NFPA No.

701

FIRE TESTS

FLAME-RESISTANT TEXTILES, FILMS 1966

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Official NFPA Definitions

Adopted Jan. 23, 1964. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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Units of Measurements

Units of measurements used here are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters. One foot = 0.3048 meters. One inch = 25.40 millimeters. One pound per square inch = 0.06805 atmospheres = 2.307 feet of water. One pound = 453.6 grams.

STANDARD METHODS OF FIRE TESTS FOR FLAME-RESISTANT TEXTILES AND FILMS

NFPA No. 701 — 1966

1966 Edition of No. 701

The 1966 edition is an extensive revision of the 1951 edition of the Standard for Flameproofed Textiles, NFPA No. 701. The change in title reflects the revisions made in the recommended test method so that synthetic textiles and plastic films can be tested as well as natural-fiber textiles.

Origin and Development of No. 701

Requirements for flameproofing of textiles were adopted by the NFPA on recommendation of the Committee on Fireproofing and Preservative Treatments in 1938. These were amended in 1939, 1940, 1941 and 1951. This standard is now under the jurisdiction of the NFPA Committee on Fire Tests; the 1966 edition was prepared by that committee.

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TABLE OF CONTENTS

STANDARD METHODS OF FIRE TESTS FOR FLAME-RESISTANT TEXTILES AND FILMS

NFPA No. 701 — 1966

Introduction

While it is not possible to make combustible textiles and films completely resistive to charring and decomposition when exposed to flame or high temperature, a degree of flame resistance can be achieved. Natural fiber textiles can be treated chemically to reduce their flammability and tendency toward smoldering, and synthetic fibers and plastic films can be formulated to be flame resistant, the flame-retardant chemicals being incorporated into the resin formulation. Both approaches may be necessary to impart flame resistance to materials in which natural and synthetic fibers are blended. The hazards introduced by combustible textiles may, of course, be avoided entirely where the use of such noncombustible fabrics as glass and asbestos is practical. It should be noted, however, that combinations of the noncombustible fibers with a relatively small percentage of combustible fiber will cancel the noncombustible effect.

Standards of flame resistance for theatre scenery, curtains, and furnishings in places of public assembly are commonly set by law. Flame-resistant fabrics are used in hotels, hospitals and similar occupancies in the interest of the preservation of lives and property from fire. Flame-resistant fabrics are also used as work clothing in industries where exposure to heat, open flames and flash fire is a possibility. Fabrics treated for flame and weather resistance are used for tents, awnings, tarpaulins, and other outdoor protective covering.

Flame-resistant synthetic materials, in the form of woven fabrics and plastic films, are used decoratively and for protective coverings. Many of these materials will soften and melt when exposed to heat and fire. They may also be subject to twisting, shrinking, dripping and elongation when subjected to fire conditions. Reinforced plastic films with flame-resistant qualities are used in air-supported structures. Transparent plastic films are often used as a temporary enclosure for greenhouses and for construction work.

An increasing range of flame-resistant treatments for natural-fiber materials is becoming available, and the selection of a particular treatment is governed by the intended use of the treated fabric. Treatments based on water soluble chemicals are generally the least expensive and most easily applied, but they are subject

to removal by the leaching action of water in laundering, scrubbing, or exposure to weather. Some treatments may be impaired by the action of the solvents used in dry cleaning, and some may gradually lose their effectiveness under conditions of storage and use not involving dry cleaning or water leaching. Such relatively temporary treatments are suitable only where proper retreatment and renewal can be assured, or for decorations and other items which are used briefly and discarded. Situations where retreatment is uncertain or not feasible indicate the choice of one of the most durable treatments which are suitable for clothing and decorative fabrics. A number of these will withstand extensive laundering and dry cleaning, although they are higher in cost than the water-soluble type, and require professional application. For outdoor use, treatments have been developed which may be expected to remain effective for the useful life of the fabric under normal conditions of weather exposure. It should be noted, however, that painting or coating a treated or noncombustible fabric may impair its flame-resistant qualities unless the coating is itself flame resistant.

A number of other factors, which will vary in importance depending upon the end use of the fabric, must be considered in selecting a flame-resistant treatment. The effect on the appearance, texture, and flexibility of the fabric is often of primary concern. Some treatments may leave a fabric objectionably stiff, or it may become tacky at high atmospheric temperatures or brittle at low temperatures. Some flame-retardant chemicals are so hygroscopic as to dampen the fabric; others may effloresce to the extent of reduced effectiveness as well as unsightly appearance. Treatment may result in a reduction in strength of the fabric, and some flame-retardant chemicals may tend to deteriorate wood or corrode metal with which the treated fabric comes in contact. In all instances, the possibility of adverse physiological reactions in persons handling or otherwise exposed to the treated fabric must be considered by the manufacturer.

