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NATIONAL BUREAU OF STANDARDS REPORT

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REVIEW OF PLASTICS FLAMMABILITY TEST METHODS

by

M. W. Sandholzer and M. P. Vaishnav

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Continuing a review of the technical basis of the Flammable Fabrics Act, a group of about 45 plastic materials were comparatively tested by the flammability test of CS192-53 for "General Purpose Vinyl Film" and by CS191-53 for the "Flammability of Clothing Textiles". On the basis of the results obtained, use of the test method of CS191-53 for determinig the flammability of both textile and plastic materials was recommended for the purposes of the Federal law. Some comparative data were obtained on the burning rates of textiles and plastics tested in the vertical position and in a position inclined at an angle of 45 degrees. Further consideration was given to the problem of testing materials from which standard sized test specimens cannot be cut, and recommendations on procedure were developed.

1. INTRODUCTION

In connection with a review of the operation and effectiveness of the Flammable Fabrics Act requested by the Secretary of Commerce, a detailed study of the commercial standards which serve to define hazardous flammability under the law has been in process. Commercial Standard 191-53 on the "Flammability of Clothing Textiles", which covers the bulk of clothing materials and has therefore been the primary flammability criterion, was considered first and the work on that standard is presented in NBS Report 8933. The study has been continued to include the flammability test procedure of Commercial Standard 192-53 on "General Purpose Vinyl Plastic Film", which is also referenced in the law but has not been called into extensive service because of the relatively limited use of plastic films in wearing apparel. Recent trends suggest, however, that plastic materials in various forms are likely to find increasing application in the clothing field, with the evaluation of their flammability hazard becoming more important.

2. PROCUREMENT OF MATERIALS

In initial work to develop familiarity with the SPI flammability tester (specified in CS192-53) and facility in its operation, various plastic films on hand were used. Meanwhile, efforts were made to obtain a collection of plastic materials representative of those used in clothing or conceivably suitable for clothing use. Procurement of a sizable group of such materials presented something of a problem, however, in view of their relatively limited clothing application and the fact that the type of plastic appearing in garments offered on the market is frequently not identified. Nevertheless, several garments were purchased and, following an extensive program of letter inquiry to plastics manufacturers, 4-6 sq. yd. samples of about 25 plastic film or plastic coated materials have been obtained to date. Not all of these materials are currently used in clothing necessarily, but were selected in some instances to represent a progressive variation in a given characteristic (such as weight) for a particular plastic material. The information supplied on the composition of the materials usually indicated only the general type of plastic involved, such as vinyl, polyethylene, etc., and in a few instances, even that was lacking.

3. COMPARATIVE DATA BY TWO TEST METHODS

In preliminary work with the tester, several points about the equipment and technique were noted which appeared unduly complicated. Threading the specimen holder, in particular, seemed awkward and time-consuming. Furthermore, the obvious basic similarity of the method to that of CS-191-53 suggested the possibility of using one test for both textiles and plastics. To explore the feasibility of combining the flammability determination and requirements for the two types of materials, a program of comparative testing by the two methods was organized.

Major points of similarity in the two methods include the general position in which the specimen is supported (45 degree angle), the width of specimen exposed (1 1/2 inches), and the type of ignition (a microflame applied to the specimen surface). They differ primarily in the duration of exposure to the igniting flame, and in the aspects of the flame spread which are noted and timed. In CS191-53 the igniting flame is applied to the specimen surface for one second only, and the time from first application of the flame until the burning of a thread 5 inches farther up the sample is automatically recorded. In CS192-53 the igniting flame remains in contact with the specimen indefinitely and the time from first application of the flame until the burning of a thread one inch farther up the specimen (called the ignition time) and the time from the burning of the first thread to that of a second thread 6 inches up the specimen from it (called the burning time) are automatically recorded. Addition of the ignition time and burning time in the CS192-53 method would, therefore, appear to provide measurement for a 7 inch length of specimen of a characteristic fairly comparable to that measured for a 5 inch length of specimen in the CS191-53 method, except for the difference in exposure to the igniting flame. In addition to the difference in time of exposure, the lower end of the specimen holder for the CS192-53 method is bent downward so that the bottom inch of the specimen is in a vertical plane instead of the inclined position of the remainder of the specimen. Thus, ignition takes place on vertically supported material, followed by the burning of material inclined at an angle of 45 degrees. The two methods also differ in numerous details, of course, but the basic similarity is such that a comparative study appeared profitable.

The materials used in developing comparative data included about 25 textile fabrics as well as the plastic types which had been acquired. Laboratory conditions and procedures and the techniques of sample preparation were kept as similar as feasible in conducting tests by the two methods. The specimens were not preconditioned other than exposure to the laboratory atmosphere, which probably did not show excessive variations in humidity inasmuch as nearly all of the tests were performed during the winter heating season. A general policy of completing both types of tests on a given material the same day was adopted. In cases where the material failed to ignite from the one second flame exposure in the CS191-53 method, application of the igniting flame was continued manually to produce ignition and provide data for comparison.

In order to obtain comparative information also on the heat produced by the burning specimens, a heat sensor, duplicating as nearly as feasible that previously installed in the cabinet of the CS191-53 method (NBS Report 8933), was provided in the cabinet of the CS192-53 method. The sensor consisted of a copper plate, 4 inches square, hung in a horizontal position above the upper end of the burning specimen and monitored by an automatic recorder through a chromel-alumel thermocouple. From the known characteristics of the plate and its increase in temperature, the heat absorbed by the plate may be calculated. For the present comparative purpose, however, the increase in plate temperature as represented by the millivolt change in the thermocouple signal is satisfactory.

Data on the burning times and heat evolution recorded by the two methods for 23 fabrics and 42 plastics are shown in Table 1. The values given are, for the most part, averages from five specimens except for those materials which did not ignite, or some specimens of which failed to burn the full length. Such failure occurred primarily with light weight plastics which melted easily and provided little fuel to support a flame. There was perhaps a slightly greater tendency toward this behavior in the CS192-53 tester than in the CS191-53 equipment.

CS192-53 requires that the average burning rate of the plastic shall not exceed 1.2 in./sec., which corresponds to a time of 5 seconds for the 6 inch length involved. In CS191-53 an average burning time of less than 4 seconds is defined as rapid and intense burning for textiles, and in the Flammable Fabrics Act that limit is lowered to 3.5 seconds for smooth-surfaced textiles. Referring to Table 1, or the graphical presentation shown in Figure 1, it will be noted that, on the basis of their present limits, the two standards would agree closely on the materials of either type which would be classed as unacceptable, differing only on one plastic material. The variance is somewhat increased if the limit stipulated by the Flammable Fabrics Act for smooth-surfaced textiles is used as the criterion. Of considerably greater interest than the particular acceptance limits used, however, is the generally linear relation between the results obtained by the two methods, especially for the plastic materials. When the data are reduced to as nearly comparable a basis as possible by taking account of both the ignition and the burning time, and the difference in specimen length in the two methods, the linearity even approaches very closely a one to one ratio as shown in Figure 2. Figure 3 graphically presents the relative heat output obtained in the two test methods, and again the relation is generally linear and approaches a one to one ratio.

The similarity in the comparative results obtained for plastics and for fabrics suggested that the two types of materials might also show a resemblance in the relations between heat output, material weight, and burning time. Accordingly, approximate weights of the plastic materials were determined and plots of material weight versus heat output and material weight versus burning time (Figures 4 and 5) were made. Plots of these same relationships for fabrics were presented in NBS Report No. 8933. Although the plastics plot of heat output versus material weight showed rather more scatter than that for fabrics, the relationships generally were quite similar for the two types of materials. In the plot of burning time against material weight, it is interesting to note the position of the present acceptance limits for fabrics, and the possible additional criterion outlined in Report No. 8933, with relation to the plastics materials. Application of any of these fabrics criteria would evidently bar from use in wearing apparel, very few of the plastic materials tested.

