



Designation: F 955 – 03

Standard Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten Substances¹

This standard is issued under the fixed designation F 955; 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 the evaluation of materials' thermal resistance to molten substance pour by describing means of measuring heat transfer.

NOTE 1—As used in this test method, the term *molten substance* refers to the three compositions (aluminum, brass, and iron) for which the procedure was validated. The test design may be adapted for use with other substances not validated as part of the test method.

1.2 This test method is applicable to materials from which finished protective apparel articles are made.

1.3 This test method does not measure the flammability of materials, nor is it intended for use in evaluating materials exposed to any other thermal exposure exclusive of the molten substance itself (see Note 1).

1.4 This test method should be used to measure and describe the properties of materials, products, or assemblies in response to molten substance pour 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 conditions. However, results of this test may be used as elements of a thermal risk assessment which takes into account all the factors that are pertinent to an assessment of the thermal hazard of a particular end use.

1.5 *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.* Specific hazard statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*²

D 123 Terminology Relating to Textiles

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 Molten Substances.

Current edition approved August 10, 2003. Published October 2003. Originally approved in 1985. Last previous edition approved in 1996 as F 955 – 96.

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.

E 457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter
F 1494 Terminology Relating to Protective Clothing

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *break-open*—in testing thermal protective material, a response evidenced by the formation of a hole in the material which allows the molten substance to pass through the material.

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

3.1.3 *dripping*—in testing thermal protective material, a response evidenced by flowing of the fiber polymer.

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

3.1.5 *heat flux*—the thermal intensity indicated by the amount of energy transmitted divided by area and time, W/m^2 ($cal/cm^2 s$).

3.1.6 *human tissue burn tolerance*—in the testing of thermal protective materials, the amount of thermal energy predicted to cause a second-degree burn in human tissue.

3.1.7 *ignition*—the initiation of combustion.

3.1.8 *melting*—in testing thermal protective material, a response evidenced by softening of the material, resulting in a nonreversible change.

3.1.9 *response to molten substance pour*—in testing thermal protective material, the observed effect of molten substance contact on textile properties or deterioration of the material.

3.1.10 *shrinkage*—a decrease in one or more dimensions of an object or material.

3.1.11 *thermal end point*—in testing of thermal protective materials, the point of where the copper slug calorimeter sensor response (heat energy measured) intersects with a predicted skin burn injury model.

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

4. Summary of Test Method

4.1 A material specimen is mounted on a vertical incline and is exposed to a molten substance pour of prescribed minimum temperature, volume, pour rate, and vertical height.

4.2 The amount of heat energy that is transmitted through the test specimen during and after the molten substance exposure is measured using two copper slug calorimeters. The heat transport response is assessed versus the Stoll curve, an approximate human tissue tolerance predictive model that projects the onset of a second-degree skin burn injury as manifested by a blister (See 12.2).

4.3 A specific set of subjective evaluations is performed on the test specimen response to the molten substance exposure using a standardized rating scale for appraisal (found in Table X.1).

5. Significance and Use

5.1 Workers may be exposed to contact with molten substances. The clothing used should provide some protection. Whether personal injury results from such contact depends on the resistance of the material from which the clothing is made to molten substance contact and the amount of heat transferred through the material to the wearer.

5.2 This test method rates materials, that are intended for protective clothing against potential molten substance contact, for their thermal insulating properties and their reaction to the test exposure.

5.3 The protective performance, 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 the test method.

5.4 Visual inspection of the specimen subjectively notes the material’s resistance to molten substance contact.

6. Apparatus

6.1 The test apparatus consists of four major components as follows:

- 6.1.1 An inclined specimen mounting and exposure board with two copper slug calorimeter thermal sensors and supports,
- 6.1.2 A pouring crucible and pouring mechanism,
- 6.1.3 A furnace for melting the test metal, and
- 6.1.4 Instruments for measuring test conditions and test results.

