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INTERNATIONAL STANDARD

ISO 7243

Second edition
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Hot environments — Estimation of the heat stress on working man, based on the *WBGT*-index (wet bulb globe temperature)

Ambiances chaudes — Estimation de la contrainte thermique de l'homme au travail, basée sur l'indice WBGT *(température humide et de globe noir)*

Reference number
ISO 7243 : 1989 (E)

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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7243 was prepared by Technical Committee ISO/TC 159, *Ergonomics*.

This second edition cancels and replaces the first edition (ISO 7243 : 1982), of which it constitutes a minor revision.

Annexes A to D of this International Standard are for information only.

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Introduction

This International Standard is one of a series (listed in annex D) intended for use in the study of thermal environments.

The aim of this series of International Standards is in particular

— the finalization of definitions for terms to be used in methods of measurement, test and interpretation, taking into account those standards already existing or which are being drafted;

— the drafting of specifications relating to the methods of measurement for physical parameters characterizing thermal environments;

— the selection of one or more methods of interpretation of the parameters;

— the establishment of recommended or maximum values for exposure to thermal environments in the regions of comfort and extreme environments (hot and cold);

— the drafting of specifications relating to the methods of measurement of the efficiency of devices or procedures for individual or collective protection against heat and cold.

In the light of the increasing interest being shown in the problems presented by the exposure of individuals to thermal environments and the fact that there are few documents or national standards in this field, it seemed desirable to publish this International Standard, without waiting for the complete series to be drafted.

The wet bulb globe temperature (*WBGT*) index is one of the empirical indices representing the heat stress to which an individual is exposed. This index is easy to determine in an industrial environment. The method for evaluating the heat stress based on this index is a compromise between the desire to use a very precise index and the need to be able to carry out control measurements easily in an industrial environment. It should be regarded as an exploratory method.

A method of estimating the thermal stress based on an analysis of the heat exchange between man and environment allows a more accurate estimation of stress and an analysis of the methods of protection. But with the present technology of measurement, the method has the drawback of being longer and more difficult to undertake. Such a method will therefore be used either directly when it is desired to carry out an intensive analysis of working conditions in heat, or in addition to the method based on the *WBGT* index when the values obtained using the first approach exceed the reference values shown.

Establishing a method of evaluating heat stress based on the *WBGT* index is only one step towards the definition of an index showing the advantages of both methods together. However, as there is no such index at present it seemed advisable to encourage immediately the development of an International Standard capable of being used in an industrial environment.

INTERNATIONAL STANDARD ISO 7243 : 1989 (E)

Hot environments — Estimation of the heat stress on working man, based on the *WBGT*-index (wet bulb globe temperature)

1 Scope

This International Standard gives a method, which can easily be used in an industrial environment, for evaluating the heat stress to which an individual is subjected in a hot environment and which allows a fast diagnosis.

It applies to the evaluation of the mean effect of heat on man during a period representative of his activity but it does not apply to the evaluation of heat stress suffered during very short periods, nor to the evaluation of heat stresses close to the zones of comfort.

2 Principle and general definition

The heat stress to which a person exposed to a hot environment is subjected is, in particular, dependent on the production of heat inside the body as a result of physical activity and the characteristics of the environment governing heat transfer between the atmosphere and the body.

The internal thermal load is the result of metabolic energy caused by activity.

A detailed analysis of the influence of the environment on heat stress requires a knowledge of the following four basic parameters: air temperature, mean radiant temperature, air speed, and absolute humidity.[3] However, an overall estimation of this influence can be made by measuring parameters derived from these basic parameters and which are a function of the physical characteristics of the space used.