4. FEASIBILITY OF COMBINING TEST METHODS

The results of the comparative survey appear to support rather strongly the suggestion that the same test method might well serve for both textile and plastic clothing materials. Inasmuch as the method described in CS191-53 is the less complicated of the two, the ease of adapting that equipment to general plastics testing was considered. In making the present tests the chief difficulty experienced in using the textile test equipment for plastics work resulted from the excessive corrosion produced by the products of combustion of the plastics. The thread guides in particular, soon became so rough from corrosion that the thread caught on them after it had burned through and did not permit the weight to fall. Slipping a thin teflon sleeving onto the guides eliminated the trouble, however, and a teflon coating could presumably serve as a general solution. It was found also that after repeated exposure to the corrosive fumes, the thread stored on the spool became noticeably weakened. It would evidently be necessary to remove the thread supply from the cabinet when much plastics testing was to be done. Corrosion of unprotected metal parts was extensive in both cabinets, and the plastics equipment of CS192-53 was poorly protected, but other instances of actual interference in the conduct of the test did not develop during the period of this study. It should be noted that the conditioning requirements of the CS191-53 method would need to be modified for plastic materials, inasmuch as many plastic films soften or melt at 105 C. In view of the generally low moisture absorption by plastics, it is quite possible that no special conditioning of the specimens would be necessary.

With the minor modifications outlined above, the textile test equipment and procedure of CS191-53 would appear to be as suitable for evaluating the flammability of plastic materials for clothing purposes as the flammability test of CS192-53. We would recommend, therefore, that reference to CS192-53 be dropped from the Federal law and that all clothing materials be evaluated by the method described in CS191-53 (with the tester modified as outlined above). We further suggest that the 4-second maximum time limit for flame spread of CS191-53 should serve satisfactorily for the classification of plastic materials.

5. COMPARISON OF INCLINED METHOD WITH A VERTICAL METHOD

In the methods of both CS191-53 and CS192-53, and also that of N.F.P.A. Standard 702 which has been suggested for reference in the Federal law, the specimen is supported in an inclined position. The inclined position generally provides a better defined flame front than the vertical position and permits more reproducible measurement on small samples, but there has been some feeling that a vertical test position would be preferable for wearing apparel, as better representing the conditions of use. It appeared that some comparative data on fabrics tested in the two positions would be of interest and the British "Vertical Strip Test" for flammability (British Standard 2963:1958) offered a suitable established vertical method. Briefly, the method determines the rate of burning from visual observation of the time required for the flame front to travel up 50 inches of a vertically suspended specimen 72 inches long and 1 1/2 inches wide. The source of ignition is a 1 1/2 inch luminous Bunsen flame, and 10 inches of the specimen burn before timing is begun.

About 20 fabric and 15 plastic materials were tested by this British vertical strip method. The specimens were not preconditioned in other than the ambient room atmosphere. All of the fabrics were tested during the cold weather heating season but, because of the production of excessive smoke and fumes, the plastics tests were made in another laboratory not heated at the time. To explore the effect of specimen width on the burning rate, tests were made on both 1 1/2 inch and 3 inch strips of most of the materials, using three specimens of each width. Table 2 shows the average time of flame travel up the 50 inch length, recorded for the various materials. The specified criterion of "the lower edge of the flame" was definite and satisfactory for the cotton, rayon, and silk fabrics, but it became indeterminate and unsatisfactory for many of the synthetic fabrics and plastics. Some of these formed long, charred ropes on which reduced flaming continued over the full length. On others the softening and stretching characteristic of heated plastic materials changed the position of the flame site so erratically that there was often no discernable "front", or dropped the flaming portion away from the specimen entirely. Hence, for the plastics generally, and to a lesser extent for the synthetic fabrics, the recorded values represent only the judgment of the operator as to a reasonable measure of the flame progress. The effect of increasing the specimen width was a generally consistent increase in the rate of burning, with the major exception of one polyethylene material. The 3 inch specimens usually required around 20-30% less time to burn the 50 inches than the 1 1/2 inch specimens, but the difference tended to be smaller among the slow burning materials and somewhat larger among the rapid-burning materials. Although the 3 inch specimens burned more rapidly than the narrower strips, the tendency to maintain flame travel up the full length of the specimen did not appear significantly increased.

To permit some comparison between the results of the British vertical test and those of the inclined methods, the results of all four methods were reduced to a rate of flame spread basis and are listed in Table 3. The rates in the vertical test were calculated from the values obtained for the 1 1/2 inch wide specimens. In addition to the position of the specimen, other differences among the methods would tend to produce the most rapid burning rate in the vertical test. All three of the inclined methods use small specimens and time the flame spread from the moment of ignition, whereas the vertical method does not begin the timing until ignition is well established and the flame travel has reached essentially its maximum rate. In the methods of both CS191-53 and CS192-53 the igniting flame is applied to the surface of the specimen, and in the results shown for CS191-53 the time required for ignition is included in the calculation of the rate. While the CS192-53 method provides separate records of the ignition time and the time of flame travel, in practice the flame spread timing frequently starts before ignition is well established and in this method also, the burning time may include part of the ignition time. The N.F.P.A. 702 method uses edge ignition of the lower end of the specimen and therefore approaches the conditions of the vertical test a little more closely, but again the ignition is included in the recorded time interval.

For the cottons and rayons the rate of flame spread showed a fairly consistent inverse relation to the weight of the material, particularly with the methods using edge ignition of the specimen. The relation did not hold as well for synthetic and plastics materials which are notably erratic in burning behavior. A number of the plastics which burned in the inclined position failed to give a reading in the vertical position.

Figures 6 and 7 show graphically the relation between the rate of flame spread in the vertical position and that indicated by the two commercial standards, which followed each other closely in most instances. It is a generally linear relation, particularly for the cotton and rayon group of materials. As would be expected, the correlation between the rates determined by N.F.P.A. Standard 702 and the vertical test, shown in Figure 8, is somewhat closer than that between the commercial standards and the vertical.

6. EFFECT OF SEAMS ON BURNING BEHAVIOR

Among the synthetic and plastic materials a considerable number failed to give readings in one or more of the test methods because the characteristic tendency to melt blocked flame travel, either by dropping the burning portion away from the specimen entirely or by the softened material contracting to form a heavy rolled edge too massive to be heated sufficiently by the flame to maintain propagation. In clothing, however, seams or decorative stitching of cotton thread might serve as a tie between burning and unburned material and provide a path by which flame spread could continue. To explore this possibility, specimens of a number of materials were prepared with a lengthwise center line of cotton thread, either hand sewn with double thread or machine stitched. There appeared to be no consistent difference between the effects of hand sewing and machine stitching. The results of comparative tests conducted in the testing equipment of CS191-53 are summarized in Table 4. The materials were selected to include three groups, the type all specimens of which regularly failed to burn, the type some specimens of which burned and others failed, and the type all specimens of which regularly burned the full length.

Among the synthetic fabrics the stitching clearly encouraged burning to the top of the specimen but did not make burning a certainty. On the materials which burned (either regularly or occasionally) without the stitching, it did not serve as a path for more rapid flame spread, but rather tended to retard flame travel a little on the faster-burning materials. In the inclined test, the stitching appeared to have little effect on the results obtained with the plastic films. Further tests made with the vertical method indicated that, in that position, stitching up the center of the specimen would encourage full length burning of a few plastic films, but again it made the flame travel neither certain nor appreciably more rapid. Hence, it would not appear that seams or stitching are a particularly significant factor in the flammability hazard of clothing, although in a few instances they may permit some extension of the flame spread.

7. TESTING OF COSTUME ITEMS

One area of wearing apparel in which synthetic and plastic materials of various types are particularly prominent is that of special costume items such as hula skirts, masquerade outfits, masks, etc. These items present a special problem in that it is often impossible to cut standard-sized test specimens from them. For hula skirts, artificial hair and other items composed of narrow but generally flexible strips of material, preparation of a reasonably standard-sized specimen requires only that a suitable cross support be provided on the specimen holder. A specimen of narrow strips made up to the thickness in which they are worn (or various thicknesses in which they are worn) can be laid on such a support and tested in the usual manner. A test proposed for inclusion in the revision of CS191-53, provides for a cross grid made of strips of the material under test, and this avoids the introduction of any other material into the test. A grid made of the No. 50 sewing thread, however, would provide a more widely applicable and more easily prepared standard support. Six cross threads about an inch apart would appear generally adequate, and would contribute no significant fuel or flame spread to the test results. The threads could be easily positioned by lines drawn across the lower plate of the specimen holder or by notches in its sides. Such a standard thread grid could also serve to support narrow trimmings and other narrow specimens, without resorting to various special arrangements.