Section 10. Scope

These requirements apply to flame-resistant materials which are used extensively in the interior furnishings of buildings and transport facilities, in protective clothing for certain occupations and situations, and for protective outdoor coverings such as tarpaulins and tents. However, the flame-resistant requirements are not dependent on the type of treatment, except that where durability to laundering or weathering is claimed, the fabric is tested for flame-resistance after being subjected to the applicable cleaning or exposure procedures.

These requirements apply to plastic films with or without reinforcing or backing, when used for decorative or other purposes inside buildings or as temporary or permanent enclosure for places of public assembly and buildings under construction.

When these materials are applied to surfaces of building or backing materials as interior finishes for use in buildings the test is to be conducted and the material classified in accordance with NFPA Method of Test of Surface Burning Characteristics of Building Materials, NFPA No. 255 (UL 723, ASTM E-84).

It is the intent of these requirements to provide tests to determine whether the flame-resistant textiles and films are comparatively difficult to ignite and whether it is comparatively difficult to propagate flame beyond the area exposed to the source of ignition. These performance tests do not necessarily indicate whether the material tested will resist the propagation of flame under severe fire exposure or when used in a manner which differs substantially from the test requirements.

Two methods of assessing flame resistance are described. Both methods will provide a comparison among textiles and films but do not necessarily indicate the behavior of a material in a large building fire or other conflagration. One test employs a relatively small sample and small igniting flame and is simple and convenient for general use. The other test requires a much larger sample and applies a more severe fire exposure which will more nearly approach severe fire conditions. The small scale test is commonly used to indicate susceptibility to flame spread from small ignition sources, and may also serve as a screening test followed by the large scale test.

Section 20. Flame Resistance Requirements

21. Test Selection

All flame-resistant textiles and films shall be capable of complying with the performance requirements of either the small or the large scale tests or both. The authority having jurisdiction shall determine whether both the small and the large scale tests are required and this will generally depend on the purpose to be served or the nature of the materials tested. For those materials which show excessive melting or shrinkage by the small scale test, then the large scale test shall be considered applicable.

Textiles which are expected to retain their flame resistance through dry cleaning, laundering, water leaching, or weathering exposures should be subjected to the applicable procedures of Section 40 before being tested by either the small scale or the large scale flame test.

22. Small Scale Test

When subjected to the small scale test described in Section 31, a material shall not continue flaming for more than two seconds after the test flame is removed from contact with the specimen. The vertical spread of flame and afterglow (smoldering combustion) on the material, as indicated by the length of char or the measurement from the bottom of the sample above which all material is sound and in original condition, shall not exceed the values shown in Table I.

Portions or residues of textiles or films which break or drip from the test specimens shall not continue to flame after they reach the floor of the tester.

TABLE I

PERMISSIBLE LENGTH OF CHAR OR DESTROYED MATERIAL — SMALL SCALE TEST

Weight of Treated Fabric Being Tested	Maximum Average Length of Char or Destroyed Material for Ten Specimens	Maximum Length of Char or Destroyed Material for Any Specimen
Ounces per Square Yard	Inches	Inches
Over 10	3½	4½
Over 6 and not exceeding 10 .	4½	5½
Not exceeding 6	5½	6½

23. Large Scale Test

When subjected to the large scale test described in Section 32, a material in single sheets or in folds shall not continue flaming for more than two seconds after the test flame is removed from contact with the specimen. The vertical spread of burning on the material in single sheets shall not exceed 10 inches above the tip of the test flame. This vertical spread shall be measured as the distance from the tip of the test flame to a horizontal line above which all material is sound and in original condition, except for possible smoke deposits. The vertical spread of burning on the folded specimens shall not exceed 35 inches above the tip of the test flame, but the afterglow may spread in the folds.

Portions or residues of textiles or films which break or drip from the test specimens shall not continue to flame after they reach the floor of the tester.

Section 30. Flame Test Methods

31. Small Scale Test

(a) Five specimens of the material, 2¾ by 10 inches, shall be cut with their long dimension in the direction of the warp and five in the direction of the filling. Each lot of five shall be cut from at least four places in the sample separated sufficiently to give indication as to the uniformity of the flame-resistant treatment.

