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Standard Test Method for Evaluation of Materials, Protective Clothing, and Equipment for Heat Resistance Using a Hot Air Circulating Oven[1]

This standard is issued under the fixed designation F2894; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers quantitative measurements and subjective observations that characterize the performance for evaluating the heat resistance of materials, protective clothing, and equipment when exposed in a hot air circulating oven.

1.2 This test method is intended to evaluate physical changes in materials, protective clothing, and equipment at a specified heat exposure.

1.2.1 The specified heat exposure in the hot air circulating oven is a combination of convective heat and radiant heat.

1.3 Materials, protective clothing, and equipment are evaluated for visible changes or subjected to a material property measurement following a specified heat exposure.

1.3.1 This test method is not to be used for the evaluation of sticking. An acceptable method for evaluating sticking of fabrics is described in NFPA 1975, Sections 7.2.1 and 8.3. The NFPA 1975 test method evaluates the thermal stability of specimens by assessing the blocking of folded specimens placed between glass plates, under a specified weight, inside an oven meeting the same characteristics of the oven used in this test method.

1.4 This test method enables the quantitative measurement of dimensional change that occurs as a result of a specified heat exposure in a hot air circulating oven.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to other units that are commonly used for thermal testing.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Flame-resistant and heat-resistant materials are described in a range of different standards and meet a range of different requirements. For materials tested in accordance with this test method, the applicable standard shall be used to establish preconditioning, conditioning, and testing conditions and requirements.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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[1] This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.80 on Flame and Thermal.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles
D1776/D1776M Practice for Conditioning and Testing Textiles
D7571 Specification for Retained Sewn Seam Strength After Exposures to Hot Air and Open Flame
E145 Specification for Gravity-Convection and Forced-Ventilation Ovens
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
F1494 Terminology Relating to Protective Clothing

2.2 *AATCC Standard:*[3]

Test Method 135 Dimensional Changes in Automatic Home Laundering of Woven and Knit Fabrics

2.3 *NFPA Standard:*[4]

NFPA 1975 Standard on Station/Work Uniforms for Fire and Emergency Services

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, use the following documents: if the terms are related to textiles, refer to Terminology D123; if the terms are related to protective clothing, refer to Terminology F1494.

3.1.2 *convective heat, n*—heat transferred by the motion of a fluid.

3.1.3 *degradation, n*—a deleterious change in one or more properties of a material.

3.1.3.1 *Discussion*—

In thermal testing of materials, protective clothing, and equipment, degradation is a material response evidenced by a change in either or both the visual properties and the performance properties of the test specimen.

3.1.3.2 *Discussion*—

Degradation generally is associated with a chemical composition change that can result in a change in a visual property, for example, color, or it can result in a change in a performance property including but not limited to strength, hand, flammability, penetration resistance, water repellency, and air permeability. A test specimen that changes in one property does not necessarily change in other properties. Evidence of degradation in performance properties usually requires additional measurements related to properties of specific interest. Discoloration is a visible material response related to degradation. When discoloration is observed, it shall be reported.

3.1.4 *dimensional change, n*—a generic term for change in length or width of a specimen subjected to specified conditions.

3.1.4.1 *Discussion*—

Dimensional change is usually expressed as a percentage of the original dimension. Positive values for dimensional change indicate growth, while negative values for dimensional change indicate shrinkage.

3.1.5 *distortion, n—in thermal testing of equipment*, a specimen response evidenced by a change in its original shape.

3.1.5.1 *Discussion*—

This type of observation is generally applied to equipment items such as protective helmets, and is based on the placement of the item on a specific holding device placed in the oven, such as a head form, and the measurement of the specimen relative to the holding device.

3.1.6 *functionality, n—in thermal testing of protective clothing and equipment*, the continued utility of the test item as determined by an assessment of its capability to function after the heat exposure in the same manner as before its exposure to heat.

3.1.6.1 *Discussion*—

This type of assessment is generally applied to items of hardware or to portions of or complete protective clothing and equipment items.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709, http://www.aatcc.org.

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.1.7 *ignition, n*—the initiation of combustion.

3.1.8 *protective clothing, n*—an item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the wearer of the clothing.

3.1.9 *protective equipment, n*—a non-clothing item of equipment that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the user of the equipment.

