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NATIONAL BUREAU OF STANDARDS REPORT

3767

METHODS OF TESTING FABRICS

FOR

HAZARDOUS FLAMMABILITY

by

Janet C. Rountree

U. S. DEPARTMENT OF COMMERCE
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Methods of Testing Fabrics for Hazardous Flammability

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Janet C. Rountree

Abstract

Four existing methods of evaluating the flammability hazard of clothing fabrics are described. By deviating slightly from the standard proceduresand by varying the conditioning of the samples, an attempt has been made to correlate and compare the usefulness of these instruments in a series of parallel tests. On the basis of the results of these tests, recommendations are made regarding a practical testing instrument.

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1. INTRODUCTION

Accidental fires with clothing fabrics, some of them resulting in severe burns to the wearer, have prompted several attempts to protect the consumer by banning unusually hazardous fabrics. To define "unusually hazardous", the burning rate of various common cloths has been measured with specially designed equipment. It is generally agreed that the most hazardous condition is represented by a dry fabric in the vertical position, but in laboratory tests other conditions are often selected for ease and accuracy of observation.

As a result, three or four testing methods have come into common use, each with its individual classification of fabrics according to degree of flammability. However, little or no effort has been made to correlate the results obtained by these methods, or to compare them as to efficiency and reliability. The present study is a brief exploration into the possibilities of such correlation and comparison.

2. TEST SPECIMENS

Eight different fabrics were selected to be tested, representing as wide a range of weight and composition as feasible. These were: cotton flannel, brushed rayon ("torch sweater"), muslin, tufted chenille (tufted in one direction only), satin, acetate, cotton print cloth, wool worsted (undyed), and Japanese silk. This range of samples included animal, vegetable and synthetic fibers, different types of surface finish, coarse and fine weaves, and weights varying from 0.53 to 10.83 ounces per square yard.

3. APPARATUS

Four instruments were chosen for comparison, two of them accepted standards and two of them research tools which have not been widely used.

3.1 Inclined Test (See Figure I)

The test basis of Commercial Standard 191-53(1) which was later incorporated into the Flammable Fabrics Act (2), this apparatus provides for a 2 in. x 6 in. sample to be supported at a 45° angle in a ventilated case. A small gas-jet flame is applied automatically for one second to the surface of the fabric near the base of the specimen, and the time for the flame to travel 5 in. is measured by an automatically-controlled stop watch. In general, any fabric for which this time is less than 4 sec., is classed as of hazardous flammability. Two other classes, Normal and Intermediate Flammability, are also defined by the Commercial Standard.

3.2 Horizontal Test (See Figure II)

Originally developed by the National Bureau of Standards, this apparatus is described in Federal Specification CCC-T-191b (3) as Method 5906. It consists of a cabinet containing a Bunsen burner and a horizontal track for the 4 in. x 12½ in. specimen holder. Two strip heaters and an immersion thermometer assist in control of the inside temperature. The loaded specimen holder is slipped into place with the edge of one end of the specimen over the burner, and the time for the flame front to travel 10 in. is recorded with a manually operated stop watch. If this time is less than 10 sec., the fabric is classified as hazardous (4).

3.3 Vertical Test (See Figure III)

This instrument was developed in the laboratory of Fire Marshal of California for the purpose of studying the effect of specimen angle on burning rate. Although the equipment was designed to support the 11 in. x 2 in. specimen at various angles, only the vertical position was used in this series of tests. A gas-jet flame is applied to the fabric surface near the bottom of the specimen, and the time of flame spread to 5 in. and to 10 in. is recorded by automatic electronic timers. No definition of hazardous flammability by this test has been established, but a limit of somewhat less than 8 sec. for 10 in. would appear a reasonable criterion, since fabrics burn more rapidly in a vertical than in an inclined position.

3.4 Semicircular Test (See Figure IV)

This apparatus has been suggested as a means for classifying fabrics with respect to their flammability characteristics. The apparatus consists of a metal, semicircular frame of 7 in. radius, to which a 21 in. x 2 in. specimen may be clamped. The edge of one end of the specimen is ignited by burning 0.1 cc of alcohol contained in a small cup placed under it, and the time for the flame front to reach consecutive 3 in. marks is noted. In the present tests, the amount of alcohol was increased to 0.2 cc and the time of flame travel was recorded on a chronograph.

It has been assumed that the flammability of a fabric is indicated by the extent of the flame spread or by an inverse function of the time to burn around the semicircular frame.

4. TEST PROCEDURE

The standard procedure for each test was followed in general, but in order to make the results comparable, a few changes were made in certain of the test equipment and procedures.

