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Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven

bsi.

National foreword

This British Standard is the UK implementation of ISO 17493:2016. It supersedes BS ISO 17493:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/3/2, Heat and Flame Personal Protective Equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Second edition
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Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven

Vêtements et équipement de protection contre la chaleur — Méthode d'essai de la résistance à la chaleur de convection au moyen d'un four à circulation d'air chaud

Reference number
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Foreword

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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).

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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.

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

This second edition cancels and replaces the first edition (ISO 17493:2000), which has been technically revised with the following changes:

— the specifications for the apparatus have been improved and completed (5.1, 5.2, 5.4, new 5.5, 5.6, 5.7);

— procedures for the calibration of the test oven have been added (new Clause 7);

— a list of ASTM standards related to ISO 17493 is given in the Bibliography.

Introduction

This test method allows for the evaluation of the heat resistance of materials, protective clothing and equipment when suspended in a hot air circulating oven at a specified temperature of typically 180 °C or 260 °C for typically 5 min. Visible observations of charring, deformation, delamination, hole formation, ignition, melting of the specimen are recorded. The exposure in the hot air circulating oven may be used either for a visual evaluation only or as a pre-treatment for a material property measurement such as shrinkage or other property measurement which is not specified in this document.

INTERNATIONAL STANDARD ISO 17493:2016(E)

Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven

1 Scope

This document describes a test method for evaluating the heat resistance of protective clothing materials or items and equipment when exposed in a hot air circulating oven. The method is intended to evaluate physical changes in a material at a given exposure temperature. Materials are evaluated for defined visible changes including the measurement of shrinkage.

Different procedures are provided depending on the type of the protective clothing material or item being tested.

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 3759, *Textiles — Preparation, marking and measuring of fabric specimens and garments in tests for determination of dimensional change*

ISO 3873, *Industrial safety helmets*

ISO 4643:1992, *Moulded plastics footwear — Lined or unlined poly(vinyl chloride) boots for general industrial use — Specification*

IEC 60584-1, *Thermocouples — Part 1: EMF specifications and tolerances*

3 Terms and definitions

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

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

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

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

3.1
charring
response of the test specimen to heat evidenced by the formation of a carbonaceous residue

3.2
clothing assembly
series of garments arranged in the order as worn

Note 1 to entry: They may contain multilayer materials, material combinations, or a series of separate garments in single layers.

3.3
component assembly
combination of all materials and *hardware* (3.7) presented exactly as the finished garment construction

3.4
deformation
response of the test specimen to heat evidenced by a change in the shape of the test specimen that is irreversible at room temperature

Note 1 to entry: *Shrinkage* (3.12) is a form of deformation.

3.5
delamination
response of the test specimen to heat evidenced by separation into two or more layers, in whole or in part

3.6
equipment
footwear, helmets, gloves, and eye or face protection devices

3.7
hardware
non-fabric items forming part of or optional extras in a garment

EXAMPLE Metal or plastic buttons or zippers and touch and close fasteners or hook and loop fasteners.

3.8
hole formation
opening, break, or discontinuity of any size in the original structure of the test specimen's fabric caused by application of heat

3.9
ignition
response of the test specimen to heat evidenced by initiation of combustion

3.10
melting
response of the test specimen to heat evidenced by a change of state from solid to liquid

Note 1 to entry: The practical observation of melting, as a material response at the end of the heat exposure, is to visually see evidence that the specimen has liquefied, in whole or in part, by displaying flow patterns or droplet formation.

3.11
separating
response of the test specimen to heat evidenced by *splitting* (3.13), *delamination* (3.5) or flaking

3.12
shrinkage
response of the test specimen to heat evidenced by a decrease in one or more dimensions

3.13
splitting
response of the test specimen to heat evidenced by breaking into two pieces, in whole or in part

4 Principle

Specimens are suspended in a hot air circulating oven for 5 min at the specified test temperature. Any visible observations such as charring, deformation, degradation, delamination, embrittlement, flaking, hole formation, ignition, melting, separating, or splitting of the specimen are recorded. Shrinkage may also be measured. Specimens may also be subject to other property determinations following heat exposure.

Observations of degradation, embrittlement, splitting, separating, or flaking can be considered as subjective and should not be used as a pass/fail criteria for a product standard.

5 Apparatus

5.1 Forced air circulating oven, capable of maintaining the test temperature over a period of 5 min and of sufficient internal volume to allow the test specimen (see Clause 6) to be suspended as specified in Clause 7.

