Inter-laboratory study for the IMO surface flammability test method: results of tests conducted at the IRC/NRC Canada

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INTER-LABORATORY STUDY FOR THE IMO SURFACE FLAMMABILITY TEST METHOD: RESULTS OF TESTS CONDUCTED AT THE IRC/NRC CANADA

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INTRODUCTION

The Robertson type flame spread apparatus was commissioned at the Fire Research Section, Institute for Research in Construction, National Research Council of Canada (FRS, IRC, NRCC) in 1983. It has been used in the International Maritime Organization (IMO) interlaboratory surface flammability tests. Materials received from the United States, Norway, and Japan were tested according to IMO Resolution A.516 (13). Information on the apparatus, its calibration, test method, list of materials tested, and results and remarks on flame spread and heat release are presented in this report.

APPARATUS

The description of the apparatus is presented in Ref. (1). Certain features have been added to it to facilitate its safe operation. For example, solenoid valves have been installed on both the main gas line that feeds the radiant panel and the acetylene line that feeds the pilot burners. These valves will shut off the gas supply if either the supply air pressure drops below a preset level, or if the temperature at the rear of the radiant panel exceeds a preset temperature limit. This feature eliminates the chance of an explosion caused by flashback, as well as freeing the operator from monitoring gauges during a test. A video camera was also mounted near the apparatus to allow test observations to be remotely monitored and recorded for later analysis.

CALIBRATION

Calibration procedures are necessary to achieve the proper operating conditions. The incident heat flux, heat release and pilot burners have been calibrated according to the IMO Resolution A.516 (13).

In calibrating the incident heat flux, two steps were taken. The first was the mechanical alignment of the sample holder guide rails and the radiant panel to achieve the correct relative spacing and angle between them. The second step was the thermal adjustment of the radiant panel. The heat flux distribution was measured with the aid of two water cooled flux meters mounted in a marinite dummy specimen at 50 mm (Gardon type/6A-10-20 model) and 350 mm (Thermopile/64-2-10 model) from the hot end of the radiant panel. The required heat flux of 50.8 kW/m^2 and 23.9 kW/m^2 at 50 mm and 350 mm points respectively was achieved by slight adjustment of the sample holder relative to the radiant panel. The heat flux is then measured at every 50 mm mark along the specimen length. The calibration results for the heat flux distribution are presented in Table (1). The heat flux distributions for NRCC and the IMO Resolution A.516 (13) are shown in Figure (1).

The calibration of stack heat release is straightforward. The calibration results are presented in Table (2) and are also shown in Figure (2).

Other steps taken during the calibration procedure included setting the correct draw on the fume hood exhaust system and measuring drafts around the apparatus during operation.

MATERIALS

Fifteen different specimens, three of each material, as shown in Table (3), were received and tested.

TEST METHOD

The tests were conducted in accordance with the IMO Resolution A.516 (13). A test begins with lighting the radiant panel and a non-contacting pilot and allowing the system to attain thermal equilibrium. This takes approximately 20 minutes. During this time the operating level is monitored by a total radiation pyrometer. A specimen consisting of a non-combustible material remains mounted in the sample position during this warmup period.

A conditioned test specimen, at 50% relative humidity and 23°C, is mounted in a specimen holder away from the heat source. The test specimen's edges and back are wrapped in aluminum foil and the specimen is backed by two 12 mm thick sheets of non-combustible material.

After thermal equilibrium has been reached and the video camera is adjusted to view the test specimen, the dummy specimen is removed very quickly and the test specimen is inserted. All test observations are recorded.

Heat release data are recorded using a data acquisition system.

The test is terminated three minutes after all flaming from the specimen has ceased or, if the specimen fails to ignite, after ten minutes exposure.

Three specimens of each material are tested. In the event that the first two specimens fail to ignite after a ten minute exposure, the third specimen is tested with the

impinging pilot. If this specimen ignites, two additional tests will be run with the use of pilot flame.

RESULTS AND REMARKS

Hardboard (Norway)

The specimens first charred and then ignited. The flame front advanced progressively to the end of the specimen. Debris fell from the specimen during the test at 415 s, 380 s, and 300 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (4) and the heat release measurements are shown in Figure (3).

Hardboard (Japan)

The specimens charred and ignited and the flame front spread to the full length of the specimens in a manner similar to Norway's hardboard material. The test results are presented in Table (5) and the heat release measurements are shown in Figure (4).

Hardboard (U.S.A.)

The specimens charred and ignited and the flame front spread to the full length of the specimens in a manner similar to Norway's and Japan's hardboard materials. The test results are presented in Table (6) and the heat release measurements are shown in Figure (5).

Wool Carpet - B2 (Japan)

A large area between the marks 0 and 150 mm charred immediately when the specimens were inserted and then the specimen quickly ignited. The specimens bubbled up in advance of the flame front. The charred surface sagged down onto the viewing rakes. Thick black smoke was produced during the tests. The flame front extinguished at 430 mm and 91 s, 355 mm and 82 s, and 355 mm and 63 s for Specimens 1, 2 and 3, respectively. The test results are presented in Table (7) and the heat release measurements are shown in Figure (6).

Wool Carpet - Low Pile (Japan)

The behaviour of the ignited specimens were similar to Japan's Wool Carpet-B2 specimen mentioned above. The flame front extinguished at 430 mm and 91 s, 355 mm and 82 s, and 355 mm and 63 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (8) and the heat release measurements are shown in Figure (7).

Wool Carpet - Low Pile (U.S.A.)

The specimen ignited quickly with rapid flame front advancement. An area of char preceded the flame front. The flame front extinguished at 400 mm and 60 s, 400 mm and 53 s, and 420 mm and 71 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (9) and the heat release measurements are shown in Figure (8).

Acrylic Carpet (U.S.A.)

The specimen burned steadily after a quick ignition. It was noticed that the flame extended beyond the rear of the stack and some of the heat release was lost toward the rear. Consequently, the heat release measurements are not accurate. The flame front extinguished at 685 mm and 277 s, 650 mm and 203 s, and 650 mm and 188 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (10) and the heat release measurements are shown in Figure (9).

Acrylic Carpet (Japan)

The specimens ignited quickly and the flame front advanced steadily. The flame front extinguished at 650 mm and 545 s, 660 mm and 760 s, and 630 mm and 661 s for Specimens 1, 2 and 3 respectively. Also, debris fell at 185 s and 160 s for Specimens 1 and 2 respectively. The test results are presented in Table (11) and the heat release measurements are shown in Figure (10).

Fiberboard - Unpainted Surface (U.S.A.)

The specimens charred and ignited quickly and the flame front spread steadily to the full length. Flaming continued behind the flame front. The test results are presented in Table (12) and the heat release measurements are shown in Figure (11).

Fiberboard - Painted Surface (U.S.A.)

The specimens ignited and the flame front spread steadily. The flame front extinguished at 520 mm and 413 s, 555 mm and 363 s, and 498 mm and 330 s for

Specimens 1, 2 and 3 respectively. The specimens continued to smoulder afterwards. The test results are shown in Table (13) and the heat release measurements are shown in Figure (12).

Low Density Wood Fiberboard - L8 (Japan)

The specimens ignited quickly between the marks 0 and 150 mm, and then the flame front moved steadily. The flame front stopped at 725 mm and 469 s, 640 mm and 232 s, and 710 mm and 304 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (14).

Lauan Wood Plate (Japan)

The specimens burned steadily and produced a residue which adhered to the top of the specimen holder and then burned. Debris fell from the specimens near the end of the test. The flame front stopped at 475 mm and 199 s, 570 mm and 596 s, 540 mm and 492 s for Specimens 1, 2 and 3 respectively. The test results are presented in Table (15) and the heat release measurements are shown in Figure (13).

Melamine Laminate - E15 (Japan)

The surface delaminated in the high radiation area. Visible flame was not observed but an area of char advanced. The specimen swelled towards the heat source. The test results are presented in Table (16) and the heat release measurements are shown in Figure (14).

Melamine Phenol Surface Finish (Japan)

The surface delaminated in the high radiation area. A small flame was visible when a gas bubble which formed between the specimen and backing plate exploded, but no flame spread was noticed. The test results are presented in Table (17) and the heat release measurements are shown in Figure (15).

PVC Flooring (Japan)

A large area between the 0 and 150 mm marks ignited. The specimen bubbled up in advance of the flame front. The charred surface sagged onto the viewing rakes. Thick smoke was produced during the test. The flame front stopped at 575 mm and 392 s, and 570 mm and 407 s for Specimens 1 and 2 whereas Specimen 3 did not ignite but charred. The test results are presented in Table (18) and the heat release measurements are shown in Figure (16).

ACKNOWLEDGEMENT

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REFERENCES

1. IMO Resolution A.516 (13), Recommendation on Fire Test Procedures for Surface Flammability of Bulkhead and Deck Finish Materials (1983).