4.1 Conditioning

Fifteen samples of each fabric were cut to be tested on each instrument. Of these, five were placed in a circulating air oven at 105° C for 30 min., then desiccated over anhydrous calcium chloride crystals for at least 15 minutes. Five more were hung singly in a room kept at standard textile conditions, 70° F and 65% relative humidity, for 4 hours before being tested. The remaining five were held under ambient laboratory conditions of temperature and humidity, which were recorded before each series of tests.

These different conditions included those required for the standard inclined test and bracketed those required for the standard horizontal test. At the same time they gave some indication of the effect on combustion rate of varying temperature and humidity.

4.2 Ignition Time

Since the ignition time of a fabric may vary with its position, it appeared desirable to measure this time as as well as the burning time. Therefore, all flame application apparatus was switched to manual control, and the flame was applied until the fabric was observed to have been ignited. In some cases, this observation was difficult, and the time of flame application may not be a true measure of ignition time. Also, since flame application was measured with a hand-held stop watch, there may be some deviation due to reflex time.

4.3 Burning Time

The time for the flame front to travel a specified distance was measured according to the directions for each test. This figure was then divided into the distance travelled to give an in./sec value, which was judged the most logical method of comparison when the full length of the sample burned. With the semicircular test, however, this was not a valid basis of comparison for some of the tests where the fabric burned only part way and was then self-extinguished, the length which burned being in a nearly vertical position where the rate of flame spread is most rapid. Such a burning rate could not properly be compared with that over the full sample length where the slower burning horizontal and downward positions were included.

4.4 Other Deviations

On the horizontal apparatus, the strip heaters were not used to regulate the temperature inside the cabinet, because the other instruments lacked such control and were operated at room temperature. On the vertical apparatus, only the 10 in. burning time was taken, since the longer length was more closely comparable to the specimens in the other tests. The amount (approximately 0.2 cc) of alcohol used in igniting fabrics on the semicircular apparatus was slightly larger than specified, for it was found very difficult to ignite a small amount of alcohol without igniting the fabric as well.

The two standard tests provide that all fabrics with a raised-fiber surface shall be brushed or combed before testing. However, in this series of tests both brushed and unbrushed specimens were included, the samples being brushed only when a preliminary test showed that it encouraged flash substantailly.

5. RESULTS

The majority of the data collected in the experiments are presented in Table I. For each test and each conditioning of the fabric, the average times of flame application and burning, and the average rate of flame spread in inches per sec., are given for five samples. The standard deviation in percent is based on the rate in inches per sec., and gives some indication of the variation in individual data. The consumption rate, given in oz/sec in., was obtained by multiplying the rate of burning by the fabric weight in oz per sq in. This figure is intended as a measure of the heat release, assuming the heat of combustion of the different fabrics to be approximately the same. For the semicircular test, the consumption rate for the first six inches of burning was also calculated, as offering a better basis of comparison of the fabrics than the value for the entire length burned. If some standard of hazard could be derived from these data, it would take into account the intensity as well as the spread of the flame front.

Table II presents ambient conditions of temperature and humidity observed during the tests. The temperature variation gives a fairly even distribution curve, but the small number of samples scattered the humidity distribution badly. In general, samples tested under ambient conditions varied little among themselves, and gave average results between those of the dried and the humidified samples.

Table III gives the results of tests made in general accordance to the specifications of Commercial Standard 191-53. These tests were made to permit comparison of the present results with those previously obtained on similar fabrics.

In Table IV the results obtained on the semicircular apparatus are given in greater detail. It will be seen that the raised-fiber fabrics burned most slowly at the high, or near-horizontal, section of the semicircle, while flat fabrics showed a steady decrease in rate of burning. Fabrics of synthetic or animal fibers had a tendency to be extinguished after a limited flame spread. The figures, V and VI, present the same data as continuous curves.

There was a definite correlation between the moisture content of the cloth and the rate of flame spread. In almost all cases the humidified samples of a material burned more slowly than those that had been oven-dried. In the case of the raised-fiber fabrics, dried samples showed a greater tendency to flash.

Tables V, VI, and VII show various classifications of the eight fabrics tested, on the basis of relative flammability. In Table V their classification under systems already established or suggested is given. The brushed rayon was clearly defined as hazardous by both of these systems, and the light-weight silk was also included in this category under Commercial Standard 191-53. Classifications of flammability have not been established for either the vertical or the semicircular test. However, from the results obtained it appears probable that the vertical test would indicate these two fabrics as hazardous (similar to their classification by the inclined test), while by the semicircular test the brushed rayon might be considered hazardous and the light-weight silk nonhazardous (similar to their classification by the horizontal test). Flame spread on the silk did not extend much beyond six inches in the semicircular test, although the rate of spread was relatively rapid for that distance.

