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THE DEVELOPMENT OF FIRE-RETARDANT COATINGS FOR FABRIC COVERED AIRCRAFT

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THE DEVELOPMENT OF FIRE-RETARDANT COATINGS FOR FABRIC COVERED AIRCRAFT

SUMMARY

Power plant fire tests conducted on small fabric-covered aircraft proved the futility of providing engine fire protection in an aircraft covered with fabric which would be destroyed by fire within a few seconds.

Fabrics treated with cellulose nitrate dope were destroyed by fire within two seconds. Fabrics treated with cellulose acetate butyrate dope were destroyed by fire within six seconds.

Fire-retardant coatings have been developed which, when applied over fabrics treated with cellulose acetate butyrate dope, markedly increase the resistance to fire of the doped fabric.

PURPOSES

The purpose of this program was to develop fire-retardant coatings for application to doped fabric aircraft surfaces which would withstand power plant fires for a sufficient time to allow extinguishment of such fires. Coatings capable of withstanding fires of 2000 degrees F for periods of 20 to 30 seconds were believed desirable and possible.

The purpose of this report is to present the data developed, such that this work can be used by the paint industry as a basis for the development of commercial fire-retardant coatings.

INTRODUCTION

Aircraft power plant fire tests conducted by the Civil Aeronautics Administration at the National Bureau of Standards in 1942 and 1943 emphasized the need for providing fire-retardant coatings for doped fabric surfaces. Although complete fireproofing is not feasible or perhaps not even possible, substantial protection can be afforded by providing a coating which will delay destruction of the fabric, after the outbreak of a fire, beyond the time interval necessary for extinguishment. Therefore, a joint program of the Civil Aeronautics Administration and National Bureau of Standards looking toward the devel-

opment of fire-retardant coatings for doped aircraft coatings was set up.

Fabrics doped with cellulose acetate butyrate do not present the fire hazard encountered with fabrics doped with cellulose nitrate. However, even the slow burning butyrate dope would not be satisfactory in power plant fires in which the doped fabric is likely to be in continuous contact with flame for a period of several seconds.

No fire-retardant film-forming materials are known which tauten airplane fabrics as effectively and as permanently as do dopes based on cellulose derivatives. Furthermore, the addition of fire-retardant resins to cellulose derivatives has very little effect in increasing their fire retardance but has a very serious effect on tautness as shown by Kline¹. Therefore, at the outset of this program it was decided to provide additional fire resistance to doped fabric by applying a fire-retardant surface coating. The essential properties required in the surface coating are as follows: (1) fire retardancy, (2) good adhesion to doped surfaces, (3) minimum effect on the tautness of the substrate doped fabric, (4) applicability by usual coating techniques, (5) flexibility, (6) resistance to weathering equivalent to that of currently used dopes, (7) resistance to action of gasoline, oil, and ethylene glycol, and (8) aerodynamic smoothness.

DESCRIPTION OF DOPED FABRIC TEST PANELS

A Materials Investigated

The materials used in this investigation are described in Table I. Materials which have been most successfully used in fire-retardant coatings are (1) film-forming substances which on pyrolysis give off large quantities of non-combustible gases, and (2) pigments which function by the production of non-combustible gases or by the formation of a

¹ Gordon M. Kline - "Fire-Resistant Doped Fabric for Aircraft," J. Res. National Bureau of Standards, 14, 575, 1935.

protective glaze which excludes oxygen². Since most of the film-forming materials must be plasticized for use, it is desirable to incorporate as much fire retardancy into the film as possible by using fire-retardant plasticizers. A number of these were included in this investigation. In addition, several commercial preparations recommended by manufacturers as flame-resistant coatings were evaluated for comparative purposes.

B Preparation of Doped Fabric Test Panels

Two types of panel frames were used: wood frames for those doped fabric assemblies which were to be tested in the full-scale wind-tunnel fire tests at Indianapolis, and metal frames for those to be placed on outdoor exposure in Washington, D. C. Grade A airplane fabric, weighing four ounces per square yard, was stretched over the 15-inch square frames which had openings 12 inches square. The fabric was then coated with ten per cent by weight of a mixture of three parts boric acid and seven parts borax, applied as a seven per cent aqueous solution. This was to minimize the tendency for the flame to be propagated underneath the fabric in the still-air burning test. Four coats of clear cellulose acetate butyrate dope conforming to Army-Navy Aeronautical Specification AN-D-1 and two coats of pigmented cellulose acetate butyrate dope conforming to Army-Navy Aeronautical Specification AN-D-2 were applied to the fabric. Application of dope was according to the procedure defined by the Navy Aeronautical Specification SR-70e. The total weight of dope applied was about 4.5 ounces per square yard. Fire-retardant coats were sprayed on this basic six-coat system, the number of fire-retardant coats depending upon the tests to which the panel was to be subjected. The weight of each fire-retardant coat was approximately two ounces per square yard.

DESCRIPTION OF TESTS AND TEST EQUIPMENT

A Evaluation of Fire Retardance

1 Still-Air Burning Test

It was necessary to select by means of a simple test optimum combinations of the fire-retardant materials to serve as a basis for further development. In the initial stages of the investigation the apparatus developed

by Brown and described by Kline³ was used. It consists of two parallel steel clamps supported by a steel frame, the distance between the two clamps being adjustable. The specimen to be tested is fastened between the clamps and ignited at one end. The time required for the flame front to travel over a given distance (five inches), as measured along the clamps between two marks, is recorded with a stop watch. Specimens used in these tests were three inches wide and eight inches long. They differed from the specimens used by Kline in that two rows of 1/8-inch diameter holes with centers 1/4-inch apart lengthwise and two inches apart crosswise were punched in the specimen. The purpose of these holes was to provide a constant air supply throughout the test. The apparatus is suitable for either horizontal or vertical burning tests.

2. Moving-Air Burning Test

It was soon found that, as the development led to coatings which were more fire-retardant, the still-air burning test was inadequate for evaluation purposes because the coatings were self-extinguishing. A moving-air burning test was developed which permitted evaluation of the more fire-retardant coatings. A sketch of this apparatus is shown in Fig. 1. A small laboratory centrifugal exhaust fan draws air through a funnel-shaped entrance port, which is adapted to accommodate a doped fabric test panel. The doped fabric panel is attached to the bottom of the entrance funnel with the fire-retardant coating on the inside. A Meker burner with air supply adjusted to give a quiet blue flame nine inches in height is placed in such a position with respect to the fabric that the current of air causes the flame to lie on the coated surface. Wind velocity in the center of the entrance port is 6.5 miles per hour, measured with a hot wire anemometer. The time intervals (1) between flame contact and ignition of coating and (2) between flame contact and charring of the fabric as seen from the outside are measured with a stop watch. For a group of 119 tests of pairs of duplicate samples, the

² J. E. Ramsbottom - "The Fire Proofing of Fabrics" p. 24, London His Majesty's Stationery Office, 1947

³ Gordon M. Kline - "Fire-Resistant Doped Fabric for Aircraft," J. Res. National Bureau of Standards, 14, 575, 1935

