NATIONAL BUREAU OF STANDARDS REPORT

7325

SURFACE FLAMMABILITY OF CELLULAR PLASTIC FOAMS

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U. S. DEPARTMENT OF COMMERCE

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ABSTRACT

Flame spread indices for twelve cellular plastic foams, including fire-retardant treated and untreated polyurethane and polystyrene foams, are reported. There appear to be no serious drawbacks to the use of the radiant panel test method for evaluating surface flammability of cellular plastic foams. Discussion is included on the use of slightly modified data techniques in particular applications.

1. INTRODUCTION

The "radiant panel" flame spread test method has been used to measure comparative surface flammability of a wide variety of building finish materials (1, 2, 3). Requiring a relatively small specimen and only a modest amount of equipment and space, it has been found possible to obtain meaningful flame spread indices ranging from about 1 to over 1000.

An investigation of the applicability of the method for measuring the flammability of cellular plastic foams was undertaken in conjunction with a round robin test series sponsored by the Flammability Committee of the Cellular Plastics Division of the Society of the Plastics Industry, Inc. For these tests, it was felt that no major changes should be effected in the standard test requirements (4), such as specimen exposure to different irradiation levels, but that modifications might be made in the techniques for obtaining more meaningful data and in their interpretation. A particular goal of this study was to examine the extent to which the test method could be used to differentiate between conventional and fire-retardant treated foams.

2. TEST METHOD

The flame spread index as originally devised provides a means for classifying materials according to their relative surface flammability properties. This numerical classification appears to be generally consistent with information available on the behavior of such materials during fires. The index is based upon measurements of

(a) the times at which surface flaming reaches equally-spaced distances along the specimen length, and

(b) the maximum temperature rise in the stack which receives the hot combustion products.

In some instances, the standard method of calculating flame spread index must necessarily be based upon limited test information and interpretation of the data and the test observations may be difficult. Upon careful analysis and interpretation of specific applications, therefore, the computations are sometimes modified to make the flame spread index more meaningful.

For cellular plastics as well as other materials, particularly those with flame-retardant treated surfaces, a significant delay may occur in the start of surface flaming, followed by a very rapid flame progression which may envelop one or more markings before a sustained flame establishes itself. In many cases, the progression of the sustained flame front after this has occurred, will be regular and times for the flame front to pass succeeding 3-in. marks may be readily measured. However, in some cases, the sustained flame front progression will be limited, providing no additional time-distance data. If the rapid flaming envelops two or more markings, the time interval(s) involved, even if measurable, would result in a disproportionately high number being used in summing up the components of the flame spread factor. In order to obtain more representative factors in such situations, the following procedures have been adopted:

(1) Measure or estimate the distance D, in inches, and the corresponding time t, in minutes, when the flaming establishes very rapidly past the 3-in. mark or past the 3- and 6-in. marks or past the 3-, 6- and 9-in. marks.

(2a) In the case where succeeding time-distance data are available, plot D on rectangular coordinates as a function of t on logarithmic coordinates.

or (2b) In the case where no succeeding time-distance data are available, determine the distance D_o corresponding to a time of 1.0 minutes from the following equation, $D = D_o + 6.5 \log_e t$.

(3a) Extrapolate the curve (or line) back to obtain estimated times for the 3-in. or 3- and 6-in. markings.

or (3b) Using the value of D_o and the same equation from (2b), calculate the corresponding times for distances of 3-, 3- and 6-, or 3-, 6- and 9-inches.

(4) Use these extrapolated or calculated times and corresponding distances to calculate the flame spread index.

For some materials (including some low-density cellular plastics), the flaming is rapid and limited to the very early part of the test exposure. Due to the response time of the stack thermocouples, a slight temperature rise may go undetected. In such cases, the value of $\Delta\theta$ for the test specimen should be determined with respect to the stack thermocouple temperature for the asbestos-cement board specimen at a time corresponding to that at which the maximum stack thermocouple temperature was observed for the test specimen. This response time correction is intended to be applied only in those cases where the temperature rise is not large. Therefore, its use is arbitrarily restricted to instances where the maximum stack thermocouple temperature for the specimen does not exceed the mean stack thermocouple temperature during test of an incombustible asbestos-cement board specimen by more than 10 degrees F. Continuous recording of the stack thermocouple temperature is required in such cases.

3. MATERIALS and TEST PROCEDURE

A total of twelve cellular plastic foam materials were made available by manufacturers and are listed in Table 1. Included was a series of four foams of the same composition in which the blowing agent was varied in order to vary the bulk density. With the exception of the latter group, the materials were designated as 2 lb/ft^3 foams; the measured densities as received are also listed in Table 1.