In Table VI the fabrics are listed in the order of decreasing flammability based on the ratio of flame spread in each test. Taking oven-dried samples as those with the least variable conditioning, the table shows how the idiosyncrasies of each instrument produced changes in the order of relative hazard. In general, the smooth-surfaced fabrics showed fairly similar behavior in the different tests, except that those of animal fibers did not burn in a horizontal position. There was greater variation in results obtained by the different methods on the fabrics with brushed or pile surface, however, largely due to differences in the tendency toward surface flash. The order developed in the semicircular test differed particularly from those in the other tests because of the combination of fabric positions in that equipment, with corresponding changes in rate of flame spread.

In Table VII the fabrics are listed in the order of decreasing flammability based on the consumption rate, as given in Table I. On this basis the inclined, the horizontal, and the vertical tests placed the fabrics in closely similar order, but the semicircular test gave a

markedly different order even when only the first six inches of burning were considered.

6. DISCUSSION

Among the data that cannot be shown on charts are the many mechanical failures inherent in complex automatic apparatus. The nuisance value of such defects is not to be disregarded, and for this reason simplicity is important in designing a standard test for general use. In this respect, the horizontal and the semicircular instruments seem to make up for their lack of precise accuracy by their ease of handling.

It will be noticed on Table I that some of the heavier and animal fiber fabrics have extremely long ignition times on the inclined and vertical instruments. This effect is produced by the difference between the surface ignition of the inclined and vertical instruments and the edge ignition of the horizontal and semicircular devices. In the former case, the flame must sometimes be played across the surface of the fabric to insure ignition, and its hottest point, just above the tip, is not used. In the case of some of the wool samples, ignition did not take place until the gas-jet flame completely penetrated the fabric, igniting the edges of the hole thus made. Where there is no danger of flash on the under surface, edge ignition gives much more satisfactory and reproducible results.

Surface flash was one of the greatest problems encountered in making the tests. Dried and brushed specimens showed the greatest tendency to flash, but the phenomenon was not confined to specimens in this condition. Rarely did all the samples in a group flash, and the speed of the flash flame itself is much more variable than that of the base flame, both of which facts introduced a larger deviation into the average. In the case of the dried and brushed torch sweater material, flash was sometimes too rapid for the instrument to record. On the semicircular apparatus, some materials tended to flash up and down, but not across the top, distorting the rate of flame spread. In developing the Commercial Standard based on the inclined test, a surface flash strong enough to ignite the base fabric was accepted as the criterion of hazardous flame intensity. Such a criterion, however, is applicable only when the igniting flame is applied to the surface rather than to the edge of the fabric. It is evident that a satisfactory interpretation of surface flash, in terms of the degree of hazard indicated, will be a difficult problem in any system of classification devised.

In comparing the results obtained on the different instruments, rate of flame spread appears to be a suitable criterion in all cases except the semicircular apparatus, in which case char length must be taken into account.

7. RECOMMENDATIONS

While the present series of experiments contained so few samples as to be inconclusive, the following recommendations might tentatively be made regarding a practical tesing instrument:

1) It should be of simple, solid construction.

2) The flame should be applied to the edge, rather than the surface of the fabric.

3) Some provision should be made for gaging flame intensity, as a basis for interpretation of the hazard of surface flash and light flames.

4) Rate of flame spread is recommended as a useful and convenient primary criterion of flammability, unless the instrument is unsuited to such measurement.

8. REFERENCES

1. Commercial Standard 191-53, "Flammability of Clothing Textiles," United States Department of Commerce.

2. "Flammable Fabrics Act," Public Law 88 - 83rd Congress Chapter 164 - 1st Session, H.R. 5069.