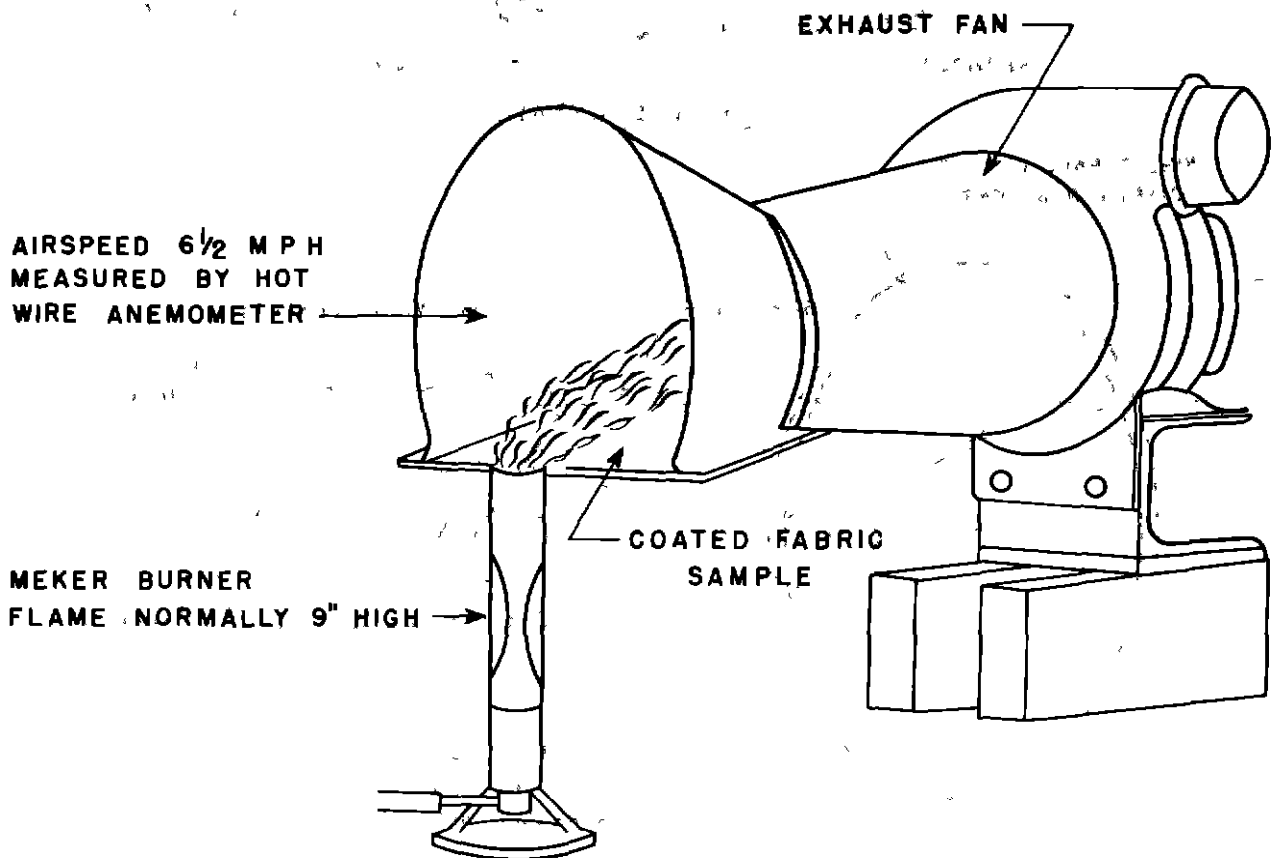


Fig 1 Apparatus for Selecting Doped Fabric Coatings by Moving Air Burning Test

standard deviation of an individual measurement was found to be 10 second.

3. Wind-Tunnel Burning Test

This test was made at the Experimental Station of the Civil Aeronautics Administration at Indianapolis, Indiana. A steel wing section of Clark Y airfoil was suspended, as shown in Fig. 2, at the outlet end of an open-type wind tunnel. A 12-inch square opening in the center of the span and chord of the lower surface was provided to admit fabric panels for test. The angle between the plane of the test panel and the axis of the wind tunnel was zero degrees. The wind tunnel was operated so as to provide a 70 mile per hour air stream. Immediately forward of the wing was mounted a spray-gun to which was supplied approximately 1.5 gallons per minute of 90-octane aviation gasoline and air at approximately 50 pounds per square inch. The spray-gun introduced a uniform spray of atomized gasoline into the air stream. At zero time, the spray

was ignited by a spark from a high-tension aircraft spark plug. This provided an envelope of burning gasoline which passed both over and under the airfoil insuring continuous contact of the test specimen with flame during the entire test. The gasoline flow was regulated by a solenoid-type electric valve. The course of the fire was observed by two observers on the ground with stop watches and by a motion picture camera aimed at a mirror so oriented in the interior of the wing section as to permit observation of the inside surface of the test panel. A large electric clock with a sweep second hand was placed in the field of view of the camera to provide an auxiliary time scale. The motion picture camera was operated at a speed of 16 frames per second. One observer noted the time for the destruction of the outer coating and the second observer noted the time of fabric failure. The destruction of the outer coating was evidenced by pieces of coating being blown away by the

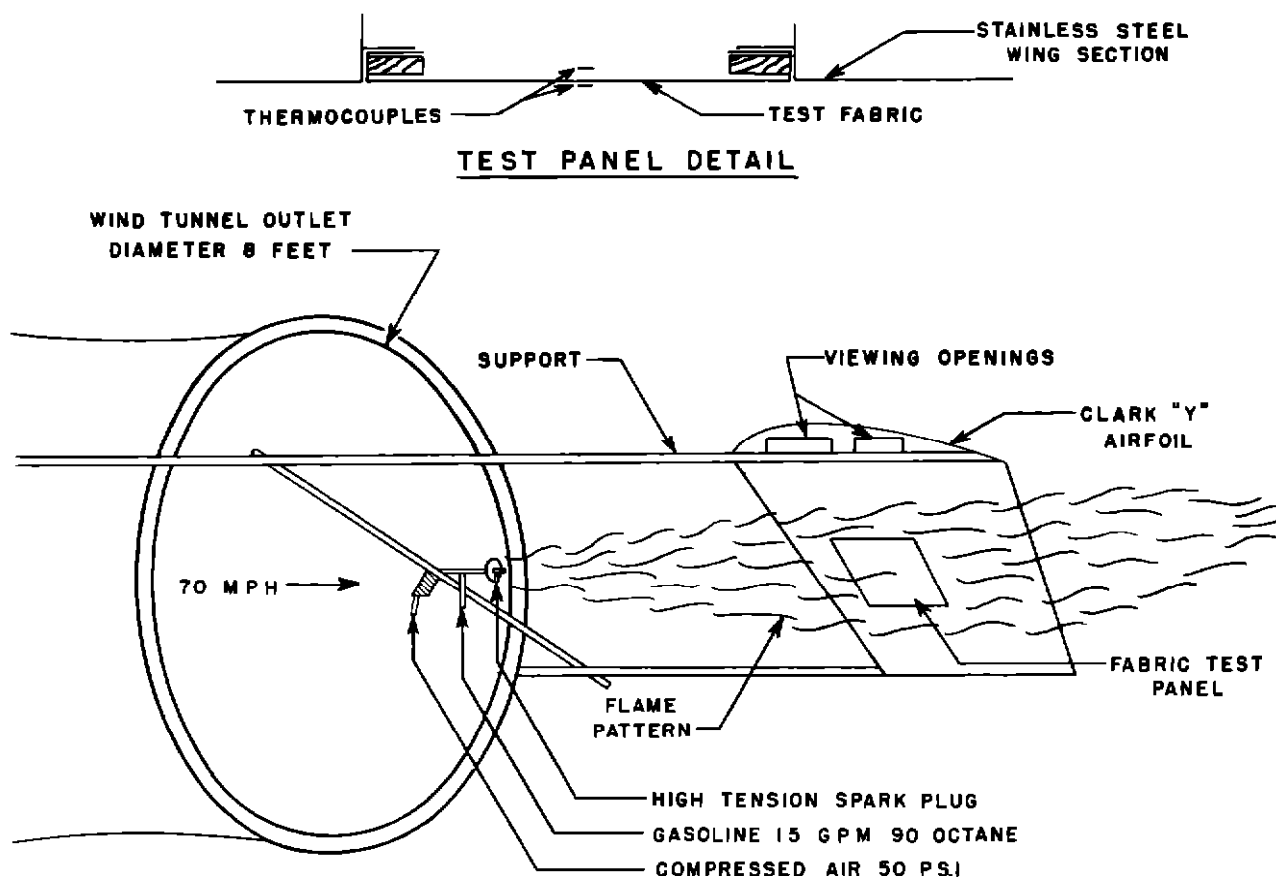


Fig. 2 Apparatus for Wind-Tunnel Burning Tests of Fire-Retardant Coatings for Doped Fabric

windstream. Failure of the fabric was evidenced by two criteria. To the outside observer, the disintegration of the fabric was quite sudden and complete. At the same time, the illumination inside the airfoil suddenly increased. In Fig. 3, prints of successive frames of the motion picture record show the fabric destruction occurring between the first and second frames. Temperatures were recorded at points immediately outside and inside the fabric by means of thermocouples and quick-acting recording pyrometers.