Testing shall be carried out at the test temperature specified in the referencing standard. If not specified otherwise, testing shall be carried out at a test temperature of $(180\ ^{+8}_{-0})$ °C or $(260\ ^{+8}_{-0})$ °C.

The test oven shall be a horizontal flow circulating oven with minimum interior dimensions such that the specimens can be suspended and be at least 50 mm from any interior oven surface or other test specimens.

The test oven shall have an airflow rate of 0,5 m/s to 1,5 m/s at the standard temperature and pressure of 20 °C at 1 atm, measured at the centrepoint of the oven.

The test oven shall have the following temperature uniformity, when determined according to the procedure specified in A.1

The maximum temperature deviation from the specified temperature levels at

— 260 °C for each of the nine thermocouples shall be no greater than 6,5 °C, and

— 180 °C for each of the nine thermocouples shall be no greater than 4,5 °C.

NOTE 1 The above performance requirement for 260 °C is equivalent to the requirement in ASTM F 2894-14 for the maximum temperature deviation specified in ASTM E 145 for IIB oven.

The time constant of the oven, determined according to the procedure of A.2 shall not exceed 660 s.

NOTE 2 The above performance requirement is equivalent to the requirement in ASTM F 2894-14 for the time constant specified in ASTM E 145 for IIB oven.

An oven sensing thermocouple shall be positioned so that it is level with the horizontal centreline of a mounted sample specimen. The thermocouple shall be equidistant between the vertical centreline of a mounted specimen placed in the middle of the oven and the oven wall where the airflow enters the test chamber. The thermocouple shall be an exposed bead, Type J or K according to IEC 60584-1, having a cross sectional area of 0,05 mm^2 (No. 30 AWG), or thermocouple with equivalent response time. The test oven shall be heated and the test thermocouple stabilized at the test temperature for a period of not less than 30 min.

5.2 Rigid, square templates for sizing material specimens

A template measuring 375 mm × 375 mm shall be used for sizing flat materials that are subject to shrinkage measurements.

A template measuring 150 mm × 150 mm may be used for flat materials that are not subjected to shrinkage measurements.

For specimens (such as straps) narrower than 150 mm in one dimension, use specimens at their normal width by 150 mm in length. Suspend these specimens with their long axis in a vertical direction.

5.3 Ruler, graduated in millimetres.

5.4 Stretching frame for measuring shrinkage of knit materials.

The frame shall be rigid and square having pins uniformly spaced, 25 mm apart, in a pattern measuring 325 mm^2 to secure knit materials before and after heat exposure. The stretching frame should be of a size on which the pins are located approximately 50 mm inward from the edge of the cut specimen size.

NOTE The stretching frame is used before the knit specimen is placed in the oven for marking the specimen for shrinkage determination. The stretching frame is not used while the knit specimen is exposed to heat in the oven. The stretching frame is used again for a specified period of time after heat exposure in the oven to return the knit specimen to its original dimensions. The knit specimen is then removed from the frame and measured for shrinkage.

5.5 Specimen mounting hardware.

Metal hooks or clamps shall be used to suspend the specimens in the centre of the oven. If the specimen is too large to be suspended, an insulating platform can be used to support the specimen in the centre of the oven. Ceramic has been found to be a suitable platform material.

5.6 Glass beads.

Beads of nominal 4 mm size made of perforated soda lime or borosilicate glass.

5.7 Headform.

The head for testing of a helmet or eye/face protection device shall be a non-conductive ISO Size K head as specified in ISO 3873.

6 Specimens

6.1 Material specimen preparation and conditioning

Samples for conditioning shall be complete items of protective clothing or equipment or flat materials at least 1 m^2.

Condition the sample for at least 24 h in a standard atmosphere at (20 ± 2) °C and (65 ± 5) % relative humidity.

Mark and cut out a square specimen using the template (5.2). If the material or item for test is narrower than 375 mm, cut the specimen 375 mm in the direction of its length and turn the specimen so as this edge serves as the width. If the item for test is less than 375 mm × 375 mm, test the complete item.

As indicated in 5.2, the specimen may be of reduced size (using a template of 150 mm × 150 mm) when the specimens are not subjected to measurement of shrinkage.

Test a minimum of three specimens.

