NATIONAL BUREAU OF STANDARDS REPORT

4364

A NEW TEST METHOD For EVALUATING FLAMMABILITY Of INTERIOR FINISHES

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U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

A new test method is described which permits use of relatively inexpensive and compact equipment for evaluation of the flame spread behavior of interior building finish materials by the use of specimens 6 by 18 in. in size. Flame spread index data are presented for a number of finish materials. Methods of construction and calibration of the apparatus are described in sufficient detail to permit duplication of the facility by others.

1. INTRODUCTION

The rate with which an accidental fire will develop into a full fledged fire involving a whole building depends primarily upon three major factors. In the absence of fire detection and fighting facilities, these are: a) the flame spread properties of the interior finish, b) the extent of compartmentation and degree of ventilation, c) the fuel contributed by and the manner of distribution of the building contents. It is only the first two of these over which the builder and approving agency has some control. In spite of a number of full-scale burn-out tests, references 1, 2, 3, the complexity of the problem has prevented more than a rather crude appreciation of the relative importance of the factors governing growth and spread of fires and the most practical methods of their control. Because of this, rather arbitrary methods have been adopted for evaluation of flame spread properties of finish materials and for specification of the degree of compartmentation desirable. The present discussion will be confined to methods of evaluating the flame spread properties of building finish materials.

Test methods for evaluating this property have been developed and studied both at the National Bureau of Standards and at other laboratories for many years. The Cocoanut Grove fire in 1942, however, was largely responsible for the impetus in the adoption by insurance underwriters, of the tunnel test, reference 4, as the standard fire hazard test method used by their laboratory. The method developed appears to classify many materials in an order which empirical experience has shown to be desirable. The cost of the test specimens however has delayed if not prevented its use by private manufacturers, testing, and government laboratories. Numerous smaller test methods have been developed and used by such groups. Examples of these include the flame resistance test method described in Federal Specification SS-A-118b, reference 5, the spread of flame test method of British Standard BS 476, reference 6, and the inclined panel test described in Federal Specification TTP-26a, reference 7.

The first of these was developed for evaluating certain combustible properties of acoustical tile but has frequently been proposed and used in the formulation of building codes. When used for this purpose it is a very severe test and classifies materials in only a qualitative fashion. The British test method was developed during the war as a result of their first hand experience with fire. The method suffers however in providing too mild a test as indicated by recent studies made at the Fire Research Station, reference 8. The third, intended for evaluation of paint finishes, also utilizes a comparatively mild fire exposure of the specimen, and consequently it has not generally been considered suitable for evaluation of flame spread properties of materials.

Because of these difficulties it appeared desirable to attempt development of a new flame spread test method which would involve use of only modest size specimens, be relatively compact and inexpensive to reproduce and use, and last but not least would evaluate the flame spread behavior of materials in a manner consistent with their observed performance during fires. This paper presents a description of the test method developed together with test data on representative building materials. Particular effort has been made to provide sufficient equipment design and calibration data to permit others to reproduce the test facility.

2. PRIMARY CONSIDERATIONS

During the flaming combustion of solids the combustible gases which sustain the flaming are released from the solid as a result of heat received by the solid itself. This heat may be supplied by some external source but in most cases where flaming occurs, it is largely supported by radiation from the flames and convection from the hot gases. The rate with which a flame can spread along the surface of a material with combustible content is thus largely determined by the rate with which its surface may be heated. The thermal properties and dimensions of the specimen as well as the size and character of the flames produced are therefore of considerable importance in determination of its flame spread behavior.

The wavering or turbulent characteristics of flames from a burning solid obscure the progress of volatilization of gases from the solid and consequently the spread of flame on its surface. In the past, it has therefore been considered desirable to use test specimens having at least one dimension large compared both to the length of the flames and to the fluctuation in flame length produced during burning. If, however, a controlled external source rather than flame radiation is used to supply heat to the non-flaming portion of the specimen, more accurate observations of the progress of the flame front are possible when using much smaller sizes of test specimens. Under these conditions, the rate of spread of this flame front does not include the heating effect that the flaming portion would normallly contribute to the unignited portion. Some method must therefore be devised for measurement of the heatin power of the flames and incorporation of this with the rate of spread of flame measurement.

The apparatus to be described makes use of a test arrangement similar to that suggested above. The specimen is oriented in front of a radiant heat source in such a manner that ignition takes place at the top of the specimen and the flame front travels downward. Flames rise away from the unignited portions of the specimen. Thermocouples placed in a stack above the upper end of the specimen furnish the necessary indication of the rate at which the flames would supply heat to unignited material under normal burning conditions.

3. TEST EQUIPMENT

Figure 1 presents a view of the experimental apparatus developed for performance of this radiant panel flame spread test. The essential components shown here include the radiant panel with its associated air and gas supply system, the specimen holder and framework for its support, the stack with thermocouples, the smoke sampling tube with its gas metering system, and the radiation pyrometer. Not shown are a hand potentiometer, a recording potentiometer and a decimal minute timer. A brief description will be given of each of these components.

3.1 Radiation Panel

The radiant panel consisted of a cast iron frame enclosing porous refractory material the assembly being imported from England.* The panel was mounted in a vertical plane. It was fed from the rear with a pre-mixed gas-air supply, combustion of which was nearly completed within its pores. After warm-up, the only visible flames from the panel surface were less than 1/8 in. in length. The panel approaches its equilibrium temperature of approximately 1472°F (800°C) in about one half hour after ignition. This particular panel was selected as being the only one available at the time which could operate at temperatures as high as 1472°F. It is quite possible that other types of burners or even electrical heaters would prove equally satisfactory. Electrically heated panels were not considered because of the power consumption which amounted to about 24 kw based on the total heating value of the gas supplied for combustion.

Air was supplied to the panel by means of a small centrifugal blower fitted with an air filter to prevent dust from obstructing the panel pores. Gas was premixed with air in a venturi mixer to which it was supplied at approximately atmospheric pressure.

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*The appendix includes a list of components used and in cases of special requirements or limited availability suggests a possible source of supply. It is possible however that other sources of supply while unknown to the writer do exist.

