



# Standard Test Method for Flame Resistance of Textiles (Vertical Test)<sup>1</sup>

This standard is issued under the fixed designation D 6413; 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.

## 1. Scope

1.1 This test method is used to measure the vertical flame resistance of textiles.

1.1.1 As a part of the measure of flame resistance, after-flame and afterglow characteristics are evaluated.

1.2 This standard shall be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled laboratory conditions and shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions.

1.3 The values stated in either SI units or other units are to be regarded separately. The values stated in each system are not exact equivalents; therefore, each system shall be used independently without combining values.

1.4 *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 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>2</sup>

D 1776 Practice for Conditioning Textiles for Testing<sup>2</sup>

D 4391 Terminology Relating to Burning Behavior of Textiles<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms relating to the combustion of textiles, see Terminology D 4391. For definitions of other textile terms used in this test method, refer to Terminology D 123.

### 3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *afterflame, n*—persistent flaming of a material after the ignition source has been removed.

3.2.2 *after-flame time, n*—the length of time for which a material continues to flame after the ignition source has been removed.

3.2.3 *afterglow, n*—glow in a material after the removal of an external ignition source or after the cessation (natural or

induced) of flaming of the material.

3.2.4 *afterglow time, n*—the time afterglow continues after the removal of the ignition source and the cessation of flaming.

3.2.5 *char length, n*—in measuring flame resistance of textiles, the distance from the fabric edge, which is directly exposed to the flame to the furthest point of visible fabric damage after a specified tearing force has been applied.

3.2.6 *charring, n*—the formation of carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.2.7 *flame, n*—as related to ignition of textiles, a controlled hot, luminous zone of gas or matter in gaseous suspension, or both, of constant size and shape that is undergoing combustion as evidenced by a low-intensity heat flux of less than 1 kw, such as candle flame or match flame.

3.2.8 *flame application time, n*—the time interval for which the ignition flame is applied to a material.

3.2.9 *flame resistance, n*—the property of a material whereby flaming combustion is prevented, terminated, or inhibited following application of a flaming or nonflaming source of ignition, with or without subsequent removal of the ignition source.

3.2.10 *glow, n*—visible, flameless combustion of the solid phase of a material.

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

3.2.12 *melting, n*—a liquification of material under the influence of heat.

3.2.13 *smoldering, n*—the combustion of a solid material without accompaniment of flame but generally with the production of smoke.

## 4. Summary of Test Method

4.1 A specimen is positioned vertically above a controlled flame and exposed for a specified period of time. The flame then is removed, and afterflame time and afterglow time are measured.

4.2 Char length is measured under a specified force.

4.3 Any evidence of melting or dripping is noted.

## 5. Significance and Use

5.1 This test method determines the response of textiles to a standard ignition source, deriving measurement values for afterflame time, afterglow time, and char length.

5.2 The vertical flame resistance, as determined by this test method, only relates to a specified flame exposure and application time.

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

Current edition approved April 10, 1999. Published August 1999.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 07.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 07.02.

5.3 This test method maintains the specimen in a static, draft-free, vertical position and does not involve movement except that resulting from the exposure.

5.4 Test Method D 6413 has been adopted from Federal Test Standard No. 191A method 5903.1, which has been used for many years in acceptance testing. The between-laboratory precision of this test method has not been established. Refer to Section 14 for single-laboratory precision.

5.4.1 If there are differences or practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, the test samples used should be as homogeneous as possible, that are drawn from the material from which the disparate test results are obtained, and that are assigned randomly in equal numbers to each laboratory for

testing. Other materials with established test values may be used for this purpose. The test results from the two laboratories should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing series. If a bias is found, either its cause must be found and corrected, or future test results must be adjusted in consideration on the known bias.

**6. Apparatus**

6.1 *Test Cabinet and Accessories*, fabricated in accordance with the requirements specified in Figs. 1-5. Galvanized sheet metal or other suitable metal can be used. The entire inside back wall of the cabinet shall be painted black to facilitate the viewing of the test specimen and pilot flame.