Heat Flux Meter used: Medtherm

Type: 70 kW/m^2 @ 50 mm and 30 kW/m^2 @ 350 mm

Diameter of the Target Receiving Radiation: 9.7 mm

Heat Flux Distribution along the centre of the exposed surface of the specimen:

Distance from the exposed end of the specimen (mm)	**Incident Heat Flux (kW/m^2)**
0	
50	50.8
100	49.5
150	45.5
200	42.5
250	36.1
300	29.0
350	23.9
400	18.3
450	13.8
500	10.0
550	7.4
600	5.4
650	4.0
700	3.1
750	2.4

Table (1) IMO Surface Flammability Test
Incident Heat Flux Distribution on the Specimen

Fuel Gas Flow (L/min)	Input Energy to the Stack (kW)	Output Signal of the Stack Thermocouple Circuit (mV)	
		Near the Hot End	Near the Cold End
2.0	1.33	0.51	0.45
5.0	3.32	1.80	1.55
8.0	5.30	3.15	2.85
11.0	7.29	4.40	3.84
14.0	9.28	5.58	5.00
17.0	11.27	6.84	5.60

Table (2) IMO Surface Flammability Test
Heat Release Calibration

Material	Thickness (mm)	Density (kg/m^3)* (kg/m^2)**	Circulated by
1. Hardboard	6	900*	Norway
2. Hardboard	5	1100*	Japan
3. Hardboard	3.4	959*	U.S.A.
4. Wool Carpet-B2	10	2.05**	Japan
5. Wool Carpet-Low Pile	9	254*	Japan
6. Wool Carpet-Low Pile	7.8	305*	U.S.A.
7. Acrylic Carpet	14	191*	U.S.A.
8. Acrylic Carpet	8	1.8**	Japan
9. Fiber Board-unpainted surface	11	305*	U.S.A.
10. Fiber Board-painted surface	11.3	292*	U.S.A.
11. Low density wood fiber board-L8	12	260*	Japan
12. Lauan Wood Plate	10.2	544*	Japan
13. Melamine Laminate-E15	1.2	1350*	Japan
14. Melamine Phenol surface finish	1.2	1360*	Japan
15. PVC Flooring	2	1551*	Japan

Table (3) Materials Tested

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Hardboard	Norway	May 29, 1985	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	34.0		35.7		29.0		32.9		3.48	
	50	35.7	1.81	37.9	1.92	34.3	1.74	36.0	1.82	1.81	0.09
	100	35.7	1.74	37.9	1.85	34.3	1.67	36.0	1.75	1.81	0.09
	150	38.2	1.74	38.8	1.77	38.4	1.75	38.5	1.75	0.31	0.02
	200	42.9	1.79	40.3	1.68	41.8	2.16	45.0	1.87	4.92	0.25
	250	58.3	2.07	52.5	1.87	63.0	2.24	58.0	2.06	5.26	0.18
	300	77.0	2.23	69.0	2.00	72.0	2.09	72.7	2.10	4.04	0.11
	350	115.0	2.75	103.0	2.46	102.0	2.44	106.6	2.55	7.23	0.17
	400	174.0	3.15	180.0	3.26	149.0	2.70	167.6	3.04	16.44	0.29
	450	258.0	3.51	253.0	3.44	223.0	3.03	244.6	3.33	18.92	0.25
	500	360.0	3.60	373.0	3.73	345.0	3.45	359.3	3.59	14.01	0.14
	550	516.0	3.77	505.0	3.69	468.0	3.42	496.3	3.63	25.14	0.18
	600			559.0	2.91	643.0	3.34	601.0	3.12	59.39	0.30
	650	928.0	3.71	925.0	3.70	818.0	3.27	890.0	3.56	62.55	0.25
	700	1165.0	3.61	1170.0	3.62	1058.0	3.28	1131.0	3.50	63.27	0.19
	750	1473.0	3.54	1454.0	3.49			1463.0	3.51	13.43	0.03
	Heat for Sustained Burning (MJ/m^2)	2.95		2.89		2.76		2.86		0.10	
	Maximum Flame Spread Distance (mm)	755.0		750.0		728.0		744.4		14.4	
	Critical Flux at Extinguishment (kW/m^2)	2.5		2.5		2.8		2.6		0.17	

Table (4) Hardboard (Norway)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
(5 mm) Hardboard	Japan	April 11, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
	at ignition	62.2		47.3		47.8		52.4		8.46	
	50	62.2	3.16	47.3	2.40	47.8	2.42	52.4	2.66	8.46	0.43
	100	62.2	3.04	50.4	2.46	49.4	2.41	53.9	2.64	7.25	0.35
F	150	63.9	2.90	52.5	2.39	51.6	2.35	56.0	2.55	6.86	0.31
L	200	64.7	2.69	60.1	2.51	60.5	2.52	61.7	2.57	2.55	0.10
A	250	68.4	2.44	79.0	2.81	74.0	2.63	73.8	2.63	5.30	0.18
M	300	85.0	2.47	106.0	3.07	97.0	2.81	96.0	2.78	10.54	0.30
E	350	121.0	2.89	155.0	3.70	138.0	3.29	138.0	3.29	17.00	0.40
	400	191.0	3.46	220.0	3.98	208.0	3.76	206.3	3.73	14.57	0.26
S	450	291.0	3.96	314.0	4.27	303.0	4.12	302.6	4.12	11.50	0.16
P	500	432.0	4.32	436.0	4.36	457.0	4.57	441.7	4.41	13.42	0.13
R	550	640.0	4.67	676.0	4.93	682.0	4.98	666.0	4.86	22.71	0.16
E	600	899.0	4.67	1042.0	5.42	989.0	5.14	976.6	5.08	72.29	0.37
A	650	1258.0	5.03	1399.0	5.59	1367.0	5.47	1341.0	5.36	73.92	0.29
D	700	1587.0	4.92			1814.0	5.62	1700.5	5.27	160.51	0.49
	750										
D	Heat for Sustained Burning (MJ/m^2)	3.70		3.91		3.94		3.85		0.13	
A	Maximum Flame Spread Distance (mm)	710		690		715		705		13.23	
T	Critical Flux at Extinguishment (kW/m^2)	3.0		3.4		2.8		3.1		0.3	
A											

Table (5) Hardboard (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Hardboard	U.S.A.	February 9, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
	at ignition	49.3		40.6		42.4		44.1		4.59	
	50	49.3	2.50	40.6	2.06	42.4	2.15	44.1	2.24	4.59	0.23
	100	49.6	2.42	41.0	2.00	43.1	2.10	44.6	2.17	4.48	0.22
F	150	50.5	2.29	43.5	1.99	44.5	2.02	46.2	2.09	3.79	0.17
L	200	51.9	2.16	44.7	1.86	54.0	2.25	50.2	2.09	4.78	0.20
A	250	60.0	2.13	57.0	2.03	63.0	2.24	60.0	2.13	3.00	0.11
M	300	79.0	2.29	74.0	2.14	84.0	2.43	79.0	2.28	5.00	0.14
E	350	104.0	2.49	102.0	2.44	110.0	2.63	105.3	2.52	4.16	0.09
	400	143.0	2.58	147.0	2.66	149.0	2.69	146.3	2.64	3.05	0.05
S	450	199.0	2.70	210.0	2.85	213.0	2.89	207.3	2.81	7.37	0.10
P	500	294.0	2.94	203.0	2.93	296.0	2.96	294.3	2.94	15.27	0.02
R	550	461.0	3.36	427.0	3.11	440.0	3.21	442.6	3.23	17.15	0.12
E	600	700.0	3.64	610.0	3.17	675.0	3.25	645.0	3.34	48.22	0.23
A	650	939.0	3.96	854.0	3.41	930.0	3.72	924.3	3.69	67.68	0.27
D	700	1335.0	4.14	1175.0	3.64	1267.0	3.93	1259.0	3.90	80.29	0.25
	750	1753.0	4.20	1518.0	3.64	1668.0	4.00	1646.3	3.95	118.98	0.28
D A T A	Heat for Sustained Burning (MJ/m^2)	2.99		2.76		2.95		2.90		0.12	
	Maximum Flame Spread Distance (mm)	800.0		800.0		800.0		800.0		0.0	
	Critical Flux at Extinguishment (kW/m^2)	2.0		2.0		2.0		2.0		0.0	

Table (6) Hardboard (U.S.A.)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Wool Carpet (B2)	Japan	July 10, 1985	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	5.0		5.2		5.1		5.1		0.10	
	50	5.2	0.264	5.5	0.278	5.1	0.259	5.3	0.267	0.17	0.008
	100	5.2	0.254	5.5	0.267	5.1	0.249	5.3	0.257	0.17	0.008
	150	5.2	0.237	5.5	0.249	5.5	0.249	5.4	0.245	0.13	0.006
	200	6.2	0.259	6.6	0.276	6.5	0.271	6.4	0.269	0.17	0.007
	250	7.1	0.254	7.8	0.277	7.8	0.279	7.6	0.270	0.31	0.011
	300	7.1	0.207	13.1	0.380	11.6	0.337	10.6	0.308	2.54	0.074
	350	11.2	0.267	13.9	0.332	19.9	0.476	15.0	0.358	3.66	0.087
	400	30.6	0.554	35.5	0.643	32.0	0.579	32.7	0.592	2.06	0.037
	450										
	500										
	550										
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	0.30		0.36		0.37		0.34		0.04	
	Maximum Flame Spread Distance (mm)	420		425		460		435		17	
	Critical Flux at Extinguishment (kW/m^2)	16.3		15.9		12.9		15.0		1.5	

Table (7) Wool Carpet-B2 (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Wool Carpet - Low Pile	Japan	July 17, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	8.7		7.2		7.6		7.83		0.77	
	50	8.7	0.44	7.2	0.36	7.6	0.39	7.83	0.39	0.77	0.04
	100	8.7	0.42	7.2	0.35	7.6	0.37	7.83	0.38	0.77	0.03
	150	9.3	0.42	8.3	0.38	7.8	0.35	8.47	0.38	0.62	0.03
	200	10.3	0.46	10.0	0.45	8.5	0.39	9.60	0.43	0.96	0.04
	250	11.6	0.41	13.8	0.49	9.5	0.34	11.63	0.41	2.15	0.08
	300	16.4	0.48	18.7	0.54	10.8	0.31	15.30	0.42	4.06	0.12
	350	23.4	0.56	29.0	0.69	15.3	0.36	22.56	0.54	6.88	0.17
	400	42.0	0.76			23.0	0.42	32.50	0.59	13.45	0.24
	450										
	500										
	550										
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	0.52		0.51		0.36		0.46		0.09	
	Maximum Flame Spread Distance (mm)	430		355		355		380		43	
	Critical Flux at Extinguishment (kW/m^2)	15.5		23.5		23.5		20.8		4.6	

Table (8) Wool Carpet - Low Pile (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Wool Carpet - Low Pile	U.S.A.	February 3, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	15.5		14.7		15.3		15.2		0.42	
	50	15.5	0.78	14.7	0.75	15.3	0.78	15.2	0.77	0.42	0.02
	100	15.8	0.77	14.9	0.73	15.4	0.75	15.4	0.75	0.45	0.02
	150	16.2	0.73	15.1	0.68	15.6	0.71	15.6	0.71	0.55	0.03
	200	16.6	0.69	15.4	0.64	15.8	0.66	15.9	0.66	0.61	0.03
	250	17.0	0.61	16.3	0.58	17.3	0.62	16.9	0.60	0.51	0.02
	300	19.7	0.57	19.0	0.55	20.5	0.59	19.7	0.57	0.75	0.02
	350	29.0	0.69	27.0	0.64	30.0	0.72	28.7	0.68	1.52	0.04
	400	56.0	1.01	49.0	0.88	49.0	0.88	51.3	0.92	4.04	0.07
	450										
	500										
	550										
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	0.72		0.66		0.70		0.69		0.03	
	Maximum Flame Spread Distance (mm)	400		400		470		406		11	
	Critical Flux at Extinguishment (kW/m^2)	18.5		18.5		16.4		17.8		1.2	