There are some costume items, however, particularly headgear, face masks, false noses, and the like, which may be formed quite rigidly into strange and uncooperative shapes, and these present a more difficult test problem. In an effort to find a procedure which would readily encompass such oddities, several different approaches were considered and briefly explored. These included ignition by timed-burning tablets, ignition of the complete mask supported on an asbestos "head", and various ways of flattening the item into approximately sheet form. None of the several procedures tried appeared to offer sufficient advantage to warrant a shift to an entirely different test method for so small a segment of the wearing apparel field. The judgment of the operator will unavoidably play a part in the testing of such widely diverse items by any method, and channeling it primarily into the selection and preparation of the specimen might well give the greatest uniformity. Many masks will permit cutting at least one fairly flat, standard-sized specimen, and from others a somewhat narrower flat specimen might be obtained and supported in the same way as other narrow materials. Presumably, the testing of rigidly odd-shaped items will be limited, and we would suggest that the standard procedure be retained (except for the oven conditioning), with the specimens prepared as nearly in accordance with the standard requirements as feasible.

8. SUMMARY

A review of the technical basis of the Flammable Fabrics Act has been continued with work on the testing of plastic materials. A group of about 45 plastic film and plastic coated and combination materials have been subjected to both the flammability test of CS192-53 for "General Purpose Vinyl Film" and that of CS191-53 for the "Flammability of Clothing

Textiles". The results of these tests indicate that, with slight modifications, the equipment and procedure specified for textiles in CS191-53 would be quite as satisfactory for plastics as the test method described in CS192-53, and would offer significant technical advantage.

To explore the relation between the vertical burning rate of a material and that of the material supported at an angle of 45 degrees, a representative group of the materials under study (both plastics and textiles) were tested by the vertical strip test of British Standard 2963:1958. The cottons and rayons showed a clearly linear relation between the burning rates in the two positions, with the vertical burning rates the more rapid. The rates calculated for the synthetic and plastic materials also showed a generally linear relation, but the vertical burning times were highly questionable because of the particularly erratic burning behavior of plastics in the vertical position. A seam of cotton thread up the center of the specimen did not increase the flammability hazard significantly in either the inclined or the vertical position.

Several approaches to the problem of testing costume items and narrow trimmings which will not provide standard-sized specimens, have been explored. It would appear that most items of that type could be accomodated rather simply by providing a support gird of sewing thread across the back plate of the specimen holder. For the relatively infrequent tests that may be required of rigidly odd-shaped masks and the like, it is suggested that the operator prepare specimens as near to the regulation size as feasible, for test by the standard ignition procedure.

Table 1. Results of Flame Tests by Two Methods

Test Materials		CS191-53		CS192-53		
Identifying designation	Primary components	Burn time	Heat output	Ignition time	Burn time	Heat output
Plastic	Materials	sec	mv	sec	sec	mv
Plastic A	-------	3.15*	0.130	0.89	4.46	----
Plastic B	-------	3.65	0.190	0.70	6.06*	----
Plastic C	-------	3.48	-----	0.77	3.54*	----
Plastic D	-------	9.81	0.245	2.65	8.67*	----
Plastic E	-------	3.68	0.153	0.91	3.73	----
Plastic F	-------	7.52	0.207	1.52	9.88*	----
Plastic G	-------	----*	-----	1.50	----*	----
Plastic H	-------	7.73*	0.285	1.67	----*	----
Plastic I	-------	----*	-----	1.66	----*	----
Plastic J (raincoat I)	-------	----*	-----	0.86	----*	----
Plastic K (raincoat II)	vinyl	7.12	0.178	1.57	5.58	0.172
Plastic L (raincoat III)	-------	13.22 (1)	0.453	1.44	6.70 12.76(1)	0.307
Plastic M (mattress cover)	-------	3.62*	0.122	1.18	4.59*	0.072
Plastic N (dress)	vinyl with knit cotton back	----*	-----	0.66	32.30*	0.140
Plastic O	-------	8.09*	0.189	1.14	9.76*	0.118
Plastic P	-------	7.28*	0.172	1.14	11.60*	0.165
Apron A	-------	7.20*	0.168	0.84	7.55*	0.148
Apron B	-------	7.00*	0.165	0.83	8.12*	0.152
Polyethylene A	polyethylene	29.10	0.282	4.25	----*	-----
Polymat	-------	15.51	0.346	5.40	15.57	-----
Composite A	neoprene and nylon	-----*	-----	4.61	-----*	-----
Composite B	neoprene and cotton	-----*	-----	4.61	-----*	-----
Composite C_1	rubber and cotton	29.62	1.943	5.93	31.91	-----
Composite C_2	rubber and cotton	39.29 64.92 (1)	2.085 1.697 (1)	5.30	42.49 107.26(1)	-----
Composite C_3	rubber and cotton	136.26	1.670	8.36	173.32	1.188
Composite D_1	rubber and nylon	16.83	0.927	1.72	23.32	0.988
Composite D_2	rubber and nylon	11.98	0.892	1.64	16.03	0.950
Composite D_3	rubber and nylon	25.63	1.486	2.37	36.20	1.639
Composite D_4	rubber and nylon	22.74	1.082	2.22	24.93	1.099
Composite D_5	rubber and nylon	21.62	1.545	2.42	25.41	1.551
Composite D_6	rubber and nylon	35.20	1.755	3.59	32.64	1.554
Composite E	polyethylene and Fiberglas	16.07	0.626	1.46	22.39	0.528
Propionate A	extruded propionate, 5 mil	7.17	0.295	2.42	13.08*	0.310
Propionate B	extruded propionate, 10 mil	16.21	0.886	4.95	17.49	0.759
Vinyl A	vinyl, 2 mil	3.52*	0.136	0.66	4.18*	0.071
Vinyl B	vinyl, 4 mil	6.27	0.250	0.82	8.65	0.203
Vinyl C	vinyl, 6 mil	11.25	0.352	1.67	13.76*	0.342
Vinyl D	vinyl, 10 mil	17.47	0.564	2.17	19.83	0.575
Vinyl E_1	expanded vinyl - cotton lining	40.34* (1)	0.575(1)	1.42	43.30*	2.000
Vinyl E_2 (back of E_1)	cotton lining-expanded vinyl	37.48 59.08 (1)	1.720 1.620(1)	4.25	45.63 82.02(1)	1.394 1.100(1)
Disposable clothing (uncoated)	polyethylene	-----*	------	1.03	-----*	-----
Disposable clothing (coated)	polyethylene	14.74	0.313	0.86	18.27*	0.312

* One or more specimens failed to burn far enough to provide a reading; value based on less than 5 specimens (sometimes on only one)

[1] The flame failed to break through to the back of the burning specimens, a situation which tended to extend the burning time and reduce the heat output. Where the flame broke through some specimens and not others, results from the two types of burning were averaged separately and the two values are shown.