6.2 Sensor Construction

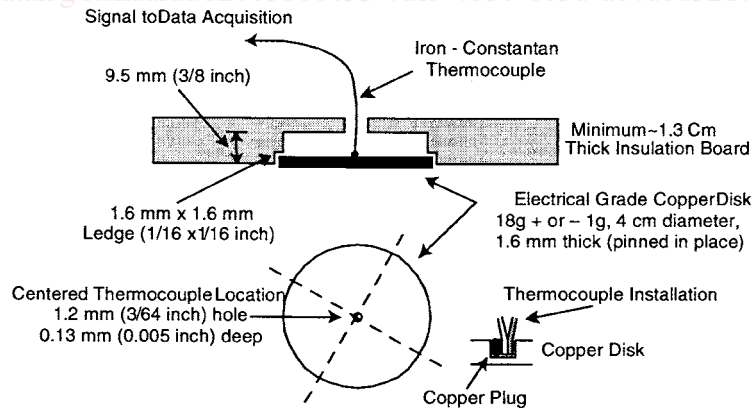
6.2.1 Each copper slug calorimeter shall be 18 ± 1 g, 40 mm diameter and 1.6 mm thick and shall be constructed from electrical grade copper with a single 30 gage, iron/constantan thermocouple wire and shall be installed as identified in Fig. 1.

6.2.2 The exposed surface of each copper slug calorimeter shall be painted with a thin coating of a flat black high temperature spray paint with an emissivity of 0.9. The painted sensor shall be dried before use and present a uniformly applied coating (no visual thick spots or surface irregularities). Note that an external heat source, for example, an external heat lamp, has been used to completely drive off any remaining organic carriers on a freshly painted surface.

6.3 Specimen/Sensor Board

6.3.1 The specimen/sensor board shall be nominally 250 mm by 406 mm [10 in. by 16 in.] and fabricated of a flame and heat resistant material with a thermal conductivity value of ≤ 0.15 W/m-K, high temperature stability, and resistance to thermal shock. The board shall be nominally 13 mm [0.5 in.] or greater in thickness.

6.3.2 The copper slug calorimeters shall be located in the centerline of the sensor board and mounted as shown in Fig. 1. The calorimeters shall be located 101 mm and 203 mm [4 in. and 8 in.] respectively, from the top of the board to the calorimeter centers as indicated in Fig. 2.



NOTE 1—Sensor Construction—Place a straight, bare tip thermocouple wire into the hole located in the center of the copper disk. Place a short “copper plug” into the center hole with the thermocouple junction by clipping a section of bare copper wire of appropriate diameter that, when combined with the thermocouple wire, will just fit into the center hole. Use a center punch to mechanically wedge the wire bundle into place. Peen around the hole to further secure the thermocouple into the copper disk. Take care not to cut the thermocouple wire during this assembly process. Check the electrical continuity and thermal response prior to using the completed copper slug calorimeter.

FIG. 1 Sensor Construction

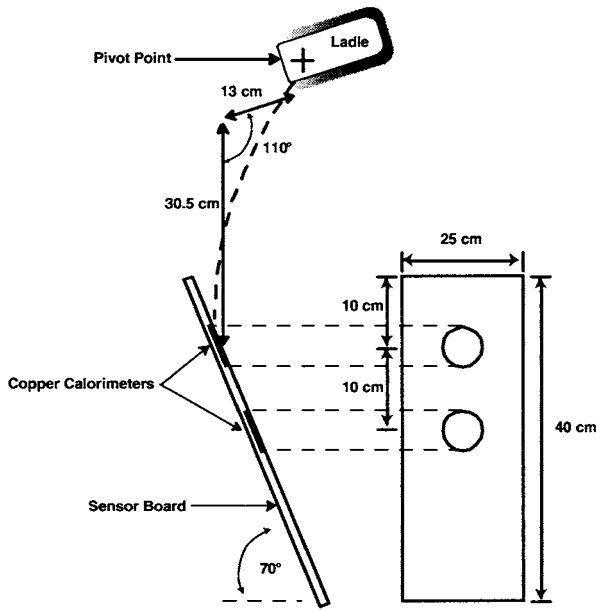


FIG. 2 Schematic of Test Apparatus

6.3.3 An attachment method shall be provided that affixes the test specimen to the board such that it covers both sensors and extends at least 25 mm [1 in.] beyond all edges.

