FIRE-RETARDING COATINGS

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FIRE-RETARDING COATINGS

The present emergency has stimulated considerable interest in fire-protective treatments for wood. Wood is replacing steel for construction purposes in many new structures, and there is some anxiety concerning potential fire danger not only from normal sources but also from incendiary bombs. There is likewise more than usual interest in fire protection for wood structures already built.

Such protection can be provided by two types of treatments, impregnation with fire-retarding chemicals and surface coverings of fire-retarding coatings. Impregnated wood has been in use to a limited extent for many years and is an established commodity. Fire-retarding coatings, on the other hand, have not received much recognition, partly because of extravagant claims made by manufacturers of preparations possessing very little fire-retarding effectiveness and partly because of a lack of standards for minimum requirements. The Forest Products Laboratory has been interested for some time in the possibilities of fire-retarding coatings to check the spread of fires of small size and has made many fire tests of the effectiveness of such materials. This mimeograph outlines what can be expected in the way of protection from known fire-retarding coating formulations and contains information on the properties of such preparations.

At the outset, it should be remembered that wood exposed to fire temperatures will char, regardless of whether it is coated or not. The best that can be expected of a paint-type coating is to stop or retard the spread of flame along the surface. The degree to which flame spread is checked is dependent on the type of coating and its thickness and on the fire conditions present, such as design of the painted structure, size of the fire, duration of exposure, presence of draft, and temperature of the air. After fires develop to large size and burn rapidly or for considerable periods, they may overcome the resistance of fire-retarding coatings; but small fires can often be kept small or even caused to die out by suitable coatings.

Various tests have been devised to measure the effectiveness of fire-retarding coatings in checking flame spread under varying conditions of severity, but insufficient work has as yet been done to determine how effective such coatings are in actual use. This Laboratory has used the fire-tube test for much of its fire-testing work. In this test, a specimen measuring 40 inches by 3/4 inch by 3/8 inch is suspended vertically within a sheet-iron cylinder 3 inches in diameter, and a Bunsen burner with an 11-inch flame is placed beneath the specimen. The percentage loss in weight of the specimen and the temperature at the top of the fire tube are recorded at intervals of 30 seconds. At the end of 4 minutes the burner is removed, but percentage losses in weight and temperatures are recorded until burning ceases. In this test, untreated or uncoated wood loses about [illegible] percent of the weight after [illegible] minutes' exposure to the flame and [illegible] percent or more of the weight when blazing and glowing cease. In evaluating the degree of protection afforded by coatings, a loss of weight of less than 30 percent after 3 minutes' exposure is considered to indicate protection against mild fires, whereas a final loss of weight of less than 25 percent is considered to indicate protection against fires of moderate severity.

Another method of test being used is a modification of one developed by Ragnar Schlyter of the Swedish Government Testing Institute. In this method two plywood panels, 12 inches by 31 inches by 3/8 inch, are stood in a vertical position, parallel to each other and 2 inches apart, with the bottom of one panel 4 inches above that of the other. A wing-top Bunson burner flame is placed between the two panels and readings are taken of the progress of the flame spread with time. With unprotected wood, the flame will spread over the surfaces and destroy the specimens but, with effective fire-retarding coatings on the exposed surfaces, the flame ceases to spread as soon as the gas burner is removed.

In recent months a flame with more intense ignition properties has been used in the Schlyter-type test, and a limited number of tests on a larger scale have been made using incendiary bombs.

The Forest Products Laboratory has used the foregoing methods to study the performance of a large number of formulations in its efforts to find good fire retardants and determine their ability to provide good protection with a reasonable number of coats. In addition to fire-retarding effectiveness, other properties must be taken into consideration. Among these are reasonable permanence of both fire-retarding effectiveness and adherence of coating to the wood, resistance to comparatively high relative humidity, and, to some extent, the appearance of the coating. Resistance to weather is also desirable but usually absent.

On the basis of the examination of numerous coatings, this Laboratory has drawn the following conclusions regarding certain types of preparations tested.