Table 1 (con't)

Test Materials		CS191-53		CS192-53		
Identifying designation	Primary components	Burn time	Heat output	Ignition time	Burn time	Heat output
Textile	Materials	sec	mv	sec	sec	mv
Net	Dacron	-----*	-----	0.56	7.08*	-------
Sheer	Dacron	16.85	0.209	0.58	20.54*	0.079
Silk I	Silk	3.46	0.117	0.85	4.61*	0.072
Silk II	Silk	4.42	-----	1.40	5.73	-----
Silk III	Silk	7.39	0.128	0.87	12.78	0.104
Cotton I (organdy)	Cotton	4.29	0.265	0.92	5.39	0.312
Cotton II (batiste)	Cotton	9.66	-----	1.82	7.53	-----
Percale sheet	Cotton	19.36	0.579	2.88	14.88 38.38 (1)	0.525 0.315 (1)
Quilted pad	Cotton	38.87	1.313	2.45	47.24	1.083
Flannelette	Cotton	18.40	0.543	0.96	15.38	0.496
Shantessa print	Cotton	20.03	0.479	1.91	25.07	0.457
Dotted Swiss	Dacron 65%, cotton 35%	11.58	0.429	0.81	11.78	0.382
Stretch poplin	Zantrel rayon 50%, cotton 50%	29.48	0.857	3.11	20.86	0.701
Bengaline (warp direction)	Rayon warp, cotton fill	35.85 48.36 (1)	0.772 0.437(1)	3.93	60.57 (1)	0.402 (1)
Bed blanket II	Rayon 74%, cotton 20%, nylon 6%	1.12(2)	-----	0.64	1.45 (1)	0.572 (1)
Pile Fabric III	Orlon pile, cotton back	20.16	1.433	1.71	32.35 (1)	0.855 (1)
Quilted robe II	Acetate cover and back, polyester pad	20.31	0.974	1.12	16.66	0.658
Raincoat (warp direction)	Cotton warp, acetate fill	21.70	0.952	3.21	20.22	0.956
Raincoat (fill direction)	Cotton warp, acetate fill	49.95 49.48(1)	0.850 0.589(1)	3.36	34.94 63.80(1)	0.750 0.600 (1)
Lined lace I	Cotton lace, acetate back	8.98	0.945	1.63	14.32	1.139
Lined lace II	Wool 50%, raffia 50%, acetate back	17.79	1.191	1.31	26.37	1.172
Taffeta	Acetate	6.67	0.491	1.50	7.35	0.496
Acetate I	Acetate, rayon, metallic thread	4.20	0.294	0.45	5.29	0.306
Acetate II	Acetate	5.95	0.428	0.82	6.41	0.438

* One or more specimens failed to burn far enough to provide a reading; value based on less than 5 specimens (sometimes on only one).

1 The flame failed to break through to the back of the burning specimens, a situation which tended to extend the burning time and reduce the heat output. Where the flame broke through some specimens and not others, results from the two types of burning were averaged separately and the two values are shown.

2 The specimens showed only a surface flash or burning and the base fabric was not ignited.

Table 2. Results from British Vertical Strip Test

Material	Average time for 50-inch flame travel: 1 1/2-in. width	Average time for 50-inch flame travel: 3-in. width
	sec	sec
Cotton and Rayon Textiles		
Chiffon, rayon	8.1	------
Cotton I, organdy	9.4	5.4
Cotton II, batiste	12.5	------
Novelty I, rayon	17.8	------
Shantessa print	16.6	11.3
Percale sheet, cotton	19.0	13.1
Flannelette, cotton	20.4	16.0
Stretch poplin	27.5	21.3
Bengaline	30.3	23.2
Quilted pad, cotton	37.1	32.5
Silk and Synthetic Textiles		
Silk I	23.1 (1)	20.3 (2)
Silk II	30.3 (2)	------
Net, Dacron	78.0 (2)	------(3)
Acetate I	25.6	21.3
Acetate II	26.7	21.6
Sheer, Dacron	----- (3)	------(3)
Dotted Swiss	19.3	11.5
Taffeta, acetate	29.8	27.8
Lace I	36.1	25.1
Quilted robe II, acetate	80.0	76.0
Pile fabric III, Orlon pile	73.0	71.0
Plastic Sheet and Coated Materials		
Polyethylene A	188	212
Disposable clothing (uncoated)	163 (2)	136
Disposable clothing (coated)	58	56
Plastic D	--- (3)	28 (1)
Plastic M (mattress cover)	--- (3)	--- (3)
Plastic O	--- (3)	--- (3)
Plastic P	--- (3)	--- (3)
Vinyl A, 2 mil	--- (3)	--- (3)
Vinyl B, 4 mil	35 (2)	--- (3)
Vinyl C, 6 mil	32 (2)	38 (2)
Vinyl D, 10 mil	52 (2)	38
Propionate A, 5 mil	--- (3)	--- (3)
Propionate B, 10 mil	--- (3)	--- (3)
Composite E (polyethylene and Fiberglas)	30	27
Vinyl E (expanded vinyl)	52	41

[1] Value based on 2 out of 3 specimens; other failed to burn to the top.

[2] Value based on 1 specimen only; others failed to burn to the top.

[3] None of the specimens burned to the top marking wire.

Table 3. Comparative Results in Vertical and Inclined Test Methods

Material	Material weight	Rate of Flame Spread British Vertical	NFPA 702	CS 191-53	CS 192-53
	oz/yd2	in/sec	in/sec	in/sec	in/sec
Cottons and Rayons					
Rayon chiffon	1.0	6.17	2.08	1.55	1.30
Cotton I (organdy)	1.5	5.32	1.61	1.17	1.11
Cotton II (batiste)	1.8	4.00	1.39	0.52	0.80
Novelty I, rayon	3.3	2.81	0.88		
Flannelette, cotton	3.7	2.45	0.71	0.27	0.39
Shantessa print	3.9	3.01	0.86	0.25	0.24
Percale sheet	3.9	2.63	0.78	0.26	0.40 (1)
Stretch poplin	6.2	1.82	0.53	0.17	0.29
Bengaline	6.5	1.65	0.45	0.10	0.10
Quilted pad, cotton	9.6	1.35	0.31	0.13	0.13
Silks and Synthetic Fabrics					
Silk I	0.6	2.16	1.67	1.44	1.30
Silk II	0.7	1.65 (1)	1.43	1.13	1.05
Net, Dacron	0.8	0.64 (1)	0.58	---- (2)	0.85
Sheer, Dacron	2.0	---- (2)	0.39	0.30	0.29
Acetate I	1.7	1.95	1.39	1.18	1.13
Acetate II	2.8	1.87	0.94	0.88	0.94
Dotted Swiss	2.8	2.59	0.89	0.43	0.51
Taffeta, acetate	3.5	1.68	0.93	0.75	0.82
Lace I	5.1	1.39	0.70	0.56	0.42
Quilted robe II	6.8	0.62	0.42	0.25	0.36
Pile fabric III	9.2	0.68	0.35	0.25	0.19
Plastic Sheet and Coated Materials					
Polyethylene A	4.1	0.27		0.17	---- (2)
Disposable clothing (uncoated)	1.3	0.31 (1)		---- (2)	---- (2)
Disposable clothing (coated)	1.8	0.86		0.34	0.33
Plastic D	3.9	1.79 (3)		0.51	0.69
Plastic M (mattress cover)	1.7	---- (2)		1.38	1.31
Plastic O	3.7	---- (2)		0.62	0.61
Plastic P	4.1	---- (2)		0.69	0.52
Vinyl A, 2 mil	1.6	---- (2)		1.42	1.44
Vinyl B, 4 mil	3.5	1.43		0.80	0.69
Vinyl C, 6 mil	5.7	1.56		0.44	0.44
Vinyl D, 10 mil	9.4	0.96		0.28	0.30
Propionate A, 5 mil	4.7	---- (2)		0.70	0.46
Propionate B, 10 mil	9.1	---- (2)		0.31	0.34
Composite E	3.4	1.67		0.31	0.27
Vinyl E (expanded vinyl)	17.9	0.96		0.12	0.13

[1] Based on results for 1 or 2 specimens only.

[2] None of the specimens burned to the top.

[3] Calculated from the results for two 3-inch specimens since none of the 1 1/2-inch specimens burned to the top.

Table 4. Effects of Stitching on the Results Obtained by the CS191-53 Method

Material	Without stitching			With stitching		
	No. of specimens		Avg.	No. of specimens		Avg.
	tested	burned	time	tested	burned	time
			sec			sec
Pink nylon net	5	0	----	11	11	7.56
Yellow nylon net	5	0	----	6	6	7.68
Red nylon chiffon	5	0	----	15	13	9.29
Green nylon chiffon	3	0	----	2	2	10.78
Dacron net	10	5	7.15	12	10	5.16
Nylon-rayon scarf	5	2	5.13	5	5	6.36
Silk chiffon	3	3	4.15	3	3	4.40
Green sheer	4	4	4.14	3	3	4.72
Plastic B	3	3	2.82	3	3	3.32
Plastic C	3	3	3.26	3	3	3.14
Plastic G	5	0	----	5	0	----
Plastic H	5	2	7.73	5	1	8.53
Plastic I	5	0	----	5	0	----

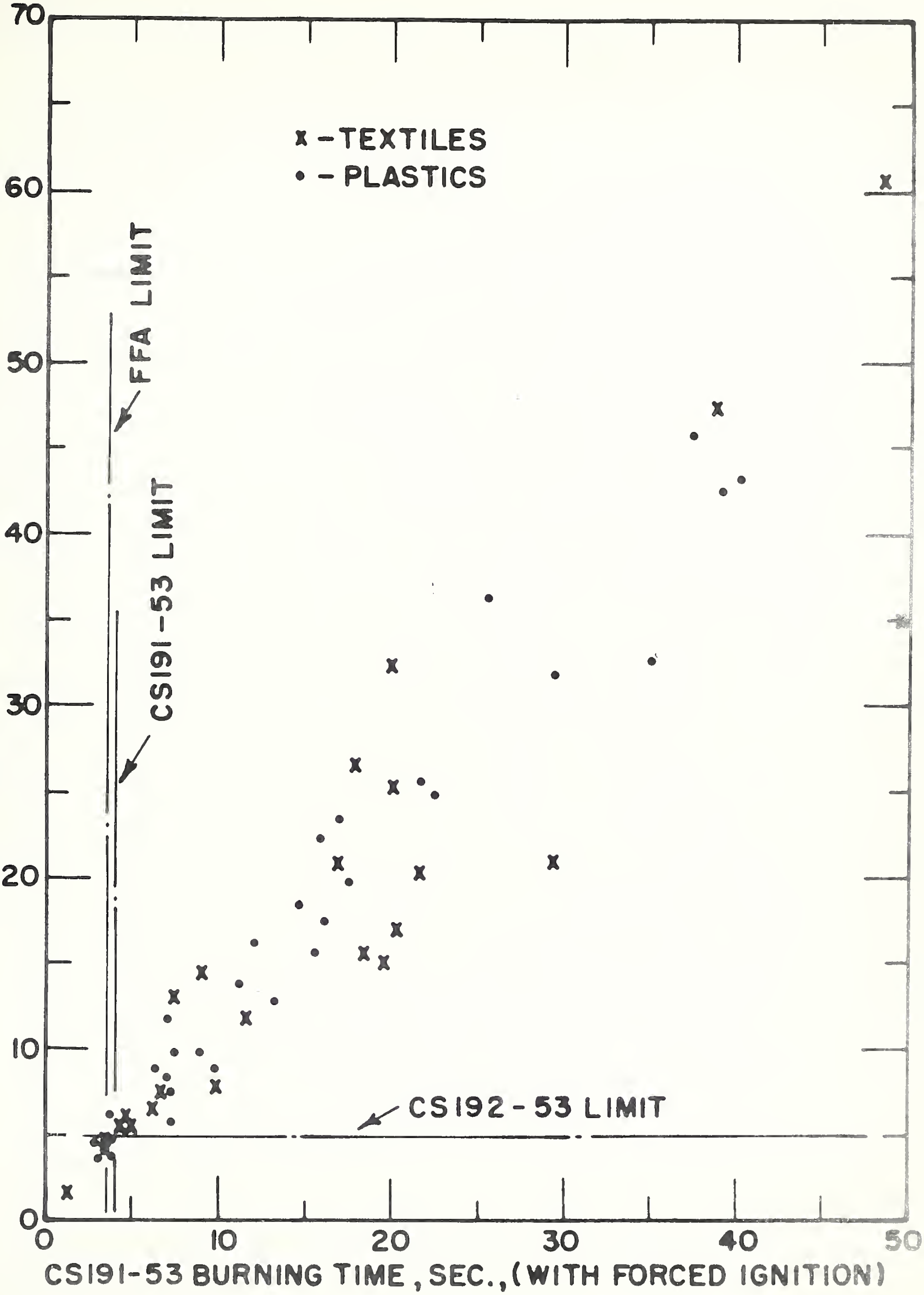

Fig. 1. Relation Between Burning Times by the Two Methods

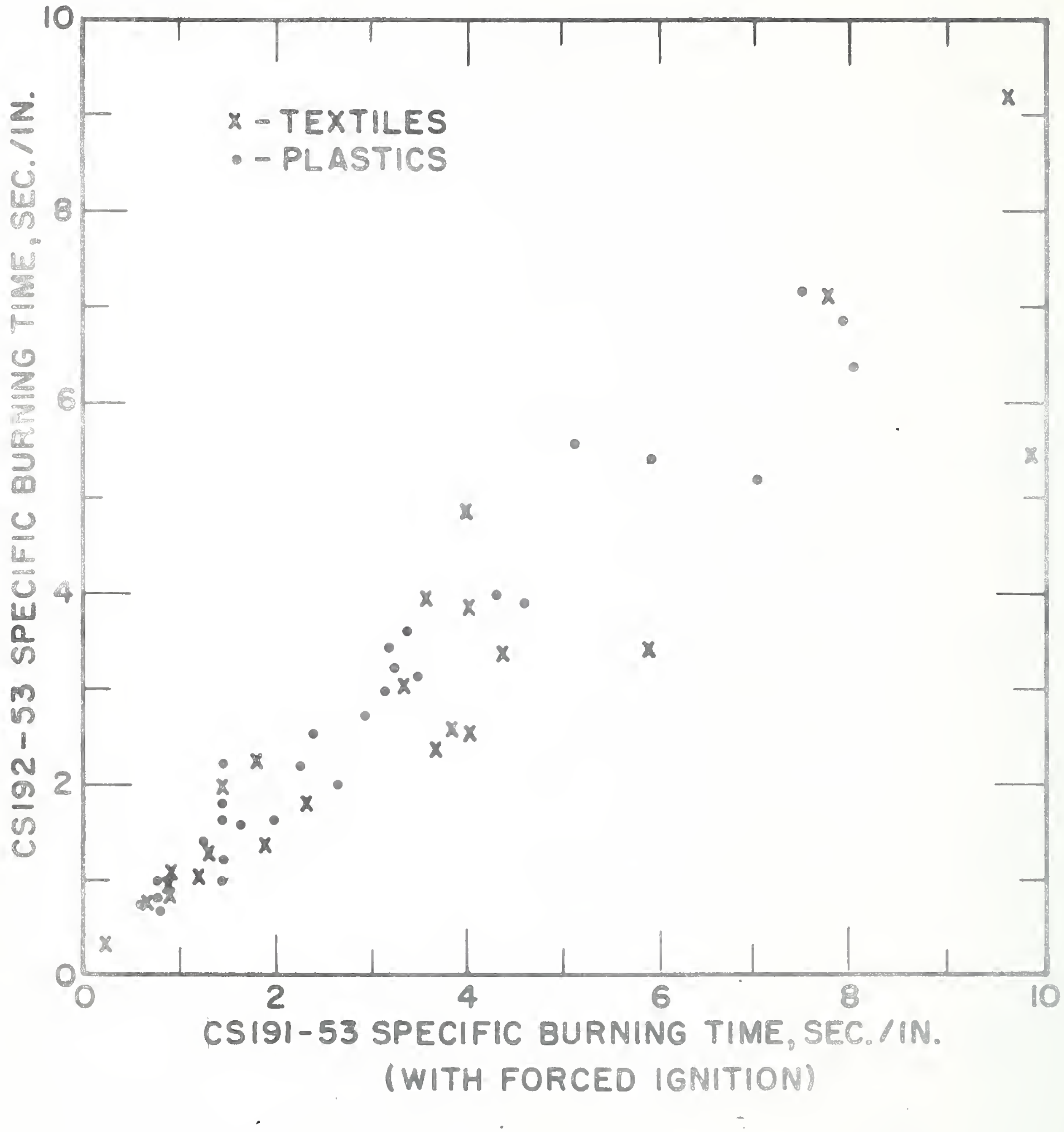

Fig. 2. Relation Between Specific Burning Times by the Two Methods

