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MAKING WOOD FIRE RETARDANT

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MAKING WOOD FIRE RETARDANT[1]

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The report of your committee is of interest and value in showing the problem the railroads have in protecting their bridges and trestles from fire and in indicating the measures that are currently being used or contemplated in the protection of such structures. Your chairman suggested that it would be of interest to the members of the committee if I would review briefly fire-retardant treatments for wood in a broad way, indicating their fields of usefulness or potential use. He has further indicated an interest in having me do a bit of crystal ball gazing as to possible future developments in new materials and new approaches that hold promise. I make no claims, however, as a prophet.

Limitations in Fire-Retardant Treatments

The railroads were early users of preservatively treated wood and have taken advantage of its economies rather fully. The advantages of the use of woods effectively treated against decay and insects have been demonstrated and the economy of treatment can be rather closely calculated in actual savings. Consistent with this combination of pioneering spirit and sound business principles it is but natural to expect that the railroads would have a substantial interest in the better protection of wood in their properties against fire and in ways and means of accomplishing this desirable objective. However, the advantages of treating wood with fire-retardant chemicals have not been and probably cannot be so clearly demonstrated as they have for preservatively treated wood. In fact, it can be safely said that the protection

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[1] Presented before the American Railway Engineering Association Committee 6, Chicago, Ill., March 16, 1950.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

of wood against fire and its deterioration under high temperature cannot be so successfully accomplished as can the protection of wood against decay and insects.

In discussing fire-retardant treatments for wood it should be kept in mind that there are two distinct aspects of fire performance. One is fire spread, and relates to the rapidity or freedom with which fire spreads over a surface that has been ignited. The other may be termed fire resistance and relates to the tendency of fire to penetrate a member or structure. The manner and extent to which the spread of fire is retarded and in which penetration of fire is resisted are often closely related. In structures, such as bridges and houses, both phases of fire performance are largely dependent upon the size, form, and arrangement of the materials of the structure and the character of the igniting fire, as well as the specific properties of the construction material itself.

Wood chars when exposed to fire or fire temperatures, irrespective of whether it has had a fire-retardant treatment or application. The rate of charring or destruction and the transmission of heat through wood may be improved slightly by fire-retardant treatments but the most significant benefit comes in reducing or delaying the spread of fire. Fire-retardant treatments and applications can only be expected to retard the burning and spread of fire to the point where the wood will not continue to burn when the ignition source is removed or exhausted.

Two general methods are available for improving the performance of wood under fire conditions. One method consists of an impregnation treatment that deposits chemicals within the wood. The other is the application of coatings or layers of other noncombustible materials over the surface of the wood.

Impregnation Processes

It has long been known that the property of dry wood to burn freely can be substantially changed by its impregnation with fire-retardant chemicals. Many water-soluble chemicals exhibit fire-retarding properties (7)[3] when present in wood but because of cost limitations or various objectionable characteristics, comparatively few are considered practical. Among the most commonly used chemicals are monobasic and dibasic ammonium phosphates, ammonium sulphate, borax, boric acid and zinc chloride. These are

[3] Numbers in parentheses refer to Literature Cited at the end of this report.

usually combined in various proportions in treating formulas. The chemicals in water solution are usually injected into wood by full-cell pressure processes to obtain predetermined absorptions. Dipping, soaking, and other superficial treatments do not usually give either sufficient absorptions or penetrations to yield significant fire-retardant effects.

More than 50 years ago wood was being treated commercially by pressure impregnation. The first important demand for fire-retardant treated wood in this country apparently came from the U. S. Navy for use in ship construction. Shortly thereafter the city of New York gave impetus to the embryo industry by adopting a revised building code, which required that wood, used in the construction of buildings over 150 feet in height, must be treated to make it so-called "fireproof." In spite of the fact that there has been much further investigative and development work done since that time the industry has not continued to grow or expand significantly or in proportion to the need for protection of wood against fire. The largest production of fire-retardant treated wood occurred during World War II. Its principal uses were for the construction of dirigible hangars and for shoring aboard ships. In 1943 65 million board feet were treated by pressure processes but by 1946 the production had dropped to less than 5 million. In 1948 it had again increased to about 9-1/2 million board feet (3).

The slowness with which fire-retardant treated wood has been accepted and used is due to several factors. First it has been difficult to demonstrate its performance under actual fire conditions and to assess the values and advantages of fire-retardant treatments in accepted terms of savings. When trestle timbers are treated with a wood preservative and put into service they are immediately placed under conditions that favor decay so it is possible to observe the effectiveness of the treatment in retarding decay. On the other hand, when wood is treated with a fire-retardant and placed in service it is not exposed immediately to fire and it may never be. Thus, there is much less opportunity to observe its ability to withstand fire in service. Relatively large amounts of fire-retardants, based on pounds of chemical per unit volume of wood, must be used to get significant fire-retardant effects. The higher concentrations of chemicals used in fire-retarding treatments are more apt to cause problems than the lower concentrations used in preservative treatments. For example, there are possibilities of reduction in strength of the wood, increased hygroscopicity, interference with painting and other subsequent processes or operations, and corrosion of metal fastenings. However, the chief drawbacks to a more extensive use of fire-retardant wood apparently are: (1) Insufficient recognition of the value of fire-retardant treated wood by engineers, architects and builders; (2) lack of generally accepted standards and specifications; and (3) cost of treatment that is not offset by compensating savings in insurance and amortization rates.

