NATIONAL BUREAU OF STANDARDS REPORT

8671

REVIEW OF FABRIC FLAMMABILITY TEST METHOD

A Progress Report

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M. P. Vaishnav

and

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U. S. DEPARTMENT OF COMMERCE

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NBS PROJECT		NBS REPORT
1002-12-4210120	April 13, 1965	8671

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ABSTRACT

A study of the technical aspects of the fabric flammability test method of Commercial Standard 191-53 is in progress. The results of a program of experimental work to determine the importance of a number of possible variables in the test procedure are reported. On the basis of these results, a standard test procedure for use in further work with the method has been selected, and a few recommendations relative to the test equipment developed. A comparative classification of a wide range of clothing and bedding materials by CS191-53 and NFPA Standard 702, together with data on their heat release behavior, will be presented in a later report.

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1. Introduction

The Federal Flammable Fabrics Act, passed in 1953, delegated to the Secretary of Commerce the responsibility of presenting to the Congress, appropriate legislative proposals at any time he might find the commercial standards referenced in the Act (CS191-53 and CS192-53) inadequate for the protection of the public interest. With a view to fulfilling that responsibility, a review of those commercial standards and the operation of the law, to date, was initiated by the Secretary. As part of that review, the National Bureau of Standards was asked to conduct a technical study of the test procedures and equipment on which the standards are based, and their application to current consumer fabrics.

Primary attention was centered on CS191-53, inasmuch as the present use of plastic films (covered by CS192-53) in clothing is very small. During the years since enactment of the law, a considerable amount of experience in the application of CS191-53 has been developed both in production control laboratories and in government and commercial testing laboratories. In preparation for the study, therefore, the Commodity Standards Division of the National Bureau of Standards solicited comments on the standard from the various organizations, agencies, and laboratories, interested in the manufacture, distribution, and hazards of clothing fabrics. The experience, problems, and suggestions on the technical aspects of the standard reported in these comments were of value in development of a program of experimental study of the test.

The present progress report presents the findings of an experimental study of the influence of a number of variables on the results of flammability measurements. A later continuation of this work will deal with performance of a number of selected fabrics as tested by the procedures of the Commercial Standard and the NFPA Standard No. 702. This later report will also include data resulting from measurements of relative heat release behavior of the fabrics.

2. Factors Selected for Study

The description of the apparatus and procedure given in the standard had not proved sufficiently explicit on several points to avoid some variation in interpretation and practice among different laboratories. Incomplete definition has also permitted modifications, apparently minor but still possibly significant, of the test equipment by the manufacturer. Although some of these differences had been the source of considerable concern to several groups, their actual importance in affecting the test results was largely unknown. Hence, the first part of the experimental program was designed to determine which of the variations to which the method was subject would significantly affect the test results and necessitate more precise definition of equipment and procedure.

A review of the comments received disclosed six points in the test method where practice among laboratories commonly varied or where a decided modification of procedure was proposed. The sources and extent of variation at these points, and the experimental approach followed in exploring its significance in each instance, are outlined below:

1. Oven drying.

The commercial standard stipulates that the specimens shall be dried in an oven for 30 minutes at 221 °F (105°C). The type of oven is not specified and ovens differ widely in the time required to regain the specified temperature after introduction of a set of specimens. Hence, the total time for which specimens may be held at a considerably elevated temperature is highly variable, and the question of the possible effect of this variable on the test results has been raised.

Tests were carried out using an oven equipped with forced air circulation, which regained the specified temperature within two or three minutes after introduction of a set of specimens. The effects of holding specimens in the oven for 10, 15, 20, 30, and 60 minutes were studied.

2. Desiccator cooling.

The standard requires that, upon removal from the oven, the specimens be "placed over anhydrous calcium chloride in a desicator until cool, but for not less than 15 minutes." No maximum time limit is imposed. The rate of cooling depends on the number of specimens stacked in the desiccator, as well as on ambient conditions, and the definition of "cool" will vary with different operators. Hence, specimens may be left in the desiccator for periods ranging from 15 minutes to several hours.

In studying the effect of this variable on the test results, desiccator times of 0, 15, 30, and 60 minutes were used. The specimens tested with no time in the desiccator were removed individually from the oven and tested immediately. Silica gel was substituted as a more effective and dependable desiccant than anhydrous calcium chloride.

