INTERNATIONAL STANDARD

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Requirements for sleeping bags —

Part 1: **Thermal and dimensional requirements**

Exigences pour les sacs de couchage —

Partie 1: Exigences thermiques et dimensionnelles

Reference number
ISO 23537-1:2016(E)

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

ISO 23537 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 136, *Sports, playground and other recreational facilities and equipment* in collaboration with ISO Technical Committee TC 83, *Sports and other recreational facilities and equipment*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 23537 consists of the following parts, under the general title, *Requirements for sleeping bags*:

— *Part 1: Thermal and dimensional requirements*

— *Part 2: Fabric and material properties*

Introduction

This is the first edition of this part of ISO 23537. It is based on continued development of the European Standard, EN 13537.

This International Standard consists of two parts which allows for separate validation of thermal properties and product and material performance. This separation of parts also allows for continued development of new product combinations as it encourages manufacturers to consider new combinations of materials which for example might not be suitable to test by traditional textile physical tests, but which can still have thermal properties evaluated.

This part of ISO 23537 considers important aspects to the thermal performance of the sleeping bag.

During the development of this part of ISO 23537, consideration was given to the need to continue to reduce inter laboratory variability of the thermal testing and a number of test parameters have been tightened as a consequence.

Consideration has also been given to the definition of extreme climate zone which is now referred to as temperatures <–20 °C.

Requirements for sleeping bags —

Part 1: Thermal and dimensional requirements

1 Scope

This part of ISO 23537 specifies the requirements and test methods as well as provisions for labelling of adult sized sleeping bags for use in sports and leisure time activities.

This part of ISO 23537 does not apply to sleeping bags intended for specific purpose such as military use and extreme climate zone expedition. It does not apply to sleeping bags for children or babies.

NOTE 1 No prediction model exists for the determination of the limiting temperatures based on the thermal resistance of the sleeping bag for children and babies. Moreover, such a model for testing cannot be developed because the necessary controlled sleep trials with children or babies in climatic chambers are, out of ethical reasons, not permitted.

NOTE 2 The limit temperature for extreme climate conditions is seen to be −20 °C.

This part of ISO 23537 describes the method for the assessment of the performance in steady-state conditions of a sleeping bag with regard to the protection against cold.

NOTE 3 Sleeping bags without homogeneous fillings designed to provide local extra insulation in certain parts pose issues with the calibration and/or test procedure. Ongoing work continues to provide suitable means of establishing temperature ratings.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 139, *Textiles — Standard atmospheres for conditioning and testing*

ISO 1096, *Plywood — Classification*

ISO 3758, *Textiles — Care labelling code using symbols*

ISO 11092, *Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)*

ISO 15831:2004, *Clothing — Physiological effects — Measurement of thermal insulation by means of a thermal manikin*

EN 13088, *Manufactured articles filled with feather and down — Method for the determination of a filled product's total mass and of the mass of the filling*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
comfort temperature
T_{comf}
lower limit of the comfort range, down to which a sleeping bag user with a relaxed posture, such as lying on their back, is globally in thermal equilibrium and just not feeling cold

Note 1 to entry: For more information, see C.7.3.

3.2
limit temperature
T_{lim}
lower limit at which a sleeping bag user with a curled up body posture is globally in thermal equilibrium and just not feeling cold

Note 1 to entry: For more information, see C.7.2.

3.3
extreme temperature
T_{ext}
very low temperature where the risk of health damage by hypothermia is possible

Note 1 to entry: For more information, see C.7.1.

Note 2 to entry: This is a point of danger which can lead to death.

3.4
maximum temperature
T_{max}
upper limit of comfort range, up to which a partially uncovered sleeping bag user just does not perspire too much

Note 1 to entry: For more information, see C.7.4.

3.5
thermal manikin
dummy with human shape and heated body surface which allows the determination of thermal transfer through the sleeping bag under steady-state conditions

Note 1 to entry: i.e. constant heat flux and temperature gradient between body surface and ambient air.

3.6
thermal resistance
thermal insulation
R_c
property of the sleeping bag which is related to the dry heat loss of the sleeping bag user, effected by the difference of temperature between the skin and the ambient air, as measured with a thermal manikin

Note 1 to entry: The dry heat loss of the sleeping bag user is a combination of conductive, convective and radiative heat transfer.

Note 2 to entry: This thermal resistance represents the insulative property of a sleeping bag, which includes the effects of the shell fabrics and filling materials, air volume in the cavity inside the sleeping bag, boundary air layer on the outer face of the sleeping bag, mattress underneath the sleeping bag and garments worn by the sleeping bag user. It is considered to be the total thermal insulation (see ISO 15831).

4 Requirements and test methods

4.1 Water vapour permeability index

When tested in accordance with ISO 11092, the material specific water-vapour permeability index (i_{mt}) of the sleeping bag shall be ≥0,45. Where front and back area of the sleeping bag are of different material combinations, both parts shall be tested.

NOTE The water-vapour permeability index is dimensionless, and has values between 0 and 1. A value of 0 implies that the material is water-vapour impermeable, that is, it has infinite water-vapour resistance, and a material with a value of 1 has both the thermal resistance and water-vapour resistance of an air layer of the same thickness.

4.2 Inside dimensions

4.2.1 Inside length

To enable labelling of the sleeping bag, the inside length of the sleeping bag shall be measured within ±3 cm. The measurement is made by turning the sleeping bag inside out and measuring the length from the position of the seam where the heel of the foot is placed to the top of the sleeping bag (excluding any vertical components of the hood), without applying any force to extend the sleeping bag length.