3.2 Specimen Holder

Figure 2 presents an assembly drawing of the specimen holder used for support of the 6 by 18 in. specimens. It comprised a simple device formed of sheet steel. Although low carbon steel was used in the initial holders it would probably be preferable to use a heat resisting chromium steel in their fabrication. Figure 3 presents general arrangement drawings of the radiant panel and support frame necessary for proper positioning of the specimen. An attempt has been made to show only those dimensions which should be maintained in reproduction of the equipment. The angle of the specimen and its position with respect to the panel were found to be critical and have been selected as a result of a series of tests.

These drawings also show the position of the tip of the pilot burner tube which was used to force ignition, when this was possible, at the top of the specimen. This burner consists of a short length of 3/16 in. OD by 1/8 in. ID stainless steel tubing the portion of which exposed to radiant energy from the panel was protected by an outer porcelain tube 7mm OD by 5 mm ID. It has been found necessary to replace this burner occasionally because of oxidation and residue deposits which collect on it. To cut down on the frequency of such replacement the pilot has been arranged to swing out of position when not in use.

The pilot was fed with acetylene premixed with air supplied from the radiant panel air supply blower. Use of an aspirating type fitting might prove to be a more desirable method of supplying the necessary air.

3.3 Stack and Thermocouples

Figure 3 shows the dimensions and position of the stack with respect to the specimen and radiant panel. The location of the eight thermocouple junctions are also shown. These junctions were formed by fusing the end of a twisted pair of Chromel and Alumel wires of No. 24B&S gage. The junctions were supported in position by means of porcelain insulators as shown in figure 4. The group of eight junctions were connected in parallel, their output being recorded by an automatic potentiometer recorder.

3.4 Smoke Sampling Device

The smoke sampling device consisted simply of a means for support of a single layer of glass fiber filter paper at a given position above the stack. An aspirator and rotameter were used to maintain a constant air flow rate of 40 ft/min (20.4cm/sec) at the face of the filter. The method of collecting and weighing the smoke deposit was used because of the usual difficulties experienced with sampling techniques and condensation problems experienced with optical methods of smoke measurement.

3.5 Associated equipment

A radiation pyrometer was used for standardization of the thermal output of the panel. The electrical output of this device was monitored by means of a portable hand balanced potentiometer. An automatic recording potentiometer was used for recording stack thermocouple temperature variations. The instrument used had a range of 32 - 932°F (0-500°C). A small timer calibrated in minutes and decimal fractions to hundredths was used for recording the time of occurrence of events during the tests.

4. TEST PROCEDURE

The procedure which was developed for performance of the flame spread test may be outlined as follows:

(a) Gas from the radiant panel was ignited and the unit allowed to heat for a one half hour period. At the end of this time a check was made of the radiant output by means of the radiation pyrometer placed in such a manner as to view a central panel area of about ten inches diameter. If necessary, adjustment was made in the rate of gas supply to maintain the radiant output at that which would be obtained from a black-body of the same dimensions operating at a temperature of 1292°F (700°C). The radiating characteristics of the panel used resulted in its operation at a surface temperature of about 1472°F (800°C).

(b) The recording potentiometer for measurement of stack thermocouple temperature rise was turned on and if necessary the thermocouples were cleaned by use of a brush.

(c). A new filter disk was placed in the smoke sampling tube and the air flow rate adjusted.

(d) The pilot was ignited, adjusted to provide a flame two or three inches in length, and placed in position in front of the radiant panel.

(e) A 6x18in. specimen previously conditioned to equilibrium with an ambient of $75 \pm 5°F$ and 50 ± 5 percent relative humidity was either (1) mounted in a cool specimen holder in the conditioning room and brought to the test equipment in a vapor barrier jacket, or (2) wrapped in a vapor barrier jacket, brought to the test equipment and quickly inserted in a cool specimen holder. In either case all but the thickest specimens were backed with $\frac{1}{2}$in. thick asbestos millboard of 60 lb/ft^3 density.

(f) The smoke sampling tube was placed in position above the stack.

(g) The specimen in the test holder was placed in position on the radiant panel frame and the electrical timer simultaneously started. The exposure of the specimen took place as promptly as possible after bringing it ot the test area. In most cases this was accomplished within three minutes. In no case were conditioned specimens allowed to stand in the test room for more than five minutes prior to test.

(h) Observations were continuously made of the development and spread of flaming on the specimen. Records were kept of the time of arrival of the flame front at points 2, 3, 6, 9, 12, 15 & 18 in. from the upper edge of the specimen. Notes were made of any other specimen behavior characteristics which appeared of interest.

(i) The test exposure was considered as completed when either (1) the flame front had progressed the full length of the specimen, or (2) the test exposure period of 15 minutes had elapsed. The specimen holder was then removed from the supporting frame and the specimen discarded.

(j) Measurement was made of the increase in weight of the smoke sampling filter paper disk and the maximum temperature rise of the stack thermocouples. These data were recorded.

(k) The flame spread index I_s of individual samples was calculated as the product of the flame spread factor F_s and the heat evolution factor Q, thus:

$$I_s = F_s Q$$

Where:

$$F_s = \left(1 + \frac{1}{t_3} + \frac{1}{t_6 - t_3} + \frac{1}{t_9 - t_6} + \frac{1}{t_{12} - t_9} + \frac{1}{t_{15} - t_{12}}\right)$$

here: t_3 ----- t_{15} correspond to the times in minutes from specimen exposure until arrival of the flame front at a position of 3 ----- 15 in. respectively along the length of the specimen.

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

here: $\Delta\theta$ is the observed maximum stack thermocouple temperature rise in degrees Fahrenheit over that observed with an asbestos cement board specimen, and β, a calibration constant, is defined by the slope of the calibration curve for the stack thermocouple temperature versus heat input rate in units of degrees F min/BTU.

5. CALIBRATION PROCEDURES

The calibration procedures used during development of the test method were of two different types. First, certain procedures were found to be necessary for standardization of the test method to permit reproducibility of test results. These will be designated as "standardization procedures". Secondly, a series of tests were performed in an effort to determine the sensitivity of the test method to small changes in orientation or assembly of the test equipment. These studies will be described under the title of "procedural variations".

5.1 Standardization Procedures

The radiant output of the panel was monitored continuously between tests by means of the radiation pyrometer. Adjustments in gas flow rate were frequently, though easily made. As previously mentioned this radiant output rate was maintained at that of a blackbody radiating at a temperature of 1292°F (700°C).