3. Thread height.

The thread guides on the specimen holder, which determine the position of the stop cord over the specimen, are not precisely described in the standard and have been subject to modifications which resulted in differing heights of the thread above the fabric surface. Specimen holders of both types are in use and the effect of thread height on the test results is therefore of decided interest.

A set of specimen holders was prepared with guides which permitted threading the stop cord at various selected heights ranging from 1/8 to 3/4 in. above the specimen surface. Primarily, however, attention was centered on a comparison of the 1/8 in. and 3/8 in. heights, the two heights appearing in commercially distributed holders.

4. Flame length.

Although the length of the igniting flame is specified in the standard, the measurement of its length depends to some extent on operator judgment and is slightly variable. In addition, the flame length is sensitive to small changes in fuel pressure and some laboratories reported difficulty in maintaining proper adjustment. Hence, information on how critical a factor the flame length might be appeared important.

The standard stipulates a flame length of 5/8 in. For the comparative study flame lengths 1/2, 5/8, and 3/4 inches were used.

5. Taping of specimen.

Some light-weight fabrics are so thin that the smooth metal of the specimen holders (which may also become slightly warped) fails to grip the material. This permits the exposed area of the specimen to sag slightly farther from the igniting flame in the case of soft, limp materials; and fabrics which shrink and curl decidedly in a flame tend to draw out of the specimen holder as they burn. To prevent such behavior, the practice of securing the specimens of very thin materials to the holder by means of an adhesive tape has been suggested. Taping is sometimes used also, to hold in a reasonably smooth, flat position, the badly wrinkled specimens of materials which might be altered by pressing.

To determine whether the practice of taping would be advisable, tests were made on both taped and not-taped specimens of the same material. The taped specimens were secured to the back section of the specimen holder by means of four short strips of masking tape, one near the top and one near the bottom of each side of the specimen.

6. Type of ignition.

Among suggestions for change to the Federal law, has been the proposal that CS191-53 be replaced by National Fire Protection Association Standard 702 as the basis for defining hazardous flammability. The two standards employ basically the same test equipment but differ in test procedure, the most notable difference being the method of igniting the specimen. In CS191-53, the igniting flame is applied to the surface of the specimen for one second, while in NFPA 702, it is applied to the edge of the specimen until ignition has occurred. The effect of this change in ignition procedure on the test results was included in the study.

In addition to the difference in procedures outlined above, the comments included several suggestions for modification of the apparatus. Most frequently mentioned was a possible advantage from the substitution of an electrical timing system for the mechanically operated stopwatch described in the standard. Some operators felt that an electrical system would provide more precise measurement and be more convenient and dependable in operation as well. To develop experience and information on the question, an electric timer was incorporated in the apparatus in such a way that it and the stopwatch were activated by the same devices and provided simultaneous records.

Another point on which some question was raised involved the positioning of the specimen in the specimen holder. The usual practice of most operators appears to have been to place the lower end of the 6-in. specimen even with the lower end of the back plate of the specimen holder. Inserted thus, the igniting flame should impinge on the surface of the material at a point 1/2 in. from the lower end of the specimen. However, this 1/2 in. spacing (which may be further reduced by only slight deviations in flame or specimen adjustment) is small enough that fabrics subject to severe shrinkage in a flame may draw the edge up to produce essentially edge ignition. Throughout the present study, the specimens were positioned about 1/8 in. lower in the holders in order to slightly increase the distance between the point of flame impingement and the specimen edge. This was accomplished by cutting the specimens 6 1/4 inches in length and positioning the upper end even with the top of back plate.

One of the modifications which have developed in the apparatus since the original design, appears in the rack which supports the specimen holder during test. In the early machines, the metal support on which the bottom of the specimen holder rests was a continuous bar running across the full width of the rack. In the currently produced machines, however, the bar has become discontinuous supporting the specimen holder at the corners but leaving the center open. While these arrangements are equally satisfactory for support of the holder, the conditions of air flow around the bottom edge of the fabric specimen will be affected by the presence or absence of the partial obstruction of the bar across the center of the rack. Although the effect of this modification was not studied extensively, sufficient comparison was made to show that it does influence the burning times of some fabrics, and should be standardized in all machines.

3. Organization of Experimental Program

Inasmuch as the test results for different types of fabrics may be affected differently by a given procedural variation, the program necessarily included a fair number of materials, although only fabrics which ignite in the one-second flame exposure would be useful. In all, eleven fabrics were used in the study of test method variances, but none was carried through every comparison.

In order to avoid unnecessary and excessively prolonged experimentation, a program of factorial experiments was designed under the guidance of the Applied Mathematics Division of the Bureau. After some preliminary trials to study the characteristics of the problem and determine the number of repetitive specimens required, one general plan for the individual series of tests was adopted. For the most part, each series of tests compared four different variables in test procedure at two levels on three different fabrics. For example, one series might compare the effect of oven times of 15 and 30 minutes, thread heights of 1/8 and 3/8 inches, edge and surface ignition, and flame lengths of 5/8 and 3/4 inches on three fabrics. Duplicate specimens were tested in each instance so that such a series employed 32 specimens in all, and each comparison was based on averages of 16 determinations. While the schedule of tests was adjusted in some series to study more than two levels of a variable at one time or develop a point of particular interest, care was taken to maintain a meaningful number of determinations in each comparison. Twenty-two such series of tests were made.

4. Test Results and Selection of Standard Procedure

The results of the test series are shown in Table 1. The overall mean burning time for the series is given in the fourth column. Each of the following columns shows the difference in burning time obtained under the comparative conditions indicated in the heading. Thus, referring to colunn 6, the average burning time for silk I was 0.26 sec. longer with a thread height of 1/8 in than with a thread height of 3/8 in. Differences which proved to be significant under statistical analysis at the 95% confidence level, are indicated by an asterisk.

The significantly longer burning times for surface ignition than for edge ignition are to be expected of course. The only materials unaffected by the type of ignition were those subject to a rapid surface flash initiated by the first touch of a flame. It is clear also that the height of the thread above the fabric is generally a significant factor in the test results and should therefore be standardized and specified. Although, for the most part, taping the specimens to the holder appeared to give slightly shorter burning times, the difference did not prove significant in any instance. This indicates that taping should be an acceptable procedure in situations where it would facilitate positioning the specimen. The absence of the metal strip across the bottom width of the specimen holder support rack permitted, in some instances, flame travel around the lower edge with resulting rapid propagation up the lower surface of the specimen. The flame length comparisons suggest that the flame length is critical chiefly as it affects the distance between the flame and the fabric, not with respect to heat output. Thus, significant differences occurred only with the shorter flame length where the tip of the flame was slightly farther from the fabric. The length of time the specimens were held in the oven had no significant effect over the range of 10-60 minutes. The period of cooling in the desiccator proved unimportant after the first 30 minutes; although the specimen holders were still warm at this time. This suggests that the time required for the desiccant to absorb the moisture introduced by a change of air, is the critical factor in the desiccator time rather than the temperature of the specimens and holders. This view is supported by continuous humidity records obtained from a humidity sensor hung in the top of the desiccator, which showed that the humidity in the closed desiccator closely approached its equilibrium level in about 10-15 minutes, while it required more than an hour for the holders and specimens to cool to room temperature. Experience with the electrical vs. mechanical timing devices suggest that, provided proper adjustment is maintained, either method may be used with satisfactory results. The time resolution with the electrically-timed system is, of course, much finer,but the need for this precision is questioned.

On the basis of these findings the following standardized procedure was selected for use in further work with the test method. The oven conditioning of 30 minutes at 105 °C was retained and a uniform period of 30 minutes in the desiccator was adopted. Specimen holders with a bent-pin type of thread guides providing a uniform thread height of 3/8 in. across the specimen were used. This was facilitated by the installation of a new guide in the cabinet above the spool. The practice of positioning the specimen 1/8 in. lower in the holder was continued. The support rack on which the specimen holder rested during the test, was used with a discontinuous support bar as provided in currently-produced machines. The flame length was maintained at 5/8 in. and checked frequently, with particular care to avoid variations toward a shorter length. Use of the electric timer concurrently with the mechanical stopwatch was continued.

5. Comments on the Test Apparatus

As noted earlier, some variations in the test method have resulted from changes in the manufacture of the equipment, which influence the procedure although they do not violate the specifications of the standard. To avoid further such inadvertent modifications, it is recommended that the drawings be adopted as part of the commercial standard, or as a subsidiary requirement of the Secretary of Commerce, and that all future revisions should be subject to approval by the Secretary of Commerce. Before such adoption, however, it is recommended that the following clarifications and additions be incorporated in the drawings:

1. At the base of specimen rack (1) Drwg D453, change 3/8 dimension on 45° line to 5/16.

2. Revise thread guide (3) in right elevation, Drwg D453, of specimen holder assembly. There should be a tolerance on height of guides above top plate, perhaps ± 0.01 in.

3. Add additional thread guide, (10) of D453, to cabinet, D450, above thread spool, at a point 8-1/4" above floor and 5-1/4" from back. Include dimensioned positions for all thread guides.

4. Make counterweight (3) on Drwg D452 of brass or increase the size of steel weight to 1" dia x 1-1/2" long. (The specified dimensions in steel do not provide sufficient weight).

5. On Drwg D454, part 25, dimension of weight diameter is indicated as changed to 3/4 in. Current production, however, involves 5/8 in. dia weight as was used in our tests. This weighs about 33 gms. The weight should be specified.

6. The drawings should include dimensions of the flame length gage and the sheet metal specimen shim and block.

Table 1. Influence of Procedure Variables on Results

Fabric			Mean Burning Time	Difference in Burning Time Caused by Variable													
				Point of Ignition (edge-surface)	Thread Height (1/8-3/8")	Taping Specimen in Holder (Taped-Not taped)	Flame Length (1/2-5/8")	Flame Length (5/8-3/4")	Flame Length (1/2-3/4")	Strip on Support Rack (Strip-No strip)	Oven Time (in minutes) (10-20)	Oven Time (in minutes) (15-30)	Oven Time (in minutes) (30-60)	Desiccator Time (in minutes) (0-15)	Desiccator Time (in minutes) (15-60)	Desiccator Time (in minutes) (30-60)
Material	Construction	Weight														
		oz/yd^2	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
Silk I (sheer)	Plain weave	0.6	3.32	-0.17 *	0.26 *	-0.11	0.18 *									
			3.23	-0.26 *	0.26 *	-0.01					0.01					0.05
Silk II (Organza)	Plain weave	0.7	3.90	-0.33 *	0.38 *	-0.05	0.20 *									
Silk III	Plain weave	1.3	6.14	-0.33 *	0.36 *	-0.07	0.40 *									
Cotton I (organdy)	Plain weave	1.5	3.77	-1.25 *	0.29 *	-0.07	0.21 *									
			3.62	-1.38 *	0.38 *	-0.08		0.01								
			3.59	-1.09 *	0.33 *				0.21 *							
Cotton II (Batiste)	Plain weave	1.8	6.84		0.37 *	0.00						-0.02	0.08	-0.28*	-0.60*	
			5.00	-3.17 *	0.35 *	-0.04					0.03					-0.09
Acetate I (sheer)	Novelty weave	1.7	3.81	-0.23 *	0.34 *	-0.04	0.38 *									
Acetate II (Taffeta)	Plain weave	2.8	5.37		0.12	0.03		-0.11		0.33 *						
			5.21	-0.88 *	0.18 *	-0.13					-0.04					0.01
Rayon I (Chiffon)	Crepe weave	1.0	2.95	-0.80 *	0.37 *	-0.18	0.25 *									
			2.72	-0.70 *	0.32 *	-0.05		-0.00								
			2.81	-0.83 *	0.36 *				0.52 *							
			3.08		0.26 *	-0.06		0.05		0.16 *						
Rayon II (Blanket)	Plain weave brushed	5.8	1.01	0.01	0.03	0.03	0.10									
			0.91	0.00	0.11 *	0.01	0.03									
			0.92	-0.01	0.12 *	-0.05		-0.01								
			0.91	0.02	0.12 *				0.02							
Rayon Pile - Cotton back	Woven back	13.4	2.60	-0.05	0.95 *	0.14	0.04									
Orlon Pile Cotton back	Knit back	9.2	16.33	-5.64*	2.16 *	0.29	0.09									

* Results significant at a confidence level of 95% or greater


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