Fifteen experimental fire-retardant coating systems were tested in the wind tunnel. In each system, one, two, three, and four coats of fire-retardant material were applied to a fabric previously doped with a standard Navy six-coat doping scheme, using cellulose acetate butyrate dope applied in accordance with Navy Aeronautical Specification SR-70e. The selection of the materials for this test was based on their performance in the laboratory

moving-air burning tests. Panels were prepared several months in advance, so that the effects of solvent retention were negligible. The formulations of these fire-retardant coats are given in Table II. Also, panels without fire-retardant coatings were tested to provide a basis of comparison. In this latter group were included panels coated with Monsanto Skylac dope, Navy specification cellulose nitrate dope, and Navy specification cellulose acetate butyrate dope, respectively.

B. Evaluation of Other Properties of Coating Systems

Not only is it desirable to provide the maximum in fire retardance in a coating, but it is also essential that the coating have a reasonably good life expectancy. The requirements for good airplane fabric coatings are severe. They must be tough enough in all kinds of weather to withstand impacts from pieces of runway gravel as well as normal flying

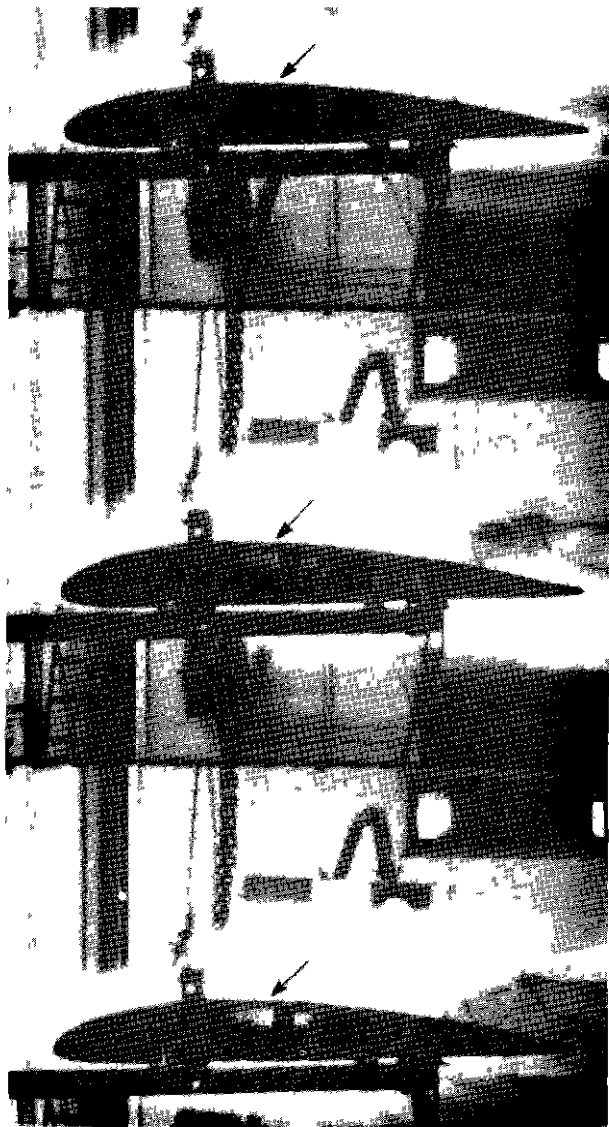


Fig. 3 Sample of Motion Picture Record of Wind-Tunnel Burning Tests of Fire-Retardant Coatings for Doped Fabrics Arrows Indicate Viewing Mirror at Test Panel

stresses, they must not interfere with the normal fabric tautness, they must be easily applied, show good adhesion to dope and be smooth.

1. Accelerated Weathering Test

In the exploratory stages of this investigation, accelerated weathering by Method 6021 of Federal Specification L-P-406a was used as a guide in the selection of coating formulations. The specimen is exposed to cycles of condensed fog alternated with ultraviolet

radiation from a General Electric S-1 sunlamp. This method has proved successful for laboratory evaluation of plastics with respect to their resistance to natural weathering. A standard exposure of 240 hours of this cyclic treatment was used as an initial screening test. A soft alkyd resin, Rezl 36-5, was found to be particularly effective as a plasticizing resin and superior to the other resins tested in imparting resistance to weathering. Most of the coatings were, therefore, built around this resin. Test films approximately ten mils thick were examined with and without pigments, both as free films and as coatings applied to doped fabrics. To be a candidate for outdoor exposure, the test film was required to show sufficient flexibility after the 240 hours of accelerated weathering to permit a 180-degree fold at room temperature without cracking. The fold was made by hand, with no attempt to control the radius of fold.

2 Outdoor Weathering Tests

Fire-retardant coatings selected for outdoor exposure were applied as top coats over panels of doped fabric. The compositions and properties of the coating systems tested by outdoor exposure are presented in Tables III to VI inclusive. Two coats were applied, the total coating weight added being approximately four ounces per square yard. The test panels were exposed continuously in Washington, D. C. on outdoor racks facing south at an angle of 45 degrees. Periodic tautness measurements and impact tests were made according to the procedures described by Kline and Reinhart⁴.

RESULTS AND DISCUSSION

A. Wind-Tunnel Burning Tests

The results of the wind-tunnel burning tests at Indianapolis are shown in Table II and Fig. 4. Fig. 5 shows the appearance, after the wind-tunnel burning tests, of panels which had been doped with cellulose nitrate and cellulose acetate butyrate dopes, with and without fire-retardant coatings on the dope surfaces. It is noteworthy that the panel doped

⁴ Gordon M. Kline and Frank Reinhart "Industrial and Engineering Chemistry," 32, 185, 1940.

Figure 1 is a stacked bar chart showing the time distribution of responses for 8 groups of subjects. The Y-axis is labeled 'SECONDS' and ranges from 0 to 10. The X-axis shows 8 groups (1-8) with 4 response categories each. The legend indicates: N (solid black), E (diagonal lines), and F (white). The data is as follows:

Group	Response	N (s)	E (s)	F (s)	Total (s)
1	1	3.5	2.5	3.0	9.0
	2	3.8	3.2	2.5	9.5
	3	3.5	2.5	2.0	8.0
	4	3.2	3.0	2.0	8.2
2	1	3.2	2.8	2.0	8.0
	2	3.5	3.0	2.5	9.0
	3	3.8	3.5	2.2	9.5
	4	3.5	3.8	2.5	9.8
3	1	3.0	3.5	2.5	9.0
	2	3.2	3.0	2.8	9.0
	3	4.2	2.5	2.5	9.2
	4	5.0	2.0	2.5	9.5
4	1	3.0	3.5	2.5	9.0
	2	3.2	2.8	2.0	8.0
	3	4.2	2.5	2.5	9.2
	4	5.0	2.0	2.5	9.5
5	1	3.0	2.5	2.5	8.0
	2	3.2	2.8	2.0	8.0
	3	3.8	3.0	2.5	9.3
	4	6.8	0.0	0.0	6.8
6	1	2.5	3.0	2.0	7.5
	2	2.8	3.5	2.0	8.3
	3	4.0	3.0	2.0	9.0
	4	6.0	0.0	0.0	6.0
7	1	2.5	4.0	2.0	8.5
	2	3.5	3.5	2.0	9.0
	3	4.0	3.0	2.5	9.5
	4	5.0	2.0	2.0	9.0
8	1	3.5	2.5	2.0	8.0
	2	3.0	3.0	2.5	8.5
	3	3.8	3.5	2.5	9.8
	4	3.5	2.5	2.0	8.0