The smoke sampling tube and associated connections were checked periodically by use of an impermeable diaphragm in place of the filter disk. Any flow that could be measured with the inlet thus blocked was a sure indication of leaks. On several occasions leaks were detected by this means. Such leaks are serious as the filter resistance to gas flow is not negligible and leaks would therefore result in low recorded smoke weight.

Periodic checks were made of the temperature rise produced by placement of an asbestos-cement board specimen in position while both the radiant panel and pilot burner were in operation.

No test method was devised to check for objectional deposits of combustion products on the thermocouples other than periodic inspection. For most cellulosic materials tested it was found that inspection and brush cleaning of the thermocouples was desirable at least once every two weeks of operation for eight hours a day. When testing hardboard specimens as well as plastics the smoke production rate required much more frequent attention to this detail.

Calibration of the stack thermocouples was only infrequently done. This calibration was performed by means of a diffusion flame from a multiported burner. This burner (ten No. 50 drill holes spaced 5/8 in. on centers in a 1/4 in. standard pipe) was placed in a horizontal position one inch below the upper edge of an asbestos-cement board specimen during normal panel operation. From observations of the maximum stack thermocouple temperature rise as a function of heat supply rate to the test burner the value of β in the flame spread index formula was measured. For the equipment used here β was found to be equal to 0.90 degrees F min/BTU. Figure 6 presents a plot of data obtained on the equipment used. There was no indication that this measurement required frequent checking.

One other calibration was performed to provide an indication of the heat input rates at the specimen surface. This involved radiometer measurements at various positions along the specimen length. The measurement was made by the use of a small copper disk radiometer fitted in one opening at a time of a series of apertures on an asbestos millboard specimen. The radiant panel was in operation but the pilot was not burning during these measurements. Figure 7 presents a calibration curve obtained in this way. It should be noted that the energy flux measured and indicated here was the sum of both the radiant flux and that arising from convection effects.

5.2 Procedural Variations

A number of tests were performed for the purpose of determining the extent to which design features of the equipment were critical

The position of the specimen relative to the radiating face of the panel was found to be critical. This position determines the energy flux at the specimen surface. While measurements were not made on the effects of changes in positioning, it appears likely that the dimensions indicated in figure 3 should be maintained to a tolerance of less than 1/8 in.

The technique used for calibration of stack thermocouples was selected to reduce the effects of slight differences in design or positioning of the parts of the apparatus. Figure 8 presents data on the effect of stack position on thermocouple temperature rise for both a typical specimen (fiberboard No. 8) and the calibration burner. It is evident that the observed thermocouple termperature rise does not require exact maintainance of the selected two inch spacing. Although this behavior of fiberboard is typical of all materials tested the same insensitivity is not observed when the calibration burner is used as a heat source. This probably results from differences which exist in the manner of heat release in the two cases. Changes in vertical position of the stack and their effect on thermocouple temperature rise measured during test of specimens were not investigated. It is expected however that the data would be quite similar to that shown in figure 8 for the calibration burner.

The importance of position of the pilot flame was studied. It was shown that the size of this flame and its position with respect to the face of the specimen were not critical as long as the flame remained in contact or at most not more than one half inch from the surface of the specimen.

Conditioning of the specimen prior to test was important as evidence by data obtained for fiberboard specimen No. 8. Flame spread index values of 353, 236 and 156 were measured for specimens conditioned to have 1, 7 and 12 percent moisture respectively. These moisture equilibrium contents correspond to widely different ambient relative humidity conditions. Because of this and the shape of the moisture equilibrium versus relative humidity curve for materials such as these, the effect of small changes from the standard conditioning temperature and humidity would not be expected to result in flame spread index changes proportional to those indicated above.

A study was made on the effect of variations in draft conditions on the measured flame spread index. Most of the test results reported in this paper were obtained while the furnace was operating under a 2 by 4 ft hood the exhaust blower of which was in operation. The air flow rate was over 600 ft^3/min through this hood. Table I presents average flame spread index data from tests of two specimens of each of four different materials. These tests were performed both with and without operation of the exhaust fan. It will be observed that when proper calibration has been made and used in flame spread index calculation, the test results are very similar for the two test conditions. Even when the results are not corrected for change of thermocouple calibration the flame spread index is changed by a factor of only about ten percent.

The apparent contradiction to this generalization, presented by the data for specimen 21 is believed to have been caused by nonuniformity of the specimens and the limited number of samples tested.

6. DISCUSSION

The test method has been used to evaluate the flame spread properties of more than 60 different materials. Data on the behavior of 29 of these are included in table II. The materials are listed in order of decreasing flame spread index. The constant in the flame spread index relation was arbitrarily chosen to yield a value of approximately 100 for red oak. Included in this table are data on all materials thus far studied for which Underwriter tunnel test data were available as a result of tests performed on samples from the same material batch. The flame front progression along the surfaces of various specimens is shown in Figure 9. The numbers on the curves correspond to specimens described in table II.

Brief study of the data presented indicates that the method selected for calculation of the flame spread index results in a numerical grading of specimens which is in general accord with experience. Furthermore, for flame spread index data above about seven and with the exception of data for plastic materials, there appears to be a fair degree of correlation between the classification of materials by both the radiant panel and tunnel test methods, figure 10. The flame spread index values resulting from tests of the three plastic materials were only about one half the classification figures assigned on the basis of tunnel tests. Specimen 32 (plastic A) did not exhibit sustained flaming and only periodic flashes were observed in the gases leaving the specimen.

The plastic samples tested had aged under normal ambient conditions for a period of 3 to 14 months subsequent to the performance of tests at Underwriters' Laboratories. A number of the materials were tested by the horizontal panel test described in Federal Specification SS-A-118b with the results shown. It is evident that this method of test does not measure the same surface flame spread property as evaluated by the radiant panel or tunnel test methods.

Experimental results of tests by the British Spread of Flame test are not available on the materials in table II. However, reference 8 presents the results of a study of flash-over times observed during a series of tests with model rooms which were finished with a wide variety of materials some of them apparently similar to those tested here. These latter have been listed in table II. It will be observed that the order in which the materials are classified is similar to that achieved with the radiant panel test method. The model test method however appears to show little difference in unfinished fiberboards whereas the method of interpretation of the radiant panel and tunnel results shows flame spread indices varying from 121 to 336.

