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

Part 3: Evaluation of thermal comfort using human subjects

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

Partie 3: Évaluation du confort thermique en ayant recours à des sujets humains

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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 14505-3 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

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

— *Part 1: Principles and methods for assessment of thermal stress*

— *Part 2: Determination of equivalent temperature*

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

Introduction

Direct methods for the assessment of thermal environments (hot, moderate, cold) in vehicles involve measurements of the responses of human subjects. There are three types: subjective methods, objective methods, and behavioural methods. *Subjective methods* quantify the responses of people to an environment using subjective scales. *Objective methods* are those which quantify the physical, physiological or mental condition of a person by the use of instrumentation or measures of an output such as performance measures. *Behavioural methods* quantify or represent human behaviour in response to an environment. Each of these methods has been developed according to basic principles and the most appropriate form of the method and combination of methods used in concert for the assessment of thermal environments in vehicles will depend upon the context and vehicle environment of interest. This part of ISO 14505 provides both principles and application of methods for the assessment of thermal comfort in vehicle environments using human subjects. The most appropriate methods for evaluating thermal comfort in vehicles are subjective. The principles for the construction of subjective assessment scales are given in ISO 10551 and are used in the development of the test method specified in this part of ISO 14505. Physiological measurements on human subjects are described in ISO 9886 and are beyond the scope of this part of ISO 14505.

This part of ISO 14505 complements standards concerned with the ergonomics of thermal environments and in particular can be used together with thermal indices that are valid for use in vehicle environments.

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

Part 3: Evaluation of thermal comfort using human subjects

1 Scope

This part of ISO 14505 gives guidelines and specifies a standard test method for the assessment, using human subjects, of thermal comfort in vehicles. It is not restricted to any particular vehicle but provides the general principles that allow assessment and evaluation. The method can be used to determine a measure of the performance of a vehicle for conditions of interest, in terms of whether it provides thermal comfort to people or not. This can be used in vehicle development and evaluation.

This part of ISO 14505 is applicable to all types of vehicles, including cars, buses, trucks, off-road vehicles, trains, aircraft, ships, submarines, and to the cabins of cranes and similar spaces. It applies where people are enclosed in a vehicle and when they are exposed to outside conditions. For those exposed to outside conditions, such as riders of bicycles or motorcycles, drivers of open sports cars and operators of fork lift trucks without cabins, vehicle speed and weather conditions can dominate responses. The principles of assessment, however, will still apply.

This part of ISO 14505 applies to both passengers and operators of vehicles where its application does not interfere with the safe operation of the vehicle.

It presents the principles of the assessment and evaluation of thermal comfort, including the use of test methods and trials. It also presents subjective methods that can be used in assessment.

This part of ISO 14505 is a basic ergonomics standard which can contribute to the development of standards concerned with specific vehicles and products.

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 12894, *Ergonomics of the thermal environment — Medical supervision of individuals exposed to extreme hot or cold environments*

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 the body heat exchange is just equal to, or too large for, heat balance at the expense of significant physiological strain that sometimes cannot be compensated

3.2
equivalent temperature
temperature of a homogenous "room", 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

3.3
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 physiological strain that sometimes cannot be compensated

3.4
HVAC-system
heating, ventilation and air-conditioning system of the vehicle/cabin

3.5
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

3.6
thermal asymmetry
degree to which opposite parts of the human body are exposed to different climatic conditions

3.7
thermoneutral zone
temperature interval within which the body maintains heat balance exclusively by vasomotor reactions

4 Assessment of vehicle environments using human subjects

Although mathematical and physical models and thermal indices can provide repeatable, reliable methods of assessment, vehicle environments are often complex, dynamic and influenced by many factors. Models and indices are therefore often limited in validity. Human subjects are required to provide a direct means of measuring thermal comfort and to validate other techniques. It is important, therefore, to develop assessment methods involving human subjects. Such methods shall only be used where ethical considerations and accepted practices involving human subjects, as provided in ISO 12894, have been carried out. They are used for one of four main reasons:

— to evaluate thermal comfort in vehicle environments;

— to set up or carry out standardized test methods of thermal comfort in vehicles;

— to compare measures of thermal comfort in vehicles with prediction methods (models, indices) based upon measures of the thermal environment in vehicles;

— to determine the relationship between objective measures, such as skin temperatures, and subjective measures of thermal comfort.