3.1.10 *radiant heat, n*—heat communicated by energy propagated through space and transmitted by electromagnetic waves.

3.2 *Definitions of Terms Related to Thermal Testing of Materials, Protective Clothing, and Equipment:*

3.2.1 *deformation, n—in thermal testing of materials, protective clothing, and equipment*, a material response evidenced by a change in shape of the test specimen that is irreversible at room temperature.

3.2.1.1 *Discussion—*

A change in shape caused by the specified heat exposure such as distortion of woven or non-woven fabrics or curling of knit fabrics shall not be identified as deformation as long as these changes are reversible at room temperature.

3.2.2 *delamination, n—in thermal testing of materials, protective clothing, and equipment*, a material response evidenced by the separation of two of more layers of the test specimen in whole or in part.

3.2.3 *dripping, n—in thermal testing of materials, protective clothing, and equipment*, a response evidenced by flowing of the polymer and by the formation of droplets from the flowing material.

3.2.4 *flaking, n—in thermal testing of materials, protective clothing, and equipment*, a material response evidenced by the unassisted loss of visible particles of material from the test specimen when the test specimen is removed from the oven for inspection.

3.2.4.1 *Discussion—*

The specimen shall not be abraded, flexed, or impacted to generate flaking.

3.2.5 *hole formation, n—in thermal testing of materials, protective clothing, and equipment*, the appearance of a visible aperture during the test exposure.

3.2.5.1 *Discussion—*

The specimen is considered to exhibit hole formation when a visible hole is produced as a result of the thermal exposure that is approximately 3 mm (0.12 in.) in diameter or greater, or if the hole is rectangular in shape approximately 3 mm (0.12 in.) in width and length or greater. Single threads across the hole do not reduce the size of the hole for the purposes of this test method.

3.2.6 *melting, n—in thermal testing of materials, protective clothing, and equipment*, the liquefaction of material under the influence of heat.

3.2.6.1 *Discussion—*

Melting is determined visually by a change in the material physical appearance such as fusing of fibers or the evidence of material flowing.

3.2.7 *separation, n—in thermal testing of materials, protective clothing, and equipment*, a material response evidenced by splitting or delaminating.

3.2.8 *splitting, n—in thermal testing of materials, protective clothing, and equipment*, a material response evidenced by the test specimen breaking into two or more pieces in whole or in part.

4. Summary of Test Method

4.1 The test method evaluates the heat resistance of materials, protective clothing, and equipment using a hot air circulating oven.

4.2 Specimens shall be exposed in the test oven at a specified temperature for a specified oven exposure time as required by the applicable material or product specification.

4.2.1 If no material or end product specification requirements for the oven temperature and oven exposure time are provided, the oven temperature shall be 260 +8/–0 °C (500 +14/–0 °F) and the oven exposure time shall be 5 min +15/–0 s.

4.3 Following heat exposure, the test specimen is removed and examined for evidence of one or more of the following phenomena: ignition, melting, dripping, separation, etc.; see 11.5.

4.4 If specified, test specimens are evaluated for dimensional change as a result of the convective heat exposure.

5. Significance and Use

5.1 This test method is used to evaluate the heat resistance of materials, clothing, and equipment when exposed to heat in a hot air circulating oven. The principal findings of this test method are observations of the specimen response to the heat exposure.

5.1.1 The majority of procedures specified in this test method apply to the evaluation of flat material specimens.

5.1.2 When evaluating non-flat materials, alternative procedures are required for mounting specimens and interpreting the effects of the heat exposure.

5.2 If specified, this test method is used for the measurement of material dimensional change following a convective heat exposure in a hot air circulating oven.

5.3 This test method is not intended to simulate the actual exposure of material, clothing, or equipment in high-heat conditions such as a fire environment.

6. Apparatus

6.1 *Test Oven*—The test oven shall be a horizontal-flow circulating oven with minimum interior dimensions of 610 mm by 610 mm by 610 mm such that a specimen can be suspended and be positioned at least 50 mm (2 in.) from any interior oven surface or other specimen.

6.1.1 The test oven shall have an air velocity of 0.5 to 1.5 m⁄s at ~~the standard temperature and pressure of 21 °C at local atmospheric pressure,~~ambient temperature and atmospheric pressure, with the heating elements off, measured at the geometric center point of the oven.

