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QUALITY ASSURANCE SPECIFICATIONS™

SFI TECHNICAL BULLETIN 3.2 EFFECTIVE: FEBRUARY 26, 2014[*]

SUBJECT: Fire Protection Material

1.0 GENERAL INFORMATION

SFI Technical Bulletin 3.2 consists of test procedures for fire protection material. In this bulletin, the word "material" is used to connote any single layer fabric or multiple layer combination of fabrics.

2.0 OBJECTIVE

SFI Technical Bulletin 3.2 consists of two test procedures for fire protection material. One determines the Thermal Protective Performance {TPP} rating of the material and the other is a test of flammability. A procedure for each test is contained herein.

3.0 TESTING

3.1 TPP TEST

This test exposes a material to the heat from a standard source and measures the amount of heat energy which, when applied to one side of the material, to exceed time-to-thermal energy limits on the other side as represented by a performance curve commonly known as the “Stoll Curve”. The material is rated for thermal resistance and insulation when exposed to a 50%/50% combination of convective and radiant energy at a level of about 2.0 cal/cm^2-sec (8.37 W/cm^2) for a short duration {cal = calories, cm = centimeter, sec = second, W = watts}. The TPP rating is a measure of the exposure energy. This method is similar, but not identical, to the ASTM F 2700-08 Standard Test Method for Unsteady-State Heat Transfer Evaluation of Flame Resistant Materials for Clothing with Continuous Heating.

3.1.1 SAMPLES

A. Square samples of material not previously laundered, each 17.8 x 17.8 ±0.2cm (7.00 x 7.00 ±0.07 in) shall be supplied. The material shall be tagged to show in which product model it is to be used. The material shall have the identical layer fabric, layer order and construction, thread and stitch composition and overall assembly as that of the product model that is being evaluated. Two of the sides of each sample shall be parallel with either the warp yarns in woven fabric samples, with the wales in knit fabric samples or with the length in non-woven fabrics. Since samples can be composed of multiple layers, this orientation may not be possible for all layers. The exposed fabric area shall be at least 100 cm^2 (15.5 in^2).

B. All samples shall be identified and weighed per ASTM D 3776 Option C and this weight shall be recorded and reported as a portion of all TPP test results.

C. The thickness of all samples shall be measured using a compressometer with a three inch diameter presser foot set at 0.05 psi, allowing five seconds to lapse between the application of the load and the thickness reading. This value shall be recorded and reported as a portion of all TPP test results.

3.1.2 APPARATUS

A. The heat exposure is from a combination of a convective heat source provided by two laboratory burners and a radiant heat source provided by a bank of nine electrically heated quartz tubes controlled by a powerstat. The rate of gas (methane or liquid propane) flowing to the burners and the angle that the burners make with respect to the horizontal can be controlled. A pneumatic shuttering mechanism activated by a digital timer allows control of exposure time to within 0.2 second[1]. If manual shutter mechanism is used actuation must be accomplished within 0.5 seconds.

B. A Data Acquisition, Recording, and Analysis System that is capable of operating the shutter, recording calorimeter response, and calculating the resulting thermal energy. The system must be also capable of determining the test endpoint by comparing the results to a pre-determined performance curve (3.1.5, and Table 1). The system must have a minimum sampling rate of four samples per second and a minimum resolution of 0.1C, with an accuracy of +/- 0.75C

1 [1]The configuration and features are typical of a commercial testing apparatus available from Custom Scientific Instruments, 13 Wing Drive, Whippany, NJ 07981. The exact specifications of the assembly shall be equivalent to their design of the original TPP testing apparatus.

C. A calorimeter (sensor) consisting of a copper disc, 4.0 cm (1.575 in) in diameter and 0.16 cm (0.063 in) thick. Four, 30 gauge iron-constantan thermocouples are secured in the disc. Three are positioned at 120° intervals at a radius of 1 cm (0.394 in) and the other at the center. The calorimeter face is painted with flat black paint and is mounted on an insulating board. The specifications of the calorimeter and insulating board are shown in ASTM F 2700-08 Figure 2. Additional mass will be needed for the assembly (insulating block, calorimeter and added mass) to weigh the test value of 1,000 grams (gm) ±10 gm.

