Weight of brick		2934.22	grams.
" " " at expiration of	1 week	2933.01	"
" " " " " "	2 weeks	2931.92	"
" " " " " "	3 "	2929.41	"
" " " " " "	4 "	2928.36	"
" " " " " "	5 "	2927.11	"
" " " " " "	6 "	2925.26	"
" " " " " "	7 "	2923.99	"
" " " " " "	8 "	2922.78	"
" " " " " "	9 "	2921.53	"
" " " " " "	10 "	2920.05	"

Whole brick immersed in boiling

	66° B.	sulphuric acid,	5	hours,	lost 0.08	per cent.
Same reweighed	" 60° B.	"	" 5	"	" 0.07	"
" "	" 50° B.	"	" 5	"	" 0.06	"
" "	" 47° B.	"	" 10	"	" 0.06	"

A piece from interior of brick immersed in boiling

	66° B.	sulphuric acid,	5	hours,	lost 0.15	per cent.
Same reweighed	" 50° B.	"	" 5	"	" 0.07	"
" "	" 50° B.	"	" 5	"	" 0.07	"
" "	" 47° B.	"	" 5	"	" 0.04	"

The edges still remained firm and sharp.

AUGUSTA, GA., January, 1895.

THE CONTRIBUTIONS OF CHEMISTRY TO THE METHODS OF PREVENTING AND EXTINGUISHING CONFLAGRATION.

BY THOMAS H. NORTON.

[*Continued from page 260.*]

At about this period several processes were introduced for the preservation of wood against decay; and claims were made that these were also valuable for rendering wood uninflammable.[1] These processes consisted essentially in the introduction into the pores of wood of metallic salts in solution, which combined with the nitrogenous matter present to form insoluble, non-fermentable compounds, and therefore removed sources of decay.

The chief methods employed were kyanizing or impregnation with mercuric chloride; burnettizing or impregnation with zinc chloride, using a three per cent. solution; boucherizing or injection of copper sulphate, using a one per cent. solution; and

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[1] Rymer-Jones, *Ecl. Eng. Mag.*, 33, 55, *1885*.

Beer's process of impregnating with borax. All of these methods give partial protection against combustion. With regard to their availability, expense and the evolution of poisonous vapors, when exposed to heat, militate against the use of corrosive sublimate. Copper sulphate, which can be absorbed to the extent of twenty kgms. per cubic meter of wood, is far inferior to many other salts as a fire protective; it colors the wood blue when exposed to atmospheric conditions, and in common with the mercuric salt, corrodes iron nails and bolts. Zinc chloride is more efficient, although in common with the two preceding salts it affects the tenacity and elasticity of wood. Borax seems to be more free from the objectionable features just enumerated, and more recent experiments have shown that its protective power is far superior to that of the copper or zinc salts, although inferior to that of sodium tungstate and ammoniacal salts.

The operation of impregnation in closed vessels by the use of a vacuum was devised by Samuel Bentham in 1794. It was successfully employed in France by Bréant and Bethel in 1830, and later in England for the purpose of kyanizing and burnettizing, as well as in connection with Payne's process.[1] In boucherizing, the copper sulphate solution is usually forced longitudinally from the butt to the trunk of a tree, just after it is felled, by an ingenious arrangement, involving the use of rubber caps and an elevated tank.[2]

In 1855 Salomon's process[3] of treatment with aluminum sulphate and calcium chloride, already described in connection with textile fabrics (p. 147) was applied to wood with some little success.

During this same year Maugham's process[3] of treating wood with a mixture of sodium phosphate and ammonium chloride, and Jackson's process, based on the combined use of zinc and ammonium salts, were both submitted to critical tests by Sir Frederick Abel,[3] who found neither as cheap or as efficient as sodium silicate. Abel reported at length to the English Board of Ordnance on the advantages offered by the use of sodium silicate, which he had recommended at an earlier date for use in the

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[1] Frémy, *Dict. de Chimie*, 10.

[2] Rymer-Jones, *Ecl. Eng. Mag.*, 33, 55, *1885*.

[3] Amer. Arch., loc. cit.

Crimea to render huts fireproof, and which was used in 1856 in camp huts at Aldershot for the Royal Engineers. By applying first a coat of silicate, then a coat of lime, and finally a second coat of silicate, Abel obtained a covering which resisted rain and showed no tendency to crack, shrink, or detach itself from the wood. The cost was one cent for five square feet. Later reports to the board made by Abel in 1870 and 1872 state that the efficiency of this protective was totally unaffected by time. In 1881 he also reports that sodium tungstate, already employed for fabrics, may be successfully used for wood, but that it offers no advantages over the sodium silicate process. It is absorbed by wood at the rate of fifty-six kgms. per cubic meter.