6.1.2 The test oven shall be equipped with an oven-sensing thermocouple which is used as part of the oven temperature control mechanism.

6.1.2.1 The oven-sensing thermocouple shall be positioned so that it is level with the horizontal centerline of a mounted sample specimen, and the oven-sensing thermocouple shall be equidistant between the vertical centerline of a mounted specimen positioned in the middle of the oven and the oven wall where the airflow enters the oven test chamber.

6.1.2.2 The oven-sensing thermocouple shall be an exposed bead, Type J or Type K, No. 30 AWG thermocouple.

6.2 *Specimen Mounting*—Metal hooks or clamps shall be used to suspend the specimens in the oven.

6.2.1 If the specimens are too large to be suspended, a suitable insulating form shall be placed in the center of the oven and the specimen shall rest on the insulating form. Ceramic has been found to be an effective material for this form.

6.2.2 In the testing of some items, such as individual pieces of hardware, loops of heat-resistant thread are used to suspend the specimen.

6.3 *Optional Stretching Frame*—The optional stretching frame, Fig. 1, consists of a rigid board, 9.5 ± 3 mm (⅜ ± ⅛ in.) thick,

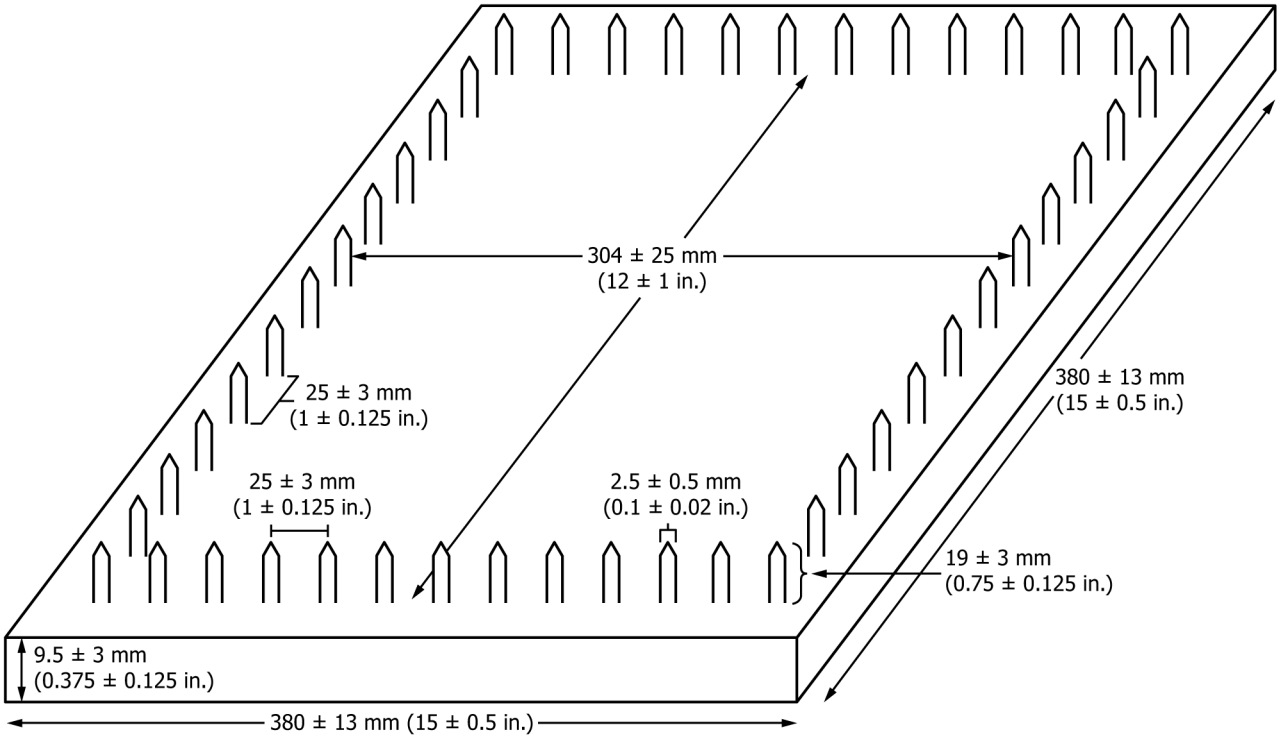

FIG. 1 Schematic of Optional Stretching Frame for Knit Material Specimens

with uniformly spaced pins along the perimeter at intervals of 25 ± 3 mm (1 ± ⅛ in.) to secure knit materials. The pins shall protrude 19 ± 3 mm (¾ ± ⅛ in.) from the surface of the board, shall have a shank diameter of 2.5 ± 0.5 mm (0.1 ± 0.02 in.), and shall be drawn to a sharply pointed tip. Construct the stretching frame with a length and width at least large enough to accommodate the test specimen size specified in 9.1.1 and 9.1.2 so that the pins are located 38 ± 12.5 mm (1.5 ± 0.5 in.) inward from the edges of the test specimen.

6.3.1 The optional stretching frame is permitted to be used before the knit specimen is placed in the oven for marking the specimen for dimensional change determination. The stretching frame is not used while the knit specimen is exposed in the oven. The optional stretching frame is also permitted to be used for a specified period of time after heat exposure in the oven to return knit specimens to their original dimensions. See 9.3.1 and 11.6.1.

7. Hazards

7.1 Normal precautions shall be taken for working around hot surfaces and flaming, melting, or dripping test specimens.

7.2 The oven shall be properly vented to ensure that harmful vapors and gases are evacuated from the laboratory.

7.3 Special care shall be exercised when using the optional stretching frame. The optional stretching frame contains a series of sharp pins, which have the potential to present a puncture hazard when not handled properly.

8. Preconditioning of Test Samples

8.1 Material samples not obtained from garments for preconditioning shall be at least 1 m^2 (1.2 yd^2) to ensure sufficient material for the test specimen size requirements in 9.1.1 and 9.1.2. The material sample shall be representative of the material utilized in the construction of the protective clothing end product.