(b) The test specimens shall be conditioned in an oven, having forced air circulation with free air flow around each specimen, at temperatures of 140 to 145 degrees Fahrenheit, for durations of not less than 1 hour nor more than 1½ hours before testing. Materials which distort or melt at the above indicated oven exposure are to be conditioned at 60–80 degrees Fahrenheit and 25–50 per cent relative humidity for not less than 24 hours. Specimens shall be removed from the oven one at a time and immediately subjected to the flame test described in Section 31(d).

(c) In conducting the flame test, the specimen shall be placed in a holder of metal which clamps each long edge of the fabric, leaving the ends free and exposing a strip 2 inches wide by 10 inches long. The holder and specimen shall be supported in vertical position within a shield 12 inches wide, 12 inches deep, and 30 inches high, open at the top, and provided with baffled vent holes amounting to 6 square inches distributed along the bottom of at least two sides. The shield shall have a door or sliding panel having an observation window of glass. Provision shall be made for moving the gas burner used in igniting the specimen into test position after the shield is closed. A rod attached to the base of the burner and extending through a slot near the bottom of one side of the shield will serve the purpose.

(d) The specimen shall be supported with its lower end ¾ inch above the top of a Bunsen or Tirrill gas burner, approximately 6 inches high and have a tube ⅜ inch inside diameter, and with the air supply completely shut off, adjusted to give a luminous flame 1½ inches long. The flame shall be applied vertically near the middle of the width of the lower end of the specimen for 12 seconds, then withdrawn, and the duration of flaming on the specimen noted. The burner shall be supported in a fixed position so that the barrel of the burner is at an angle of 25 degrees from the vertical.

(e) After all flaming and afterglow on the specimen has ceased, the length of char or material destruction shall be determined immediately. The length of char in this test is defined as the distance from the end of the specimen which was exposed to the flame to the end of the tear made lengthwise of the specimen through the center

of the charred area in the following way: A hook is inserted in the specimen, on one side of the charred area, ¼ inch in from the adjacent outside edge and ¼ inch up from the bottom. A weight, which inclusive of the hook is equal to that specified for the fabric in Table II, is attached to the hook. The specimen is then grasped on the opposite side of the charred area with the fingers, and raised gently until it supports the weight. The specimen will tear through the charred area until fabric strong enough to carry the load is reached. When it is not feasible to measure char, the material destruction can normally be judged as the measurement from the bottom of the sample to a horizontal line above which all material is sound and in original condition.

TABLE II

TEARING WEIGHTS — SMALL SCALE TEST

Weight of Treated Fabric Being Tested	Total Tearing Weight for Determination of Length of Char
Ounces per Square Yard	Pounds
2 to 6 inclusive	0.25
Over 6 and not exceeding 15	0.5
Over 15 and not exceeding 23	0.75
Over 23	1.00

32. Large Scale Test

(a) The following method for conducting flame tests of materials employs a larger specimen and a larger test flame than are specified for the small scale test, Section 31. This method is also useful for investigating the flammability of fabrics when hung in folds.

(b) For conducting flame tests of fabrics in single sheets, a specimen 5 inches by 7 feet shall be used. For conducting flame tests of fabrics hung in folds, a specimen 25 inches by 7 feet shall be cut and folded longitudinally so as to form four folds, each approximately 5 inches wide, uniformly over the length (spacing about ½ inch).

(c) At least 10 specimens in single sheets and at least 4 specimens in folds shall be cut from each fabric. They shall be taken from as widely separated and symmetrically located sections as possible over the entire area of the sample of each fabric. One-half of the specimens of each kind shall be cut with the long dimension in the direction of the warp, and the balance of the specimens shall be cut with the long dimension in the direction of the fill.

(d) The test specimens shall be conditioned in an oven, having forced air circulation with free air flow around each specimen, at temperatures of 140 to 145 degrees Fahrenheit for durations of not less than 1 hour nor more than 1½ hours before testing. Materials which distort or melt at the above indicated oven exposure are to be conditioned at 60–80 degrees Fahrenheit and 25–50 per cent relative humidity for not less than 24 hours. Specimens shall be removed from the oven one at a time and immediately subjected to the flame test described in Section 32(e).

(e) The apparatus for conducting the flame test shall consist of a sheet-iron stack 12 inches square transversely, 7 feet high and supported 1 foot above the floor on legs. The stack shall only be open at top and bottom and shall be provided with an observation window of wired glass extending the full length of the front.