5 Principles of assessment

5.1 Subjective methods

Subjective methods quantify the response of people to an environment using subjective scales. Such scales are based upon psychological continua (or constructs) that are relevant to the psychological phenomenon of interest. It is important to know the properties of the scales in order to correctly interpret the results. Scales of thermal sensation (hot or cold), preference, comfort, and stickiness are often used in thermal comfort assessment. Advantages of subjective methods are that they are simple to administer and are directly related to the psychological phenomenon. Disadvantages are that they can interfere with what they are measuring, some groups may not be able to perform the subjective task (for example, babies, children, people with disabilities) and there is no reason given as to why such a response is provided. ISO 10551 should be used for guidance on the construction of subjective scales. Five types of scales are identified. These are: Perceptual (How do you feel now? e.g. hot); Affective (How do you find it? e.g. comfortable); Preference (How would you prefer to be? e.g. cooler); Acceptance (acceptable/unacceptable); Tolerance (Is the environment tolerable?). From these basic subjective dimensions, questionnaires of subjective scales can be developed. The subjective assessment methods presented in this part of ISO 14505 are concerned with thermal comfort and therefore do not consider “tolerance”.

5.2 Objective methods

Objective methods are those which quantify the physical or mental condition of a person by the use of instrumentation or measures of an output such as performance measures. The principle of the method is that the measure can be interpreted in terms of the human condition of interest (e.g. thermal comfort). An example would be the measurement of mean skin temperature of the body that would vary with the thermoregulatory response to heat and cold (providing a rationale for the method) and that has been shown in research to correlate with subjective responses of comfort. Another example would be skin wetness. Disadvantages of objective methods can be that they might interfere with what they are attempting to measure, the correlation between the measure and thermal comfort is not perfect and that thermal comfort is a psychological phenomenon, a condition of mind. An advantage of objective measures is that they are often independent of, and can be used to complement, the results of other methods such as subjective measures. ISO 9886 should be used to provide methods for measurement and interpretation of physiological strain in terms of body core temperature, mean skin temperature, heart rate and body mass loss. Other measures, such as heart rate variability, may also be relevant.

5.3 Behavioural methods

Behavioural methods quantify or represent human behaviour in response to an environment. The particular aspect of human behaviour observed is related to the human condition of interest (for example, thermal comfort in vehicles) and a method of interpretation is required. Examples would include changes in posture, movement patterns (for example, away from uncomfortable environments), and popularity of sitting positions(for example, if some seats were in a cold draught they would be occupied “last”). Advantages of behavioural methods include minimum interference with what is being measured and a direct “active” measure of discomfort. Disadvantages include the difficulty in establishing validity and reliability of the method and direct interpretation of the results in terms of thermal comfort. For example, a change in posture could be due to chair discomfort or other “non-thermal” reasons.

5.4 Assessment of thermal comfort

Thermal comfort assessment is most effectively carried out using subjective methods. This is because comfort is a psychological phenomenon and a subjective rating provides a direct and quantifiable method. The simple test method provided in this part of ISO 14505 therefore uses subjective methods. Both objective and behavioural methods can be used to complement the test method provided, however, they would require expert advice beyond the scope of this part of ISO 14505.

6 Design of human subject trials

6.1 Aim of trial

The design of any vehicle test or trial using human subjects will depend upon the specific aims of that test or trial. However, there are general principles and these are outlined below.

A typical thermal comfort trial involves driving vehicles over a route and measuring operating conditions and thermal responses of passengers. For specific investigations, simulators are often used.

An optimum trial design will achieve its aim with efficient use of resources. To achieve this it is important to be clear about the specific aim or aims. For example, if the aim is to compare three types of vehicle seats for thermal comfort then a repeated measures design, where all subjects sit on all seats (in a balanced order) in identical conditions, could provide the best comparison of the seats. Contrast this with the evaluation of a thermal comfort index where a wide range of environmental conditions, including seats, can be optimum. If both aims need to be met then it is essential that both types of requirement are met in the design. It is necessary, therefore, to be specific about the aims of the trial.

6.2 Selection of human subjects

A valid method of evaluating environments would be to use a panel of experts. This technique is used in wine tasting, for example, where acknowledged experts give opinions concerning the quality of wines. This technique depends upon identifying unbiased acknowledged experts. This is not possible in the area of thermal comfort and the trial designs should specifically avoid bias.