4.2.2 Maximum inside width

To enable labelling of the sleeping bag, the maximum inside width shall be measured within ±2 cm. The measurement is made by turning the sleeping bag inside out and measuring the circumference at the widest point without stretching the fabric. If the maximum inside width of the sleeping bag is not in the chest area, then the position of the widest point of the sleeping bag shall be indicated on the label. The circumference is halved to provide the width of the sleeping bag. If the sleeping bag has elastic seams, a force of (10 ± 1) N may be used to extend these seams prior to measurement, for instance by using a spring balance.

4.2.3 Inside foot width

To enable labelling of the sleeping bag, the foot width shall be measured within ±2 cm. The measurement is made by turning the sleeping bag inside out and measuring the circumference at a distance (30 ± 1) cm towards the hood from the position where the heel of the foot is placed. The circumference is halved to provide the width of the sleeping bag. If the sleeping bag has elastic seams, a force of (10 ± 1) N may be used to extend these seams prior to measurement, for instance by using a spring balance.

4.3 Total mass

The total mass of sleeping bags filled with feather and/or down shall be determined in accordance with EN 13088.

For sleeping bags filled with materials other than feather and down, samples shall be conditioned according to ISO 139 at 20 °C air temperature and 65 % relative air humidity and the mass of the sleeping bag (without stuff sack) shall be determined. The deviation of the total mass from the declared nominal value shall be ≤7 %.

4.4 Thermal properties

4.4.1 Principle

The thermal resistance of the sleeping bag is measured with a thermal manikin which meets the requirements and test procedure of ISO 15831 and which is inserted into the sleeping bag and placed in a controlled atmosphere.

A physiological model is then applied which uses this thermal resistance to determine ambient temperatures corresponding to a range of utility of the sleeping bag.

4.4.2 Thermal manikin

A thermal manikin according to ISO 15831 with the body height of (1,70 ± 0,15) m shall be used.

During the test, the manikin shall be dressed with the following garments:

— two-piece suit (upper part with long sleeves, trousers) with a material specific thermal resistance tested (R_{ct}) in accordance with ISO 11092 of

$$R_{ct} = (0{,}040\ \mathrm{m^2{\cdot}K/W}\ \text{to}\ 0{,}060\ \mathrm{m^2{\cdot}K/W}) \qquad (1)$$

— knee-length socks with a material specific thermal resistance tested in accordance with ISO 11092 of

$$R_{ct} = (0{,}040\ \mathrm{m^2{\cdot}K/W}\ \text{to}\ 0{,}060\ \mathrm{m^2{\cdot}K/W}) \qquad (2)$$

The thermal manikin's skin temperature shall be in accordance with ISO 15831:2004, Clause 7.

4.4.3 Climatic room

The test shall be performed in a climatic room with an air speed, a heat flux and a relative humidity in accordance with ISO 15831:2004, Clause 7.

The ambient temperature shall be (10 ± 5) °C. During the test, the fluctuation of the ambient temperature shall be in accordance with ISO 15831:2004, 5.2.1.

NOTE Very insulative sleeping bags might not allow the heat flux to be ≥20 W/m². In these cases, an ambient temperature of the lowest value within this range is seen as appropriate.

4.4.4 Thermal resistance

4.4.4.1 Thermal resistance posture 1 $R_c(1)$

The thermal resistance posture 1 $R_c(1)$ is measured with the thermal manikin completely inserted into the sleeping bag and lying on its back. The bag's zippers, if any, are closed. The bag's hood, if present, covers the manikin's head, and the cords of the hood are tightened as much as possible without using any additional aids (e.g. clothes pins, etc.) not supplied with the sleeping bag.

For sleeping bags that have hood draw cords with which the hood aperture can be closed to <120 mm diameter or <375 mm perimeter, a cold-protective mask[1)] shall be used on the manikin's face. For sleeping bags with hood draw cords with which the hood aperture cannot be closed to <120 mm diameter or <375 mm perimeter, a cold-protective mask shall not be used on the manikin's face. For sleeping bags that do not have a hood or do not have hood draw cords, a cold-protective mask shall not be used.

The thermal resistance posture 1 $R_c(1)$ is determined using either the serial or the parallel calculation method according to ISO 15831. A combination of these two calculation methods is also possible. With a given thermal manikin, the decision as to which calculation model is appropriate shall be based on the results of the calibration procedure including the correlation for the individual thermal manikin, as described in 4.4.9.

1) Mask, Extreme Cold Weather, U.S. G.I., is the trade name of a product supplied by Colemans. This Information is given for the convenience of users of this documents and does not constitute an endorsement by ISO of the products named. Equivalent products may be used if they can be shown to lead to the same results.

4.4.4.2 Thermal resistance posture 2 $R_c(2)$

The thermal resistance posture 2 $R_c(2)$ is measured with the thermal manikin only partly inserted into the sleeping bag, and lying on its back. The upper part of the sleeping bag is pulled up only to the thermal manikin's arm pits; and the arms of the thermal manikin lie outside the bag's upper part. The zippers of the sleeping bag, if any, are completely opened. The bag's hood, if present, is placed below the thermal manikin's head without tightening the cords. No cold-protective mask is on the thermal manikin's face.

The thermal resistance posture 2 $R_c(2)$ is determined using the parallel calculation method according to ISO 15831.

4.4.5 Artificial ground

The test shall be operated with the thermal manikin placed into the sleeping bag in accordance with 4.4.4.1 or 4.4.4.2, lying on a foam mattress with a material specific thermal resistance R_{ct} = (0,85 ± 0,06) $m^2 \cdot K/W$ when tested in accordance with ISO 11092 and placed on an artificial ground. This ground shall consist of a wooden board according to ISO 1096, large enough that no part of the manikin or the sleeping bag protrudes over the board, with a thickness of (20 ± 2) mm.