6.2 Glove, footwear, helmet and eyewear specimen preparation and conditioning

Small items of protective clothing or equipment may be tested whole such as gloves, footwear, helmets or eyewear, as long as the oven specifications specified in 5.1 are met. A minimum of three different items shall be tested.

Condition these items for at least 24 h in a standard atmosphere at (20 ± 2) °C and (65 ± 5) % relative humidity.

7 Calibration of test oven

7.1 Temperature and air velocity uniformity

Determine the temperature uniformity of the oven. Annex A provides one method for the assessment and verification of temperature uniformity.

The maximum temperature deviation from the specified temperature levels at

a) 260 °C for each of the nine thermocouples shall be no greater than 6,5 °C, and

b) 180 °C for each of the nine thermocouples shall be no greater than 4,5 °C.

Determine that the air velocity at the geometric centre of the oven is 0,5 m/s to 1,5 m/s. This determination is to be made at a standard temperature of 20 °C and at local atmospheric pressure.

7.2 Daily

Prior to testing each day, install a verification thermocouple of equal type and performance as the oven sensing thermocouple in the centre of the empty oven.

Adjust the oven temperature control until the verification thermocouple measures the specified testing temperature, as if conducting a test. Maintain for 5 min.

When conducting a test, use the oven temperature setting that produced the desired temperature as measured by the verification thermocouple.

8 Procedures

8.1 Procedure for flat textile or other sheet materials

Mark and measure specimens in accordance with the procedures specified in ISO 3759 with the exception that the distance between the two marks in each pair shall be 275 mm.

Turn on the oven and heat to test temperature. Allow the oven to stabilize at the specified temperature (see 5.1) for a minimum of 30 min.

Suspend the specimen by metal hooks at the top and centred in the oven so that the entire specimen is not less than 50 mm from any oven surface or other specimen, and airflow is parallel to the plane of the material.

Do not open the oven door for more than 15 s. Shut off the air circulation while the door is open and turn the air circulation on when the door is closed. The total oven recovery time after the door is closed shall not exceed 30 s.

Expose the specimen, mounted as specified, in the test oven for 5 min ($^{+15}_{-0,0}$ s) at the specified temperature (see 5.1). The test exposure time shall begin when the test thermocouple recovers to the test temperature.

Immediately after the specified exposure, remove the specimen and examine it for evidence of charring, deformation, delamination, hole formation, ignition, melting, separating, or splitting.

Five minutes after the specified exposure, where required, measure the specimen's marked dimensions to determine percentage shrinkage in both main directions. Using the stretching frame (5.4), pull knit fabric specimens to their original dimensions for 10 min, then remove the specimens from the frame, and allow the specimens to relax for 10 min prior to measurement to determine pass/fail.

If, in stretching knit fabric specimens, the specimens break or cannot be stretched to the original dimensions, then this observation shall be reported in lieu of the measured shrinkage.

Subject heat-exposed specimens to other evaluations as required.

8.2 Procedure for protective gloves

Measure the glove length from the tip of the middle finger to the end of the glove body on the palm side. Measure the glove width on the palm side 25 mm below the base of the fingers.

Turn on the oven and heat to test temperature. Allow the oven to stabilize at the specified temperature (see 5.1) for a minimum of 30 min.

Fill the glove body with glass beads, clamp the opening of the glove together and suspend the specimen in the clamp in the oven so that the entire glove is not less than 50 mm away from any oven surface or other specimen, and airflow is parallel to the plane of the glove palm.

Optionally, the glove can be tested also without being filled with glass beads.

NOTE Glass beads are used to simulate the heat sink created by a hand in a glove or a foot in the footwear. However, when the glove is filled with glass beads and suspended, the weight of the filler can affect the test result of shrinkage. In this case, additional optional testing without filler can allow to obtain additional information about the shrinkage behaviour of a glove.

Do not open the oven door for more than 15 s. Shut off the air circulation while the door is open and turn the air circulation on when the door is closed. The total oven recovery time after door is closed shall not exceed 30 s.

Expose the specimen, mounted as specified, in the test oven for 5 min ($^{+15}_{-0,0}$ s) at the specified temperature (see 5.1). The test exposure time shall begin when test thermocouple recovers to the test temperature.

Immediately after the specified exposure, remove the specimen and examine it for evidence of charring, deformation, delamination, hole formation, ignition, melting, separating, or splitting.

Five minutes after the specified exposure, remove the glass beads and remeasure the glove length and width as indicated above to determine the percentage shrinkage in each direction.