The standard test method (4) with the modifications described, was used for these tests, except that pre-drying of the specimens was omitted. With one exception, four replicate tests were performed on each material. A continuous record of the stack thermocouple temperature was obtained by use of a pen-type recording potentiometer. The chart speed was 3 in./min and, using a 5 millivolt "bucking" signal, the temperature scale could be read to less than 1 degree C per mm of chart. An event marker pen on the same recorder was actuated by a hand-operated microswitch to measure the time for flames to advance past the 3-in. markings. Measurements were also made of the deposit of smoke on a glass fiber filter paper placed in the stack above the burning specimens.

4. RESULTS and DISCUSSION

Typical distance-time data for the 2 lb/ft^3 foams are shown in Figure 1 which also includes data for balsa wood for comparison. Cellulosic materials previously tested (1) generally plot as straight lines on semi-logarithmic coordinates and a similar pattern is observed with many cellular plastics. However, a distinctive upward curvature is observed for materials 1 and 5 corresponding to an unusual type of flame propagation. The shape of the curve for material 9 appeared to be due to rapid enhancement of flaming following the separation of a protective char coat during the test.

The temperature rise modification in computation of the flame spread index suggested in Section 2 was necessary in only a few instances and is noted in Table 2 which summarizes the test results. The extrapolation technique was used only to fill in an occasional unrecorded distance-time point and did not materially affect the computations. From Table 2, it is seen that the flame spread index for the 2 lb/ft^3 fire-retardant treated polyurethane foams ranged from 10 to 1440 whereas, the two untreated foams (Nos. 2 and 5) were rated at 1490 and 2220, respectively. Two direct comparisons showing the marked improvement of fire-retardant over untreated polyurethane and polystyrene foams are available, i.e., 2 versus 3, and 7 versus 8, respectively.

The opportunity for exploring the effect on the flame spread index of an appreciable range of material bulk density appeared to be more convenient with plastic foams than with natural or processed cellulosic materials. Accordingly, one cellular plastic foam was made available in four densities corresponding to an eight-fold density change. Unfortunately, this foam was a flame-retardant type, and, upon separation of its protective char coat during test, a rapid enhancement of flaming for all specimen densities resulted, severly hampering measurement of flammability differences due to density. Although density appears to have an appreciable effect, it is evident that an untreated foam, or a flame-retardant treated foam with normal surface flammability behavior would be more suited for evaluating density effects.

With few exceptions, the quantity of smoke deposited by the cellular plastic foams tested was significantly greater than that from typical cellulosic materials.

Limited comparisons (not shown) were made with preliminary data from other test methods used in the round robin series. For those tests which provide a numerical indication of the burning rate (ASTM D1692, ASTM D757, and Nat. Aniline CF-TM-11), the range of values for eight materials was considerably less than the corresponding range in the flame spread indices. In some instances, the burning rate values for fire-retardant and untreated foams were not significantly different or were in reverse of the expected order.

Table 1. Cellular Plastic Foam Materials

NBS Symbol	Material	Measured Density pcf	Add'tl Information (Supplied by Mfr.)
1	Flexible polyester urethane, fire-retardant	1.87	
2	Flexible polyether urethane	1.84	
3	Flexible polyether urethane fire-retardant	1.96	2, 3-dibromopropyl phosphate retardant
4	Rigid polyester urethane, fire-retardant	2.44	
5	Rigid polyether urethane	1.71	Trichlorofluoromethane blowing agent
6	Rigid polyether urethane fire-retardant	1.81	
7	Polystyrene	1.77	White
8	Polystyrene, flame-retardant	2.04	Indigo
9	Rigid polyurethane, flame-retardant	1.90	Trichloro-monofluoromethane blowing agent
10	" " " "	3.79	" "
11	" " " "	8.85	" "
12	" " " "	15.6	" "

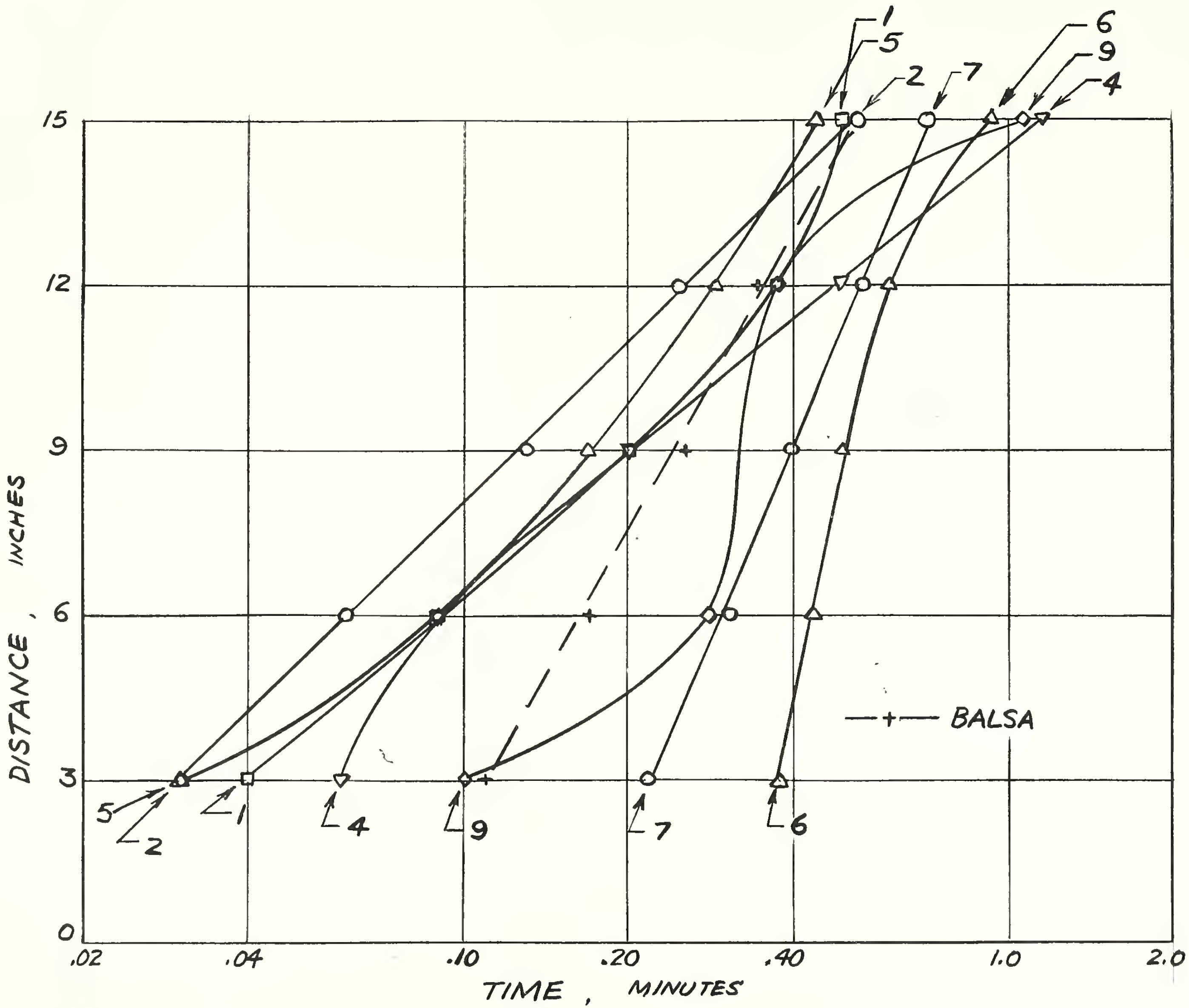
Table 2. Surface Flammability Test Results

Mean values based on four replicate tests

Symbol	Flame Spread Index I_s Mean	Flame Spread Index I_s Coeff. of Var. %	Heat Evolution Factor Q	Smoke Deposit mg.	Remarks
1	1000	9.7	15.4	1.0	No melting or dripping
2	1490	13.4	15.3	1.0	Rapid melting and dripping
3	10	51.0	4.2	3.1	Rapid melting and dripping. Some flaming to 3 in.
4	1440	28.9	26.3	7.4	No melting or dripping
5	2220	13.0	29.1	3.5	No melting or dripping
6	880	39.4	15.5	6.9	Intumescence. No melting or dripping
7	114*	14.5	3.1	1.7	Melting and flaming drips
8	13*	100.0	1.4	0.5	Some flaming to 3 and 6 in.
9	1090	12.8	11.9	11.3	Separation of protective char coat during test results in very rapid flaming (9–12)
10	3200	14.8	34.4	12.8	
11	2590	83.0	36.0	20.4	
12	1310	24.6	38.3	33.1	

*Based upon stack thermocouple temperature for asbestos-cement board at time of maximum. See discussion, Section 2.

FIG. 1 TYPICAL SURFACE FLAMMABILITY DATA



U. S. DEPARTMENT OF COMMERCE
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THE NATIONAL BUREAU OF STANDARDS

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Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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