6.3.4 The sensor board shall be inclined at an angle of 70° from horizontal.

6.3.5 The sensor board shall be located so that it meets the pour geometry illustrated in Fig. 2, where the molten substance is introduced at the centerline of the board.

6.4 *Pouring Crucible*—The pouring crucible shall be suitable for the substance being poured and for handling temperatures up to at least 56°C [100°F] above the pouring temperature. Crucible sizes appropriate for specific substances are shown in Table 1. The crucible shall be attached to a tilting mechanism capable of turning the ladle at the rate of one revolution per 4.7 ± 0.2 s. The crucible shall be pivoted at a point 25 mm [1 in.] below the top of the crucible on the vertical. When tilted, the tilted action shall be stopped mechanically after a rotation of $10 \pm 5^\circ$ from the vertical (Fig. 2). See also Appendix X2.

6.5 *Furnace*—A suitable furnace for melting and heating the test substance is needed. The furnace and lining must be of a type that the chemistry of the substance is not changed during contact with the furnace nor throughout the term of the test series.

6.6 Pouring height shall be 305 mm [12 in.] (See Fig. 2).

6.7 *Data Acquisition System*—The system shall be capable of recording the calorimeter outputs as required by the test.

6.7.1 The temperature data (calorimeter outputs) shall be acquired at a minimum sampling rate of four samples per second per calorimeter. The acquisition system shall be able to record temperatures to 150°C [300°F], have at least a resolution of 0.1°C [0.2°F], and measuring accuracy of $\pm 0.75^\circ\text{C}$ [$\pm 1.4^\circ\text{F}$].

7. Materials

7.1 Description of standard substances for test purposes is included in Table 1.

8. Hazards

8.1 Perform the test in a ventilated area to carry away combustion products, smoke, and fumes. Care shall be exercised in handling the hot substance. A full fire extinguisher, preferably of the carbon dioxide type, shall be readily available. Use normal safety practices for the handling of the molten substance and potentially flammable materials. Place a catch pan filled with dry sand under the assembly. *Extreme care shall be taken to prevent contact between the molten substance and water because explosive quantities of steam can result.*

8.2 The sensor board and calorimeter assembly become heated during prolonged testing. Use protective gloves when handling these hot objects and during the pour.

9. Sampling and Specimen Preparation

9.1 *Lot Size*—For acceptance sampling purposes, a lot is defined as 4572 m [5000 yd] or a single shipment of a single style of material, whichever is smaller. A lot may constitute all or part of a single customer order.

9.2 *Lot Sample*—As a lot sample, take a 2 m [2.2 yd] full-width piece of material from both the beginning and end of the lot.

9.3 *Test Specimens*—Cut and identify three test specimens from each sample. Make each test specimen at least 305 ± 2 mm by 460 ± 2 mm [$12 \pm 1/16$ by $18 \pm 1/16$ in.]. Do not cut samples closer than 10% of the material width from the edge and arrange the specimens across the sample swatch so as to get as representative a sampling as possible.

9.4 *Sensor Care*:

9.4.1 *Initial Temperature*—Cool the sensor after a pour exposure with a jet of air to approximately 21°C [70°F] just prior to positioning the test specimen.

TABLE 1 Test Parameters^A

NOTE 1—When this test method is used for substances other than below, use a pour temperature equal to use temperature or sufficiently above the melting point to give reproducible pouring characteristics.

	Substance	Pour Temperature (min)	Weight of Test Substance	Substance Specification
A	Iron	2800°F [1538°C]	2.2 lb [1000 g]	Eutectic iron ^B
B	Aluminum	1400°F [760°C]	2.2 lb [1000 g]	Alloy 1100
C	Brass	2100°F [1149°C]	2.2 lb [1000 g]	Alloy 875 ^C

^A See Appendix X3.

^B Carbon equivalent = $4.3 \pm 0.15\%$. Carbon equivalent = $\% C + \frac{Si}{4} + \frac{P}{2}$ (approximately 2% Si).

^C 82/14/4%, Cu/Zn/Sn.