Have a test subject, whose hands are of suitable dimensions for the tested gloves, don the gloves before the exposure to check the size. The test subject shall then don the exposed gloves 15 min after the heat exposure and flex the gloves a total of 25 times by clenching and unclenching the hands repeatedly into a fist. Record any changes in the gloves as a result of heat exposure and flexing.

8.3 Procedure for protective footwear

Turn on the oven and heat to test temperature. Allow the oven to stabilize at the specified temperature (see 5.1) for a minimum of 30 min.

Fill the footwear with glass beads, fasten all closures, and position the footwear in the exact centre of the oven, using a non-conductive stand in the centre of the oven or oven rack (with the toe of the footwear facing the oven door). Ensure that the footwear item is not less than 50 mm away from any oven surface. Test only one footwear item at a time.

Optionally, the footwear can be tested also without being filled with glass beads or with being filled by another light material with low heat storage.

NOTE When the glass beads are filled in shoes which has soft trunk, the shoes can deform with the weight. In this case, additional optional testing without filler or with another filler can allow to obtain additional information about the behaviour of footwear.

Do not open the oven door for more than 15 s. Shut off the air circulation while the door is open and turn the air circulation on when the door is closed. The total oven recovery time after door is closed shall not exceed 30 s.

Expose the specimen, mounted as specified, in the test oven for 5 min ($^{+15}_{-0,0}$ s) at the specified temperature (see 5.1). The test exposure time shall begin when test thermocouple recovers to the test temperature.

Immediately after the specified exposure, remove the specimen and examine it for evidence of charring, deformation, delamination, hole formation, ignition, melting, separating, or splitting.

Subject the footwear to a whole shoe flexor and flex for 10 000 cycles according to ISO 4643:1992, Annex B. Record any changes in the footwear as the result of heat exposure and flexing.

8.4 Procedure for protective helmets and eye or face protection devices

Turn on the oven and heat to test temperature. Allow the oven to stabilize at the specified temperature (see 5.1) for a minimum of 30 min.

Place the helmet or eye/face protection device on a non-conductive ISO Size K headform as specified in ISO 3873, if not specified differently in the manufacturer's instructions. Mount and adjust the item on the headform in accordance with manufacturer's instructions. Position the headform in the exact centre of the oven (with the face of headform facing the oven door) using a non-conductive stand in the centre of the oven or oven rack. Ensure that the headform with helmet or eye/face protection device is not less than 50 mm away from any oven surface and airflow is parallel to the plane that bisects the headform in half (from front to back). Test only one helmet or eye/face protection device at a time.

Do not open the oven door for more than 15 s. Shut off the air circulation while the door is open and turn the air circulation on when the door is closed. The total oven recovery time after door is closed shall not exceed 30 s.

Expose the specimen, mounted as specified, in the test oven for 5 min ($^{+15}_{-0,0}$ s) at the specified temperature (see 5.1). The test exposure time shall begin when test thermocouple recovers to the test temperature.

Immediately after the specified exposure, remove the specimen and examine it for evidence of charring, deformation, delamination, hole formation, ignition, melting, separating, or splitting while still on the headform. Note in particular, any deformation of helmet components that show a change in position by more than 40 mm with respect to the original position on the headform. Also, evaluate the functionality of any hardware, or components, such as chin straps, nape devices or adjustment bands.

8.5 Procedures for small items and accessories on clothing

Turn on the oven and heat to test temperature. Allow the oven to stabilize at the specified temperature (see 5.1) for a minimum of 30 min.

For specimens that are narrower than 150 mm, use specimens with their normal width by 150 mm in length. Suspend these specimens with their long axis in the vertical direction.

When shrinkage measurements are specified, mark and measure specimens in accordance with the procedures specified in ISO 3759.

NOTE For some types of specimen, marking and measurement of only one dimension can be possible.

Prepare specimens using one of the following procedures.

a) Attach specimens to the clothing fabric in the same orientation and method of attachment as used in the making of the clothing.

b) Suspend the specimen by metal hooks at the top and centred in the oven so that the entire specimen is not less than 50 mm from any oven surface or other specimen, and airflow is parallel to the plane of the material.

Do not open the oven door for more than 15 s. Shut off the air circulation while the door is open and turn the air circulation on when the door is closed. The total oven recovery time after the door is closed shall not exceed 30 s.

Expose the specimen, mounted as specified, in the test oven for 5 min ($^{+15}_{-0,0}$ s) at the specified temperature (see 5.1). The test exposure time shall begin when test thermocouple recovers to the test temperature.

