Flammability tests of loose-fill insulation: cellulose and polystyrene

Rose, A.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338099
Internal Report (National Research Council of Canada. Division of Building Research), 1977-06-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

DBR INTERNAL REPORT NO. 440

FLAMMABILITY TESTS OF LOOSE-FILL INSULATION (CELLULOSE AND POLYSTYRENE)

by A. Rose

Checked by: G.W.S. Approved by: L.W.G. Date: June 1977

Prepared for: C.G.S.B. Committee on Loose-Fill Insulation

In ASTM E84 and standards based upon it which use the so-called 25-ft or Steiner tunnel, the mounting method for testing loose-fill insulation (mineral or cellulosic) is covered in an Appendix (A1.6 in ASTM E84-70, X1.6 in ASTM E84-76a, and A1.10 in ULC S102-1975). The insulation material is packed at the density specified by the manufacturer to a 2-in. depth on 14-mesh galvanized insect screening stretched on three frames of 3- by 2- by 3/16-in. angle iron, 99 1/2 in. long by 20 in. wide. The frames are placed on the shoulders of the tunnel and the material exposed to the burner flame through the screening.

To arrive at the flame-spread classifications (FSC) listed in its "Building Materials Directory,"[1] Underwriters' Laboratories Incorporated (ULI) multiplies the observed flame spread by 5.128 and an empirical factor of 1.4 for observed flame spreads up to 8 ft to correct for the thermal effect of the screen. The 1977 edition of the Directory lists 33 treated cellulosic materials, tested in some cases at two or more densities. The "corrected" FSC values so listed range from 15 to 60. All except two fall in the 15 to 40 range, at 2.0 to 3.0 lb/cu ft density.

Some early commercial tests of fire-retardant-treated cellulosic loose-fill material at DBR had cast some doubt on the sensitivity of the test to retardant level when using the prescribed screens. In conversations with W. Kleinfelder of ULI, FSC values of 200 to 300 for untreated newsprint-based loose-fill were quoted, but no samples of such materials were available. Two untreated samples from Canadian sources gave "corrected" ratings of 42 and 50, respectively, on the screens. In later tests on the floor by the method now proposed the ratings were 315 and 550, respectively. It was suggested that the screening used at ULI and DBR might have differed, but a sample obtained from ULI proved to be identical with that used here.

FLOOR MOUNTING METHOD: EQUIPMENT & TECHNIQUE

The existing test method for soft floor coverings, ULC S102.2-1975,[2] has been extended to the testing of thermoplastic materials, such as acrylic lighting diffusers. It has also been proposed as the test method for polycarbonate glazing and polystyrene foams. A sheet of No. 14 asbestos paper is placed on the preheated floor, the outlet elbows of the Tee burner are turned 45 deg forward and downward, and the 6 turbulence-producing G-26 firebricks are placed in their usual positions, as in the testing of carpets.

The most practical support suggested as a rigid and inexpensive carrier for loose-fill insulation during conditioning and placement on the floor of the furnace was a set of trays fabricated from 1- by 2-in. (diamond pattern) 14-gauge expanded metal mesh. This mesh, available up to 48 by 96 in. in size, was formed into trays 1 in. deep and 17 in. wide. Two were made the maximum possible length (94 in.) and one was 90 in. long. The trays were lined on the bottom and edges with No. 14 asbestos paper.

In a later version, one 94-in. tray was slotted to clear the thermocouple pipe and bring the exposed material closer to the end of the tunnel floor (25 ft total, 19.5 ft net). The fire-end tray projected 4 in. upstream of the Tee burner. In the DBR tunnel it is offset 7 in. downstream from the burner riser pipe through the floor.

PRELIMINARY FLAME-SPREAD TESTS

One untreated control and three treated cellulosic materials were supplied by an Ontario producer for preliminary tests. The retardants were alum, borax and a 75/25 alum/borax mix, respectively, all at a 20 per cent add-on level (20 parts of retardant per 100 parts of fibre), according to the supplier.