Table (9) Wool Carpet-Low Pile (U.S.A.)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Acrylic Carpet	U.S.A.	February 6, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	12.2		12.1		12.4		12.2		0.15	
	50	12.2	0.62	12.3	0.62	12.6	0.64	12.4	0.63	0.21	0.01
	100	12.5	0.61	12.6	0.61	12.8	0.62	12.6	0.61	0.15	0.00
	150	12.9	0.59	13.0	0.59	13.1	0.59	13.0	0.59	0.10	0.00
	200	13.5	0.56	13.5	0.56	14.0	0.58	13.6	0.56	0.29	0.01
	250	16.2	0.58	16.1	0.57	16.8	0.60	16.4	0.58	0.38	0.01
	300	20.0	0.58	22.0	0.64	22.0	0.64	21.3	0.62	1.15	0.03
	350	27.0	0.64	28.0	0.67	29.0	0.69	28.0	0.66	1.00	0.03
	400	36.0	0.65	39.0	0.71	39.0	0.71	38.0	0.69	1.73	0.03
	450	51.0	0.69	54.0	0.73	53.0	0.72	52.6	0.71	1.53	0.02
	500	74.0	0.74	72.0	0.72	72.0	0.72	73.0	0.73	0.01	0.01
	550	100.0	0.73	103.0	0.75	102.0	0.74	101.6	0.74	1.53	0.01
	600	144.0	0.75	148.0	0.77	143.0	0.74	145.0	0.75	2.54	0.02
	650	211.0	0.94	202.0	0.91	187.0	0.75	200.0	0.87	12.12	0.10
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	0.67		0.69		0.68		0.68		0.01	
	Maximum Flame Spread Distance (mm)	685		650		650		662		20	
	Critical Flux at Extinguishment (kW/m^2)	3.5		4.0		4.0		3.8		0.3	

Table (10) Acrylic Carpet (U.S.A.)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Acrylic Carpet	Japan	July 10, 1985	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
	at ignition	13.5	0.612	14.5	0.661	15.6	0.708	14.5	0.660	0.85	0.039
	50	14.1	0.716	14.7	0.746	15.6	0.790	14.8	0.751	0.60	0.030
	100	15.6	0.761	14.7	0.716	16.7	0.813	15.6	0.763	0.81	0.040
F	150	16.6	0.756	19.1	0.870	18.2	0.830	18.0	0.819	1.03	0.047
L	200	19.6	0.817	20.2	0.842	18.3	0.764	19.4	0.808	0.78	0.033
A	250	21.4	0.763	24.5	0.872	22.6	0.803	22.8	0.813	1.27	0.045
M	300	28.4	0.822	28.8	0.836	29.8	0.864	29.0	0.841	0.60	0.017
E	350	39.4	0.941	46.7	1.117	39.4	0.942	41.8	1.000	3.46	0.083
	400	49.6	0.898	60.0	1.086	55.0	0.996	54.9	0.993	4.25	0.077
S	450	89.0	1.210	74.0	1.006	72.0	0.979	78.3	1.065	7.59	0.103
P	500	121.0	1.210	100.0	1.000	107.0	1.070	109.3	1.093	8.73	0.087
R	550	205.0	1.497	240.0	1.752	230.0	1.679	225.0	1.643	14.72	0.107
E	600	410.0	2.132	370.0	1.924	354.0	1.841	378.0	1.966	23.55	0.122
A	650			545.0	2.180	610.0	2.440	577.5	2.310	32.50	0.130
D	700										
	750										
D A T A	Heat for Sustained Burning (MJ/m^2)	1.11		1.23		1.18		1.17		0.06	
	Maximum Flame Spread Distance (mm)	630		650		660		647		12	
	Critical Flux at Extinguishment (kW/m^2)	4.50		4.00		3.80		4.10		0.29	

Table (11) Acrylic Carpet (Japan)

Specimen ½" Fiberboard (unpainted surface)	Specimen Supplied By U.S.A.	Date of Test February 7, 1984	Ambient Temp. 22 (°C)	Humidity 50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
	at ignition	13.5		12.0		11.9		12.5		0.89	
	50	13.5	0.68	12.0	0.61	11.9	0.60	12.5	0.63	0.89	0.04
	100	13.7	0.69	12.2	0.59	11.9	0.58	12.6	0.62	0.96	0.05
F	150	14.0	0.64	12.5	0.57	12.3	0.56	12.9	0.59	0.92	0.04
L	200	14.4	0.60	12.9	0.54	12.6	0.53	13.3	0.56	0.96	0.03
A	250	15.3	0.54	14.3	0.51	14.0	0.50	14.5	0.52	0.68	0.02
M	300	17.4	0.50	18.0	0.52	17.1	0.50	17.5	0.50	0.46	0.01
E	350	22.0	0.53	24.0	0.57	24.0	0.57	23.3	0.56	1.15	0.01
	400	30.0	0.54	34.0	0.61	34.0	0.61	32.6	0.59	2.30	0.04
S	450	50.0	0.68	51.0	0.69	52.0	0.70	51.0	0.69	1.00	0.01
P	500	77.0	0.77	74.0	0.74	79.0	0.79	76.6	0.76	2.52	0.03
R	550	111.0	0.81	107.0	0.78	109.0	0.79	109.0	0.79	2.00	0.02
E	600	164.0	0.85	166.0	0.86	159.0	0.83	163.0	0.85	3.60	0.02
A	650	221.0	0.88	238.0	0.95	219.0	0.98	226.0	0.93	10.44	0.05
D	700	296.0	0.92	301.0	0.93	298.0	0.92	298.3	0.92	2.52	0.01
	750	387.0	0.93	393.0	0.94	372.0	0.89	384.0	0.92	10.81	0.02
D A T A	Heat for Sustained Burning (MJ/m^2)	0.71		0.71		0.71		0.71		0.00	
	Maximum Flame Spread Distance (mm)	800.0		800.0		800.0		800.0		0.0	
	Critical Flux at Extinguishment (kW/m^2)	2.0		2.0		2.0		2.0		0.0	

Table (12) Fiberboard-Unpainted Surface (U.S.A.)

Specimen ½" Fiberboard Painted Surface		Specimen Supplied By U.S.A.		Date of Test January 31, 1984		Ambient Temp. 22 (°C)		Humidity 50 (%)	
		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	20.8		18.4		27.2		22.1		4.54	
	50	20.8	1.06	18.4	0.93	27.2	1.38	22.1	1.13	4.54	0.23
	100	20.8	1.02	18.7	0.91	27.6	1.35	27.4	1.09	4.65	0.22
	150	21.7	0.98	19.2	0.87	28.0	1.27	23.00	1.04	4.53	0.21
	200	23.1	0.95	20.4	0.85	28.5	1.18	24.00	0.99	4.12	0.15
	250	76.0	0.92	27.0	0.96	31.0	1.10	28.00	0.99	2.65	0.09
	300	35.0	1.01	34.0	0.99	38.0	1.10	35.66	1.03	2.08	0.06
	350	49.0	1.17	54.0	1.29	50.0	1.19	51.00	1.22	2.65	0.05
	400	93.0	1.68	68.0	1.23	82.0	1.48	81.00	1.46	17.52	0.22
	450	164.0	2.23	105.0	1.42	123.0	1.67	130.00	1.77	30.23	0.41
	500	290.0	2.90	173.0	1.73			231.00	2.31	87.73	0.82
	550			274.0	2.00			274.00	2.00		
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	1.48		1.26		1.28		1.34		0.12	
	Maximum Flame Spread Distance (mm)	520.0		555.0		498.0		524.0		28.7	
	Critical Flux at Extinguishment (kW/m^2)	9.3		7.5		10.5		9.1		1.5	

Table (13) Fiberboard-Painted Surface (U.S.A.)

Specimen Low Density Wood Fiber Board (L8)	Specimen Supplied By Japan	Date of Test July 15, 1985	Ambient Temp. 22 (°C)	Humidity 50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
	at ignition	10.1	0.457	8.4	0.382	8.1	0.370	8.9	0.403	0.85	0.038
	50	10.2	0.519	8.4	0.426	8.1	0.413	8.9	0.453	0.93	0.047
	100	10.2	0.498	8.4	0.409	8.1	0.397	8.9	0.435	0.93	0.045
F	150	10.2	0.465	8.4	0.382	9.2	0.417	9.3	0.421	0.75	0.034
L	200	11.1	0.464	9.8	0.407	10.0	0.417	10.3	0.429	0.59	0.025
A	250	13.2	0.470	12.3	0.437	11.6	0.414	12.4	0.440	0.65	0.023
M	300	17.4	0.505	17.1	0.497	15.3	0.445	16.6	0.482	0.92	0.027
E	350	23.1	0.552	24.5	0.585	22.4	0.536	23.3	0.558	0.87	0.020
	400	35.2	0.637	35.8	0.648	33.0	0.597	34.7	0.627	1.21	0.022
S	450	55.4	0.754	53.0	0.721	48.0	0.653	52.1	0.709	3.09	0.042
P	500	82.0	0.820	79.0	0.790	75.0	0.750	78.7	0.787	2.87	0.029
R	550	125.0	0.913	118.0	0.861	115.0	0.840	119.3	0.871	4.19	0.031
E	600	189.0	0.983	174.0	0.905	159.0	0.827	174.0	0.905	12.25	0.064
A	650	270.0	1.080			277.0	1.108	273.5	1.094	3.50	0.014
D	700	353.0	1.094			294.0	0.911	323.5	1.003	29.50	0.092
	750										
D A T A	Heat for Sustained Burning (MJ/m^2)	0.73		0.62		0.66		0.672		0.06	
	Maximum Flame Spread Distance (mm)	725.0		640.0		710.0		692.0		37.0	
	Critical Flux at Extinguishment (kW/m^2)	2.80		4.20		3.00		3.30		0.62	

