa) = 1000 Pa; air velocity (v) = 0.15 ms^{-1}; clothing insulation 1.0 Clo; and metabolic rate estimate of 100 Wm^{-2} provides a PMV = 0.9. However with a 15% accuracy adjustment, a metabolic rate value of 85 Wm^{-2} provides PMV = 0.7 and 115 Wm^{-2}, PMV = 1.1.

ISO 9920 Ergonomics of the thermal environment – Estimation of the thermal insulation and evaporative resistance of a clothing ensemble

ISO 9920 provides an extensive database of the thermal properties of clothing and garments. The properties are based upon measurements on heated manikins where basic (or intrinsic) thermal insulation is measured as well as vapour permeation properties of garments and ensembles. The major question of **validity** is therefore whether measurements on manikins represent the 'true dynamic' properties of clothing as worn by people. Although the influence of air penetration (and pumping) is discussed it is not sufficiently quantified in detail. The **scope** of the standard excludes the effects of absorption of water, buffering, textile comfort, rain, snow, and special protective clothing such as heated clothing. It also, 'does not deal with the separate insulation on different parts of the body and discomfort due to the asymmetry of a clothing ensemble'. The **reliability** of the manikin measures is generally considered to be high for repeated measures on the same manikin. However results may vary between manikins. How well a clothing ensemble of interest can be matched with values in the database is debatable. This is also relevant to **usability**. Another issue of usability is whether users have sufficient training in how to interpret and use the information provided.

It is important to have a view of how accurately the standard can predict clothing insulation properties. No guidance is provided on this. If we assume around ± 15% accuracy and combine it with metabolic rate (± 15% accuracy) the results in Table 2 show how the PMV/PPD indices vary for sitting at rest in a business suit and light activity in a business suit. It can be seen that predictions of discomfort will vary within the accuracy of metabolic rate and clothing insulation estimates. Inaccuracies in estimates of environmental variables will increase this uncertainty.

Table 2: The influence of accuracy of estimate of metabolic rate and clothing insulation on PMV and PPD values

$t_a = t_r$ = 24 °C; Pa = 1000 Pa; v = 0.15 ms^{-1}			
M Wm^{-2}	Clo m^2 °C W^{-1}	PMV	PPD %
50	0.130	-1.0	27.7
58	0.155	0.0	5.0
66	0.180	0.4	8.8
85	0.130	0.5	10.5
100	0.155	0.9	22.6
115	0.180	1.2	36.4

References

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Humphreys, M A and Nicol, J F (1996), Conflicting criteria for thermal sensation within the Fanger Predicted Mean Vote equation. Proceedings of CIBSE/ASHRAE Joint National Conference, Harrogate, UK, 29th September – 1st October 1996

Appendix 1

ISO TC 159 SC5 - Ergonomics of the Physical Environment: Summary of work

ISO TC159 SC5 produces international standards in the area of the Ergonomics of the physical environment. As this has a wide scope and standards are produced in other areas of standardization (e.g. vibration) within ergonomics this has been confined to thermal environments (WG1), lighting (WG2) and danger signals and communication in noisy environments (WG3). Working Group 1 produces standards concerned with heat stress, cold stress and thermal comfort as well as supporting standards concerned with the thermal properties of clothing and metabolic heat production due to activity. It also considers physiological measures, skin reaction to contact with hot, moderate and cold surfaces and thermal comfort requirements for people with special requirements. Working Group 2 is concerned with the ergonomics of lighting and is strongly guided by the international lighting commission (CIE). Working Group 3 considers communication in noisy environments including warning and danger signals and speech. Recent new work items have included the effects of combined stress environments and also the performance of glazing in terms of visual and thermal comfort.

Published Standards and Standards in development

- ISO 7243: 1995 Hot environments - Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature).
- ISO 7726: 1998, Thermal environments - Instruments and methods for measuring physical quantities.
- ISO 7730: 1994, Moderate thermal environments - Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.
- ISO 7731: 1986, Danger signals for workplaces - auditory danger signals.
- ISO 7933: 1989, Hot environments - Analytical determination and interpretation of thermal stress using calculation of required sweat rate.
- ISO 8995: 1989, Principles of visual ergonomics - The lighting of indoor work systems.
- ISO 8996: 1990, Ergonomics - Determination of metabolic heat production.
- ISO 9886: 1992, Evaluation of thermal strain by physiological measurements.
- ISO 9920: 1995, Ergonomics of the thermal environment - Estimation of the thermal insulation and evaporative resistance of a clothing ensemble.
- ISO 9921-1: 1996, Ergonomic assessment of speech communication. Part 1: Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method).
- ISO 10551: 1995, Ergonomics of the thermal environment - Assessment of the influence of the thermal environment using subjective judgement scales.
- ISO 11399: 1995, Ergonomics of the thermal environment - Principles and application of international standards.
- ISO 11428: 1994, Ergonomics - Visual danger signals - general requirements, design and testing.
- ISO 11429: 1994, Ergonomics - System of danger and non-danger signals with sound and light.

Technical Reports

- ISO TR 11079 (Technical Report): 1993, Evaluation of cold environments - Determination of required clothing insulation, IREQ.

