



## Standard Test Method for Flammability of Apparel Fabrics by Semi-Restraint Method<sup>1</sup>

This standard is issued under the fixed designation D 3659; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Editorial changes were made throughout September 1993.

### 1. Scope

1.1 This test method<sup>2</sup> provides a laboratory research procedure for assessing the flammability properties of fabrics in a vertical configuration in which the test specimen is permitted limited mobility from the vertical plane of suspension. This test is intended to simulate the flammability performance of an A-line type garment on a mannequin under the prescribed conditions.

1.2 *This test method should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

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

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 123 Terminology Relating to Textiles<sup>3</sup>

D 1776 Practice for Conditioning Textiles for Testing<sup>3</sup>

#### 2.2 Federal Standard:

No. FF 3-71 Flammability of Children's Sleepwear, Sizes 0 to 6X.<sup>4</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *flammability, n*—those characteristics of a material that pertain to its relative ease of ignition and relative ability to sustain combustion.

3.1.2 *semi-restraint, adj*—of or relating to a method of mounting that allows an object a limited degree of movement (for example, contraction or expansion of a fabric).

3.1.3 For definitions of other textile terms used in this test method, refer to Terminology D 123.

### 4. Summary of Test Method

4.1 This test method is used to evaluate the burning characteristics of a vertically hanging strip of fabric that is partially restrained at the lower corners. The data obtained are a measure of the degree of destruction of a material when exposed for 3 s to a small, open flame at the lower edge. The measurements of burn time and mass loss are converted into the rate of area spread of flame and the average destroyed area.

### 5. Significance and Use

5.1 This method simulates the burning characteristics of a vertically hanging garment supported at the shoulders, hanging away from the body of a mannequin, and ignited at the lowest edge. This method can be used to determine the effects of finishes and other fabric treatment on the burning properties of the material.

5.2 Test Method D 3659 for testing textile materials for ARAD is considered satisfactory for acceptance testing of commercial shipments since current estimates of between-laboratory precision are acceptable reasons. In cases of disagreement arising from differences in values reported by the purchaser and the seller when using this method for acceptance testing, the statistical bias, if any, between the laboratory of the purchaser and the laboratory of the seller should be determined with each comparison being based on testing specimens randomly drawn from one sample of material of the type being evaluated.

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-13 on Textiles, and is the direct responsibility of Subcommittee D13.52 on Flammability.

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<sup>2</sup> Data illustrating correlation of this method with mannequin tests using A-line type dresses are filed under Research Report No. RR:D13-1057 at ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Related information is available in the following publications: (a) Anderson, J., "Development of a Semi-Restrained Vertical Fabric Flammability Test Concept," *Textile Chemist and Colorist*, Vol 5, No. 10, October 1973, p. 215; (b) Anderson, J., and Grasso, M., "Fabric-Garment Flammability Testing: A New Concept," *Modern Textiles*, November 1973, p. 42; (c) Anderson, J., and Grasso, M., "Preliminary Report on the ASTM Round Robin for the Semi-Restrained Flammability Test," *American Dyestuff Reporter*, Vol 63, No. 11, November 1974, p. 60; and (d) Anderson, J., Grasso, M., and Gavlak, M., "The Development of the Semi-Restrained Fabric Flammability Test," *Textile Chemist and Colorist*, Vol 7, No. 6, June 1975, p. 23.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 07.01.

## 6. Apparatus and Materials

6.1 *Test Chamber*,<sup>5</sup> as specified in Fed. Std. No. FF 3-71, or equivalent, with all the internal components removed (support bars in 9.5 and guide for the specimen holder, burner, and flame-height guide) and modified as directed in Annex A1 and Annex A2.

6.2 *Methane Gas, 97% Pure*<sup>6</sup>—A cylinder with appropriate reducing valves to maintain a pressure of 2.25 to 2.75 psi (15.5 to 18.9 kPa) at the burner inlet.

6.3 *Hood*, or other suitable enclosure, to provide a draft-free environment around the test chamber. After each specimen burn, a hood or enclosure shall have a fan or other suitable means of exhausting smoke, fumes, etc., produced during testing.

6.4 *Conditioning Equipment*—A forced-draft oven capable of maintaining a temperature of  $221 \pm 5^\circ\text{F}$  ( $105 \pm 2.8^\circ\text{C}$ ).

6.5 *Desiccator*, with silica gel desiccant or equivalent, of suitable size to allow test samples to hang free.

6.6 *Stop Watch*, or other timing device to measure time to 0.1 s.

6.7 *Balance*, having a capacity of 99 g and sensitive to 0.01 g.