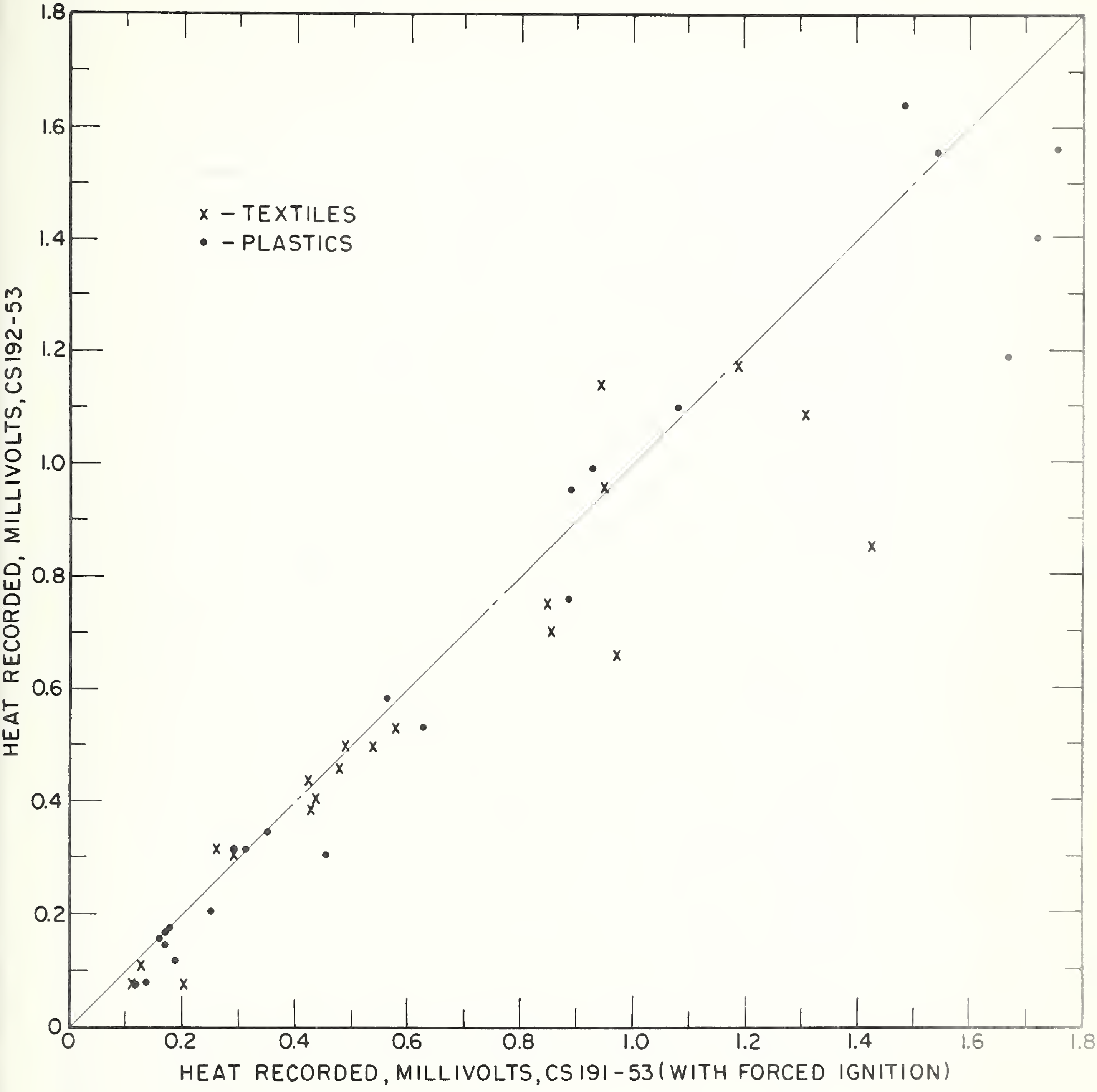

Fig. 3. Relation Between Heat Recorded by the Two Methods

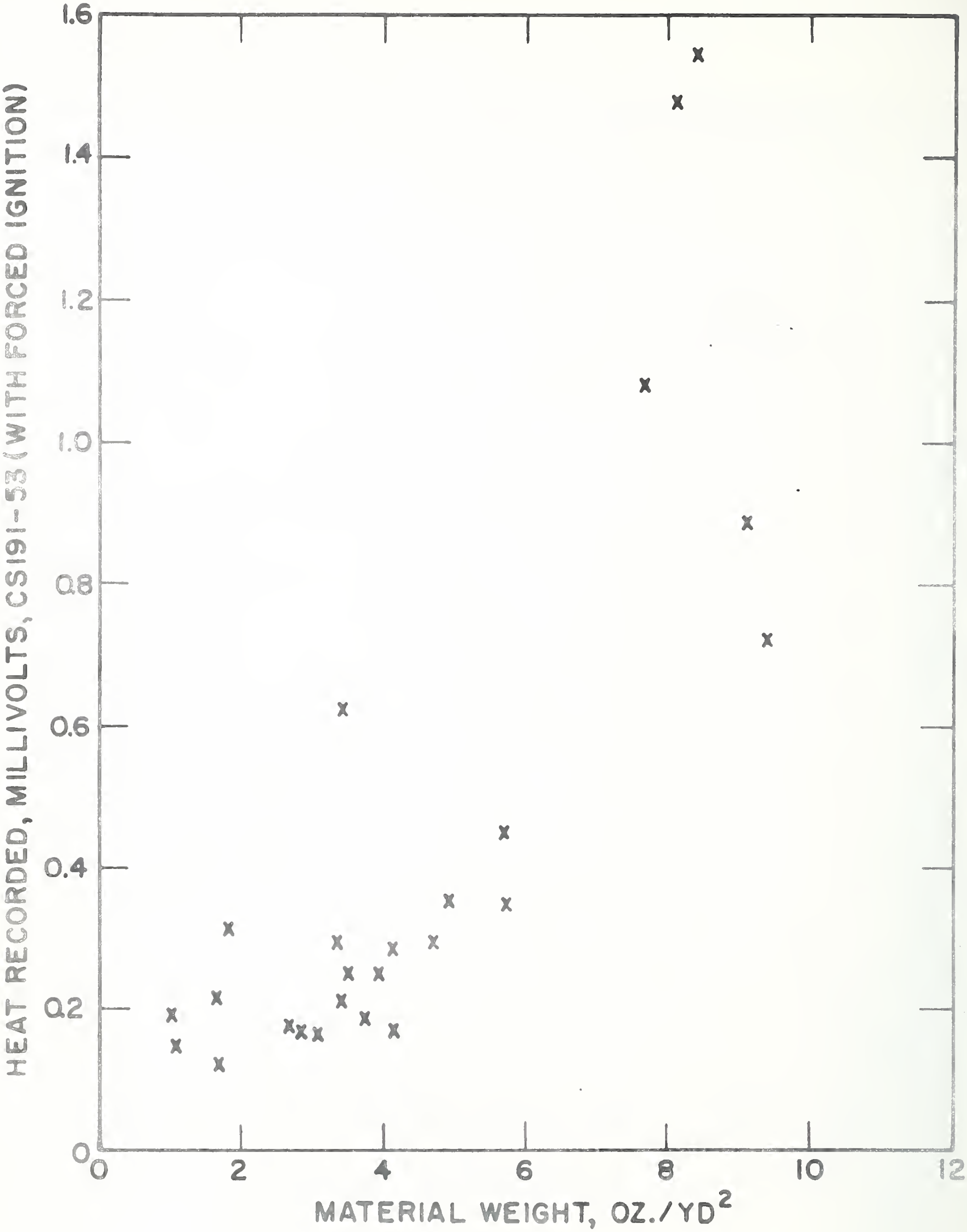

Fig. 4. Relation of Heat Output to Material Weight for Plastics

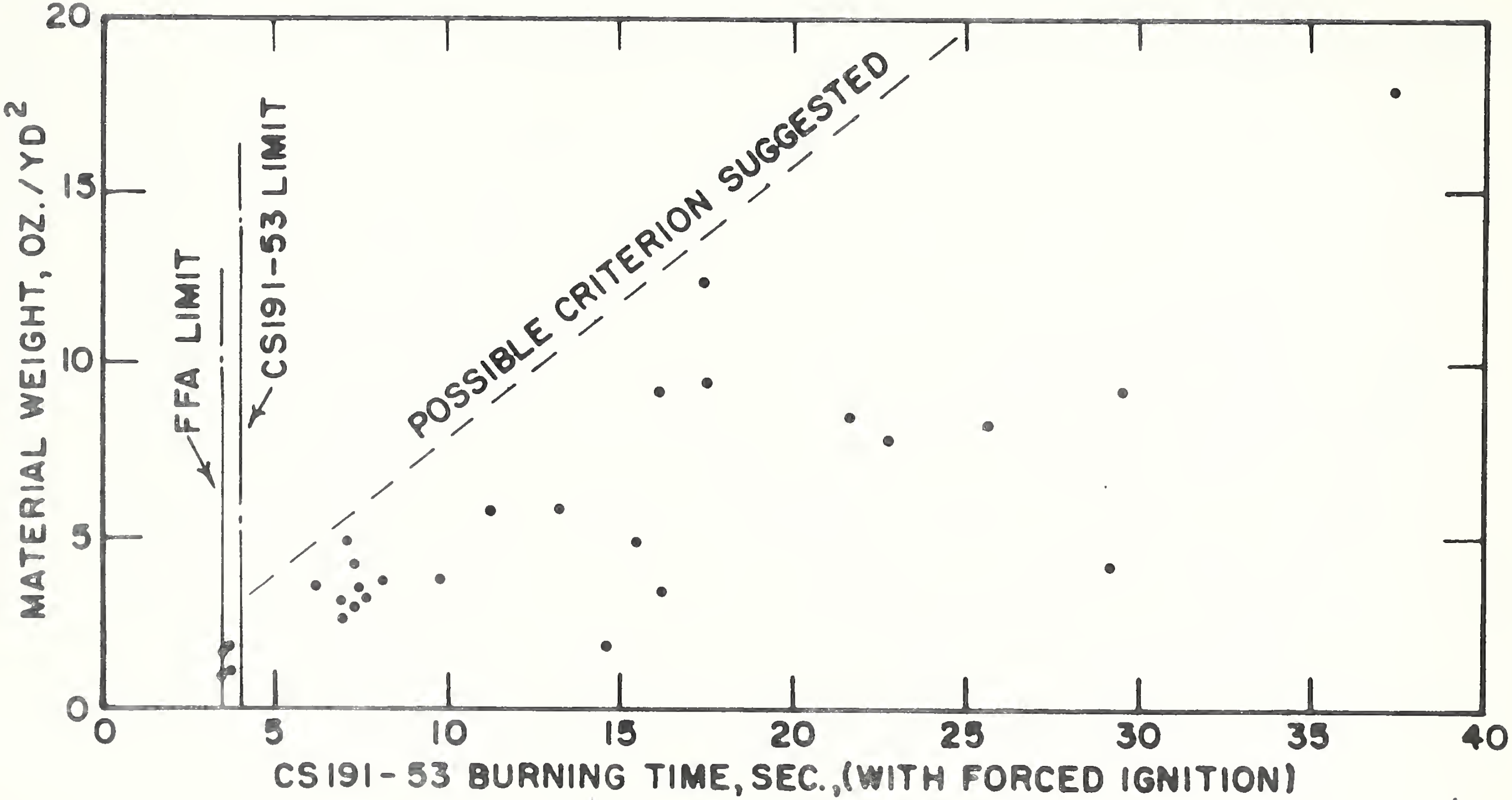

Fig. 5. Relation of Material Weight to Burning Time for Plastics

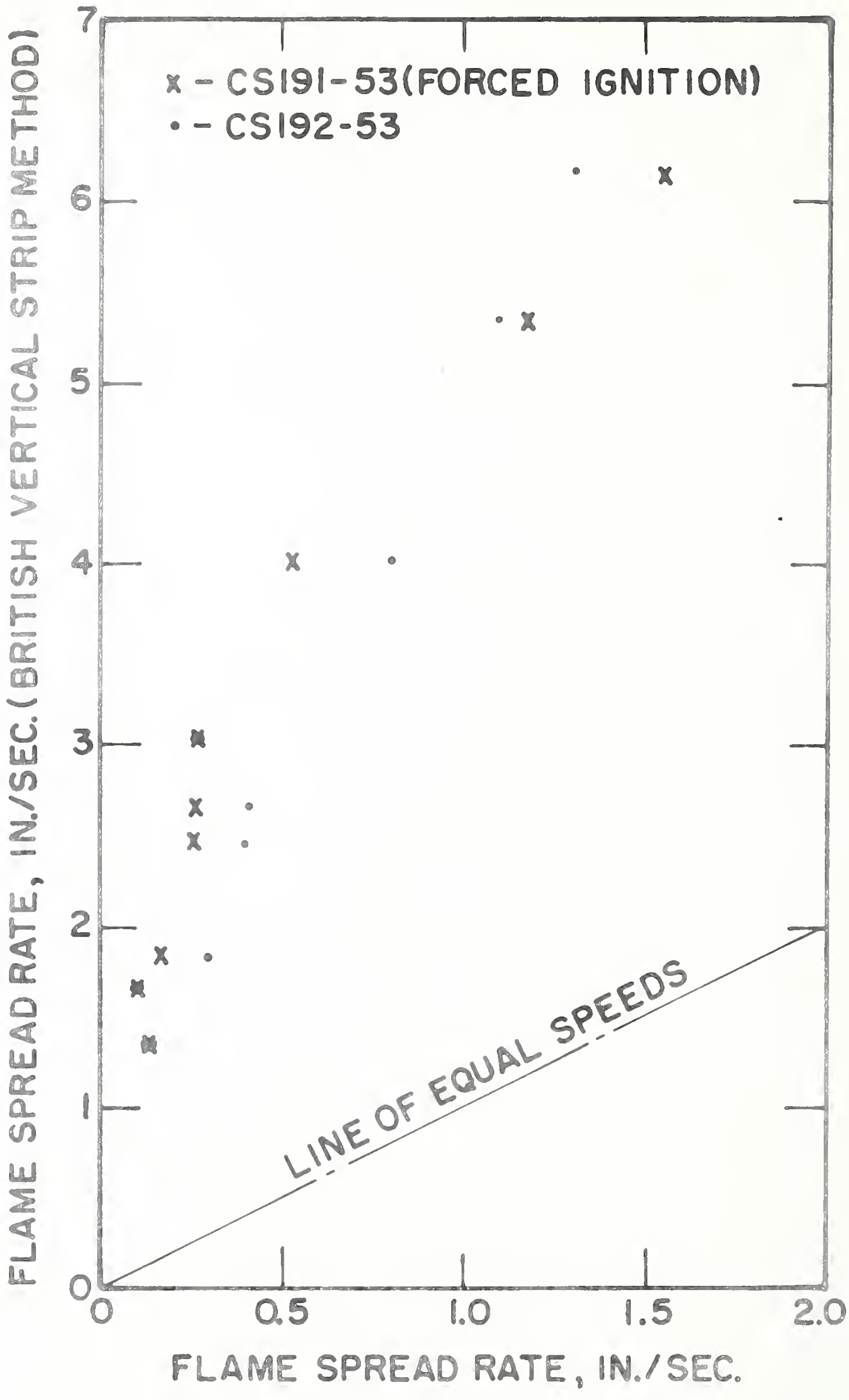

Fig. 6. Relation Between Vertical and Inclined Burning Rates for Cotton and Rayon Fabrics