The *WBGT* index combines the measurement of two derived parameters, natural wet-bulb temperature (t_{nw}) and the globe temperature (t_g) and in some situations, the measurement of a basic parameter, air temperature (t_a) (dry bulb temperature). The following expressions show the relationship between these different parameters:

— Inside buildings and outside buildings without solar load:

$$WBGT = 0{,}7\, t_{nw} + 0{,}3\, t_g$$

— Outside buildings with solar load:

$$WBGT = 0{,}7\, t_{nw} + 0{,}2\, t_g + 0{,}1\, t_a$$

This method of estimating heat stress is based on the measurement of these different parameters and the calculation of mean values taking into account any space-time variations of these parameters.

The data collected and dealt with in this way are compared with the reference values and then it is necessary

— either to reduce directly the heat stress or strain at the work-place by appropriate methods;

— or to carry out a detailed analysis of the heat stress using methods that are more elaborate but are also usually longer and more difficult to apply.

These reference values correspond to levels of exposure to which, under the conditions specified in annex A, almost all individuals can be ordinarily exposed without any harmful effect, provided that there are no pre-existing pathological conditions.

Moreover, the fixing of these levels of exposure in relation to the health of the individual in no way prejudices those which might possibly be fixed for other important reasons such as the alteration of psychosensorimotor reactions likely to cause accidents at work.

3 Measurement of parameters characteristic of the environment

Measurement of the *WBGT* index necessitates the measurement of two derived parameters, natural wet bulb temperature and globe temperature and the measurement of a basic parameter, air temperature.

3.1 Measurement of derived parameters

The information supplied by the sensor for measuring the derived parameters is always dependent on the physical characteristics of the sensor used, all things being equal. These [illegible] in 3.1.1 and 3.1.2.

3.1.1 Natural wet bulb temperature sensor

The natural wet bulb temperature is the value indicated by a temperature sensor covered with a wetted wick which is ventilated naturally, i.e. placed in the environment under consideration without forced ventilation. The natural wet bulb temperature is thus different from the thermo-dynamic temperature determined with a psychrometer.

The temperature sensor shall comply with the following characteristics:

a) Shape of the sensitive part of the sensor: cylindrical.

b) External diameter of the sensitive part of the sensor: 6 mm ± 1 mm.

c) Length of the sensor: 30 mm ± 5 mm.

d) Measuring range : 5 °C to 40 °C.

e) Accuracy of measurement : ± 0,5 °C.

f) The whole sensitive part of the sensor shall be covered with a white wick of a highly water-absorbent material (for example, cotton).

g) The support of the sensor shall have a diameter equal to 6 mm, and 20 mm of it shall be covered by the wick to reduce conduction from the support to the sensor.

h) The wick shall be woven in the shape of a sleeve and shall be fitted over the sensor with precision. Too tight or too loose a grip is detrimental to the accuracy of measurement.

i) The wick shall be kept clean.

j) The lower part of the wick shall be immersed in a reservoir of distilled water. The free length of the wick in the air shall be 20 mm to 30 mm.

k) The reservoir shall be designed in such a way that the temperature of the water inside cannot rise as a result of radiation from the environment.

3.1.2 Globe temperature sensor

The globe temperature is the temperature indicated by a temperature sensor placed in the centre of a globe having the following characteristics:

a) Diameter: 150 mm.

b) Mean emission coefficient: 0,95 (matt black globe).

c) Thickness: as thin as possible.

d) Measuring range: 20 °C to 120 °C.

e) Accuracy of measurement:

— range 20 °C to 50 °C: ± 0,5 °C;

— range 50 °C to 120 °C: ± 1 °C.

Any device for measuring the natural wet bulb temperature or the globe temperature which, after calibration in the specified measuring ranges, provides results to the same degree of accuracy may also be used.

3.2 Measurement of air temperature

The air temperature, a basic parameter, may be measured by any suitable method, whatever the shape of the sensor used. It is, however, necessary to comply with the measurement precautions relating to air temperature measurement.

The air temperature sensor shall, in particular, be protected from radiation by a device which does not impede the circulation of air around the sensor. The measuring range for the air temperature is 10 °C to 60 °C and the accuracy ± 1 °C.