Borax-Linseed Oil Fire-retardant Paints

Linseed oil base paints of good fire-retarding effectiveness can be made by replacing an appreciable portion of the pigment with finely ground borax. The percentage of borax required varies with the kind of pigment. The following table gives four examples of single pigment formulations, heavy coats of which were found to provide sufficient protection to keep the final loss in weight in the fire-tube test under 25 percent; 3 or 4 thick coats or approximately 1 gallon per 125 square feet are required.

Coatings of ordinary thickness undoubtedly would provide protection against comparatively weak fires, but for highest resistance thick coatings must be used. This type of paint is good for interior use from the standpoints of appearance, moderate moisture resistance, and permanence. It will not retain its effectiveness, however, after repeated exposure to rain and for that reason it is not suitable for outdoor use.

Pigment	Formula A	Formula B	Formula C	Formula D
	Percent by weight			
White lead[1]	41.0			
Titanium-calcium		30.0		
Lithopone			24.0	
Zinc oxide				21.0
Borax	32.0	35.0	39.5	50.0
Raw linseed oil	22.8	30.8	32.3	24.8
Turpentine	3.6	3.6	3.6	3.6
Japan drier	.6	.6	.6	.6

[1]Basic carbonate white lead.

Water Solutions of Fire-retarding Chemicals

Sodium silicate

Sodium silicate is an excellent fire retardant when freshly applied. Very good protection is furnished for a limited time by three coats of the commercial viscous syrup (water glass) diluted with a minimum quantity of water necessary to give a liquid of suitable brushing consistency. The addition of a small quantity of liquid soap or other wetting agent improves the wetting properties of the silicate solution. Moderate protection is furnished by 2 coats.

Sodium silicate is available in a number of grades based on the soda-silica ratio. The grades with a high silica ratio are preferred for fire-retarding coatings. The fire protection given by sodium silicate is largely due to its property of intumescence; that is, the coating swells when exposed to heat to a frothy mass that hardens and thus insulates the wood against heat.

The serious weakness of both the straight sodium silicate coatings and the silicate coatings containing zinc oxide, titanox, and iron oxide, as so far revealed in tests is their instability. A series of tests on fire-tube specimens coated with various silicate formulations and exposed to different relative humidity conditions revealed the following: Exposure to relative humidities in excess of 65 percent causes a serious decrease in effectiveness after only 1 month and higher humidities cause the high silica-ratio coatings to check, crack, and peel. Under similar conditions, low silica-ratio compositions become soft and may even drip. The property of intumescense is absent in silicate coatings exposed to high relative humidities. For dry situations, the effectiveness continues over a much longer period, being retained under favorable conditions for more than a year; but it is seldom that use conditions are such that high humidities are always avoided. The explanation given for the decrease in effectiveness with time, especially under high moisture conditions, is that the carbon dioxide of the air in the presence of moisture reacts with the sodium silicate to convert it to sodium carbonate and silica. These compounds do not have the fire-retarding effectiveness of sodium silicate.

The inclusion of pigments in the silicate formulations improves the appearance and brushing properties of the preparations. The British[1] recommend such a pigmented sodium silicate preparation for the protection of wood in attics against incendiary bomb fires. The British formula is:

Sodium silicate solution (Sp. Gr. 1.41 to 1.42 Silica-soda ratio 3.2 to 3.4)	- 112 lbs.
Kaolin	- 150 lbs.
Water	- 100 lbs.

Three to 4 coats of this preparation are required to give good protection. One gallon will cover approximately 100 square feet (4 coats).

Ammonium phosphate and other fire-retarding chemicals

Strong solutions (25 percent or higher) of such good fire-retarding chemicals as monoammonium phosphate, diammonium phosphate, a mixture of ammonium sulfate and monoammonium phosphate, and a high-solubility mixture of borax and boric acid have fire-retarding properties when applied to wood. These solutions, however, are not syrupy, as is water glass, and the quantity of dry chemical that can be applied per coat is so small that an unpractical number of coats is necessary to build up the coating weight sufficiently to give protection comparable to that obtained with 3 to 4 coats of borax-linseed oil paint or 2 to 3 coats of sodium silicate. Nevertheless, 3 coats of saturated solutions of good fire-retarding chemicals do have definite, although moderate, fire-retarding effectiveness.

Alginate Preparations

A new type of fire-retarding coating developed at the Forest Products Laboratory recently consists of finely ground fire-retardant chemical dissolved and suspended in an aqueous sodium or ammonium alginate gel. Tests have shown this type of preparation to possess excellent effectiveness. The alginates, manufactured from an extractive of kelp, are good thickening agents. One- to 2-percent aqueous solutions are very viscous gels. On a basis of percentage by weight, concentrations of ammonium alginate gels are more viscous than sodium alginate gels, a 1.6-percent ammonium alginate gel having approximately the same viscosity as a 2-percent sodium alginate gel.

[1] B.S./Air Raid Precaution Series 39, February 1940.

The cost of the ammonium compound is, however, proportionately higher. No chemical reaction occurs between these alginates and ammonium fire-retardant salts. Borax causes the gel to set, but boric acid and mixtures of boric acid and borax are compatible with the gel. The best formulations thus far prepared, considered from all angles, contain monoammonium phosphate, but fairly satisfactory preparations can be made from a mixture of borax and boric acid. The use of the alginate makes it possible to incorporate in the preparation a quantity of fire-retardant considerably in excess of that required to saturate the solution. The undissolved portion is held in suspension. Pigments may also be introduced into such preparations.

Three methods have been used for making these preparations. These methods, using typical ammonium phosphate formulas, are described below:

Method I

	Parts by weight
Monoammonium phosphate	50
Two percent sodium alginate gel	50

1. Prepare the alginate gel by adding 2 parts by weight of sodium alginate to 98 parts of hot water. Stir until a uniform gel is obtained.

2. Grind in a pebble mill equal parts by weight of monoammonium phosphate and alginate gel. A grinding period of 12 to 24 hours is sufficient.

Method II

	Parts by weight
Monoammonium phosphate	54
China clay	6
Two percent sodium alginate gel	40

1. Prepare alginate gel.

2. Grind monoammonium phosphate and china clay together in a pebble mill until the material is reduced to approximately 200 mesh.

3. Mix in a blade mixer 60 parts by weight of the phosphate-clay powder and 40 parts by weight of the alginate gel until a uniform preparation is obtained.

The main purpose of the china clay is to facilitate grinding and prevent lumping of the ammonium phosphate in storage. Inclusion of the clay also improves the brushing properties of the paint and produces a coating somewhat finer grained than a pure ammonium phosphate coating.

Method III

	Parts by weight
Monoammonium phosphate	88.5
China clay	10.0
Dry sodium alginate	1.5

1. Grind sodium alginate to 325 mesh.

2. Grind the prescribed quantities of monoammonium phosphate, china clay, and powdered sodium alginate until the particle size of the ammonium phosphate is approximately 200 mesh.

The above procedure will produce a powder similar to calcimine or dry casein paint. To prepare it for use, add 4 to 5 parts by weight of water to 6 parts by weight of the powder and stir until the powder is mixed thoroughly with the water. Allow to stand for at least an hour and stir again until a smooth mixture is obtained.

The same technique can be used to prepare such borax-boric acid formulations as the following:

	Parts by weight	
	Formula 1	Formula 2
Borax ($Na_2B_4O_7.10H_2O$)	25	22.5
Boric acid	25	22.5
Two percent alginate gel	50	50
China clay	--	5

The properties of preparations with a monoammonium phosphate base may be summarized as follows:

The paints have good brushing properties, producing smooth coats. The solids remain in suspension during application and, although they settle after standing for some time, can be returned to suspension very readily by stirring. The preparations are stable for an indefinite period so far as is known. Solutions of monoammonium phosphate are corrosive to many metals. If the paints are packaged in uncoated metal containers or are to be applied by spray-gun, the addition of the corrosion inhibitor, sodium dichromate, is desirable. Two to 3 percent of the ammonium phosphate content is sufficient. The body of the preparations is such that sufficient dry fire-retardant can be applied in 2 or 3 coats to give sufficient protection to keep the final loss in weight, as measured by the fire-tube, under 25 percent. Heavy coats of these preparations stopped the spread of fire in the severe Schlyter test and in tests involving the high temperatures developed by different types of incendiary bombs. The coverage per gallon is approximately [illegible] square feet for 3 coats.

M12[illegible]

The coatings on drying are flat white, resembling casein paints or calcimine. Their adherence to wood is good. Relative humidities up to 91 percent have no effect upon monoammonium phosphate, but at humidities higher than this, the phosphate takes on water. Under ordinary conditions, the fire-retarding effectiveness should be retained indefinitely.

The borate coatings do not have so good fire-retarding effectiveness as the phosphate coatings on an equal weight basis so that it is necessary to use them in slightly heavier coats to obtain the same effectiveness. The borate coatings, especially those with a high percentage of boric acid, withstand high relative humidities better than do the ammonium phosphate coatings.

The formulations given are illustrative of moderately heavy-bodied preparations. If still heavier-bodied paints suitable for trowelling or coarse spray are desired, they can be prepared by increasing the percentage of solids. If thinner mixtures are desired, they can be made by decreasing the percentage of solids or using a less viscous alginate gel. Likewise, if colored paints are desired, they can be made by substituting suitable pigments for the china clay.

Whitewash

Whitewash is generally regarded as having fire-retarding properties. Significant effectiveness cannot, however, be obtained with a 1-coat application. The following two whitewash formulations that were tested gave moderate protection when three coats were applied:

National Fire Protection Handbook (8th edition) formula - page 424.

> Mix together 10 parts slaked lime, 1 part of Portland cement, and sufficient salt water to give a mixture of rather stiff consistency.

Formula 9 (Bulletin No. 304-D - National Lime Association)

> Casein - 5 lbs.
> Borax 3 lbs.
> Lime paste 8 gals. (Approximately 8 gallons of stiff lime paste are produced by slaking 25 pounds of quicklime with 10 gallons of water, or by soaking 50 pounds of hydrated lime in 6 gallons of water.)

> Directions as given by the association: "Soak the casein in 4 gallons of hot water until thoroughly softened (about 2 hours). Dissolve the borax in 2 gallons of water and add this solution to the casein. When both are cold, slowly add the borax-casein solution to the lime paste, stirring constantly and vigorously. Thin to desired consistency. Do not prepare a larger quantity of this formula than can be used in 1 day, as it may deteriorate."

So far as is known, no detailed study has been made of the effect of moisture and time on the retention of the fire-retarding effectiveness of whitewash.

Casein Paints

Casein paints possess moderate fire-retarding effectiveness if at least 3 coats are applied. The effectiveness is increased if borax is introduced into the formula.

It is to be noted that the degree of fire protection provided by 3 coats of whitewash or casein paint is by no means comparable with that provided by 3 coats of borax-linseed oil paint, sodium silicate, or the phosphate-alginate preparations.

Synthetic-resin Formulations

Preparations of urea-formaldehyde resins containing ammonium phosphate provide good protection. This type of resin also intumesces when exposed to heat, and the frothy mass chars to form a protective coating of combustion resistant carbon. The formulations that have been tested tend toward brittleness and serious checking which, in some cases, caused the coating to chip or scale from the wood. While this type of coating is still in the experimental stage, the initial work done holds sufficient promise to indicate that additional research may remove the objectionable features.

Loose-texture Compositions

Certain compositions applied by spray gun in a thickness of 1/2 to 1 inch are in use for heat insulation purposes. These coatings contain such materials as mineral wool, asbestos, or shredded cellulosic materials treated with fire-retarding chemicals, with only sufficient binder to hold the mass loosely together. Such coatings have good fire-retarding properties and are useful where a combination heat-insulating, fire-retarding preparation is desired. Coatings of such compositions thinner than those necessary for heat insulation purposes would possess sufficient fire retardance to be useful for fire protection only. The soft, spongy nature of these coatings would limit their use for fire protection to such applications as ceilings and attics, or other places where resistance to wear is not required. The adherence of certain types of this material to laboratory-size specimens of wood was not good, especially under fire conditions, but how serious this defect would be on large installations under fire conditions is not known.