In these early tests the insulation was distributed at the rate of 1.2 kg (2.64 lb) per tray to a depth of 1 in., giving a density of approximately 2.9 lb/cu ft.

To minimize the disturbance of the material during handling and positioning in the furnace, an 18-in. width of 1-in. hexagonal mesh fence netting was fastened along one edge of each tray, pulled across the material, and hooked on the projecting points on the opposite edge of the tray. One observer of a typical test remarked that close contact of the fence netting with the insulation near the edges of the tray appeared to be reducing lateral flame spread to some extent. Later work suggested that this was a minor factor; it was found that the fence netting was not essential if proper care was taken in the handling of the trays. No loss of fine material or dust was noted during the tests because of the 240-fpm airflow through the furnace. The netting was therefore omitted during subsequent tests on the floor.

In addition to the four materials already mentioned, a number of blends of the treated and untreated material were prepared to test the sensitivity of the method to changes in retardant content. Subsequent work suggested that the retardants in the three treated samples were not well dispersed in the fibre mass. In addition, at this time, there were difficulties with equipment, particularly the air conditioning of the storage area, hence these preliminary results will not be discussed at length. The untreated (raw pulp) control had a FSC of 315 on the floor and a corrected FSC of 42 on the ceiling at 2-in. depth on the prescribed screens.

The test conditions finally decided upon included adequate conditioning at 37 to 41 per cent R.H., and, on the basis of velocity measurements with the loaded trays in position, shimming up the cover of the furnace 1 in. to maintain the original cross-sectional area in tests on the floor.

SECOND SERIES OF FLAME-SPREAD TESTS

As already mentioned, a review of the preliminary tests suggested that the blending of treated and untreated material was not a satisfactory way to prepare a series of samples of different retardant contents. Furthermore it was realized that, even with the maximum uniformity of composition obtainable by normal mechanical dispersion of the retardants, repeatability of results was likely to be poor because of the erratic and discontinuous type of propagation in samples with FSC values below 125 by the established methods of calculation (ASTM E84-70 or ULC S102.2-1975).

The typical flame propagation for samples in this range of FSC is characterized by very rapid ignition and rapid advance of a moderately continuous flame from the burner to 3 to 4 ft beyond the zero mark of the tunnel, sometimes followed by recession to the zero mark. Further advances are generally erratic, with a tendency for the very feeble detached flame front to skip along high spots in the middle of the sample or to proceed in a narrow continuous band along the walls for limited distances. A vigorous and sustained flame front usually develops only when it approaches the end of the tunnel, whether or not propagation has been essentially continuous or follows a major retreat or even an almost complete self-extinguishment at a point downstream of the zero mark at some time during the 10-min test.

In the light of these observations and experiences, the committee responsible for the preparation of CGSB Standard 51-GP-60P[3] was asked to obtain a graded series of samples with chemical retardant systems that would have a reasonable probability of meeting all other performance requirements for such materials.

Two retardant systems were prepared. Samples with four different levels of retardant in each system were prepared by a three-pass grinding operation in 10-bag lots at approximately 30 lb per bag. These were shipped to the Energy and Services Section of DBR. Ten bags of an untreated control sample (No. 9) were also supplied.

The samples were identified as follows:

System A - Borax (5-Hydrate): Boric Acid, 2:1

Mix #1 - 24 per cent add-on
#2 - 20 per cent add-on
#3 - 12 per cent add-on
#4 - 7 per cent add-on

System B - Borax: Boric Acid: Alum, 2:1:1

Mix #5 - 25 per cent add-on
#6 - 18 per cent add-on
#7 - 11 per cent add-on
#8 - 7 per cent add-on

Mix #9 - untreated control (raw pulp)

All samples were conditioned at 37 to 41 per cent R.H., 70-72 °F before testing. The duration of conditioning is recorded with the results in Table I. All had a minimum of 24 h conditioning on the trays or in shallow boxes in the preliminary rapid survey of single samples of each mix. In subsequent repeat tests the minimum conditioning time was 48 h, as indicated in Table I.