6.1.1 The test cabinet shall be set up in a laboratory hood or with comparable equipment so that combustion gases can be

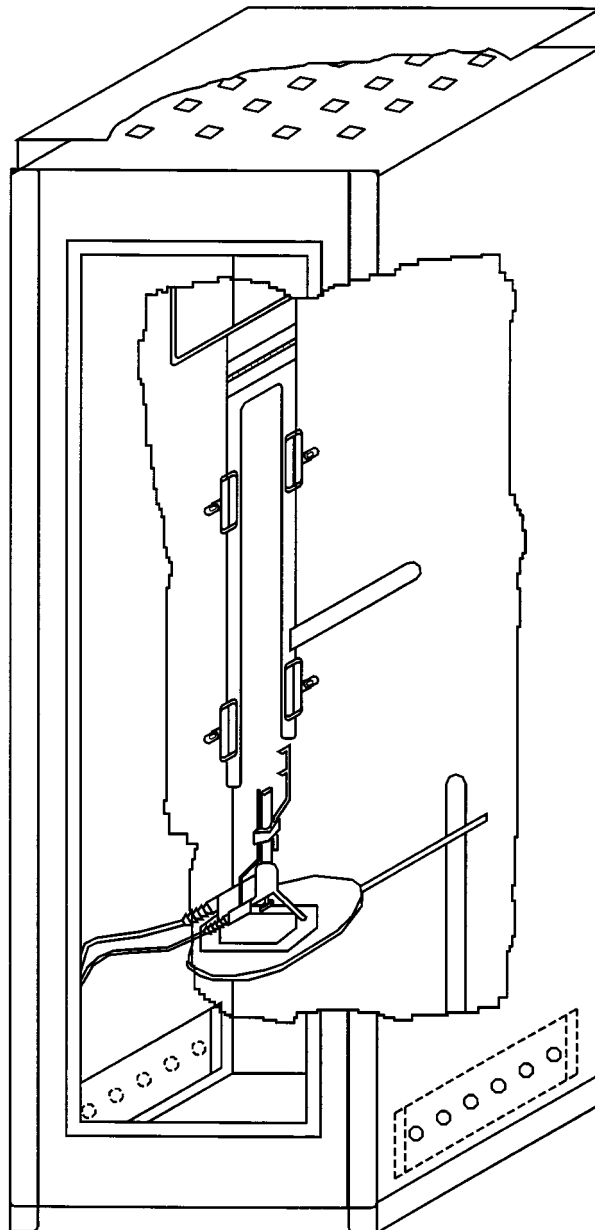
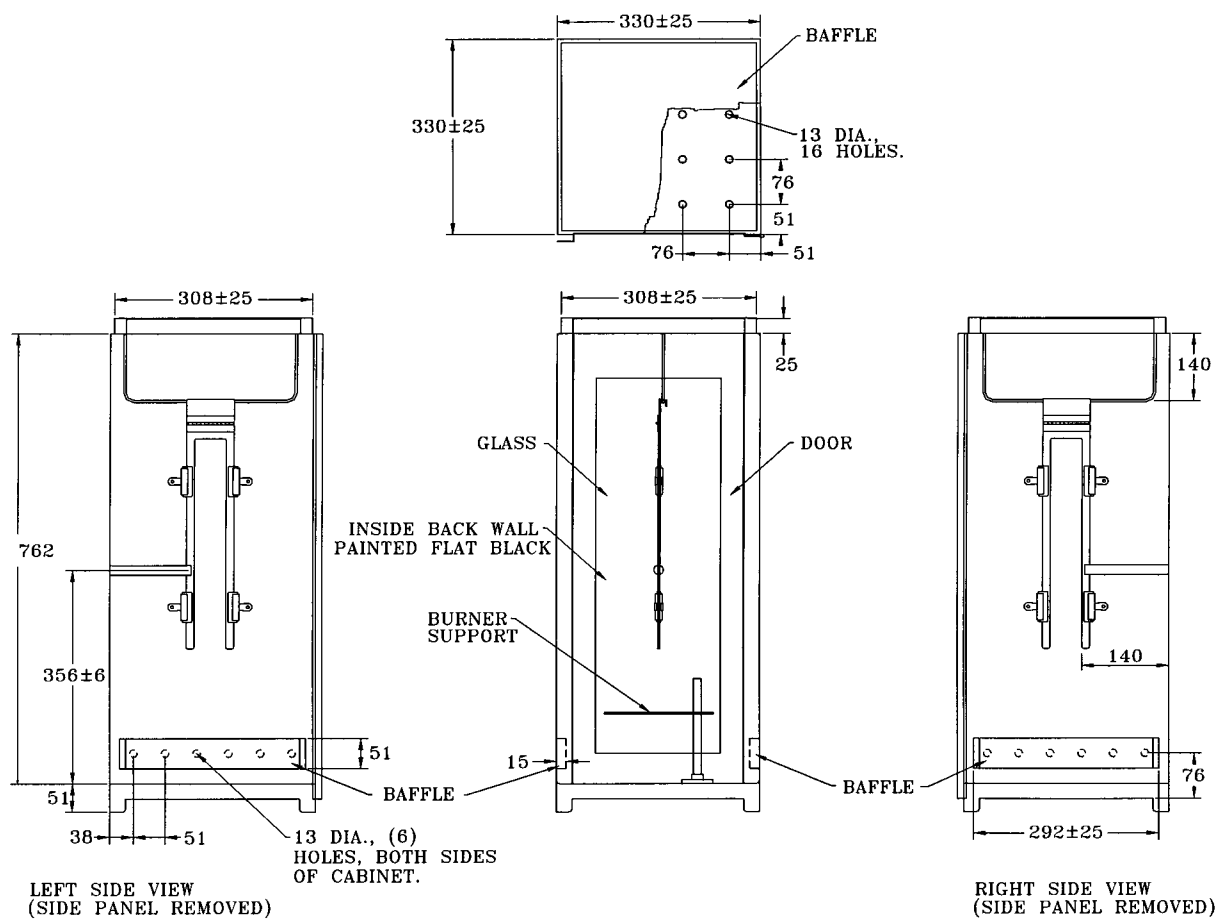


FIG. 1 Test Apparatus



ALL DIMENSIONS IN mm  
**FIG. 2 a Test Apparatus Construction Details**

removed from the test lab environment. Precautions must be taken to minimize the draft through the laboratory hood while testing. Open doors or windows are examples of unnecessary causes of drafts and must be avoided. A ventilation smoke tube kit<sup>4</sup> may be used to check for the presence of drafts.

6.2 *Burner*, equipped with a needle valve to adjust flame height (see Fig. 4).

6.2.1 The burner shall be constructed by combining a 10 mm (0.38 in.) inside diameter barrel  $76 \pm 6$  mm ( $3 \pm 0.25$  in.) long with a base from an adjustable valve burner. A Tirrill burner is recommended, but a Bunsen burner modified to conform to this test method also will suffice.

6.2.2 The pilot light tube shall have an inside diameter of approximately 1.5 mm (0.06 in.) and shall be spaced 3 mm (0.12 in.) away from the burner edge.

6.2.3 Gas controls and connections shall be as specified in Fig. 5. The solenoid valve shall be capable of being fully opened or fully closed in less than 0.2s and activated by an adjustable timer.