8.1.1 If the material width is less than 1 m (1.1 yd), the sample shall be the full width of the material, and the length of the sample shall be sufficient to meet the test specimen size requirements of 9.1.1 or 9.1.2.

8.1.2 Precondition samples of protective clothing as complete items.

8.1.3 Precondition samples of protective equipment as complete items.

8.2 Precondition samples as required by the applicable material or end product specification.

8.2.1 If no material or end product specification requirements for preconditioning are provided, precondition samples according to the temperature, relative humidity, and conditioning time required by Practice D1776/D1776M.

8.2.2 If the test specimen form is not included in Practice D1776/D1776M, condition the test specimen at 21 ± 1 °C (70 ± 2 °F) and 65 ± 2 % RH for 8 h.

9. Preparation of Test Specimens

9.1 After preconditioning, cut test specimens to the specified size for testing.

9.1.1 Cut each material test specimen from the material sample or from the protective clothing complete item to a size of 380 ± 13 mm by 380 ± 13 mm (15 ± 0.5 in. by 15 ± 0.5 in.).

9.1.2 Smaller size material test specimens of 150 ± 6 mm by 150 ± 6 mm (6 ± 0.25 in. by 6 ± 0.25 in.) shall be acceptable for materials that are not to be subjected to dimensional change measurement.

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

9.1.4 Protective clothing test specimens are permitted to be tested in the form and size of the complete items.

9.1.4.1 Components of protective clothing, such as hardware, are permitted to be tested as individual items.

9.1.5 Test protective equipment specimens in the form and size of the complete items.

9.2 Test a minimum of three test specimens from each preconditioned sample. Testing a greater number of specimens is permitted to improve precision of test results.

9.3 Mark test specimens to be evaluated for dimensional change in accordance with AATCC Test Method 135.

9.3.1 Where the optional stretching frame is specified, it shall be used to mark knit fabric specimens for dimensional change determinations.

9.3.1.1 Place the knit fabric specimen onto the optional stretching frame prior to marking, exercising care that the specimen remains in its relaxed state when placed onto the optional stretching frame.

9.3.1.2 Remove the knit fabric specimen from the optional stretching frame and mark knit fabric specimens such that the benchmarks fall within the perimeter of the pinholes created by the optional stretching frame.

9.4 *Room Temperature Conditioning*—Unless otherwise directed by the applicable specification for the material or end product, condition test specimens, including non-woven specimens, at a temperature of 21 ± 1 °C (70 ± 2 °F) and 65 ± 2 % relative humidity, until equilibrium is reached, as determined in accordance with Practice D1776/D1776M, or for 8 h, whichever results in the shorter conditioning time. Test specimens within 5 min after removal from conditioning.

10. Preparation and Calibration of Apparatus

10.1 At least once every twelve months, determine the temperature uniformity of the oven in accordance with Specification E145 using the procedure in Section 4 of the Test Method for Temperature Uniformity for a Type IIB oven at 260 °C (500 °F) with the following exceptions: change the time period that the temperatures of the nine thermocouples are recorded from 24 h to 4 h, and record the temperature of the nine thermocouples at least every 5 min. The maximum temperature deviation from 260 °C (500 °F) for each of the nine thermocouples shall be no greater than 6.5 °C (11.7 °F), as specified in Specification E145 for a IIB oven.

~~10.1.1 During the same time period not to exceed two days during which the oven temperature uniformity is determined, confirm that the air velocity of the oven is 0.5 to 1.5 m/s at the standard temperature and pressure of 21 °C at local atmospheric pressure, measured at the geometric center point of the oven.~~

10.2 Prior to heating the oven with the oven door closed and air circulation activated, confirm that the air velocity of the oven is 0.5 to 1.5 m/s at ambient temperature and atmospheric pressure when measured at the geometric center point of the oven with a vane anemometer. The air velocity shall be recorded as the average of measurements taken every 10 s for 2 min and shall be conducted monthly at a minimum.

NOTE 2—Airflow can be manipulated using exhaust and intake dampers on the oven. Atmospheric conditions can affect airflow differently day to day. Oven recovery time can be affected by the intake and exhaust setting. Fully open dampers can result in longer recovery times exceeding the requirements in 11.3. Be sure adjustments for airflow do not affect recovery time once the oven is brought up to the testing temperature.

10.3 For ovens with a single temperature-sensing thermocouple, prior to commencement of testing each week, install a verification thermocouple of equal type and performance as the oven-sensing thermocouple in the center of the empty oven test chamber.

10.3.1 With the oven door closed and air circulation activated, activate the empty oven and adjust its temperature control until the oven-sensing thermocouple installed as described in 6.1.2.1 in the center of the oven reaches the specified testing temperature.

10.3.2 Maintain the testing temperature in center of the oven for 5 min while recording the verification thermocouple reading and oven-sensing thermocouple reading at the end of each 30-s period for the 5-min duration.

10.3.3 Calculate the difference between the two thermocouple readings for each of the ten periods, and then average the ten values to determine an average correction factor (ACF) in units of degrees Celsius.

10.3.3.1 The ACF is a positive number if the verification thermocouple is lower than the oven-sensing thermocouple, and the ACF is a negative number if the verification thermocouple is higher than the oven-sensing thermocouple.

10.3.4 Calculate the oven-sensing thermocouple compensated setting (OSTCS) by adding ACF and the specified test temperature.

10.3.5 Use the OSTCS as the test temperature.

10.4 For ovens with dual temperature-sensing thermocouples, prior to commencement of testing each month, install a verification thermocouple of equal type and performance as the oven-sensing thermocouple in the center of the empty oven test chamber. Follow the procedure in ~~10.2.1~~10.3.1 – ~~10.2.5~~10.3.5 to determine the OSTCS.

11. Procedure

11.1 Heat the test oven and stabilize the oven-sensing thermocouple temperature reading at the OSTCS for a period of not less than 30 min.

11.2 Suspend the specimen by non-fixed metal hooks or clamps at the top of the oven and centered in the oven such that the entire specimen is not less than 50 mm (2 in.) from any oven surface, and the airflow is parallel to the plane of the specimen material.

11.2.1 For woven or non-woven specimens evaluated for dimensional change, the specimens shall be hung with the warp or machine direction vertically.

11.2.2 Where specimens cannot be suspended by metal hooks or clamps, position the specimen in the center of the oven on a insulated form such that the entire specimen is not less than 50 mm (2 in.) from any oven surface or other specimen, and air flow is parallel to the plane of the specimen.

11.2.3 For woven material specimens, note the direction vertical or horizontal for the warp and fill directions of the material specimen. For non-woven material specimens, note the direction vertical or horizontal for the machine direction and cross direction of the material specimen.