3. Federal Specification, "Textile Test Methods," CCC-T-191b, 15 May 1951.

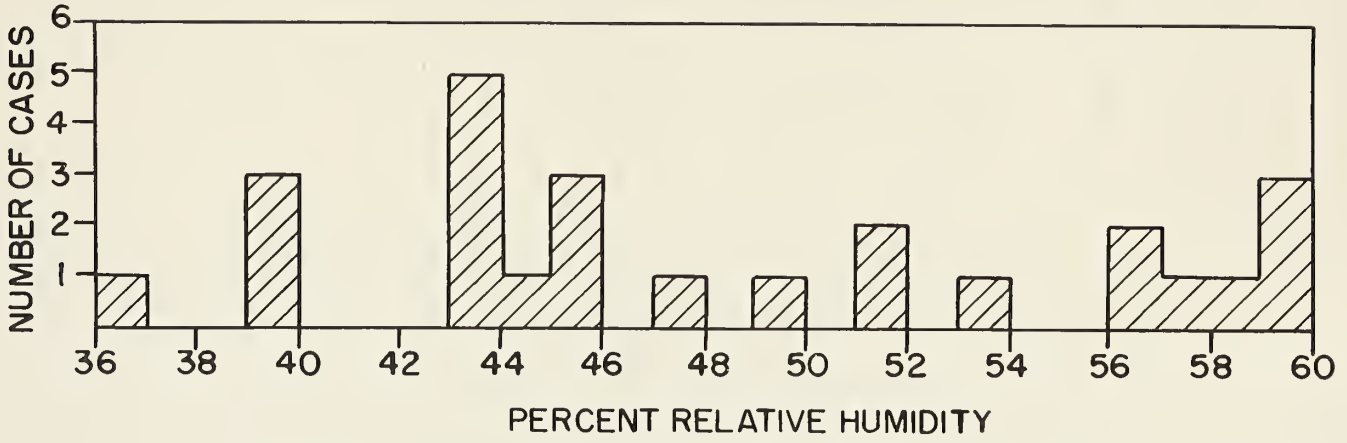
4. "Inflammable Textiles," Hearings before the Committee on Interstate and Foreign Commerce, House of Representatives, Eightieth Congress, First Session, March 4 and 5, 1947.