(f) The single-sheet specimen is to be suspended vertically in the stack with its full width facing the observer so that the bottom of the specimen is 4 inches above the top of a Bunsen burner having ⅜-inch diameter tube and placed on the floor below the stack. The gas supply to the burner is to be natural gas or a mixture of natural and manufactured gases having a heat value of approximately 800–1000 Btu per cubic foot. With a gas pressure of 4¼ inches (108 mm) of water, the burner is to be adjusted to produce an 11-inch oxidizing flame having an indistinct inner cone. The specimen is to be lightly restrained laterally with clamps and guide wires attached to its outer edges. For the folded specimen the conditions of test are to be the same as above except that it is to be suspended vertically with the edges of the folds facing the observer. The folds are to be spread apart about ½ inch by means of guide rods inserted at the top and bottom ends.

The flame shall be applied vertically near the middle of the width of the lower end of the specimen in a single sheet, or to the middle of the width of the lower end of the middle fold of the specimen in folds. The position of the specimen relative to the test flame shall be maintained by guide wires attached to the outer edges of the specimen. The burner shall be supported in a fixed position so that the barrel of the burner is at an angle of 25 degrees from the vertical.

(g) The test flame shall be applied to the specimen for two minutes, then withdrawn, and the duration of flaming combustion on the specimen recorded. After all flaming and afterglow on the specimen has ceased, the length of char shall be determined. For purposes of this test, the length of char is defined as the vertical distance on the specimen from the tip of the test flame to the top of the charred area resulting from spread of flame and afterglow. For synthetic textiles and films the length of char is defined as the

vertical distance from the tip of the test flame to a horizontal line, above which all material is sound and in essentially original condition.

Section 40. Cleaning and Weathering Procedures

41. Application

These procedures shall be applied to fabrics which are expected to retain their flame-resistant qualities through dry cleaning, laundering, weathering, or other exposures to water. The probable durability of a treatment relative to the life of the fabric is difficult to assess, but in general, flame-retardant treatments tend to be either very tenacious or quite easily removed. It is believed that such accelerated exposure tests as those described in this section provide sufficient testing to permit a reasonable appraisal of the durability of the treatment (under the conditions for which it was designed) for the useful life of the fabric.

Each fabric shall be subjected to only those exposure procedures which are applicable to its intended use. It shall meet the flame resistance requirements of Section 20 after passing through the appropriate exposure cycles.

42. Accelerated Dry Cleaning

(a) A sample of the treated fabric shall be agitated for 25 minutes in a suitable dry cleaning apparatus containing a solution of 1,000 parts perchlorethylene and six parts of dry cleaning soap. The volume of solution employed shall be in excess of that required to saturate the sample. The sample shall then be rinsed three times in pure perchlorethylene for periods of 5 minutes each, centrifuged and allowed to dry at room temperature on a horizontal screen. When dry the sample shall be pressed or steamed. The above procedure shall be repeated a total of ten times.

(b) In order to simulate the wet cleaning sometimes encountered in dry cleaning practice, the sample of treated fabric shall be agitated in perchlorethylene base solution, rinsed, centrifuged, and dried as described in the foregoing procedure. The sample shall then be placed on a porcelain, marble, or slate slab and treated with water containing 0.1 per cent neutral soap at temperature of 90 to 100 degrees Fahrenheit. The fabric shall be kept thoroughly wet for 15 minutes. The sample shall then be rinsed for five minutes in water at 90 to 100 degrees Fahrenheit, centrifuged, and allowed to dry at room temperature on a horizontal ventilated screen. When dry the sample shall be pressed or steamed. The above procedure shall be repeated a total of ten times.

43. Accelerated Laundering

A sample of the treated fabric shall be washed in a 0.25 per cent solution of tallow soap of low titer dissolved in water not exceeding 50 parts per million hardness. A suitable automatic machine with a fixed operating cycle of approximately 28 minutes shall be used. The cycle shall consist approximately of a 12-minute washing in the soap solution at 125 degrees Fahrenheit, three 2½-minute rinsing periods, and a 3-minute extraction period, the remaining time to be allotted to inlet or outlet of the water in the machine. The sample shall be allowed to dry at room temperature on a horizontal ventilated screen, moistened, and pressed with a flat iron at a temperature of 275 to 300 degrees Fahrenheit. The above procedure shall be repeated a total of ten times. If the material is to be subjected to a special use more laundering may be required.