Table (14) Low Density Wood Fiberboard-L8 (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Lauan Wood Plate	Japan	July 16, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	35.4		41.4		34.8		37.2		3.65	
	50	35.4	1.78	41.4	2.10	34.8	1.77	37.2	1.88	3.65	0.19
	100	35.4	1.73	41.4	2.02	35.1	1.71	37.3	1.92	3.55	0.17
	150	36.1	1.54	42.2	1.92	35.8	1.53	38.0	1.66	3.61	0.22
	200	37.8	1.58	43.3	1.81	40.8	1.70	40.6	1.69	2.75	0.11
	250	43.8	1.56	51.3	1.82	48.2	1.71	47.8	1.69	3.76	0.13
	300	54.0	1.56	66.0	1.91	61.0	1.74	60.3	1.74	6.03	0.17
	350	75.0	1.79	92.0	2.20	84.0	2.01	83.6	2.00	8.50	0.21
	400	112.0	2.02	130.0	2.35	121.0	2.19	121.0	2.19	9.00	0.17
	450	165.0	2.24	195.0	2.65	179.0	2.43	179.6	2.44	15.01	0.21
	500			277.0		309.0		293.0		22.50	
	550			422.0				422.0			
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	1.76		2.09		1.90		1.92		0.16	
	Maximum Flame Spread Distance (mm)	475.0		570.0		540.0		528.3		48.6	
	Critical Flux at Extinguishment (kW/m^2)	11.8		6.7		8.3		8.9		2.6	

Table (15) Lauan Wood Plate (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
Melamine Laminate (E15)	Japan	July 15, 1985	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	32.7	1.486	37.9	1.725	29.6	1.346	33.4	1.519	3.44	0.156
	50	32.7	1.663	37.9	1.926	30.9	1.567	33.8	1.719	2.99	0.152
	100	33.9	1.655	37.9	1.825	30.9	1.508	34.3	1.671	2.87	0.140
	150	33.9	1.543	38.6	1.754	31.4	1.428	34.6	1.575	2.97	0.135
	200	36.7	1.529	39.4	1.644	32.8	1.366	36.3	1.513	2.74	0.114
	250	44.8	1.595	39.6	1.408	36.5	1.299	40.3	1.434	3.44	0.122
	300	47.8	1.388	50.6	1.468	46.8	1.358	48.4	1.405	1.59	0.046
	350	65	1.554	62.0	1.482	67.0	1.601	64.7	1.546	2.06	0.049
	400										
	450										
	500										
	550										
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	1.52		1.55		1.41		1.49		0.07	
	Maximum Flame Spread Distance (mm)	360.0		360.0		370.0		363.0		4.7	
	Critical Flux at Extinguishment (kW/m^2)	22.70		22.70		21.60		22.30		0.52	

Table (16) Melamine Laminate-E15 (Japan)

Specimen Melamine Phenol Surface Finish		Specimen Supplied By Japan				Date of Test February 23, 1984		Ambient Temp. 22 (°C)		Humidity 50 (%)	
		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	20.0	0.90	20.0	0.90	20.0	0.90	20.0	0.90	0.0	0.0
	50			20.0	1.02			20.0	1.02	0.0	0.0
	100			20.0	0.98				0.98	0.0	0.0
	150										
	200										
	250										
	300										
	350										
	400										
	450										
	500										
	550										
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	0.00		0.00		0.00		0.00		0.00	
	Maximum Flame Spread Distance (mm)	50.0		100.0		50.0		66.7		28.9	
	Critical Flux at Extinguishment (kW/m^2)	50.8		48.0		50.8		49.9		1.6	

Table (17) Melamine Phenol Surface Finish (Japan)

Specimen	Specimen Supplied By	Date of Test	Ambient Temp.	Humidity
PVC Flooring	Japan	February 21, 1984	22 (°C)	50 (%)

		Specimen 1		Specimen 2		Specimen 3		Average		Std. Deviation	
	Flame Spread Distance (mm)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)	Time (s)	Time × Flux (MJ/m^2)
FLAME SPREAD DATA	at ignition	17.6		22.5		18.9		19.66		2.53	
	50	17.6	0.89	22.5	1.14	18.9	0.96	19.66	0.99	2.53	0.12
	100	19.9	0.97	24.0	1.17	20.9	1.02	21.60	1.05	2.14	0.10
	150	21.5	0.98	24.7	1.12	22.5	1.02	22.90	1.04	1.64	0.07
	200	23.4	0.97	25.6	1.07	24.3	1.01	24.43	1.01	1.11	0.05
	250	28.5	1.01	28.0	0.99	28.0	0.99	28.17	1.00	2.88	0.01
	300	34.0	0.98	36.0	1.04	34.0	0.99	34.66	1.00	1.15	0.03
	350	42.0	1.00	41.0	1.18	42.0	1.00	41.66	1.06	0.57	0.10
	400	54.0	0.98	55.0	0.99	61.0	1.10	56.66	1.02	3.79	0.06
	450	79.0	1.07	83.0	1.12	92.0	1.25	84.66	1.15	6.65	0.09
	500	155.0	1.55	168.0	1.68			161.50	1.62	9.19	0.09
	550	242.0	1.76	271.0	1.98			256.50	1.87	20.51	0.15
	600										
	650										
	700										
	750										
	Heat for Sustained Burning (MJ/m^2)	1.14		1.24		1.05		1.14		0.09	
	Maximum Flame Spread Distance (mm)	570.0		575.0		490.0		545.0		47.7	
	Critical Flux at Extinguishment (kW/m^2)	6.9		6.5		11.0		8.1		2.5	

Table (18) PVC Flooring (Japan)

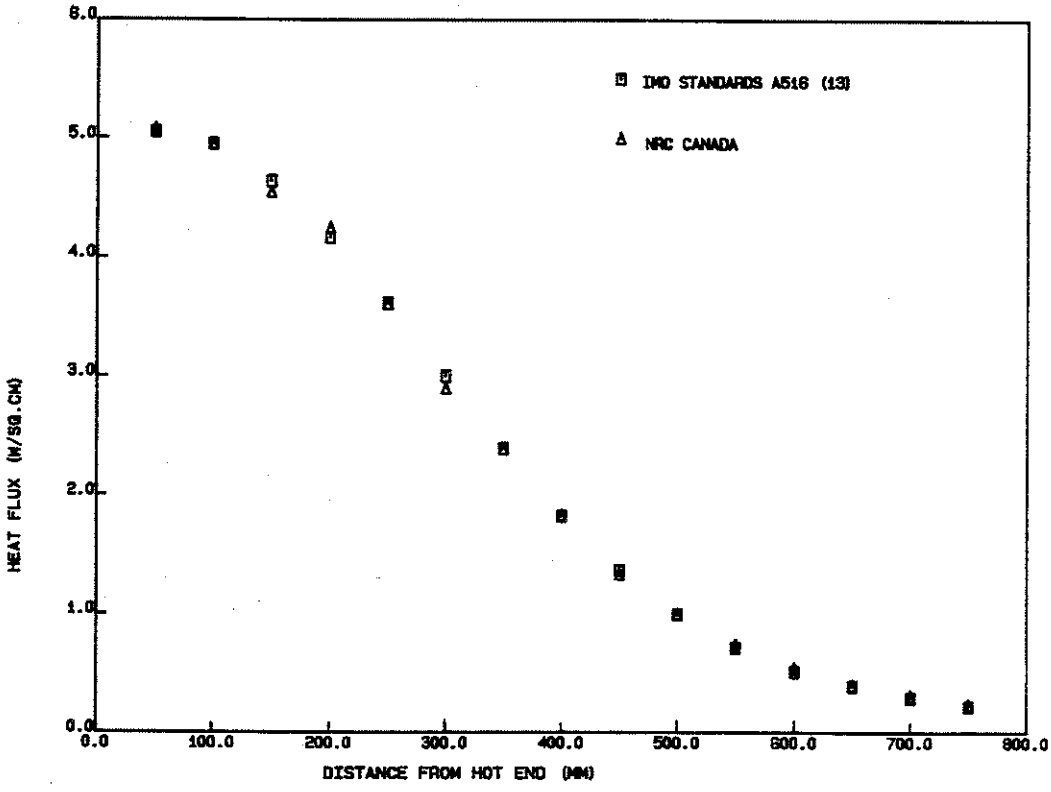

Figure (1) Incident Heat Flux Distribution

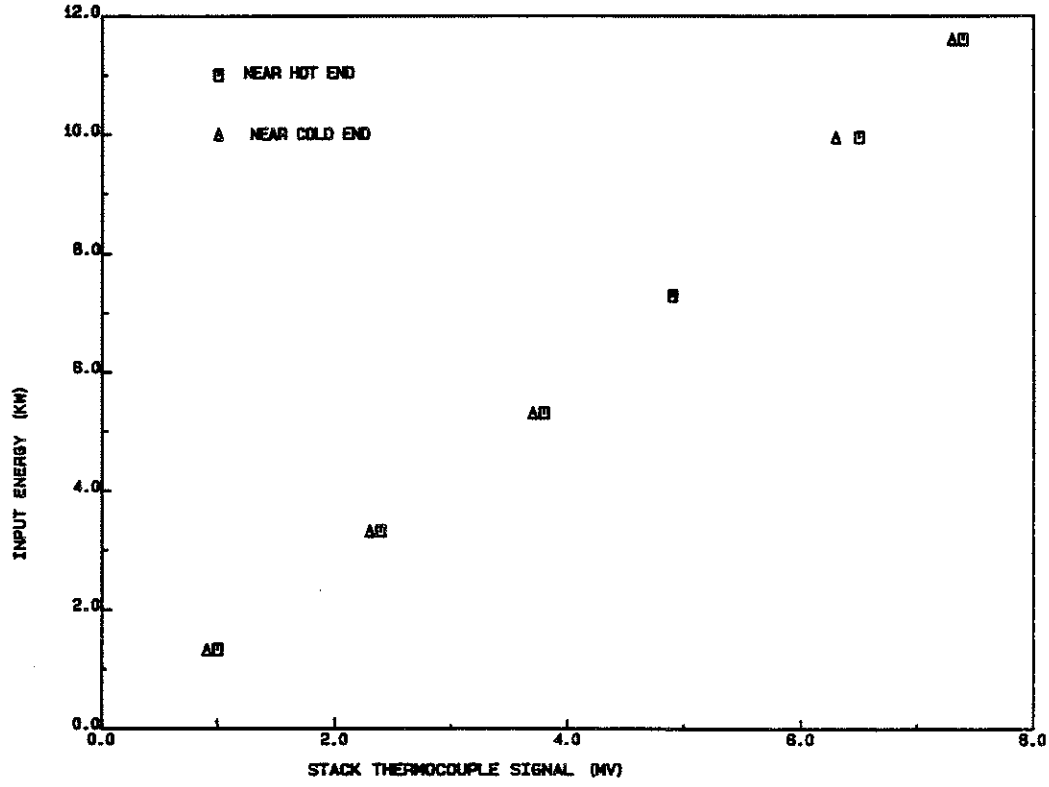

Figure (2) Stack Heat Release Calibration

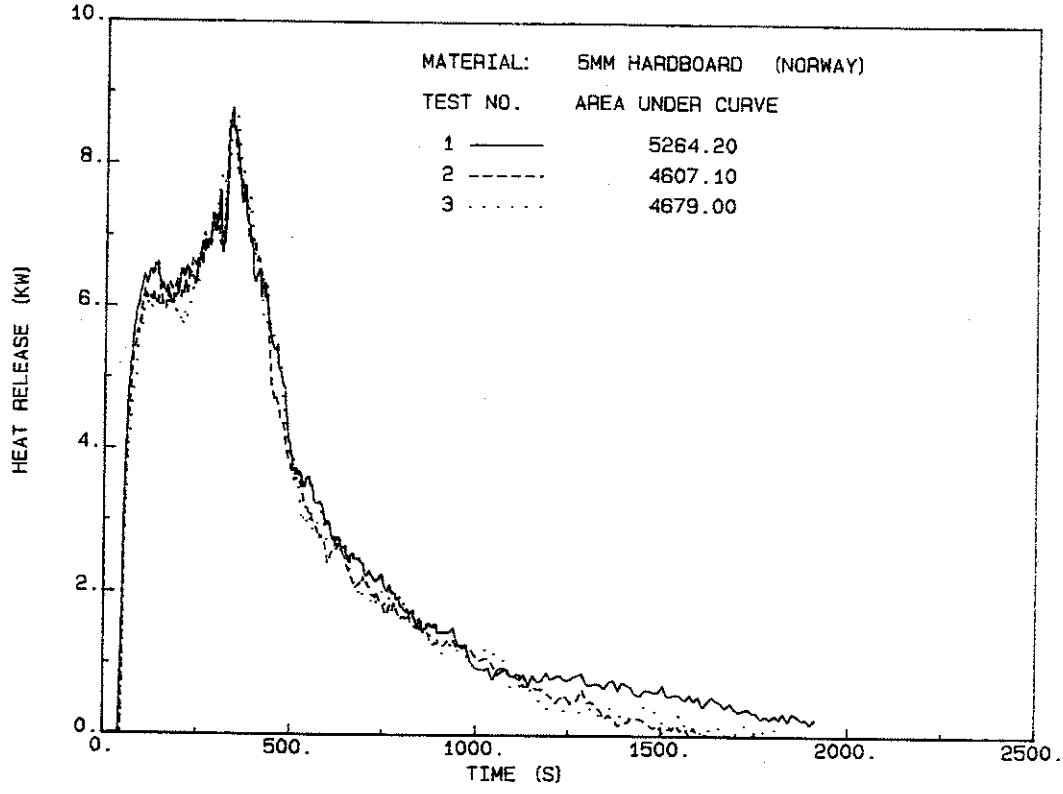

Figure (3) Heat Release vs Time
Hardboard (Norway)

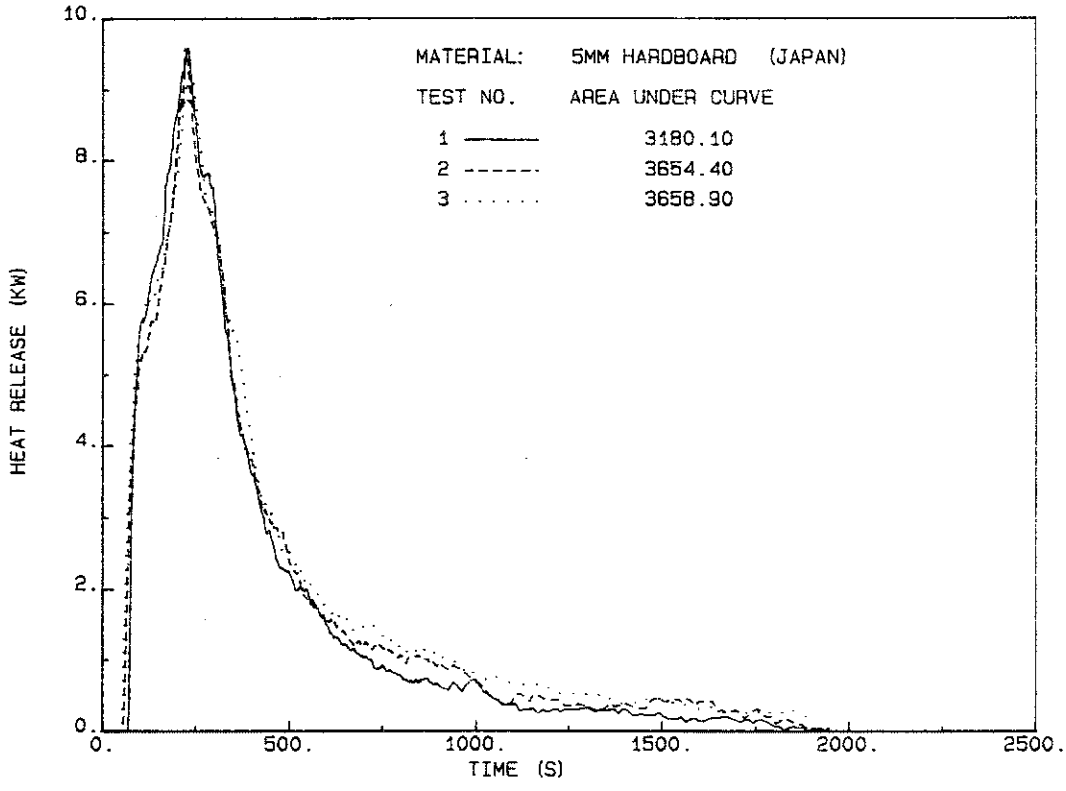

Figure (4) Heat Release vs Time
Hardboard (Japan)

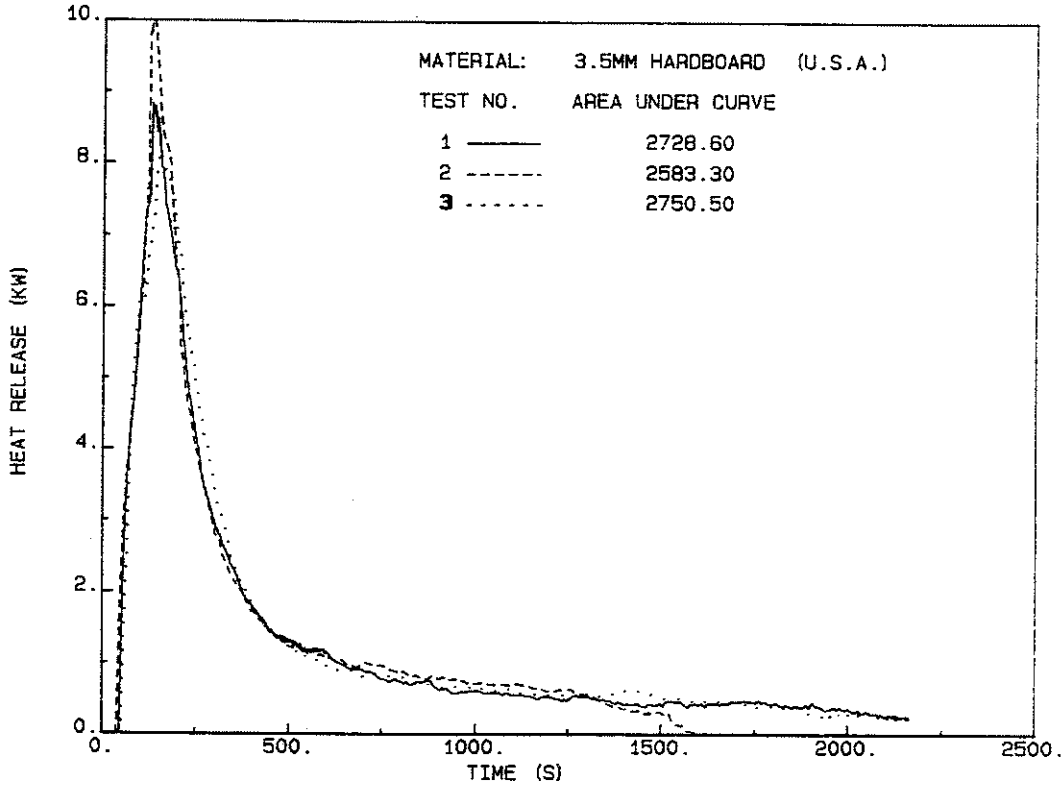

Figure (5) Heat Release vs Time
Hardboard (U.S.A.)

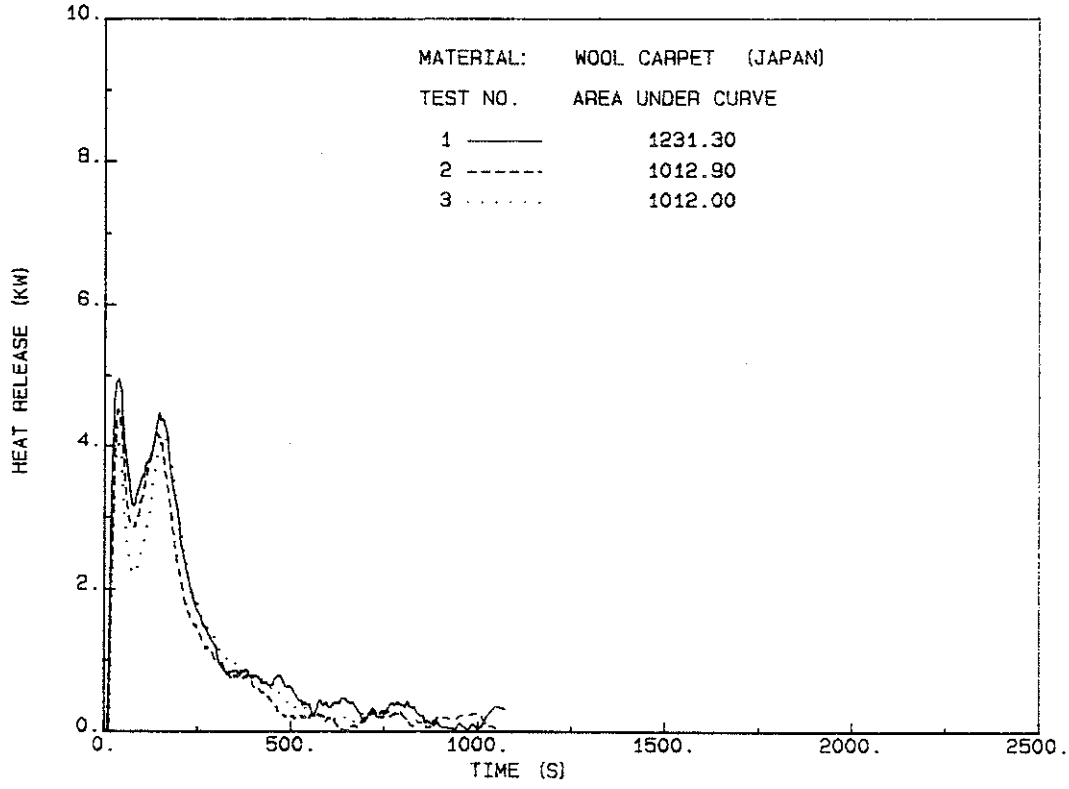

Figure (6) Heat Release vs Time
Wool Carpet-B2 (Japan)

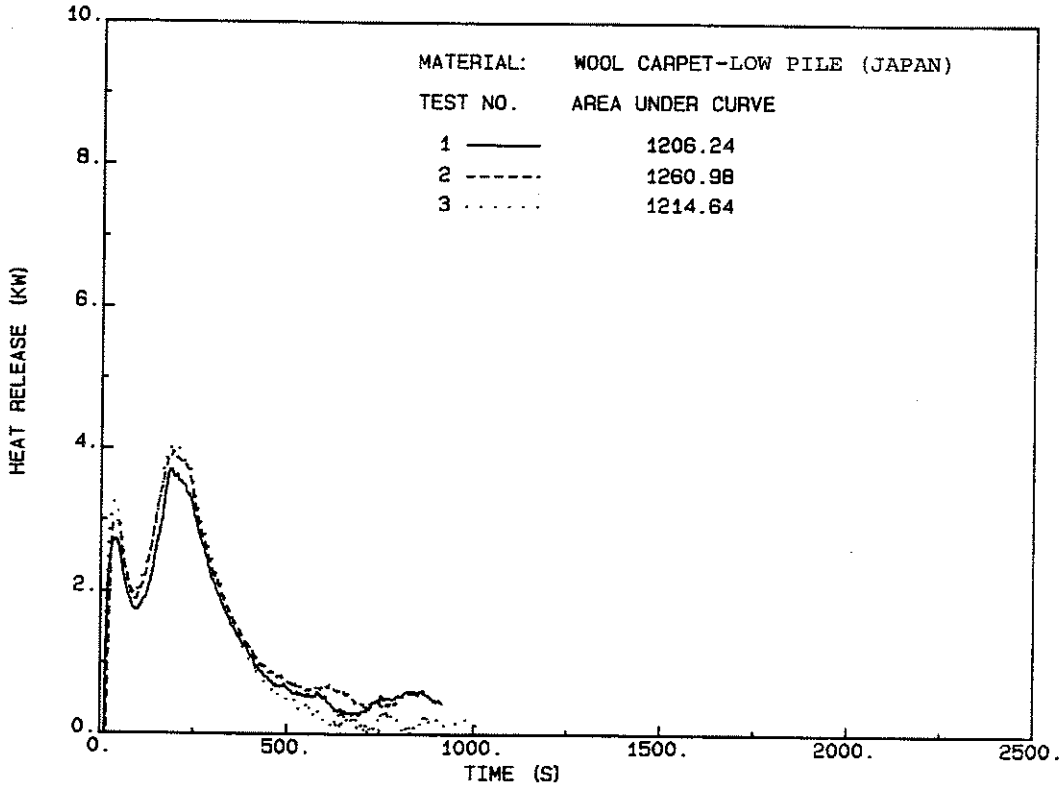

Figure (7) Heat Release vs Time
Wool Carpet-Low Pile (Japan)

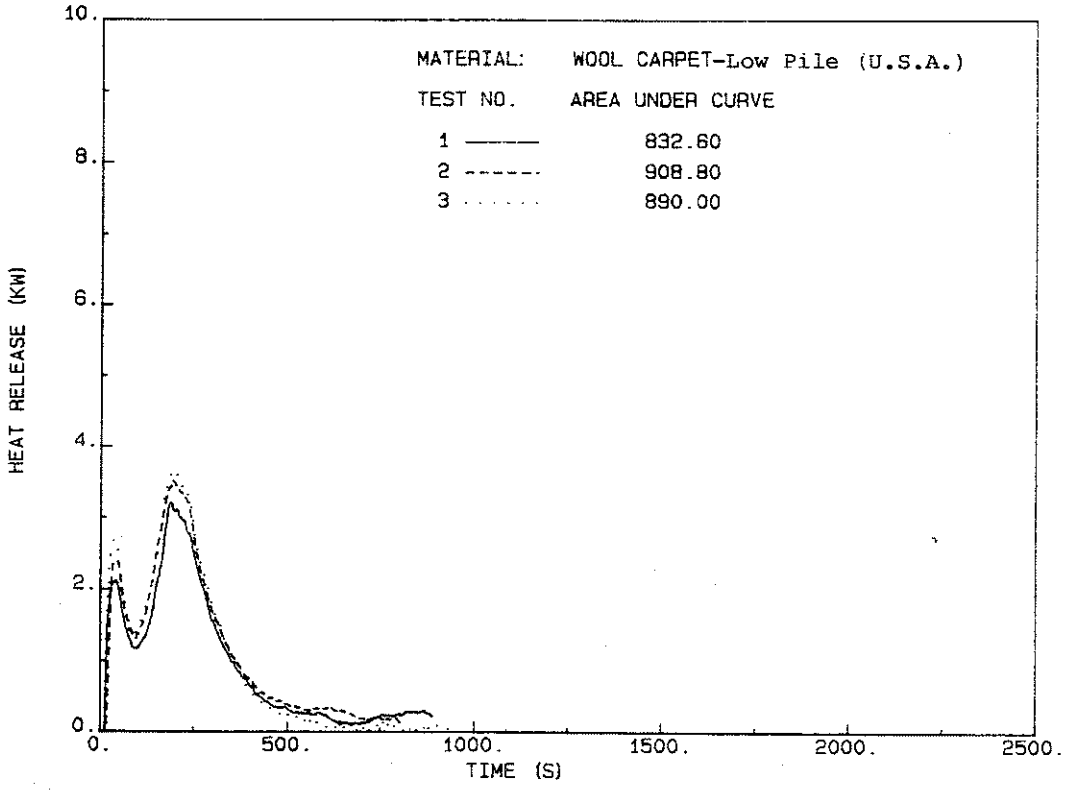

Figure (8) Heat Release vs Time
Wool Carpet-Low Pile (U.S.A.)

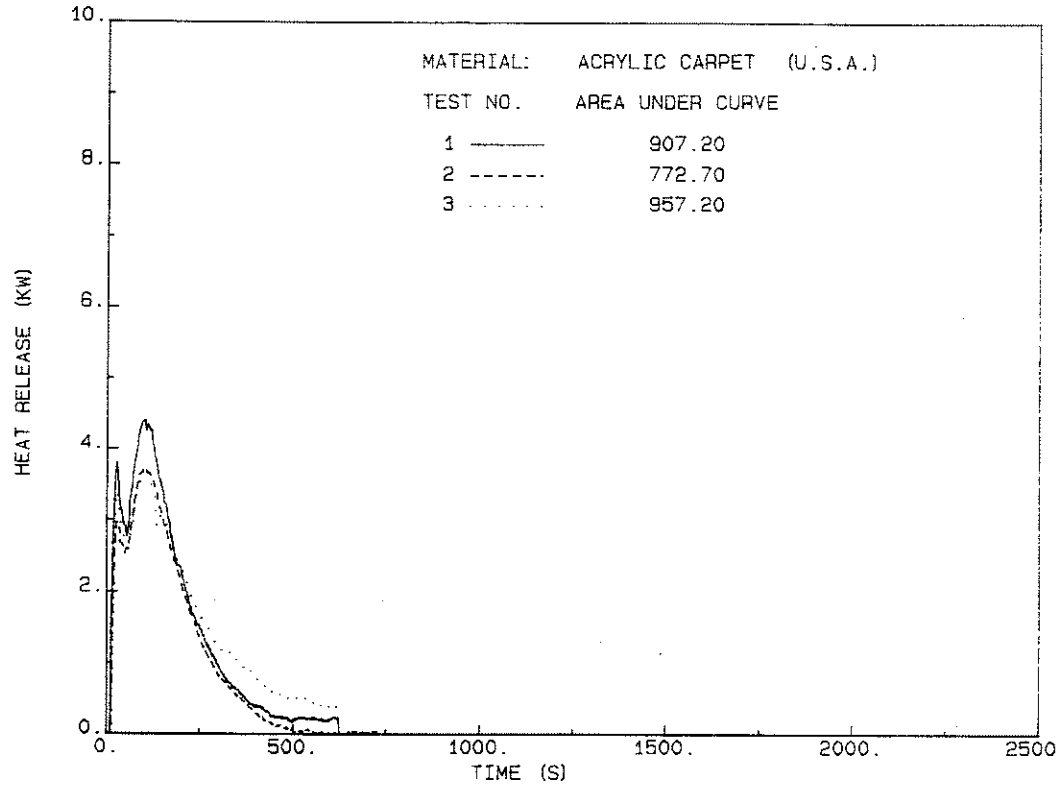

Figure (9) Heat Release vs Time
Acrylic Carpet (U.S.A.)

