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Ergonomics of the thermal environment — Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions

Ergonomie des ambiances thermiques — Stratégie d'évaluation du risque pour la prévention de contraintes ou d'inconfort dans des conditions de travail thermiques

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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.

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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 15265 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

Introduction

This International Standard is one of a series intended for use in the estimation of the thermal environment. It was developed by ISO/TC 159/SC 5/WG 1, *Thermal environments* on the basis of the results of the BIOMED II "HEAT STRESS" research project conducted with the support of the European Union.

Other standards of this series describe how the parameters influencing human thermoregulation in a given environment must be estimated or quantified. Others specify how these parameters must be integrated in order to predict the degree of discomfort or the health risk in these environments. The present document was prepared to standardize the methods that occupational health specialists should use to approach a given problem related to stress and discomfort in thermal working conditions and progressively collect the information needed to control or prevent the problem.

Ergonomics of the thermal environment — Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions

1 Scope

This International Standard describes a strategy for assessing and interpreting the risk of physiological constraints, or of discomfort, while working in a given climatic environment.

It is applicable in any working situation with steady or varying conditions of the climate, metabolic rate or clothing.

This International Standard does not describe a single procedure, but a strategy in three stages that can be used successively to gain deeper insight in the working conditions, as it is needed to draw the most appropriate conclusions about the risk involved and identify the best control and prevention measures.

It is definitely oriented towards the prevention and/or control of these working problems in the heat or cold. The risk of heat or cold disorders and/or discomfort is therefore assessed only to the extent that it is required to reach this goal.

However, users must comply with national legislations that may require that risk assessment be performed more systematically.

As the strategy is oriented towards prevention and the design of the working conditions, it concerns an average subject. At the last step of each stage of the strategy, interindividual differences are taken into consideration through medical supervision (in the short term) and surveillance (in the long term).

The International Standards on which this strategy is based include, however, already some degree of safety, as their limits and/or recommendations tend to protect the majority of the fit workers.

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 Philosophy of the strategy

The main objective of the assessment of the risks linked to the thermal working environment is not to quantify the risks, but to prevent or to eliminate, or at least to reduce, the risks.

The number of working situations with thermal problems is high and it would be utopian and not practical to require to study them all in detail. This would actually be useless, since, in the majority of cases, solutions can be found easily, based on simple and straightforward ***Observations***. In some cases, however, a more detailed ***Analysis*** is necessary, including measurements, and in some particular cases, an ***Expertise*** can be required, based on more sophisticated evaluation techniques.

The strategy is therefore based on a progressive approach in three stages with the characteristics summarised in Table 1.

The method was prepared to determine whether, and in what circumstances, there is a problem and to collect the information just needed to eliminate it, or at least, to improve the condition.

Table 1 — Comparison of the characteristics of the three stages of the strategy

Modalities	**Stage 1** ***"Observation"***	**Stage 2** ***"Analysis"***	**Stage 3** ***"Expertise"***
When?	When a "problem" is detected	More complicated cases	Very complex cases
How?	Qualitative observations	Ordinary measurements	Specialised measurements and evaluation
Cost?	Low	Average	High
Duration (order of magnitude)	2 h	1 day	A few days
By whom?	Workers + management from the company	Same + specialists	Same + specialists + experts
Competency — work situation: — ergonomics:	 High Average	 Average High	 Low Specialised

Stage 1 — ***Observation*** is to be conducted by people from the company with full knowledge of the working conditions but without necessarily a training in ergonomics. Its aim is to characterise the working situation in all circumstances, during the day and during the whole year, and not at a specific time.

Stage 2 — ***Analysis*** is conducted by the same persons with the assistance of specialists with a specific training in ergonomics of the thermal environment. It will deal with the working situation in particular circumstances (summer, night, ...) identified during the first stage and will require common measurements.

Stage 3 — ***Expertise*** is conducted by the same persons, with the additional assistance of experts highly specialised. It will deal with highly complex thermal working circumstances and require sophisticated or special measurements.

4 Stage 1: "*Observation*"

4.1 Objectives

The objectives of this stage are

— to collect information about the work situation, in general, concerning the working conditions, the climatic conditions and the heat or cold sources,

— to define the straightforward technical measures that can be directly implemented to prevent/control the risk, and

— to determine whether a more thorough "***Analysis***" is necessary.

4.2 Procedure

4.2.1 Describe the working condition which is known to, or which is likely to, raise a thermal problem. This is, for instance, "workshop A in the morning during the winter", or "when cleaning the oven, in any season".

4.2.2 Evaluate the situation for each of the six parameters separately, using the scales described in Table 2. Report also the average opinion of the workers

Remember that the main point of the procedure is not the score in itself, but the analysis of the reasons for that score and the determination of how to improve it.