Patera, who studied the subject very extensively, recommended in 1871,[1] the use of magnesium borate for wood, finding it fully equal to sodium tungstate. He urged also very strongly the use of a mixture of one part strong ammonia and two parts gypsum, especially for roofing. Severe tests applied to this protective yielded such satisfactory results that the Austrian Minister of Finance recommended it for all government buildings where woodwork was exposed. Patera also advises the use of a coating of one part of ammonium sulphate, two parts gypsum, and three parts water. Another protective covering recommended by him is obtained by first coating wood twice with a saturated solution of three parts of alum and one part of copperas, and then applying a coat of clay mixed in copperas solution.

The successful use of sodium silicate led to the employment of various siliceous paints. One devised by Vilde and Schambeck[2] seems to have given good results. Its composition is pulverized glass twenty parts, pulverized porcelain twenty parts, pulverized stone twenty parts, quicklime ten parts, waterglass thirty parts. The thick syrup is applied with a brush and hardens quickly.

Ransome's siliceous paint,[3] introduced in 1871, consisted of a mixture of pure quartz and waterglass. After application it was coated with calcium chloride in order to render it perfectly insoluble. It has not been used of late years.

Another process involves the application of three coats of dilute

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[1] Loc. cit.

[2] Sc. Amer. Cyclop. of Receipts, p. 217.

[3] Amer. Arch., loc. cit.

waterglass, then of two coats of the same mixed with powdered glass; finally of one of thick waterglass.[1] Other preparations consist simply of more or less dilute waterglass, to which zinc oxide or ferric oxide has been added.[1] A most important modification of the simple silicate is that known as cyanite[1] and prepared by introducing aluminum hydroxide into waterglass, so that it is practically a basic aluminum silicate. It is a perfectly colorless liquid, and is applied with a brush. The cyanite is manufactured in England, and is employed in the English War Department by the Woolwich Arsenal, and by the Department of Railroad Inspection. That the product is variable would be indicated by Helbig's analysis[2] in 1888, when he found nothing present but waterglass.

Among other recent preparations is the ignifuge of Martin[3] of France (1880) used for impregnation, and composed of ammonium chloride fifteen parts, boric acid six parts, borax three parts, water 100 parts.[1] Another French preparation is that of Vendt and Herard,[4] 1885, also for impregnation. It consists of alum twelve parts, borax five parts, sodium thiosulphate three parts, potassium sulphate ten parts, water seventy parts. Somewhat peculiar are the following combinations, also used in France;[5] the first a solution of lead sulphate in neutral tartrates; the second an ammoniacal solution of a mixture of calcium acetate and calcium chloride. Brocher's preparation,[1] manufactured near Dresden, and used to some extent in Germany, is of unknown composition, and involves the use of three different liquids in the course of the application of the several coats. Objection has been made to it for this reason, as well as on account of the tendency of the solutions to solidify before use.

The general recognition of the utility of protective coatings led gradually to the extended use of asbestos. E. G. Erichsen,[6] of Copenhagen, in 1881, devised a new protective which consisted of a soluble silicate, metallic oxides, and lime, with ten to twenty

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[1] Boudin et Douny, Rapport.

[2] Archiv. f. Hygien. *1888*, 111.

[3] Troost, *Bull. de la Soc. d'Encouragement, 1880*, p. 384.

[4] *Génie civ.*, 6, 227.

[5] Frémy, *Dict. de Chimie*, 10.

[6] Amer. Arch., loc. cit.

per cent. of asbestos. It was applied with a trowel and formed a sort of fire-proof enamel which could be washed with water. Erichsen's preparation was extensively used in Europe, both on the continent and in England.

A further step forward was made in 1883, by C. J. Mountford,[1] of Birmingham, England, who brought out a preparation which consisted of asbestos ground and reground in water, sodium or potassium aluminate and waterglass. When liable to exposure to atmospheric agencies, it receives, further, a certain amount of oil driers and gummy matters and sometimes zinc oxide or barium sulphate. The United Asbestos Co., of England, has manufactured this product on a large scale for ten years, and it has been extensively employed, especially in England. Among other important edifices treated with it are the Parliament Buildings, the British Museum, South Kensington Museum, the Crystal Palace, various theaters, Royal palaces, etc. The cost of this material is eighteen cents per kilogram, and 100 kgms. suffice to cover, with three coats, a surface of fifty-four square meters, so that the cost per square meter is about thirty-three cents. It is a thick, gray product, easily applied, presents a satisfactory appearance when used alone on wood, and furnishes an excellent basis for the application of other paints.[2]

This represents probably the best type of protective coating, thus far devised. There are also two other English preparations of some repute, the nature of which is apparently analogous to the above; Bell's asbestos paint and Blane's fire-proof and water-proof paint;[2] while, in America, a single firm manufactures an asbestos paint.