4 Measurement or estimation of metabolic energy[1)]

The quantity of heat produced inside the body is an element of heat stress. It is therefore essential to determine it in order to evaluate the latter. Metabolic energy which presents the total quantity of energy consumed inside the body, is a good estimation of this for most industrial situations (negligible external work).

Metabolic rate may be determined

— either by measuring the oxygen consumption of the worker;

— or by estimating it from reference tables.

Due to the nature of the *WBGT* index it is sufficient to estimate the metabolic rate according to the reference tables.

The estimation of metabolic rate requires some practice and shall preferably be done by individuals having some experience in this field.

In the absence of an evaluation using reference tables, classification of the activities may be restricted to five main classes, namely: resting, low metabolic rate, moderate metabolic rate, high metabolic rate, very high metabolic rate. Table 1 is intended to facilitate such a classification. The values given have been established for continuous activities.

In case of difficulty in interpreting the data, the metabolic rate considered to be the most accurate is the metabolic rate measured directly on the individual.

1) ... d is in preparation.

Table 1 — Classification of levels of metabolic rate

Class	Metabolic rate range, M		Value to be used for calculation of mean metabolic rate		Examples
	related to a unit skin surface area	for a mean skin surface area of 1,8 m^2			
	W/m^2	W	W/m^2	W	
0 Resting	$M < 65$	$M < 117$	65	117	Resting
1 Low metabolic rate	$65 < M < 130$	$117 < M < 234$	100	180	**Sitting at ease :** light manual work (writing, typing, drawing, sewing, book-keeping); hand and arm work (small bench tools, inspection, assembly or sorting of light materials); arm and leg work (driving vehicle in normal conditions, operating foot switch or pedal). **Standing :** drill (small parts); milling machine (small parts); coil winding; small armature winding; machining with low power tools; casual walking (speed up to 3,5 km/h).
2 Moderate metabolic rate	$130 < M < 200$	$234 < M < 360$	165	297	Sustained hand and arm work (hammering in nails, filling); arm and leg work (off-road operation of lorries, tractors or construction equipment); arm and trunk work (work with pneumatic hammer, tractor assembly, plastering, intermittent handling of moderately heavy material, weeding, hoeing, picking fruit or vegetables); pushing or pulling lightweight carts or wheelbarrows; walking at a speed of 3,5 km/h to 5,5 km/h; forging.
3 High metabolic rate	$200 < M < 260$	$360 < M < 468$	230	414	Intense arm and trunk work; carrying heavy material; shovelling; sledge hammer work; sawing, planing or chiselling hard wood; hand mowing; digging; walking at a speed of 5,5 km/h to 7 km/h. Pushing or pulling heavily loaded handcarts or wheelbarrows; chipping castings; concrete block laying.
4 Very high metabolic rate	$M > 260$	$M > 468$	290	522	Very intense activity at fast to maximum pace; working with an axe; intense shovelling or digging; climbing stairs, ramp or ladder; walking quickly with small steps, running, walking at a speed greater than 7 km/h.

5 Measurement specifications

5.1 Measurement specifications relating to the heterogeneity of the environment

When certain parameters do not have a constant value in the space surrounding the worker, it is necessary to determine the *WBGT* index at three positions corresponding to the height of the head, abdomen and ankles in relation to the ground. When the worker is standing, the measurements shall be performed 0,1 m, 1,1 m and 1,7 m above the floor; when seated, 0,1 m, 0,6 m and 1,1 m above the floor. Measurements used to determine the indices shall preferably be carried out simultaneously.