Where instructions for laundering a fabric are supplied by the manufacturer or finisher, those instructions should be followed in preference to the above procedure. This above procedure is intended to simulate ordinary home laundering practice. Commercial laundering is likely to be more severe, and commercial practices may vary considerably in the choice of detergents, temperatures, bleaches and sours, and in the mechanical wear imposed on the fabric. If the fabric will be subjected to commercial laundering in use, however, an attempt should be made to simulate a probable commercial procedure for test purposes.

44. Scrubbing

Certain articles of flame-resistant fabric not ordinarily washed by home or commercial laundering methods are sometimes scrubbed vigorously on one or both sides, applying laundry soap (or other detergent) and water with a stiff bristle brush. The fabric is then thoroughly rinsed with water and dried. Where treated fabrics are likely to be cleaned in this manner during their use, test specimens shall be subjected to flame tests after repeated cycles of scrubbing as outlined.

45. Accelerated Water Leaching

A sample of the treated fabric shall be totally submerged in a vessel containing tap water at room temperature for a period of 72 hours. The vessel shall have a capacity of at least 4 gallons of water. The water shall be drained from the tank and replenished at 24-hour intervals during the immersion period. At the conclusion of the immersion period, the sample shall be removed from the test vessel and dried at room temperature.

46. Accelerated Weathering

One of the two procedures described below shall be followed:

(a) The apparatus shall consist of a vertical carbon arc with solid electrodes 0.5 inches in diameter (1 cored electrode is used if the arc operates on alternating current) and uniform in composition throughout, mounted at the center of a vertical metal cylinder. The arc shall be surrounded by a clear globe of No. 9200 PX Pyrex glass 0.0625 inches thick or other enclosure having equivalent absorbing and transmitting properties. The electrodes shall be renewed at intervals sufficiently frequent to insure full operative conditions of the lamp. The globe shall be cleaned when carbons are removed or at least once in each 36 hours of operation. The arc shall be operated on 13 amperes direct current or 17 amperes, 60 cycles alternating current with the voltage at the arc of 140 volts. The specimens for test shall be mounted on the inside of the cylinder facing the arc. The diameter of the cylinder shall be such that the distance of the face of the specimen holder from the center of the arc is 14¾ inches. The cylinder shall rotate about the arc at a uniform speed of approximately three revolutions per hour. A water spray discharging about 0.7 gallons per minute shall strike each specimen in turn for about 1 minute during each revolution of the cylinder. Specimens shall be subjected to this exposure for 360 hours. They shall then be allowed to dry thoroughly at a temperature between 70 and 100 degrees Fahrenheit.

(b) The apparatus shall consist of a vertical carbon arc mounted at the center of a vertical cylinder. The arc is designed to accommodate two pairs of carbons, No. 22, upper carbons, and No. 13, lower carbons; however, the arc burns between only one pair of carbons at a time. The arc shall be operated on 60 amperes and 50 volts across the arc for alternating current or 50 amperes and 60 volts across the arc for direct current. The specimens for test shall be mounted on a rotating rack inside the cylinder and facing the arc. The diameter of the rotating rack shall be such that the distance from the center of the arc to the face of the specimen is 18¾ inches. The rack shall rotate about the arc at a uniform speed of about 1 revolution in 2 hours. No filters or enclosures shall be used between the arc and the specimens. Spray nozzles shall be mounted in the cylinder so that the specimens shall be exposed to wetting once during each revolution of the rack. Specimens shall be subjected to this exposure for 100 hours. They shall then be allowed to dry thoroughly at a temperature between 70 and 100 degrees Fahrenheit.

Section 50. Field Test: Clamp Test

51. General

The following method for conducting flame tests of materials was designed for use on curtains and similar furnishings in place. It uses a vertical clamp, with attachment for supporting the candle, that enables a vertical edge or slit of the fabric to be placed in horizontal position for testing. The clamping of the material in the device will prevent spread of fire to portions of the material beyond the area exposed in the clamp. Due care must, however, be taken in any use of open flames in the presence of combustible materials.

52. Scope

These requirements supplement those provided in Sections 10–40 inclusive. This field test is intended to accomplish the same result as that achieved by flame tests in Sections 31 and 61, and the same general requirements apply.