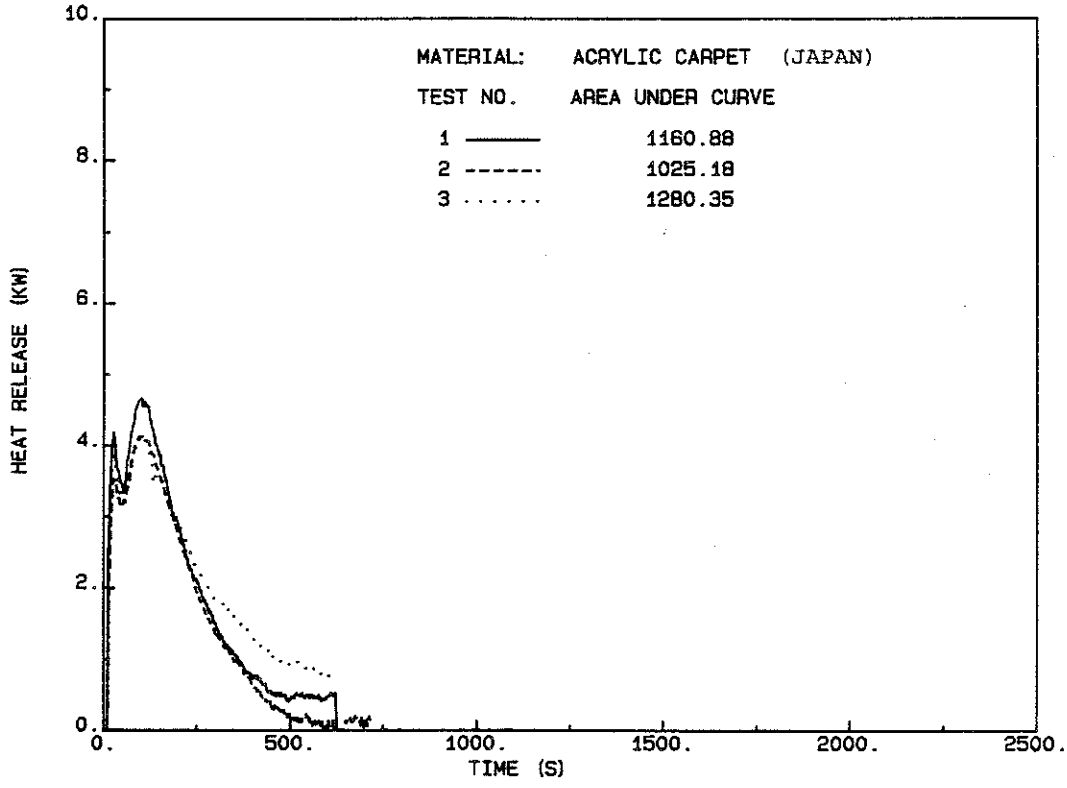

Figure (10) Heat Release vs Time
Acrylic Carpet (Japan)

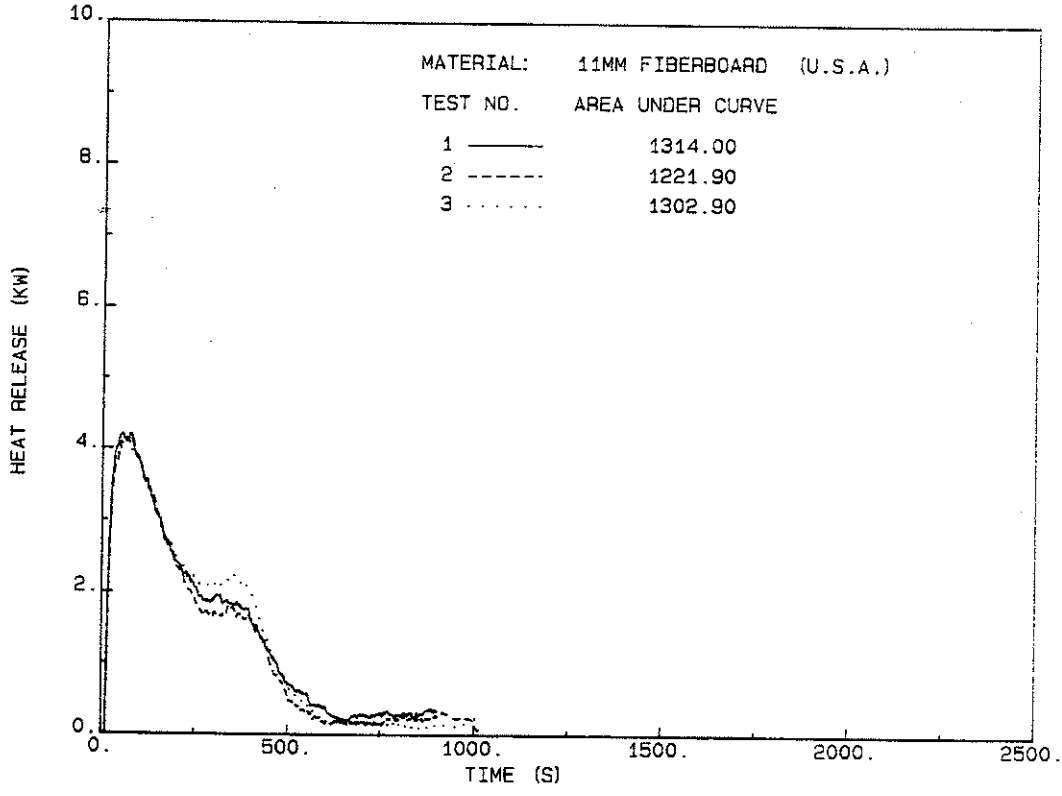

Figure (11) Heat Release vs Time
Fiberboard- Unpainted Surface (U.S.A.)

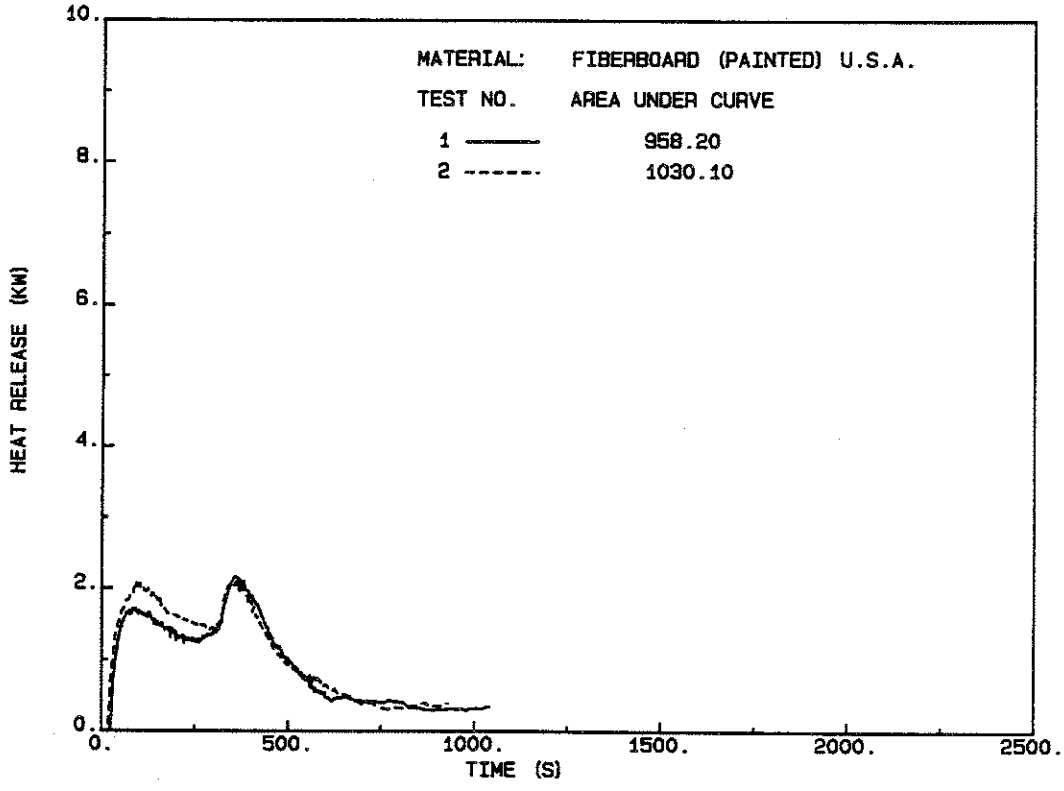

Figure (12) Heat Release vs Time
Fiberboard-Painted Surface (U.S.A.)

