ing to Rücker, that all matter is atomic in plan, that it 'consists of discrete parts capable of independent motions,' * that the atomic theory has a basis of fact. This conclusion is regarded as positive and necessary, whatever the characteristics of those parts may prove to be. Such simple facts probably led Lord Kelvin to conclude, as he wrote to Professor Holman, "we may expect the time to come when we may understand the nature of the atom. With great regret I abandon the idea that a mere configuration of motion suffices." †

Wiedemann's deduction from his study of the light from sodium vapor and incandescent platinum, that the energy needed for producing 'pendulous movement' of atoms or molecules giving light-effects must be very insignificant in comparison with the total energy employed, may throw some light both on this question and on that relating to the 'cheapest form of light.'

It is by this scientific method of gradual revelation of the secrets of nature and this foresight of the coming knowledge, this discovery of methods and this apprehension of the continuity of law, that the chemist has come to such perfection in the analysis of all known substances and in the synthesis of many valuable and useful compounds; as in his production of all the coal-tar products, in the reinforcement of nature in the production of artificial madder and increasingly numerous lists of other materials of commerce. It is through this art of revelation and of prophecy that the physicist has shown the way to the engineer in the utilization of electrical energy and the distribution of light, power and intelligence, and has given the astronomer the means of analysis of the most distant stars and measurement of their rate of approach or recession. Thus the geologist learns the history of the earth, the lesson of its construction and the tale of a coming time of progressive decline in all its forms of life, and even roughly computes the past and the future period of its life, from superheated to a cold and dead estate. The building of a science gives progress to civilization, reinforces real learning and advances the individual man to higher life.*

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(To be continued.)

* President's address before the British Association for the Advancement of Science, 1901.

† Science, June 22, 1900, p. 988, E. H. Hall.

* The use of the 'curve of progress' sometimes finds curious and unexpected application. The study of the curve of progress of the speed of the horse was years ago attempted by this method, and it was found by the author of this address that the 'two-minute horse' might be expected at about the commencement of the twentieth century. Several periods of smooth progress, broken, 'catastrophically,' by improvements or by inventions, were observed, as when the four-wheeled 'wagon' was superseded by the 'sulky' and when the pneumatic tire was introduced. In each curve the trend has, at the break, become approximately asymptotic. The horse had nearly reached his limit and the reduction of load was the only recourse, in further promotion of progress.—*Sci. American Supplement*, December 1, 1894.

ON SOME RECENT ADVANCES IN THE FIRE-PROOFING TREATMENT OF WOOD.†

The saturation of wood with chemical solutions has mainly two objects in view, either to prolong the life of the wood by rendering it as resistant as possible to decay, or to make it resistant to the attack of fire and to cause it when exposed to flame to carbonize as slowly as possible without, of or from itself, contributing to the increase of the flame. We will take up the second of these two lines of treatment for present discussion.

The treatment of wood with a view of making it fire-resistant is not a matter of

† Read before Section C of the American Association for the Advancement of Science, Pittsburgh meeting, June, 1902.

recent years. The Bavarian chemist Fuchs in 1820 applied the newly discovered silicate of soda to the fireproofing of wood and employed it in the rebuilding of the Munich theater for the treatment of both the wood work and the hangings of the theater. Gay Lussac in 1821 suggested the salts of ammonia and borax. Tungstate of soda also figured at an early day in the list of fireproofing salts as well as the salts of zinc and the chlorides of the alkalies and calcium and magnesium. Antedating all of these, however, going back indeed to the records of ancient Greece and Rome, was alum, which has always been a favorite fireproofing material, used both alone and in admixture with other compounds.

All of these materials can under circumstances exert a notable fire-retarding effect and have served as the basis of a variety of patented processes for the treatment of wood.

But we must not lose sight of the fact that the problem of satisfactorily impregnating wood for fireproofing purposes is a mechanical as well as chemical one and it will be best to look at the mechanical side of it for a few moments. The typical apparatus until recently employed everywhere wherewith to saturate lumber with fireproofing solutions was a large cylinder, running from 60 in. diameter and 70 to 80 ft. long to 84 in. diameter and 105 ft. long; closed at one end, with a movable head at the other, swinging horizontally or lifting vertically to open or close. It was fastened when closed by a complicated system of radial bolts to the external end of the cylinder. The cylinder itself, composed of steel plates riveted together, was intended to be filled with truck loads of lumber and when the entrance door was closed and locked, the wood was subjected, after some preliminary treatment, to hydraulic pressure through the medium of the treating solution, which envelopes the surface of each piece of lumber and which the pressure was intended to force into it at every point.