Mixes 1, 2, 3, 4 and 9 were tested on the ceiling in the prescribed manner. The "corrected" FSC values are reported in Table I. In the tests with the materials on the floor (except mixes 1 and 9) the FSC values were calculated by the usual methods of ASTM E84-70 or ULC S102.2-1975 (indicated in the table as "1975") and by the "area" or "GWL" method now prescribed by ASTM E84-76a (indicated by "GWL"). The methods are reproduced in excerpts from the appropriate standard in Appendixes A and B, respectively of this report.

The "GWL" method appears to be more realistic than the "1975" method in the case of the typically erratic and discontinuous propagation observed in some tests with mixes 3, 5, and 6.

In the second test of mix No. 3 and the third test of mix No. 6 the flame fronts advanced smoothly to 14 ft in 2.63 min and 7 ft in 1.60 min, respectively, then self-extinguished. In such cases a third and less widely recognized method of calculation is sometimes used. In this so-called "rate method," FSC = $\frac{28.2\ d\ (ft)}{t\ (min)}$. In the above cases the corresponding values are thus 150 and 123 respectively.

Observation of the char pattern in tests where the flame reached the end of the furnace indicated that the 6 turbulence-inducing bricks were keeping the pattern reasonably well centred but were limiting the involvement of material both upstream and downstream of the bricks for a distance of 12 to 15 in. In some cases these "protected" areas ignited after the initial flame front had advanced almost to the end of the tunnel and then self-extinguished.

In the fifth test on mixes Nos. 3 and 6 and the fourth test on No. 7, all 6 bricks were raised 2 in. above the surface on expanded metal mesh supports. No significant effect on the char pattern, manner of propagation or FSC was noted. A test was carried out on mix No. 7 with the bricks removed. The char pattern was symmetrical and the FSC was very close to the average for the other 5 tests by either of the two recognized methods of calculation.

TESTS ON POLYSTYRENE BEADBOARD AND LOOSE-FILL INSULATION

At an ad hoc meeting of the committees responsible for the development of CGSB 51-GP-27M[4] on shredded polystryene, DBR was requested to investigate the feasibility of a flame-spread test for loose-fill insulation produced by grinding low-density (0.8 to 1.2 lb/cu ft) beadboard waste as a logical extension of the work on cellulosic loose-fill material.

A coarsely-ground sample of loose-fill material and samples of 1- and 2-in. beadboard were obtained from supplier A. The loose-fill material was tested in the lined trays already described. The beadboards were placed on No. 14 asbestos paper and had cutouts in the boards for the 6 firebricks. Approximately 1.0 kg was required to fill the three trays in the test on loose-fill material.

The results were as follows:

	Ignition Time, sec	FSC (ULC S102.2)
Loose-fill (A), 1-in.	30	183
Beadboard (A), 1-in.	33	35
Beadboard (A), 2-in.	48	240

In a second series of tests made three weeks later, the loose-fill sample from supplier A was rechecked. A much finer sample of loose-fill from another source, B, and new samples of 1- and 2-in. beadboards from the original source were also tested.

The results were as follows:

	Ignition Time, sec	FSC (ULC S102.2)
Loose-fill (A), 1-in.	23	300
Loose-fill (B), 1-in.	40	30
Beadboard (A), 1-in.	33	100
Beadboard (A), 2-in.	35	250

The finely-ground sample of loose-fill (B), unlike the coarser material (A), was blown off the first 3 to 4 ft of the tray and piled into a drift about 2 in. deep 3 to 4 ft downstream from the burner. The loose-fill materials, whether coarse or fine, burned vigorously in small clumps without first melting into small pools or even coalescing before ignition. The beadboards, on the other hand, melted into the usual pools on the asbestos paper before ignition.

DISCUSSION

The feasibility and convenience of testing loose-fill cellulosic insulation on the floor are evident. Repeatability (within-lab) is probably adequate for control purposes considering the inherent non-uniformity of such heterogeneous mixes, the difficulty of obtaining representative samples from the production line, and the influence of relative humidity and conditioning time on the more hygroscopic materials in the mixes. Some of the variability recorded in Table I is probably due to differences between lots where two or three bags were sampled for replicate tests.

The selection of a reasonable maximum FSC value calculated by either method should be deferred until the lab-to-lab reproducibility of the test method has been thoroughly examined. The only other tunnel furnace in Canada (ULC) has outside-mounted observation windows. It does not use bricks on the floor in either S102 or S102.2 tests. Some variability between the two tunnels is to be expected.

Untreated ("Regular") polystyrene beadboard is no longer produced in Canada. Whether any large-scale method of test for loose-fill material produced from SE (self-extinguishing) grades is realistic or useful is debatable. The capabilities of the test on the floor (described previously) should not be extended in an effort to examine the influence of particle size (fineness of grind), fire-retardant level or density of packing on the nominal FSC of material from different sources. Certainly the testing of very fine material, such as "B" in the results already quoted, may require the use of fence netting or an even finer screen on top to restrain the material on the first tray in the tunnel.

If the purpose of any test is merely to confirm the adequacy of the level of halogenated retardants present, then the LOI (limiting oxygen index) method, as prescribed in ASTM D2863-70[5] is a much cheaper and more convenient tool than the tunnel furnace test.

REFERENCES

1. Underwriters' Laboratories Incorporated. Building Materials Directory. Part I - Listed Building Materials, January 1977.

2. Underwriters' Laboratories of Canada. Standard Test Method for Fire Hazard Classification of Flooring and Floor Covering Materials. ULC S102.2-1975.

3. Canadian Government Specifications Board. Provisional Standard for Thermal Insulation, Cellulose Fibre, Loose-Fill. 51-GP-60P.

4. Ibid. Provisional Standard for Thermal Insulation, Polystyrene, Loose-Fill. 51-GP-27M.

5. ASTM. Standard Method of Test for Flammability of Plastics Using the Oxygen Index Method. D2863-70.

TABLE I

FLAME SPREAD CLASSIFICATIONS OF LOOSE-FILL INSULATION

Mix	Days Conditioned	Flame-Spread Classification			Remarks
		S102 (corrected)	S102.2		
			1975 Method	GWL Method	
A-1	5	15	40	—	
A-2	1	20	45	39	
A-3-1	1	20	127	145	
3-2	3		70	76	*14 ft, 2.63 min, FSC' = 150
3-3	3		157	181	
3-4	3		116	117	
3-5	3		83	69	Bricks raised
3-6	3		137	146	
A-4-1	1	32	147	162	
4-2	2		183	240	
4-3	2		186	283	
B-5-1	3		71	30	
5-2	2		63	38	
5-3	4		63	39	
B-6-1	1		100	92	
6-2	2		81	28	
6-3	4		35	36	*7 ft, 1.60 min, FSC' = 123
6-4	3		91	53	
6-5	3		95	66	Bricks raised
6-6	3		105	103	
B-7-1	1		170	205	
7-2	4		144	176	
7-3	4		138	157	
7-4	4		152	162	Bricks raised
7-5	3		172	235	
7-6	3		153	192	Bricks removed
B-8-1	1		170	266	
C-9	3	50	550	-	Raw control

$$*FSC' \text{ (rate method)} = \frac{28.2\ d\ (ft)}{t\ (min)}$$

APPENDIX A

EXCERPT FROM ASTM E84-70

"Standard Method of Test for Surface Burning Characteristics of Building Materials"

6. Classification

6.1 The flame spread classification (FSC) shall be determined as follows:

6.1.1 For materials on which the flame spreads 19 1/2 ft (5.94 m);

6.1.1.1 In 5 1/2 min or less, the classification shall be 100 times 5 1/2 min divided by the time in min (t) in which the flame spreads 19 1/2 ft (5.94 m), (FSC = 550/t);

6.1.1.2 In more than 5 1/2 min but not more than 10 min, the classification shall be 100 times 5 1/2 min divided by the time in min (t) that the flame spreads 19 1/2 ft (5.94 m), plus 1/2 the difference of 100 minus this result, (FSC = 50 + 275/t);

6.1.2 For materials on which the flame spreads less than 19 1/2 ft (5.94 m), and then ceases to continue or recedes in a 10 min test period;

6.1.2.1 When the extreme flame spread distance (d) is more than 13 1/2 ft (4.11 m) and less than 19 1/2 ft (5.94 m), the classification shall be 100 times 5 1/2 min times the distance (d) divided by 19 1/2 ft (5.94 m) times 10 min, plus 1/2 the difference of 100 minus this result, (FSC = 50 + 1.41d) (FSC (metric) = 50 + 4.62d);

6.1.2.2 When the extreme flame spread distance (d) is 13 1/2 ft (4.11 m) or less, the classification shall be 100 times the distance (d) divided by 19 1/2 ft (5.94 m), (FSC = 5.128d) (FSC (metric) = 16.84d).

APPENDIX B

EXCERPT FROM ANSI/ASTM E84-76a

"Standard Test Method for Surface Burning Characteristics of Building Materials"

7. Classification

7.1 The flame spread classification (FSC) shall be determined as follows:

7.1.1 The total area (A_T) under the flame spread time-distance curve shall be determined by ignoring any flame front recession. For example, in Fig. 8 the flame spreads 10 ft (3.05 m) in 2 1/2 min and then recedes. The area is calculated as if the flame had spread to 10 ft in 2 1/2 min and then remained at 10 ft for the remainder of the test or until the flame front again passed 10 ft. This is shown by the dashed line in Fig. 8. The area (A_T) used for calculating the flame spread classification is the sum of areas A_1 and A_2 in Fig. 8.

7.1.2 If this total area (A_T) is less than or equal to 97.5 min·ft, the flame spread classification shall be 0.564 times the total area (FSC = 0.564 A_T).

7.1.3 If the total area (A_T) is greater than 97.5 min·ft, the flame spread classification shall be 5363, divided by the difference of 195 minus the total area (A_T) (FSC = 5363/(195-A_T)).

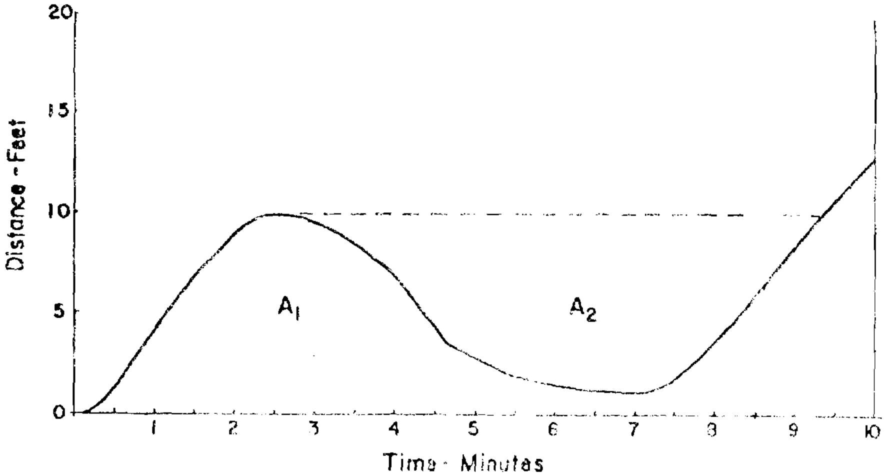

FIG. 8 Example of Time-Distance Curve with Flame Front Recession.