It is usual to identify a “random” sample of human subjects as representative of the population of interest. This is a question of statistical sampling, and relevant factors such as age, gender, driving experience and anthropometry could be identified and influence subject selection. The number of subjects selected will depend upon the aim and experimental design. A calculation can be made based upon the power of a statistical test; i.e. the probability of accepting the alternative hypothesis (for example, vehicle A is more comfortable than vehicle B), given that it is true. This is a rather academic approach and requires assumptions to be made about the strength of effect expected which is rather circular, as this is an objective of the trial. Of practical importance will be the allocation of subjects to treatments. If there are three cars and three types of glazing being compared (i.e. nine conditions) then nine subjects would allow a 9×9 Latin square design. That is where each subject is exposed to each condition in a different, balanced, order. A repeated measures design is where all subjects are exposed to all conditions. It is generally considered that, for normally distributed responses, increasing the number of subjects provides a diminishing return in terms of a sample representing a population. Numbers of eight or more are often considered as an acceptable sample size. It is also useful to consider approximate probability. For example, if two vehicles were compared by four subjects then the probability of all four subjects preferring vehicle A to vehicle B due to chance (when there is actually no difference in comfort between the vehicles) is 1/2 to the power of 4 = 1/16 = 6,25 %. So four subjects would not be sufficient to make a decision at a 5 % level even in the case of an extreme result.

An example of practical significance is whether the testers would be satisfied that if all their subjects preferred A to B then this would be considered sufficient evidence that A is more comfortable than B. It is useful, therefore, to estimate how many subjects it would take for practical significance to be established. It may be that statistical significance can be established with the use of large groups of subjects, but the effect could be small and not of practical significance. The above provides practical guidance, whereas a more rigorous statistical approach can be taken in any particular test; nevertheless, the “rules of thumb” above can be useful.

6.3 Measurement of subject responses

6.3.1 General

The responses of the subjects that will be measured will be selected according to the aims of the trial. Typically subjective responses are taken to quantify thermal comfort. Objective measures are sometimes used, mainly mean skin temperature (and sometimes sweat loss), to complement subjective measures. In a novel situation, subjective scales should be established from “first principles” by establishing subjective continua using psychological techniques. Subjective scales for assessing thermal comfort have, however, become established. Examples are provided below. It is important to note that the way in which a scale is presented and administered can influence results. A single-sheet questionnaire, for example, could be preferable to a number of pages. The exact question asked should be established.

The frequency of completion of the questionnaire must be balanced with the overall experimental aim of design. Translation of scales (from English, for example) as well as cultural aspects of the subject sample will be issues. Knowledge of the previous ratings or of other subjects' responses is not normally provided. Subject training and pilot trials will be necessary. Some scales are used for ratings of overall "comfort" as well as for areas of the body. The following scales have been developed from the guidance provided in ISO 10551.

6.3.2 Subjective scales

a) Thermal sensation scale

"Please rate on the following scale how YOU feel NOW":

+3 Hot

+2 Warm

+1 Slightly warm

0 Neutral

−1 Slightly cool

−2 Cool

−3 Cold

This scale corresponds to the ISO sensation scale. It is useful to use the standard scales, as results can be compared directly with International Standards assessments as well as with the results of other studies. The emphasis to the subject is how *YOU* (himself or herself — not another person or a general view of the group) feels (how the person actually feels, not how the environment seems to be) *NOW* (at that time). The form of the scale is in discrete intervals, although, by joining with a line a continuous form of the scale can be used; for example, a rating between 1 and 2 (indicated by a mark on the line between 1 and 2) would indicate that the subject felt between "slightly warm" and "warm" and this would be given a numerical value, for example, 1.3. Continuous forms also apply to the scales below. An extension of the scale, if required, would be to use the terms "very hot" and "extremely hot" (or "very cold" and "extremely cold").

b) "Uncomfortable" scale

3 Very uncomfortable

2 Uncomfortable

1 Slightly uncomfortable

0 Not uncomfortable

c) Stickiness scale

3 Very sticky

2 Sticky

1 Slightly sticky

0 Not sticky

Scales b) and c) have a similar form with an absence of effect at the base of the scale and increasing strength of effect up the scale. An important point is that a consistent word — uncomfortable or sticky — is used for each rating. This presents the specific psychological continuum as well as ensuring that the scale is unidimensional. “Uncomfortable” is a negative effect of the environment as is “stickiness”. It is unlikely that the scales are independent dimensions and they should be used to complement each other. It may be that people can be slightly warm and not uncomfortable but it is unlikely that a sedentary, clothed subject would feel cold, very sticky, and not uncomfortable.