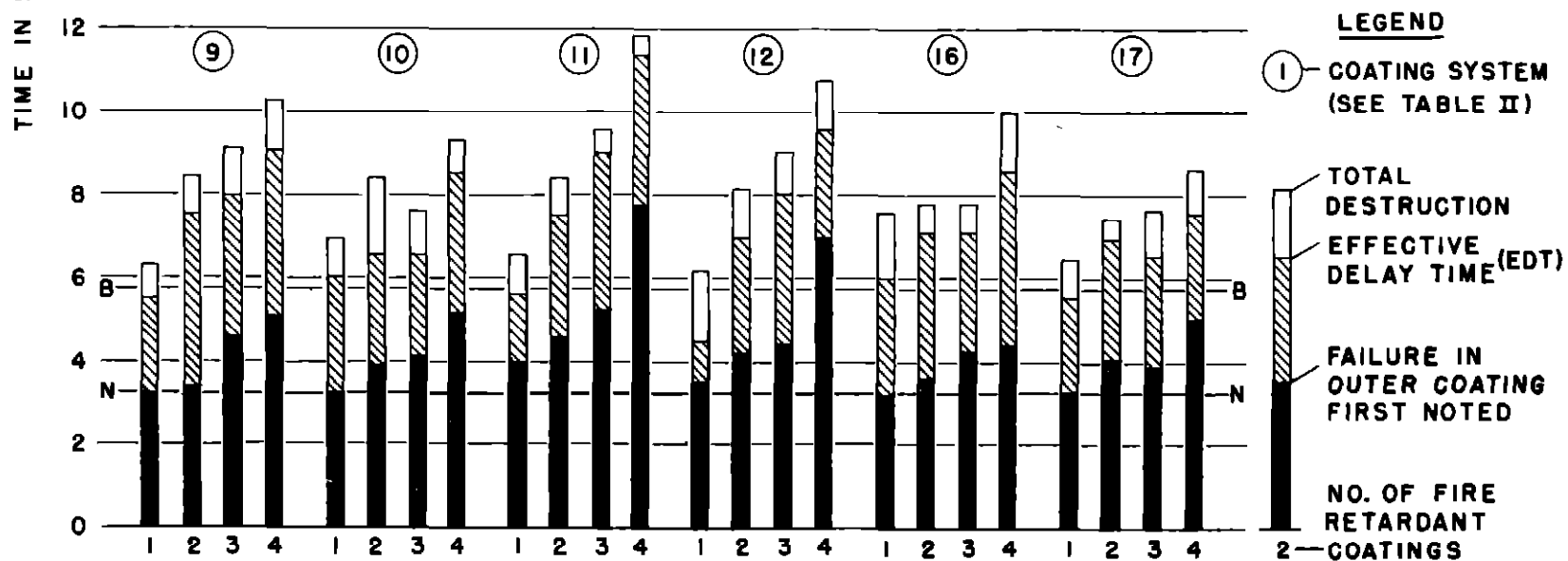
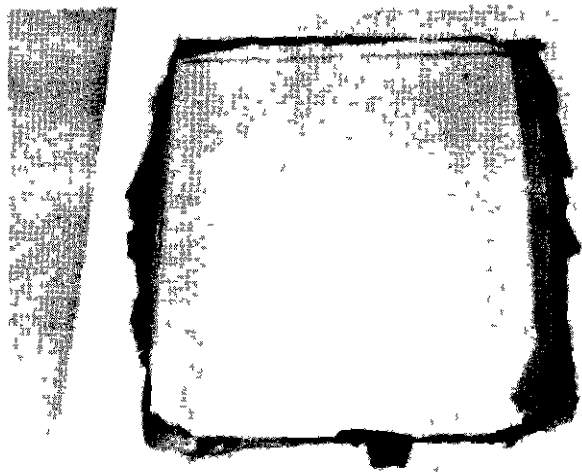
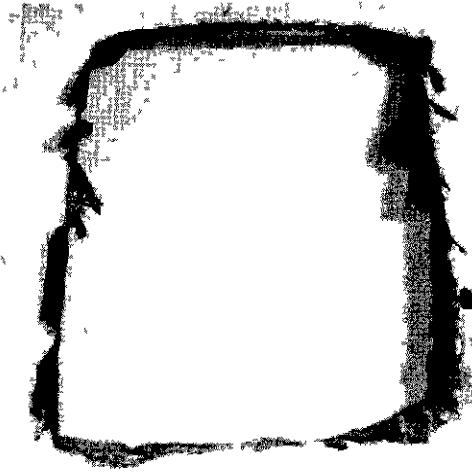


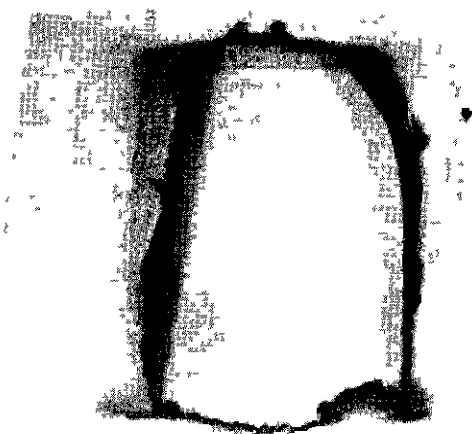
Fig. 4 Burning Times of Doped Fabrics Covered with Fire-Retardant Coatings in Wind-Tunnel Test



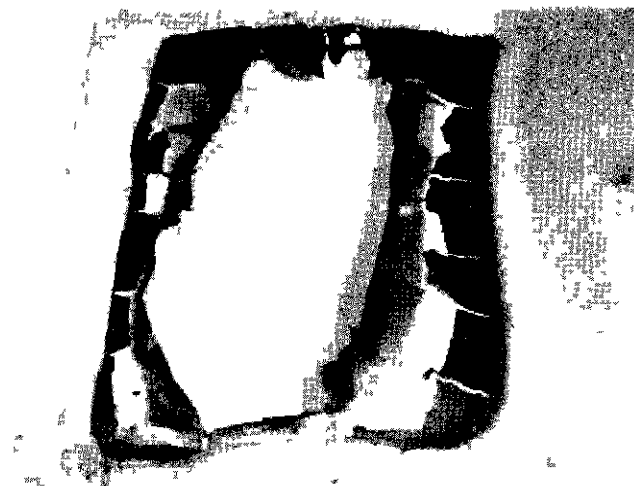
N3



N5



B6



11D

Fig. 5 Appearance of Panels After Simulated Power Plant Fire Tests in the Wind-Tunnel at Indianapolis

N 3 - Cellulose nitrate dope, destruction time, 2 seconds

N 5 - Cellulose nitrate dope plus four coats of fire-retardant coating No. 11
(see Table II), destruction time, 4 seconds

B 6 - Cellulose acetate butyrate dope, destruction time, 6 seconds

11 D - Cellulose acetate butyrate dope plus four coats of fire-retardant coating
No. 11 (see Table II), destruction time, 12 seconds

with cellulose nitrate and coated with a fire-retardant coating is destroyed more quickly and extensively than the panel coated with cellulose acetate butyrate dope only.

Coating failure in this investigation is taken as the time required for the coating to be destroyed to such an extent that it is partially swept away by the windstream. During this interval, the temperature on the outside of the panel rises considerably more rapidly than the temperature on the inside. When the coating is completely swept away, the temperature on the inside rises sharply. The time until this rise of temperature on the inside occurs is somewhat of a measure of the fire-retardant effectiveness of the coating. The coating, in blistering, apparently acts as a blanket and flame deflector. The sharp temperature rise occurs when this blanket is removed so that the doped surface is again in contact with the flame. The time-temperature

relations are shown in Fig. 6. The times shown by the bar graphs in Fig. 4 for total destruction as evidenced by fire break-through are taken from the motion picture records, which are considered to be somewhat more reliable than either the data from the manually operated stop watch, or the data from the time-temperature charts. The values of times given Fig. 4 and in Table II are the original data for a single panel.

In general, increased fire protection was given by increasing the number of fire-retardant coats, with the exception of coating system No. 2 for which no explanation is apparent.

The zone of incident flame from the burning gasoline was sharply confined to half the panel area. This provided a criterion of extent of propagation of the fire to areas not in contact with the original flame. The burnt areas of the fire-resistant panels were con-

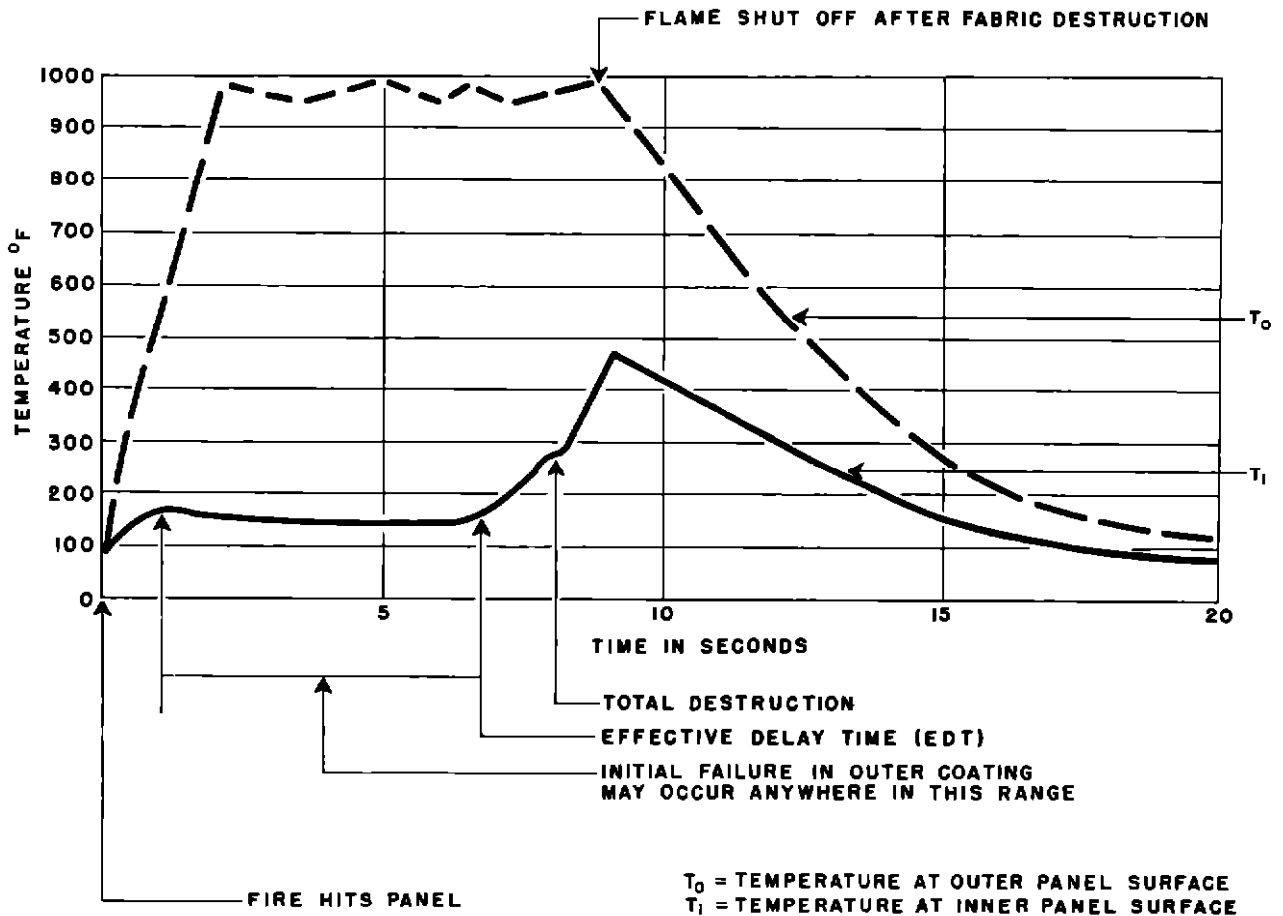


Fig. 6 Typical Time-Temperature Record of a Test Panel During Wind-Tunnel Burning Test

fined to those regions immediately in contact with the flame. This was true also of the panels coated with cellulose acetate butyrate dope only, but was not true of the panels coated with cellulose nitrate dope. In some instances, the cellulose nitrate panels were completely consumed. Under the conditions of fire, the cellulose acetate butyrate melted before it ignited. This melting of the coating occurred also with the chlorinated neoprene systems, Nos. 5 and 6.

An almost universal property of all the fire-retardant systems was the development of blisters brought about by the generation of gases incident to the pyrolysis of the fire-retardant materials. The only exception was system No. 11 which did not exhibit the blisters characteristic of the other systems, but instead seemed to be one big bubble. Zinc borate was the pigment used in this latter system which showed the best fire-retardant properties of any system tested. From the point of view of keeping the coating in place for as long a period as possible, the formation of small blisters is better than the formation of one large bubble, which might easily be blown loose by the windstream.

During the progress of the tests, it became quite apparent that an important limiting factor in protection was the brittleness of the burnt outer coating. Some improvement can be expected if the outer coating is designed to have greater mechanical strength after burning, so that it will not be so easily blown away by the windstream. There appear to be no systematic differences in the results obtained with the several plasticizers investigated.

Afterglow, although a significant property in the still-air burning tests because of re-ignition, was not important in either the laboratory moving-air or wind-tunnel burning test. However, it was noted in the wind-tunnel tests that large sections of the aluminized coating on a panel doped with cellulose acetate butyrate containing aluminum pigment were ignited and blown away as a shower of burning particles downstream. This could conceivably constitute a reignition hazard.

Since coating systems examined in the wind-tunnel tests were selected from those showing up best in the laboratory tests, the differences in fire-retardant effectiveness among these various systems is relatively

small. Therefore, it is difficult to choose a particular system as being clearly the best. However, there is no doubt that these coatings are substantially superior in fire retardancy to a cellulose acetate butyrate system alone. Their superiority over cellulose nitrate systems is very marked.

B. Outdoor Weathering Test

The program of accelerated weathering was designed so as to select systems which could be expected to remain flexible after a normal period of service. Those systems which retained their flexibility after 240 hours of accelerated weathering were incorporated into panels placed on outdoor exposure for evaluation of their weather-resistant properties. The compositions and properties of the coating systems tested by outdoor exposure are presented in Tables III to VI, inclusive.

The tautness readings shown in the tables represent the deflection in thousandths of an inch produced at the center of a doped fabric test panel by a concentrated load of one pound. Therefore, low readings mean good tautness. A value of 100 is taken as the boundary between satisfactory and unsatisfactory tautness. The tendency to poor tautness which results from the use of the non-tautening fire-retardant coatings can possibly be neutralized in part by the use of a hot application dope, which gives a high degree of tautness, as the substrate. Thus, the tautness of the composite system might be made equivalent to that of standard cellulose acetate butyrate doped fabric. However, the hot dope systems require further development to correct poor flexibility before they will be satisfactory for such use. Although the boric-acid-borax treatment does act as an effective fire-retardant for fabric, there was evidence that the adhesion of cellulose acetate butyrate dope to fabric was lower in panels containing the boric acid and borax than in panels not containing boric acid and borax. Very few of the coatings tested in this program are as durable or as flexible as the cellulose acetate butyrate dope which is taken as a standard for comparison. The formulas which showed relatively early failure on impact (brittle failure) i.e., in less than six months, are not recommended for further consideration. There are, however, several coating systems which ought to be considered seriously for further development by interested lacquer manufacturers. These will be

discussed in detail.

1. Vinyl and Vinylidene Chloride Resin Coatings (Table III)

Half of the Vinylite VYHH coatings developed poor adhesion to dope upon exposure. Panel 625 had white pigment in the substrate dope and showed evidence of erosion. Panel 674 was removed because of impact failure after short exposure.

Stabilizers such as urea and basic lead carbonate were effective in prolonging the coating life as may be seen by comparing panel 761, which had no stabilizer, with panels 732 and 733, which had stabilizers.

The coatings using the vinylidene chloride-acrylonitrile copolymer (Dow Resin X-124) as film-forming base show, in general, very favorable properties, both from the point of view of fire retardancy and of weathering. The superior performance of panels 730 and 731 in comparison with panel 760 demonstrates the effectiveness of urea and basic lead carbonate as stabilizers. The use of equal parts of calcium carbonate and antimony oxide as pigment in formula 96 appears to be a factor in the very marked superiority in fire resistance as compared with the fire resistance of the coatings from formulas 547 and 548, in which a larger proportion of antimony oxide was used. This variable needs further exploration.

2. Chlorinated Rubber Coatings (Table IV)

The four chlorinated rubber coatings which gave best results in the outdoor weathering tests are formulas 2, 84, 543, and 544. However, the erosion of formulas 2 and 84, incident to the use of the water-soluble magnesium ammonium phosphate in the pigment, may be responsible for the failure to show brittleness simply because of the reduction of coating thickness. Formulas 543 and 544 show superior fire retardancy, as compared with formula 2, with respect to both self-extinguishing and afterglow. Another promising coating is formula 534, one prepared by adding chlorinated rubber to an aluminum-pigmented vinyl chloride acetate lacquer (Amercoat 1138) formula No. 534. Preliminary accelerated weathering tests of Amercoat 1138 over cellulose acetate butyrate doped fabric were unfavorable. However, use of the mixture gave good results both in accelerated and natural weathering, except for a single early brittle failure.

3. Chlorinated Neoprene Coatings (Table V)

Formulas 545 and 546 (panels 768 and 729), containing urea and basic lead carbonate as stabilizers, show the best resistance to weathering. Formula 97 (panels 630 and 631) appeared better in the laboratory burning tests. A formula nearly like formula 97, namely formula 470, showed up excellently in the wind-tunnel fire tests (see Table II and Fig. 4, wind-tunnel test coating No. 6). It is probable that the use of equal parts of calcium carbonate and antimony oxide plus one of the stabilizers would yield a coating having the improved weathering resistance of formulas 545 and 546 and the fire retardancy of formula 97. The chlorinated neoprene formulas gave the smoothest coatings of any of the materials tested.

4. Chlorinated polyisoprene Coatings (Table VI)

Formulas 466 and 540 (panels 699 and 701) gave the best all around performance in the outdoor weathering test, although both panels became slack on one occasion during a prolonged wet spell. The mixed base coating, using chlorinated polyisoprene (Parlon X) and Amercoat 1138, showed an early brittle failure but otherwise gave good performance.

CONCLUSIONS

1 Simulated power plant fire tests of doped fabrics coated with fire-retardant coatings, conducted under wind-tunnel conditions, demonstrated that it is possible to increase the critical time interval between the instant of first contact of fire with fabric and the instant of fabric destruction from the present value of two seconds with cellulose nitrate dope or six seconds with cellulose acetate butyrate dope to twelve seconds with a fire-retardant coating applied over cellulose acetate butyrate dope.

Coatings of superior fire-retardant characteristics warranting further development include N.B.S. Coating Systems Nos. 251, 451, 469, and 470.

2. A laboratory method for the quick evaluation of relative performance of fire-retardant coatings is described. This test will facilitate the further development of fire-retardant coatings.

3. The protective action of fire-retardant coatings on cellulose nitrate dope is too small

to be of any value.

4. The results of outdoor exposure tests reveal several fire-retardant coating systems with good weathering characteristics which are recommended for further development. Among the systems warranting further development are N.B.S. Formulas Nos. 534, 547, 548, 96, 545, and 466.

5. The use of a mixture of boric acid and borax as fabric impregnant, while effective as a fire-retardant, has a deleterious effect on adhesion of dope to fabric which becomes apparent on outdoor exposure.

RECOMMENDATIONS

It is recommended that

1. The data given in this report be used as a basis for the development of commercial fire-retardant coatings

2. Test panels incorporating the developed coatings be furnished to the Power Plant Section, Civil Aeronautics Administration

Experimental Station, Indianapolis 21, Indiana for evaluation of fire retardance.

3. Test panels be prepared in accordance with Navy Aeronautical Specification SR-70e, Section D-6. Panels should be mounted on square wooden frames, outside dimension 15 inches plus or minus 1/8-inch inside dimension 12 inches square. The fabric used should be AN-C-121 weighing four ounces per square yard and should be untreated (no boric acid-borax). The dope used should be AN-D-1 and AN-D-2 (white dope) Total weight of dope should be 4 1/2 ounces per square yard. Various weights of fire-retardant coatings should be used on series of panels to assure that an optimum point can be established between the weight of coating and the consequent fire retardance.

4. Manufacturers engaging in this work use panels as described in recommendation No. 3 for accelerated and outdoor weathering tests, and that these panels, after the weathering tests, be submitted for fire testing.

TABLE I - MATERIALS INVESTIGATED IN FIRE-RETARDANT COATING DEVELOPMENT

Trade Name	Chemical Classification	Manufacturer
FILM BASES		
Phiolite	Rubber hydrochloride	Goodyear Tire and Rubber Co
Insul-X	Chlorinated rubber	Insul-X Co, Inc
Parlon 125	Chlorinated rubber	Hercules Powder Co
Parlon R	Chlorinated neoprene	"
Parlon X	Chlorinated polyisoprene	"
Mathieson Rubber 153b	Butadiene-dichlorostyrene	Mathieson Alkali Works
Vynlite VYHH	Vinyl chloride acetate	Bakelite Corp
Resin 256-27	"	American Resinous Chemicals Corp
Resin X-124	Vinylidene chloride - acrylonitrile	Dow Chemical Co
Resin X-120	Vinylidene chloride - vinyl chloride	"
Resin F-120	Vinylidene chloride - acrylonitrile	"
Mathieson Plastic 153a	Polydichlorostyrene	Mathieson Alkali Works
Amercoat 1138	Vinyl chloride - vinyl acetate solution (45% solids)	American Pipe and Construction Co
Amecco Paint	Fire retardant paint	Amecco Chemicals Inc
Pyropex Dope	Ethyl cellulose dope	Sherwin-Williams Co
Skylac Dope	Cellulose acetate butyrate dope	Monsanto Chemical Co
MODIFYING RESINS		
Acryloid C-5	Acrylic resin	Resinous Products and Chemical Co
Acryloid B-72	"	"
Acryloid B-75	"	"
Arochem 345	Alkyd resin	U S Industrial Chemicals, Inc
Arochem 520	"	"
Aroclor 5460	Chlorinated diphenyl	Monsanto Chemical Co
Aroplaz 945	Alkyd resin	U S Industrial Chemicals, Inc
Aroplaz 930	"	"
Arprene 700	Phenolic resin	"
Bakelite XR-976	"	Bakelite Corp
Bakelite XR-13630	"	"
Beckasol 31	Alkyd resin	Reichhold Chemicals Inc
Clorafin 70	Chlorinated paraffin	Hercules Powder Co
Lewisol 24	Alkyd resin	John D Lewis, Inc
Lewisol 33	"	"
Rezyl 869	"	American Cyanamid Co
Uformite	Urea-formaldehyde	Resinous Products and Chemical Co
PLASTICIZERS		
Aroclor 1254	Chlorinated diphenyl	Monsanto Chemical Co
--	Butyl-2-methyl-2-nitropropyl phthalate	Commercial Solvents Corp
--	Camphor	E I du Pont de Nemours and Co, Inc
Clorafin 42	Chlorinated paraffin	Hercules Powder Co
--	Dibutyl phthalate	U S Industrial Chemicals
Flexol DCP	Diethyl phthalate	Carbide and Carbon Chemicals Corp
--	Diphenyl phthalate	Eastman Kodak Co
Dow No 6	Triethylene glycol di-2-ethylbutyrate	Dow Chemical Co
Flexol 3GH	Chlorinated paraffin	Carbide and Carbon Chemical Corp
Halowax 4001	Hydrogenated methyl abietate	Union Carbide and Carbon Corp
Hercolyn	Hexachlorethane	Hercules Powder Co
--	Phenyl salicylate	--
Salol	Butyl phthalyl butyl glycolate	Eastman Kodak Co
Sanicizer B-16	Methyl phthalyl methyl glycolate	Monsanto Chemical Co
Sanicizer M-17	Tricresyl phosphate	"
--	Triphenyl phosphate	Eastman Kodak Co
--	Phthalic alkyd soft resin	"
Rezyl 36-5		American Cyanamid Co
PIGMENTS		
	Antimony oxide	
	Asbestos fibers	
	Calcium carbonate	
	Magnesium ammonium phosphate	
	Titanium dioxide	
	Zinc borate	

TABLE II - COMPOSITIONS AND PROPERTIES OF FIRE-RETARDANT COATINGS TESTED IN WIND-TUNNEL FIRE TESTS AT INDIANAPOLIS

Wind-Tunnel Test Coating System No. N B S Formula No	1 120	2 121a	3 255	4 469	5 251	6 470	7 471	8 96	9 434	10 472	11 451	12 450	15 540	16 556	17 558
Composition ^a															
Film base															
Vinylite VYHH				26											
Parlon 125	26	26	26		26	26									
Parlon R															
Parlon X							26			27	30	30	30	30	26
Dow X-124								26							
Resin 256-27									48						
Amercoat 1138			40												
Mathieson Rubber 153b														8	
Polydichlorostyrene															10
Plasticizer															
Rezyl 36-5	26	26	26	26	13	13	14	26		27	14	14	14	14	14
Aroclor 1254														8	
Dibutyl phthalate	4		4		6 5		10	4			8	8			10
Diocetyl phthalate													16		
Dow No 6		4		4	6 5					6					
Hexachlorethane									12						
Diphenyl phthalate						6 5		4							
Tricresyl phosphate						6,5									
Clorafin 42	4	4	4	4			10				8	8			
Pigment															
Antimony oxide	20	20		20	24	24	20	20	20	20			20	20	20
Calcium carbonate	20	20		20	24	24	20	20	20	20			20	20	20
Magnesium ammonium phosphate												40			
Zinc borate											40				