6.2.4 On the side of the barrel of the burner, opposite the burner pilot light there shall be a flame height gage constructed of metal spaced approximately 13 mm (0.50 in.) from the

barrel and extending above the burner. The gage shall have two prongs approximately 8 mm (0.32 in.) long marking the distances of 19 mm (0.75 in.) and 38 mm (1.50 in.) above the top of the burner.

6.2.5 The burner shall be movable when placed in the cabinet and capable of adjustments to center the burner directly below the center bottom edge of the specimen when performing the tests.

6.3 *Gas Regulator Valve System*, a control system with a delivery rate designed to furnish gas to the burner under a pressure of  $17.2 \pm 1.7$  kPa ( $2.5 \pm 0.25$  lbf/in.<sup>2</sup>) at the burner inlet. The manufacturer's recommend delivery rate for the valve system shall include the required pressure.

6.4 *Gas Mixture*, methane, 99 % pure.

6.5 *Test Specimen Holder*, constructed as shown in Fig. 3. The assembly is shown in Figs. 1 and 2.

6.6 *Specimen Holder Clamps*, capable of firmly holding the test specimen in the test specimen holder.

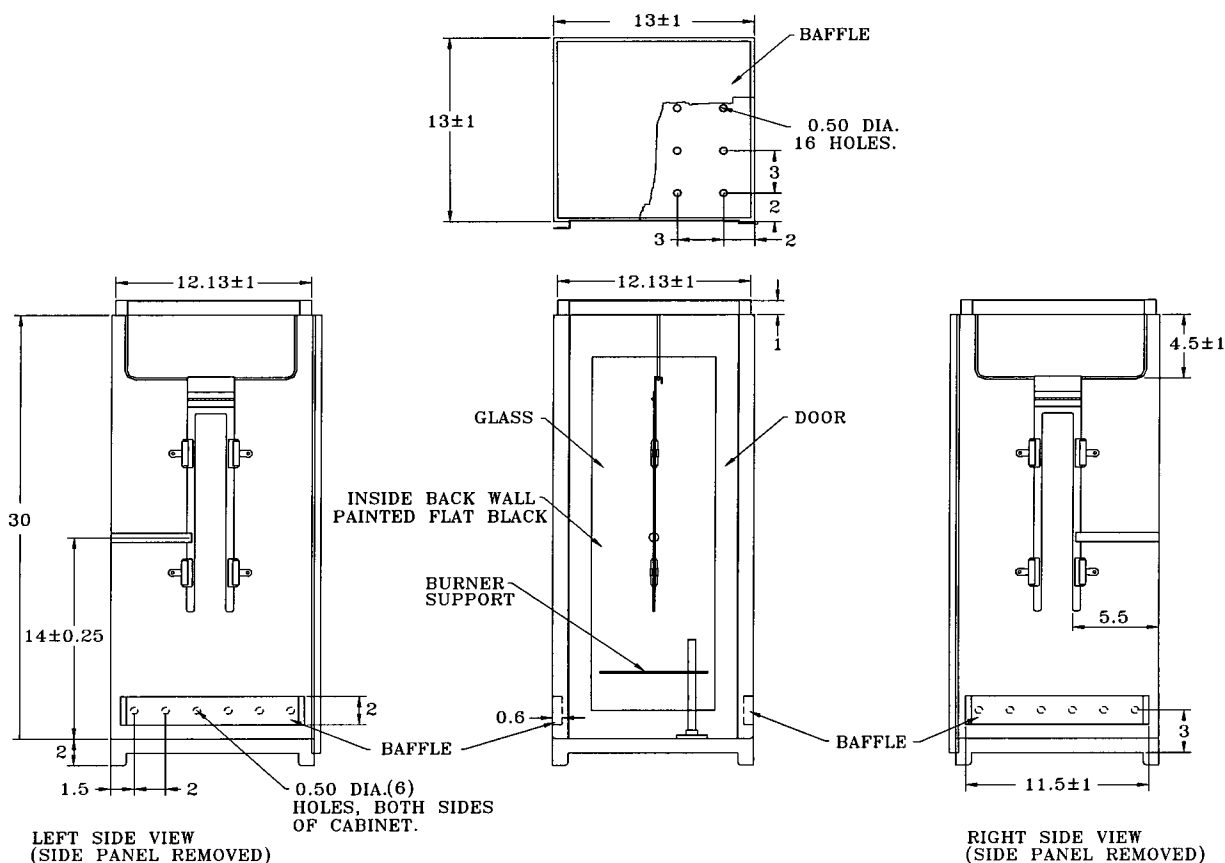
6.7 *Laboratory Hood*, in which to carry out the test.

6.8 *Stop Watch*, or other device to measure the burning time to 0.2 s.

6.9 *Measuring Scale*, graduated in increments of at least 3 mm (0.12 in.) to measure the length of char.

6.10 *Metal Hooks and Weights*—Metal hooks and a range of weights to produce a series of total loads, which will be used

<sup>4</sup> A ventilation smoke tube kit is available from A-Line Safety Appliance Company, Pittsburgh, PA 15230.



ALL DIMENSIONS IN INCHES

FIG. 2 b Test Apparatus Construction Details (continued)

to determine char length. The metal hooks shall consist of 1-mm (0.04-in.) diameter steel wire, 76 mm (3 in.) long. The hook is formed by bending the wire to 45° angle forming a hook 3 mm (0.5 in.) from one end. This hook is used for puncturing the fabric.

6.11 *Flame Impingement Timer*, a timer and electrical gas solenoid used to control the interval, which gas is supplied to the burner.

## 7. Hazards

7.1 Normal precautions applicable to pressurized flammable gases, open flames, hot flames, hot surfaces, burning fabrics and combustion, off gases and solid residue shall be employed.