Table I. Comparative Tests of Fabric Flammability
Table of Averages

Material	Condition	Weight	Inclined Test: Flame Application	Inclined Test: Burning Time	Inclined Test: Rate	Inclined Test: Standard Deviation	Inclined Test: Consumption Rate	Horizontal Test: Flame Application	Horizontal Test: Burning Time	Horizontal Test: Rate	Horizontal Test: Standard Deviation	Horizontal Test: Consumption Rate	Vertical Test: Flame Application	Vertical Test: Burning Time	Vertical Test: Rate	Vertical Test: Standard Deviation	Vertical Test: Consumption Rate	Semicircular Test: Flame Application	Semicircular Test: Burning Time	Semicircular Test: Rate	Semicircular Test: Standard Deviation	Semicircular Test: Consumption for Total Burning	Semicircular Test: Consumption for 6 in. Burning
		oz/yd^2	sec	sec	in./sec	%	oz/sec in.*	sec	sec	in./sec	%	oz/sec in.*	sec	sec	in./sec	%	oz/sec in.*	sec	sec	in./sec	%	oz/sec in.*	oz/sec in.*
Cotton flannel	Ambient	6.65	2.9	49.5+	0.10	10.7	5.3	4.8	144.0+	0.07	10.0	3.5	3.0	18.2+	0.56	10.1	28.5	4.8	N.A.	0.17	36.7	8.8	14.0
do.	Oven	6.65	2.9	14.3-	0.35	5.1	18.0	2.4	108.0+	0.09	2.2	4.7	3.0	15.2+	0.74	28.9	38.0	1.8	N.A.	1.51	88.1	77.5	18.3
do.	Humidified	6.65	5.4	51.5+	0.10	15.2	5.1	3.5	154.0+	0.06	3.1	3.3	5.0	25.0+	0.42	19.6	21.4	3.1	149.0	0.19	30.9	10.0	16.4
Brushed rayon	Ambient	8.37	1.3	6.9-	1.62	84.0	104.6	2.6	46.8-	0.89	64.3	57.5	1.0	4.0-	3.17	42.0	87.9	1.4	88.8+	0.25	17.5	15.9	27.9
do.	Oven	8.37	0.8	0.6-	11.80	56.1	762.3	2.1	64.0-	0.67	100.2	43.0	1.0	2.2-	7.08	67.8	457.4	1.3	14.0-	2.85	41.5	177.6	234.0
do.	Humidified	8.37	1.1	3.7-	6.13	75.7	396.0	0.7	5.4-	2.41	26.7	155.7	1.1	7.7-	1.36	18.4	87.9	1.7	58.2+	0.60	77.1	38.9	20.3
Muslin	Ambient	2.10	2.1	9.3	0.54	4.8	8.7	2.2	65.2	0.16	6.7	2.7	1.8	5.1	2.09	22.7	33.9	2.1	89.3	0.24	0.9	3.8	29.5
do.	Oven	2.10	1.9	6.0	0.86	13.7	13.9	2.1	52.6	0.19	4.7	3.1	1.7	5.1	2.10	23.5	34.0	1.7	83.8	0.25	4.4	4.1	46.5
do.	Humidified	2.10	2.2	7.5	0.68	14.9	11.1	2.3	66.0	0.15	2.0	2.5	2.5	6.1	1.69	14.9	27.4	1.4	92.1	0.23	3.9	3.7	34.7
Tufted chenille	Ambient	10.83	1.2	19.6-	0.27	19.3	22.6	2.2	208.5+	0.05	12.2	4.1	1.6	22.2+	0.48	21.6	40.2	1.8	117.4	0.18	4.3	15.0	31.5
do.	Oven	10.83	1.1	18.9-	0.33	35.7	27.8	2.0	127.6+	0.11	61.4	9.5	2.0	9.7+	1.28	36.8	107.0	1.1	N.A.	0.26	12.5	22.0	25.6
do.	Humidified	10.83	1.1	32.2-	0.16	13.2	13.3	2.0	232.3+	0.04	4.7	3.6	1.4	18.0	0.56	7.8	46.6	2.8	N.A.	0.25	18.9	21.2	19.3
Acetate satin	Ambient	3.07	3.5	8.0	0.68	24.5	16.0	4.5	67.2	0.15	10.6	3.6	4.1	9.5	1.12	19.7	26.5	2.2	N.A.	0.33	62.7	7.8	7.7
do.	Oven	3.07	3.1	7.5	0.69	16.3	16.4	3.5	58.9	0.18	16.9	4.2	2.9	8.5	1.20	11.5	28.4	3.0	117.0	0.18	7.7	4.3	13.4
do.	Humidified	3.07	3.5	8.3	0.60	3.0	14.3	3.6	57.4	0.18	9.7	4.2	2.6	12.8	0.82	18.2	19.4	2.3	119.8	0.18	1.7	4.2	12.2
Cotton print cloth	Ambient	3.32	4.4	9.8	0.52	7.4	13.2	3.1	116.2	0.09	2.3	2.2	6.0	11.0	0.96	23.2	24.7	2.4	158.1	0.13	1.5	3.4	24.8
do.	Oven	3.32	5.6	9.7	0.52	8.1	13.3	2.6	107.1	0.09	4.3	2.4	3.5	7.0	1.50	18.5	38.4	2.4	152.1	0.14	2.2	3.5	23.0
do.	Humidified	3.32	5.8	11.2	0.45	7.1	11.5	3.0	105.0	0.10	7.3	2.5	2.8	7.3	1.43	18.2	36.6	1.2	161.1	0.13	1.5	3.3	23.0
Wool worsted	Ambient	4.92	DNI	----	----	----	----	5.4	IBE	----	----	----	25.6	IBE	----	----	----	4.8	N.A.	0.40	5.7	15.4	16.5
do.	Oven	4.92	17.2	20.1	0.25	7.2	9.5	4.0	IBE	----	----	----	27.2	35.0	0.29	13.1	11.0	3.7	N.A.	0.45	11.1	17.1	33.5
do.	Humidified	4.92	29.1	19.2	0.26	7.6	10.0	6.3	IBE	----	----	----	DNI	----	-----	----	----	4.9	N.A.	0.34	10.5	13.1	14.7
Japanese silk	Ambient	0.53	1.0	3.4	1.50	8.0	6.2	1.0	IBE	----	----	----	1.7	N.A.	4.17	0	17.1	7.6	N.A.	3.27	35.8	13.4	9.8
do.	Oven	0.53	1.0	2.8	1.78	3.6	7.3	0.9	IBE	----	----	----	1.4	2.7	3.74	9.3	15.3	5.5	N.A.	3.02	32.8	13.4	11.5
do.	Humidified	0.53	1.0	3.5	1.43	7.1	5.9	0.8	IBE	----	----	----	N.A.	2.8	4.07	36.7	16.7	7.8	N.A.	1.20	5.6	4.9	----

* All numerical values given for consumption rate are x 10^{-4}.
\+ Indicates base fabric burning only.
\- Indicates surface flash followed by base fabric ignition.

DNI Did not ignite.
IBE Ignited but extinguished.
N.A. No average possible.