D. A precision water-cooled radiometer is required to determine the radiant component of the heat exposure[2].

E. A precision water-cooled heat flux transducer is required to determine the total heat exposure[3].

3.1.3 CALIBRATION

The instrument is calibrated to ensure the delivery of a steady heat exposure at 2.00 ±0.05 cal/cm^2-sec (8.37 ±0.21 W/cm^2). The calibration consists of adjusting the heat level and balancing the combination of convective and radiant heat to provide a 50%/50% ±10% combination. This is determined using the heat flux transducer and the radiometer.

A. The calorimeter mass (m), area (A) and heat capacity (C_p) at the mean testing temperature must be known. The thermocouples should be connected to the recorder through an appropriate "zero junction" reference. It is recommended that direct millivolt readings be used since analog output from a digital thermometer yields a broken "stepped" curve making analysis difficult[4].

[2] A Medtherm Model 64P-5-24 radiometer available from Medtherm Company, P.O. Box 412, Huntsville, AL 35804 or a Hy-Cal Model R-8015-C radiometer available from Hy-Cal Engineering, 9650 Telestar Avenue, El Monte, CA 91731 or an equivalent.

[3] A Medtherm Model 64-5-20 heat flux transducer available from Medtherm Company, P.O. Box 412, Huntsville, AL 35804 or equivalent.

[4] Conversion tables from millivolt to degrees are available from Omega Engineering, Inc., P.O. Box 4047, Stamford, CT 06907.

B. Calculate the expected temperature rise of the calorimeter over 10 seconds commensurate with an incoming heat flux (Q) of 2.0 cal/cm^2-sec using Equation 1.

$$\Delta T = \frac{(Q)(t)(A)}{(m)(C_p)} \qquad (1)$$

where:

ΔT = temperature rise in 10 seconds (^{o}C)
Q = incoming heat flux (2.0 cal/cm^2-sec)
t = 10 seconds
A = area of calorimeter face (cm^2)
m = calorimeter mass (grams {gm})
C_p = heat capacity of copper (cal/gm-^{o}C)

C. Place the radiometer at the same position as that of the plane of the fabric face during the actual testing. Measure the heat flux obtained from the radiant quartz panel alone at various powerstat settings. Set up a table of powerstat values versus radiant flux output. The time required for the panel to reach a steady output should be determined during successive measurements.

D. Gas flames have a significant radiant component, usually about 30%. This should be determined using the radiometer. The radiant component of the flames must be added to the output of the quartz panel to arrive at the required 50% radiant component.

E. Set the powerstat to a yield of about 0.4 cal/cm^2-sec (1.67 W/cm^2). Turn on the gas flames and set at about one-third of full flowmeter deflection. Gas pressure should not exceed 6 pounds per square inch {psi}. Make sure the flames converge on the center of the sample. If not, adjust the burner angles.

F. Raise the temperature of the calorimeter to about 32^{o}C (90^{o}F).

G. Place the calorimeter block directly on the sample holder. Close the shutter and swing the holder into position above the heat sources.

H. Select the appropriate command on the Data Recording and Operation System to operate the shutter and record calorimeter response.

I. If the temperature rise in 10 seconds indicated from the system is If smaller than calculated from Equation 1, boost the flames using the flowmeter and measure again as in steps F through H.

J. Repeat this procedure, using small increments of the flowmeter to change the flames, until a heat flux of 2.00 ±0.05 cal/cm^2-sec (8.37 ±0.21 W/cm^2) is achieved at the calorimeter face.

K. Remove the calorimeter block and replace with the radiometer. Measure the total radiant flux at the set exposure level. If it is less than 1.0 cal/cm^2-sec (2.09 W/cm^2), boost the output of the radiant panel. Recheck using the radiometer.

L. Replace the radiometer with the calorimeter and measure total flux as before. If the flux is too high, the flames must be adjusted. Decrease the flame output and repeat steps F through L. Several cycles may be required to obtain the correct balance.

Note: The copper calorimeter is somewhat less sensitive to pure radiant heat at low flux levels than the radiometer. Therefore, a small increase in radiant output of the quartz panel may not translate to an equivalent rise in the overall flux registered by the calorimeter. The radiometer must be used however, because it is the true radiant flux at the fabric face that is of interest, coupled with the total heat as sensed by the calorimeter.

M. Record the settings of the flowmeter gas pressure gauge and the powerstat.

N. Check the total incident heat flux with the copper calorimeter after each run.

3.1.4 PROCEDURES

A. The test sample is mounted in the sample holder positioned above the heat source and is protected by a water-cooled shutter before and after the test run. The heat transferred is measured by the instrumented calorimeter located behind the test sample.