Such is the history of the different methods of restricting the combustion of wood which have been presented during this century.

Let us next note the means devised to test comparatively the value of the diverse materials recommended.

TESTS FOR FIRE-PROOF PREPARATIONS.

In Versmann and Oppenheim's extended investigation on protectives for textiles,[3] the study was carried on in such a way as

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[1] Amer. Arch., loc. cit.

[2] Boudin et Donny, Rapport.

[3] Report to the British Association, *1859*.

effectually to eliminate one after another of the salts experimented upon until a small group was left, the efficiency of each member of which, under varying conditions, was satisfactorily demonstrated. The usefulness of impregnation by sodium tungstate is easily illustrated by exposure to a flame of strips of cotton cloth, some of which have been soaked in a tungstate solution, while others are in the ordinary condition. The merits of the different protectives for wood, as each one in turn came before the public, until a recent date were usually tested by application to a small hut or the like, within which an active fire of very combustible material was started. Such was the custom of Sir Frederick Abel[1] in his series of experiments already referred to.

Some thirty years ago Professor Pepper, of London, made comparative tests on four salts, strongly recommended for impregnating wood, and as a result placed them in the following order, the most efficient first:[2]

1. Ammonium phosphate.
2. Sodium tungstate.
3. Borax.
4. Alum.

The most thorough and valuable study in this field was made in 1887 by two Belgian chemists, Professors Boudin and Donny, of the University of Gand (Ghent) at the request of the Belgian Minister of Public Works.[3] They submitted to rigorous comparative tests all of the preparations then in vogue, some nineteen in number, and it is to be regretted that their exhaustive report has not been reproduced *in toto* in our journals.

P. Lochtin,[4] in 1893, introduced a simple and easy, if not perfectly exact method of testing, which he applied to about fifty chemical compounds, and brought out several interesting facts. We will consider first his more elementary methods, taking up later the more improved ones of Boudin and Donny.

Lochtin used strips of thick filter-paper fifty cm. long and five cm. broad, which are soaked in solutions of the substances submitted to experiment, usually a series for each substance of five-

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[1] Amer. Arch., loc. cit.

[2] Sc. Amer. Cyclop. of Receipts, p. 217.

[3] Rapport sur les procédés destinés á assurer l'ininflammabilité des bois, Gand, *1887*.

[4] *Dingler's poly. Jour.*, 290, 230.

tenths, one, two, three and five-tenths, five, ten, fifteen, and twenty per cent. solutions of the anhydrous compound. After being hung on lines and drying at ordinary temperature, the lower ends, where greater quantities accumulate, are clipped off. When insoluble precipitates are to be obtained in the paper, it is first soaked in a solution of the soluble salt, then dried, then soaked in a solution of the precipitating reagent, dried, washed, soaked for six to twelve hours in water, washed, and finally dried. The strips are then folded lengthwise, and while held horizontally, with the folds beneath, kindled at one end. Observation then shows whether the foreign substance hinders or helps combustion, and what is the minimal relative weight of a salt or the minimal strength of its solution, necessary to render the paper uninflammable.[1]

Experiment indicates that different substances, although in solutions of equal strength, are retained unequally by the paper; the amount retained increasing in proportion to the insolubility or ease of crystallization of a compound. Very soluble substances are absorbed in almost equal proportions. It is also worthy of note that apart from compounds which are practically storehouses of oxygen, as the chlorates, there are substances which distinctly favor combustion, the alkaline sulphates for example. As illustrations of Lochtin's method, a strip soaked in a twenty per cent. solution of sodium sulphate is kindled at one end. It is observed that it burns easily and readily to the end, as readily as if no foreign matter were present. Again, four strips of paper soaked in ammonium chloride solutions, *a* in a twenty per cent. solution, *b* in a five per cent. solution, *c* in a two per cent. solution, and *d* in a one per cent. solution, are in turn held in the flame. No propagation of flame is shown by *a*; *b* shows a small flame, which is extinguished quickly on removal from the source of heat; *c* yields a larger flame, which burns for about five cm. after removal; and *d* furnishes a still larger flame, which burns to the end. It is evident that the use of a two per cent. solution affords partial protection, and of a five per cent. solution, full protection against inflammability. I have found in personal experience an advantage in using for elementary tests the thin slips of pine wood about eight cm. long and one cm. wide, easily

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[1] *Dingler's Poly. Jour.*, 290, 230.

obtained from any tobacconist. These are preferable to Lochtin's strips, as they can be used for testing protective coverings as well as solutions; and in the case of the latter the distribution of the foreign substance throughout the strip is more uniform. The experiments conducted before you, illustrate the relative resistance imparted by a number of the preparations already enumerated.