## 7. Sampling

7.1 Take a lot sample, as directed in an applicable material specification, such as the sampling plan provided in Fed. Std. No. FF 3-71, or as agreed upon between the purchaser and the seller.

## 8. Test Specimens

8.1 Cut out five individual test specimens  $15.0 \pm 0.1$  in. ( $381.0 \pm 2.5$  mm) long and  $6.0 \pm 0.1$  in. ( $152 \pm 2.5$  mm) wide, with the 15-in. dimension parallel to the length of the fabric. Do not take specimens nearer the selvage than one tenth the width of the fabric unless otherwise specified.

8.2 For centering purposes, make a mark at the center point along the top 6-in. (152-mm) edge.

## 9. Preparation of Apparatus

9.1 The broad direction of the fan burner must be perpendicular to the bottom edge of the fabric (see Fig. 1).

9.2 Attach the hose connecting the burner to the gas supply.

9.3 Open the gas cylinder valve and adjust the gas flow pressure from 2.25 to 2.75 psi (15.5 to 18.9 kPa).

9.4 Open the needle valve on the side of the test chamber, light the burner, and adjust the flame height to 1.5 in. (38 mm) by use of the flame-height guide located on the back wall of the test chamber.

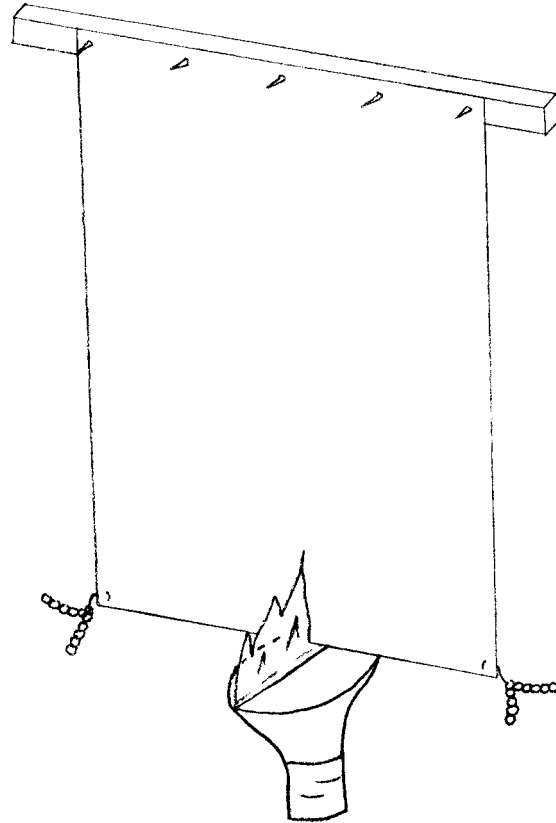
9.5 Clean the residue from the support bar. Periodically check the support bar for weight accuracy. If the bar weight varies by  $\pm 0.05$  g, replace or restamp with the corrected weight on the bar.

## 10. Conditioning

10.1 Two optional conditioning procedures are provided, as follows:

<sup>5</sup> A kit for modifying the tester is available from the U.S. Testing Co., 1514 Park Ave., Hoboken, NJ 07030.

<sup>6</sup> Available from the Matheson Co., Inc., East Rutherford, NJ 07071.



**FIG. 1 Semi-Restraint Sample Set-Up**

### 10.1.1 Option A, Method for Oven-Dried Specimens:

10.1.1.1 Attach each test specimen to the support bar by pinning the fabric 0.125 in. (3.2 mm) below the top edge centering the fabric mark on the center pin (see Fig. 1).

10.1.1.2 Place all prepared test specimens without touching each other in the forced-draft oven to allow free circulation of air around each specimen. Specimens may sway during drying and touch each other. Dry the specimens for 30 min at  $221 \pm 5^\circ\text{F}$  ( $105 \pm 2.8^\circ\text{C}$ ). After a 30-min exposure at the correct temperature, remove the specimens from the oven and place over the silica gel desiccant or equivalent in a desiccator until it is cool to touch, but not less than 30 min nor more than 1 h.

### 10.1.2 Option B, Method for Conditioned Specimens:

10.1.2.1 Mount the test specimens as stated in 10.1.1.1.

10.1.2.2 Precondition the test specimens as directed in Practice D 1776.

10.1.2.3 After preconditioning, expose the test specimens to a temperature of 65 to 80°F (18 to 27°C) and a relative humidity less than 55 % for at least 16 h prior to testing.

## 11. Procedure

11.1 Weigh the conditioned test specimen with the support bar obtained from 10.1.1 or 10.1.2 and record its weight to the nearest 0.01 g. For oven-dried samples, if more than 60 s have elapsed between the removal of a specimen from the desiccator and the initial flame impingement, recondition the specimen. Record the mass stamped on the support bar.