d) Preference scale

“Please rate on the following scale how YOU would like to be NOW”:

+3 Much warmer

+2 Warmer

+1 Slightly warmer

0 No change

−1 Slightly cooler

−2 Cooler

−3 Much cooler

Preference scales are used in assessment as they provide a “value” judgement from subjects. If a subject rates a sensation of “slightly warm”, for example, it does not indicate whether or not he or she *wishes* to be “slightly warm”. The preference rating compares how the subject *is*, with how he or she would *like* to be. No change will indicate a form of acceptability, preference and satisfaction.

Other scales can be useful depending upon the aims of the experiment. If a percentage of satisfaction is required then a “forced” (the subject must choose) yes or no response to “Are you satisfied?” would give a direct measure. Ratings of pleasure could be of interest. These can be confounded with visual stimuli (for example, driving through the countryside on a sunny day) but solar radiation can elicit pleasant and unpleasant thermal responses and should be taken into account. Ratings of acceptability will be useful to vehicle manufacturers. They require a sophisticated judgement based upon what a subject would feel is acceptable in that context. A combination of scales integrated into a questionnaire provides a useful measurement tool. The scales will complement each other and give a detailed profile of thermal comfort. Subjective ratings from individual parts of the body will provide some indication of why subjects gave their “overall” rating.

6.4 Selection of operating conditions

The operating conditions used will determine the environments that are assessed for comfort. In vehicle trials it would be difficult to create identical operating conditions from day to day. When using a traditional experimental design (for example, comparison of vehicles, vehicle seats or glazing types) then this will be necessary. This might only be possible in climatic chambers, although there are parts of the world where consistent weather conditions prevail. If consistent conditions are required, it is important to remember that vehicle HVAC-system settings, starting conditions, time of day, solar direction, and subjects’ clothing should all be controlled. In field trials where it is more difficult to control experimental variables, it is very important that the experimenter is vigilant in identifying influencing factors and controlling what he or she can control. It is also important to make a note of any extraneous factors or loss of control for later consideration of their influence. If the aim of the vehicle trial is to evaluate a thermal comfort model, then an appropriate range of conditions should be investigated. If specific products are being evaluated, then the operating conditions and their order of presentation to subjects will be determined by practical issues (for example, changing glass in a vehicle) as well as the repeated measures design, using a Latin square, for example. The integration of subject numbers, measurements and operating conditions (to achieve an aim), along with available resources and cost, will determine the overall experimental design. Although the results are not known, it is useful to draw empty graphs of data that will be obtained and ensure that relevant data will be collected, the aim achieved and decisions made.

6.5 Analysis and interpretation of results

It is useful to present the results in graphic and tabular form. This should include individual subject and average data for each measure of interest. Analysis of results is concerned with answering questions. (For example, is thermal comfort in vehicle A greater than that in Vehicle B? Does the thermal comfort index indicate thermal sensation? etc.) Preliminary analysis should attempt to answer the questions by referring directly to graphs and tables. Further analysis will involve data processing and could lead to statistical tests. These should be decided upon *a priori*. This part of the analysis will involve making assumptions about properties of the numerical data. The properties of the subjective scales need to be interpreted. It is not necessarily the case that a rating of 6 on a scale represents twice the perceived intensity of a rating of 3. Is rating 4, “very sticky”, really twice the level of a rating of 2, “slightly sticky”? To establish this, research into the properties of scales will be necessary. Parametric statistical tests (e.g. *t* tests, analysis of variance) assume such properties (interval and ratio data). Although parametric tests are often robust in terms of violation of their assumptions, it is often safer, and almost as efficient, to use non-parametric statistics where category (nominal data, e.g. Chi squared test) or rank order (ordinal or ordered metric data, e.g. Wilcoxon matched pairs signed ranks test) can be assumed. In this case, a rating of 4 would be assumed to be greater than a rating of 2 (but not assumed to be twice the level), which is probably reasonable for the subjective scales described above. Detailed consideration should be given for specific cases. Whichever statistical test is used, a decision can be made based upon the probability of the outcome if it had occurred due to chance. The synthesis of the results for each of the measures (skin temperature, sensation, uncomfortable, etc.) often shows consistent trends that can lead to overall discussions and conclusions.