The flaming behavior of the specimens might be selected as an indication of low, intermediate and high flame spread characteristic. Thus specimens with a flame spread index of less than four rarely exhibited sustained surface flaming. In the index range of 4 to 140 sustained flaming usually occurred only over a portion of the specimen. For flame spread indices above 140 flaming occurred over the full specimen length during the 15 min test period.

The flame spread characteristics evaluated are only those of the exposed surface of the specimen. Evidence of this is provided by specimens 8, 13, 9, 12, 11, 14 and 15 which all incorporate essentially the same $\frac{1}{2}$ in. fiber board backing and yet with the varying types of surface treatment exhibit flame spread index values ranging from 244 down to 1.2. This should provide ample evidence that consideration must be given to the maintenance of an unbroken protective surface on the material when used as finish material. In cases where materials such as the one in question are used for application directly to studs or over other enclosed open spaces it appears highly desirable that both surfaces be treated in the same fashion. In cases such as this, Underwriters' Laboratories handles the problem by specifying that the classification assigned is only applicable when the finish is applied over a solid backing.

Some appreciation of the reproducibility of the test method may be derived from the data presented in table III. Here, s, the coefficient of variation (the standard deviation expressed as a percentage of the mean value of the flame spread index) is shown for four different materials. The value of s has been computed from the individual values of the flame spread index for the replicate tests performed. It will be noticed that s for specimen No. 8 is very nearly of the same magnitude for a series of tests performed on a single day as compared to the value for tests run over a period of time, in this case 120 days. Thus the major portion of the variability of test data appears to be a result of variations, either between specimens, or in the test method itself within a single day. The nearly constant size of the coefficient of variation for the fiber board specimens No. 8, 23, and 28 provides an indication of its relative independence of flame spread index for such materials over the range of 121 to 278. The value of s = 18.5 percent for red oak specimens which were selected to cover a range of densities appears to indicate the increase in variability of the samples themselves.

The data shown for both calibration burner and fiber-board specimen in figure 8 make it quite clear that the calibration method used should not be considered as providing an absolute calibration of heat output rates of materials. The refinements necessary to achieve this objective were considered inappropriate for the application intended.

Smoke measurements are also reported in table III. These are reported as milligrams of smoke deposit for the volume flow rate maintained during the period of test. The results are also presented on a relative basis using a value of 100 for red oak which is the standard used by Underwriters' Laboratories. There appears to be a general correlation although big differences are observed in several instances. For materials exhibiting low flame index data the radiant panel test method appears to result in higher observed smoke release rates than result with use of the tunnel test method.

The test method described appears to present a simple reproducible method of measuring the flame spread behavior of building finish materials. The method of presentation of test results was arbitrairly selected to yield classification numbers somewhat similar to those reported by Underwriters' Laboratories on the basis of tunnel tests. Because of the lack of quantitative data on, and the intangible nature of, the flammable "hazard" of materials, it is not at present possible to define the exact relation which exists between flame spread index and the actual hazard of the material.

CONCLUSIONS

The following conclusions seem justified on the basis of the work reported:

1. A new flame spread test method has been devised for evaluation of the flammability characteristics of interior finish materials.

2. The new test method involves the use of comparatively inexpensive and compact test equipment and requires test specimens of but 6 by 18 in. size.

3. A method for expression of test results has been devised which appears to classify materials in an order similar to that indicated as desirable from experience with such finish materials.

4. With the exception of data on a few materials there appears to be a general correlation between the flame spread results as obtained by the radiant panel and tunnel test method over the flame spread index range of 10 to 280.

APPENDIX

List of components used with a possible source of supply for those of special requirements or limited availability.

1. Radiant panel -- 12 in. by 18 in. type 1 surface combustor, manufactured by Radiant Heating Ltd., Barnsbury Park, London N.1, England.

2. Radiation pyrometer -- Miniature Radiamatic, Series 939A4, with special extension tube, manufactured by Minneapolis-Honeywell Regulator Company, Philadelphia 44, Pennsylvania.

3. Glass fiber paper -- Type 1106BH All-Glass Filter Media, distributed by Mine Safety Appliances Co., 201 N. Braddock Ave., Pittsburgh 8, Pennsylvania.

4. Potentiometer recorder -- Range: 0 to 1000°F.

5. Portable potentiometer -- Range: 0 to 5mv (corresponding to temperature range: 0 to 1900°F with radiation pyrometer listed above).

6. Flowmeter -- Capacity: 7000 cc air/min.

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TABLE I

EFFECT OF EXHAUST DRAFT CONDITION
On
FLAME SPREAD INDEX RESULTS

Specimen No.	Material	Flame Spread Index **		
		Fan On	Fan Off	
			Corrected	Uncorrected†
28	Fiberboard "A"	278	281	256
23	Hardboard Common "M"	114	116	105
21	Fiberboard "C"	61*	85	77
26	Gypsum Board "G"	4.7*	4.6	4.2

** Average flame spread index for two specimens. All tests run on same day.

† Flame spread index based on calibration data for stack thermocouples with fan on.

* Differences between test results and data shown in Table II result from limited number of samples tested and variations between samples.

