



Designation: F 1060 – 01

Standard Test Method for Thermal Protective Performance of Materials for Protective Clothing for Hot Surface Contact¹

This standard is issued under the fixed designation F 1060; 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 is used to rate textile materials for thermal resistance and insulation when exposed for a short period of time to a hot surface with a temperature up to 600°F (316°C). This test method is applicable to woven fabrics, knit fabrics, battings, and sheet structures intended for use as clothing for protection against short exposure to hot surfaces. It is not intended for use in evaluating materials exposed to any other thermal exposure such as radiant energy or open flames. This test method is currently useful as a research and development tool.

1.2 This test method should be used to measure and describe the properties of materials, products, or assemblies in response to heat under controlled laboratory conditions and should not be used to describe or appraise the thermal hazard or fire risk of materials, products, or assemblies under actual exposure conditions.

1.3 The values as stated in SI units are to be regarded as the standard. The values in parentheses are given for information only.

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 Textiles²

D 1776 Practice for Conditioning Textiles for Testing²

D 4391 Terminology Relating to The Burning Behavior Of Textiles³

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

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² Annual Book of ASTM Standards, Vol 07.01.

³ Annual Book of ASTM Standards, Vol 07.02.

F 1494 Terminology Relating to Protective Clothing⁴

3. Terminology

3.1 *Definitions*—In testing thermal protection clothing material, the response to hot surface contact is indicated by the following descriptive terms:

3.1.1 *charring*—the formation of a carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.1.2 *embrittlement*—the formation of a brittle residue as a result of pyrolysis or incomplete combustion.

3.1.3 *heat flux*—the thermal intensity indicated by the amount of energy transmitted per unit area and per unit time ($\text{cal}/\text{cm}^2\cdot\text{s}$) (watts/cm^2).

3.1.4 *human tissue heat tolerance*—in the testing of thermal protective materials, the amount of thermal energy predicted to cause a pain sensation or a second degree burn in human tissue.

3.1.5 *ignition*—the initiation and continuation of combustion.

3.1.6 *melting*—a response evidenced by softening of the material, resulting in a nonreversible change.

3.1.7 *shrinkage*—a response evidenced by reduction in specimen size.

3.1.8 *sticking*—a response evidenced by softening and adherence of the material to the hot surface or other material.

3.1.9 *thermal end point*—in the testing of thermal protective materials, the point at which the sensor response on the recorder chart intersects the human tissue burn tolerance criteria overlay.

3.2 For all terminology related to protective clothing, see Terminology F 1494.

3.3 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 measures the performance of insulative materials. A material is placed in contact with a standard hot surface. The amount of heat transmitted by the material is compared with the human tissue tolerance and the obvious effects of the heat on the material are noted.

⁴ Annual Book of ASTM Standards, Vol 11.03.

4.2 The temperature of the hot surface is measured/controlled with a thermocouple and the heat transmitted by the test specimen is measured with a copper calorimeter. The calorimeter temperature increase is a direct measure of the heat energy received.

4.3 A contact pressure of 3kPa (0.5 psi) is used to compare material performance under controlled conditions. If a different pressure is chosen to represent a specific use condition, where it is used should be noted under test conditions (13.1.2.3).

4.4 The material performance is determined from the amount of heat transferred by the specimen and the observed effect of the heat exposure on the specimen. The thermal protection is the exposure time required to cause the accumulated heat received by the sensor to equal the heat that will result in a pain sensation (see Table 1) or cause a second degree burn in human tissue (see Table 2), as predicted from comparison of heat transfer data with human tissue heat tolerance curves (see Table 1 and Table 2).

5. Significance and Use

5.1 This test method rates textile materials intended for use as protective clothing against exposure to hot surfaces, for their thermal insulating properties and their reaction to the test conditions.

5.2 The thermal protection time as determined by this test method will relate to the actual end-use performance only to the degree that the end-use exposure is identical to the exposure used in this test method, that is, conductive energy from hot surfaces up to 600°F (300°C) and under a pressure of 3kPa (0.5 psi).

5.3 The procedure maintains the specimen in a static, horizontal position under a standard pressure and does not involve movement.

5.4 This test method for materials for thermal protective performance is intended for use in comparing the relative performance of various materials.

6. Apparatus

6.1 *General Arrangement*—The arrangement of the individual components of the test apparatus is shown in Fig. 1.

6.1.1 Alternatively, transmit temperature output readings to a data acquisition unit, then computer process to obtain the test result.

6.2 *Hot Plate*—Shall have a flat heated surface with the smallest dimension, a minimum of at least 200 mm (8 in.) and

have the ability to achieve a temperature of at least 371°C (700°F) and to permit temperature control within 2.8°C (± 5°F).

6.3 *Surface plate*—The flat plate shall be 6.4 mm (¼ in.) thick, 140 by 140 mm (5.5 by 5.5 in.) wide, with a 2.4 mm (¾ in.) hole drilled from the edge to the center of the plate (Fig. 2). Use either electrolytic copper or T-1100 aluminum surface plates. The surface plate must be flat, smooth, and free from pits and cavities. (Flatness is indicated by negligible light passing between a straight edge and the plate surface.) Loss of the original mill finish (as judged with the naked eye) or warping, or both, may result in failure to achieve calibration with the reference standard.

6.4 *Sensor*—A copper calorimeter mounted in an insulating block with added weight and constructed as shown in Figs. 3 and 4 with the standard characteristics listed below. The following equations permit the determination of the total incident heat energy from the copper calorimeter:

$$q = \frac{mass \times C_p \times (Temp_{final} - Temp_{initial})}{area \times (time_{final} - time_{initial})} \tag{1}$$

where:

- q = heat flux (cal/cm²s),
- $mass$ = mass of the copper disk/slug (g),
- C_p = heat capacity of copper (0.09426 cal/g°C at 100°C),
- $temp_{final}$ = final temperature of copper disk/slug at $time_{final}$ (°C),
- $temp_{initial}$ = initial temperature of copper disk/slug at $time_{initial}$ (°C),
- $area$ = area of the exposed copper disk/slug (cm²),
- $time_{final}$ = ending time (s), and
- $time_{initial}$ = starting time (s).

For a copper disk/slug that has a mass of 18.0 g and exposed area of 12.57 cm², the determination of heat flux reduces to:

$$q = \frac{0.135 \times (Temp_{final} - Temp_{initial})}{(time_{final} - time_{initial})} \tag{2}$$

If you use a copper disk/slug with a different mass and/or exposed area, the constant factor should be adjusted correspondingly. Also note that a different mass/surface area sensor will give different rates of temperature change to incident heat energy so the calculations made later will need to note this and make appropriate changes to correct (for example, see 10.3, 12.1.2, 13.1.3.1). The calorimeter must fit securely in the insulating block and its surface must be flush with the face of

TABLE 1 Human Tissue Tolerance to Pain Sensation

Exposure Time	Heat Flux		Total Heat		Calorimeter Equivalent		
	cal/cm ² -sec	W/cm ²	cal/cm ² -s	W sec/cm ²	ΔT°, F	ΔT°, C	ΔmV
1.0	0.640	2.70	0.640	2.70	8.53	4.74	0.250
1.5	0.475	2.00	0.713	3.00	9.51	5.28	0.275
2.0	0.385	1.61	0.770	3.22	10.27	5.71	0.293
3.0	0.280	1.17	0.840	3.51	11.20	6.22	0.322
5.0	0.195	0.82	0.975	4.08	13.00	7.22	0.375
7.0	0.155	0.65	1.085	4.54	14.47	8.04	0.420
10.0	0.118	0.49	1.180	4.94	15.73	8.74	0.458
20.0	0.076	0.32	1.520	6.36	20.27	11.26	0.582
30.0	0.060	0.25	1.800	7.53	24.00	13.33	0.690
50.0	0.060	0.25	3.000	12.55	40.00	22.22	1.150

TABLE 2 Human Tissue^A Tolerance to Second Degree Burn

Exposure Time, s	Heat Flux		Total Heat		Calorimeter ^B		Equivalent, ΔmV
	cal/cm ² ·s	W/cm ²	cal/cm ² ·s	W/cm ²	ΔT, °F	ΔT, °C	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1.2	5.0	1.20	5.0	16.0	8.9	0.46
2	0.73	3.1	1.46	6.1	19.5	10.8	0.57
3	0.55	2.3	1.65	6.9	22.0	12.2	0.63
4	0.45	1.9	1.80	7.5	24.0	13.3	0.69
5	0.38	1.6	1.90	8.0	25.3	14.1	0.72
6	0.34	1.4	2.04	8.5	27.2	15.1	0.78
7	0.30	1.3	2.10	8.8	28.0	15.5	0.80
8	0.274	1.15	2.19	9.2	29.2	16.2	0.83
9	0.252	1.06	2.27	9.5	30.2	16.8	0.86
10	0.233	0.98	2.33	9.8	31.1	17.3	0.89
11	0.219	0.92	2.41	10.1	32.1	17.8	0.92
12	0.205	0.86	2.46	10.3	32.8	18.2	0.94
13	0.194	0.81	2.52	10.6	33.6	18.7	0.97
14	0.184	0.77	2.58	10.8	34.3	19.1	0.99
15	0.177	0.74	2.66	11.1	35.4	19.7	1.02
16	0.168	0.70	2.69	11.3	35.8	19.8	1.03
17	0.160	0.67	2.72	11.4	36.3	20.2	1.04
18	0.154	0.64	2.77	11.6	37.0	20.6	1.06
19	0.148	0.62	2.81	11.8	37.5	20.8	1.08
20	0.143	0.60	2.86	12.0	38.1	21.1	1.10
25	0.122	0.51	3.05	12.8	40.7	22.6	1.17
30	0.107	0.45	3.21	13.4	42.8	23.8	1.23

^A Stoll, A. M. and Chianta, M. A., "Method and Rating System for Evaluations of Thermal Protection," *Aerospace Medicine*, Vol 40, 1969, pp. 1232–1238 and Stoll, A. M. and Chianta, M. A., Heat Transfer through Fabrics as Related to Thermal Injury, "Transaction-New York Academy of Sciences," Vol 33 (7), Nov. 1971, pp 649–670.
^B A calorimeter with an iron/constantan thermocouple.

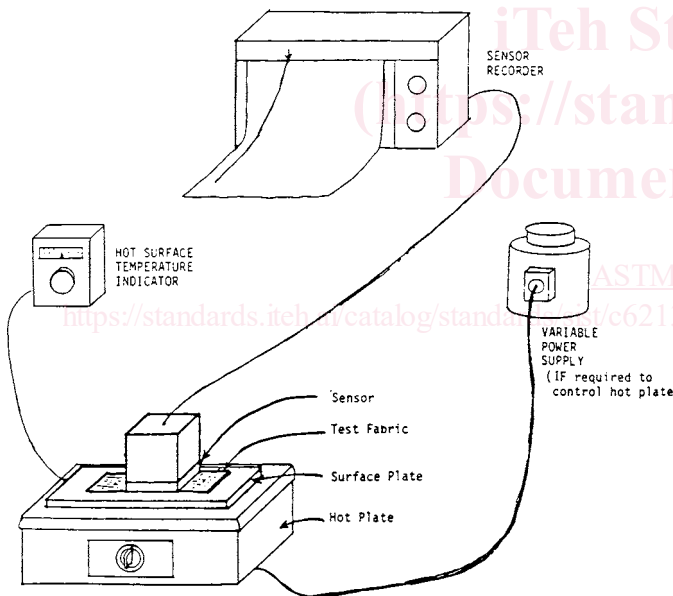
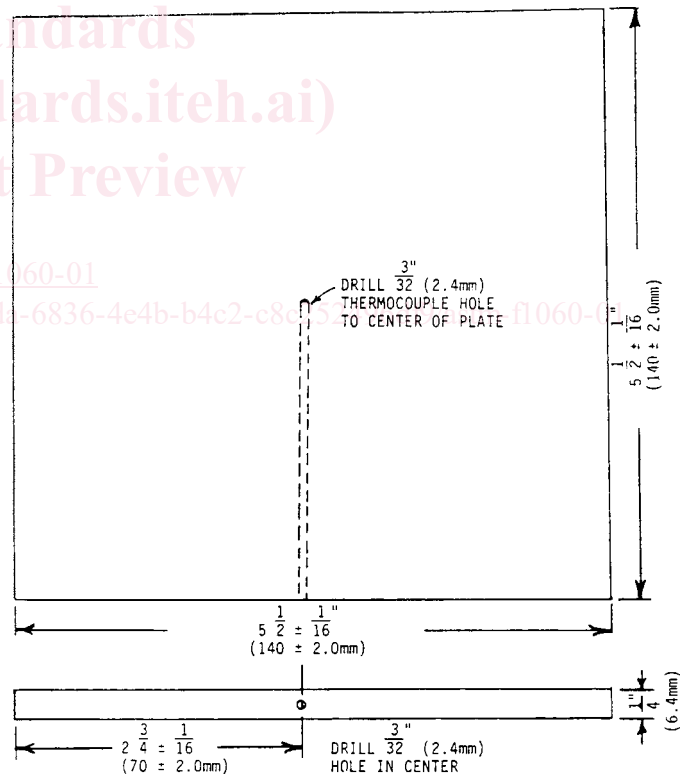


FIG. 1 Thermal Protective Performance Apparatus, Hot Surface Contact



Material: Electrolytic Copper or T-1100 aluminum
 FIG. 2 Surface Plate

the insulating block. (**Warning**—Surface variations may result in failure to achieve calibration with the reference standard.)

6.5 Calibration Specimen—Six new, not previously tested sheets of ordinary newspaper with total thickness of 0.53 ± 0.05 mm (0.021 ± 0.002 in.).

6.6 Recorder—Any strip chart recorder with full-scale deflection of at least 150°C (300°F) or 10 mV and sufficient sensitivity and scale divisions to read sensor response to 1°C (±2°F) or ±0.05 mV. A chart speed to read exposure time to ±0.1 s is required, 13 mm/s (0.5 in./s) is satisfactory.

7. Hazards

7.1 Perform the test in a hood or a ventilated area to carry away degradation products, smoke, and fumes. Exercise care to prevent contact with hot surfaces. Use protective gloves when handling hot objects. Have an appropriate portable fire extinguisher nearby.