B. The test sample and calorimeter are held in a special assembly designed to provide transverse friction and is intended to simulate restrained conditions existent in some clothing assemblies. The test sample is installed in the assembly so that the side to be worn facing outwards faces the heat source. The calorimeter and insulated board are placed on the other side, with the calorimeter in contact with the fabric surface. Add mass to the insulating block until the assembly (insulating block, calorimeter and added mass) is 1,000 gm ±10 gm.

C. Position the insulating block and calorimeter assembly (see 3.1.2.C of this document) directly on top of the sample to be tested with the black surface facing downward. Use the appropriate command on the Data Acquisition and Operating System to operate the shutter and record the calorimeter response until a sensor temperature rise of 35° to 40°C (95° to104°F) or 1.7 to 2.0 mV. The shutter shall be closed by the Operating System, and the calorimeter weight assembly shall be removed and cooled. The sample holder and exposed sample shall be removed.

D. At least three material samples are tested. If disparity between the three readings exceeds ±5% of the mean value, testing should continue until three consecutive readings within these limits are obtained, exception: Three readings are not required to be within ±5% of the mean value for leather faced samples if all 3 readings are at least 125% of the required level.

E. Follow the procedures for calorimeter care and surface reconditioning as described in paragraph 6.5 of ASTM F 2700-08.

F. If copper is showing on the calorimeter, the surface shall be completely repainted with a thin layer of flat black spray paint. At least one calibration run shall be performed after repainting to reestablish the baseline for subsequent testing (must be within ±5% of original values).

G. In conducting tests, follow all precautions and safety practices outlined in ASTM F 2700-08.

H. After conclusion of testing or sooner if deemed necessary, one calibration run shall be performed. If variation with the last previous total heat flux calorimeter reading deviate more than ±5%, all testing per paragraph 3.1.4 must be repeated.

3.1.5 PERFORMANCE CURVE

For the purpose of calculating TPP, the “Stoll Curve” will be recorded in the Data Acquisition and Operating System as represented in Table 1[5].

A. Use Equation 2 to make the transformation from q to ΔT (delta T).

$$\Delta T = \frac{(q)(A)}{(m)(C_p)} \qquad (2)$$

where:

ΔT = actual calorimeter temperature rise for a given q.
(Other factors same as Equation 1)

[5] Taken from Stoll, A. M. and Chianta, M. A., “Method and Rating System for Evaluation of Thermal Protection,” Aerospace Medicine, Vol 40, 1969, pp. 1232-1238. Values not provided are calculated using an equation derived by fitting a least-squares power series to each point of the furnished data. The equation is: Total heat (cal/cm^2) = 1.206 (cal/cm^2-sec) x exposure time (sec)$^{0.288}$.

Table 1							
Exposure Time	**Heat Flux**		**Total Heat**		**Calorimeter Equivalent**		
Seconds	**Cal/cm²s**	**KW/m²**	**Cal/cm²s**	**KW/m²**	**∆T°F**	**∆T°C**	**∆mV**
1	**1.20**	**50**	**1.20**	**50**	**16.0**	**8.9**	**0.46**
2	**0.73**	**31**	**1.46**	**61**	**19.5**	**10.8**	**0.57**
3	**0.55**	**23**	**1.65**	**69**	**22.0**	**12.2**	**0.63**
4	**0.45**	**19**	**1.80**	**75**	**24.0**	**13.3**	**0.69**
5	**0.38**	**16**	**1.90**	**80**	**25.3**	**14.1**	**0.72**
6	**0.34**	**14**	**2.04**	**85**	**27.2**	**15.1**	**0.78**
7	**0.30**	**13**	**2.10**	**88**	**28.0**	**15.5**	**0.80**
8	**0.274**	**11.5**	**2.19**	**92**	**29.2**	**16.2**	**0.83**
9	**0.252**	**10.6**	**2.27**	**95**	**30.2**	**16.8**	**0.86**
10	**0.233**	**9.8**	**2.33**	**98**	**31.1**	**17.3**	**0.89**
11	**0.219**	**9.2**	**2.41**	**101**	**32.1**	**17.8**	**0.92**
12	**0.205**	**8.6**	**2.46**	**103**	**32.8**	**18.2**	**0.94**
13	**0.194**	**8.1**	**2.52**	**106**	**33.6**	**18.7**	**0.97**
14	**0.184**	**7.7**	**2.58**	**108**	**34.3**	**19.1**	**0.99**
15	**0.177**	**7.4**	**2.66**	**111**	**35.4**	**19.7**	**1.02**
16	**0.168**	**7.0**	**2.69**	**113**	**35.8**	**19.8**	**1.03**
17	**0.160**	**6.7**	**2.72**	**114**	**36.3**	**20.2**	**1.04**
18	**0.154**	**6.4**	**2.77**	**116**	**37.0**	**20.6**	**1.06**
19	**0.148**	**6.2**	**2.81**	**118**	**37.5**	**20.8**	**1.08**
20	**0.143**	**6.0**	**2.86**	**120**	**38.1**	**21.2**	**1.10**
25	**0.122**	**5.1**	**3.05**	**128**	**40.7**	**22.6**	**1.17**
30	**0.107**	**4.5**	**3.21**	**134**	**42.8**	**23.8**	**1.23**

