INTERNATIONAL STANDARD

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Requirements for sleeping bags —

Part 1: Thermal, mass and dimensional requirements for sleeping bags designed for limit temperatures of -20°C and higher

Exigences pour les sacs de couchage —

Partie 1: Exigences thermiques, de masse et dimensionnelles pour les sacs de couchage conçus pour les températures limites de -20 °C et plus

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Contents

Page

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 of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 23537-1:2016), which has been technically revised. It also incorporates the Amendment ISO 23537-1:2016/Amd.1:2018.

The main changes are as follows:

— update of Clause 3;

— update of the scope to exclude extreme climate conditions;

— revision of requirements for lower temperature limits;

— revision of test methods;

— revision of Clause 7;

— revision of the reference values of thermal resistance for calibration of thermal manikin.

A list of all parts in the ISO 23537 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 23537-2 specifies requirements for material performance.

This document considers important aspects to the thermal performance of the sleeping bag.

In this document, 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.

A rationale is given in Annex E.

Requirements for sleeping bags —

Part 1:
Thermal, mass and dimensional requirements for sleeping bags designed for limit temperatures of -20°C and higher

1 Scope

This document specifies the requirements, test methods and other provisions for the labelling of adult sized sleeping bags for use in sports and leisure time activities at a limit temperature ≥ -20 °C regarding thermal characteristics, dimensions and mass.

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

NOTE 1 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.

This document 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 2 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 possible.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 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 13088:2018, *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.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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 at the threshold of feeling cold

Note 1 to entry: For more information, see C.6.3.

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 at the threshold of feeling cold

Note 1 to entry: For more information, see C.6.2.

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.6.1.

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

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

Note 1 to entry: For more information, see Annex F.

3.5
thermal manikin
dummy with human shape and heated body surface that 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
R_c
property of the sleeping bag that is related to the dry heat loss of the sleeping bag user, affected 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

4.1 Thermal properties for lower temperature limits

Depending on the thermal resistance posture 1 $R_c(1)$, the values for the extreme temperature (T_{ext}), limit temperature (T_{lim}) and comfort temperature (T_{comf}) as given in Table 1 shall be used. If the thermal resistances posture 1 $R_c(1)$ measured for the sleeping bag is in between the values in Table 1, a linear interpolation shall be performed on the basis of the nearest upper and lower values of the thermal resistances posture 1 $R_c(1)$.

Test in accordance with 5.1.6.

Table 1 — Lower temperature limits of the range of utility

Thermal resistance posture 1 $R_c(1)$ $m^2 \cdot K/W$	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

4.2 Water vapour permeability index

The material specific water-vapour permeability index (i_{mt}) of the sleeping bag shall be ≥0,45.

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.

Test in accordance with 5.2.

4.3 Inside dimensions

4.3.1 Inside length

The inside length of the sleeping bag shall be given with a tolerance of ±3 cm. Test in accordance with 5.3.1.

4.3.2 Maximum inside width

The maximum inside width of the sleeping bag shall be given with a tolerance of ±2 cm. Test in accordance with 5.3.2.

4.3.3 Inside foot width

The inside foot width of the sleeping bag shall be given with a tolerance of ±2 cm. Test in accordance with 5.3.3.

4.4 Total mass

The total mass of the sleeping bag shall be given with a tolerance of ±5 %. Test in accordance with 5.4.

5 Test methods

5.1 Testing of the thermal properties

5.1.1 Principle

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

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

The manikin test in this document is suitable for mummy-shaped bags, which appropriately fit to the manikin without being tight. The temperature rating result can be applied to other sized mummy bags that use the same materials and insulation construction and are proportionally scaled up or down from the tested bag.

5.1.2 Thermal manikin

5.1.2.1 General

A thermal manikin in accordance with ISO 15831 with a body height of (1,70 ± 0,15) m shall be used. During the test, the manikin shall be dressed in the following garments:

— two-piece suit (upper part with long sleeves, trousers) with a material specific thermal resistance (R_{ct}) of 0,040 m^2·K/W to 0,060 m^2·K/W when tested in accordance with ISO 11092.

— knee-length socks with a material specific thermal resistance (R_{ct}) of 0,040 m^2·K/W to 0,060 m^2·K/W when tested in accordance with ISO 11092.

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

5.1.2.2 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[1)] in accordance with Table A.1. For measurement accuracy, see Annex B.

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 $R_c(1)$ of the reference set of sleeping bags given in Table A.1.

The deviation of the corrected values of the thermal resistances posture 1 $R_c(1)$ 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) the repeatability of the measurement on each sleeping bag shall be better than 4 % (variation coefficient).

5.1.3 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 Highly insulative sleeping bags might not allow the heat flux to be ≥20 W/m^2. In these cases, an ambient temperature of the lowest value within this range is seen as appropriate.

5.1.4 Artificial ground

The test shall be operated with the thermal manikin placed into the sleeping bag in accordance with 5.1.6, lying on a foam mattress with a material specific thermal resistance R_{ct} = (0,85 ± 0,06) m^2 K/W when tested in accordance with ISO 11092 and placed on an artificial ground. This ground shall consist of a wooden board in accordance with 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.

