These determinations furnish, we believe, satisfactory proof that the method which has been described, secures a practically complete precipitation of the phosphorus, even when the amount present is only 0.02 per cent., and also that the ratio of phosphorus to molybdenum in the solution is constant and independent of the amount of phosphorus present; also that the ratio is not affected by the presence of silicon or arsenic in the solution. The cast iron used contains 0.84 per cent. of silicon. As regards arsenic, we have applied Marsh's test for arsenic to the yellow precipitate obtained from two grams of steel No. 2, and obtained only a very faint arsenic mirror, much fainter than that obtained under the same conditions, from 0.02 mgm. of arsenious oxide. If we suppose the arsenic to have been present in a compound analogous to the phosphorus compound, the molybdenum associated with it would correspond to only 0.0003 per cent. of phosphorus. The determinations with the cast iron also furnish evidence that the conversion of phosphorus into phosphoric acid is as complete by solution in nitric acid and oxidation with potassium permanganate as by solution in aqua regia and evaporation with nitric acid. The volumetric determinations with the cast iron are more accordant than the gravimetric. In view of the great difficulties known to exist in the way of securing pure magnesium pyrophosphate, we believe the volumetric determination will usually be found to be more accurate.

TERRE HAUTE, December 20, 1894.

THE CONTRIBUTIONS OF CHEMISTRY TO THE METHODS OF PREVENTING AND EXTINGUISHING CONFLAGRATION.[1]

BY THOMAS H. NORTON.

Received December 24, 1894.

I have felt it desirable on this occasion to direct your attention to a brief review of the services which the chemist has thus far rendered in the battle with fire, to the field of investigation still open, to the methods of testing and experimentation in this branch, and to the application of fact already gained to American conditions. In the choice of this subject, I have, in common

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[1] Abridged from the author's opening address before the Section of Chemistry of the American Association for the Advancement of Science, at the Brooklyn Meeting, August, 1894.

with some of my predecessors, left the domain of pure science to consider more closely certain economic aspects of chemistry, and enter, to some extent, into the province of chemical engineering, which is now recognized in our leading schools as entitled to distinct and separate treatment. A further reason which has influenced me is the practical absence, to this time, in our works of reference, of any attempt to collate and classify the knowledge gained in this field.

The total annual loss of insured property by fire is about $200,000,000, and of this sum nearly one-half occurs in the United States,—$90,344,075 in 1893. Foreigners marvel at this reckless disregard of the immense losses by fire shown by our countrymen, for from eighty to ninety per cent. of the 15,000 fires which occur annually, can be traced to easily preventable causes, and chiefly to faulty construction. Consider, for a moment, the tax which is being paid this Moloch. Our total loss of property amounts to one-fifth of the net profits of all the industries of the country. Propose to a trader or manufacturer cooly to throw one-fifth of the annual profits into the grate! Yet this is what our productive industries, as a whole, have been and are doing in an unconcerned, if not cheerful, manner. The direct loss by conflagration is. however, not the only factor. Our fire departments and water supply cost us $30,000,000 annually; while the loss of wages to mechanics and other productive forces, and numerous contingent amounts, swell the actual total loss to a most serious sum. The fire department of London costs but one-third of that of New York City; and the same ratio applies to most European cities. During a residence of ten years in French and German cities, I saw the fire engines called out but five times; while the average resident of an American city is apt to witness a call at least once a week. England's annual fire bill is but little over $10,000,000.

With these facts in view, is it not time to call a halt, to bring all the forces of science to bear in the battle, and redeem our America from what is nothing more or less than a servile bondage?

If we seek the reason for this vast difference in relative fire loss between the Europe of to-day and America, it is not to be found in a superiority of facilities for extinguishing conflagrations. The equipment of American fire departments is far better than that of the fire departments abroad. It results simply from the fact that the European architect and builder have profited from the experience of the past, and learned that prevention is better than cure. The prevalent method of construction in New York is such, architects assure me, that the business part of the city awaits only the proper combination of circumstances to be the scene of a conflagration rivalling that of Chicago.