3.1.6 INTERPRET RESULTS

A. The Data Acquisition and Operating System will then determine the value of the end point from calculations representing time to thermal energy curves. The thermal end point is the calculated intersection of the calorimeter response curve and a curve representing the values in Table 1.

B. The exposure energy to the thermal end point is defined as the TPP rating and is calculated as follows:

TPP Rating (cal/cm^2) = Exposure heat flux (cal/cm^2-sec) x exposure time (sec)

TPP Rating (W-sec/cm^2) = Exposure heat flux (W/cm^2) x exposure time (sec)

3.2 FLAMMABILITY TEST

This test will determine the resistance of cloth to flame and glow propagation and tendency to char. This method is similar, but not identical to, ASTM D6413, Standard Test Method for Flame Resistance of Textiles (Vertical Test).

3.2.1 SAMPLES

A 61 x 30 cm (24 x 12 in) sample of material not previously laundered, shall be supplied from which several test samples are cut. The material shall be tagged to show in which product model it is to be used. Prepare five rectangular samples, 7.0 x 30.5 cm with a tolerance of ±0.3 cm for both dimensions (2.75 by 12.00 $\pm$0.13 in), with the long dimension parallel to either the warp or filling direction of the cloth.

3.2.2 APPARATUS

A. A cabinet and accessories, fabricated in accordance with the requirements specified in ASTM D6413[6]. Galvanized sheet metal or other suitable metal is used. The entire inside back wall of the cabinet is painted black to facilitate the viewing of the test sample and pilot flame.

B. A burner equipped with a variable orifice to adjust the flame height, a barrel having a 0.95 cm (0.375 in) inside diameter and a pilot light.

1. The burner may be constructed by combining a 0.95 cm (0.375 in) inside diameter barrel, 7.62 $\pm$0.64 cm (3.00 $\pm$0.25 in) long from a fixed orifice burner, with a base from a variable orifice burner.

[6] The test cabinet is available from U.S. Testing Company, 1941 Park Avenue, Hoboken, NJ 07030 or The Govmark Organization, Inc., P.O. Box 807, Bellmore, NY 11710.

2. The pilot light tube has a diameter of approximately 0.16 cm (0.063 in) and is spaced 0.32 cm (0.125 in) away from the burner edge with a pilot flame 0.32 cm (0.125 in) long.

3. The necessary gas connections and the applicable plumbing is as specified except that a solenoid valve may be used in lieu of the stopcock valve to which the burner is attached. The stopcock valve or solenoid valve, whichever is used, is capable of being fully opened or fully closed in 0.1 second.

4. On the side of the barrel of the burner, opposite the pilot light, there is a metal rod of approximately 0.32 cm (0.125 in) diameter spaced 1.27 cm (0.5 in) from the barrel and extending above the burner. The rod has two 0.79 cm (0.313 in) prongs marking the distances of 1.91 cm (0.75 in) and 3.81 cm (1.5 in) above the top of the burner.

5. The burner is fixed in a position so that the center of the barrel of the burner is directly below the center of the sample.

C. A gas regulator valve system with a delivery rate designed to furnish gas to the burner under a pressure of 17.2 ±1.7 kilopascals {kPa} (2.5 ±0.25 psi) at the burner inlet. The manufacturer's recommended delivery rate for the valve system shall be available at the required pressure[7].