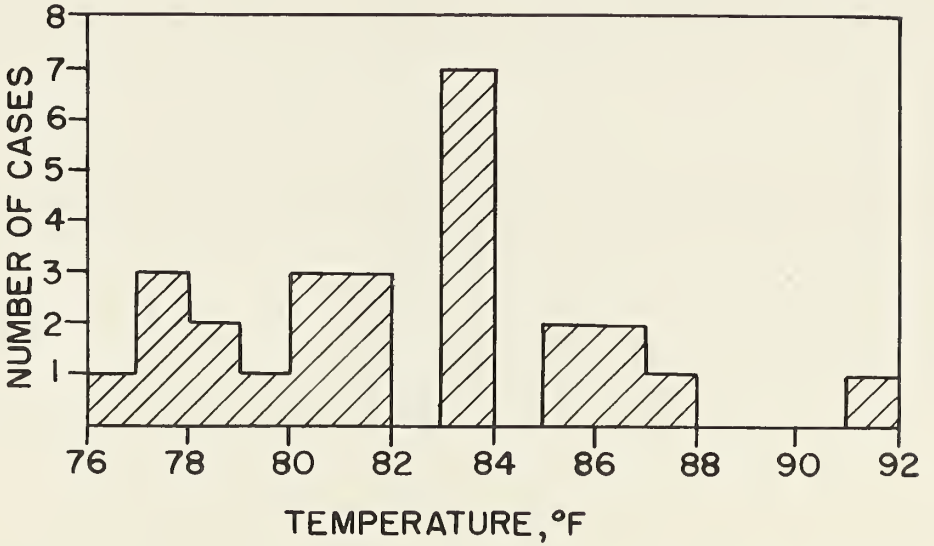


TABLE II VARIATION IN AMBIENT CONDITIONS OF TEMPERATURE AND HUMIDITY

Table III. Results of Tests According to Commercial Standard 191-53

Material	Average Burning Time sec	Standard Deviation %
1. Cotton flannel	7.32-	57.9
2. Tufted chenille	10.6-	6.8
3. Brushed rayon	1.08-	8.9
4. Muslin	8.36	11.6
5. Acetate satin	DNI	----
6. Cotton print cloth	DNI	----
7. Wool worsted	DNI	----
8. Japanese silk	3.44	2.5

- Indicates surface flash followed by base fabric ignition.

Table IV. Results on Semicircular Apparatus

Material	Condition	Average Flame Spread Times for 3-inch Sections of Specimen							Char*
		0-3 sec	3-6 sec	6-9 sec	9-12 sec	12-15 sec	15-18 sec	18-21 sec	in.
Cotton flannel	Ambient	8.8	13.2	18.8	45.8	39.0	28.6	54.9	
do.	Oven	5.4	11.4	16.4	38.2	11.4	----	----	15.0
do.	Humidified	8.0	10.8	12.0	37.8	35.0	22.8	22.5	
Brushed rayon	Ambient	4.4	9.5	10.5	19.9	23.0	11.5	10.1	
do.	Oven	0.4	1.2	3.4	4.1	4.7	1.1	2.5	
do.	Humidified	3.4	15.7	15.6	28.4	21.2	7.6	7.6	
Muslin	Ambient	1.3	2.0	2.3	7.3	22.5	26.6	27.4	
do.	Oven	0.9	1.2	2.8	7.8	20.8	23.9	26.3	
do.	Humidified	1.1	1.7	2.5	7.4	23.8	27.4	28.3	
Tufted chenille	Ambient	4.9	11.0	17.8	29.2	17.7	18.6	18.3	
do.	Oven	6.0	13.6	13.0	22.6	17.3	10.6	11.2	
do.	Humidified	11.4	14.6	----	----	----	----	----	6.0
Acetate satin	Ambient	4.6	13.8	11.7	11.3	23.7	17.5	33.5	
do.	Oven	3.0	7.5	9.4	15.8	25.5	26.6	28.0	
do.	Humidified	3.0	8.7	10.2	17.4	21.7	28.7	30.2	
Cotton print cloth	Ambient	2.7	3.5	4.5	12.4	40.1	46.2	48.6	
do.	Oven	3.1	3.6	3.6	12.9	39.7	43.8	45.5	
do.	Humidified	3.5	3.2	4.2	14.6	40.6	47.0	48.0	
Wool worsted	Ambient	6.4	7.4	8.5	----	----	----	----	9.0
do.	Oven	4.9	4.8	9.1	----	----	----	----	9.0
do.	Humidified	7.4	8.0	11.9	----	----	----	----	10.0
Japanese silk	Ambient	1.5	1.0	----	----	----	----	----	6.5
do.	Oven	0.7	1.5	----	----	----	----	----	7.0
do.	Humidified	1.9	---	----	----	----	----	----	4.5

*Char length given only in cases where all samples burned less than 21 inches.

