NATIONAL BUREAU OF STANDARDS REPORT

4757

FLAME SPREAD PROPERTIES

OF

INTERIOR FINISHES

by

D. Gross and J. J. Loftus

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

1956

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major field laboratories in Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside back cover of this report.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Ceramic Engineering. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Applications Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

Radio Propagation Engineering. Frequency Utilization Research. Tropospheric Propagation Research.

Radio Standards. High Frequency Standards Branch: High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Microwave Standards Branch: Extreme High Frequency and Noise. Microwave Frequency and Spectroscopy. Microwave Circuit Standards.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
1002-10-4871	July 11, 1956	4757

FLAME SPREAD PROPERTIES
OF
INTERIOR FINISHES

by

D. Gross and J. J. Loftus

for
Office of Chief of Engineers,
Department of Army

Directorate of Construction,
U. S. Air Force

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

FLAME SPREAD PROPERTIES OF INTERIOR FINISHES

ABSTRACT

Flame spread data, as measured by the radiant panel method, are presented for composite assemblies representative of a wide variety of interior finishes applied to common wall base materials. The data have been analyzed by statistical methods to show the extent to which the base material and the surface finish material are important in controlling the flame spread behavior.

1. INTRODUCTION

In the specification of interior wall finishes for buildings, the flame spread behavior of the materials considered is often as important as ease of application, appearance, durability or other qualities. The previous lack of a simple method of test has delayed the comprehensive study of this fire characteristic of materials. Completion of the development of the radiant panel flame spread test method at the National Bureau of Standards has now made this study possible. The data obtained on a large variety of interior wall finishes and the effect of the base materials to which they are applied supplements information previously obtained on the flame spread behavior of materials(1).

---

(1) A Method For Measuring Surface Flammability of Materials Using a Radiant Energy Source by A. F. Robertson, D. Gross and J. Loftus to be published in the Proceedings of the American Society for Testing Materials, 1956.

2. MATERIALS

The specimens studied comprised a series of representative finish materials including liquid coatings, films, sheets and panels applied to five common wall base materials; plywood, fiberboard, gypsum board, asbestos-cement board and plaster. The surface of the base material to which any subsequent coatings were applied was the smooth, finished side. Twenty-five wall covering and finish materials were applied to the base materials employing a variety of application materials. Manufacturers' suggestions and standard techniques were used wherever practical. Two types of protected metals and an unbacked plastic also were tested. Table I lists the base, finish and application materials and includes a short description of the material where available. Table II lists the schedule employed in the preparation of the test assemblies.

After the application of the finish material, the assemblies were dried for not less than 72 hours and then were cut to produce five specimens each 6 by 18 in. The specimens were placed in a room maintained at 75°F and 50 percent relative humidity for not less than one week conditioning prior to testing.

3. METHOD OF TEST

The apparatus used for the tests is shown in Figure 1. It consisted of a radiant panel, a frame for support of the test specimen and associated measuring equipment.

The radiant panel consisted of a cast iron frame enclosing a 12 in. by 18 in. porous refractory material. The panel was mounted in a vertical plane and a pre-mixed gas-air mixture supplied from the rear burned in intimate contact with the refractory surface providing a radiant heat source. The panel approached its equilibrium temperature in about one-half hour after ignition and its energy output was maintained by regulation of the gas flow according to the indication of a radiation pyrometer. The radiant output is that which would be obtained from a black body of the same dimensions operating at a temperature of 670°C.

A small metal stack was placed under the hood above the test specimen to receive the hot products of combustion and smoke. A group of eight thermocouples of equal resistance and connected in parallel were placed within the stack, the output being recorded by an automatic potentiometer recorder. A sampling tube was also placed within the stack to collect a deposit of smoke on a glass fiber filter paper. An aspirator was used to draw the stack gases through the paper at a rate maintained constant throughout the test and the weight of the resultant deposit was determined after completion of the test.

The test specimen measuring 6 in. by 18 in. was placed in a formed sheet metal holder and was backed up with a sheet of asbestos millboard of 60 lb per cu ft density. The loaded specimen holder was then placed in position on the supporting frame (inclined 30° to the panel face) at time zero and observations were then made of the progress of the flame front, the occurrence of flashes, etc. A pilot igniter fed by an air-acetylene mixture served both to initiate flaming at the upper edge of the test specimen and to ignite combustible gases rising from the specimen. An electrical timer calibrated in minutes and decimal fractions to hundredths was used for recording the time of occurrence of events during the tests. The test duration was 15 minutes or until sustained flaming had traversed the entire 18 inch length of specimen, whichever time was less.

The flame spread index I_s was computed as the product of the flame spread factor F_s and the heat evolution Q, thus $I_s = F_s Q$

where $F_s = 1 + \frac{1}{t_3} + \frac{1}{t_6 - t_3} + \frac{1}{t_9 - t_6} + \frac{1}{t_{12} - t_9} + \frac{1}{t_{15} - t_{12}}$

here t_3 .... t_{15} correspond to the times in

minutes from specimen exposure until arrival of the flame front at a position 3 .... 15 in., respectively, along the length of the specimen.

$$Q = 0.1 \Delta\Theta/\beta$$

here: 0.1 is a constant arbitrarily chosen to yield a flame spread index of approximately 100 for red oak, $\Delta\Theta$ is the observed maximum stack thermocouple temperature rise in degrees Fahrenheit over that observed with an asbestos cement board specimen, and β is the maximum stack thermocouple temperature rise for unit heat input rate to the calibration burner, in units of degrees F min/BTU.

4. RESULTS

Previous work had indicated that variations in the specimen structure, such as orientation of grains, pores or laminations or variations in the thickness and bond of the finish or protective coating may appreciably affect the flame spread behavior of a material. Data dispersion as indicated by the coefficient of variation has ranged from five percent for materials of good structural uniformity to over 60 percent for those of coarse, non-uniform structure. The testing program was designed to obtain a statistical measure of the variance assignable to finish material, base material, combined effects, consistent and random errors.

To test for the existence of "order within a day" and "day-to-day" effects as well as to estimate the extent of the testing program necessary, a series of tests of eight finish materials on each of four base materials in duplicate was performed in an ordered sequence. The results are shown in Table IA in the appendix. The flame spread indices varied from 1.0 to 715 and included test assemblies from each of four general groups of finish materials. The results indicate that variations due to the testing order during the day (i.e. whether tested in the morning, noon or afternoon) and variations due to testing over a period of time (day or weeks) were not significant as compared with variations observed between duplicate specimens. Based on the behavior of the finish materials on asbestos-cement board (base material IV), it was decided to complete the testing program of the

finish materials on three base materials (plywood I; fiberboard II; gypsum board III) with the exceptions noted in Table II. To complete four replicate sets for each of 28 finishes as applied to the various base materials, a random testing procedure was employed. The averaged results are given in Table III and Table IV. The weight of the smoke deposit reported is the average for replicate specimens and is based upon at least three determinations except in the instances where a smoke deposit of less than 1.0 mg was obtained in the first two determinations.

5. STATISTICAL ANALYSIS

For many materials, the standard deviation of a single observation has been found to be almost proportional to the magnitude of the flame spread index. The assumption of this proportionality for the entire population tested permits the use of a logarithmic transformation which stabilizes the variance. Such a transformation has been used both in the analysis of variance which is summarized in Table IIA of the Appendix and in preparing Figure 2.

The statistical measure used to compare precision is the ratio (F ratio) of the square of the standard deviation of the variable to the square of the standard deviation of the error. Thus, the listed F ratios show that variations assignable to finish material and base material are more than 200 times the standard deviation. A smaller but still significant variation ($F > 25$) is assignable to the combined effect of (or interaction between) finish and base material.

The standard deviation of a mean flame spread index is given by the ratio of the standard deviation of a single observation to the mean multiplied by $\frac{1}{\sqrt{n}}$ where $\frac{s.d.}{\bar{I}_s} = 0.278$ for this analysis and n is

the number of replicate tests. Table IIIA in the Appendix shows the estimated standard deviation associated with several mean values of the flame spread index when averages of 1, 2, 4 or 5 tests are used. Thus for four replicate tests, the flame spread index has a standard deviation of 13.9 percent of the mean.

6. DISCUSSION OF RESULTS

The base material as well as the surface finish material (and associated application materials) are important factors in the flame spread behavior of a composite test assembly. While a thick finish material almost completely masks any base material effect, the base material behavior predominates in those test assemblies with thin vinyl (M) or polyvinyl chloride (Q) films. This is readily seen in Figure 2 in which the dashed line represents the base material behavior.

Paints (U, V, W and X) and other thin coverings (C, F) in the thickness range .003 to .010 in. considerably reduced the flame spread index of base materials I, II and III. Three mil (.003 in.) aluminum foil reduced the flame spread index to 1.0. In the thickness range .010 to .050 in., higher flame spread index values were obtained with these finish materials on a fiberboard base than on the other base materials. The base material does not appreciably affect the flame spread index of an assembly in which the finish material is greater than .050 in. thick (B, H, K, L, N, O, P, R, T). Finish materials of the same general type but of different manufacture may vary considerably in flame spread characteristics (N vs O).

It can be seen from Table III that the flame spread indices for most finish materials on asbestos-cement board and on plaster are significantly lower than on other base materials, with the index for finish materials on fiberboard generally the highest. One measure of the effect of base material is given by the ratio of the flame spread index for a finish material on a fiberboard base to its flame spread index on a gypsum board base. The correlation with finish material thickness is evident from Figure 3 and Table V.

Other commonly used interior finish materials previously tested and reported[1] have been included in Table IV for comparison purposes.

Smoke measurements furnish an indication of the interference to be expected in fire-fighting or evacuation procedures during a fire rather than fire intensity or rapidity of flame spread. A smoke deposit of 1.0 mg or less is generally obtained with materials which do not evolve appreciable quantities of smoke according to visual observations. Over half the assemblies tested evolved less than 1.0 mg of smoke deposit. It was observed that finish materials on a fiberboard base generally produced greater smoke deposits than the same finish materials on plywood, gypsum board or asbestos-cement board bases. Polystyrene tile (K) evolved a very heavy quantity of sooty smoke and considerable smoke was also produced by linoleum tile (T), plastic-coated wall covering (L) and the vinyl counter top materials (N, O).

In order to present a more simple tabulation of the results, the test assemblies have been grouped according to the flame spread index data. Table VI gives a listing of the test assemblies in order of increasing flame spread values for three base materials.

It should be emphasized that the method of test measures the flame spread properties of the exposed surface of the test assembly only. Where assemblies of this type are used for application directly to studs or over other enclosed open spaces, it appears highly desirable to obtain information on the flame spread properties of the interior stud space lining as well.

ACKNOWLEDGEMENT

The authors wish to acknowledge the valuable contribution of J. M. Cameron, Statistical Engineering Section, whose statistical analysis of the test results aided considerably in its interpretation.

TABLE I. MATERIALS LIST

	SYMBOL	MATERIAL	DESCRIPTION	THICKNESS	DENSITY
				IN.	LB/FT^3
BASE MATERIAL	I	PLYWOOD	EXTERIOR TYPE DOUGLAS FIR GRADE A-C	1/4	39.0
	II	FIBERBOARD	BUILDING BOARD CLASS D FINISH	1/2	19.4
	III	GYPSUM BOARD		3/8	50.5
	IV	ASBESTOS-CEMENT BOARD		3/16	99.3
	V	PLASTER	1/16 IN. WHITE COAT; 7/16 IN. SAND BASE COAT; 3/8 IN. GYPSUM LATH	1/2	75.7
FINISH MATERIAL	A	ALUMINUM WALL TILE	LINKED WALL TILE; 4 IN. SQUARE, LIGHT GREEN	.020	161.5
	B	ENAMELED WALL COVERING	ENAMEL BAKED ON FELT BACKING; 4-1/2 IN. SQUARE TILE DESIGN, GREEN WITH DARK GREEN BORDER	.055	64.9
	C	FABRIC WALL COVERING	BAKED ENAMEL ON COTTON MUSLIN, LIGHT GREEN	.009	80.9
	D	WALLPAPER	POLYVINYL COATED, LIGHT GREEN	.008	40.3
	E	WALLPAPER 5 COATS	EMBOSSED, LIGHT GREEN	.035	41.8
	F	WALLPAPER 1 COAT	EMBOSSED, LIGHT GREEN	.007	41.8
	G	WOOD VENEER	RANDOM-GRADE OAK WOOD VENEER ON COTTON MUSLIN	.019	54.5
	H	CORK TILE	STANDARD WEIGHT TILE, 6X12 IN. NATURAL COLOR	.125	30.8
	I	WALL CLOTH	PLASTIC COATING ON COTTON MUSLIN, LIGHT GREEN	.011	70.3
	J	BURLAP	IMPORTED JUTE FIBER, NATURAL COLOR	.025	30.4
	K	POLYSTYRENE	WALL TILE, 8-1/2 IN. SQUARE, LIGHT GREEN	.075	65.4
	L	PLASTIC-COATED WALL COVERING	CLEAR PLASTIC COATING ON FELT BACKING; 4-1/2 IN. SQUARE TILE DESIGN, GREEN WITH DARK GREEN BORDER	.050	66.9
	M	VINYL FILM	SELF-ADHESIVE, KNOTTY PINE DESIGN	.004	56.6
	N	VINYL COUNTER TOP	VINYL SURFACE ON FELT BACKING, TURQUOISE	.070	83.0
	O	VINYL COUNTER TOP	VINYL SURFACE ON FELT BACKING, CARIBBEAN TURQUOISE	.062	79.8
	P	MELAMINE	BAKED MELAMINE FINISH ON MASONITE HARDBOARD PLAIN SURFACE TILEBOARD, APRIL GREEN	.150	71.8
	Q	POLYVINYL CHLORIDE	TRANSPARENT FILM	.003	69.2
	R	MELAMINE	MELAMINE-SURFACED HIGH PRESSURE LAMINATE ON HARDBOARD; LINEN FINISH, GREEN	.150	78.3
	S	ACRYLIC	TRANSPARENT SHEET	.250	74.5
	T	LINOLEUM TILE	LAMINATED TILE, 9 IN. SQUARE, MARBLEIZED GREY	.125	86.0
	U	LATEX PAINT	FLAT INTERIOR FINISH, DADO GREEN		86.5*
	V	ALKYD PAINT	FLAT, AQUA		100.0*
	W	OLEORESINOUS PAINT	FLAT, WHITE		97.5*
	X	ALKYD PAINT	GLOSS, LIGHT GREEN		77.5*
	Y	VARNISH	INTERIOR VARNISH, CLEAR COLOR		55.0*
	Z	SHELLAC	WHITE		57.6*
	DD	PROTECTED METAL	MICA-IMPREGNATED, ASPHALT-COVERED STEEL, COATED BOTH SIDES, U.S.S. 22 GAUGE FLAT STOCK, BLACK	.077	241.0
	HH	PROTECTED METAL	ASPHALT AND ASBESTOS-COVERED STEEL, WEATHER-COATED ONE SIDE, U.S.S. 22 GAUGE FLAT STOCK, BLACK	.074	241.0
APPLICATION MATERIAL	a	ENAMEL UNDERCOAT	ALKYD FLAT, WHITE		
	b	PRIMER-SEALER	ALKYD, WHITE		
	c	OIL PIGMENT	LIGHT CHROME GREEN		
	d	WALL TILE ADHESIVE	RESIN TYPE, WHITE		
	e	WALL COVERING PASTE	BROWN		
	f	SIZE	COLD WATER SIZING		
	g	WALLPAPER PASTE	WHEAT PASTE		
	h	OIL STAIN	DARK OAK COLOR		
	i	PLYWOOD CONDITIONER	CLEAR COLOR		
	j	GLUE	TILEBOARD ADHESIVE		
	k	TILEBOARD CEMENT	RESIN TYPE		
	l	LINOLEUM PASTE			
	m	LINOLEUM LINING FELT	ASPHALT-SATURATED LINING FELT		
	n	WALL TILE CEMENT	WATERPROOF WALL TILE CEMENT		
	p	WALL TILE GROUT	WATERPROOF WALL TILE GROUTING COMPOUND, WHITE		

* LIQUID DENSITY

Table II. Schedule for Preparation of Test Assemblies

Finish Material	Application Materials (in order of application to base material)	Base Materials: Plywood I	Fiber-board II	Gypsum board III	Asbestos cement board IV	Plaster V
A	n,p	x	x	x	x	
B	ℓ,m***,ℓ***	x	x	x	x	
C	f,g	x	x	x		
D	f,g	x	x	x	x	x
E*	f,g*	x	x	x		
F	f,g	x	x	x		x
G	f,g	x	x	x		
H	e	x	x	x	x	
I	f,g	x	x	x		
J	f,g	x	x	x		
K	d	x	x	x		
L	ℓ,m***,ℓ***	x	x	x	x	
M	Z	x	x	x		
N	ℓ,m,ℓ	x	x	x	x	
O	ℓ,m,ℓ	x	x	x		
P	k	x	x	x		
Q		x	x	x		
R	j	x	x	x		
S						
T	e	x	x	x		
U	i**,b	x	x	x	x	
V	i**,b	x	x	x		
W	i**,b,c	x	x	x		
X	i**,b,a	x	x	x	x	
Y	i,b	x				
Z	h,i,b	x				
DD						
HH						

* 5 coats
** Applied on plywood base only
*** Applied on plywood and fiberboard bases only

TABLE III. FLAME SPREAD AND SMOKE DEPOSIT DATA

	FINISH MATERIAL	PLYWOOD BASE		FIBERBOARD BASE		GYPSUM BOARD BASE		ASBESTOS-CEMENT BOARD BASE		PLASTER BASE	
		FLAME SPREAD INDEX	SMOKE MG	FLAME SPREAD INDEX	SMOKE MG	FLAME SPREAD INDEX	SMOKE MG	FLAME SPREAD INDEX	SMOKE MG	FLAME SPREAD INDEX	SMOKE MG
I	FABRIC WALL COVERING	18	1.9	24	2.1	4.5	<1.0				
C	FABRIC WALL COVERING	29	<1.0	25	<1.0	3.1	<1.0				
A	ALUMINUM WALL TILE	33	1.7	39	3.4	6.2	<1.0	2.4	<1.0		
N	VINYL COUNTER TOP	40	7.7	52	7.7	34.	8.1	30	6.5		
W	OLEORESINOUS PAINT	58	<1.0	18	<1.0	3.5	<1.0				
E	WALLPAPER 5 COATS	61	<1.0	116	<1.0	35.	<1.0				
F	WALLPAPER 1 COAT	64	<1.0	76	<1.0	5.6	<1.0			0.0	<1.0
V	ALKYD PAINT FLAT	69	<1.0	40	<1.0	0.8	<1.0				
P	MELAMINE	90	6.4	80	5.7	57.	4.1				
R	MELAMINE	92	3.5	122	4.7	84.	3.0				
U	LATEX PAINT	93	1.3	66	<1.0	8.9	<1.0	1.6	<1.0		
X	ALKYD PAINT GLOSS	97	1.7	108	<1.0	8.0	<1.0	1.7	<1.0		
D	WALLPAPER	98	<1.0	193	<1.0	20.	<1.0	1.2	<1.0	0.0	<1.0
B	ENAMELED WALL COVERING	110	6.0	116	4.9	67	2.1	46	2.3		
O	VINYL COUNTER TOP	121	7.9	196	8.3	97	7.6				
M	VINYL FILM	128	2.4	144	2.2	21	1.1				
T	LINOLEUM TILE	129	10.1	172	13.1	106	8.5				
Y	VARNISH	162	<1.0								
G	WOOD VENEER	163	<1.0	197	<1.0	58	<1.0				
J	BURLAP	163	<1.0	279	<1.0	108	<1.0				
Q	POLYVINYL CHLORIDE	209	<1.0	109	<1.0	23	<1.0				
L	PLASTIC-COATED WALL COVERING	293	8.2	394	8.7	253	7.0	57	4.9		
K	POLYSTYRENE	590	13.7	520	20.1	335	17.5				
H	CORK TILE	642	1.5	560	1.7	610	1.7	496	1.2		
Z	SHELLAC	832	<1.0								
	BASE MATERIAL NO FINISH	195	0.8	110	0.5	22	0.1	0.0	0.0		

Table IV. Additional Flame Spread and Smoke Deposit Data

Finish Material	Flame Spread Index	Smoke Deposit mg
Unbacked Materials		
S Acrylic	616	2.8
DD Protected Metal	1.6	< 1.0
HH Protected Metal	7.3	< 1.0
Materials Previously Tested		
Aluminum foil (.003") on plywood	1.0	0.1
Cellulose - mineral board	1.3	0.1
Mineral-base acoustic tile	10.5	0.0
Fire-retardant paint on plywood	33	1.2
Red oak	99	0.3
Perforated fiberboard acoustic tile	116	0.3
Common hardboard	136	4.1

Table V. Effect of Base Material

Finish Material	Thickness in.	Ratio $\frac{I_s \text{ on Fiberboard base}}{I_s \text{ on Gypsum board base}}$	Ratio $\frac{I_s \text{ on Fiberboard base}}{I_s \text{ on Asbestos-cement board base}}$
Q	.003	4.74	
V	.003	50.0	
W	.004	5.15	
U	.004	7.42	60
M	.004	6.85	
X	.005	13.5	57
F	.007	13.6	
D	.008	9.65	85
C	.009	8.05	
I	.011	5.33	
G	.019	3.40	
A	.020	6.29	14
J	.025	2.58	
E	.035	3.32	
L	.050	1.56	5.1
B	.055	1.73	2.4
O	.062	2.02	
N	.070	1.53	1.4
K	.075	1.55	
H	.125	0.92	1.3
T	.125	1.62	
P	.150	1.40	
R	.150	1.45	

Table VI. Summary of Results Arranged in Order of Increasing Flame Spread Index Values for Three Base Materials

Flame Spread Index Range 0-50:

Plywood Base		Fiberboard Base		Gypsum Board Base	
I	Fabric wall covering	W	Oleoresinous paint	V	Alkyd paint flat
C	Fabric wall covering	I	Fabric wall covering	C	Fabric wall covering
A	Aluminum wall tile	C	Fabric wall covering	W	Oleoresinous paint
N	Vinyl counter top	A	Aluminum wall tile	I	Fabric wall covering
		V	Alkyd paint flat	F	Wallpaper 1 coat
				A	Aluminum wall tile
				X	Alkyd paint gloss
				U	Latex paint
				D	Wallpaper
				M	Vinyl film
				Q	Polyvinyl chloride
				N	Vinyl counter top
				E	Wallpaper 5 coats

Flame Spread Index Range 50-100:

W	Oleoresinous paint	N	Vinyl counter top	P	Melamine
E	Wallpaper 5 coats	U	Latex paint	G	Wood veneer
F	Wallpaper 1 coat	F	Wallpaper 1 coat	B	Enameled wall covering
V	Alkyd paint flat	P	Melamine	R	Melamine
P	Melamine			O	Vinyl counter top
R	Melamine				
U	Latex paint				
X	Alkyd paint gloss				
D	Wallpaper				

APPENDIX

Table IA. Flame Spread Index Values for Analysis of "Order Within a Day" and "Day-to-day" Effects

Day ↓ / Order of Test →	1	2	3	4	5	6	7	8
1	L-I 228	N-II 32	B-III 67	H-IV 410	A-I 27	D-II 150	U-III 7.4	X-IV 1.0
2	N-I 47	L-II 284	H-III 580	B-IV 41	D-I 81	A-II 43	X-III 7.8	U-IV 1.6
3	B-II 137	H-I 458	L-IV 57	N-III 33	U-II 61	X-I 85	A-IV 3.2	D-III 15
4	H-II 595	B-I 112	N-IV 32	L-III 360	X-II 113	U-I 86	D-IV 1.6	A-III 6.7
5	A-III 9.9	D-IV 1.4	U-I 93	X-II 102	L-III 220	N-IV 29	B-I 91	H-II 434
6	D-III 24	A-IV 2.7	X-I 113	U-II 75	N-III 37	L-IV 51	H-I 715	B-II 79
7	U-IV 2.5	X-III 7.7	A-II 69	D-I 110	B-IV 32	H-III 686	L-II 406	N-I 39
8	X-IV 3.0	U-III 8.2	D-II 197	A-I 43	H-IV 582	B-III 58	N-II 66	L-I 408

Symbols for Test Assembly Designation:

Finish Material		Base Material	
A	Aluminum wall tile	I	Plywood
B	Enameled wall covering	II	Fiberboard
D	Wallpaper	III	Gypsum board
H	Cork tile	IV	Asbestos-cement board
L	Plastic-coated wall covering		
N	Vinyl counter top		
U	Latex paint		
X	Alkyd paint gloss		

APPENDIX

Table IIA. Analysis of Variance

(based upon common logarithm of flame spread index)
4 replicate tests on each test assembly

8 Finish Materials on 4 Base Materials

A,B,D,H,L,N,U,X

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Finish	39.4180	7	5.6311	329
Base	23.5800	3	7.8600	460
Finish x Base	12.9686	21	0.6175	36.1
Replicates (Error)	1.6412	96	0.017096	
		127		

16 Finish Materials on 3 Base Materials

C,E,F,G,I,J,K,M,O,P,Q,R,T,V,W,base materials(no finish)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Finish	39.1125	15	2.6075	202
Base	17.0332	2	8.5166	658
Finish x Base	10.3374	30	0.3446	26.6
Replicates (Error)	1.8638	144	0.012943	
		191		

If the standard deviation of a measurement, I_s, is proportional to the mean, i.e. s.d.$(I_s) = \lambda \bar{I}_s$, then the standard deviation of $\log_{10} I_s$ is given approximately by $[\text{s.d.}(\log_{10} I_s)]^2 = 0.189\lambda^2$.

On the analysis for the 8 test assemblies on 4 base materials, $0.017096 = 0.189\lambda^2$ or $\lambda = 0.30$.

On the analysis for the 16 test assemblies on 3 base materials, $0.012943 = 0.189\lambda^2$ or $\lambda = 0.26$.

For the combined analysis, $0.014604 = 0.189\lambda^2$ or $\lambda = 0.278$.

APPENDIX

Table IIIA. Estimated Standard Deviation of Mean for a Number of Replicate Tests

Mean	Number of Replicate Tests			
	1	2	4	5
1	.278	.196	.139	.124
10	2.78	1.96	1.39	1.24
50	13.9	9.80	6.95	6.20
100	27.8	19.6	13.9	12.4
200	55.6	39.2	27.8	24.8
300	83.4	58.8	41.7	37.2
500	139	98.0	69.5	62.0

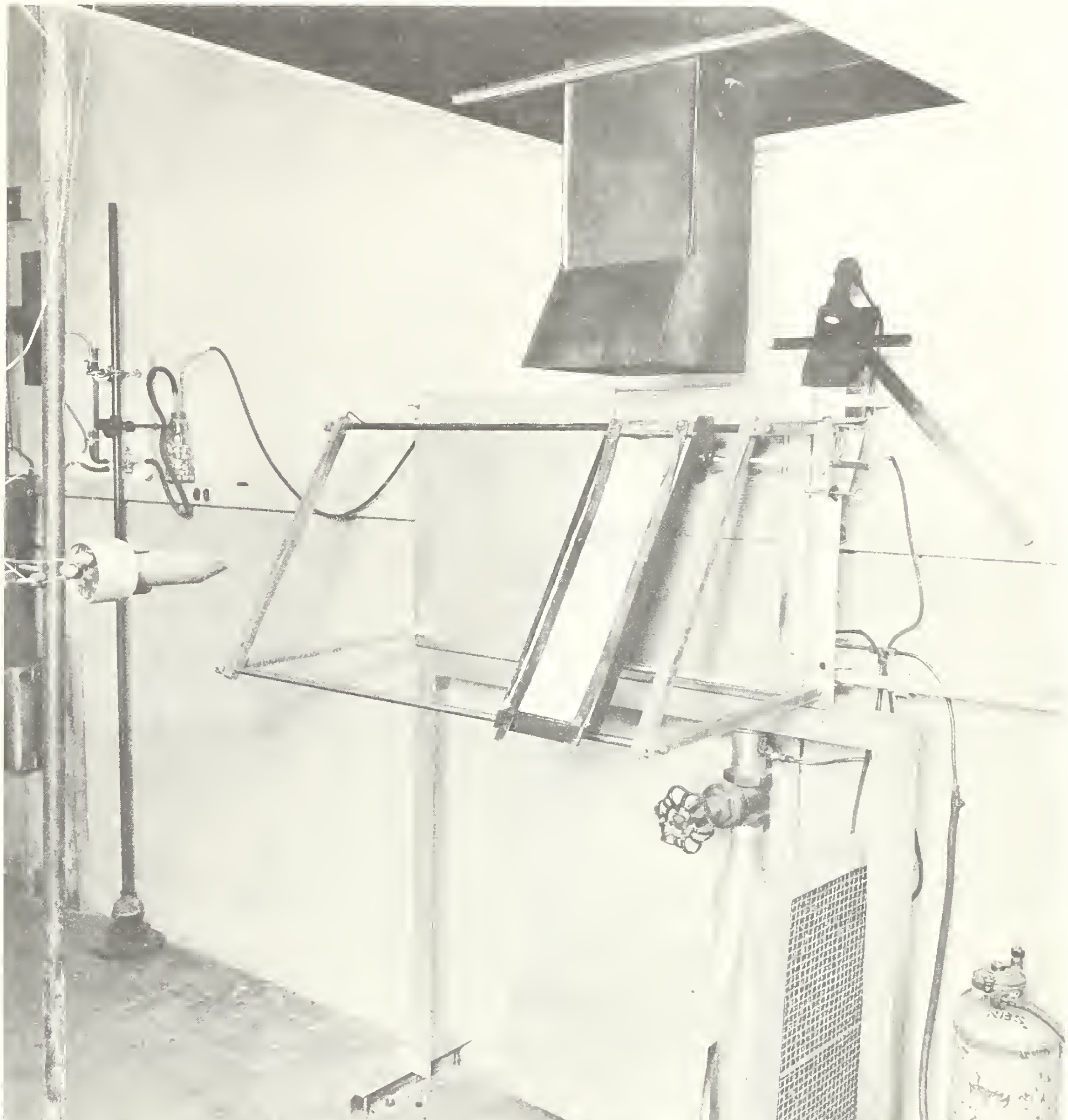

Figure 1. Radiant Panel Test Apparatus

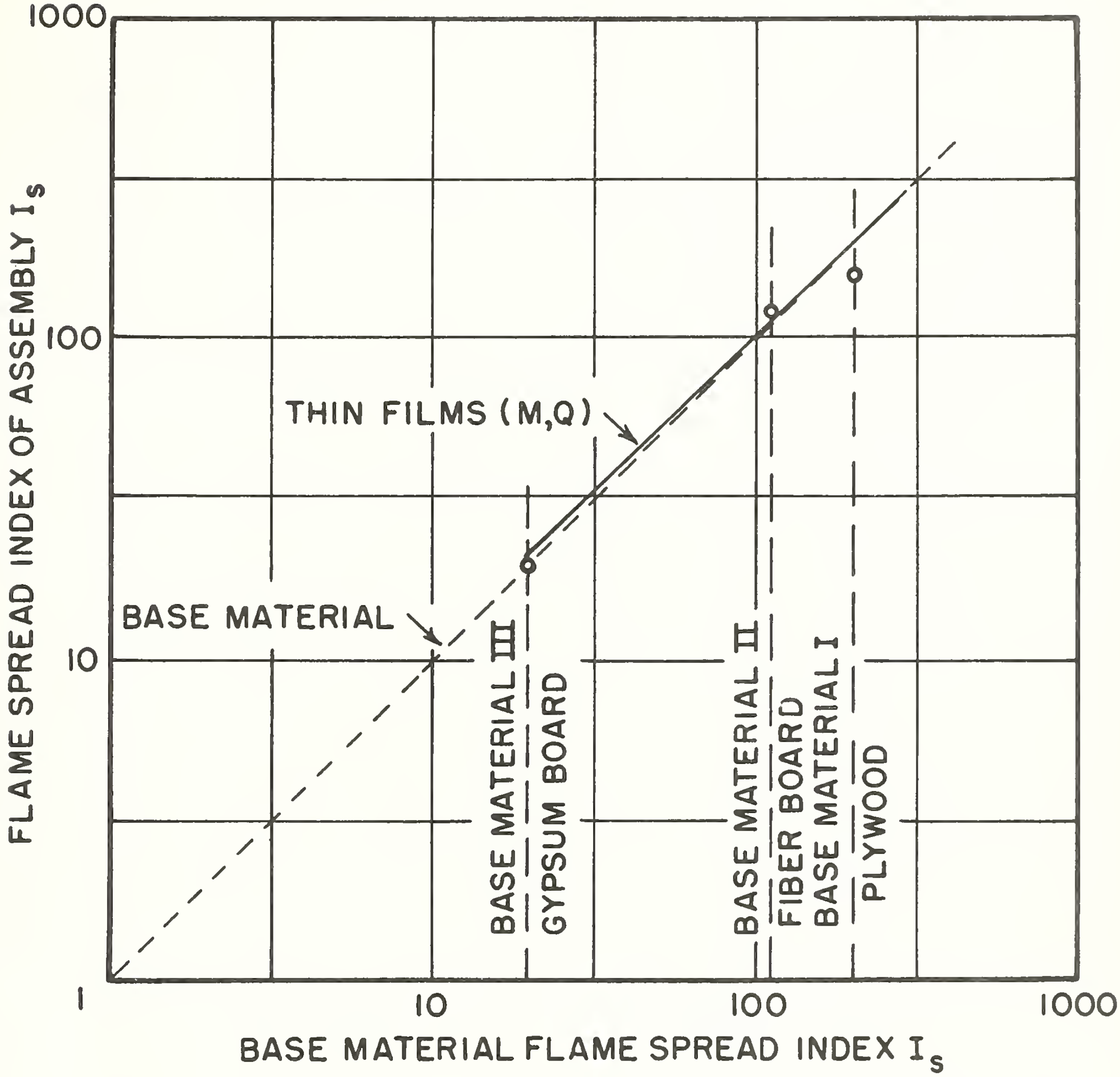

FIG. 2 COMPARISON BETWEEN FLAME SPREAD INDEX OF TEST ASSEMBLIES WITH THIN FILMS AND FLAME SPREAD INDEX OF BASE MATERIAL

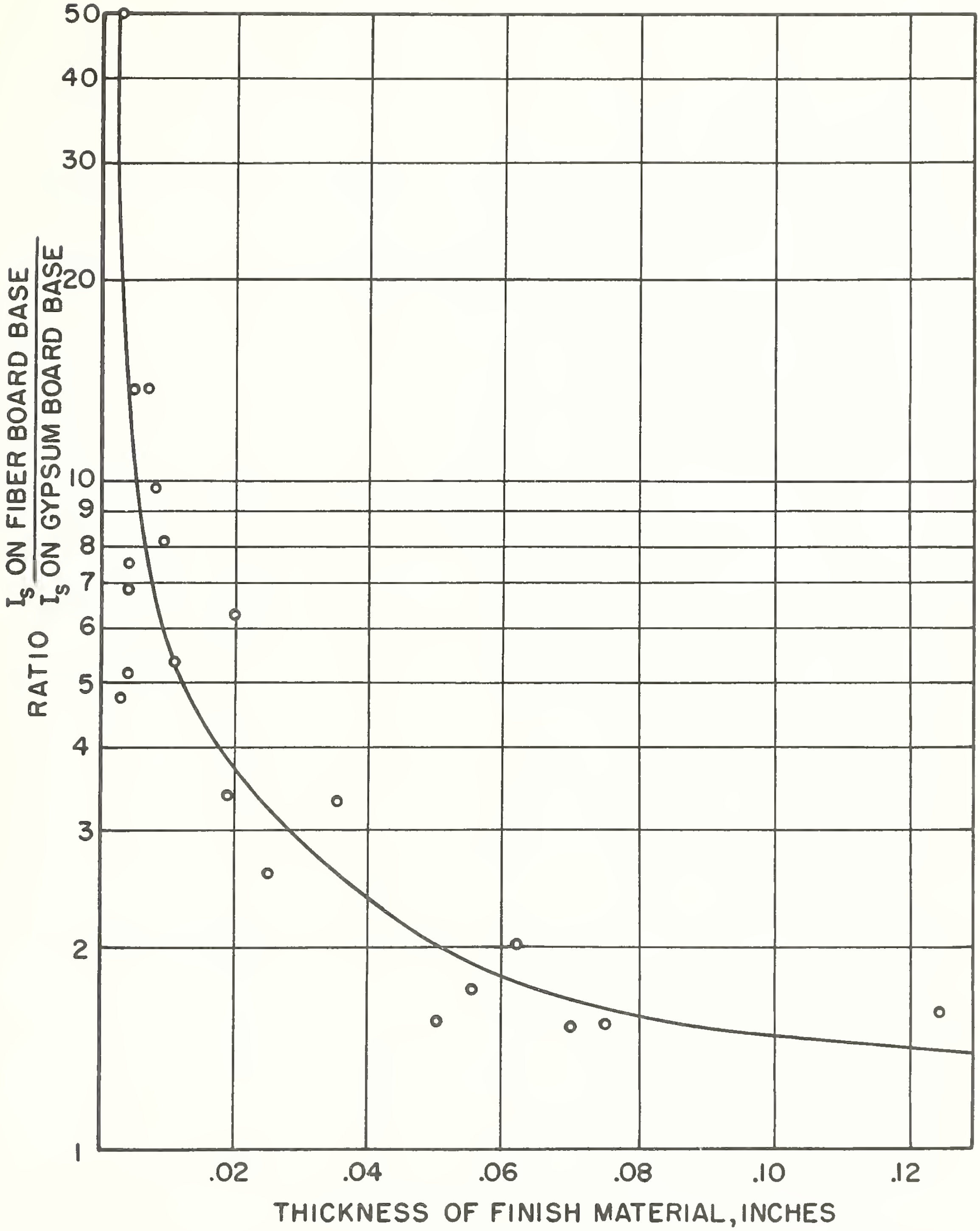

FIG. 3 EFFECT OF FINISH MATERIAL THICKNESS UPON FLAME SPREAD INDEX RATIO FOR TWO BASE MATERIALS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS