NFPA No.

701

FIRE TESTS

FLAME RESISTANT TEXTILES, FILMS 1969

Seventy-five Cents

NATIONAL FIRE PROTECTION ASSOCIATION

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

NFPA No. 701 — 1969

1969 Edition of No. 701

This 1969 edition supersedes the 1968 edition of the Standard and differs from that edition due to the following amendments which were adopted by the National Fire Protection Association Annual Meeting on May 15, 1969. Entire Section 50 was revised and new text, entitled "Field Test," was added to the Appendix.

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, which was an extensive revision of the previous edition, was prepared by that committee as was the 1968 edition, and this 1969 edition.

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Scope: Standard for fire testing procedures. Cooperates with other Committees dealing with special fire test procedures, including Flameproofing and Preservative Treatments and Wearing Apparel. Also cooperates with the American Society for Testing and Materials.

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

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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 sample of the treated fabric shall be agitated for approximately 15 minutes in a suitable dry cleaning apparatus (used by commercial dry cleaners) containing a solution of 1,000 parts perchlorethylene and 10 to 15 parts of dry cleaning soap or detergent. The volume of solution employed shall be in excess of that required to saturate the sample. The sample is rinsed for at least 5 minutes in pure perchlorethylene and dried in a dryer at 135° to 150° F. The above procedure shall be repeated until ten complete cycles of cleaning and drying have been accomplished.

43. Accelerated Laundering

A sample of the treated fabric shall be washed in an automatic commercial washing machine using a solution containing 0.15 percent solution of tallow soap and a 0.20 to 0.25 percent alkali.

The following operating cycle† shall be followed:

Operation	*Time, Min.*	*Temp. — Deg. F.*
1. Sudsing	6	130
2. Sudsing	6	160
3. Sudsing	6	160
4. Bleaching	8	150
5. Rinsing	2	160
6. Rinsing	2	160
7. Rinsing	2	160
8. Rinsing	2	130
9. Bluing	3	100
10. Souring	3	100

†This cycle is intended for white fabrics. For colored fabrics, the bleaching and bluing operations are omitted and the temperature of the "Sudsing" and "Rinsing" operations is reduced 30° F.

The sample shall then be dried in a drying tumbler at 250° F. The above procedure shall be repeated until ten complete cycles of washing and drying have been accomplished. 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 which simulates a typical commercial laundering practice.

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: Match Flame Test

51. Test Method

(a) Samples, in dry condition, are to be selected for tests and are to be a minimum of 1½ in. wide and 4 in. long. The fire exposure shall be the flame from a common wood kitchen match (approximate length 2⁷⁄₁₆ inches; approximate weight 29 grams per hundred), which is reasonably equivalent to that of a standard small-scale test described in Section 31, applied for 12 seconds.

(b) The test shall be performed in a draft-free and safe location. The sample shall be suspended (preferably held with a spring clip, tongs or some similar device) with the long axis vertical, with the flame applied to the center of the bottom edge, and the bottom edge ½ in. above the bottom of the flame. After 12 seconds of exposure, the match is to be removed gently away from the sample.

(c) During the exposure, flaming shall not spread over the complete length of the sample or in excess of 4 inches from the bottom of the sample (for larger size samples). There shall be not more than 2 seconds of afterflaming. Materials which break and drip flaming particles shall be rejected if the materials continue to burn after they reach the floor.

Note: For discussion of limitations and interpretations of results of this field test, see Appendix.

APPENDIX

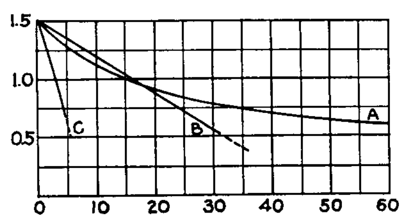
FLAME-RESISTANCE TREATMENTS

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.

Mean rate in
inches per second
for 6-inch length.



Percentage of Weight of Fabric

A — Boric Acid.
B — Borax.
C — Boric Acid and Borax (50:50).

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.

Formula No. 7:

Ammonium sulfamate, $NH_4OSO_2NH_2$	80 pounds
Diammonium phosphate, $(NH_4)_2HPO_4$	20 pounds
Water	50 gallons

This solution, when applied by ordinary methods, produces a weighting of about 15 per cent, which is effective. It is an efficient flame and glow-retardant agent. Some deterioration when heated; in drying and pressing, high temperatures should be avoided.

Weather Exposed Textiles

Flame-resistant treatments for tents, awnings, tarpaulins and other fabrics exposed to the weather must be renewed at frequent intervals or must be of a special character combining water-retardant with flame-retardant chemicals in order to prevent the leaching out of the flame-retardant chemicals in the course of time.

A wide variety of chemicals may be used for flame-resistant fabrics exposed to the weather. Many of the formulas used include chlorinated paraffin, chlorinated synthetic resins, or chlorinated rubber in combination with various water-insoluble metallic salts, plasticizers, stabilizers, synthetic resins, pigments, binders, mildew inhibitors, etc. Such mixtures are not water soluble and are used with hydrocarbon solvents, or are suspended in water emulsions. The effective application of such treatments calls for techniques and equipment ordinarily available only for factory processing. Application of flammable paint to these treated fabrics will present a fire hazard.

Weather resistant flame-resistant fabrics with and without striping are listed by Underwriters' Laboratories, Inc. These are comparatively difficult to ignite and do not propagate flame, even when in drafts, beyond the area exposed to the source of ignition, when used in single sheets (as in open awnings, tarpaulins, etc.) or in folds. Flameless or smoldering combustion which occurs on ignition may spread in folds, but in the case of single sheets does not extend beyond the area exposed to ignition. The treatment may be expected to remain effective under ordinary conditions of exposure for the useful life of the fabric. However, laundering will reduce the effectiveness of the treatment when so indicated in Underwriters' Laboratories, Inc.'s listings of individual fabrics.

NONCOMBUSTIBLE FABRICS

Noncombustible fabrics include those woven wholly from inorganic yarns, either glass or asbestos alone, or in combination with each other. Glass fabrics listed by Underwriters' Laboratories, Inc., for use as draperies are woven from glass yarns, which do not burn or propagate flame. Such materials cannot emit hazardous fumes if exposed to fire. Glass fabrics have many uses in addition to their use for decorative purposes; *e.g.*, for mattress covers or as ticking for glass fiber-filled mattresses.

Asbestos fiber has relatively low strength, and cotton fibers are commonly used with asbestos to give asbestos cloth greater strength. Depending upon the amount of cotton used, such asbestos cloth may actually propagate flame. Fabrics woven from combinations of glass and asbestos fibers have satisfactory strength and are noncombustible.

Any combustible fiber or combustible coloring or coating material, if used in sufficient quantity, may make a glass or asbestos fabric combustible.

Field Test

Field tests for flame resistance — what are they or what should they be, what do they mean, how dependable are they? These are complex and controversial questions, and the answers can vary considerably depending upon many factors and circumstances. If field tests are to be used as part of a regulatory program, it is vitally important that their function and validity be understood.

With rare exceptions, small-scale field tests leave something to be desired, and cannot be as good or as reliable as formal laboratory tests. Therefore it is strongly recommended that whenever possible, tests should be performed strictly in accordance with the requirements of Paragraph 22 for the laboratory test. The greatest deficiency in field tests is that in most instances, the size and number of samples which can be taken for test are very limited. In the context of this field test, the test flame can be subject to much variation, and a completely draft-free location for testing is seldom available.

Field testing is most useful and meaningful for confirmatory purposes, as just one part of a regulatory program which gives the authority having jurisdiction control over the installation of fabrics and other decorative materials. In other words, a field test should be primarily to verify that a material is probably what it has been represented to be. The field test has much less value when the authority having jurisdiction has no supplementary information about what is being tested and therefore is forced to rely solely on the field test findings.

There are only two types of decorative materials for which field tests can be deemed to provide foolproof and totally adequate results: those made entirely of noncombustible inorganic material, and those which ignite and burn readily on exposure to a small flame. For example, with only a little experience an inspector will have no difficulty in identifying an all-glass fabric by means of a very small-scale field test, and nothing more is necessary. The only effect of a small fire exposure on a glass fabric is to burn off the surface coloring if any, and the threads themselves are virtually undamaged. This result is not obtained with any other type of decorative fabric, and it is readily recognized. At the other extreme, if a material ignites and burns readily with a very small scale test, showing no semblance of flame resistance, again nothing more is necessary since the material obviously is not acceptable.

Between these two extremes, field tests have a limited and a varying degree of reliability. In this large group, comprising the great majority of materials the inspector is likely to encounter in the field, the most reliable results will be obtained in the testing of cellulose-based materials (cotton, rayon and paper) flame-retardant treated with the common inorganic salt formulations such as those listed in this Appendix. These materials retain their shape reasonably during testing, and the results are not greatly affected by differences in sample size or severity of fire exposure. On the other hand, the least reliable results are obtained with chemically treated fabrics of synthetic fibers, or flexible plastic films and laminates. These materials are subject to a variety of physical changes when exposed to fire, such as shrinking, curling, melting, elongating and similar distortions, making the testing of small samples quite difficult and the results ambiguous. Furthermore, some of these thermo-plastic materials are apt to appear flame resistant with small flame exposures, but ignite and burn fiercely with larger and longer exposures.

Probably the most difficult and controversial question relates to the minimum number of samples which should be tested. The answer must be dictated by a number of factors, and certainly a good general rule would be the more samples,