A third method of comparative testing was devised by Boudin and Donny.[1] A cylinder of light iron rods forty cm. long and twenty-five cm. in diameter is mounted upon an horizontal axis so that it can be easily kept in rotation. Beneath this cylinder is a series of five Bunsen burners, consuming 1000 liters of gas hourly. The wood used for the experiments is in the form of rectangular sticks thirty-nine cm. long and fifteen mm. square. After treatment by injection or painting, bundles of four sticks of each preparation—the individual sticks kept apart by light wedges—are attached by wire to the rods of the cylinder, parallel to its axis, and at equal distances from each other. A bundle of sticks which have not been treated serves as point of comparison in each charge of the cylinder. The row of lamps is next lighted, and the cylinder turned at the rate of six revolutions per minute, so that all of the bundles are uniformly and evenly exposed to the action of the flame. The time is then noted at which each bundle takes fire, or is seriously affected by the heat; and when the combustion of a bundle becomes sufficiently active to affect its neighbors, it is removed. As an example of the working of this method the following series of tests may be quoted from the Belgian report:

Wood not treated took fire at the end of one and three-fourths minutes.

Wood treated with zinc sulphate or alum, at the end of three and one-half minutes.

Wood treated with ammonium sulphate or copper sulphate at the end of five minutes.

Wood treated with borax, or boric acid, or Martin's ignifuge, or Brocher's preparation, at the end of eight minutes.

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[1] Rapport.

Wood treated with sodium tungstate, at the end of ten minutes.

Wood treated with calcium chloride or ammonium chloride, at the end of fifteen minutes.

Wood treated with waterglass alone, or with lime, or with powdered glass and kaolin, or cyanite, or the Bell, Blane, or United Asbestos Co. preparations, or ammonium phosphate, at the end of thirty to forty minutes.

The two latter were charred throughout without the production of flame.

A still more rigorous and decisive test has been devised by Boudin and Donny,[1] one which places the experimenter as nearly as possible in the conditions which ordinarily precede the outburst of a conflagration; *viz.*, the production of a flame of greater or less intensity in immediate contact with inflammable material; such as happens when an oil lamp is overturned, a box of matches is kindled by the gnawing of an inquisitive rat, or the like.

The test is simple in its nature, and depends, as in the preceding method, upon the use of wooden rods subjected to a protective treatment. A convenient size is that of twenty cm. in length and fifteen mm. square. Thirty-six rods of the same preparation are used to form a small open construction by simply superimposing rows of six alternately crossed upon each other, leaving in the center an open space about six cm. wide for the reception of burning material. The whole arrangement is one permitting of the freest possible circulation of air, a condition which is further aided by placing the construction upon a piece of heavy wire gauze, supported upon two bricks. Little bundles of splints, weighing thirty-five grams each, are used as sources of combustion. They are introduced into the central space, lighted, and the result carefully noted. If combustion be not communicated to the construction by the burning of a single charge, a second is added, and so on. It is easily seen from the series of experiments with these constructions carried on before you, that this method of the two Belgian chemists is of the most searching and exacting nature, and yields comparative results of the highest value.

In such a series of tests, for example, a construction of ordinary wood takes fire at the end of one minute, is in complete combustion two minutes later, and at the end of ten minutes leaves a mass of ashes. Wood treated with ammonium chloride takes fire at the end of three minutes and undergoes complete combustion. Wood covered with cyanite takes fire at the end of three minutes and burns slowly for fifteen minutes, leaving the exterior intact. Wood treated with three coats of waterglass stands exposure to four successive charges of combustible, with but little evidence of the propagation of fire, although the suriace of the rods is deeply altered by the exudation and swelling of the silicate. Wood treated with ammonium phosphate, or the United Asbestos Co. preparation, is scarcely affected after four successive charges. The construction remains intact with the interior slightly charred.

RESULTS THUS FAR ATTAINED.

Leaving the methods of testing, let us now briefly summarize the results of experiment, and experience with fire protectives up to the present date. For textile fabrics, sodium tungstate and magnesium borate yield, unquestionably, the best results, when materials are to be ironed, while ammonium phosphate or sulphate is preferably used in other cases.

The use of the tungstate, especially, is widespread in England. It may be of interest to know that in the laundry of the Queen's palace, all fabrics of vegetable origin are treated with a solution of neutral sodium tungstate of 28° Tw. containing three per cent. of sodium phosphate. This solution is added to the starch also when the latter is employed.

Abel's researches[2] show that in naval warfare, calcium chloride is valuable to protect rope mantelets, while canvas is well protected by stannic oxide and still better by the double silicate of sodium and lead.

The efficacy of sodium tungstate, as well as of the ammonium salts, for the scenery and decoration of theaters, has also been firmly established.