Before leaving these general considerations, it should be said that there are many hopeful indications of an awakening from this apathy, and ample recognition should be made of the earnest effort, inaugurated of late years in New England, to lessen fire risk ; the application of the so-called slow-burning principle of construction, especially to factories. By the adoption of this principle it has been possible to reduce insurance rates from one and one-half to two and one-half per cent. down to two-sevenths of one per cent.

FIRE EXTINGUISHERS.

Passing to the more specific treatment of the subject, we find that, as in medicine, so in the matter of protection against loss by fire there are two distinct lines of action : prevention and cure, or the adoption of such measures as to render an outbreak of fire difficult, and a conflagration practically impossible ; and the provision of the proper facilities for the rapid subjugation and limitation of fire under full headway. As in medicine, also, there is a growing conviction that the prophylactic treatment is the more important. It is hence particularly in this direction that the activity of the chemist has been chiefly called into play.

Let us first briefly review the methods of extinguishing fire.

In this field but little has been done to add to the efficacy of the agent used from time immemorial—ordinary water. In addition to its cheapness and universal distribution, water possesses, over other liquids, peculiar advantages for the purpose in view—high specific heat and the formation of a vapor which is non-poisonous. Sulphur dioxide has been used to some extent; in fact it is an old-fashioned method in European countries to extinguish burning chimneys by kindling sulphur on the hearth. A quicker production of the gas is effected, more particularly for use in confined spaces, by introducing receptacles of burning carbon disulphide; and cylinders of liquid sulphur dioxide, have, under similar circumstances, been successfully employed. The advantage in the use of this gas consists entirely in its exclusion of the air necessary to maintain combustion. The slower diffusion consequent upon high density renders it superior for this purpose to other available gases. This advantage is, however, largely counterbalanced by its irritant, poisonous nature, and it has never been accepted as one of the recognized agencies of general application.

Of much greater value is carbon dioxide, the efficacy of which is likewise based upon its ability to prevent the access of air to the material in process of combustion. The ease with which this is accomplished is shown by the familiar experiments of our lecture courses in chemistry. For practical results in dealing with ordinary fires, it is found best to employ a highly charged aqueous solution of the gas. Such solutions as those prepared for use as a beverage, have frequently been used in emergencies. One large soda-water establishment has been able to extinguish several fires in its own factory and in the neighborhood by the prompt use of the carbonated water in its receptacles. A quick-witted pharmacist recently extinguished a serious fire in his store from benzene, by quickly using a pailful of soda-water drawn from his own fountain, the case being one in which simple water would have failed to accomplish the purpose.

The so-called chemical fire-engines, now regularly used in our public fire departments, are all constructed upon the principle of charging a quantity of water when used with carbon dioxide and ejecting a stream of the carbonated water by the pressure of the gas itself. In the size most frequently employed the supporting truck carries two cylindrical tanks of steel or copper, holding about eighty gallons of water and twenty-eight pounds of sodium bicarbonate with a leaden jar containing fourteen pounds of sulphuric acid. At the moment of using, by a simple mechanical device, the acid is admitted to the solution and a pressure of 140 pounds to the square inch is developed. The tanks are charged alternately while in operation so that it is possible to maintain a continuous jet of one-fourth of an inch. The whole apparatus is light and easily drawn by two horses. There is also in use a combined manual and chemical fire engine devised by Foster. The pumps fill, with water, the compartments in which the chemicals are dissolved and whence the solutions come together in a generating chamber where the gas is evolved. Such engines are capable of throwing per minute thirty gallons of water containing 250 gallons of carbon dioxide to a distance of ninety feet. This type is also arranged for connection with high pressure mains. Very careful tests carried out in 1883 showed conclusively the great value of a small quantity of carbonated water in extinguishing fierce flame, especially in a confined situation and when combustion had not penetrated much beneath the surface. The same principle was applied earlier by Baragwanath and others in a variety of forms, to portable extinguishers. Dick's extinguisher, largely used in England, is a cylindrical tank of seven gallons, easily carried on the back. giving a pressure of from 70 to 120 pounds, and possessing a projectile range of fifty feet. The peculiar feature of this type is the storing of the sulphuric acid in a glass container, which is easily broken when the apparatus is to be used. Zabel's apparatus, like Dick's. is charged with sodium bicarbonate, but the acid used is contained in a cylinder from which it is liberated by simple inversion. Devices, essentially the same, have been introduced by Masnata and VanWisker. In Carter's extinguisher the sulphuric acid is replaced by tartaric acid.

Platt's extinguisher has been successfully used for many years, and is valued on account of its simplicity; the turning of a valve and the inversion of the apparatus bringing it at once into operation. Other efficient extinguishers of American origin are the Babcock, the Harkness, and the "Climax." In the latter, sulphuric acid is replaced by oxalic acid, and in both the Harkness and "Climax" the carbonated solution is forced out by a pump. The Babcock extinguisher is filled with a solution of sodium bicarbonate, and has in its upper part a vessel of acid suspended by lateral pivots to a stirrup depending from the top of the apparatus. The stopper of this vessel is worked by a rod through the top of the extinguisher. By withdrawing the stopper, the vessel tilts over and mingles the acid with the solution producing at once the necessary pressure.[1]

The most recent and perhaps most efficient of chemical extinguishers is that introduced in 1893 by Dr. Henry P. Weidig, and extensively tested throughout our country during the past twelve months. It is adapted not only for portable use, but also for replacing ordinary town engines and for permanent installation in factories and on board ships, etc.

The apparatus consists of a steel vessel containing liquid carbon dioxide so arranged that it may be brought in connection with a receptacle filled with carbonated water, or a solution of ammonium carbonate, under any desired pressure. The carbonated water meets in its exit pipe with a stream of ammonia gas emanating from a cylinder of liquid anhydrous ammonia. The carbon dioxide is thus bound in the form of a soluble salt, ammonium carbonate. The solution thus formed is forcibly ejected, and, on reaching a fire, the heat not only volatilizes the water but decomposes the salt, so that a mixture of steam, carbon dioxide, and ammonia is the result. One volume of water will yield under these circumstances twenty-five volumes of the two latter gases.

The principle of rapidly filling a confined space where fire has broken out with inert gases has been extended to the use of the gaseous products issuing from the combustion under boilers. In certain industrial establishments devices are introduced by which the current of the mixture of nitrogen, carbon dioxide, and aqueous vapor can be directed, at will, into a given apartment. The results are quite effective, combustion being promptly and permanently stopped. Other additions than carbon dioxide to the water used in extinguishing fires have proved of doubtful utility when submitted to practical tests. The list of such proposed additions includes potash (Kaiser), clay (Glaser), a mixture of sodium sulphite, and four parts sodium alum (patented 1884 in Austria, by Trotha, and sold in the form of cartridges), salt, alum, waterglass, copperas, Glauber's salt, borax, magnesium chloride, sodium phosphate, and soda.

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[1] Hexamer, *Journal of the Franklin Institute*, August, *1885*.

Ammonia gas alone has been recommended. Its lightness and irritant properties render it, however, much less efficient than carbon dioxide or sulphur dioxide.

Hand grenades,[1] consisting of glass bottles, usually of a spherical form, charged with aqueous solutions of various chemicals, have found their way of late years into somewhat extended use. They are conveniently arranged in the corridors of large buildings, and are intended for use in extinguishing incipient outbreaks of fire. The grenade is to be thrown with such force into the center of combustion that it breaks and scatters its contents upon the burning material. The salts present are supposed to act by either giving off incombustible gases or by incrusting the burning articles, thereby excluding air. In practice, however. it is found that these grenades render but slight service, as they are frequently unbroken when thrown, especially against non-resistant substances. They are supposed to be charged with strongly carbonated water, or with a saturated solution of ammonium chloride, sodium chloride, sulphite, or thiosulphate. Analysis, however, shows quite a variety of composition in the contents. Sir Frederick Abel,[2] in 1881, found one to contain a strong solution of salt and waterglass. Geissler examined three current types with the following results:[3]

Hayward's Grenade.—Gross weight 1,120 grams; weight of liquid. 750 grams; composition, an aqueous solution of 15.7 per cent. calcium chloride and 5.6 per cent. magnesium chloride.

Harden's Grenade.—Gross weight. 900 grams; weight of liquid, 555 grams; composition. an aqueous solution of 19.5 per cent. sodium chloride, and 8.9 per cent. ammonium chloride.

Schonberg's Grenade.—Gross weight, 770 grams; weight of liquid, 440 grams; composition, an aqueous solution of 1.66 per cent. sodium carbonate, and 6.4 per cent. sodium chloride.

It may be noted in passing that the salts in these grenades cost about one per cent. of their selling price.

Finally, mention should be made of extinguishing powders,[4] the use of which is literally a fighting of fire with fire. They

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[1] Hexamer, *loc. cit.*

[2] Amer. Arch. 13 and 14.

[3] Pharm. Centrbl., *1885*. 447.

[4] Hexamer, *loc. cit.*

are well devised to produce, by rapid combustion at the expense of the oxygen in saltpeter, a sufficient volume of inert gas—chiefly sulphur dioxide and carbon dioxide—to prevent the circulation of air about a fire, and thereby cut off the supply of atmospheric oxygen for further combustion. Their application is, of necessity, limited to small enclosed spaces without many openings for ventilation, and they have been found chiefly valuable in drying rooms where easily volatile products are being driven off, as in connection with the manufacture of oilcloth. The ingredients are coarsely powdered and readily ignited. They are often packed in cartridges and provided with fuses. They burn without explosion, with a bright white flame, a strong odor, and much smoke. Each pound yields about four and eight-tenths cubic feet of gas, which consists of two and three-tenths sulphur dioxide, one and one-tenth parts carbon dioxide, and one and four-tenths parts nitrogen. One pound should be used for every 240 cubic feet of an enclosed space. The composition of the best known of these powders is as follows:

Bucher's powder	KNO_3	60 parts.
	S	36 "
	C	4 "
Heeren's powder	KNO_3	63 parts.
	S	29 "
	C	4 "
	Fe_2O_3	4 "
Schweizer's powder	KNO_3	58 parts.
	S	36 "
	C	3 "
	Fe_2O_3	$1\frac{1}{4}$ "
	SiO_2 (sand)	75 "
Gruneberg's powder	KCl	20 parts.
	KNO_3	50 "
	S	50 "
	MnO_2	1 "
	Rosin	10 "
Zeisler's powder	KNO_3	60 parts.
	S	36 "
	C and CaO	4 "

Johnston's powder	Equal parts of KCl, KNO_3, MnO_2 and Rosin, moistened with waterglass and pressed into briquettes.	
Phillips' Fire Annihilator (introduced in 1851.)	KNO_3	60 parts.
	C	20 "
	$CaSO_4 + 2H_2O$	5 "

This latter was pressed in the form of a hollow brick. The central cavity contained sugar, and potassium chlorate and a vial of sulphuric acid, the latter so arranged as to be easily broken by a simple mechanical device. The brick was usually placed within a double cylindrical receiver containing water, so that the ignition of the powder caused not only the evolution of a large volume of gas, but also, by its heat, a liberation of a considerable amount of aqueous vapor.

In reviewing this portion of our subject it would appear that but few opportunities are afforded the chemist for further contributions of value. It would seem advisable, however, to study the feasibility of extending the use of carbon dioxide along lines similar to those in which automatic sprinklers have found such satisfactory application. In many factories and in numerous stores and warehouses the sprinkler, while most effective in quenching flame or hampering its progress, causes serious damage to manufactured products or materials for manufacture. The advantages of carbon dioxide over water under these conditions are manifest. It is not difficult to conceive of a system of piping, opening naturally at the level of the floor, through which either automatically or under the control of a watchman, a powerful current of the gas could be directed into any apartment where flame was apparent. In the many cases where the losses by water do and would naturally far exceed the losses by direct combustion, there is but little doubt that the use of the invisible, inert, harmless gas would enormously limit the destruction of valuable property.

We come now to the most important division of our subject; namely, the methods of preventing loss or suffering by fire through the use of structural materials, textile fabrics, and the like, which are either entirely incombustible or slowly combustible or from which the property of rapid combustion has been largely removed by special treatment. A structure built entirely of stone. brick, iron, cement, etc., is an illustration of the first type. A structure of brick with heavy beams of wood, heavy floors of plank, no hidden air-spaces, and a general absence of the lighter forms of woodwork, illustrates the second type,—the slow combustion construction. The third type is to be found in an edifice of wood, the component parts of which, either by impregnation or by suitable coatings, have lost the property of ready inflammability.

The study of the choice of materials and their most efficient grouping as employed in the first and second methods of construction, apart from architectural considerations, falls purely within the domain of the mechanical engineer. It involves the question of strains and stresses under ordinary conditions and under the conditions of an elevated temperature.

It is in the special field of rendering such easily combustible substances as wood and the vegetable fibers used in textile fabrics more or less resistant to flame that the chemist has been able to render service.

Could our methods of building be limited to the completely fire-proof or the slow-burning system of construction, and interior decoration and equipment be restricted to the use of non-combustible materials, it is evident that the chemist would have but little to do. But mechanical considerations, canons of taste and questions of outlay will, for a long time to come, sustain the extended use of wood in the erection and finishing of many classes of edifices, especially of our homes. The beginnings of our towns and cities are almost entirely in wood, and the same may be said of the suburbs of our centers of population. It will be many years before the rural residence and the home of the laborer in America will be as universally constructed of non-combustible materials as in Great Britain, France, Germany, and other European countries. In such a country as Japan it is almost impossible to imagine any general departure from the time-honored and picturesque national construction of bamboo. The restriction of fabrics to fibers of animal origin is likewise out of the question.

In noting the historical development of the work of the chemist in the field as above outlined, we will first consider the methods which have been applied to textile fabrics and paper, and next those which have been used to render wood uninflammable.

TREATMENT OF TEXTILES AND PAPER.

The first experiments in this direction were made in England in 1735 by Obadiah Wild,[1] who secured a patent for rendering the cartridge cases used by the navy resistant to flame. This process consisted of the addition of a mixture of alum, borax, and copperas, to the paper pulp employed. Early in the present century the subject attracted the attention of several chemists. De Hemptine, of Belgium, in 1821, made quite an extended study of mixtures, similar to that of Wild, and other substances. At the same time Brugnatelli recommended the use of potassium silicate, Hermbstadt of ferrous sulphate, De Lisle of an unnamed compound.[1] Gay Lussac[2] was deeply interested in the subject. In 1830, as the results of his experiments, he recommended the use of various chlorides, phosphates, borates, tartrates, and carbonates without, however, considering the difficulties involved in their application on a large scale. The employment of the alkaline carbonates was later urged strongly by Prater, while Fuchs[1] and Bethel in 1838 advocated waterglass and others, gypsum. Several patents were taken out during this period by the different investigators. Still later Chevalier recommended the use of a mixture of borax and ammonium sulphate. The use of ammonium sulphate alone was proposed by De Breza in 1838, and that of ammonium chloride by Froggant in 1857. In 1855 M. Solomon,[3] of Paris, submitted to the English Board of Ordnance a process for rendering canvas uninflammable. It consisted of immersing the materials for a day in each of the following baths:

I. Aluminum sulphate,	30 parts	II. Dry calcium chloride,	20 parts
Glue (gelatin),	10 "	Glue,	10 "
Water,	60 "	Water,	70 "

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[1] Versmann and Oppenheim. Report to the British Association. *1859*

[2] *Ann. chim. phys.*., 18, 211.

[3] Amer. Arch.. 13 and 14.

[TO BE CONTINUED.]