Current work programme

Ergonomics of the thermal environment - ISO TC 159 SC5 WG1

- ISO 15742 Ergonomics of the Physical Environment - Combined effects of thermal environment, air pollution, acoustics and illumination.
- Revision of ISO 7933: 1989, Hot environments - Analytical determination and interpretation of thermal stress using calculation of required sweat rate.
- Revision of ISO 8996: 1990, Ergonomics - Determination of metabolic heat production.
- Revision of ISO 9886: 1992, Evaluation of thermal strain by physiological measurements.
- Revision of ISO 7730: 1993, Moderate thermal environments - Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.
- Revision of ISO TR 11079 (Technical Report): 1993 to an International Standard. Evaluation of cold environments - Determination of required clothing insulation, IREQ.
- ISO DIS 11371 Ergonomics of the thermal environment - vocabulary and symbols.
- ISO DIS 12894: 1993, Ergonomics of the thermal environment - medical supervision of individuals exposed to hot or cold environments.
- ISO/ NP 13732 Part 1. Ergonomics of the thermal environment - methods for the assessment of human responses to contact with surfaces. Part 1: Hot surfaces.
- ISO CD 13732 Part 2. Ergonomics of the thermal environment - methods for the assessment of human responses to contact with surfaces. Part 2: Moderate surfaces.
- ISO/NP 13732 Part 3. Ergonomics of the thermal environment - methods for the assessment of human responses to contact with surfaces. Part 3: Cold surfaces.
- ISO NP 14405: Ergonomics of the thermal environment - Evaluation of the thermal environment in vehicles.
- ISO NP 14415: Ergonomics of the thermal environment - Application of international standards to the disabled, the aged and other handicapped persons.
- ISO NP 15265: Ergonomics of the thermal environment - Risk of stress or discomfort.
- ISO NP 15743: Ergonomics of the thermal environment - Working practices for cold indoor environments.

Lighting - ISO TC 159 SC5 WG2

- Revision of ISO 8995, 1989: Principles of Visual ergonomics - The lighting of indoor work systems.

Danger signals and communication in noisy environments - ISO TC 159 SC5 WG3

- ISO 9921: Ergonomic assessment of speech communication in noisy environments - revision of Part 1 and to include Parts 0, 2 and 3. Principles, criteria, prediction and assessment.
- Revision of ISO 7731: 1986, Danger signals for workplaces - auditory danger signals.

Appendix 2

ISO 7726: Thermal environments – instruments and methods for measuring physical quantities

ISO 7726 provides a specification of instruments for measuring the thermal environment. The environmental measures are used in the thermal comfort assessment method (e.g. ISO 7730). The required accuracy of the measures is provided as well as the operating range and response time of the measuring instruments. Descriptions of instruments, principles of the measurement and practical precautions are described. Naturally, the accuracy of the environmental measures as well as practical issues of where and when to measure the environment will contribute to the effectiveness of any thermal comfort assessment.

ISO 10551: Ergonomics of the thermal environment – Assessment of the influence of the thermal environment using subjective judgement scales

If thermal comfort is a psychological phenomenon, then it is most accurately assessed using subjective judgements. Where the population of interest is available or to complement the analysis of ISO 7730, subjective assessment scales can be used to assess thermal comfort. ISO 10551 presents the principles and methodology behind the construction and use of subjective scales. Five types of scale are presented: perceptual, affective, preference, acceptance, and tolerance.

ISO TS 13732: Methods for the assessment of human response to contact with surfaces - Part 2: Human contact with surfaces at moderate temperature

Where the skin is in contact with solid surfaces at moderate temperature (around 10 to 40 °C) people will feel a sensation from hot to cold which will influence thermal comfort responses. ISO TS 13732 Part 2 (Parts 1 and 3 cover hot and cold surfaces respectively) is a technical specification (not a full standard but a preliminary version, due to uncertainty in the data or method, which may become a future standard) that 'presents principles and methods for predicting the thermal sensation and degree of discomfort for people where parts of the body are in contact with solid surfaces at moderate surface temperatures'. Responses to contact with the feet (heated floors) and hands are considered in detail.

ISO 14505 Parts 1 to 4: Ergonomics of the thermal environment: Thermal comfort in vehicles

This proposed four part standard is under development. It is primarily concerned with the assessment of thermal comfort in vehicles. Part 1 presents the principles and methods of assessment and considers the applicability of other thermal comfort standards to vehicle environments. Part 2 is concerned with the determination of the

Equivalent Temperature Index as an appropriate thermal comfort index for vehicles. Part 3 will be concerned with the use of thermal manikins to assess the thermal comfort in vehicles and Part 4 will be concerned with the use of human participants to assess thermal comfort in vehicles.

ISO 14415: Ergonomics of the thermal environment: The application of International Standards for people with special requirements

This standard (under development) considers the thermal comfort requirements for people with disabilities, illness, pregnancy, the aged, and other persons with special requirements. It considers the effects of sensory impairment and paralysis, body shape, impairment of sweat secretion and vasomotor control and metabolic rate. Hot, moderate, and cold environments are considered, as is the applicability of current international standards.