7.2 Conduct the tests in a hood to contain the gases evolved during testing and for exhaust of the gases after each test.

## 8. Preparation of Apparatus

8.1 Adjust gas pressure to  $17.2 \pm 1.7$  kPa ( $2.50 \pm 0.25$  lbf/in.<sup>2</sup>) and ignite pilot flame. Adjust the pilot flame to a height of approximately 3 mm (0.12 in.) when measured from its lowest point. Be sure that the tip does not alter shape of the test flame during the 12s exposure time.

8.1.1 Adjust the burner flame using the needle valve in the base of the burner to achieve a flame height of 38 mm (1.50 in.). This height is achieved by fully closing the air opening on the burner tube base and fully opening the solenoid valve.

NOTE 1—Tape may be used to close off the air openings on the burner.

8.1.2 Position the burner so that the middle of the lower edge of the specimen holder is centered 19 mm (0.75 in.) above the burner.

NOTE 2—It may be necessary to turn off nearby lights to make sure of the accuracy of intersect of the midpoint of the flame with the mounting clamp.

8.2 Adjust the timer to provide a  $12 \pm 0.2$ -s flame to the specimen.

NOTE 3—Using a hand-held timer or stopwatch, verify the flame time.

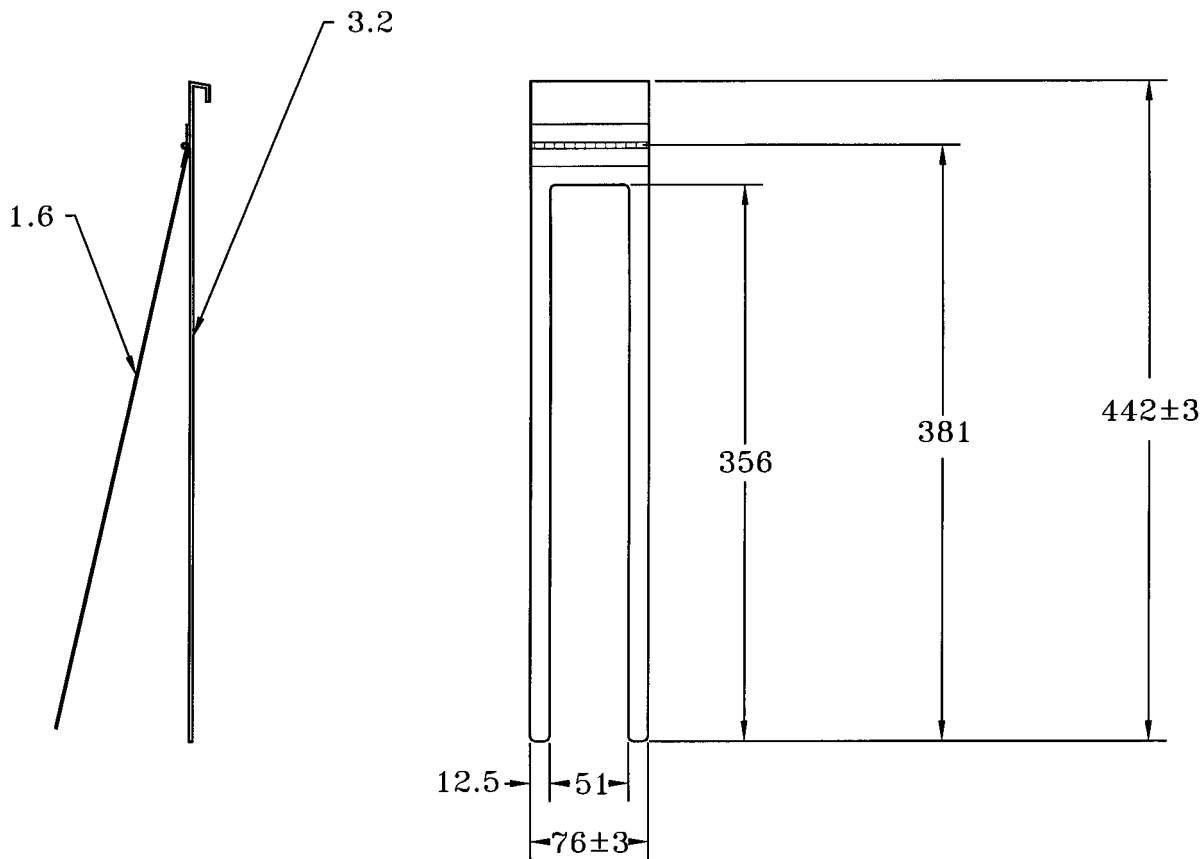
8.2.1 Do this by measuring the interval between the opening and closing of the solenoid with an accurate laboratory timer or stopwatch.

## 9. Sampling

9.1 *Primary Sampling Unit*—Consider rolls of fabric or fabric components of fabricated assemblies to be the primary sampling unit, as applicable.

9.2 *Laboratory Sampling Unit*—As a laboratory sampling unit take from rolls at least one full-width piece of fabric that is 1 m (1 yd) long along the selvage (machine direction), after removing first a 1-m (1-yd) length. For fabric components of fabricated assemblies the entire assembly may be used.

9.3 *Test Specimens*—From each laboratory sampling unit, cut five lengthwise and five widthwise test specimens 76 mm (3.0 in.) by 300 mm (12 in.). For woven fabrics, the long dimensions are cut parallel to the warp yarns for lengthwise



ALL DIMENSIONS IN mm.

FIG. 3 a Specimen Holder Construction Details

tests and parallel to the filling yarns for widthwise tests. Take lengthwise specimens from different positions across the width of the fabric. Consider the long direction as the direction of the test. Label to maintain specimen identity.