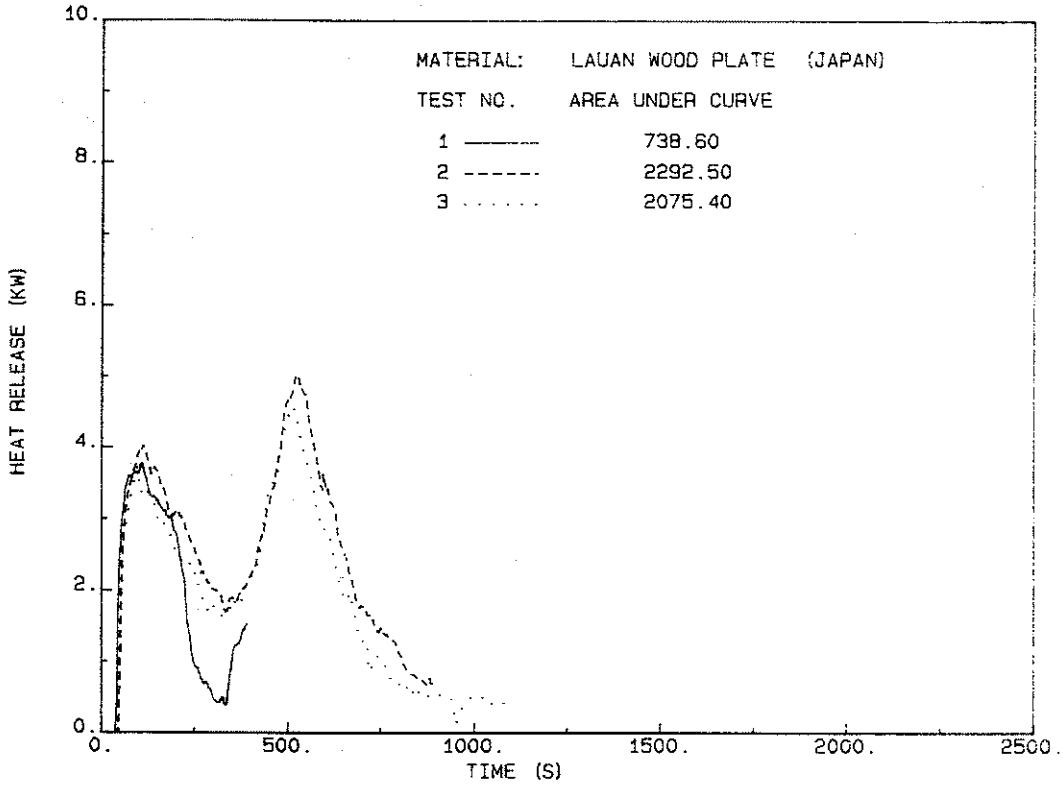

Figure (13) Heat Release vs Time
Lauan Wood Plate (Japan)

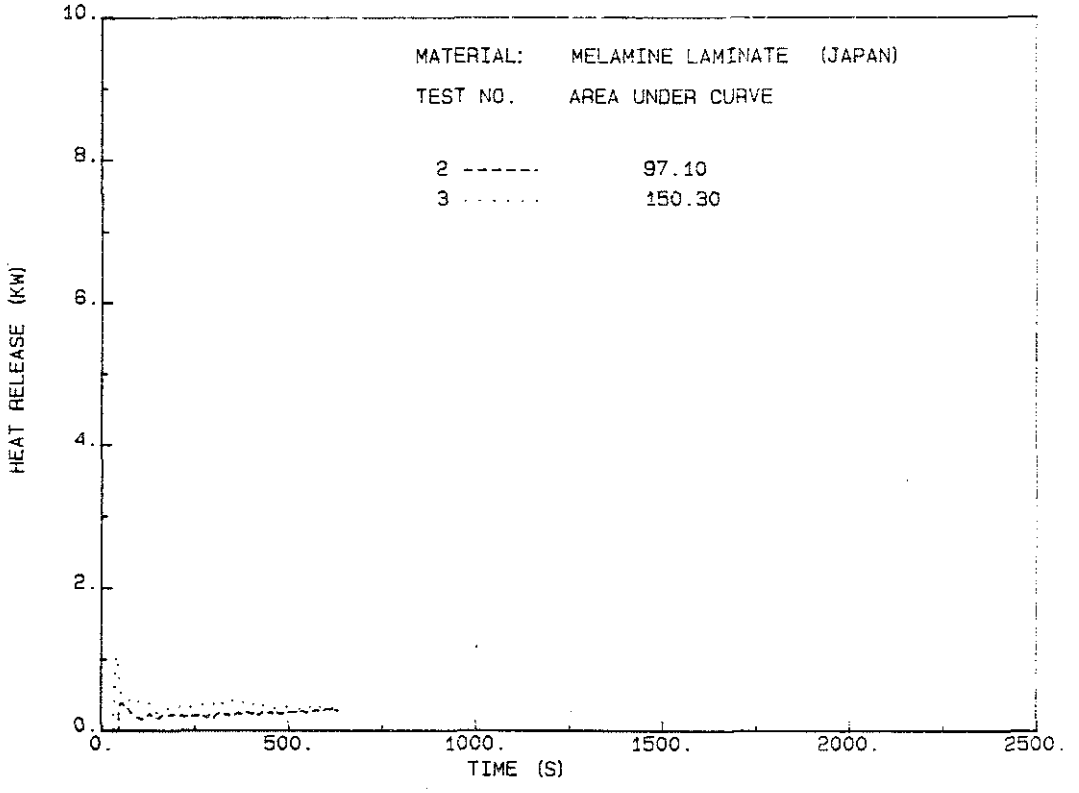

Figure (14) Heat Release vs Time
Melamine Laminate-E15 (Japan)

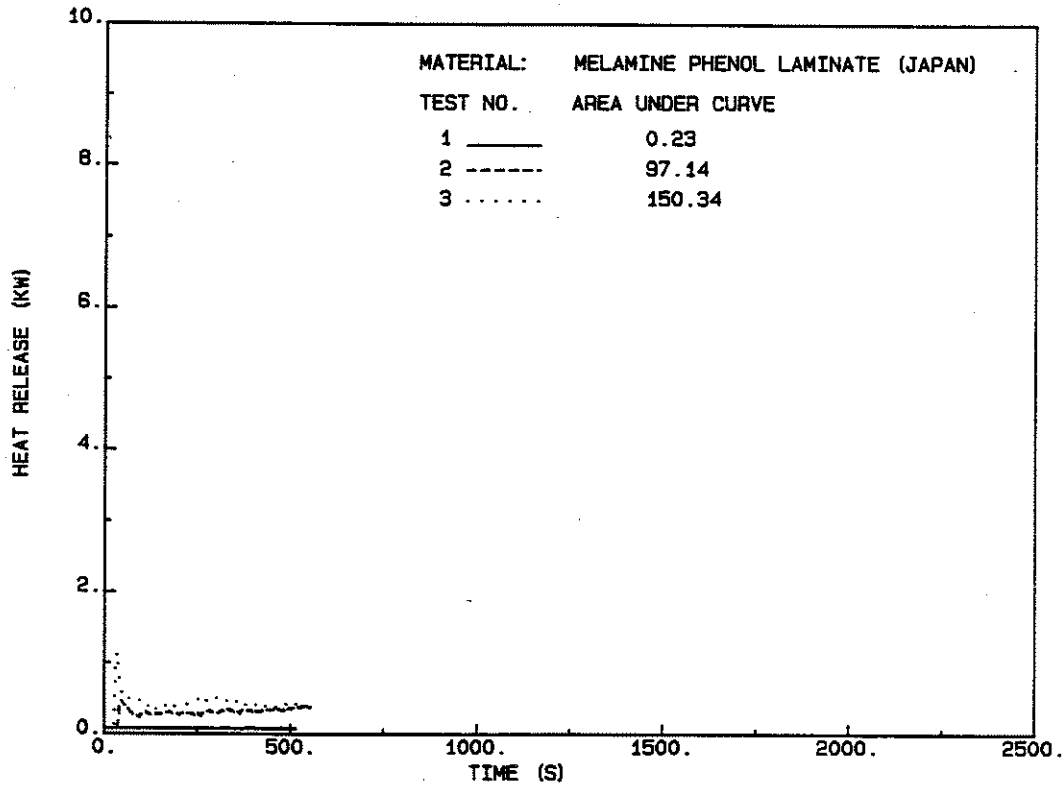

Figure (15) Heat Release vs Time
Melamine Phenol Laminate (Japan)

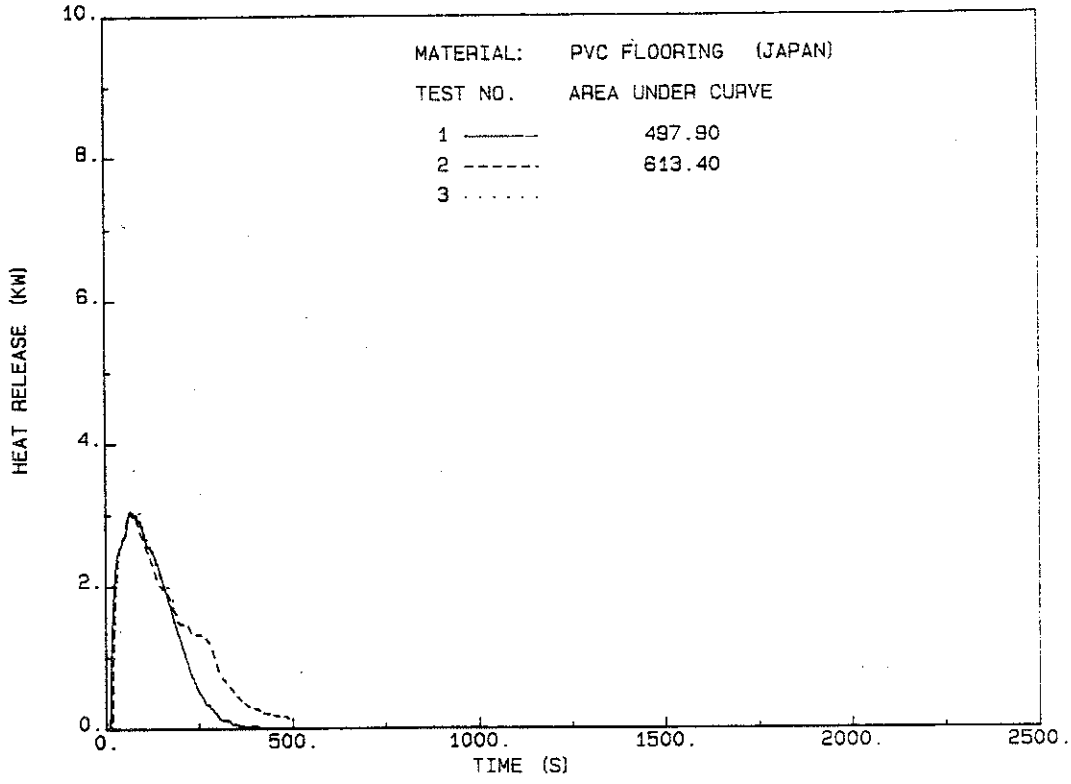

Figure (16) Heat Release vs Time
PVC Flooring (Japan)