Table 2 — Scoring scales for the "*Observation*" method

Score	Condition
	Air temperature
– 3	generally freezing
– 2	generally between 0 °C and 10 °C
– 1	generally between 10 °C and 18 °C
0	generally between 18 °C and 25 °C
1	generally between 25 °C and 32 °C
2	generally between 32 °C and 40 °C
3	generally greater than 40 °C
	Humidity
– 1	dry throat/eyes after 2-3 h
0	normal
1	moist skin
2	skin completely wet
	Thermal radiation
– 1	cold on the face after 2-3 min
0	no radiation discernible
1	warm on the face after 2-3 min
2	unbearable on the face after more than 2 min
3	immediate burning sensation
	Air movements
– 2	cold strong air movements
– 1	cold light air movements
0	no air movements
1	warm light air movements
2	warm strong air movements
	Physical work load
0	office work: easy, low muscular constraints, occasional movements at normal speed
1	moderate work with arms or legs: use of heavy machines, steadily walking
2	intense work with arms and trunk: handling of heavy objects, shovelling, wood cutting, walking rapidly or while carrying a heavy load
3	very intense work at high speed: stairs, ladders
	Clothing
0	light, flexible, not interfering with the work
1	long, heavier, interfering slightly with the work
2	clumsy, heavy, special for radiation, humidity or cold temperatures
3	special overalls with gloves, hoods, shoes
	Opinions of the workers
– 3	shivering, strong discomfort for the whole body
– 2	strong local discomfort; overall sensation of coolness
– 1	slight local cool discomfort
0	no discomfort
1	slight sweating and discomfort; thirst
2	heavy sweating, strong thirst, work pace modified
3	excessive sweating, very tiring work, special clothing

4.2.3 Report the results in Table 3

Table 3 — Table of scores for the present situation

Parameters	**– 3**	**– 2**	**– 1**	**0**	**1**	**2**	**3**
Air temperature							
Humidity	—	—					—
Thermal radiation	—	—					
Air movements	—						—
Physical work load	—	—	—				
Clothing	—	—	—				
Opinions of the workers							

4.2.4 If the situation is not ideal (scores outside −1 to 1), identify the reason for this and describe the importance of the problem (sources, surfaces, location …).

The scales in Table 2 are designed so that the optimum situation is zero in each case. When one or several parameters deviate from this optimum, prevention measures should be taken, and, the greater the deviation, the higher the need for solutions.

If the industrial process does not strictly impose the thermal parameters, look for ways to improve the situation, considering the examples of prevention measures given in Annex A.

Determine, if necessary, the measures to be taken in the short-term: hot or cold drinks, recovery periods, work organization, clothing…. Short-term measures should remain temporary measures. They indicate the need for a further "***Analysis***" to solve technically the problem.

Estimate what the scores might be if the situation was improved as envisaged. Judge, on the scales described in Table 2, the condition in the future, taking into account the prevention/control measures. When this prediction of the future situation is difficult to do or does not appear to be reliable, this indicates the need for a further "***Analysis***" to estimate the residual risk and identify the additional control measures.

4.2.5 Report these scores in Table 4

Table 4 — Table of scores for the anticipated situation

Parameters	**– 3**	**– 2**	**– 1**	**0**	**1**	**2**	**3**
Air temperature							
Humidity	—	—					—
Thermal radiation	—	—					
Air movements	—						—
Physical work load	—	—	—				
Clothing	—	—	—				

4.2.6 Decide whether a more detailed "Analysis" is needed to quantify and to solve the problem. For this, consider the number of scores outside the range from −1 to 1 for the anticipated situation in the future.

At the end of the "***Observation***", the user must determine whether, for this working situation, a more thorough "***Analysis***" is necessary.

5 Stage 2: "*Analysis*"

5.1 Objectives

For the conditions selected during stage 1: "***Observation***", the objectives of stage 2: "***Analysis***" are

- to quantify the risk of thermal discomfort or constraint as a function of the minimum and maximum values of the climatic parameters,
- to determine the optimum work organization,
- to determine whether an "***Expertise***" (stage 3) is needed, and
- to justify to the employer the cost of prevention measures identified in stage 1, if necessary.

5.2 Procedure

5.2.1 Analyse the sequence of activities at the work place.

a) Description of the activities.

b) Mean and maximum durations.

c) Period concerned by the working situation.

d) Number of workers exposed.

e) Factors to quantify accurately:

- air temperature: if there is an abnormal increase or decrease;
- humidity: if different from outside;
- radiation: if there is exposure to sun or to very hot or cold surfaces;
- air movements: if there is an air draught;
- work load: if high or unknown;
- clothing characteristics: if special clothing is required.

The information should be reported in a form similar to Table 5.

Table 5 — Summary of information concerning the sequence of activities to analyse

Activity	Duration		Exposed workers	Factors to quantify
	Mean	Maximum		

5.2.2 Evaluate the working situation:

a) during this period, representative day(s) concerning the climatic and working conditions;

b) outside climatic conditions: temperatures, humidity, sun exposure, rain...;

c) measurement or estimation of the mean and maximum values during the representative day(s);

d) computation of the following indices according to the relevant standards:

- Required Clothing Insulation (IREQ);
- Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD);
- Wet Bulb Globe Temperature (WBGT);
- Predicted Heat Strain (PHS) and Duration Limit of Exposure (DLE).

The information should be reported in a form similar to Table 6.

Table 6 — Evaluation of the working conditions for each activity

Parameters	Activity		Activity	
	Mean	**Max.**	**Mean**	**Max.**
t_a RH t_g v_a M I_{cl}				
IREQ PMV PPD WBGT PHS/DLE				

The symbols and appropriate units are in accordance with ISO 13731.

t_a Air temperature

RH Relative humidity

t_g Globe temperature

v_a Air velocity

M Metabolic rate

I_{cl} $m^2 \cdot k \cdot W^{-1}$ (for clothing insulation)

5.2.3 Assess the class of the risk in the present situation using the following scale.

Table 7 — Classes of risk

Class	Criteria
Immediate constraint	DLE < 30 min
Constraint in the short term	I_{clr} < $IREQ_{min}$ and DLE < 120 min
Constraint in the long term	PMV < −2 and $IREQ_{min} \leqslant I_{clr} \leqslant IREQ_{neutral}$
Cold discomfort	−2 ⩽ PMV < −0,5
Comfort	−0,5 ⩽ PMV ⩽ 0,5
Warm discomfort	0,5 < PMV ⩽ 2
Constraint in the long term	DLE < 480 min
Constraint in the short term	DLE < 120 min
Immediate constraint	DLE < 30 min

In the last three cases, derive the following information:

— predicted mean water loss over the 8-h day;

— predicted risk of increase of the internal temperature of the body.

5.2.4 Determine the acceptability of this working condition by comparing the mean and maximum duration of each activity to the maximum allowable exposure times (DLE).

5.2.5 Define prevention/control techniques for each parameter as well as the optimum work organization.

5.2.6 Determine the residual risk after implementation of these prevention/control measures, using the criteria of 5.2.3 above. The acceptability can be determined by comparing the DLE predicted for each activity with the actual work duration.

5.2.7 Decide whether there is a need for a stage 3: “Expertise”.

5.2.8 Define the protection measures in the short term.

5.2.9 Define the requirements for medical surveillance in the short term.

5.2.10 Define the requirements for medical surveillance in the long term.

The results of the “***Analysis***” can be summarised in a form similar to Table 8.

Table 8 — Risk assessment and control measures for each activity

Assessment	Activity	Activity
Risk a) Class of risk b) If heat stress: — Sweating rate — Water loss per day — DLE		
Acceptability		
Prevention/control measures		
Residual risk a) Class of risk b) Acceptability		
Need for an *Expertise*		
Short term measures		
Medical surveillance		

6 Stage 3: "*Expertise*"

6.1 Objectives

The objectives at this stage are

— to better characterise some heat or cold sources and/or some thermal phenomena in the working environment by means of specific measurements, and

— to characterise the overall exposure of the workers and look for special prevention/control measures to be implemented through a more refined analysis of the activities and the climatic parameters.

6.2 Procedure

6.2.1 Determine conditions to study in great detail and representative days.

6.2.2 Assess the risk in the present situation.

6.2.3 For each sequence of activities, collect data concerning: duration, air temperature, humidity, radiation, air velocity, metabolic rate, clothing insulation, in the average and extreme conditions.

6.2.4 Assess the risk per activity and globally using the thermal indices:

— Required Clothing Insulation (IREQ) for cold conditions;

— PMV-PPD for comfortable and uncomfortable situations;

— Predicted Heat Strain (PHS) for conditions with heat constraint.

6.2.5 Define prevention/control measures.

6.2.6 Search for modifications to be brought to each parameter, to the whole set of parameters, and/or to the work organization (rest phases...).

6.2.7 If required, perform detailed and specialised analyses of each heat or cold source.

6.2.8 Assess the residual risk after implementation of the prevention/control measures.

6.2.9 Determine the personal protection measures.

6.2.10 Define the requirement for medical surveillance in the long term.

Annex A
(informative)

Examples of prevention measures

A.1 Air temperature

Locate the sources of heat or cold in the periphery.

Eliminate the sources of hot or cold air.

Insulate the hot surfaces.

Exhaust hot or cold air locally.

Ventilate without draughts.

Use clothes with lower or higher insulation.

A.2 Humidity

Eliminate the leaks of vapour and water.

Enclose the surfaces cooled with water or any evaporating surface.

Use clothes waterproof but permeable to vapour.

A.3 Thermal radiation

Reduce the radiating surfaces.

Use reflecting screens.

Insulate or treat the radiating surface.

Locate workstations away from radiating surfaces.

Use special protective clothes reflecting radiation.

A.4 Air movements

Reduce or eliminate air draughts.

Use screens to protect locally against draughts.

Locate workstations away from air draughts.

A.5 Physical work load

Reduce the movements during work.

Reduce displacements.

Reduce the speed of movements.

Reduce the efforts, use mechanical assistance.

Improve the postures.

A.6 Clothing

Improve the design of the clothing.

Select more suitable materials.

Look for lighter materials.

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