53. Performance Requirements — Clamp Test

When tested by the method described in Section 54, a specimen shall not continue flaming for more than two seconds after the test flame is removed from contact with the specimen. The average length of char in three tests shall not be more than 2½ inches for heavy ducks and drapery material, and not more than 4½ inches for any material. By length of char is meant the length from the zero point on the scale to the point on the scale opposite the end of a tear through the charred area. This tear shall be made by hand with enough force to tear through the charred or scorched portion but not sufficient to break undamaged threads. Synthetic textiles and plastic films shall not be subjected to measurements for char length but shall be measured for the amount of sound material destroyed. Materials which break or drip flaming particles shall be rejected if the materials continue to burn after they reach the floor.

54. Test Method

(a) The test clamp, as illustrated, shall hold the portion of the curtain or other fabric to be tested at any convenient edge or slit. The candle shall be of paraffin and of ¾ inch nominal diameter. It shall be swung away from the fabric and the tapered portion allowed to burn away until a normal constant flame is reached. The wick shall bend to near the outer boundary of the flame and burn to a length that remains constant at about ⅝ inch. The

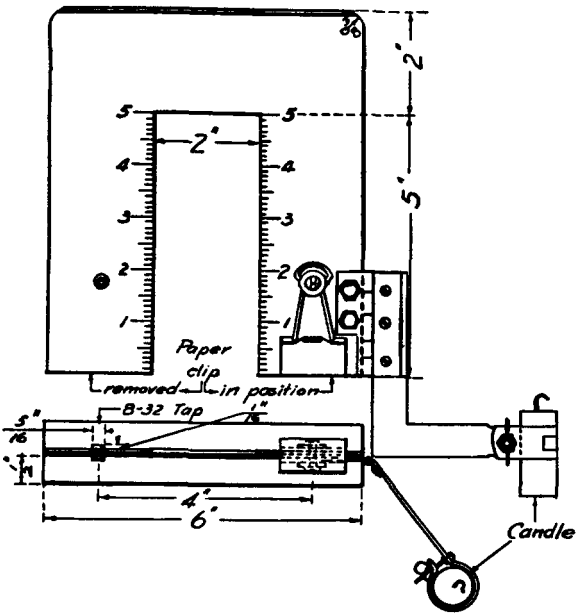

Fig. 1

Test Clamp for Making Flame Tests of Textiles in Place

The clamp is made of No. 14 gage rolled brass (0.065 inches) and is made of two pieces in duplicate as shown, with graduations to 1/10 inch on one side of one piece. The clamp is chromium plated with outside surfaces polished.

candle shall then be adjusted in its holder until the top of the wick is 1/10 inch below the bottom edge of the fabric or zero point on the graduated scale. The candle flame shall be applied to the exposed edge of the fabric for 12 seconds. The tear shall be made by applying pressure by hand against the side of the specimen as mounted in the clamp.

(b) The clamp shall be made of duplicate pieces of sheet metal about 1/16 inch thick, held with spring type paper clamps 1¼ inches wide. The candle holder shall be made of a ¾-inch hose clamp bolted to a window screen corner angle and hinged to the front clamp member with a brass hinge 2 by ½ inches, the lower portion of one leaf of which is cut away to clear the paper clamp. The hinge and clamp support shall be mounted in such a manner that the clamp will swing against a stop when its center is directly under the middle of the 2 inches wide exposed lower edge of the specimen.

Section 60. Field Test: Match Flame Test

61. Test Method

In conducting this test, a sample of the material shall be taken to a location where the test may be conducted safely. The sample shall be held in a vertical position and tested by application of a flame from a common paper match held in a horizontal position, ½ inch under the sample, and at a constant location for a minimum of 15 seconds. Observations are made to determine that the sample does not ignite and spread flame over its surface after the match flame is removed. Materials which break or drip flaming particles shall be rejected if the materials continue to burn after they reach the floor.

APPENDIX

FLAME-RESISTANCE TREATMENTS

Decorative Textiles

Hundreds of different chemicals have been used or tested for flame-retarding fabrics. Many proved reasonably effective flame-retardants, but only a few are in general use. Many chemicals are not suitable because of objectionable characteristics such as moisture absorption, change in color or deterioration of the fabric, deterioration under high-temperature drying or pressing, corrosion of metal in contact with the fabric, toxicity, requiring an excessively heavy weighting of the fabric to be effective, requiring difficult techniques in application, or being unduly expensive.

Mixtures of two or more chemicals are usually more effective than the same chemicals used alone. Figure 2 shows that borax and boric acid together are far more effective than the same weight of either chemical alone.