The mean value of the *WBGT* index is obtained from the following three weighted indices, using the following formula:

$$WBGT = \frac{WBGT_{head} + (2 \times WBGT_{abdomen}) + WBGT_{ankles}}{4}$$

If analysis prior to heat stress at the point studied or at points of a related type have shown that the environment was practically homogeneous (heterogeneity $\leqslant$ 5 %), a simplified procedure consisting in carrying out only one determination of the *WBGT* index at abdomen level may be adopted. Whatever the circumstances, in case of dispute in the interpretation of the analysis, the *WBGT* index determined in accordance with the normal procedure (three measurements) shall be considered as the reference value.

For a rapid determination of the *WBGT* index it is enough to carry out one measurement at the level where the heat stress is maximum. The use of this procedure induces a security biased over-evaluation of the heat stress. The use of this procedure shall be noted in the evaluation report.

In the case where it is impossible to situate the sensors at the normal place of work, they should be situated where they will be exposed to approximately the same influence from the en-

5.2 Measurement specifications relating to the time variations of the parameters

If the analysis of the work-place and of the activity have shown that a parameter does not show a constant value in time, a representative mean value has to be determined.

The most accurate procedure consists in measuring the continuous development of this parameter as a function of time and deducing from it the mean value by integration.

As this method can only be used with difficulty in many cases, the variations of each parameter considered are thus classified into almost constant levels. The mean value of the parameter considered is then obtained by weighting the levels of the different categories by the total time during which each of these levels was obtained.

The time base T for the calculation of the mean values is a period of work/resting of 1 h, which is representative of the maximum for heat stress. It shall be calculated from the beginning of a period of work.

The mean value of a parameter p (for example: metabolic rate, globe temperature or *WBGT* in the case of simultaneous measurement of the three parameters of the environment), for which the development as a function of time has been broken down into "n" levels is therefore expressed by the following formula

$$\bar{p} = \frac{(p_1 \times t_1) + (p_2 \times t_2) + \ldots + (p_n \times t_n)}{t_1 + t_2 + \ldots + t_n}$$

where

$p_1, p_2, \ldots, p_n$ is the level of the parameter obtained during the time $t_1, t_2, \ldots, t_n$;

$t_1 + t_2 + \ldots + t_n = T = 1$ h.

The number of measurements to be carried out depends on the variation speed of the parameters, the response characteristics of the sensors used and the desired accuracy of measurement.

5.3 Mean value of the metabolic energy

The above considerations apply to the determination of the mean value of the metabolic rate based on values measured or estimated from reference tables. If the metabolic rate is simply classified under one of the five main classes mentioned in clause 4, the mean metabolic rate level is determined as above by taking, for each elementary activity, the mean value of the metabolic rate given in table 1.

In case of dispute in the interpretation of the data, the mean parameter taken to be the most accurate is that calculated from the variations of the parameter measured continuously, followed by that calculated from the greatest number of levels accurately determined.

6 Period and duration of measurements

6.1 Period of measurements

The determination of the *WBGT* index in accordance with this International Standard allows only the estimation of the heat stress to which a worker is subjected at the time when the measurements were carried out. Consequently, it is therefore recommended that these be carried out at the period corresponding to the maximum heat stresses, i.e. generally during the hot summer period and in the middle of the day or when the heat-generating equipment is in operation.

6.2 Duration of the measurements

The duration of each measurement depends on the response time of the sensor, which on certain occasions may be considerable (globe temperature especially).

It will be possible to carry out only a single measurement or estimation for each of the levels used for each parameter. The duration of the measurements is therefore distinct from the duration of the analysis proper (time base) as defined in 5.2.

7 Reference values

The values of the *WBGT*-index given in annex A are given as a reference. They are based on data available in the scientific literature.

If these values are exceeded, it is necessary

— either to reduce directly the heat stress at the work-place under consideration by appropriate methods (control of the environment, of the level of activity, of the length of time spent in the environment, and using individual protection);

— or to carry out a detailed analysis of the heat stress in accordance with more elaborate methods.

The reference value corresponding to a given situation for an individual normally clothed (thermal insulation index I_{cl} = 0,6 Clo)[1], physically fit for the activity being considered and in good health, is given in annex A.