Lumber and timbers are the principal forms in which wood has been pressure treated with fire-retardants. The treated lumber has gone largely into interior trim and doors where building codes or regulations require such treatment. Treated timbers have found specialized uses where fire hazards are considered critical or where possible fire damage may be large. Since the fire-retardant chemicals are water soluble and hence more or less leachable, the usefulness of treated material under exterior exposure and periodically wet conditions has not been well established.

Some progress has been made in the development and adoption of standards and specifications for fire-retardant wood. In bulletin 442 (Dec. 1943) of the A.R.E.A., Committee 6 presented a report on "Fire-Retardant Wood for Railway Buildings" in which a specification was proposed for the treatment of timbers and lumber (1). Other efforts have resulted in the proposal and in some cases the adoption of other specifications, classifications, and standards by the A.S.T.M. (2), U. S. Navy Bureau of Yards and Docks (8) and Bureau of Ships (9), Underwriters Laboratories, U. S. Forest Products Laboratory, and others. While various test procedures and requirements have been proposed and in some cases put in effect, there is still lacking and much need for a better correlation and understanding of the significance of such tests and requirements in terms of performance under actual fire conditions.

Some preservatives add fire-retardant properties to wood but not to a significant degree unless the retentions are substantially in excess of those normally used for protection against decay and insects. Borax, boric acid, zinc chloride, and most arsenic compounds are of this type. When used alone or preferably in combination with other effective fire retardant chemicals they have formed the base for most current treatments of wood in which combination decay and fire-retardant properties are sought. Several such combination treatments are available commercially or have been patented. Although further evaluation of these combined treatments are needed, they appear to offer the best hope at the present time of substantially reducing by treatment the fire hazard in wood bridges and similar structures.

One of the more important questions upon which further information is needed for such treatments is the permanence of the fire-retarding qualities. It has generally been assumed that, when exposed to the weather, the fire-retardant effectiveness of the treated wood gradually decreases through the leaching of the chemicals. However, service data are not available to indicate performance from the fire protection standpoint and only insufficient data are available on leaching rates, from which estimates might be based.

The results of some tests have indicated that the rate and amount of leaching in contact with water can be materially and significantly reduced by applying surface coatings or a sealer to the treated wood. The California Division of Highways reports (5) that a sand-cement-paint composition was highly effective in preventing the leaching of zinc chloride and chromated zinc chloride and in preserving the fire-retardant properties but somewhat less effective for certain other preservatives. Bescher, Henry, and Dreher also report reduced leaching of chromated zinc chloride compounds when the treated wood was given a second shallow impregnation with a "fire-retardant, water-repellent sealer" (4). There appears, therefore, to be substantial evidence that the fire-retardant properties of salt-treated timbers can be substantially preserved under rather severe service conditions.

Fire-Retardant Coatings

Many coating materials provide fire-retarding effects in varying degree to wood (10). As in the case of impregnation treatments the degree of protection provided by coatings is related to the inherent properties of the product, the amount and thoroughness of application, and the severity of the fire exposure.

Fire-retardant coatings have received even less recognition than impregnation treatments because of the lack of standards enabling the purchaser to know whether he was purchasing an effective and durable product or one of little or no merit. Some progress has, however, been made in getting general agreement upon standard methods for evaluating the effectiveness of fire-retardant coatings. Some of the proposed methods are described in Research Bulletin No. 32, "Fire Hazard Classification of Building Materials," by Underwriters Laboratories, Inc.; Federal Specification SS-A-118, Acoustical Units; and Forest Products Laboratory Report 1443, "Fire-Test Methods Used in Research at the Forest Products Laboratory."

Interior-Type Fire-Retardant Coatings

Most fire-retardant coating preparations that have been developed are of value primarily for interior use and are not durable under exterior exposures. In general these coatings can be grouped into the following broad classifications:

Solutions of water-soluble chemicals.--Plain water solutions of effective fire-retardant chemicals, such as the ammonium phosphates, mixtures of ammonium sulphate and monoammonium phosphate, borax and boric acid, have been offered as fire-retardant coatings. While strong solutions of these chemicals possess inherently good fire-retarding properties most woods will absorb only a relatively small quantity of solution with a surface application and the degree of protection secured by such treatment is low. Only by several applications of strong solutions of these chemicals can even a moderate degree of fire-retarding effectiveness be obtained.

Solutions of sodium silicate either alone or in combination with inert materials have formed the basis of a number of proprietary fire-retardant paints. While fresh sodium silicate coatings are quite effective against fire spread, they lose their effectiveness with time and especially under damp conditions.