The artificial ground is held at least 100 mm above the floor by some kind of support which allows air circulation underneath the artificial ground.

4.4.6 Test samples and pre-treatment

Before testing, the sleeping bag shall be dry tumbled in a dryer with a capacity of ≥250 l without any additional load for 15 min at a temperature of <30 °C. After this dry tumbling and immediately prior to the test, it shall be conditioned for ≥12 h in the ambient conditions of the test.

4.4.7 Test procedure

The test shall be performed according to the requirements in 4.4.2, 4.4.3, and 4.4.5.

For each specific thermal manikin, the position of the arms and legs in relation to the torso of the manikin, the wooden board and the artificial ground shall be defined as part of the calibration procedure and remain the same in all the tests performed according to this part of ISO 23537.

Calculate the value of the thermal resistance posture 1 $R_c(1)$ and/or the thermal resistance posture 2 $R_c(2)$ by applying the correlation gained from the calibration procedure as given in 4.4.9.

Three separate tests shall be completed; each commencing from the insertion of the manikin into the sleeping bag. The arithmetic mean value of the thermal resistance of the sleeping bag shall then be calculated.

If the tests cannot be completed using three separate sleeping bags, then use of a single bag is permissible however it shall undergo the pre-treatment in accordance with 4.4.6 in between individual tests, and the test report shall show a single bag was used.

4.4.8 Calculation of temperatures of the range of utility

The sleeping bag's comfort, limit and extreme temperatures (T_{comf}, T_{lim}, T_{ext}) shall be determined on the basis of the thermal resistance posture 1 $R_c(1)$, according to the physiological model described in Annex C. The sleeping bag's maximum temperature T_{max} may be determined optionally on the basis of the thermal resistance posture 2 $R_c(2)$, according to the physiological model also described in Annex C.

The temperatures of the sleeping bag's range of utility may also be obtained with acceptable accuracy using Table 1 and Table 2. If the thermal resistances posture 1 $R_c(1)$ and the thermal resistances posture 2 $R_c(2)$ measured for the sleeping bag are in between the values in Table 1 or Table 2, a linear interpolation shall be performed on the basis of the nearest upper and lower values of the thermal resistances posture 1 $R_c(1)$ or the thermal resistances posture 2 $R_c(2)$. The temperature limits to be given in the graph for the ranges of utility (see Figure 1) are rounded to the nearest integral number.

Table 1 — Lower temperature limits of the range of utility

Thermal resistance posture 1 $R_c(1)$ $m^2·K/W$	**Extreme temperature** T_{ext} °C	**Limit temperature** T_{lim} °C	**Comfort temperature** T_{comf} °C
0,500	+5,0	+14,2	+17,2
0,540	+2,8	+12,7	+15,9
0,580	+0,6	+11,2	+14,6
0,620	−1,5	+9,7	+13,3
0,660	−3,7	+8,1	+12,0
0,700	−5,8	+6,6	+10,7
0,740	−7,9	+5,1	+9,4
0,780	−10,1	+3,6	+8,1
0,820	−12,2	+2,2	+6,9
0,860	−14,3	+0,7	+5,6
0,900	−16,3	−0,8	+4,3
0,940	−18,4	−2,3	+3,1
0,980	−20,5	−3,7	+1,8
1,020	−22,5	−5,2	+0,6
1,060	−24,5	−6,7	−0,7
1,100	−26,5	−8,1	−1,9
1,140	−28,5	−9,5	−3,1
1,180	−30,5	−11,0	−4,4
1,220	−32,5	−12,4	−5,6
1,260	−34,4	−13,8	−6,8
1,300	−36,4	−15,2	−8,0
1,340	−38,3	−16,7	−9,2
1,380	−40,2	−18,1	−10,4
1,420	−42,2	−19,5	−11,6

Table 2 — Upper temperature limit of the range of utility

Thermal resistance posture 2 $R_c(2)$ $m^2·K/W$	**Maximum temperature** T_{max} °C
0,200	+31,1
0,240	+29,6
0,280	+28,2
0,320	+26,7
0,360	+25,2
0,400	+23,8
0,440	+22,3
0,480	+20,9

Table 2 *(continued)*

Thermal resistance posture 2 $R_c(2)$ $m^2 \cdot K/W$	**Maximum temperature** T_{max} °C
0,520	+19,4
0,560	+18,0
0,600	+16,5
0,640	+15,1
0,680	+13,6
0,720	+12,2
0,760	+10,7
0,800	+9,3

4.4.9 Calibration of thermal manikin

In order to calibrate a specific thermal manikin and the related operating conditions, the measurement shall be performed on the reference set of sleeping bags[2)] whose thermal resistance $R_c(1)$ covers the range 0,700 $m^2 \cdot K/W$ to 1,300 $m^2 \cdot K/W$.

A linear or exponential correlation shall be found between the thermal resistance figures issued from the measurement and the reference values for the thermal resistances posture 1 $R_c(1)$ and the thermal resistances posture 2 $R_c(2)$ of the reference set of sleeping bags (see Table A.1).

NOTE See Annex A.

The deviation of the corrected values of the thermal resistances posture 1 $R_c(1)$ and the thermal resistances posture 2 $R_c(2)$ obtained by applying this linear or exponential correlation from the reference thermal resistance values of the reference set of sleeping bags shall fulfil the following requirements:

a) mean deviation with the complete set of the reference sleeping bags is <5 % (variation coefficient);

b) no individual deviation is >10 % (variation coefficient);

c) global bias (i.e. mean value) on the complete set of the reference sleeping bags ≤5 % (variation coefficient).

Additionally, the repeatability of the measurement on each sleeping bag shall be better than 4 % (variation coefficient).

5 Test report

The test report shall include at least the following:

a) reference and description of the sleeping bag sample;

b) if only one sleeping bag was used for the 3 measurements (see 4.4.7), a note saying that only one sleeping bag was used;

2) The reference sets of sleeping bags are available from: a) SWEREA IVF AB, Box 104, SE- 431 22 Mölndal (Sweden); b) Hohenstein Laboratories GmbH & Co. KG, Schloss Hohenstein, D - 74357 Bönnigheim (Germany); c) AITEX, Plaza Emilio Sala 1, E - 03801 Alcoy (Alicante) (Spain). This Information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the sleeping bags named.

c) description of operating conditions, and especially:

   1) description of the thermal manikin, garments worn and artificial ground;

   2) ambient conditions in the climatic room (temperature, humidity, wind speed);

d) results of the test (thermal resistance $R_c(1)$ and/or $R_c(2)$ of the sleeping bag sample);

e) calculated temperatures of the range of utility of the sleeping bag sample T_{ext}, T_{lim}, T_{comf} and/or T_{max};

f) a reference to this part of ISO 23537, i.e. ISO 23537-1: 2016;

g) details of deviations from this part of ISO 23537, if applicable;

h) date of test.

6 Labelling

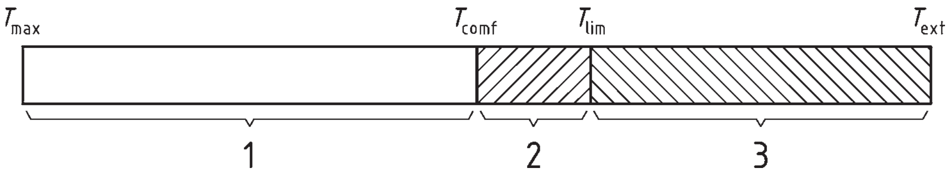
6.1 Graph for the range of utility

The range of utility for the sleeping bag sample shall be given on the label for marking (see 6.2) in the form of a graph.

The transition range shall be marked. The risk range shall also be marked and, simultaneously, the hazards existing in such environmental temperatures shall be pointed out. The comfort range may be marked.

The ranges shown in the graph shall be termed “comfort range”, “transition range” and “risk range”. These terms shall be given below the respective range. At the temperature limits T_{max}, T_{comf}, T_{lim}, and T_{ext} the respective values shall be given in °C.

The graph including its given data shall be used in a linear form. An example is shown in Figure 1. The colouring and the scale of the graph can be designed freely.



Key

1 comfort range

2 transition range

3 risk range

Figure 1 — Example for a graph for the range of utility

Below the graph, a warning note shall be included with the following wording:

“WARNING: In the risk range a strong sensation of cold has to be expected. There is a risk of health damage by hypothermia.”

For a warning of misuse of temperature rating, see Annex D.

6.2 Marking

At least the following information shall be permanently attached to the sleeping bag (e.g. by printing on the sleeping bag or by sewn-in labels):

a) reference to this part of ISO 23537, i.e. ISO 23537-1;

b) composition of the filling, shell fabric and lining;

c) ranges of utility (graph);

d) care labelling, according to ISO 3758;

e) name of the brand;

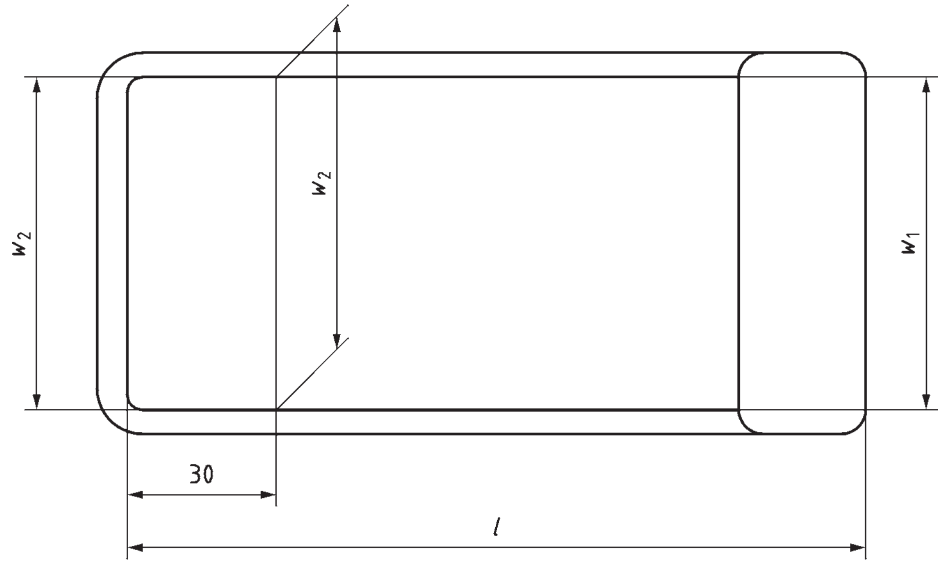
f) name or reference number of the product.