Immediately after the specified exposure, remove the specimen and examine it for evidence of charring, deformation, delamination, hole formation, ignition, melting, separating, or splitting.

Five minutes after the specified exposure, where required, measure the specimen's marked dimensions to determine percentage shrinkage in each marked direction.

9 Test report

The test report shall include the following information:

a) the number and the year of publication of this document, i.e. ISO 17493;

b) all details necessary for the identification of the sample tested (including method of preparation, if applicable, i.e. in case of gloves, whether gloves have been filled with glass beads, i.e. the preferred way of testing, or optionally not filled with glass beads);

c) the dimensions of material specimen or type of specimen tested;

d) the specified test temperature and time of exposure;

e) observations of the specimen condition following oven exposure, including the following:

   — any ignition of the specimen;

   — any melting or dripping of the specimen;

   — any charring of the specimen;

   — any hole formation of the specimen: in case of hole formation, the size shall be reported;

   — any separation of the specimen: including splitting or delamination;

   — any deformation of the specimen;

   if any observations mentioned above are recorded, pictures of the specimen showing observation shall be included in the report

f) the percentage shrinkage of the specimen if specified in either length or width direction, as compared to the original specimen dimensions (for textiles or sheet materials and gloves);

g) specific effect of heat to any component of whole protective clothing or equipment items including the functionality of components;

h) any changes in the specimen following flexing (if applicable) or other tests.

Observations of degradation, embrittlement, splitting, separating, or flaking can be considered as subjective and should not be used as pass/fail criteria for a product standard.

Annex A
(normative)

Temperature uniformity and time constant of hot air circulating oven

A.1 Temperature uniformity

Place nine calibrated thermocouples (if calibrated thermocouples are not available, nine thermocouples made from the same spool of wire may be used provided that they give the same value for temperature when placed adjacent to one another in the testing chamber at the temperature of test) made from iron or copper-constantan wire, having a cross sectional area of 0,20 mm^2 (No. 24AWG) and having a junction size of not more than 2 mm (0.08 in), in the empty testing chamber with shelves in place and vents open. Locate one thermocouple in each of the eight corners of the oven approximately 5 cm (2 in) from each wall and place the ninth thermocouple within 2.5 cm (1 in) of the geometric centre of the chamber. A minimum length of 30 cm (12 in) of lead wire for each thermocouple shall be inside the oven to minimize the conduction of heat from the thermocouple.

Bring the oven to the specified temperature and allow it to reach a steady state (see NOTE). Record the temperatures of the nine thermocouples at least every 5 min for a period of at least 4 h, and determine from the record the maximum deviation of each point from the desired temperatures. The ambient room temperature shall vary by not more than a total of 10 °C, and the line voltage for electrically heated ovens shall vary by not more than a total of 5 % during the test.

NOTE Some ovens can require as much as 24 h to reach a steady state.

A.2 Time constant

Heat the oven to within 10 °C of the maximum operating temperature for which it is designed and allow it to stabilize for at least 1 h. Prepare a standard specimen consisting of a smooth brass cylinder 9,5 mm ± 0,1 mm (0.375 in ± 0.005 in) in diameter and 57 mm ± 1 mm (2.25 in ± 0.05 in) in length, and solder one junction of a differential thermocouple to it.

Open the door of the oven for 1 min while the standard specimen and differential thermocouple are being suspended in the testing chamber. Suspend the specimen vertically within 25 mm (1 in) of the geometric centre of the chamber by means of a hook, metal cord, clamps or fine wire (with a cross sectional area of 0,05 mm^2, No. 30 WG). Place the free junction of the differential thermocouple in the air space of the chamber at least 75 mm (3 in) removed from the specimen. Then close the door and either record or measure the temperature differential every 10 s. Determine the time in seconds required for the temperature difference to decrease to one tenth of the original or maximum value (for example, from 120 °C to 12 °C) and consider this to be the time constant of the oven.

It is important that the door of the oven is open a very short time. Therefore, the suspension of the standard specimen should occur quickly.

Bibliography

[1] ASTM E145-94, *Standard Specification for Gravity-Convection and Forced-Ventilation Ovens*

[2] ASTM F2894-14, *Standard Test Method for Evaluation of Materials, Protective Clothing and Equipment for Heat Resistance Using a Hot Air Circulating Oven*

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