TABLE II (Continued)

Wind-Tunnel Test Coating System No	1	2	3	4	5	6	7	8	9	10	11	12	15	16	17
N B S Formula No	120	121a	255	469	251	470	471	96	434	472	451	450	540	556	558
VOLATILES															
Solvent															
Methyl ethyl ketone	60		60	60				100	100		100	100	100		100
Cellosolve acetate	30		30												
Butyl acetate	10	20	10	40		20									
Ethyl acetate		80													
Diacetone alcohol					50										
Aromatic petroleum naphtha, Type I						60									
Tollac							60			0					
Toluene														100	
Xylene						20	40			40					
U S No 8					50										
Properties															
Fabric destruction time (wind tunnel), sec ^b	8.2	6.4	7.5	8.8	10.2	10.0	8.0	7.8	10.3	9.4	11.8	10.8	10.0	7.6	8.5
Fabric char time (laboratory moving air), sec	12	16	11	9	12	10	10	17	10	--	12	16	--	10	11
Accelerated weathering ^c	P	P	G	VG	G	G	G	P	P	--	G	P	--	G	P
Panel No. in outdoor exposure test	655	656	--	674	--	--	--	621	--	--	--	--	701	--	--

a Figures in table are in percent of nonvolatiles and volatiles, respectively
The solutions were made up to contain 25 percent nonvolatiles

b Times given in this table are for panels with four fire-retardant coats
See Figure 4 for results of tests with one, two, and three fire-retardant coats

c Code for behavior of coating in accelerated weathering test
P = poor
G = good
VG = very good

TABLE III - VINYL AND VINYLIDENE CHLORIDE FIRE-RETARDANT COATINGS TESTED IN WASHINGTON

NBS Panel No	624	625	674	732	733	761	621	697	671	730	731	760
NBS Formula No ^b	62	62	469	549	550	562	96	96	96	547	548	561
Dope Pigmentation	A1	W	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1

Composition^a

NONVOLATILES												
Film base												
Vinylite VYHH	27.2	27.2	26	25.9	25.9	26						
Dow Resin X-124							26.2	26.2	26.2	25.9	25.9	26
Plasticizer												
Rezyl 36-5	27.2	27.2	26	14	14	14	26.2	26.2	26.2	13.9	13.9	14
Diphenyl phthalate	2.7	2.7					3.9	3.9	3.9	10	10	10
Dow No. 6	2.7	2.7	4	19.9	19.9	20						
Clorafin 42	20.1	20.1										
Dibutyl phthalate							3.9	3.9	3.9	10	10	10
Pigment												
Calcium carbonate	20.1	20.1	20	10	10	10	19.9	19.9	19.9	10	10	10
Antimony oxide			20	29.9	29.9	30	19.9	19.9	19.9	29.9	29.9	30
Stabilizer												
Phenyl salicylate			4									
Urea				0.3						0.3		
Basic lead carbonate					0.3						0.3	

TABLE III (Continued)

N B S Panel No	624	625	674	732	733	761	621	697	671	730	731	760
N B S Formula No	62	62	469	549	550	562	96	96	96	547	548	561
Dope Pigmentation ^b	Al	W	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al

VOLATILES

Solvents												
Methyl ethyl ketone	60	60	100	60	60	60	100	100	100	100	100	100
Butyl acetate	40	40		40	40	40						

Properties

Fabric char time, moving-air test, sec	7	7	9	9	12	--	17	17	17	8	9	--
Burning characteristics ^c	A,B,E	A,B,E	A,B,E	A,B,E	A,B,E	--	A,B,E	A,B,E	A,B,E	A,B,E	A,B,E	--

Outdoor weathering

Initial tautness, mils	106	113	68	81	84	80	106	86	100	96	93	98
Tautness range ^d , mils	73/131	69/139	60/98	63/125	60/127	68/123	71/142	68/S	82/133	69/137	61/137	75/140
Time to first brittle failure, mo	10	8	4	9	9	5	10	14	2	--	--	6
Total exposure, mo	11	11	5	11	11	7	31	21	5	17	17	14
Condition of panel ^e	B,D	C,D	F	G,D	B,D	B,D	A,D	A,D	D	A,D	A,D	A,D

a Figures in table are in percent by weight of nonvolatiles and volatiles, respectively. The solutions were made up to contain 25 percent nonvolatiles. All fabrics were coated with 10 percent by weight of a mixture of three parts boric acid and seven parts borax before doping.

b Code for pigmentation

Al = aluminum

B = blue-gray

G = gray

W = white

c Code for burning characteristics

A = afterglow

B = blistering

E = self-extinguishing

d S = slack

e Code for condition of outdoor weathering panels^a

A = exposure test continuing

B = poor adhesion of top coat to dope substrate

C = erosion of top coat

D = tautness poor in warm weather

E = fine cracking of top coat

F = experimental hot-application dope substrate

G = poor adhesion of dope to fabric

TABLE IV - CHLORINATED RUBBER FIRE-RETARDANT COATINGS TESTED IN WASHINGTON

	N B S Panel No	583	584	585	586	587	588	592	593	594	622	623	626	627	655	656	669	726	727
	N B S Formula No	1	2	3	46	50	60	83	84	78	88	88	80	80	120	121a	534	543	544
	Dope Pigmentation ^b	G	G	G	G	G	G	G	G	G	Al	W	Al	W	Al	Al	Al	Al	Al
Composition ^a																			
		NONVOLATILES																	
Film base																			
Parlon 125		42.9	42.9	42.9	38.2	38.2	40.0	26.1	26.1	27.2	27.2	27.2	26.1	26.1	26.2	26.0	26.0	25.7	25.7
Amecco paint													40.0 ^f	40.0 ^f					
Amercoat 1138																	40.0 ^f		
Plasticizer																			
Rezyl 36-5		--	--	--	38.2	38.2	40.0	26.1	26.1	27.2	27.2	27.2	26.1	26.1	26.2	26.0	26.0	14.0	14.0
Dibutyl phthalate		7.1	7.1	7.1	5.7			3.9							3.9		4.0		
Diphenyl phthalate					5.7	5.7	4.0	3.9	3.9	2.7	2.7	2.7	3.9	3.9			4.0		
Triphenyl phosphate		21.4	21.4	21.4															
Dow No. 6							4.0			2.7	2.7	2.7				4.0		10.0	10.0
Clorafin 42											20.1	20.1				4.0		10.0	10.0
Chlorowax				14.3			6.0			20.1									
Flexol JGH						5.7			3.9				3.9	3.9	3.9				
Pigment																			
Zinc borate		28.6			12.2			40.0											
Calcium carbonate				14.3			6.0			20.1	20.1	20.1			19.9	20.0		10.0	10.0
Magnesium ammonium phosphate			28.6			12.2			40.0										
Antimony oxide															19.9	20.0		30.0	30.0
Stabilizer																			
Urea																		0.3	
Basic lead carbonate																			0.3

TABLE IV (Continued)