6.3 Information supplied to the consumer

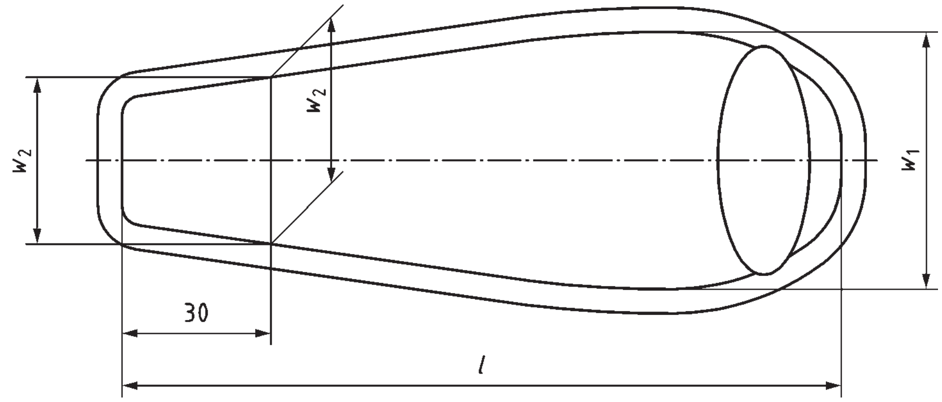
At least the following information shall be supplied to the consumer together with the sleeping bag at the point of sale:

a) inside length, maximum inside width and foot width in centimetres in a graphical symbol (for an example, see Figure 2);

Dimensions in centimetres



a) rectangular sleeping bag



b) mummy shaped sleeping bag

Key

l inside length

w_1 maximum inside width

w_2 inside foot width

Figure 2 — Graphical symbols

b) total mass of the sleeping bag:

  1) for sleeping bags of <1 000 g rounded to the nearest 10 g;

  2) for sleeping bags of ≥1 000 g rounded to the nearest 50 g;

c) name and address of the brand;

d) reference to this part of ISO 23537, i.e. ISO 23537-1;

e) if only compliance to this part of ISO 23537 is claimed, a note saying that the indicated reference to part of ISO 23537 only covers the thermal requirements of the sleeping bag and not its fabric properties.

Annex A
(normative)

Reference values of thermal resistance for calibration

A.1 General

The reference values for thermal resistances posture 1 $R_c(1)$ and the thermal resistances posture 2 $R_c(2)$ are those obtained with the thermal manikin "Charlie 3"[3)] operated in the specific conditions described in this Annex.

A.2 Thermal manikin

The thermal manikin "Charlie 3" has a human shape with trunk, head with hair, mobile arms and legs, hands and feet. Its dimensions correspond to German standard garment size 50/52. Its mass is 44 kg. When laid within a sleeping bag, the manikin has his left arm folded over the chest, and his right arm lying alongside the torso.

The body of the manikin is divided into 16 segments with independent surface temperature sensors and electric heating wires. The heating is monitored to maintain surface temperature of the corresponding segment at a constant value of (31 ± 0,1) °C; the surface of the manikin is made from a material of high thermal conductivity so as to guarantee uniformity of surface temperature. The power provided for heating is measured with an accuracy of ±2 %.

A.3 Garments and artificial ground

The garments and artificial ground used in the test with "Charlie 3" are those specified in 4.4.2 and 4.4.5.

A.4 Operating conditions

Air temperature within the climatic room is (15 ± 0,1) °C, and air speed is (0,3 ± 0,1) m/s. The air flow direction is vertical.

Measurement is made when thermal steady-state conditions are obtained. The heat loss of each of the 16 segments of the manikin "Charlie 3" is then recorded. Thermal resistance posture 1 $R_c(1)$ of the sleeping bag is calculated according to the serial calculation method, as described in ISO 15831.

Thermal resistance posture 2 $R_c(2)$ of the sleeping bag is calculated according to the parallel calculation method according to ISO 15831.

A.5 Reference thermal resistances of the reference set of sleeping bags

The reference values of the thermal resistances of the reference set of sleeping bags are listed in Table A.1.

3) "Charlie 3" is the name of the thermal manikin of Hohenstein Laboratories GmbH & Co. KG. This Information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the thermal manikin named. Equivalent thermal manikins may be used if they can be shown to lead to the same results.

Table A.1 — Reference values of thermal resistance

Sleeping bag sample	Thermal resistance posture 1 $R_c(1)$ $m^2 \cdot K/W$	Thermal resistance posture 2 $R_c(2)$ $m^2 \cdot K/W$
A	0,779	0,368
B	0,867	0,387
C	0,938	0,397
D	1,290	0,474
E	1,309	0,430
F	0,623	0,323

Annex B
(informative)

Precision of test results

B.1 Repeatability

In an inter-laboratory test involving six different thermal manikins and six different sleeping bags, for the thermal resistances posture 1 $R_c(1)$ and the thermal resistance posture 2 $R_c(2)$, the precision with three repeated measurements on the same sleeping bag specimen, has been found to be 3,6 % (variation coefficient).

B.2 Reproducibility

An inter-laboratory test involving six different thermal manikins and six different sleeping bags has shown a reproducibility of the thermal resistances posture 1 $R_c(1)$ and the thermal resistance posture 2 $R_c(2)$ of 5 % (variation coefficient).

Annex C
(normative)

Physiological model for calculation of range of utility

C.1 Thermal balance and calculation of temperatures of the range of utility

Temperatures of the range of utility are the ambient air temperatures which equilibrate thermal balance of the sleeping bag user:

$$M = H_c + H_e + H_{res} + \Delta S \qquad \text{(C.1)}$$

where

M is the metabolic heat production of the sleeping bag user (see C.2);

H_c is the dry thermal loss through the sleeping bag and from uncovered areas of the body (detailed in C.3);

H_e is the thermal loss due to evaporation of sweat on the skin surface (see C.4);

H_{res} is the respiratory thermal loss (detailed in C.5);

ΔS is the change of body heat content of the sleeping bag user (see C.6).