5.1.5 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.

5.1.6 Thermal resistance for 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,

1) The reference sets of sleeping bags are available from:
a) SWEREA IVF AB, Box 104, 431 22 Mölndal (Sweden);
b) Hohenstein Laboratories GmbH & Co. KG, Schloss Hohenstein, 74357 Bönnigheim (Germany);
c) AITEX, Plaza Emilio Sala 1, 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 products named. Equivalent products may be used if they can be shown to lead to the same results.

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.) that are 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, i.e. extreme cold weather, U.S. G.I.[2)], shall be used on the manikin's face. For sleeping bags with hoods, 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.

NOTE Test rectangular bags can encounter excessive heat loss in bare head area when tested, which would result in overly conservative results.

The thermal resistance posture 1 $R_c(1)$ is determined using either the serial or the parallel calculation method according to ISO 15831. The same calculation method shall be used for the sleeping bags being tested as was used for the reference set of sleeping bags.

5.1.7 Test procedure

The test shall be performed in accordance with the requirements in 4.1.

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 in accordance with this document.

Calculate the value of the thermal resistance posture 1 $R_c(1)$ by applying the same calculation method and correlation gained from the calibration procedure as given in 5.1.2.2.

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 5.1.5 in between individual tests, and the test report shall show a single bag was used.

5.1.8 Calculation of temperatures of the range of utility

The sleeping bag's extreme temperature (T_{ext}), limit temperature (T_{lim}) and comfort temperature (T_{comf}) shall be determined on the basis of the thermal resistance posture 1 $R_c(1)$, in accordance with the physiological model described in Annex C.

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

5.2 Testing of the water vapour permeability index

Test in accordance with ISO 11092.

All different material combinations of the sleeping bag shall be tested.

2) Mask, extreme cold weather, U.S. G.I. is the trade name of product supplied by Coleman. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5.3 Measurement of inside dimension

5.3.1 Inside length

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.

5.3.2 Maximum inside length

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.

5.3.3 Inside foot width

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.

5.4 Testing of the total mass

For determining the total mass of the sleeping bag (without stuff sack), the sleeping bag shall be conditioned in accordance with ISO 139 at 20 °C air temperature and 65 % relative air humidity.

The total mass of sleeping bags filled with feather and/or down shall be determined in accordance with EN 13088:2018, Clauses 7 and 8.

The total mass of sleeping bags filled with materials other than feather and down shall be determined by weighing it on a scale with an accuracy of ± 0,5.

6 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 5.1.7), a note saying that only one sleeping bag was used;

c) description of operating conditions, and especially:

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

e) ambient conditions in the climatic room (temperature, humidity, wind speed and direction);

f) results of the test (thermal resistance $R_c(1)$ of the sleeping bag sample) with the calculation method used and what correction was applied;

g) calculated temperatures of the range of utility of the sleeping bag sample T_{ext}, T_{lim}, and T_{comf};

h) a reference to this document, i.e. ISO 23537-1:2022;

i) details of deviations from this document, if applicable;

j) date of test.

7 Labelling

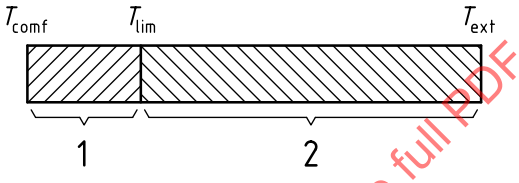
7.1 Graph for the range of utility

The range of utility for the sleeping bag sample shall be given on the label for marking (see 7.2) 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 "transition range" and "risk range". These terms shall be given below the respective range. At the temperature limits 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 transition range

2 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 must be expected. There is a risk of health damage by hypothermia.

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

7.2 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 document, i.e. ISO 23537-1:2022;

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

c) ranges of utility (graph, see Figure 1 as example);

d) care labelling, in accordance with ISO 3758;

e) name of the brand;

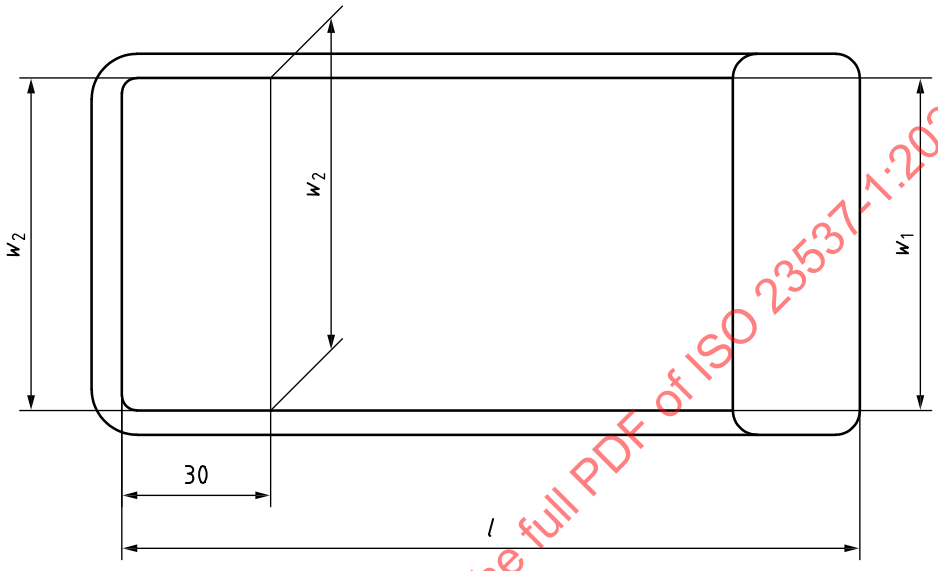
f) name or reference number of the product.

7.3 Information supplied to the consumer

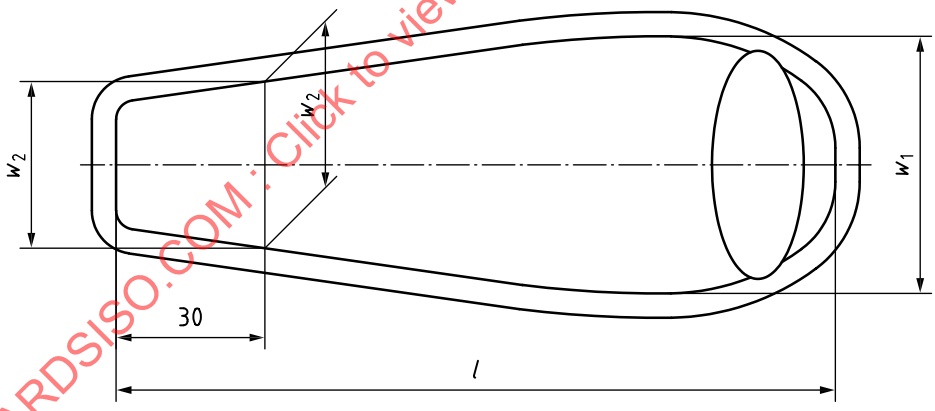
At least the following information shall be supplied to the consumer together with the sleeping bag at the point of sale:

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) a reference to this document, i.e. ISO 23537-1:2022.

Annex A
(normative)

Reference values of thermal resistance for calibration of thermal manikin

A.1 General

The reference values of the thermal resistance posture 1 $R_c(1)$ for the calibration of sleeping bags as shown in Table A.1 were calculated using "Charlie 3"[3] and the garments, artificial ground and operating conditions described below.

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 5.1.2.1 and 5.1.4.

A.4 Operating conditions

Air temperature within the climatic room is (10 ± 5) °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.

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 document and does not constitute an endorsement by ISO of the product named. Equivalent products 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 $R_c(1)$ $m^2 \cdot K/W$
A	0,779
B	0,867
C	0,938
D	1,290
E	0,623

Annex B
(informative)

Precision of test results

B.1 Repeatability

In an interlaboratory test involving six different thermal manikins and six different sleeping bags, for the thermal resistances posture 1 $R_c(1)$, 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 interlaboratory test involving six different thermal manikins and six different sleeping bags has shown a reproducibility of the thermal resistances posture 1 $R_c(1)$ 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 that equilibrate thermal balance of the sleeping bag user. They are given in Formula (C.1):

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

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

It is given in Formula (C.2):

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

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 Formula (C.3):

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

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 ($m^2 \cdot K/W$). 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

It is given in Formula (C.4):

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

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 ($m^2 \cdot Pa/W$) 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 that 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:

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

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 given in Formula (C.7):

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

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).

$$p_{sat}(t) = 133{,}3 \cdot 10 \exp\left[-2\,919{,}611 / (t + 273) - 4{,}795\,18 \log(t + 273) + 23{,}037\,33\right] \quad \text{(C.8)}$$

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 $i_{m,eff}$. It is calculated by Formula (C.9).

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

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):

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

Respiratory heat loss, H_{res}, is calculated by Formula (C.10).

$$H_{res} = M\left[0{,}552\,4 - 0{,}001\,44\,(t_a + 273) - 0{,}006\,32\,p_a / (t_a + 273)\right] \quad \text{(C.10)}$$

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 in accordance with Formula (C.7).

C.5 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.6 Physiological data assumed for calculation of temperatures of utility

C.6.1 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.6.2 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 $R_{e,eff}$: $R_{e,eff} = 60\ R_{c.eff}/0,54$

C.6.3 Comfort temperature

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 $R_{c,eff}$: $R_{c,eff} = 0,9\ R_c(1)$

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

C.7 Approximate calculation of the temperature of utility

The limiting temperatures of a sleeping bag may be approximated using Formulae (C.11) to (C.13):

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

$$T_{lim} = -36{,}35\ R_c(1) + 32{,}00 \quad \text{(C.12)}$$

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

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 document 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 document does not provide any guarantee against local cooling.

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

In this document, sleeping bags are considered as dry. High moisture content can lower thermal performance.