D. A gas mixture, methane, 99% pure (as specified in ASTM D6413).

E. Metal hooks and weights to produce a series of total loads to determine length of char. The metal hooks consist of No. 19 gauge steel wire or equivalent and are made from 7.62 cm (3 in) lengths of the wire and bent 1.27 cm (0.5 in) from one end to a 45° hook. One end of the hook is fastened around the neck of the weight to be used.

F. A stop watch or other time measuring device to determine the burning time within 0.2 second.

G. A measuring scale or metal tape graduated in increments of at least 0.1 cm (0.039 in) to measure the length of char.

[7] The gas regulator and gas mixture are available from Matheson Gas Products, P.O. Box 85, East Rutherford, NJ 07073 or Air Products and Chemicals, Inc., P.O. Box 538, Allentown, PA 18105.

3.2.3 CALIBRATION

The pilot flame is adjusted to approximately 0.32 cm (0.125 in) in height measured from its lowest point to the tip. The burner flame is adjusted by means of the needle valve in the base of the burner to give a flame height of 3.81 cm (1.5 in) with the stopcock fully open and the air supply to the burner shut off and taped. The flame height is obtained by adjusting the valve so that the uppermost portion (tip) of the flame is level with the tip of the metal prong specified for adjustment of flame height. It is an important aspect of the evaluation that the flame height be adjusted with the tip of the flame level with the tip of the metal prong. Fully close the stopcock in preparation for inserting of the sample in the apparatus.

3.2.4 PROCEDURE

For each sample, the fabric is evaluated for after-flame time, after-glow time and char length.

A. The apparatus is set up in a draft free area.

B. All samples to be tested are at moisture equilibrium under standard atmospheric conditions. The conditioning atmosphere is 21 $\pm 1^{o}$C (70 $\pm 2^{o}$F) with a relative humidity of 65 $\pm$5%. If the test cabinet is not subject to this environment, then the samples are placed in a controlled chamber for one hour under the specified conditions. Each sample to be tested is exposed to the test flame within 20 seconds after removal from the standard atmosphere.

C. The sample in its holder is suspended vertically in the cabinet in such a manner that the entire length of the sample is exposed and the lower end is 1.91 cm (0.75 in) above the top of the gas burner.

D. After inserting the sample, the stopcock is opened and the burner flame is applied vertically at the middle of the lower edge of the sample for 12 seconds and the burner turned off. The cabinet door remains shut during testing.

E. The after-flame time is the time the sample continues to flame after the burner flame is shut off. It is measured to the nearest 0.2 second.

F. The after-glow time is the time the sample continues to glow after it has ceased to flame. It is also measured to the nearest 0.2 second. If the sample glows more that 30 seconds, the sample holder containing the sample is removed from the test cabinet without any unnecessary rate of movement of the sample which will fan the glow, and suspended in a draft free area in the same vertical position as in the test cabinet. When more than one glowing sample is suspended outside the test apparatus, the samples are spaced at least 15.2 cm (6 in) apart. The samples shall remain stationary until all glowing has ceased.

G. After each sample is removed, the test cabinet is cleared of fumes and smoke prior to testing the next sample.

H. After both flaming and glowing have ceased, the char length is measured. The char length is the distance from the end of the sample, which was exposed to the flame, to the end of a tear (made lengthwise) in the sample through the center of the charred area as follows. The sample is folded lengthwise and creased by hand along a line through the highest peak of the charred area. The hook is inserted in the sample, or a hole, 0.64 cm (0.25 in) diameter or less, is punched out for the hook at one side of the charred area 0.64 cm (0.25 in) from the adjacent outside edge and 0.64 cm (0.25 in) in from the lower end. A weight of sufficient size such that the weight and hook together equal the total tearing load required in Table 2 is attached to the hook.

Table 2

Specified weight of cloth before any fire retardant treatment or coating		Total tearing weight for determining char length	
Grams/meter²	Ounces/yard²	Grams	Pounds
68 to 204	2.0 to 6.0	114	0.25
>204 to 510	>6.0 to 15.0	227	0.50
>510 to 781	>15.0 to 23.0	341	0.75
>781	>23	455	1.00

I. A tearing force is applied gently to the sample by grasping the corner of the cloth at the opposite edge of the char from the load and raising the sample and weight clear of the supporting surface. Then lower the assembly and remove the hook and weight. The end of the tear in the sample is marked off on the edge and the char length measurement is made, to the nearest 0.32 cm (0.125 in), along the undamaged edge.

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