N B S Panel No	583	584	585	586	587	588	592	593	594	622	623	626	627	655	656	669	726	727
N B S Formula No	1	2	3	46	50	60	83	84	78	88	88	80	80	120	121a	534	543	544
Dope Pigmentation ^b	G	G	G	G	G	G	G	G	G	Al	W	Al	W	Al	Al	Al	Al	Al
VOLATILES																		
Solvent																		
Cellosolve acetate																20 0	30 0	
Ethyl acetate	30 0	30 0	30 0													80 0	60 0	60 0
Butyl acetate	20 0	20 0	20 0	40 0	40 0	40 0	40 0	40 0	40 0	40 0	40 0	40 0	40 0	20 0	20 0	10 0	40 0	40 0
Methyl ethyl ketone	50 0	50 0	50 0	60 0	60 0	60 0	60 0	60 0	60 0	60 0	60 0	60 0	60 0	60 0		60 0		
Properties																		
Fabric char time moving-air test, sec	9	7	7	10	8	6	11	--	5	8	--	11	--	12	16	--	14	11
Burning characteristics ^c	A B	A B	A,B,E	A,B	B,E	A,B E	A,B,E	--	A,B,E	A,B,E	--	A,B,E	--	A,B,E	A,B E	--	B,E	B,E
Outdoor weathering																		
Initial tautness, mils	85	70	80	121	100	100	97	91	81	108	115	102	116	80	85	90	94	86
Tautness range ^d , mils	82/148	68/124	68/117	100/141	99/124	94/123	71/115	68/121	65/103	80/141	67/135	72/126	69/139	58/120	67/116	69/5	68/145	64/127
Time to first brittle failure, mo	15	--	4	4	4	4	2	12	2	10	19	--	8	6	3	4	--	--
Total exposure, mo	15	19	9	9	9	9	7	16	7	20	11	11	11	7	7	17	18	18
Condition of panel ^e		C		B,D				C				C,D	C,D	D	D		A,D	A,D

a Figures in table are in percent by weight of nonvolatiles and volatiles, respectively. The solutions were made up to contain 25 percent nonvolatiles. All fabrics were coated with 10 percent by weight of a mixture of three parts boric acid and seven parts borax before doping.

b Code for pigmentation

Al = aluminum
B = blue-gray
G = gray
W = white

c Code for burning characteristics

A = afterglow
B = blistering
E = self-extinguishing

d S = slack

e Code for condition of outdoor weathering panels

A = exposure test continuing
B = poor adhesion of top coat to dope substrate
C = erosion of top coat
D = tautness poor in warm weather
E = fine cracking of top coat
F = experimental hot-application dope substrate
G = poor adhesion of dope to fabric

f Pigment content included in film base figure

TABLE V - CHLORINATED NEOPRENE FIRE-RETARDANT COATINGS TESTED IN WASHINGTON

N B S Panel No	628	629	630	631	672	673	698	728	729
N B S Formula No	100	100	97	97	536	252	250	545	546
Dope Pigmentation ^b	A1	W	A1	W	A1	A1	A1	A1	A1
Composition ^a	NONVOLATILES								
Film base									
Parlon R	26 0	26 0	26 0	26 0	16 0	30 0	30 0	25 8	25 8
Amercoat 1138						40 0 ^f			
Plasticizer									
Rezyl 36-5	26 0	26 0	26 0	26 0	60 0	15 0	15 0	13 9	13 9
Diphenyl phthalate	4 0	4 0	4 0	4 0		7 5	7 5		
Dibutyl phthalate			4 0	4 0	3 0			10 0	10 0
Tricresyl phosphate						7 5			
Dow No 6							7 5		
Aroclor 1254					3 0			10 0	10 0
Flexol 3GH	4 0	4 0							
Pigment									
Calcium carbonate			20 0	20 0	9 0		20 0	10 0	10 0
Magnesium ammonium phosphate	40 0	40 0							
Antimony oxide			20 0	20 0	9 0		20 0	30 0	30 0
Stabilizer									
Urea								0 3	
Basic lead carbonate									0 3

TABLE V (Continued)

N B S Panel No	628	629	630	631	672	673	698	728	729
N B S Formula No	100	100	97	97	536	252	250	545	546
Dope Pigmentation ^b	A1	W	A1	W	A1	A1	A1	A1	A1

VOLATILES

Solvent									
Methyl ethyl ketone	34.0	34.0	34.0	34.0				100	100
Toluene	33.0	33.0	33.0	33.0					
Trichloroethylene	33.0	33.0	33.0	33.0					
Diacetone alcohol					50.0		50.0		
Union solvent No. 8					50.0		50.0		
Aromatic petroleum naphtha, Type I						60.0			
Xylene						20.0			
Butyl acetate						20.0			

Properties

Fabric char time, moving-air test, sec	14	14	23	23	--	9	12	10	12
Burning characteristics ^c	A,B,E	A,B,E	A,B,E	A,B,E	--	A,B,E	A,B,E	B,E	A,B,E

Outdoor weathering

Initial tautness, mils	86	90	94	93	71	68	87	97	92
Tautness range ^d , mils	74/121	74/116	74/121	58/104	61/102	65/109	59/115	67/135	64/133
Time to first brittle failure, mo.	--	8	--	10	2	2	13	9	--
Total exposure, mo	11	11	11	11	5	5	16	18	18
Condition of panel ^e	C,E	C	C,E	C,E	F	F	G	A,E	A,E

a Figures in table are in percent by weight of nonvolatiles and volatiles, respectively. The solutions were made up to contain 25 percent nonvolatiles. All fabrics were coated with 10 percent by weight of a mixture of three parts boric acid and seven parts borax before doping.

b. Code for pigmentation

A1 = aluminum
B = blue-gray
G = gray
W = white

c Code for burning characteristics

A = afterglow
B = blistering
E = self-extinguishing

d S = slack

e Code for condition of outdoor weathering panels

A = exposure test continuing
B = poor adhesion of top coat
C = erosion of top coat
D = tautness poor in warm weather
E = fine cracking of top coat
F = experimental hot-application dope substrate
G = poor adhesion of dope to fabric

f Pigment content included in film base figure

TABLE VI - CHLORINATED POLYISOPRENE AND MISCELLANEOUS FIRE RETARDANT COATINGS TESTED IN WASHINGTON

	N.B.S. Panel No.	670	699	700	701	724	725	720	721	708	709	722	723
	N.B.S. Formula No.	535	466	467	540	451	451	h	h	Pyropex		Skylac	
	Dope Pigmentation ^b	A1	A1	A1	A1	W	G	W	W	W	W	B	B
Composition ^a													
Film base													
Parlon X		26 0	30 0	30 0	30 0	30 0	30 0						
Amercoat 1138		40 0											
Plasticizer													
Rezyl 36-5		14 0	14 0	14 0	14 0	14 0	14 0						
Dibutyl phthalate		10 0	16 0				8 0	8 0					
Aroclor 1254		10 0		16 0									
Flexol DOP					16 0								
Cloradin 42							8 0	8 0					
Pigment													
Zinc borate							40 0	40 0					
Calcium carbonate			20 0	20 0	20 0								
Antimony oxide			20 0	20 0	20 0								

TABLE VI (Continued)

	N B S Panel No	670	699	700	701	724	725	720	721	708	709	722	723
	N B S Formula No	535	466	467	540	451	451	h	h	Pyropex		Skylac	
	Dope Pigmentation ^b	A1	A1	A1	A1	W	G	W	W	W	W	B	B
VOLATILES													
Solvent													
Methyl ethyl ketone			100	100	100	100	100						
Tollac		60 0											
Xylene		40 0											
Properties													
Fabric char time, moving-air test, sec	--	--	--	--	12	9	5 ^h	5	5	5	5	5 ^h	5
Burning characteristics ^c	--	--	--	--	A,B,E	B,E							
Outdoor weathering													
Initial tautness, mils	113	97	84	93	109	110	74	81	59	59	80	85	
Tautness range ^d , mils	74/139	66/S	66/108	70/S	67/141	57/143	71/103	70/100	53/S	53/S	65/116	60/120	
Time to first brittle failure, mo	4	14	2	13	4	9	7	9	--	--	10	--	
Total exposure, mo	18	21	15	21	11	11	11	11	19	19	19	19	
Condition of panel ^e	D	A		A	B,D	B D		G	A	A	A,D	A,D	

a Figures in table are in percent by weight of nonvolatiles and volatiles, respectively. The solutions were made up to contain 25 percent nonvolatiles. All fabrics were coated with 10 percent by weight of a mixture of three parts boric acid and seven parts borax before doping, except where otherwise noted (see note g).

b Code for pigmentation

A1 = aluminum

B = blue-gray

G = gray

W = white

c Code for burning characteristics

A = afterglow

B = blistering

E = self-extinguishing

d S = slack

e Code for condition of outdoor weathering panels

A = exposure test continuing

B = poor adhesion of top coat

C = erosion of top coat

D = tautness poor in warm weather

E = fine cracking of top coat

F = experimental hot-application dope substrate

G = poor adhesion of dope to fabric

f Pigment content included in film base figure

g No boric acid/borax mixture on fabric

h No fire retardant coating.