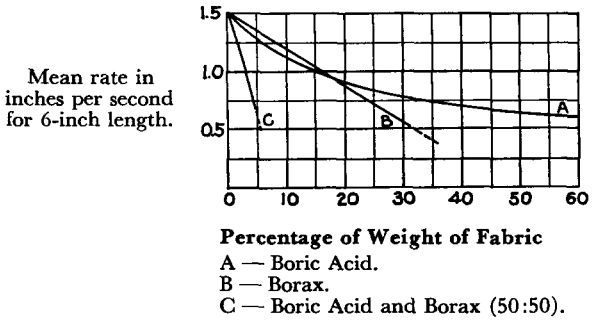

Fig. 2. Rate of Flame Propagation

(Diagram is from Second Report of Fabrics Coordinating Research Committee. London: H. M. Stationery Office. Department of Scientific and Industrial Research publication. 1930. 188 pages. Also see Nicholls, A.H., review of this report in NFPA *Quarterly*, Vol. 24, No. 2, October 1930, page 184.)

There are many proprietary flame-retardant preparations which vary greatly in effectiveness, cost and other factors such as tendency to absorb moisture. The purchaser should consult responsible testing authorities prior to purchase and use.

Many concerns specialize in the effective flame-resistance treatment of theater scenery, draperies and other fabrics, using standard flame-retardant chemicals. It is advisable to deal only with concerns of known reliability, or if dealing with an unknown concern, to have treated fabrics tested for adequacy of treatment.

Most of the treatments used are not resistive to water since the chemicals are water-soluble. A few have been developed that resist leaching action from exposure to weather, laundering, or dry cleaning.

Most of the treatments in use cause very little reduction in the strength of the fabric, but when subjected to higher than normal temperature and sunlight, some of the treatments cause decided loss in strength. It is often important that change in color and texture shall not be caused by the flame-resistant treatment of fabrics, and there are a number of treatments that will meet this requirement. Few of the treatments used contain chemicals that would cause poisoning or injury from handling of the treated fabric.

Methods of Application

Water soluble flame-retardant chemicals may be applied by immersion of the fabric in a solution, by spraying, or by brushing. The objective is to deposit in the fabric the desired amount of the flame-retardant chemicals, measured in terms of percentage increase in weight of the fabric after treatment and drying, as compared with the original weight. As long as uniform treatment and the desired increase in weight are obtained, the particular method of application and the proportion of water used in the solution are unimportant. Good results may be obtained by dipping, spraying or brushing; the method selected is dictated by convenience and the character of the fabric to be treated.

Effective flame-resistant treatments may be obtained by the use of non-proprietary solutions of flame-retardant chemicals in water, without professional assistance, after some experience and testing of the results. The chemicals should be dissolved in clean water. Warm water and stirring will dissolve chemicals more quickly.

It is desirable to wash new fabrics containing sizing prior to treatment so as to secure proper absorption of flame-retardant chemicals. Commercial wetting agents may be added to the treating solution to increase penetration of flame-retardant ingredients.

When a piece of fabric is immersed, usually at room temperature, in a flame-retardant solution, the container must be large enough so that all the fabric is thoroughly wet and there are no folds which the solution does not penetrate, if too small tubs or tanks were used.

Care must be used in the wringing of the immersed material. If a mechanical wringer is used, more of the solution is likely to be extracted and a more concentrated solution may be necessary to obtain the desired weighting, Best results will be obtained if the articles can be dried in a horizontal position. Drying in a vertical position permits a certain amount of drainage of the solution, depending upon the wetness of the wrung articles. It is advisable to increase the weighting if horizontal drying is not feasible.

Where solutions are applied by brushing or spraying some skill is required for uniform application; repeated application may be necessary to secure the desired weighting.

It is difficult to treat cellulose acetate fabrics. Flame-resistance of fabrics made from proprietary synthetic fibers requires separate consideration, taking into account the effectiveness and suitability of the treatment for the given fabric.

Formulas

The nonproprietary flame-retardant formulations described in the following are applied mainly to fabrics used for decorative or other purposes inside buildings. They are intended to provide protection against small sources of ignition such as matches, cigarette lighters, sparks, small coals, and smoldering cigars and cigarettes, and do not necessarily protect a fabric against flaming combustion under severe fire exposure, or when hung in folds or parallel strips. Renewal of the treatment is required after a certain time, and after every laundering, dry cleaning, or exposure to weather where the flame-retardant chemicals are subject to leaching by water. Where flame-resistance is required by law, it is common practice to require renewal of treatments at least annually.

Formulas are stated in terms of parts by weight and, also, where water is the solvent, in avoirdupois weight of chemicals and volume of water in United States gallons.