TABLE II RADIANT PANEL FLAME SPREAD DATA

No.	Material	Material Property			Flame Spread Data		
		Nominal Thickness	Bulk Density	Moisture*	No. of Tests	Flame Spread Index I_s	Coeff. of Variation s
		in.	lb/ft³	%			%
17	Fbd. Perf. Tile, Finish Removed	1/2	15.7	5.4	5	336	14.7
28	Fbd. "A" (FPL)	1/2	20.0	8.0	6	278	5.1
8	Fbd. "J" Unfinished	1/2	18.0	7.0	9	236	5.0
30	Plywood Unfinished Exterior Fir	1/4	42.3	6.8	4	143	32.2
18	Hardboard Common "H"	7/32	59.8	3.8	5	136	12.4
23	Hardboard Common "M" (FPL)	1/4	63.5	3.8	6	121	6.9
16	Fbd. Perf. Tile	1/2	16.7	5.8	5	116	13.6
13	Fbd. "J" + Paint A 250 ft²/Gal	1/2	18.3	6.5	5	107	44.0
24	Red Oak (FPL)	3/4	40.0	6.5	5	99	10.9
21	Fbd "C" (FPL)	1/2	19.7	6.0	5	94	18.3
9	Fbd "J" Factory Finish	1/2	20.2	6.6	5	83	15.9
12	Fbd "J"+ Paint B 250 ft²/Gal	1/2	17.0	6.2	5	59	17.2
34	Plastic "C"	1/8	81.5		5	56	8.4
11	Fbd "J"+ Paint B 125 ft²/Gal	1/2	17.8	6.9	5	27	26.0
33	Plastic "B"	1/8	98.0		5	30	19.5
26	Gypsum Board "G" (FPL)	3/8	50.5		5	14.3	44.5
3	Gypsum Board "K"	3/8	47.4		5	13.3	29.9
6	Mineral Base Tile	3/4	19.3	3.4	5	10.5	60.0
25	Gypsum Board "L"	1/2	51.2		4	7.9	105.0
32	Plastic "A"	1/8	89.4		5	4.0	42.3
22	Fbd "I" Fire Retardant Finish (FPL)	1/2	19.0	6.4	5	4.5	53.8
14	Fbd "J"+ Mineral Spray	1/2	21.9	7.7	5	3.4	28.9
7	Glass Fiber Batt	1	4.3	1.2	5	1.8	60.5
2	Cellulose Mineral Board	7/8	47.8	7.5	5	1.3	48.6
5	Glass Fiber Tile	3/8	10.3	0.6	5	1.2	77.7
15	Fbd "J"+ 1/8" Mineral Surface	5/8	42.2	7.5	5	1.2	50.7
31	Plywood Fir Ext. + Aluminum Foil	1/4	41.6	6.3	3	0.9	65.7
4	Glass Fbd.	2	11.0	0.4	5	0.6	37.3
1	Asbestos Cement Board	3/16	117.0	0.6	5	0	

(FPL) Designates materials received from Forest Products Laboratory
* Based on weight after drying at 221°F (105°C)
† Tests on same materials but samples from other batches.
Fbd. Fiberboard
Perf. Perforated

TABLE II CONTINUED

Flame Spread Data				Smoke Data			No.
Flame Spread Index I_s	UL Flame Spread Factor	SS-A-118b Classification	Flash-over Time (British)	Deposit	Based on Red Oak	UL Smoke Factor	
			min	mg			
336				0.1	30		17
278	285		5.00	0.4	130	357	28
236				0.2	70		8
143		D		0.3	100		30
136				4.1	1400		18
121	113	D	6.15	5.2	1700	1900	23
116				0.3	100		16
107				0.4	130		13
99	100	D		0.3	100	100	24
94	77	D		0.2	70	94	21
83				0.2	70		9
59		D		0.6	200		12
56	130			9.7	3200	752	34
27			10.35	0.9	300		11
30	60			5.7	1900	368	33
14.3	10	C		0.0	0	0	26
13.3				0.1	30		3
10.5	10†			0.0	0		6
7.9	12.8		16.36	0.1	30	17	25
4.0	20			3.3	1100	556	32
4.5	14	D		0.5	170	14	22
3.4				0.2	70		14
1.8				0.2	70		7
1.3	9-10†		16.45	0.1	30	0†	2
1.2	10-15†			0.3	100		5
1.2		C		0.2	70		15
0.9		D		0.1	30		31
0.6		B		0.2	70		4
0	0	A	17.10	0.0	0		1

TABLE III

Reproducibility of Test Data

Specimen		Tests on one Day		Tests of a Period of Month	
No.	Material	No. Specimens	Coefficient of variation	No. of Specimens	Coefficient of variation
24	Red Oak	5	10.9%		
19	Red Oak*			19	18.5%
23	Hardboard	6	6.9		
28	Fiberboard "A"			8	8.8
8	Fiberboard "J"	8	5.1	9	5.0

* Includes data on samples covering a density range of 30.7 to 46.9 lb/ft^3

Figure 1
Radiant panel flame spread test equipment.