9.3.1 Cut specimens representing a broad distribution diagonally across the width of the laboratory sampling unit. Ensure specimens are free of folds, creases, or wrinkles. Avoid getting oil, water, grease, etc., on the specimens when handling.

9.3.2 If the fabric has a pattern, ensure that the specimens are a representative sampling of the pattern.

## 10. Conditioning

10.1 Bring the laboratory sampling units or test specimens to moisture equilibrium as directed in Practice D 1776, except no preconditioning is necessary.

10.2 Each specimen to be tested shall be exposed to the test flame within 4 min after removal from the standard atmosphere or placed in a desiccator without desiccant or equivalent after conditioning for storage until testing and transfer to the testing area.

## 11. Procedure

11.1 Mount and expose each specimen to the flame within 4 min of removal from the conditioning area or storage.

11.2 Clamp the test specimen between the two halves of the holder, with the bottom of the specimen even with the bottom

of the holder. With the holder held vertically, secure the specimen in the holder with a minimum of four clamps. Position two clamps near the top of the holder, one on each side to stabilize the specimen. Similarly, position two clamps at the bottom of the holder, one on each side.

11.3 Turn off the hood ventilation. Insert the specimen holder containing the specimen into the test cabinet and position the burner with the middle of the lower edge of the test specimen centered 19 mm (0.75 in.) above the burner and leveled with the bottom metal prong.

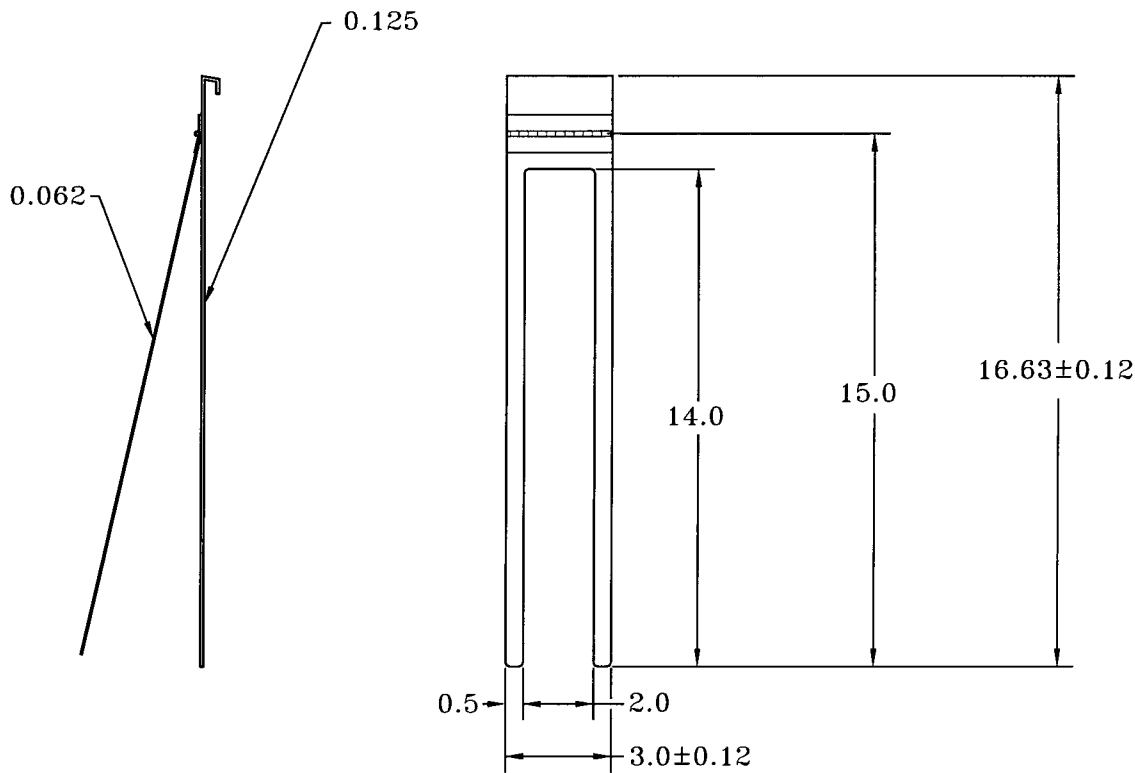
11.4 Start the flame impingement timer and expose the specimen for the  $12 \pm 0.2$  s. Observe the specimen for melting or dripping during the flame exposure. Record any observations. Immediately after the flame is removed, start a stopwatch for measurement of the afterflame and afterglow time.

11.5 Observe how long the specimen continues to flame after the 12 s exposure time. Record the afterflame time to within 0.2 s.

11.6 Observe how long the specimen continues to glow after the afterflame ceases or after removal of the flame if there is no afterflame. Record this afterglow time to the nearest 0.2 s. Do not extinguish the glow because of potential effect on char length.

11.7 Remove the specimen holder from the test cabinet. Turn on the hood ventilation to clear the test cabinet of fumes and smoke. Allow the specimen to cool.

11.8 Measure the char length as shown in Fig. 6.



ALL DIMENSIONS IN inches.

FIG. 3 b Specimen Holder Construction Details (continued)

11.8.1 Make a crease by folding the specimen along a line through the peak of the highest charred area and parallel to the sides of the specimen.

11.8.2 Puncture the specimen with the hook approximately 6 mm (0.25 in.) from the bottom edge and from the side edge of the specimen

11.8.2.1 Attach a weight of sufficient mass to give a combined mass of the weight with the hook that will result in the appropriate tearing force. See Table 1 to determine the designated total tearing force for fabrics of different basis weights.