Formulas Nos. 1 to 5 are from Circular C455 of the National Bureau of Standards. (See References.) Formulas Nos. 6 and 7 are from York Research Corp. of Conn., Stamford, Conn. (New York: American Hotel Association, 221 West 57th St.). Research Report No. 8, March 3, 1947. 30 pages. Research Report No. 14, August 18, 1947. 30 pages.

Formula No. 1:

Borax, $Na_2B_4O_7 \cdot 10H_2O$	6 parts	6 pounds
Boric acid, H_3BO_3	5 parts	5 pounds
Water	100 parts	12 gallons

The fabric is steeped in a cool solution until thoroughly impregnated, then dried. Heavy applications by spray or brush are usually reasonably effective. Such applications may have to be repeated two or three times with drying between applications to obtain the desired degree of flame-resistance. The treatment has been used for many kinds of fabrics, including theater scenery. It is recommended for rayon. As in the case of most of the other formulas listed, care must be taken in ironing the fabric to avoid discoloration by heat.

The treatment is effective in weighting from 8 to 12 per cent, depending upon the type of fabric. Hand-wringing the above solution from a fabric leaves a weighting of 10 to 12 per cent after drying.

Formula No. 2:

Borax, $Na_2B_4O_7 \cdot 10H_2O$	7 parts	7 pounds
Boric acid, H_3BO_3	3 parts	3 pounds
Water	100 parts	12 gallons

The amount of water may be varied, and should depend upon the absorptive capacity of the fabric to be treated. For rayon and sheer fabrics, the same quantities of borax and boric acid may be used in 17 gallons of water. Loadings from 8 to 10 per cent of the weight of the dry cloth usually will be found effective. Hand-wringing the above solution from a fabric will give approximately these weightings. Fabrics so treated retain their flexibility and softness. They do not become dusty, feel damp, or lose their strength under ordinary conditions of use. The chemicals are nonpoisonous and do not promote the growth of destructive micro-organisms.

Formula No. 3:

Borax, $Na_2B_4O_7 \cdot 10H_2O$	7 parts	7 pounds
Boric acid, H_3BO_3	3 parts	3 pounds
Diammonium phosphate, $(NH_4)_2HPO_4$	5 parts	5 pounds
Water	110 parts	13 1/5 gallons

This formula gives very satisfactory results both in flame-resistance and glow-resistance. It will be found effective in weightings of 7 to 15 per cent, depending upon the fabric treated. Hand-wringing the above solution from a fabric leaves weighting of about 10 to 12 per cent.

Formula No. 4:

Diammonium phosphate, $(NH_4)_2HPO_4$	7.5 parts	7½ pounds
Ammonium chloride, NH_4Cl	5 parts	5 pounds
Ammonium sulfate $(NH_4)_2SO_4$	5 parts	5 pounds
Water	100 parts	12 gallons

Either the solution can be applied directly to the cloth, or it can be used in making a starch sizing. The formula has been used for flame-resisting curtains and for cotton fabrics in general. The ammonium chloride and, to less extent, the ammonium phosphate, are hygroscopic; therefore this formula may not be advisable for flame-resisting materials exposed to dampness. The treatment is effective in weightings of 10 to 18 per cent, depending upon the type of fabric treated. Hand-wringing the above solution from a fabric leaves a weighting of about 16 to 18 per cent.

Formula No. 5:

Ammonium sulfate $(NH_4)_2SO_4$	8 parts	8 pounds
Ammonium carbonate, $(NH_4)_2CO_3 \cdot H_2O$	2.5 parts	2½ pounds
Borax, $Na_2B_4O_7 \cdot 10H_2O$	8 parts	8 pounds
Boric acid, H_3BO_3	3 parts	3 pounds
Starch	2 parts	2 pounds
Dextrin	0.4 parts	6½ ounces
Water	100 parts	12 gallons

The amount of water may be varied. The mixture should be applied at 86 to 100 degrees Fahrenheit. This solution is useful for many fabrics, particularly for laces and curtains, and is effective in loadings of 14 to 28 per cent, depending upon the fabric. Hand-wringing the above solution from a fabric leaves a weighting of about 28 per cent.

Formula No. 6:

Diammonium phosphate $(NH_4)_2HPO_4$	100 pounds
Water	50 gallons

This solution, when applied by ordinary methods, produces a weighting of about 10 per cent, which is effective. It has superior flame and glow-retardant properties.