The comparative results of Lochtin's experiments on pure cel-

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[1] F. Fischer, *Ding. Poly. Jour.*, 245, 36.

[2] Amer. Arch., 13 and 14.

lulose[1] may well be summarized here as they offer a valuable classification and furnish useful hints; although it must not be forgotten that the tests were elementary in their nature, and the conclusions, hence, open to criticism, as is, in some cases, evident.

Lochtin divides compounds into three classes, with reference to the effects on combustibles. (1) The *antipyrenes*, which render cellulose uninflammable when present in relatively small amounts, and when used in weak solutions. (2) *Indifferent substances* which are effective only when present in large amounts. (3) *Substances which favor combustion.*

I. ANTIPYRENES.

Quantities of anhydrous substances required to render cellulose uninflammable.

	Minimal strength of solution used in per cent.	Minimal relative weight (cellulose = 100).
NH_4Cl	1.5	4.2
$(NH_4)_2HPO_4$	1.5	4.5
$(NH_4)_2SO_4$	1.5	4.5
$ZnCl_2$	1.5	4.0
$CaCl_2$	1.5	4.5
$MgCl_2$	1.5	4.5
$Al_2(OH)_6$	1.5	3.8
$KAl(SO_4)_2$	2.0	..
$ZnSO_4$	1.5	4.5
$SnCl_2$	2.5	..
$Na_2B_4O_7$	1.5	8.5
B_2O_3	2.5	10.0

II. INDIFFERENT SUBSTANCES.

HKO	7.5	..
$MgSO_4$	7.5	15
NaCl	7.5	35
Na_2SiO_3	17.5	50
SiO_2	12.5	30
KCl	20.0	45
Na_2HPO_4	7.5	30
K_2HPO_4	20.0	..
$Al_{2}3(B_4O_7)$	12.5	24
$AlPO_4$	10.0	30
$Ca_{3}2(PO_4)$	12.5	30
$MgHPO_4$	12.5	30
ZnB_4O_7	7.5	20
$ZnHPO_4$	15+	..
WO_3	10+	15+
Na_2WO_4	10+	15+
$(NH_4)_2WO_4$	7.5	10+
Clay (air dry)	..	75
$NaC_2H_3O_2$ and $KC_2H_3O_2$	7.5—5	..

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[1] *Ding. poly. Jour.*, 290, 230.

III. SUBSTANCES FAVORING COMBUSTION.

Na_2SO_4, Na_2SO_3, Na_2CO_3, Na_2SnO_3, $Mg(OH)_2$, K_2SO_4, $ZnCO_3$, $CaCO_3$, $MgCO_3$, $CaSO_4$, $FeSO_4$.

In reviewing the above tables, it is of importance to note that the aluminum hydroxide used is that obtained by double decomposition between sodium aluminate and sodium bicarbonate. The product formed by the action of ammonia on aluminum sulphate is of no value. It will be seen, also, that the somewhat expensive sodium tungstate is much less effective than many other compounds, the chemical nature of which debars them, however, from ordinary application. Thus, (apart from cost), acid or alkaline reaction, difficulty in solution, hygroscopic properties, or readiness to decompose, on contact with hot iron or otherwise, handicap, as it were, most of the antipyrenes. The chief value of Lochtin's work is to be found in the recognition of aluminum hydroxide as so pronounced an antipyrene and the fixing of the conditions under which it is deposited in the most effective form.

The most important and decisive results with regard to the efficiency of the different current protectives of wood are furnished by Boudin and Donny.[1] Using a classification based upon their rigorous and conclusive tests, we can arrange the protectives in the following series, ascending from the least effective to the most effective.

I. PREPARATIONS OF LITTLE VALUE.

1. Injection of sodium tungstate (56 kgms. per m^3).
2. “ “ copper sulphate 20 “ “
3. “ “ calcium chloride 50 “ “
4. “ of ammonium chloride 48 “ “
5. Coating of waterglass (43 per cent. solid residue), 1 coat, 286 grams per m^2.
6. Coating of waterglass and zinc oxide, 4 coats, 1 kgm. per m^2.
7. “ “ Martin's ignifuge, No. 4, 2 coats, 450 grams per m^2.
8. “ “ Brocher's preparation, 3 “
9. “ “ Blane's asbestos paint, 2 “ 1 kgm. per m^2.
10. “ “ cyanite (basic aluminum silicate), 2 coats, 450 grams per m^2.

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[1] Rapport.

II. PREPARATIONS OF SOME VALUE WHICH LESSEN, IN A MARKED DEGREE, THE INFLAMMABILITY OF WOOD.

11\. Covering of cyanite, 3 coats, 570 grams per m^2.

12\. " Bell's asbestos paint, 3 coats, 820 grams per m^2.

13\. " waterglass[1] and ferric oxide, 4 coats, 700 grams per m^2.