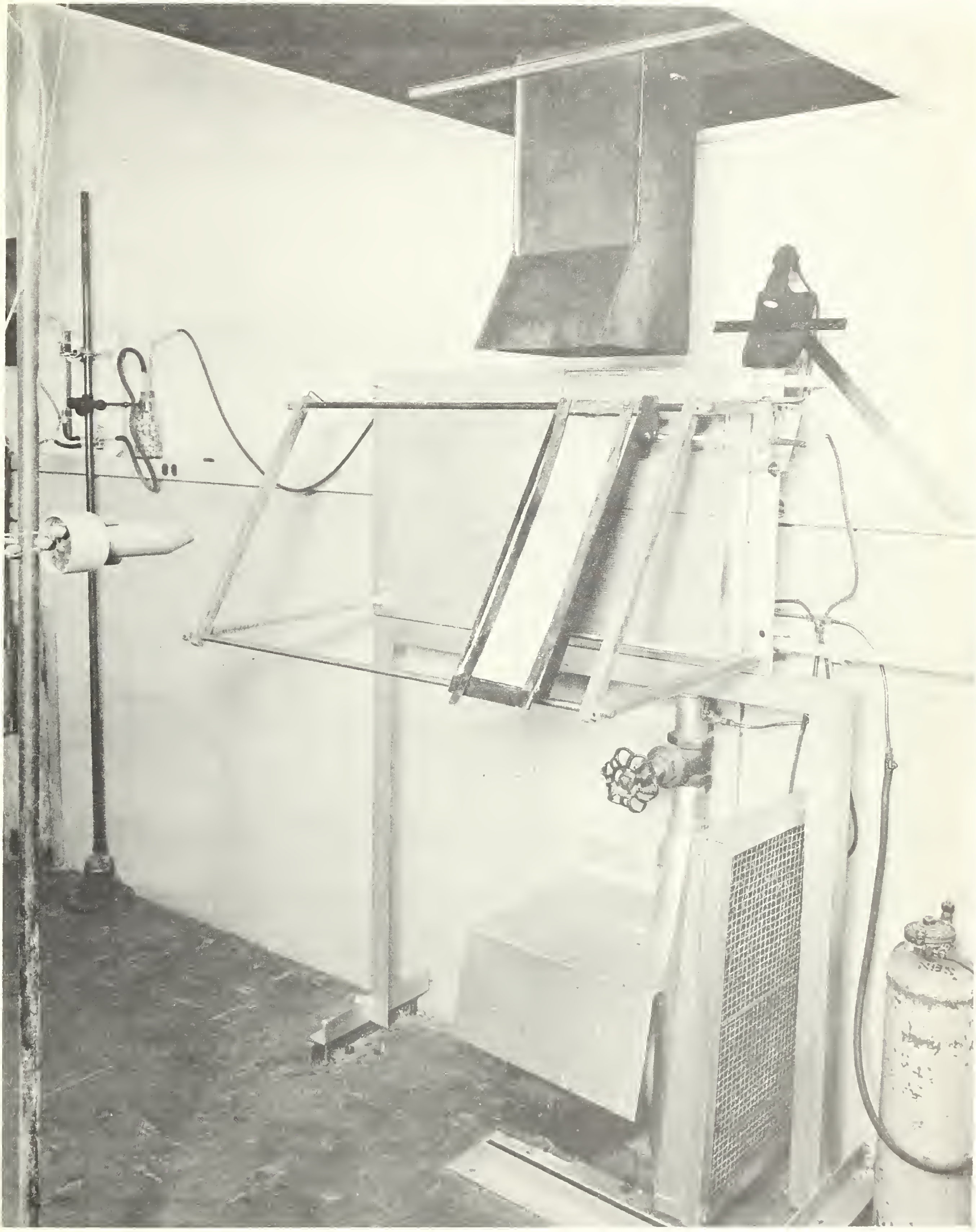


Figure 1

Figure 2

Specimen holder.

Figure 4

Detail of thermocouple mounting arrangement.

Figure 5

Smoke sampling tube and parts.

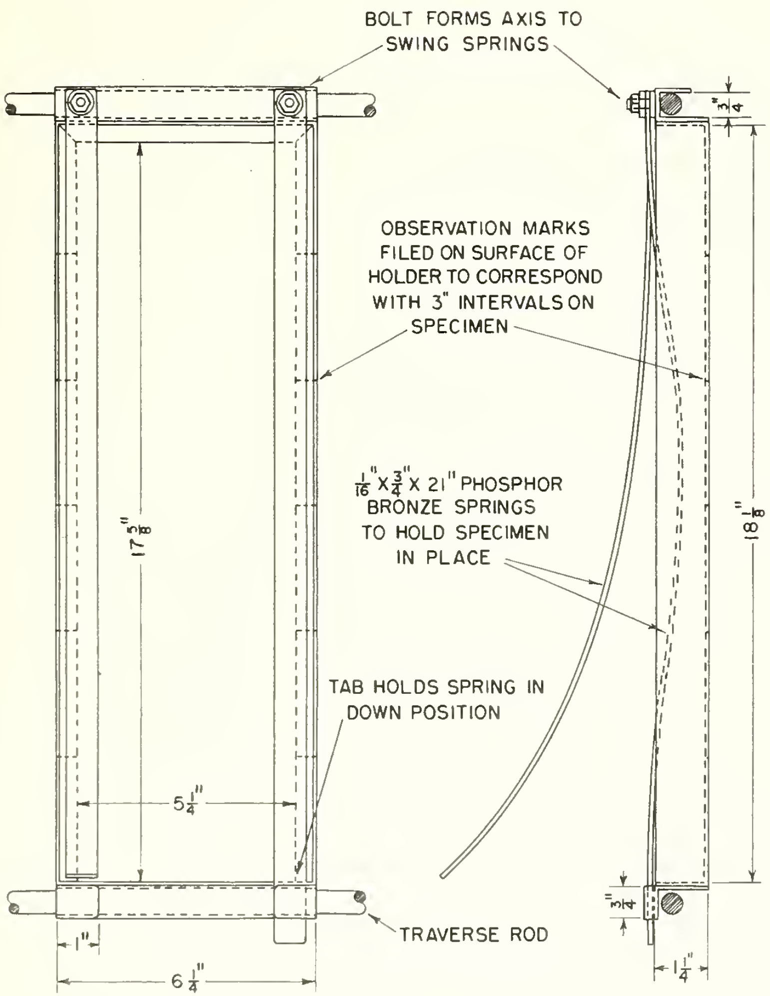


FIGURE 2

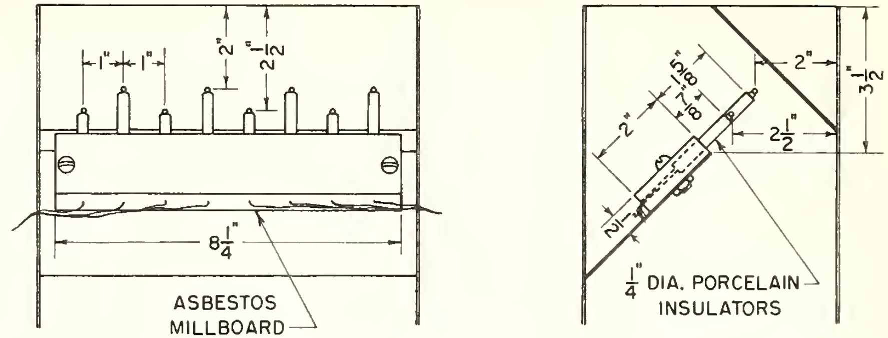


FIGURE 4

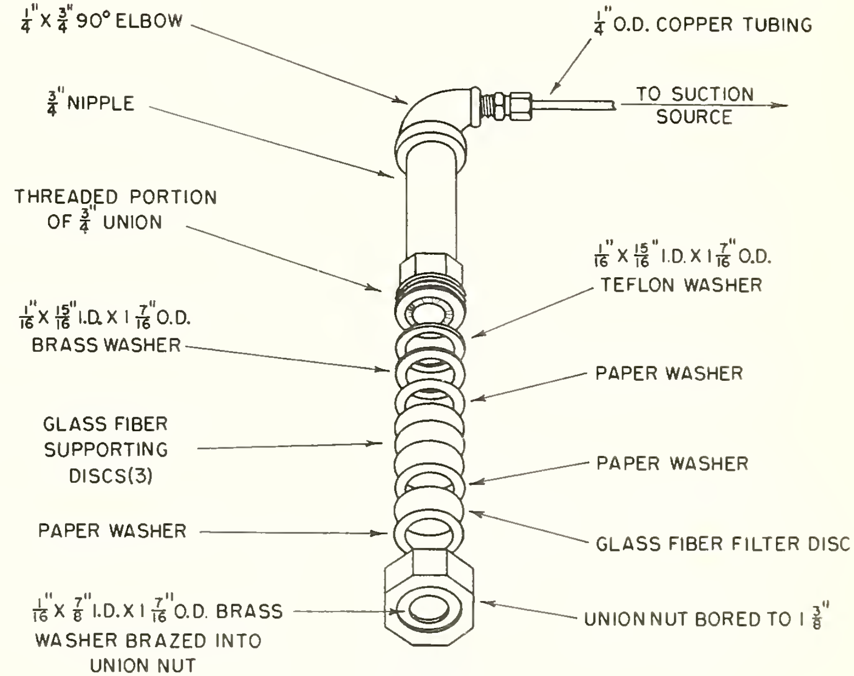
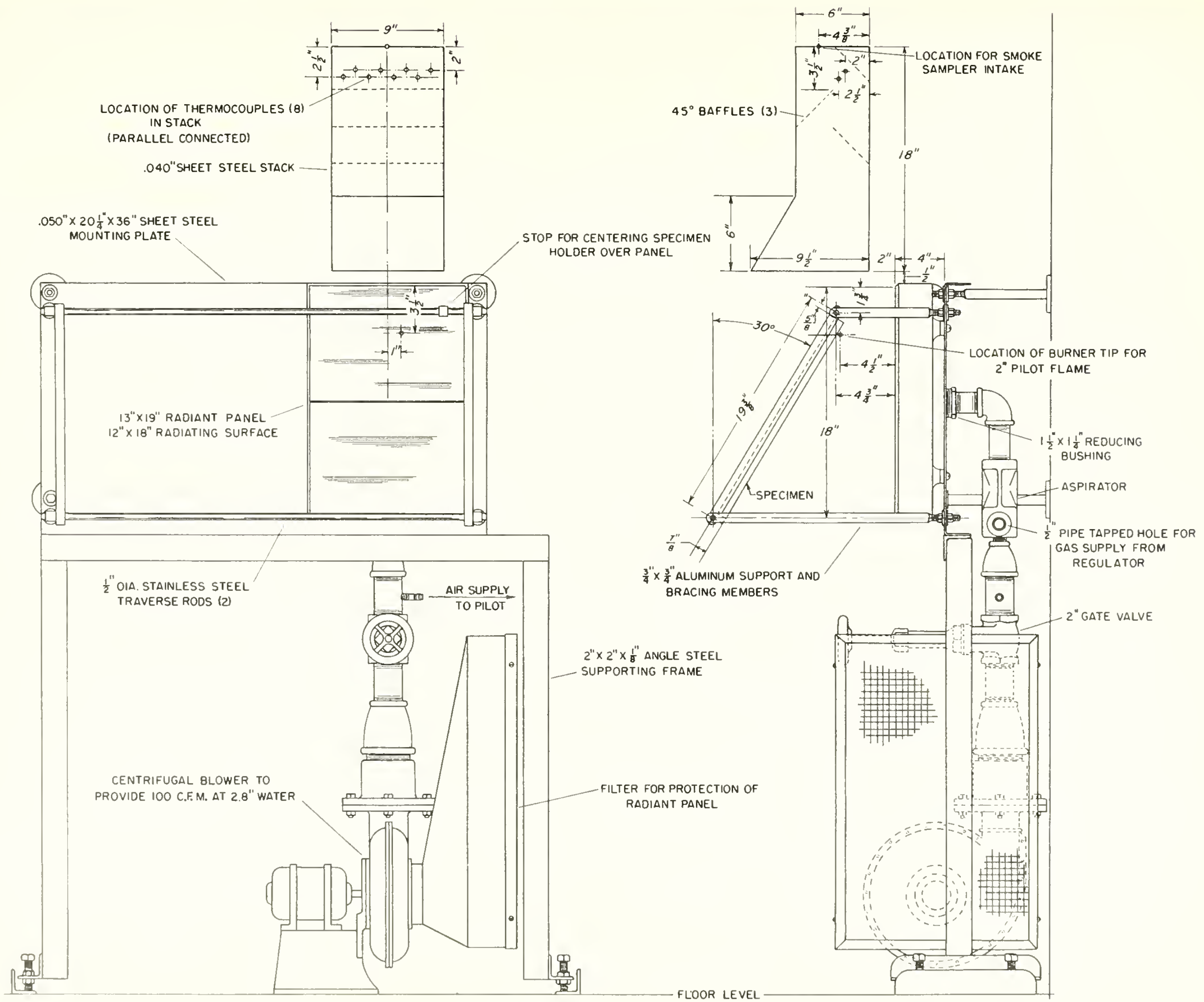


FIGURE 5

Figure 3

Drawing of test equipment
showing important dimensions



LOCATION OF THERMOCOUPLES (8) IN STACK (PARALLEL CONNECTED)
.040" SHEET STEEL STACK
.050" X 20 1/4" X 36" SHEET STEEL MOUNTING PLATE
STOP FOR CENTERING SPECIMEN HOLDER OVER PANEL
13" X 19" RADIANT PANEL 12" X 18" RADIATING SURFACE
1/2" DIA. STAINLESS STEEL TRAVERSE RODS (2)
AIR SUPPLY TO PILOT
2" X 2" X 1/8" ANGLE STEEL SUPPORTING FRAME
CENTRIFUGAL BLOWER TO PROVIDE 100 C.F.M. AT 2.8" WATER
FILTER FOR PROTECTION OF RADIANT PANEL
FLOOR LEVEL
LOCATION FOR SMOKE SAMPLER INTAKE
45° BAFFLES (3)
LOCATION OF BURNER TIP FOR 2" PILOT FLAME
1 1/2" X 1 1/4" REDUCING BUSHING
ASPIRATOR
SPECIMEN
1/2" PIPE TAPPED HOLE FOR GAS SUPPLY FROM REGULATOR
3/4" X 3/4" ALUMINUM SUPPORT AND BRACING MEMBERS
2" GATE VALVE
9"
2"
2 1/2"
3 1/2"
1"
6"
4 3/8"
18"
9 1/2"
4"
1/2"
30°
4 1/2"
4 3/4"
19 3/8"
5/8"
7/8"

FIGURE 3

Figure 6

Typical stack thermocouple calibration curve.

Figure 7

Energy flux incident at specimen surface.

Figure 8

Effect of position of stack on thermocouple temperature rise.

Figure 9

Progress of flame along specimen length for several materials. (Numbers correspond with specimen number in table II).

Figure 10

Comparative data from two different flame spread test methods.

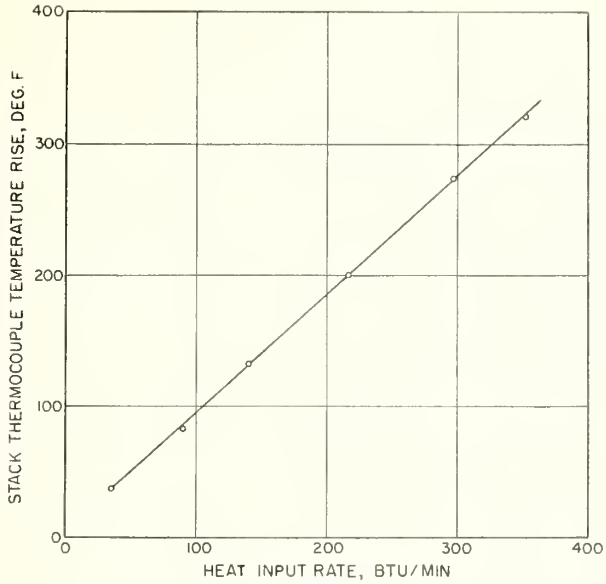


FIGURE 6

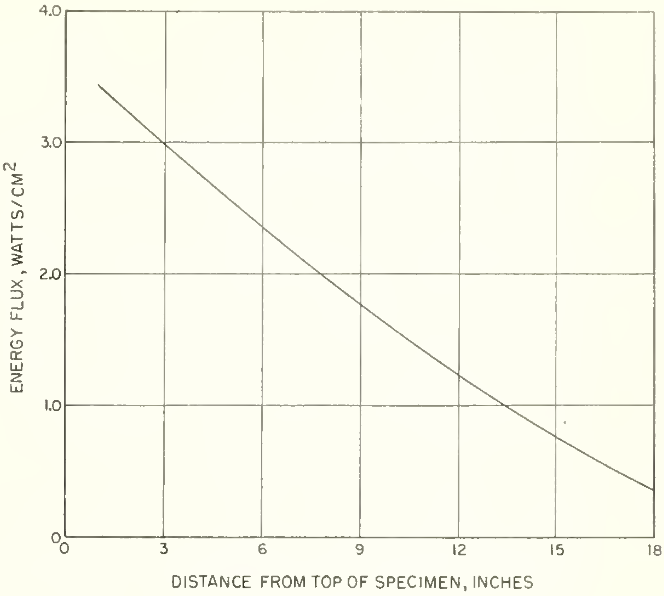


FIGURE 7

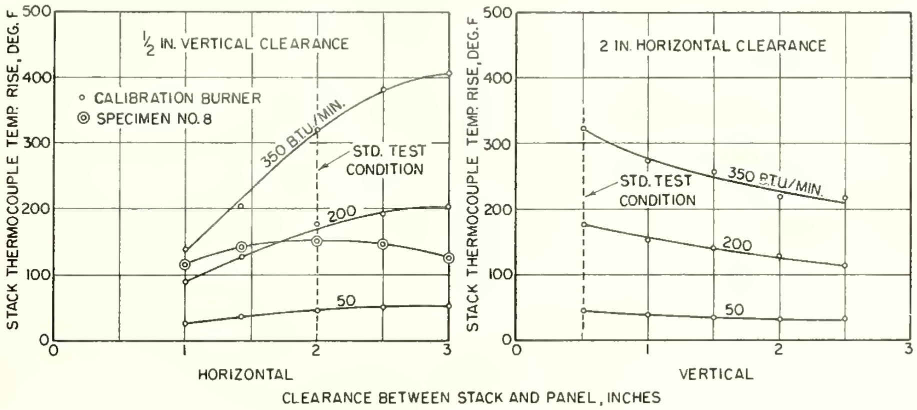


FIGURE 8

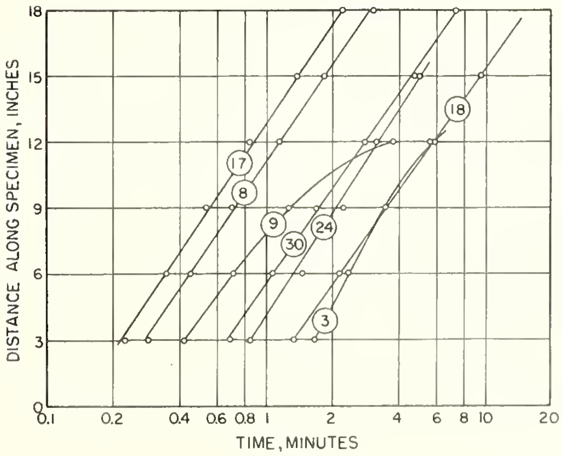


FIGURE 9

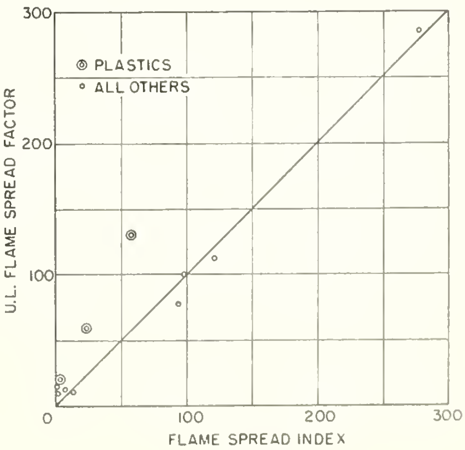


FIGURE 10

THE NATIONAL BUREAU OF STANDARDS

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