These reference values are representative of the mean effect of heat on the individual over a fairly long period of work. They do not take into account the peak values of heat stress to which individuals may be subjected for short periods (a few minutes) either as a result of a particularly hot environment, or of momentarily intense physical activity. In fact, in such cases, the heat stress may exceed the permissible values without the reference values representative of a mean activity or mean environment being exceeded.

When there is doubt with regard to the metabolic rate value to be adopted, the reference value to be used is that corre-

1) A unit for thermal resistance of clothing: 1 Clo = 0,155 m^2·K/W

sponding to the higher metabolic rate, if necessary class 4 if all measurement or estimation is impossible.

NOTES

1 If the clothing worn is not a standard working garment (permeable to air and steam, with a thermal insulation index I_{cl} = 0,6 Clo), the reference values shall be modified in the light of the special properties of the garment and the environment being considered. In general wearing of clothing which is impermeable to water vapour necessitates a decrease in the reference values. On the other hand wearing of reflecting clothing may result in an increase in the reference values. In all cases, due to difficulties of estimating the corrections, it is recommended to consult a specialist when the characteristics of the clothing ensemble differ significantly from the specified reference clothing.

2 Annex B also gives as a guide some reference values for *WBGT* established for various work/resting cycles based on the hypothesis that the value of *WBGT* at the location reserved for resting was equal or very close to the value of *WBGT* at the work-place.

3 A partial acclimatization may be achieved in 7 days by a gradual increase of heat stress. Annex B gives, as an example, a method of acclimatization based on the gradual increase of the working periods and the allocation of additional resting. One considers as non-acclimatized all persons who have not been exposed daily to heat during the preceding working week.

8 Evaluation report

The evaluation report of the heat stress to which an individual is subjected in a given situation should indicate the following data:

a) place where the evaluation was carried out (for example: factory, workshop, work-place);

b) period at which the evaluation was made (year, month, day, hour);

c) authority or individual carrying out the evaluation;

d) detailed results of the measurements or estimations of the parameters (reference);

e) mean value of *WBGT* and its position in relation to the reference values.

Annex C shows, as an example, a method of presenting the results.

Annex A
(informative)

Table of reference values of the *WBGT* heat stress index

Table A.1 — Reference values corresponding to a given situation

Metabolic rate class	Metabolic rate, *M*		Reference value of *WBGT*			
	Related to a unit skin surface area	Total (for a mean skin surface area of 1,8 m^2)	Person acclimatized to heat		Person not acclimatized to heat	
	W/m^2	W	°C		°C	
0 (resting)	$M < 65$	$M < 117$	33		32	
1	$65 < M < 130$	$117 < M < 234$	30		29	
2	$130 < M < 200$	$234 < M < 360$	28		26	
3	$200 < M < 260$	$360 < M < 468$	No sensible air movement 25	Sensible air movement 26	No sensible air movement 22	Sensible air movement 23
4	$M > 260$	$M > 468$	23	25	18	20

NOTE — The values given have been established allowing for a maximum rectal temperature of 38 °C for the persons concerned.

Annex B
(informative)

Curves showing reference values of *WBGT* and method of acclimatization to heat

B.1 Curves showing reference values of *WBGT* established for various work/resting cycles

The curves are plotted on the assumption that the value of *WBGT* at the location reserved for resting is equal or very close to the value of *WBGT* at the work-place (time base equal to 1 h; sensible air movement; person acclimatized to heat). These curves are given for information only in figure B.1. They may facilitate the reorganization of the work by changing the work/rest cycles. Strict application of this International Standard with weighting of the different values of *WBGT* measured is preferable.

B.2 Method of acclimatization to heat

Acclimatization is the state resulting from a physiological adaptation process which increases the tolerance of an individual when he has been exposed to a given environment for a sufficient period of time. In comparison with an individual who is not acclimatized, an individual who is acclimatized shows less physiological strain for the same heat stress.

Acclimatization of this nature may be achieved either artificially by means of repeated controlled exposure in an acclimatization chamber, or naturally by the individual carrying out the work of his trade for short periods to begin with and then for increasingly longer periods.

The work/rest cycles for acclimatized and non-acclimatized persons are determined by estimating the *WBGT* according to this International Standard and the reference values in annex A. The increase of the duration of the work period from the non-acclimatized to the acclimatized state should take place gradually over a period of 7 days.

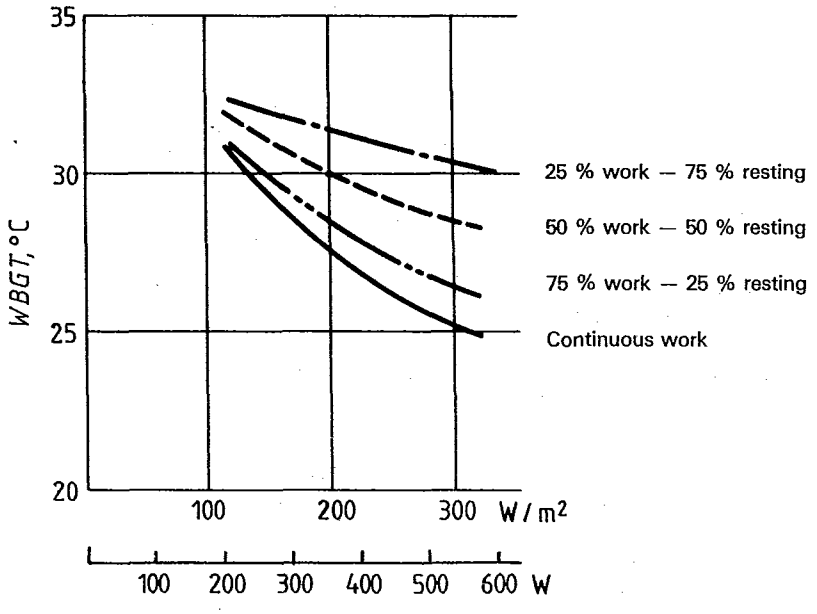

Figure B.1

Annex C
(informative)

Example of an evaluation report

Authority or person carrying out the evaluation:	**HOT ENVIRONMENTS** DETERMINATION OF *WBGT* HEAT STRESS INDEX (WET BULB GLOBE TEMPERATURE) IN ACCORDANCE WITH ISO 7243	Date: Ref.:

Description of the work-place and measuring position (if necessary, use the back of this page for making a drawing of the place):

Period when evaluation was carried out	Year: Month: Day: Time:	External atmospheric conditions:
Degree of acclimatization of the person working at the place being considered		Clothing:
Time base for calculation of the mean value of *WBGT*, T = 1 h		

Detailed results of the measurements or estimation

Parameters	Indications concerning the measurement			Levels				Exposure length	Mean value
	Continuous measurement (see curve No...)	Discontinuous measurement	Estimation	Homogeneous environment	Heterogeneous environment				
					Head	Abdomen	Ankles		
Globe temperature, t_g °C									
Natural wet-bulb temperature, t_{nw} °C									
Air temperature, t_a °C									
WBGT (overall measurement or calculated) °C									
Metabolic rate, M W/m^2									

Comments:

Overall result

WBGT heat stress index

Reference value of *WBGT* for clothing I_{cl} = 0,6 Clo	Person acclimatized to heat
	Person not acclimatized to heat

Reference value of *WBGT* according to clothing

Conclusion:

Annex D
(informative)

Bibliography

[1] ISO 7726, *Thermal environments — Instruments and methods for measuring physical quantities.*

[2] ISO 7730, *Moderate thermal environments — Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.*

[3] ISO 7933, *Hot environments — Analytical determination and interpretation of thermal stress using calculation of required sweat rates.*

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