14\. Covering of waterglass[1] and powdered glass, 6 coats, 900 grams per m^2.

15 Covering of waterglass[1] (undiluted),[2] 3 coats, 475 grams per m^2.

III. PREPARATIONS OF THE HIGHEST EFFICIENCY WHICH PREVENT ALMOST ENTIRELY THE PROPAGATION OF FIRE IN WOOD.

16\. Covering of the United Asbestos Co. paint (waterglass, sodium aluminate and asbestos), 3 coats, 850 grams per m^2.

17\. Injection of ammonium phosphate, absorption of 75 kgms. per m^3 after boiling for twelve hours in a sixteen per cent. solution of the salt.

These two protectives would seem therefore the high-water mark of what chemists have attained in their efforts to render wood inflammable. With regard to the permanence of their protective power, it has been observed that, after the lapse of two years, wood treated with the asbestos preparation had lost, in no measure, its resistant qualities, while that injected with ammonium phosphate showed an exceedingly slight diminution in the efficiency. No diminution was noticed at the end of nine months in the resistance of injected wood, kept at ordinary temperature, or at 45° C., or covered with a coat of oil-paint. It should be noted also that the solution of ammonium phosphate does not affect nails and other objects in iron even after contact for several months; also that the solutions of the salt must be nearly saturated in order to yield satisfactory results.

Boudin and Donny's experiments would tend to indicate a

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[1] In all these tests a waterglass of forty-three per cent. solid residue was used. It was generally diluted with water, but this additional water is not included in the weight per m^2.

[2] Wood, when first covered with waterglass, presents a varnished appearance. This is not retained long, as the coating soon begins to scale, and the surface is covered with a white efflorescence.

slight lessening in the strength of wood which has been injected. The general conclusions drawn from their investigations are:

1. The incombustibility of wood, *i. e.*, its non-alteration when under the influence of heat, cannot be attained. It is possible, however, to secure its non-inflammability, so as to preserve ordinarily any structure exposed to an accidental fire, or at least to allow time for the arrival of the ordinary extinguishing appliances, unless it be filled with combustible material.

2. Of the preservative processes used, injection of saline solutions or the application of protective coverings, the former would seem ill adapted for timber of large dimensions, but of manifest value for the less bulky forms of wood. In all such cases the use of ammonium phosphate, in saturated solution, offers such incontestable advantages, that, despite its high price, it should be employed unless excluded absolutely by limitations of expense. (Ammonium phosphate can be obtained for about $50 per 100 kgms., and as a cubic meter of wood absorbs seventy-five kgms., the cost per cubic meter would be about $38.)

3. In the majority of cases protective coatings are preferable. The most efficacious is that containing sodium aluminate and asbestos in waterglass, while waterglass alone, or with the addition of aluminum hydroxide, is of great value.

EXPLANATION OF THE ACTION OF PROTECTIVES.

Such being the practical results attained, it is of interest for us next to know in just what way these chemical compounds act to prevent inflammability. It is, in fact, a matter of surprise that the experimentation in this field has been so largely empirical, neither preceded nor followed by theoretical considerations.

In studying the effects of heat on ordinary wood, the following will be noted:[1] When exposed for some time to a temperature of 200° C., wood becomes light brown and its strength is materially affected. At 300° it is charred completely, losing all power of resistance, but still without a trace of flame. If, however, the wood be in contact with flame, or be exposed to a red heat, change takes place rapidly, and if air have free access it bursts into flame, and combustion does not cease until the entire mass be reduced to ashes.

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[1] F. Fischer, *Ding. poly. Jour.*, 245, 36; Boudin et Donny, Rapport.

When wood protected by a suitable coating, such as water-glass, is exposed to a temperature of 200° C., it acts exactly as ordinary wood. Wood, however, which has been injected with saline solutions, as ammonium phosphate, is more liable to change. It assumes a deep brown tint, and the resistance to strain is greatly lessened. At 300° all forms of protected wood are carbonized, exactly as the ordinary wood, and without flame.

At a red heat, or in contact with flame, prepared wood is completely destroyed; but there is a vast difference between its rate of destruction and that of non-protected wood. At first there is a pronounced period of direct resistance. In cases where external applications have been made, the heat gradually penetrates the protective coating, jets of gas issue through fissures in it, and their combustion contributes to the intensity of the surrounding sources of heat, until, finally, combustion is complete. In the case of wood impregnated with suitable saline solutions, resistance to the flame is likewise marked, but much gas is evolved. This gas is not inflammable but seems, on the contrary, to interfere seriously with the combustion of the surrounding fire. Complete charring is finally reached. It is evident in both cases that the ordinary effects of heat upon wood are seriously hindered or retarded. The first effect of heat, as we have seen, is to produce gas and leave carbon. This gas, if allowed to burn with the oxygen of the air, furnishes a fresh supply of heat to bring about further evolution of gas. But as organic matter and the resultant charcoal are both poor conductors of heat, gasification would proceed very slowly unless the coal on the surface also changed to gas by burning with atmospheric oxygen (as well as by reducing the carbon dioxide and water present), thereby increasing the available temperature. The maintenance of a sufficiently high surrounding temperature must eventually cause the penetration of enough heat into the body of wood exposed to produce complete gasification and carbonization, and finally complete combustion of the charcoal. This action can be retarded evidently by two distinct agencies. The first is the evolution of an inert or non-combustible gas or vapor from the wood through the influence of heat; the second is the presence of an external coating, which is not only a poor conductor of heat, but also protects the outside zone of charcoal from contact with atmospheric oxygen. It is in one or both directions that fire protectives render service.

The ammonium salts are good types of the first class. Ammonium chloride and ammonium sulphate are readily vaporized and dissociate, the first into ammonia and hydrochloric acid, the second into ammonia, nitrogen, water, ammonium, sulphite, etc. Ammonium phosphate decomposes slowly to metaphosphoric acid (sixty-two per cent. of its weight), ammonia, and nitrogen monoxide. It is probably this slowness of decomposition which renders the phosphate superior to the other ammonium salts. In the case of magnesium chloride, zinc chloride, etc., hydrochloric acid is driven off. In the case of other salts, such as the alums, the borates, copper sulphate, and sodium tungstate, large amounts of water of crystallization are necessarily liberated in the form of aqueous vapor. It is a matter of surprise that this fact, that the storage of considerable amounts of water in the solid form in the interior of wood is a potent factor in the protective value of a number of antipyrenes, should have escaped the attention of chemists. It is an easy matter to calculate the volume of aqueous vapor capable of being formed from a given weight of $Na_2B_4O_7 + 10H_2O$ or $Na_2W_4O_{13} + 10H_2O$ or $K_2Al_2(SO_4)_4 + 24H_2O$. There is no question but that such salts, as the above, retard the attack of flame chiefly through this agency at first, although after the expulsion of the water of crystallization, the presence of the saline substance coating the charred surface and acting as a poor conductor of heat, as well as preventing the access of oxygen, continues the protection for a certain time. It is in the varying ability of different compounds to form coherent, continuous protective coatings after exposure to heat that we find the reason of the superiority of one composition, for external application, over another. Thus, waterglass alone gives good results. When wood treated with it is heated, we notice a puffing out and swelling, a certain amount of vapor escapes, and the residue is left as a light, voluminous, fairly coherent covering, through which air can penetrate but slowly to the charred surface beneath, and heat is likewise conducted but slowly. The addition of aluminum hydroxide to the waterglass seems to increase the resistant properties of this envelope, while the further addition of asbestos and the substitution of sodium aluminate for aluminum hydroxide, forming thereby practically a quadruple silicate of sodium, magnesium, calcium, and aluminum, give the highest resistant power.

It may be pertinently inquired, why does the presence of some salts seem apparently to help combustion? Lochtin explains this action[1] by the uneven distribution of some substances during drying or precipitation, more, proportionately, remaining on the surface of the paper or wood used. Here they form porous but slightly compact crusts; and these favor continued glowing or combustion by preventing a loss of heat.

PRACTICAL APPLICATION OF THE KNOWLEDGE GAINED.

With this exposition of the results attained in the contest with fire—the fruit almost exclusively of the work of European chemists—what should be the practical application of the knowledge gained to our own conditions in America? It is evident that there should be a rigorous insistence on the use of protective agencies for *all* wood employed in buildings containing material of permanent value, such as deposits of archives, museums, libraries, etc. Equally rigorous should be the requirement in the construction of exhibition buildings; of churches, theaters, and all structures wherein large assemblages are held; of the stands about our fields for athletic amusements; of cars and craft for transportation by land or water; and above all, of the edifices of our institutions of learning.

The applications enumerated above are nearly all easily within the reach of legislative enactment, as they affect the interests or lives of the public.

How far the use of protective agents may be introduced into ordinary construction, and into household equipment it is difficult to say.[2] In England the custom of protecting wearing apparel of vegetable fiber is widespread. No reason exists why American women, earnest in reform, should not advocate a

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[1] *Ding. poly. Jour.*, 290, 230.

[2] *Ding. poly. Jour.*, 245, 36.

similar custom here. There is no question, however, but that great stress should be laid upon the wisdom of impregnating the curtains, draperies, and hangings of our homes.