11.8.3 Apply the tearing force as follows. Grasp the corner of the specimen on the opposite bottom fabric edge from where the hook and weight are attached. Raise the specimen upward in a smooth continuous motion until the total tearing force is supported by the specimen. Note any fabric tear in the charred area of the specimen. Mark the end of the tear with a line across the width of the specimen and perpendicular to the fold line.

11.8.4 Measure the char length along the undamaged edge of the specimen to the nearest 3 mm (0.12 in.).

**12. Calculation**

12.1 *Afterflame Time*—Calculate the average afterflame time to the nearest 0.5 s for the lengthwise and widthwise directions for each laboratory sample.

12.2 *Afterglow Time*—Calculate the average afterglow time to the nearest 0.5 s for the lengthwise and widthwise directions for each laboratory sample.

12.3 *Char Length*—Calculate the average char length to the nearest 3 mm (0.12 in.) for the lengthwise and widthwise

directions for each laboratory sample.

**13. Report**

13.1 State that the samples were tested as directed in Test Method D 6413. Describe the materials or product tested.

13.2 Report the following fabric lengthwise and widthwise information for individual specimens, for the laboratory sampling unit and for the lot as applicable to a material specification or contract order.

13.2.1 Afterflame time.

13.2.2 Afterglow time.

13.2.3 Char length.

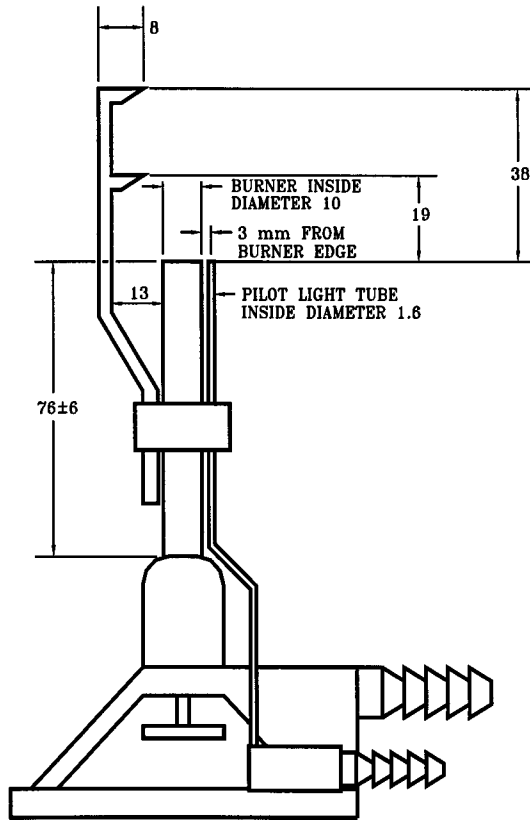
13.2.4 Occurrence of melting or dripping, if any.

**14. Precision and Bias**

14.1 *Precision:*

14.1.1 *Single Laboratory Study*—Seven flame resistant woven fabrics were tested in one laboratory, using one operator to determine char length, afterflame time, and afterglow time and three values measured on each specimen by the procedure. Ten specimens were taken from each fabric sample, five in the lengthwise (machine) and five in the widthwise (cross-machine) direction. This single-laboratory data set is analyzed and used in writing a temporary precision statement, pending a full interlaboratory study. Until the full study is completed, users of the test method are advised to exercise conventional statistical caution in making any comparisons of the test results.

14.1.2 *Char Length*—Variances for lengthwise and widthwise specimens are similar, ranging in value from 0.043 to 0.632, with an average value of 0.320 in.<sup>2</sup>(standard deviation



ALL DIMENSIONS IN MILLIMETERS

FIG. 4 a Burner and Flame Height Gage Construction

= 0.566 in.) as determined by analysis of variance. Critical differences, based on this value and a 95 % probability level, may be applied either to lengthwise average comparisons, or to widthwise average comparisons, to determine significance.

14.1.3 *Afterflame*—Variances for lengthwise and widthwise specimens are similar, ranging in value from 0.008 to 0.106 with an average value of 0.053 2 (standard deviation = 0.230) as determined by analysis of variance. Critical differences, based on this value and a 95 % probability level, may be applied either to lengthwise average comparisons, or to widthwise average comparisons, to determine significance.

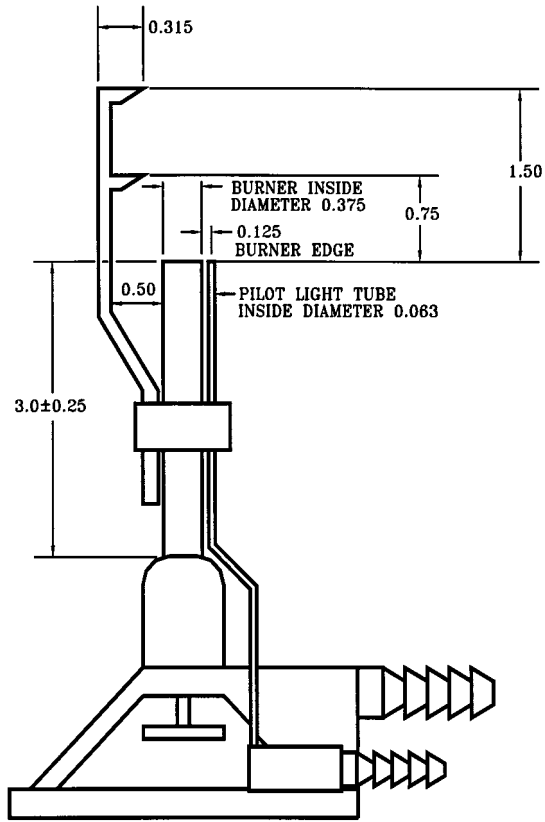
14.1.4 *Afterglow*—Variances for lengthwise and widthwise specimens were more dissimilar, but became similar, when four fabrics, with lengthwise and widthwise variances less than 0.9 and with an average value of 0.278  $S^2$  (standard deviation = 0.570) were placed in Group 1, and two fabrics, with lengthwise and widthwise variances greater than 1.0 and with an average value of 1.870  $S^2$  (standard deviation = 1.367) are

placed in Group 2, both as determined by analysis of variance. One fabric could not be placed in either group. A table of critical differences is calculated for each of the two groups, based on each group's variance value and a 95 % probability level. Apply the appropriate group table values, either to lengthwise average comparisons, or to widthwise average comparisons, depending on whether or not the variance values for the averages being compared fall closer to 0.28 or closer to 1.87.