7 Test method for assessing thermal comfort in vehicle

Thermal comfort in a vehicle environment should be assessed using the test method given in Annex A.

Annex A provides a test method for the assessment of thermal comfort in a vehicle environment. It is based upon the principles and guidance provided in Clauses 5 and 6 and should be implemented with regard to those principles and guidance. The test method can be used to determine whether, for the operating conditions of interest, the vehicle can be considered to have provided thermal comfort to the occupants of the vehicle.

Annex A
(normative)

Test method for assessment of vehicle thermal comfort

A.1 Principle

The test methodology for determining the thermal comfort of people exposed to a vehicle environment consists of identifying the conditions for the test and taking subjective responses of human subjects.

A.2 Aim of the test

The aim of the test is to measure the thermal comfort of people exposed to a vehicle environment.

A.3 Test conditions

Conditions shall be selected to be representative of those of interest and shall be typical vehicle conditions.

The conditions for the test will determine the thermal environment to which the passenger or vehicle operator is exposed. This is what is being tested (can the vehicle provide thermal comfort to people under those conditions?). They will depend upon such factors as road type (rail track, air or sea state, etc.), weather, HVAC-system control settings, seat type, posture and position of the person in the vehicle, glazing type, and others. A number of tests could have to be conducted in order to measure a range of conditions. The vehicle environment to which the test subjects are exposed will be determined by the interaction of the air temperature, radiant temperature, air velocity, humidity, activity and clothing insulation (including that of the seat) around the body.

A.4 Selection of subjects

At least eight subjects shall be selected. They shall be representative of the population of people who use the vehicle and shall have no vested interest in the results of the test.

A.5 Method

The vehicle shall be operated over the conditions of interest for no less than 30 min. Subjective ratings of sensation, comfort, stickiness, preference, acceptability and satisfaction shall be taken every 10 min throughout the test, including at the beginning and the end (final reading still in the conditions under test).

NOTE 1 Annex B provides an example of a thermal comfort assessment questionnaire.

NOTE 2 In Annex B, some scales have been set so that positive values are towards hot, 0 is neutral and negative values are towards cold.

A.6 Analysis of results

The results for each scale (overall and local) shall be integrated over eight subjects and the final two ratings (e.g. at 20 min and 30 min for a thirty-minute test, i.e. 16 values per scale). Frequency, median and the range of the values shall be determined.

A.7 Interpretation of results

The acceptability of the results will depend upon the level of quality of the environment required. The vehicle environment tested CANNOT be considered comfortable if the criteria given in Table A.1 are met.

Table A.1 — Criteria for determining whether a vehicle's thermal environment CANNOT be considered comfortable

Scale	Median (16 pts.)	Range (16 pts.)
7 pt. sensation	> +1 (slightly warm) OR < −1 (slightly cool)	If any 3 values are > +2 (warm) OR < −2 (cool)
4 pt. uncomfortable	> +1 (slightly uncomfortable)	If any 3 values are > +2 (uncomfortable)
4 pt. stickiness	> +1 (slightly sticky)	If any 3 values are > +2 (sticky)
7 pt. preference	> +1 (slightly warmer) OR < −1 (slightly cooler)	If any 3 values are > +2 (warmer) OR < −2 (cooler)
2 pt. acceptability	—	If > 3 values indicate that it is unacceptable
2 pt. satisfaction	—	If > 3 values indicate that they are dissatisfied
If more than eight subjects are used then criteria should be adjusted accordingly (i.e. in proportion to the criteria for "Range" above).		

Annex B
(informative)

Example of single-sheet subjective questionnaire

Separate sheets, indicated by circling the appropriate time (Pre, 0, 5, etc.) are completed by the subject every 5 min.

Thermal Comfort Assesment: Date: ……….. Subject: ……….. Time: ……….. Session: ………..