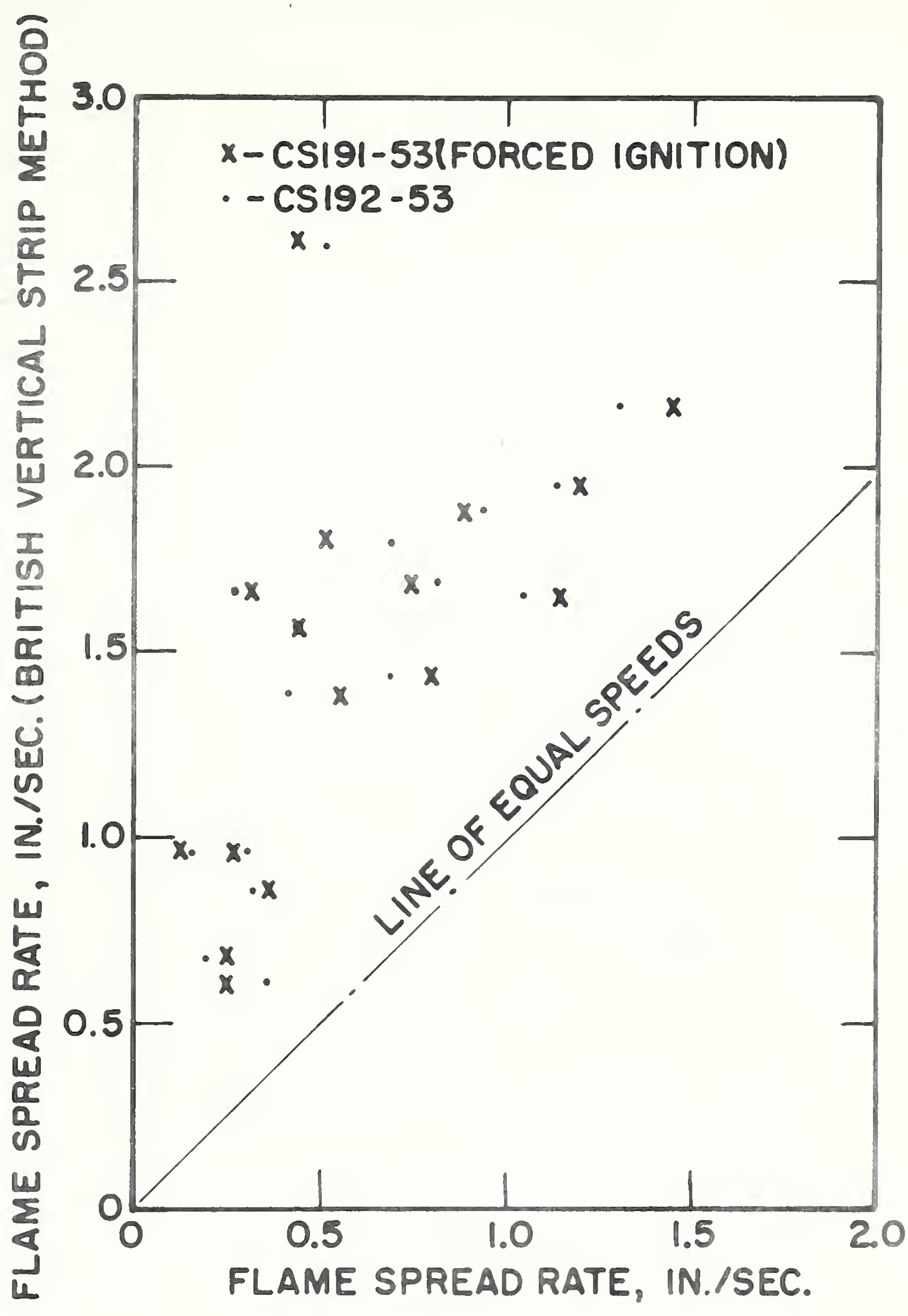

Fig. 7. Relation Between Vertical and Inclined Burning Rates for Silk and Synthetic Fabrics and Plastics

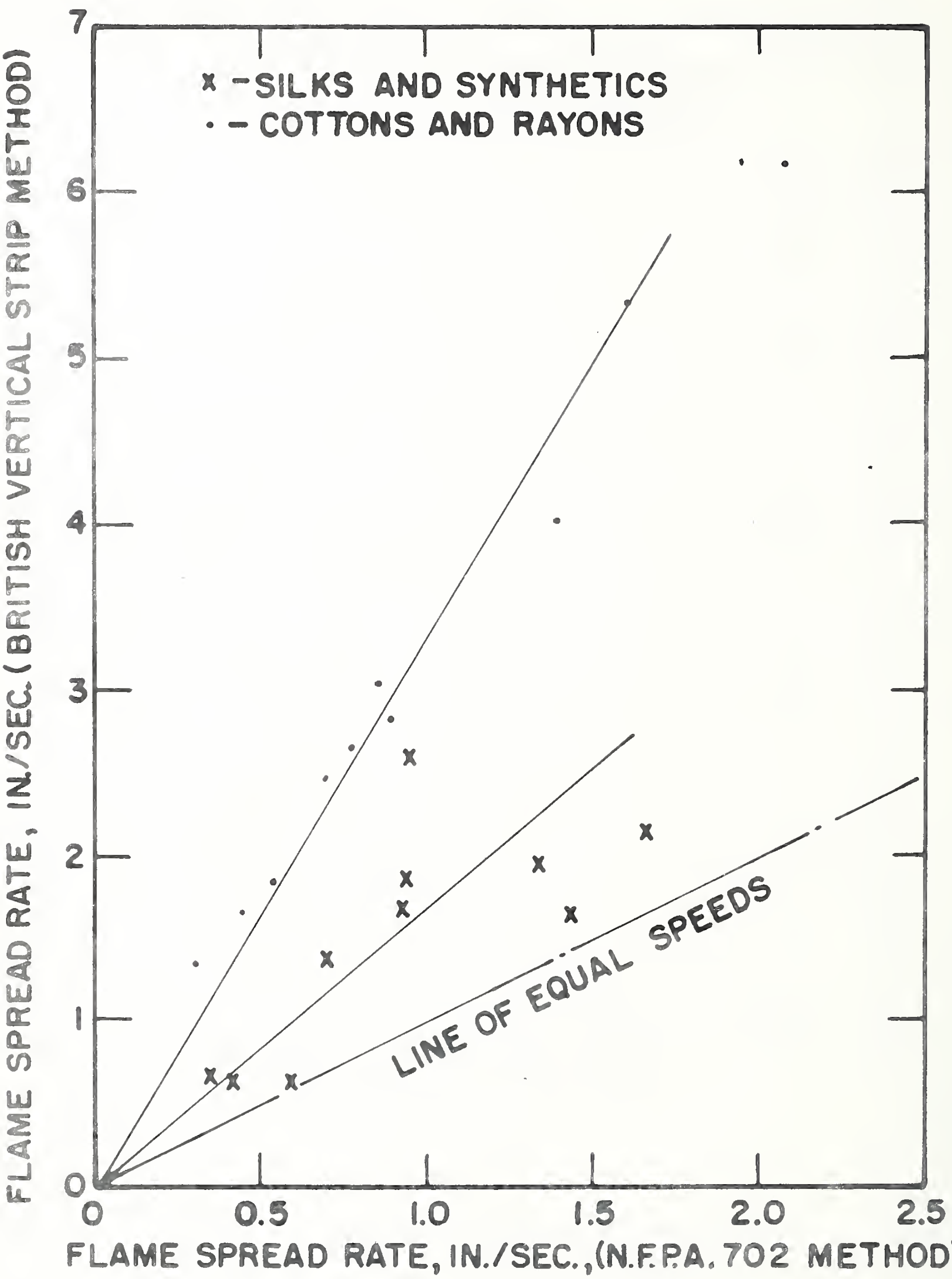

Fig. 8. Relation Between the Vertical Burning Rate and the Inclined Rate Determined by the N.F.P.A. 702 Method

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