14.2 *Bias*—The procedure of this test method produces a value that can be defined only in terms of a test. There is no independent, referee test method by which bias may be determined. This test method has no known bias. Tables 2-4

## 15. Keywords

15.1 afterflame; afterglow; char length; flammability; textiles; vertical flame



ALL DIMENSIONS IN INCHES.

FIG. 4 b Burner and Flame Height Gage Construction (continued)

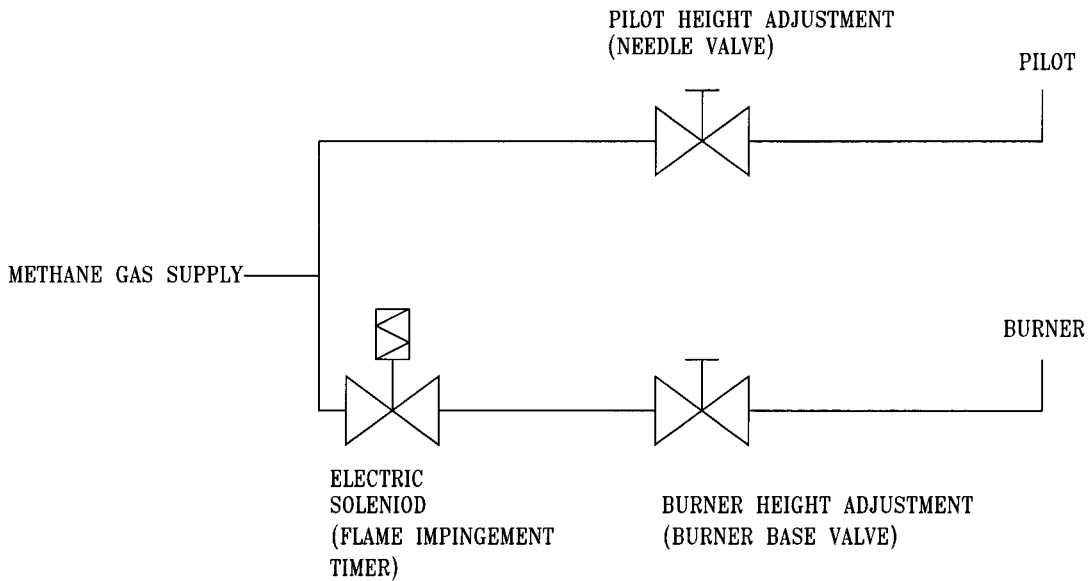
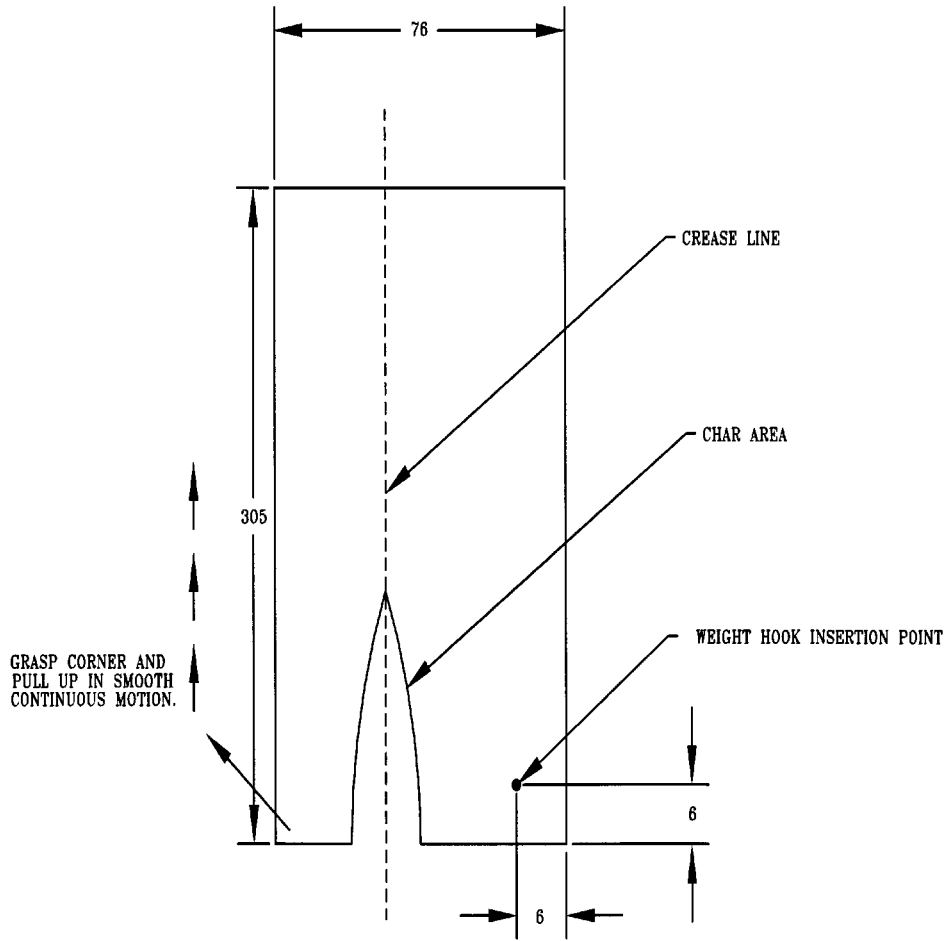
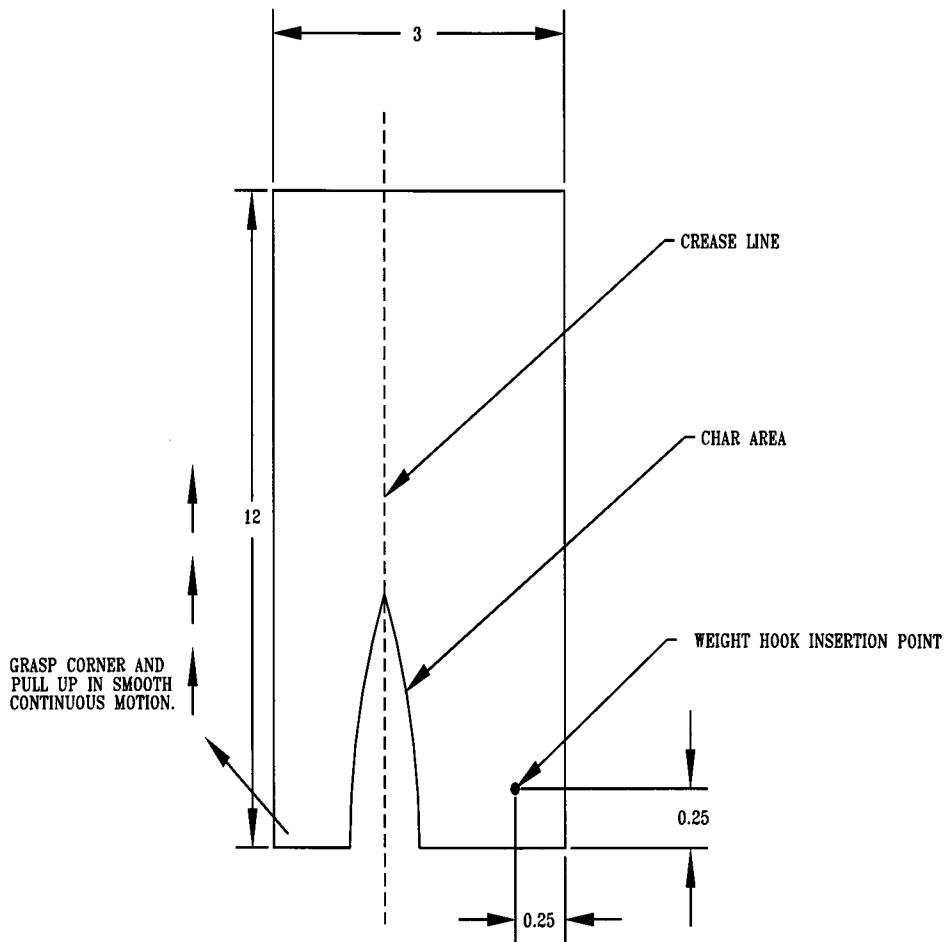