Suspensions of chemicals in water solutions.--A new type of fire-retardant coating developed at the U. S. Forest Products Laboratory (10) consists essentially of an aqueous gel of sodium or diammonium alginate and fire-retardant chemicals. The use of the alginate makes it possible to incorporate into the coating mixture a quantity of fire-retardant chemical considerably in excess of that required to saturate the solution. The ammonium fire-retardant salts and mixtures of borax and boric acid are compatible with the gel. The consistency of the preparation is such that sufficient material can be applied in 2 or 3 coats to provide good fire-retarding effects.

Coatings similar to the borate alginate preparations may be made by using methyl cellulose as the thickening agent or vehicle. It may be used with borax, boric acid, or mixtures of borax and boric acid but not with ammonium phosphate because the latter chemical causes coagulation.

Linseed oil base paints.--Linseed oil paints of good fire-retarding effectiveness have been prepared at the Forest Products Laboratory by replacing a substantial portion of the pigment with finely ground borax (10). Heavy coatings of this type of paint are required to afford good degrees of protection against the spread of flame. Commercial paints of this type are available.

Synthetic resin coatings.--Certain types of synthetic resins, such as phenol formaldehyde, urea formaldehyde, ethylidene urea-formaldehyde, and dicyandiamide in combination with ammonium phosphate, provide good protection against flame spread. As with a number of other coatings, their effectiveness is due mainly to the swelling of the resin to a frothy mass and hardening when exposed to heat and its protection against combustion by the ammonium phosphate present. Some of the more effective commercial fire-retardant paints are of this type.

Casein and whitewash paints.--Casein and whitewash paints are generally regarded as having some fire-retarding properties especially when applied in heavy coats. The degree of protection is increased when borax is introduced in the formula but even then three coats of such preparations are not of the same order of effectiveness as a similar number of coats of the better coatings of other types previously described.

Exterior Type Fire-Retardant Coatings

One inherent major weakness of all the preparations described so far is their inability to retain effectiveness under exposure to water, due to the removal of the water-soluble fire retardants. Some will offer slightly more resistance to moisture than others but none of them is considered satisfactory for exterior exposure.

So far as is known, no water-insoluble compound has been found that is equal in fire-retarding effectiveness to such water-soluble compounds as ammonium phosphate, borax, and sodium silicate. Some progress, however, is being made in the formulation of coatings that are durable under exterior exposure and provide some protection against flame spread. Compounds of low water solubility that have fire-retardant properties are zinc borate, chlorinated paraffin, and chlorinated rubber.

In recent years a number of proprietary paints have appeared on the market with chlorinated paraffin as the base. These paints, while possessing moderate fire-retarding properties, do not give a performance equal to that of the better interior paints. A limited amount of testing at the Forest Products Laboratory has shown that a zinc-borate-linseed-oil coating has moderate fire-retarding effectiveness. While the development of these types of coatings for exterior use is encouraging, none of them has the degree of effectiveness that warrants placing a great deal of confidence in its ability to check fire spread under moderate to severe fire conditions.

Still other water-resistant types of materials with some fire-retardant properties have found occasional use or offer possibilities for the protection of wood. The current report of subcommittee 6 of A.R.E.A. Committee 7 indicates that several railroads have developed and have used rather extensively a special patented asphalt compound which gives promise of being especially fire resistant. Bituminous-base compounds, in which asbestos and other noncombustible, inert materials are included, seem to be promising as fire-retardant coatings for wood where appearance is not especially important.

Comparison of Impregnation and Coating Methods

Good fire-retardant effects in wood can be obtained with both impregnation and coating applications. For new construction and repair of existing structures, pressure impregnation with effective fire-retardant chemicals seems to offer the best possibility of obtaining lasting fire-retardant effects in wood structures. The quantities of material used and the initial costs involved are relatively high and the possibility of adversely affecting the strength and other properties of the wood are greater than with coatings. For existing structures surface applications offer the principal means of increasing their fire-retardant properties. Coatings are more temporary in effect but are renewable and have less possibility of affecting the wood adversely.

Possibilities for Improvement

There are other developments and research results that hold promise that fire-retardant treatments and coatings may ultimately be available that are satisfactory under exterior conditions. Significant developments have apparently been going on in the textile field in the production of washable fire-retardant fabrics (6) -- some of which may be applicable to wood. One of these is a urea-ammonium phosphate treatment in which the phosphate is believed to combine chemically with the cellulose of the fiber and thereby produce an insoluble compound that is fire-retardant.

Another new flame-retardant material is recommended by the Du Pont Company for the treatment of fabrics. The active flame-retarding constituents are reported to be salts of titanium and antimony, which react with the cellulose molecule changing it chemically but not physically. A similar result might be possible in the treatment of wood.

The metal ammonium phosphates, such as those of zinc and copper, are highly insoluble and have some fire-retardant effects but their potential use has not been fully explored.

In the rapidly expanding fields of resin and plastics development, and the modification of wood by chemical means lie a hope and possibility that better treatments and methods will be found for protecting and making wood more resistant to fire under various service conditions.

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SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products, and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

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