Table V. Classifications of Fabrics by Established Systems

Test Method	Normal Flammability	Intermediate Flammability	Rapid and Intense Burning
Commercial Standard 191-53 (Inclined test)	Cotton flannel Chenille Muslin Acetate satin Print cloth Wool worsted	----	Brushed rayon Japanese silk

	Nonhazardous	Hazardous
Federal Specification CCC-T-191b, 5906 (Horizontal test)	All other fabrics, all conditions	Brushed rayon, humidified

Table VI. Fabrics Listed in Order of Decreasing Rate of Flame Spread for Oven-dried Samples

	Inclined	Horizontal	Vertical	Semicircular*
1.	Brushed rayon	Brushed rayon	Brushed rayon	Silk
2.	Silk	Muslin	Silk	Brushed rayon
3.	Muslin	Acetate	Muslin	Cotton flannel
4.	Acetate	Chenille	Print cloth	Wool
5.	Print cloth	Print cloth	Chenille	Chenille
6.	Cotton flannel	Cotton flannel	Acetate	Muslin
7.	Chenille	Silk	Cotton flannel	Acetate
8.	Wool	Wool	Wool	Print cloth

*Based on first 6 inches of burning.

Table VII. Fabrics Listed in Order of Decreasing Flammability Based on Consumption Rate of Oven Dried Specimens

Inclined Test	Horizontal Test	Vertical Test	Semicircular Test*
Brushed rayon	Brushed rayon	Brushed rayon	Brushed rayon
Chenille	Chenille	Chenille	Muslin
Cotton flannel	Cotton flannel	Print cloth	Wool worsted
Acetate satin	Acetate satin	Cotton flannel	Chenille
Muslin	Muslin	Muslin	Print cloth
Print cloth	Print cloth	Acetate satin	Cotton flannel
Wool worsted	---	Wool worsted	Acetate satin
Silk	---	Silk	Silk

*Based on first 6 inches of burning.