With cylinders of such enormous diameters and riveted plates, the pressure that can be withstood is relatively light and as a consequence the time of saturation is necessarily long.

The preliminary treatment before referred to is usually a steaming of the wood, followed by application of a vacuum for the purpose of facilitating the final step of impregnation. A pressure of 150 lbs. is quite as much as can be maintained as an average in such a cylinder and to effect a complete saturation, even with soft woods one inch thick, requires in such a case from 36 to 40 hours. A core saturation in heavier timbers such as 4 x 4 in. or 6 x 6 in. is rarely if ever obtained even in soft woods, and never in the hard woods.

A radical improvement upon this method of working was effected by Mr. Jos. L. Ferrell, of Philadelphia, in the invention of the apparatus now in use by the U. S. Fireproof Wood Co. of Philadelphia, and which was described and figured in the *Scientific American* of July 28, 1900. By the replacement of the hinged gate by a heavy gate, sliding between vertical guides against a phosphor-bronze bearing and placed in a massive gate housing near the end of the cylinder, which is of heavy cast tubing, he was able to use pressures ranging from 400 to 1,500 pounds in extreme cases. By the intervention of a hydraulic accumulator he was able to perfectly cushion the shock of the high-pressure pumps so as to prevent all bruising of the wood when under strong pressure. No preliminary steaming or vacuum is necessary, but after the receiver is full of liquid and the pressure is applied, the liquid penetrates and, in what seems an incredibly short space of time, has followed the medullary rays from end to end of the lumber and effected what is bound to be a thorough core saturation. One hundred per cent. saturation (weighed wet) is readily effected in ten minutes and after the kiln drying the permanent gain in the weight of the wood will be found to be from 5 to 10 per cent., distributed throughout its whole cellular structure and not on the surface or in the exterior layers only.

Hard woods in large sizes up to 12 by 12 in. have been so treated, and upon being sawed through have been found to have perfect heart saturation.

With the mechanical side of the fireproofing treatment thus perfected, let us turn again to the choice of a chemical which shall prove as fire-resistant as possible and impart this quality to the wood. Some of the qualities that such a chemical should possess may be briefly reviewed.

1. It must not be of a hydroscopic nature, because in such case it would destroy paint and keep the surface of the wood in an undesirable moist condition. For this reason the chlorides of calcium, magnesium, and zinc are excluded, although an attempt has been recently made in a German patent to produce for this purpose a basic chloride of calcium which it is claimed is free from this drawback and is recommended for fireproofing of wood.

2. It must not be a volatile substance, because in such case it will gradually be liberated from the cells of the wood and show as an efflorescence, besides leaving the wood after a time weaker in its fire resistant character. The ammonia salts, notably the sulphate and chloride, will not stand this test at all satisfactorily. In the dry kiln, the liberation of ammoniacal gas begins already at 125° F. and the efflorescence is frequently recognizable even when the surface has been varnished if the wood has been exposed to strong sunshine for any length of time. Of course such efflorescence speedily ruins the appearance of a varnished wood.

3. The chemical used must not allow of fungus growth, for in such case the wood will decay more rapidly than untreated wood. Here again the ammonia salts, including the phosphate as well as sulphate, are unsatisfactory, as when the conditions of warmth and moisture are favorable the treated wood develops a fungus rapidly and deteriorates in strength.

4. If possible the chemical should have exactly the opposite character, viz., a distinct preservative effect, so that the life of the treated wood should exceed that of untreated wood.

5. There should be no noxious gas liberated in the heating or carbonizing of the wood.

6. The chemical used must not be poisonous in character, so that splinters impregnated with it, if by accident run into the flesh or wounding it, shall not endanger life or health.

7. It should not cause the corrosion or rusting of metal which in the form of screws or bolts are passed through it.

8. The cost must be moderate, as its practical utilization will be barred if the materials be such as to make the process an expensive one.

After a most exhaustive series of experiments, extending over several years with a wide range of compounds, Mr. Ferrell, the inventor of the fireproofing method just referred to, has found in sulphate of alumina a compound that appears to answer all the requirements as stated. It has the additional feature of no slight importance in its bearing upon the fireproofing effect, that when strongly heated it leaves an infusible and non-conducting residue to cover and protect the cellular structure throughout the wood. It absolutely prevents the propagation not only of flame throughout the wood but even of a glow because of its non-conducting and unalterable character.