Neutral, Pre, 0, 5, 10, 15, 20, 25, 30, Post

1. Thermal Environment

Please rate on these scales how YOU fell NOW

	Overall	Head	Trunk		Arms	Upper legs		Lower legs		Feet
			Front	Rear		Front	Rear	Front	Rear	
		1	2	3	4	5	6	7	8	9
+3 Hot										
+2 Warm										
+1 Slightly warm										
0 Neutral										
−1 Slightly cool										
−2 Cool										
−3 Cold										

	Overall	Head	Trunk		Arms	Upper legs		Lower legs		Feet
			Front	Rear		Front	Rear	Front	Rear	
		1	2	3	4	5	6	7	8	9
3 Very uncomfortable										
2 Uncomfortable										
1 Slightly uncomfortable										
0 Not uncomfortable										

	Overall	Head	Trunk		Arms	Upper legs		Lower legs		Feet
			Front	Rear		Front	Rear	Front	Rear	
		1	2	3	4	5	6	7	8	9
3 Very sticky										
2 Sticky										
1 Slightly sticky										
0 Not sticky										

2. Please rate on the scale how YOU would like to be NOW

Much warmer	Warmer	Slightly warmer	No change	Slightly cooler	Cooler	Much cooler
+3	+2	+1	+0	−1	−2	−3

3. Please indicate how acceptable YOU find this thermal environment NOW

☐ 0 Acceptable

☐ 1 Unacceptable

4. Please indicate how satisfied YOU are with this thermal environment NOW

☐ 0 Satisfied

☐ 1 Dissatisfied

Annex C
(informative)

Practical example of vehicle thermal comfort assessment using test method

C.1 Aim

To establish whether the thermal conditions in a passenger car could be considered as providing thermal comfort.

C.2 Method

Eight male front-seat passengers were each driven separately around a road circuit for 1 h with controls set for thermal comfort. Weather conditions and time of day were similar for each test drive. Subjects completed a questionnaire (see Annex B) every 10 min throughout the test.

C.3 Results

In the results of the test given in Table C.1, greater deviation from 0 implies greater discomfort.

NOTE Only "overall" ratings are used for the purposes of this example.

C.4 Interpretation

Comparison of the results with criteria in Table A.1. Median values are within limits for comfort. Number of individual indications of discomfort is not sufficient for the environment to be considered "UNCOMFORTABLE".

C.5 Conclusion

The environment tested can be considered as providing thermal comfort.

Table C.1 — Subjective ratings

Subject	Time after start min	Sensation	Uncomfortable	Sticky	Preference	Acceptable	Satisfied
A	50	0	0	0	−0,2	0	0
	60	0	0	0	0	0	0
B	50	0	0	0	−0,1	0	0
	60	−1	0	0	0	0	0
C	50	0	0	0	−0,2	0	0
	60	0	0	0	0	0	0
D	50	0	0	0	0	0	0
	60	−0,5	0	0,2	0	0	0
E	50	0	0	0	−0,2	0	0
	60	0	0	0	−0,2	0	0
F	50	0	0	0	−0,3	0	0
	60	−0,5	0	0	0	0	0
G	50	0	0	0	+0,2	0	0
	60	0	0	0	+0,2	0	0
H	50	0	0	0	0	0	0
	60	0	0	0	0	0	0
Median		0	0	0	0	0	0
No. of values where discomfort criteria are met (see Table A.1)		0	0	0	0	0	0

Annex D
(informative)

Practical example of assessment of thermal comfort properties of vehicle glazing

D.1 Aim

To compare the thermal comfort of a vehicle ride for two types of vehicle glazing.

D.2 Method

Eight male front-seat passengers were driven separately around a road circuit for 30 min with controls set for thermal comfort. Each passenger experienced two drives, each corresponding to a different type of glazing. Half of the passengers experienced glazing A first and half glazing B first. Weather conditions and time of day were similar for each drive. Vehicles used were identical other than for the glazing type.

D.3 Results

See Table D.1.

D.4 Interpretation

Comparison of the results with the criteria given in Table A.1. The ride for glazing A can be considered comfortable.

The ride for glazing B CANNOT be considered comfortable, as > 3 values indicate “dissatisfied” (see Table A.1).

A Wilcoxon matched pairs signed ranks test conducted on the most severe sensation rating (20 min or 30 min) for each subject (i.e. eight matched ratings) indicates that the ride under glazing B is significantly ($p < 0,05$) more uncomfortable than under glazing A.

D.5 Conclusion

For the conditions tested, glazing B provided an uncomfortable ride and had poorer performance in terms of thermal comfort than glazing A.

Table D.1 — Subjective ratings

Subject	Time after start min	Glazing A						Glazing B					
		Sensation	Uncomfortable	Sticky	Preference	Acceptable	Satisfied	Sensation	Uncomfortable	Sticky	Preference	Acceptable	Satisfied
A	20	−2	0	0	1	0	0	−3	1	0	2	1	1
	30	−2	0	0	1	0	0	−3	1	0	2	1	1
B	20	−1	0	0	0	0	0	−2	1	0	1	0	0
	30	−1	0	0	1	0	0	−2	1	0	1	0	0
C	20	−1	0	0	0	0	0	−1	1	0	1	0	0
	30	0	0	0	1	0	0	−1	1	0	1	0	0
D	20	−1	0	0	1,2	0	0	−1,8	1,3	0	1,2	0	0
	30	−1	0,6	0	1	0	0	−1,3	1	0	1,4	0	0
E	20	0	0	0	−0,2	0	0	−0,1	0,8	0	0,2	0	0
	30	0	0	0	−0,1	0	0	−0,9	0,8	0	0,2	0	0
F	20	−1	0	0	0.4	0	0	−0,8	0,5	0	0,7	0	0
	30	−1	0	0	0,2	0	0	−0,4	0,2	0	0,5	0	0
G	20	0	0,2	0	0,2	0	0	−0,2	1	0	1	0	1
	30	−0,2	0,2	0	0,2	0	0	−0,5	1,3	0	1,3	0	1
H	20	0	0	0	0	0	0	−1	0	0	0,7	0	0
	30	0,5	0	0	0	0	0	−1,2	0,9	0	0,9	0	0
Median		−1	0	0	0,2	0	0	−1	1	0	1	0	0
Number of “discomfort” ratings		0	0	0	0	0	0	2	0	0	0	2	4

Annex E
(informative)

Practical example of assessment of thermal comfort properties of vehicle seats

E.1 Aim

To compare the thermal comfort of vehicle ride for two types of vehicle seat.

E.2 Method

Eight male front-seat passengers were driven separately around a road circuit for 90 min with controls set for thermal comfort. Each passenger experienced two drives corresponding to two types of vehicle seat. Half of the passengers experienced seat A first and half seat B first. Weather conditions and time of day were similar for each drive. Vehicles used were identical other than for the seat type.

E.3 Results

See Table E.1.

E.4 Interpretation

Comparison of the results with the criteria given in Table A.1. The ride for seat A can be considered comfortable. The ride for seat B CANNOT be considered comfortable as > 3 values indicated sensation outside of limits for comfort and > 3 values indicated that it was unacceptable and people were dissatisfied. A Wilcoxen matched pairs signed ranks test conducted on the most severe sensation rating (80 min or 90 min) for each subject (i.e. eight matched ratings) indicates that the ride in seat B was significantly ($p < 0,05$) more uncomfortable than that in seat A.

E.5 Conclusion

For the conditions tested, seat B provided an uncomfortable ride and had poorer performance in terms of thermal comfort than seat A.

Table E.1 — Subjective ratings

Subject	Time after start min	Seat A						Seat B					
		Sensation	Uncomfortable	Sticky	Preference	Acceptable	Satisfied	Sensation	Uncomfortable	Sticky	Preference	Acceptable	Satisfied
A	80	1	0	0	–1	0	0	2	2	2	–2	0	1
	90	1	1	1	–1	0	0	2	2	2	–2	0	1
B	80	1	0	0	–1	0	0	2	2	2	–1	0	1
	90	1	1	1	–1	0	0	3	2	2	–2	0	1
C	80	1	1	0	–1	0	0	3	2	2	–2	0	1
	90	2	1	1	–1	0	0	3	2	2	–2	0	1
D	80	2	1	1	–1	0	0	3	2	2	–2	0	1
	90	2	2	1	–2	0	0	3	2	2	–3	0	1
E	80	0	0	0	0	0	0	1	1	1	–2	1	1
	90	0	0	0	0	0	0	1	1	1	–2	1	1
F	80	1	0	0	0	0	0	1	1	1	–1	0	0
	90	1	0	0	0	0	0	1	1	1	–1	0	0
G	80	0	0	0	0	0	0	3	2	2	–2	0	0
	90	0	0,2	0	–0	0	0	3	2,5	2,7	–3	1	1
H	80	0	0	0	0	0	0	2,2	1,5	1,2	–2	1	1
	90	0,2	0	0	–0	0	0	2,8	2	2	–2	1	1
Median		1	0	0	–0	0	0	2,5	2	2	–2	1	1
Number of “discomfort” ratings		0	0	0	0	0	0	9	1	1	3	5	13

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