The calculation is performed through an iterative process on ambient temperature and mean skin temperature, until thermal equilibrium expressed by Formula (C.1) is fulfilled.

The temperatures of the range of utility obtained depend on the consideration of physiological stress for the sleeping bag user (metabolic heat production, thermal debt, skin temperature and posture) which is detailed in C.7.

Ambience is always considered as homogeneous (radiative temperature equal to air temperature) and with 50 % relative humidity.

C.2 Metabolic heat production, M

$$M = M_b + M_s \qquad \text{(C.2)}$$

where

M_b is the basic metabolic heat production for an activity of lying at rest, in Watt per square metre (W/m^2) (see C.7);

M_s is the additional metabolic heat production due to shivering, in Watt per square metre (W/m^2) (see C.7).

C.3 Dry heat loss, H_c

As ambience is always considered as homogeneous (radiative temperature equal to air temperature), dry heat loss through the sleeping bag is calculated by:

$$H_c = \frac{(t_{sk} - t_a)}{R_{c,eff}} \tag{C.3}$$

where

H_c is the dry heat loss through the sleeping bag, in Watt per square metre (W/m^2);

t_{sk} is the mean skin temperature of the sleeping bag user, in degrees Celsius (°C), which depends on physiological stress retained (detailed in C.7);

t_a is the ambient air temperature, in degrees Celsius (°C);

$R_{c,eff}$ is the effective thermal resistance of the sleeping bag, expressed in square metre Kelvin per Watt (m^2·K/W). The effective thermal resistance is related to the thermal resistances $R_c(1)$ and $R_c(2)$ according to C.7 and thus like other factors, depends on the posture adopted by the sleeping bag user in the bag.

C.4 Evaporative heat loss, H_e

$$H_e = \frac{w(p_{sk} - p_a)}{R_{e,eff}} \tag{C.4}$$

where

H_e is the evaporative heat loss, in Watt per square metre (W/m^2);

w is the skin wettedness [see Formula (C.5)];

p_{sk} is the partial water vapour pressure on wetted skin, in Pascal (Pa), [see Formula (C.6)];

p_a is the partial water vapour pressure in the ambient air, in Pascal (Pa), [see Formula (C.7)];

$R_{e,eff}$ is the effective water vapour resistance of the sleeping bag, expressed in square metre Pascal per Watt (m^2·Pa/W) according to C.7 and thus like other factors depends on the posture adopted by the sleeping bag user in the bag.

Skin wettedness (w) may be regarded as the proportion of skin area which is exposed to and participates in evaporation. The value retained for activity of resting in cold conditions is 6 %, which corresponds to insensible perspiration:

$$w = 0,06 \tag{C.5}$$

Water vapour pressure on wetted skin is given by:

$$p_{sk} = p_{sat}(t_{sk}) \quad \text{(C.6)}$$

where

p_{sk} is the water vapour pressure on wetted skin, in Pascal (Pa);

t_{sk} is the mean skin temperature of the sleeping bag user, in degrees Celsius (°C), which depends on physiological stress retained (see C.7);

$p_{sat}(t_{sk})$ is the saturated water vapour pressure at skin temperature t_{sk}, in Pascal (Pa) and calculated by Formula (C.8).

Partial water vapour pressure in the ambient air is:

$$p_a = \frac{Rh_a}{100 \cdot p_{sat}(t_a)} \quad \text{(C.7)}$$

where

p_a is the partial water vapour pressure in the ambient air, in Pascal (Pa);

Rh_a is the relative humidity in the ambient air, in per cent (%);

t_a is the ambient air temperature, in degrees Celsius (°C);

$p_{sat}(t_a)$ is the saturated water vapour pressure at temperature t_a, in Pascal (Pa) and calculated by Formula (C.8).

$$p_{sat}(t) = 133,3 \cdot 10 \exp[-2919,611 / (t+273) - 4,79518 \log(t+273) + 23,03733] \quad \text{(C.8)}$$

NOTE The value t is either t_a or t_{sk}..

where

$p_{sat}(t)$ is the saturated water vapour pressure, in Pascal (Pa), at temperature t;

t is the temperature, in degrees Celsius (°C).

The effective water vapour resistance $R_{e,eff}$ of the sleeping bag is related to the effective thermal resistance $R_{c,eff}$ and to the effective water vapour permeability index $i_{m,eff}$:

$$R_{e,eff} = \frac{60 \cdot R_{c,eff}}{i_{m,eff}} \quad \text{(C.9)}$$

where

a) sleeping bag user fighting against cold, with the user completely inside the sleeping bag and curled up to minimize the thermal loss:

$i_{m,eff} = 0,54$

b) sleeping bag user not fighting against cold, with the user completely inside the sleeping bag but lying in a relaxed posture (for instance lying on the back):

$i_{m,eff} = 0,52$

c) sleeping bag user fighting against overheating, with the user not completely inside the sleeping bag (for instance with the arms lying outside the sleeping bag):

$i_{m,eff} = 0,30$

C.5 Respiratory heat loss, H_{res}

$$H_{res} = M \cdot [0,5524 - 0,00144 \cdot (t_a + 273) - 0,00632 \cdot p_a / (t_a + 273)] \quad (C.10)$$

where

H_{res} is the respiratory heat loss, in Watt per square metre (W/m^2);

M is the metabolic heat production, in Watt per square metre (W/m^2), issued from Formula (C.2);

t_a is the ambient air temperature, in degrees Celsius (°C);

p_a is the partial water vapour pressure in the ambient air, in Pascal (Pa), calculated according to Formula (C.7).

C.6 Change of body heat content, ΔS

Change of body heat content results in decreasing or increasing internal body temperature. The physiological model presented here is made for thermal equilibrium, and thus the change of body heat content is assumed to be zero:

$\Delta S = 0\ W/m^2$

C.7 Physiological data assumed for calculation of temperatures of utility

C.7.1 Extreme temperature, T_{ext}

This temperature is calculated for a person with characteristics of a so-called standard woman (25 years old, 60 kg, 1,60 m, 1,62 m^2 body surface area) in a situation of high cold stress, combined with shivering to increase the basic metabolic heat production, which can be maintained only for a limited duration of 6 h. The sleeping bag user is curled up in the sleeping bag so as to minimize thermal loss through the sleeping bag. The data for this temperature consists of:

a) basic metabolic heat production: $M_b = 44,4\ W/m^2$

b) additional metabolic heat production due to shivering: $M_s = 25,4\ W/m^2$

c) effective thermal resistance of the sleeping bag $R_{c,eff}$: $R_{c,eff} = R_c(1)$

d) effective water vapour resistance of the sleeping bag $R_{e,eff}$: $R_{e,eff} = 60\ R_{c,eff}/0,54$

C.7.2 Limit temperature, T_{lim}

This temperature is calculated for a standard man (25 years old, 70 kg, 1,73 m, 1,83 m^2 body surface area) in a situation of fighting against cold (posture is curled up inside the sleeping bag), but in thermal equilibrium and just not feeling cold (no shivering). The data for this temperature consists of:

a) basic metabolic heat production: $M_b = 47,5\ W/m^2$

b) effective thermal resistance of the sleeping bag $R_{c,eff}$: $R_{c,eff} = R_c(1)$

c) effective water vapour resistance of the sleeping bag $R_{e,eff}$: $R_{e,eff} = 60 \cdot R_{c,\ eff}/0,54$

C.7.3 Comfort temperature, T_{comf}

This temperature is calculated for a standard woman (25 years old, 60 kg, 1,60 m, 1,62 m^2 body surface area) who is just not feeling cold (no shivering) in a relaxed posture. The data for this temperature consists of:

a) basic metabolic heat production: $M_b = 44,4\ W/m^2$

b) effective thermal resistance of the sleeping bag $R_{c,eff}$: $R_{c,eff} = 0,9 \cdot R_c(1)$

c) effective water vapour resistance of the sleeping bag $R_{e,eff}$: $R_{e,eff} = 60 \cdot R_{c,\ eff}/0,52$

C.7.4 Maximum temperature, T_{max}

This temperature is calculated for a standard man (25 years old, 70 kg, 1,73 m, 1,83 m^2 body surface area) in a posture with his arms lying outside the sleeping bag, The data for this temperature consists of:

a) basic metabolic heat production: $M_b = 48,1\ W/m^2$

b) skin wettedness: $w = 0,35$

c) effective thermal resistance of the sleeping bag $R_{c,eff}$: $R_{c,eff} = R_c(2)$

d) effective water vapour resistance of the sleeping bag $R_{e,eff}$: $R_{e,eff} = 60 \cdot R_{c,eff}/0,30$

C.8 Approximate calculation of the temperatures of utility

The limiting temperatures of a sleeping bag may be approximated using the following formulae:

$$T_{ext} = -50,91\ R_c(1) + 29,61 \quad \text{(C.11)}$$

$$T_{lim} = -36,35\ R_c(2) + 32,00 \quad \text{(C.12)}$$

$$T_{comf} = -30,96\ R_c(1) + 32,29 \quad \text{(C.13)}$$

$$T_{max} = -36,07\ R_c(2) + 38,19 \quad \text{(C.14)}$$

Annex D
(informative)

Warning of misuse of temperature rating

The insulation of a sleeping bag varies widely with the conditions of use (wind, radiative ambience, posture and clothing of the sleeping bag user, ground insulation, eventual humidity in the sleeping bag etc.).The perception of cold of the user is also individually different (influence of acclimatization, physical and psychological state, food etc.).

The limiting temperatures of the range of utility as determined in this part of ISO 23537 only compare performance of sleeping bags with regard to standardized test conditions. They do not take into account all possible variations in conditions of use and in individual reactions, and therefore should be considered only as a guideline, that needs personal adaptation for practical use.

In particular, it shall be noted that the extreme temperature is a very theoretical limit. It shall therefore only be considered as a point of danger that should not be approached, unless the sleeping bag user has a wide personal experience. Furthermore, it has been determined through tests and practical experience that internal dimensions and the dimensions of the user have a significant effect on the performance of the sleeping bag.

The determination of the comfort temperature uses the available knowledge of published data and is based on the thermal balance of the whole body. The human body is very sensitive to local discomfort: a local thermal bridge might not influence the global insulation of the sleeping bag, but might greatly affect the sensation of cold of the sleeping bag user. It shall be emphasized that the test method in this part of ISO 23537 does not provide any guarantee against local cooling.

The temperatures of the range of utility relate to indoor conditions. For outdoor use, wind may affect insulation of the bag to a large extent, especially if the shell fabric of the sleeping bag is air permeable.

In this part of ISO 23537, sleeping bags are considered as dry. High moisture content might lower thermal performance.

Annex E
(informative)

Rationale

The primary aim of this part of ISO 23537 is to provide information to the consumer by specifying a test procedure and an evaluation model to quantify the thermophysiological function of sleeping bags.