It is to be hoped that the slow burning principle may soon be extended to domestic architecture, but even with our present methods, it is easily possible with the outlay of a few per cent. on the cost of the house to lessen enormously its fire risk. All beams, joists, studding, etc., which are later to be hidden, can be coated during the process of erection. Siliceous coatings can also be applied to all surfaces outside and inside which are ultimately to be painted. Finally, woods to be used for interior finish can be protected by steeping in a solution, preferably of ammonium phosphate, if not of one of the cheaper antipyrenes, before being varnished. Such a house, if isolated, and presupposing the use of wire lath, is practically fireproof in nineteen out of twenty cases of ordinary conflagration. If provided with brick walls and slate roof, the risk is greatly lessened, and it is not difficult to recognize that blocks or districts of such construction are free from *all* danger of conflagration: that, in fact, fire will be confined exclusively to such rooms or houses as may be used for the storage of combustible material. Insurance, under such conditions, approaches almost the vanishing-point; and the freedom of apprehension from loss by fire is not to be measured by dollars and cents. We are here entering upon the proper province of another science. The chemist has provided the means of coping successfully with the dangers of combustion. It is for the economist to insist on the utilization of his achievements, in assuring increased comfort and security to society. Suffice it only to add that existing structures may, to a great extent, be protected especially for those few precious minutes between the discovery of a fire and the arrival of aid, by the generous application of the siliceous compositions to all exposed woodwork. The direct value of such treatment has been promptly recognized in England by a decrease of fifty per cent. in the insurance rates on houses so treated.

FIELD FOR FURTHER INVESTIGATION.

Finally, what remains for the chemist to do in this field?

Indirectly he may accomplish much in lessening the fire risk. First in the study of illuminants. Whatever tends to displace the use of petroleum for domestic lighting tends, by so much, to diminish the national fire bill, as this one substance is a most prolific cause of conflagration. It is to be hoped that the way may be opened to an economical and convenient use in this connection of our vegetable oils, now so abundant ; or to the introduction of a fuel-gas saturated with hydrocarbons, so safe and economical that it may be promptly accepted for domestic lighting. The possibilities offered in this direction by the extended utilization of calcium acetylide are also most hopeful. Next there is little doubt but that the early approach of the era of cheap aluminum will effect an important revolution in the use of structural materials, the light, unchangeable metal tending to displace wood in many of its external and internal applications. In this field American chemists have taken the lead.

With regard to the production of new protectives it is hardly probable that the last word has been said. We have seen how experiment, beginning with sodium silicate, led successively to the addition of aluminum hydroxide, of lime, of lead salts, of powdered glass, and of finely divided asbestos to the convenient syrupy medium. There is but little doubt that other combinations, less expensive or more effective than those now in vogue, await the experimenter.

The high rank of aluminum hydroxide among protectives, as shown by Lochtin, should lead to extended research with regard to its availability under different conditions, and its most economical application.

The utility of magnesium borate, so warmly recommended by Patera and Fischer, should be definitely established by comparative tests. It is not unlikely that combinations of the borates and silicates may also be found to render good service. Experiments on the deposition of insoluble tungstate in fabrics are also worthy of being carried out.

With regard to protection, by impregnation, it is doubtful whether any better agency than ammonium phosphate can be found. It would, however, be advisable to study the economical production of this salt for the purpose in question. Might it not be possible to attain cheapness by using successive baths of ammonium sulphate and sodium phosphate; or could not acid calcium phosphate be brought advantageously into the reaction?

A further field of investigation is the possible combination of injection and painting, impregnation with such deliquescent chlorides, as zinc chloride, or magnesium chloride, being followed by a simple external coat of a siliceous paint. Then the most favorable time for injecting or steeping wood with saline solutions should be definitely ascertained. Is it, after completed seasoning, or when the wood is perfectly green, as advocated by Jones?

The question of the most economical combination of protection against fire and of preservation from decay and insect attack, remains also to be settled.[1] Another important phase is the highest attainable efficiency, from the use of salts which store up, in wood, considerable amounts of water of crystallization, such as gypsum; for it must be borne in mind that every volume of solid water of crystallization yields 1700 volumes of aqueous vapor at 100° C.

It is largely along these lines that we may expect to see advance made in the province whose survey we now complete.

In conclusion, let me express the earnest hope that individually and collectively the influence of this Association may be helpfully thrown in favor of any general effort to lessen our tribute to fire. We have made ourselves felt in movements to combat the twin, although antithetic, evils of drought and flood by the preservation and extension of our forests, as well as in other economic directions. Can we not do the same in availing ourselves of the work of Gay Lussac, Fuchs, Versmann, Oppenheim, Abel, Tessier, Patera, and other chemists, by bringing into the American home and the American community that peaceful security and liberation from a dreaded tax, which comes with the practical abolition of danger from conflagration?

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[1] Rymer-Jones, *Ecl. Eng. Mag.*, **33**, 55. *1885*.