Sulphate of alumina in concentrated

solution is far more efficient than an alum solution; in fact it would seem as if the alkaline sulphate of the alum simply detracted from the power of the aluminum sulphate in the matter of making wood fire-resistant.

I have before referred to the way in which sulphate or phosphate of ammonia act to make wood fire-resistant, viz., by rapidly liberating ammonia gas, which has the effect of checking the flames on the surface of the wood. The fiercer the flame which plays against such wood the more rapid the liberation and exhaustion of the protecting vapor. There is no residual protective substance remaining in the wood and the carbonization of the fiber proceeds apace.

On the other hand, so soon as the sulphate of alumina of the superficial layer of the wood impregnated with this chemical is decomposed by the heat of a flame, a deposit of alumina is formed, the non-conducting properties of which make it a barrier against the propagation of the carbonizing effect and protect the interior in a very notable degree. An actual experiment, one of a large number which I carried out jointly with the inventor, will illustrate this. If a piece of wood be saturated with a solution of sulphate of alumina of 30° B. strength to a depth of not more than three eighth inch from the surface and the point of the inner blue cone of a strong Bunsen flame be made to impinge upon it and kept in such a position, a boring effect takes place while an abundant separation of alumina will be observed. The average resistance of a piece of one-inch white pine so treated to the complete boring result, with final penetration of the flame to the other side, will be over three hours. If a similar piece of one-inch white pine be 'heart-saturated' with ten times the quantity of sulphate of ammonia and the same Bunsen flame be applied under exactly similar conditions, the average resistance to complete penetration will not be over seventy minutes. These results have been obtained repeatedly and in instances the disproportion was much greater.

Some very interesting observations have been made on the physical changes which the fireproofing material undergoes on the continued application of heat. As a result of repeated measurements, it is found that the residual alumina occupies a space from two and a half to three times as great as the dried salt from which it is formed. Hence in forming it apparently expands to fill out the air spaces and intercellular spaces of the wood very fully. This results in the formation of a very compact non-conducting barrier which interposes itself to the action of the flame and protects the layers of woody tissue upon which it is formed. The protection is therefore a real and much more lasting one than that which could come from the liberation of a gas whose action, from the nature of things, could be evanescent only.

In working on a large scale, where heavy timbers or boards in the rough are treated, the saturation with the sulphate of alumina solution is always carried out until complete 'heart saturation' is attained as the wood has to be sawed, planed, mortised and otherwise worked and cut into and all surfaces that will be exposed later must be fire-resistant to the fullest degree.

As, irrespective of the large number of both soft and hard woods that, because of their practical value, had to be tested, the same kind of wood will differ greatly in its physical characters, according as it may be heart-wood or sap-wood, and according as it may be young wood or thoroughly matured, a vast number of saturation tests have been made in establishing the efficiency of the different methods of working and the value of different solutions. No deduction has been thought to be of value that was not based upon a large number of tests carried out under similar conditions so as to obtain an average that could be relied on. The immensity of the task may be understood when it is stated that 88,000 saturations and fire tests with complete attending records have been made of different thicknesses of 19 different varieties of wood and 46 chemical formulæ, requiring the constant application of the inventor and his assistants and running through a period of over six years.

One remaining question and a very important one is what effect has the fireproofing treatment upon the structural strength of the wood. When the older methods of saturation whereby the wood was steamed and then subjected to pressure for long periods was the only one available, it was recognized that a compression of the cellular structure of the exterior layers of the wood took place so that the wood was distinctly weakened and the results for tensile strength and bending and breaking tests were accepted as necessarily lower than for the same wood untreated. With the superior method of impregnation now adopted, however, no such allowance is necessary and the treated wood is in no way inferior in strength to the untreated. Professors Mason and Bliss, of the University of New York, have made a large number of physical tests upon the wood treated by the Ferrell process and have established this important fact very fully. The whole matter however of the fire-resistant properties of wood treated by different processes together with physical tests upon the same is now under investigation by a Commission appointed by the 'Bureau of Building Construction of the City of New York' and I have no doubt that its report when published will throw much additional light upon this most important subject.

SAMUEL P. SADTLER.

PHILADELPHIA, July, 1902.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

TWENTIETH ANNUAL REPORT OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE.

THE Committee on Indexing Chemical Literature, appointed by your body in 1882, respectfully presents to the Chemical Section its Twentieth Annual Report, covering the ten months ending June 1, 1902.

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