FIG. 5 Schematic of Methane Gas Controls and Adjustments



ALL DIMENSIONS IN MILLIMETERS

FIG. 6 a Char Length Measurement



ALL DIMENSIONS IN INCHES

FIG. 6 b Char Length Measurement (continued)

TABLE 1 Tearing Force for Char Length Determination

g/m <sup>2</sup>	Fabric Basis Weight <sup>A</sup> oz/yd <sup>2</sup>	Total Tearing Force	
		g	oz
68 to 203	2.0 to 6.0	100	4.0
over 203 to 508	over 6.0 to 15.0	200	8.0
over 508 to 780	over 15.0 to 23.0	300	12.0
over 780	over 23.0	475	16.0

<sup>A</sup>The Fabric Basis Weight refers to the weight of cloth before the addition of any fire retardant treatment or coating.

TABLE 2 Within-Laboratory Critical Differences

Char Length (in.) (95 % Probability Level)		
N <sup>A</sup>	SE <sup>B</sup>	CD <sup>C</sup>
1	0.57	1.58
3	0.33	0.91
5	0.25	0.71
7	0.21	0.60

<sup>A</sup>N = Number of determinations per average.

<sup>B</sup>SE = Standard Error for N determinations.

<sup>C</sup>CD = 2.8 SE

TABLE 3 Within-Laboratory Critical Differences

Afterflame (s) (95 % Probability Level)		
N <sup>A</sup>	SE <sup>B</sup>	CD <sup>C</sup>
1	0.23	0.64
3	0.13	0.37
5	0.10	0.29
7	0.09	0.24

<sup>A</sup>N = Number of determinations per average.

<sup>B</sup>SE = Standard Error for N determinations.

<sup>C</sup>CD = 2.8 SE.

**TABLE 4 Within-Laboratory Critical Differences**

Afterglow (s) (95 % Probability Level)		
Group 1 (Variance approximately 0.28)		
$N^A$	$SE^B$	$CD^C$
1	0.53	1.48
3	0.30	0.85
5	0.24	0.66
7	0.20	0.56
Group 2 (Variance approximately 1.87)		
$N$	$SE$	$CD$
1	1.37	3.83
3	0.79	2.21
5	0.61	1.71
7	0.52	1.45

<sup>A</sup> $N$  = Number of determinations per average.

<sup>B</sup> $SE$  = Standard Error for  $N$  determinations.

<sup>C</sup> $CD$  = 2.8  $SE$ .

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