FIG. I

FIG. II

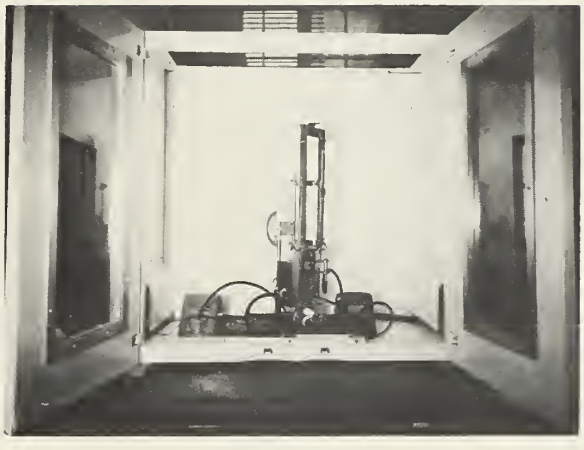


FIG. III

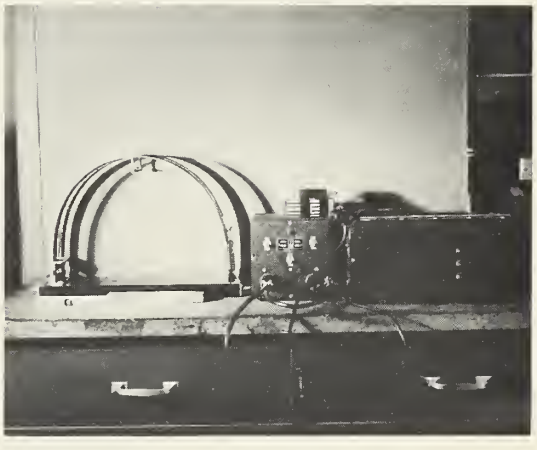


FIG. IV

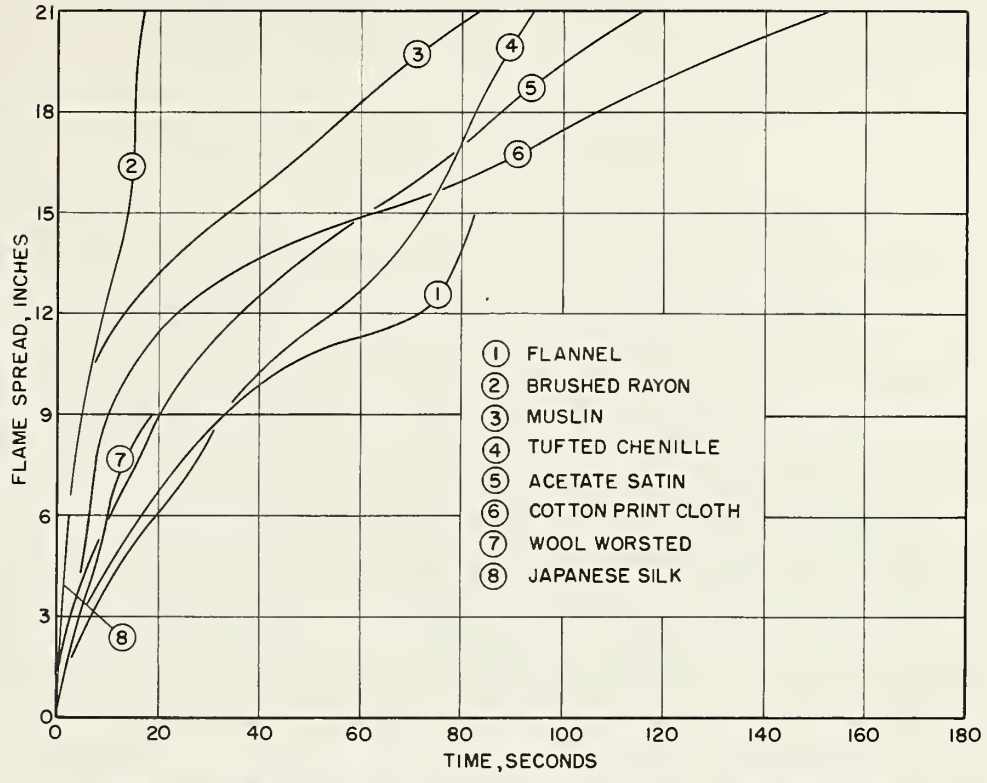


FIG. V FLAME SPREAD FOR OVEN-DRIED SAMPLES ON SEMI-CIRCULAR APPARATUS

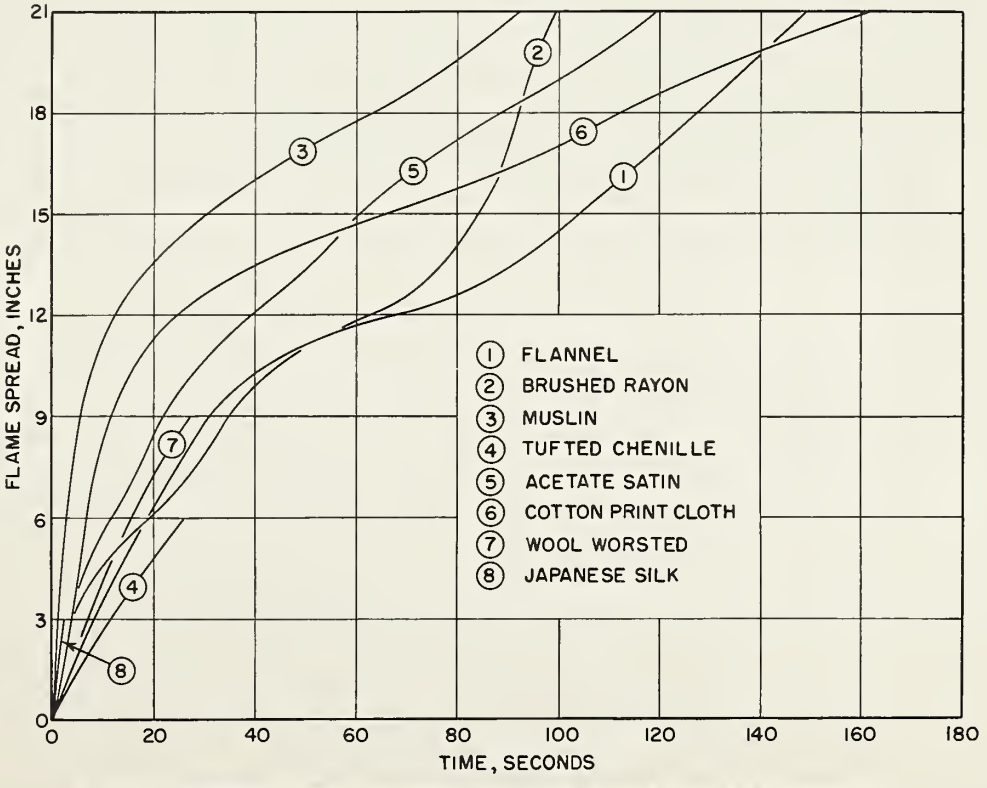


FIG. VI FLAME SPREAD FOR HUMIDIFIED SAMPLES ON SEMI-CIRCULAR APPARATUS

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