This function is determined by the sleeping bag's thermal insulation and by its moisture management properties. Both shall be adapted to the ambient climate conditions (temperature, humidity, wind speed) under which the sleeping bag is used, as well as to the physiological processes in the human body. A correct adaption is the prerequisite for good sleep quality and is achieved if the body's heat content is balanced. This means that the heat which is always (i.e. also with a sleeping person) created within the body by metabolic processes shall be dissipated in the same amount as it is produced. Generally, maintaining this heat balance in a sleeping bag is made difficult by the fact that, on the one hand, the amount of metabolic heat within the body depends on the person's weight. For example, while sleeping, a 50 kg person produces around 60 W heat, while a 110 kg person produces about 100 W. On the other hand, the heat flow from the sleeper's body to the surrounding air is not only determined by the sleeping bag's thermal insulation to which the thermal insulation of the sleepwear and possibly of the mat underneath the sleeping bag shall be added, but also by the ambient temperature. If this heat flow is too high, the body's heat content decreases, and the person will feel cold and, in extremer cases, can even die due to hypothermia.

If the heat flow is too low, the body's heat content increases, and the person begins to sweat. The purpose of this process is to cool the body via the evaporation of sweat on the skin. This cooling is quite effective, but only if the sweat can actually evaporate. This means that the sleeping bag shall also have a good "breathability". This demand is underscored by the fact that a person, even without actively sweating, in any case during the night dissipates about 1/4 l of moisture from the body's interior through the skin. If the sleeping bag's "breathability" or moisture management is not good enough, the person will not only feel uncomfortably moist, but also the body will be overheated, with the sleep being impaired or even made impossible.

Naturally, the thermophysiological comfort affected by a sleeping bag is determined from a large number of variables. These variables have been taken into account by the test methods with a thermal manikin and a Skin Model described in this part of ISO 23537, and by the thermophysiological model used to evaluate the test results and to translate them into the temperature limits of what is called the sleeping bag's range of utility.

With the Skin Model ("sweating guarded-hotplate"), standardized in ISO 11092, the sleeping bag's moisture management is tested and quantified via the water vapour permeability index in 4.1. The minimum value of 0,45 demanded for this index ensures that the sleeping bag's "breathability" is at least satisfactory.

With the manikin, standardized in ISO 15831, the thermal insulation effected by the sleeping bag is measured. This thermal insulation is not only created by the bag itself, but is also influenced by the garments worn within the bag and the mat possibly placed underneath the bag, as well as, for example, by the person's weight compressing the bag's bottom part, and by the ambient wind speed and humidity. Therefore, in this part of ISO 23537, test conditions have been defined in such a way that the test results are repeatable and also comparable between different test houses. This has been verified by several round robin tests performed prior to the publication of this part of ISO 23537, with the precision achieved given in Annex B.

More particularly, the test conditions chosen also take into account that in practical use in a cold climate a person will turn the head into the sleeping bag's hood in order to protect the face from cold air. Because the head of the manikins presently available the head cannot be turned, for sleeping bags including a hood, this situation is simulated by placing a mask on the manikin's face.

Similarly, the test conditions also take into account use in a hot climate. Due to the fact that at higher ambient temperatures it would be unrealistic to use the sleeping bag completely closed, and with the hood tight around the head, a second posture for the manikin is specified. In this second posture, the bag's zippers are fully opened and the hood is turned down, leaving the manikin's arms and shoulders, as well as the head, uncovered.

The thermophysiological model applied in this part of ISO 23537 to convert the sleeping bag's thermal insulation into its temperature range of utility is the result of extensive physiological research. The limiting temperatures derived from this evaluation model have been proved to be correct by numerous sleep trials with human subjects performed scientifically by different research institutes. These sleep trials have been conducted in climatic chambers with controlled ambient climate conditions, and with sensors attached to the subjects' body, transmitting physiologically relevant data such as rectal and skin temperatures, humidity next to the skin, metabolic heat and sweat production of the subjects, as well as sweat uptake of the sleeping bag and sleepwear. Via the heart rate, the sleep quality was monitored; and the persons' subjective comfort sensations were quantified via scales in questionnaires.

It can be stated in general that the thermophysiological model used in this part of ISO 23537 to determine a sleeping bag's range of utility out of its effective thermal insulation is not the only one possible. However, this model is the only one of its kind to date whose results has been scientifically validated with statistically sufficient accuracy.

In particular, this thermophysiological model takes into account that, as outlined above, a person's metabolic heat production depends on their weight, and the heat flux from the body on its surface area (which also depends on weight and additionally on height).Because of this variability, the model differentiates between a heavier and taller "standard man" with a higher metabolic heat production while sleeping, and a comparatively lighter and smaller "standard woman" with a lower heat production within her body. The "standard woman" starts to feel cold in the sleeping bag at the "comfort temperature" introduced in the standard, whereas the "standard man" starts to be uncomfortably cold at the "limit temperature" which, depending on the sleeping bag's thermal insulation, is several °C lower than the "comfort temperature".

Below the "limit temperature" practically everybody feels too cold, and when approaching the "extreme temperature" the "standard woman" is in danger of suffering health-damaging hypothermia. At the "maximum temperature" however, a person with a body stature similar to the "standard man" will feel uncomfortably hot in the sleeping bag.

These temperatures, limiting the range of utility of a sleeping bag, and depending on its thermal insulation, are shown in Table 1 and Table 2. The intention of the standard is that at the Point of Sale sleeping bags are marked with these temperature limits. Such a marking provides the consumer with an objective criterion to compare different sleeping bag products with regard to their physiological performance, and helps them to select a product which is physiologically suitable for the climate conditions in which it is intended to be used.

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