11.2 Hang the specimen support bar in the support bracket attached to the height adjustment fixture. Adjust the knob of the specimen-height guide to raise or lower the test specimen so

the bottom edge of the specimen meets the required height as indicated by the guide attached to the fan-flame gas burner.

11.3 Insert the restraining chain hooks in the lower corners 0.25 in. (6 mm) from the specimen bottom (Fig. 1). Insert the right restraining chain hook in the lower right corner of the specimen and insert the left restraining hook in the lower left corner of the specimen. (It is important that the ends of the hooks be kept sharpened.)

11.4 Close the cabinet door and impinge the burner flame on the bottom edge of the specimen by moving the burner under the specimen for 3.0 s and then removing it (Note 1). Start the timer immediately when the flame impinges on the fabric. Stop the timer when the specimen self-extinguishes, or when there is no longer any fabric burning below the pins.

NOTE 1—For fabrics that will ignite only with ignition times longer than 3.0 s, forced ignition may be used but the ignition time must be reported as a qualification of test results.

NOTE 2—Run the exhaust fan until no traces of fumes are detected.

11.5 Weigh the remaining (unburnt and charred) portion to the nearest 0.01 g. Include in this mass the fragments attached to the chain. This weighing should be completed within 60 s after the testing of the specimen. Do not include in the mass any material that falls to the floor of the chamber.

11.6 Record the total elapsed time indicated on the timer to the nearest 0.1 s.

11.7 Test each of the remaining specimens in the same manner.

## 12. Calculations

12.1 Calculate the average total burn time per specimen,  $\bar{T}$ , to the nearest 0.1 s using Eq 1:

$$\bar{T} = T/n \quad (1)$$

where:

$\bar{T}$  = average total burn time per specimen, s,

$T$  = total time, s, and

$n$  = number of specimens.

12.2 Calculate the average specimen mass loss,  $\bar{W}$ , using Eq 2, Eq 3, and Eq 4:

$$\bar{S} = (B + S) - B \quad (2)$$

$$\bar{U} = (B + U) - B \quad (3)$$

$$\bar{W} = \bar{S} - \bar{U} \quad (4)$$

where:

$\bar{W}$  = average specimen mass loss, g,

$S$  = specimen mass, g,

$\bar{S}$  = average specimen mass, g,

$B$  = bar mass, g,

$U$  = unburnt and charred fabric mass, g, and

$\bar{U}$  = average unburnt and charred fabric mass, g.

12.3 Calculate the average destroyed area (ADA),  $\bar{A}$ , using Eq 5:

$$\bar{A} = (C \times \bar{W})/\bar{S} \quad (5)$$

where:

$C$  = total specimen area, 90 in.<sup>2</sup>, and

$\bar{A}$  = average destroyed area (ADA).

12.4 Calculate the average rate of area destroyed,  $\bar{R}$ , using Eq 6:

$$\bar{R} = \bar{A}/\bar{T} \quad (6)$$

where:

$\bar{R}$  = average rate of area destroyed (ARAD).

## 13. Report

13.1 State that the specimens were tested as directed in ASTM Test Method D 3659. Describe the material(s) or product(s) sampled and the method of sampling used.

13.2 Report the following information:

13.2.1 Individual and averaged total time,

13.2.2 Individual and averaged calculated mass of specimens and of unburnt and charred fabric,

13.2.3 Individual and averaged calculated specimen mass loss,

13.2.4 Calculated average destroyed area (ADA) to the second decimal,

13.2.5 Calculated average rate of area destroyed (ARAD) to the second decimal, and

13.2.6 Conditioning option used.

## 14. Precision and Bias

14.1 *Summary*—In comparing two averages of 5 observations each, the difference in the average rate of area destroyed (ARAD) should not exceed 0.36 in.<sup>2</sup>/s in 95 out of 100 cases when both observations are taken by the same well-trained operator using the same piece of test equipment and specimens randomly drawn from the same sample of material. Larger differences are likely to occur under all other circumstances. The true value of the ARAD can only be defined in terms of a specific test method. Within this limitation, Test Method D 3659 has no known bias. Sections 14.2-14.4 explain the basis for this summary and for evaluations made under other conditions.

14.2 *Interlaboratory Test Data*—An interlaboratory test was run in 1976 in which randomly drawn samples of seven materials were tested in each of five laboratories. One operator in each laboratory tested five specimens of each material. The components of variance for ARAD results expressed as standard deviations were calculated to be:

Single-operator component	0.29 in. <sup>2</sup> /s
Between-laboratory component	0.00 in. <sup>2</sup> /s

14.3 *Critical Differences*—For the components of variance reported in 14.2, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the following critical differences: