A PRACTICAL TREATISE

ON THE FABRICATION OF

MATCHES, GUN COTTON, COLORED FIRES

AND

FULMINATING POWDERS.

BY

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PREFACE.

IN 1830, the fabrication of matches was not yet, properly speaking, a special industry. It was limited to a few poor families, who not having the means to purchase in any quantity the materials necessary to the fabrication, were forced to sell, from day to day, the product of their labor in order to be able to purchase new material.

The want of a machine which would economically manufacture wooden matches presented an insurmountable barrier to the development of that industry.

The work was done by hand, with imperfect tools, which very often wounded those who used them. After the invention of the first machine to cut matches, a single man could manufacture daily from 1800 to 2000 matches.

Chemical improvements favored also the development of this industry; oxygenated tinder-boxes largely increased; and, at last, the invention of inflammable mastic produced a complete revolution.

This new fabrication, of German origin, was established in other countries after a certain time.

In 1836 few factories were in operation, but since that time these establishments have greatly multiplied. Notwithstanding this rapid progress, the hygienic character of the business has not been much improved. While it may be considered as an industry most injurious to health, yet hygienists have not given us much light on the subject. The accidents which their fabrication, cartage, use, etc., are liable to produce in so great numbers have not yet been the object of scientific investigation.

The question of gun cotton is probably one of the most interesting which has risen into notice in the midst of the scientific movement of these last thirty-five years. The doubt has increased concerning the real value of this product and its applications. It is, therefore, useful to collect carefully all the elements of the question, to arrange them methodically, and to judge them with calmness and impartiality. It is with these views that this work has been composed.

First, we have shown the present state of knowledge concerning the composition and nature of its pyroxylic products, its ballistic properties, its applications in pyrotechny, surgery, photography, mining, etc.; its preparation, and the accidents which are liable to take place during this preparation; the accidents no less serious which result from the handling of gun cotton, and its application to fire-arms.

Lastly, we have shown the causes of these accidents, the means to prevent them, and the processes of distinguishing gun cotton from ordinary cotton, not only in common use, but also in cases where it will be necessary to proceed to a judiciary inquest.

To the fabrication of matches and gun cotton, we have added researches upon a subject well worth the attention of hygienists.

Every one knows what development has taken place in the fabrication of fulminating powder, since percussion guns have been invented and used for war purposes; but, what is not so much known, is that this fabrication is of all industries, not only the most unhealthy, but the most dangerous.

To state those dangers, and in a few words indicate the means which science offers in order to prevent them, is one of the objects of the last section of this work.

NEW LEBANON, June 25, 1864.

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MATCHES, GUN COTTON, COLORED FIRES, AND FULMINATING POWDERS.

SECTION I.

CHEMICALS USED IN THE FABRICATION OF MATCHES.

CHAPTER I.

PHOSPHORUS.

Formula Ph. *Equivalent* = 32.

1. History.

Phosphorus was discovered in 1669, by Brandt, alchemist of Hamburg. He was engaged in researches on the philosopher's stone, or the art of converting common metals into gold. Brandt thought, that by mixing urine with the metals that he wished to transmute, he should succeed better; but instead of obtaining what he was searching for, he discovered a new body, luminous by itself, burning with an energetic power. It was the *phosphorus.* Surprised by the appearance of this new body, he sent a specimen to Kunckel, a German chemist, who showed it to Kraft, of Dresden. This latter found it so marvellous, that he immediately started for Hamburg, with the intention of buying the secret of its preparation; and, accordingly, he bought it for two hundred dollars, on condition that the secret would not be revealed. Kunckel, wishing to know it, and seeing that Kraft would not reveal it to him, resolved to discover it by experimenting himself, and, after many trials, he succeeded in 1674.

However, the process of preparation was kept secret till 1737, at which epoch, a stranger coming to Paris, made some of it before four commissioners named by the Academy of Sciences, *Hellot*, *Dufay*, *Geoffroy*, and *Duhamel.* When the preparation was made public, Hellot described it, with details, in 1737,* and Rouelle repeated it in his public lectures of the same

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* Mémoire de l'Académie des Sciences, for 1737.

year. The process consisted in evaporating to dryness, putrefied urine, and heating strongly the residue in an earthen retort, the neck of which communicated with water.

Phosphorus was prepared by this process for some time; and a few years after, by the advice of Margraff, a salt of lead was added to it. Notwithstanding this useful addition, phosphorus was so rare that it passed for an object of curiosity, to be found only in chemical laboratories.

In 1674, Gahn discovered it in bones, and with Scheele published a process which permitted of obtaining it in considerable quantities. It is this same process, slightly modified, which is now followed.

Phosphorus becoming more common, chemists could study its properties. The most remarkable works on this subject are those of *Pelletier*, who combined it with sulphur and some metals; *Lavoisier*, who discovered its combinations with oxygen; *Dulong* and *Davy* studied its different acids, and *Berzelius* not only examined them, but also their combinations with bases.

2. Physical Properties.

Phosphorus is solid, insipid; pure, it is so flexible that it can be bent seven or eight times without breaking. One six hundredth part of sulphur is sufficient to render it brittle.

The nail scratches it easily, the knife cuts it without any difficulty.

Its specific gravity = 1.77. Its odor is weak, and similar to hydrogen gas or arsenic in vapor. Sometimes it is transparent and colorless, sometimes transparent and yellowish, sometimes half transparent as horn, sometimes black and opalescent.

In the dark it is always luminous, provided it has the contact of the air; from that property, its name of two Grecian words, φωσ, light, and φορος, bearing.

3. Chemical Properties.

Phosphorus melts at 111°.45, and boils at 554°. Its vapor is colorless, with a density =

4.328. Exposed to a heat of 140 to 158°, and suddenly cooled, it becomes black; by cooling slowly, it stays transparent and colorless; a moderate cooling gives it the aspect of horn; from black it becomes colorless by fusion, to become black again by cooling.

Mr. Thenard was the first to observe these phenomena. He thought they were common to every kind of phosphorus, but since, he has had occasion to ascertain that such is not the case. He found that phosphorus was susceptible only of those different aspects, even after distilling as often as three or four, and even eight or ten times.

The distillation of phosphorus must be made carefully, and in small quantities, otherwise the facility with which this body burns renders it dangerous.

The phosphorus must be introduced into a small glass retort, fixed in a small furnace. The neck of the retort, which must be kept warm, communicates with water at about 190°. Heat the phosphorus by degrees till it boils, and continue the heat till the whole is distilled.

The distillation is made below red heat, and does not require even 392°. It always leaves in the retort, a little red powder of oxide of phosphorus.

Solar light colors it red without rendering it opalescent; and this change is effected, not only in the air, but also in vacuum.

Phosphorus kept over mercury, in a glass tube full of oxygen, at a temperature of 80°, and under a pressure of thirty inches, does not absorb oxygen in twenty-four hours; but if the temperature remaining the same, the pressure is diminished, so as to be only two or three inches, the phosphorus begins to be surrounded by a white vapor. It becomes luminous in the dark, it dissolves the gas oxygen by degrees, and forms *hypo-phosphoric acid.* The less the pressure, the less heat is needed to produce combustion; nevertheless, it will not burn at 41° or below.

If in the above experiment the pressure is increased, the combustion is determined only at a higher temperature.

The addition of more or less quantities of nitrogen, or hydrogen, or carbonic acid, to a given volume of oxygen, produces the same effect. The diminution of pressure is the reason why phosphorus is luminous in the the air, burns slowly in it, and absorbs oxygen to isolate the nitrogen.

Phosphorus is reduced sensibly in vapor, at the ordinary temperature, in all gases which do not attack it.

Phosphorus burns in a mixture of air and oxygen, containing four of oxygen and three of nitrogen, the oxygen being absorbed.

If solid phosphorus acts very slowly on oxygen, it is very different when melted; it immediately absorbs and solidifies the gas, and the result is *phosphoric acid*. The disengagement of heat is so violent that the eyes cannot bear it.

Besides phosphoric and hypo-phosphoric acids, phosphorus produces two other acids, and one oxide, then it unites with oxygen in five proportions.

It possesses the property of combining with a great many simple bodies, viz., hydrogen, sulphur, selenium, chlorine, bromine, iodine, and all metals. Its union with carbon and nitrogen is a problem. Those that it can make with barium, silicium, fluorine, have not been studied.

As phosphorus has a great action on air, it must be kept in bottles containing no particle of this fluid. For this purpose, boiled water is cooled without the contact of the air, and the phosphorus is introduced into it. The bottle is shut, and kept in a dark place; but, notwithstanding this precaution, phosphorus covers itself with a white crust composed of four of phosphorus and one of water. To preserve it from this alteration, it must be moulded in the form of sticks, and kept in this state in bottles full of water.

4. NATURAL STATE.

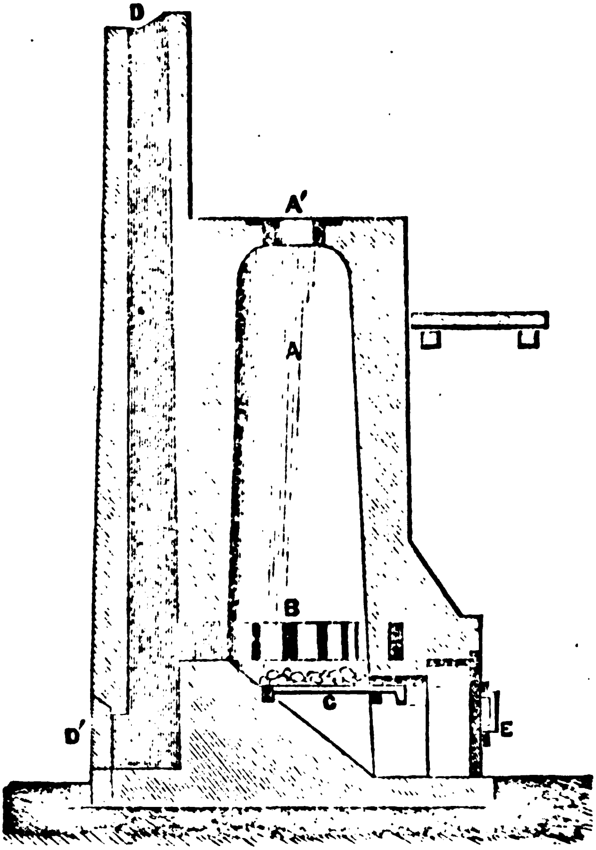
Since phosphorus burns with so much facility, it does not exist pure in nature; and in which it has been met only in combination with other bodies, viz., with oxygen, and metallic oxides, in some phosphates, particularly the phosphate of lime, which forms the solid basis of bones of animals, in the milt of the carp, and a part of the cerebral matter and nerves, substances composed of oxygen, carbon, nitrogen, and phosphorus.

5. EXTRACTION.

Phosphorus is extracted from calcined bones, which have been heated to the red heat in contact with the air, so as completely to destroy the organic matter. This combustion can easily be made in a lime-kiln. This kiln is surmounted with a reverse cone, terminated by a pipe, more or less long, so that the gases can be directed into a chimney.

Oven.—A particular disposition which permits an avoidance of the disagreeable odor, and renders the operation more economical in burning all the gases, is indicated in Fig. 1.

Fig. 1.



This disposition consists in a cylindrical oven, *A*. The upper aperture of which, *A′*, is narrow and provided with a cast iron muff; near the lower part, the aperture *B* is put in communication with the body of the furnace with a circular gallery leading to the chimney *D*; a grate *C*, supported by two transverse bars, which are fixed in the beginning of the operation, the door *E* being open. The grate is loaded with combustibles, which are lighted under it. When the fire is well-lighted, shut the door *E*, and in the low part of the chimney *D*, by an aperture *D′*, light a few handfuls of shavings to establish a draught. Shut the aperture *D′*, when the flame passes by the aperture in the circular gallery, and thence into the chimney. Begin to load with bones, the organic matter of which accelerates the combustion which is complete; all the gaseous products passing through an incandescent mass. When the furnace is full, shut almost completely for a few minutes the upper mouth *A′*, then withdraw the bars of the grate *C*, so that the burned bones fall on to the ground. After this operation, shut again the door *E*; fill the furnace with new bones, and from time to time extract the burned bones through the door *E*, which is shut immediately, and new bones are introduced by the aperture *A′*. The combustion is uninterrupted, and operated without any other combustible than the substance of the bones itself. The incombustible residue of this operation is so formed:—

Sub-phosphate of lime . . .	80	to	82
Carbonate of lime	15	to	17
Sand	5	to	1
	100		100

Pulverization of the Bones.—The burned bones are reduced to a fine powder, and passed through a sieve; the coarse powder is ground over again and again, until the whole is entirely powdered.

Decomposition by Sulphuric Acid.—To produce this decomposition, that is, to transform the sub-phosphate of lime ($8CaO3PhO_5$) into sulphate, and bi-phosphate, and the carbonate of lime ($CaOCO_2$) into sulphate of lime, use a quantity of sulphuric acid, equivalent to the lime contained in the bones, in excess of the quantity which could form a bi-phosphate of lime, that is, for 100 of powdered bones, 66 of concentrated sulphuric acid, or rather the equivalent = 100 in acid not concentrated, and marking 50°.

The operation is effected in a tub lined with lead. Pour, at first, twenty-five gallons of boiling water, then forty pounds of acid at 50°, in which you dilute by degrees, with a wooden spatula, forty pounds of powdered bones.. An effervescence is produced by the disengagement of carbonic acid gas. When the effervescence has stopped, begin four times a similar operation; then you have in the tub, 160 pounds of bones decomposed by 160 pounds of acid, at 50°. The matter, while warm, must be stirred from time to time to favor the reaction. Leave 24 hours, stirring occasionally; leave it to rest 12 hours, and decant the clear liquid by a wooden tube, which leads it to the filters, and then into the evaporating pans.

Washing.—Dilute the first settlement with a quantity of water equal to the first; leave it to settle, and use this liquid to pass it on five or six other deposits. By this way the washing liquors are saturated to 10 or 12° in the fifth or sixth barrel, while the first is exhausted by the successive additions of water. Take out the deposit, and begin another operation.

This methodical washing can be substituted by a methodical filtration, in barrels provided each with a double bottom, and covered with a cloth.

All the solutions being saturated enough, are concentrated to 24°, and are put into a leaden vessel, in which the sulphate of lime, rendered insoluble by the concentration, is deposited.

Decant the liquid, which runs through a flannel filter to eliminate the sulphate of lime. Evaporate till it marks 33°. Leave it to settle, and decant anew.

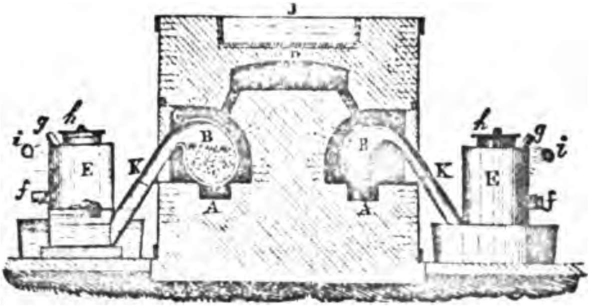
Concentration—Mixing—Desiccation.—The filtration being completed, evaporate to syrupy consistence till the liquid marks 50°. This syrup, mixed with 20 per cent. of its weight of finely powdered charcoal, is submitted to a last evaporation till completely dry, in a cast-iron kettle, heated brown red, and stirring all the time.

The excess of sulphuric acid decomposed by the carbon disengages a large quantity of sulphurous acid, and it is for this reason that the operation must be performed under a chimney with a good draught.

When the mixture is as dry as possible, proceed to its decomposition at a red heat, so as to have the carbon react on the phosphoric acid which constitutes the phosphate acid. It takes the oxygen from this acid, and permits the phosphorus, set free, to pass to the distillation.

Decomposition of the Mixture, and Distillation of the Phosphorus.—This operation is effected in earthen retorts, which are filled three-quarters full. The retorts are inspected, so as to be sure that they are sound; they are covered with a coating of argillaceous earth, they are dried slowly and completely, then placed on two ranks into a furnace, with a double vault, as represented in the Fig. 2.

Fig. 2.



Each rank of five retorts is heated by a hearth situated a little above and below the hole *A*. The flame which extends under the vault escapes by vent-holes, situated above each retort. These vent-holes are gradually larger, better to regularize the temperature. The products of the combination engage under a general vault *D*, which direct there towards the central chimney. A lead basin *J*, put on cast-iron plates, is used to concentrate a part of the solutions; utilize the lost heat, and prevent the top of the furnace from becoming too warm.

The beak of each of the retorts *B* is joined to an adapter in copper *K*, which itself enters into the beak of a receiver of copper *E*. These two joints are carefully heated with a mixture of hydrated lime mixed with blood, iron filings, and powdered sulphur, or a mixture of dry powdered clay and linseed oil forming a thick paste.

The receiver presents a large aperture through which the arm can easily pass, and which is shut by a covercle *h*; a little adjutage *g* is left open for the disengagement of gases, and another lateral adjutage *f* is used as a "too full." All the retorts being thus disposed, brick up the front part of the oven *C*, under the vault, then light the fire, that is gradually raised for 12 hours, so as to avoid sudden changes, which would break the retorts. Begin to heat with coal, which, by its regular combustion, and its less calorific power of equal volume, decrease the chances of breaking the retort; terminate it by using dry wood, the lower flame of which surrounds the retorts better. Keep up the temperature till all disengagement of gases has stopped. At first, it disengages air mixed with vapor of water, then hydrogen and oxide of carbon produced by the action of the charcoal on the water of the acid phosphate. Later, when the acid begins to decompose, phosphuretted hydrogen is mixed with the oxide of carbon, and this gas produces white vapors, which are sure signs of the beginning of the production of phosphorus. The volume of the liquid now increases in the receiver. Let a part run out by the adjutage *f*, to avoid too great a pressure. Raise the temperature, so as to sustain the disengagement, and when it has completely stopped, which is the case after three days and two nights, the operation is completed.

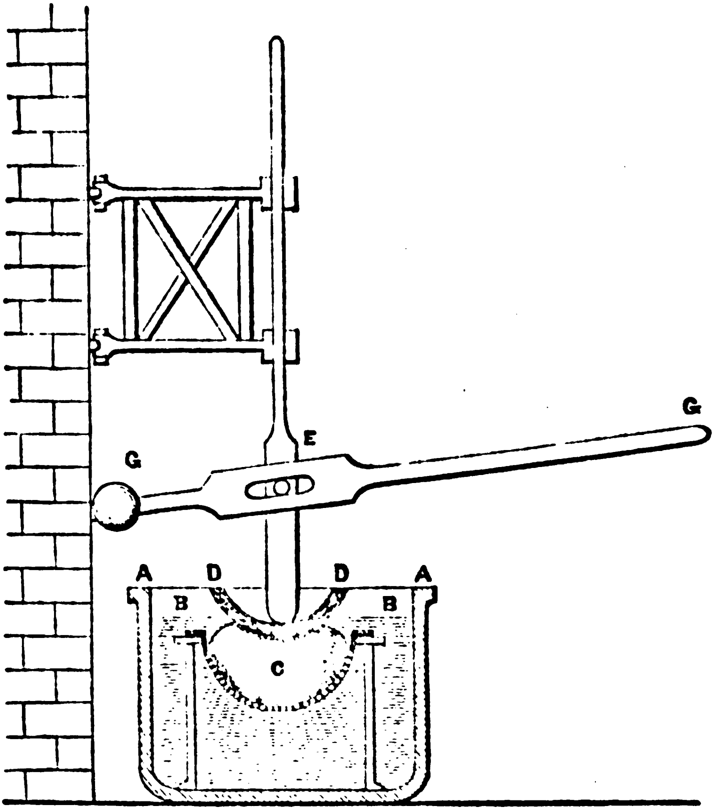
If the beak of the receiver is not large enough, it will fill towards the end of the operation, and it is necessary to clear it every hour with a little bone spatula, being careful to have the hand covered with a glove of chamois skin, and well saturated with water. It is usual to press and immerse in water the the first portions of phosphorus, which swim to the surface, and which may take fire during the operation. When the inside opening of the tube *K* is clear, the arm and the aperture *h* must be surrounded by a wet cloth, and the tube *g* ought to be shut to prevent the entrance of the air, which might cause a combustion of that part of the phosphorus which is on the surface. It often happens that the temperature rises in the receiver, in which case it can be cooled by pouring cold water into it, which is taken out by the adjutage *f*. It is better to fix under all the receivers a kind of gutter, as indicated in the Fig. 2; then dispose in front of the receivers a tube *i*, which is adapted, at will, to the cork of a superior reservoir, so that by opening this cork the water is projected in a fine stream by the tube *i*, on the receivers, and cools them.

6. PURIFICATION AND MOULDING, OR GRANULATION OF PHOSPHORUS.

When the distillation is completed, take out the adapter *K*, and dip it into cold water. Extract the phosphorus of each receiver to clear it from the dirt it may contain. Then filter it through a chamois skin; for this purpose agglomerate it by melting it under water at 140°; when solidified by cooling, envelop it in a damp chamois skin, of which make a little knot *C* (Fig. 3), which is dipped immediately in a copper dish kept in the middle of a receiver *A*, full of water at 122°. When the fusion is complete, press the little knot with a wooden dish *DD*, on which you press with a lever *G*, *G*, so as to cause a very slowly graduated pressure. The melted phosphorus passes through the skin, and reassembles liquid in the bottom of the vasis.

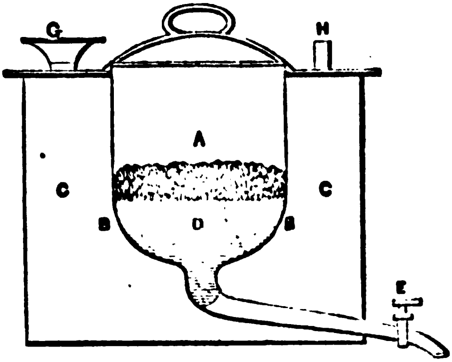
The operation of producing phosphorus is more complete and less dangerous by filtering it while warm on animal black. The black is spread on a bed of about 5 inches on the false

Fig. 3.



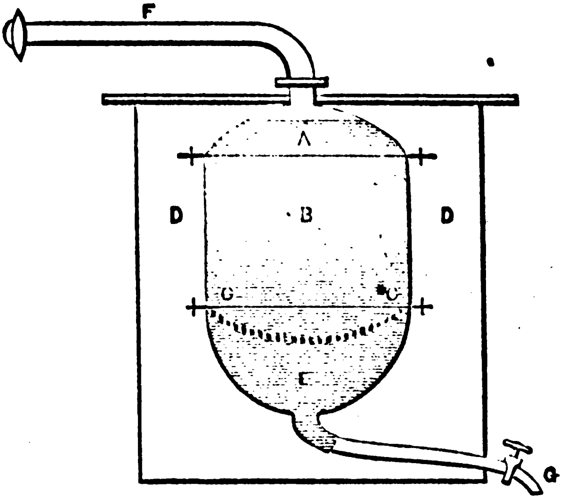
bottom, pierced with holes *B*, *B*, of a cylindrical receiver *A* (Fig. 4).

Fig. 4.



This receiver has previously been two-thirds filled with water heated to 140° by the water-bath *C*. The water covers the phosphorus; it filters spontaneously through the black, passes under the false bottom in *D*, and it can then be run out by the faucet *E*, put in communication by a tube with another cylindrical receiver *B* (Fig. 5), terminated by two hemispherical cups. This latter receiver, also heated over a water-bath *D*, *D*, has a false bottom pierced with holes, and covered with a chamois skin *C*, *C*. The receiver *B* being full of water,

Fig. 5.



open the faucet of communication *E* (Fig. 4), adapted to the tube *F* (Fig. 5). The phosphorus displaces the water, and deposits on the chamois skin. It is covered by a bed of water *A*.

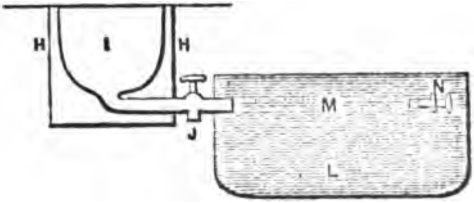
Then adapt the tube *F* to a pump, with which draw the hot water, and stamp it again in the receiver *A*. The pressure compels the phosphorus to go through the chamois skin, and it passes under the false bottom in *E*. Let it run by the tube *G*, to which is adapted a draught-tube, which conducts it under the water of an inferior receiver.

We see that the operation is conducted without danger, and with economy. The last operation consists in moulding the phosphorus. The process generally followed consists in forcing it up through a tube, by aspirating the air with the mouth, being careful to keep a bed of water interspered between them. Shut afterwards with the finger the upper end of the tube, which is carried immediately in a receiver full of cold water, where the phosphorus solidifies and contracts. It is extracted in the form of cylindrical translucent sticks.

Another method of moulding it is indicated by Fig. 6. The phosphorus is liquefied exactly to its point of fusion over a water-bath *H*, *H*, in an elliptical or conical vasis *I*, in the bottom of which is an elbowed tube, terminated by a faucet *J*, soldered to the partition of a receiver

L, *L* containing water. Into the socket of the faucet a glass tube *M*, *M*, the faucet being then opened, the phosphorus runs into the tube

Fig. 6.



where it comes to within 1 or 1¼ inches of the end, and solidifies. Shut with the finger or with an obturator *N*, the end of the tube. Take it out and dip it into a receiver full of cold water, so as to extract the stick of phosphorus, when replace the tube, and repeat the same operation. It is better to leave the tube *M*, *M*, fixed at the end of the faucet, and attach to the cork *N* a piece of copper rod. When the phosphorus is solidified around that rod, draw the cork which carries away the cylinder of phosphorus. The faucet staying open, the liquid phosphorus continues to flow into the tube, and to solidify. Thus you obtain a length of solid product limited only by the quantity of matter, and which is cut at will into sticks more or less long.

The same disposition renders the moulding in form of grains very easy. It is sufficient to pour on a shelf, at the surface of the cold water, and to the height of the tube, a bed of tepid water at about 104°, and of a thickness of two or three inches, which does not mix with cold water on account of its density; then open moderately the faucet *J*, so that the phosphorus can run drop by drop. It is easy to understand that every drop in traversing the cold mass solidifies, and then the phosphorus collects in the form of grains at the bottom of the receiver. This granular form is more convenient for weighing than the cylindrical.

In the above operation, a double furnace containing ten retorts, produces 24 pounds of phosphorus. The time of the full operation is four days. With four of such furnaces, by admitting 300 days' work in the year, the product will be 7200 pounds of phosphorus.

Each retort costs from 50 to 60 cents, and when of crucible earth costs 80 cents. They are used but once, for the residuum is so hard that it cannot be extracted without breaking the retort. A chamois skin lasts only once, for its pores being full of dirt the phosphorus cannot filter through it.

The chances of breaking the retort diminish the production from 11 to 9 and even 8 per cent. of burnt bones.

CHAPTER II.

AMORPHOUS PHOSPHORUS.

In 1851, Dr. Schrotter made known the mode of preparation on a large scale, and the properties of this kind of phosphorus isomeric with the white one.

PROPERTIES.

Amorphous phosphorus has a violaceous brown-red color, opalescent, hard, easy to pulverize. Its specific gravity = 1.964 at the temperature of 50°, whilst at the same temperature the specific gravity of the ordinary phosphorus = 1.830. It becomes luminous at 392°, is not inflammable in the air except if its temperature is above 392°; and a remarkable phenomenon is that it will burn under the influence of direct solar rays at a temperature of 131°. It can be preserved in the air without alteration, and sulphuret of carbon, ether, naphtha, and alcohol cannot dissolve it. This variety, hardened by a prolonged heat, is more resisting, and has that very remarkable property of not being venenous, and of being inflamed in the air by rubbing in presence of chlorate of potash. These two properties explain the utility of its application in the fabrication of matches.

PREPARATION.

To obtain amorphous phosphorus according to Schrotter's process, the white phosphorus must be kept in a close vessel at the temperature of 536° for from eight to twelve days, heating it very gradually for two days, a little above 464°, to avoid the ebullition of the phosphorus. Then heat by degrees up to 536°, being careful not to exceed this point, for amorphous phosphorus will be reduced into vapors, and form again the ordinary phosphorus. These conditions are realized with three concentric receivers of cast-iron, having the form of crucibles. The largest one constituting a water-bath, containing an alloy of equal parts of lead and tin. The second vessel dipped in this one contains powdered sand forming a sand-bath, in which is placed the third vessel, which last one contains the phosphorus, and transmits the temperature received by the intermediary of the two baths of alloy and sand.

Schrotter placed in this third vessel, a china vessel, having a similar form, and this latter receives the phosphorus.

A cast-iron covercle is adapted to the third vessel; this covercle is maintained by a screw, which presses strongly on the centre. In all cases, the covercle of the third vessel has a furrow in which is fitted the threaded end of a copper tube curved as a syphon; and of which the opposite end goes into a little kettle containing mercury. This pipe is provided with a faucet to shut off the communication between the receiver and the mercury when the operation is completed. During all the time that, with the help of the two baths, the temperature is maintained at 536°, a little lamp should be placed under the tube to keep the temperature sufficiently high to liquefy the phosphorus which can be carried away by the phosphuretted hydrogen gas, and will shut the tube if not heated.

After gradually heating the double bath to disengage the air and vapor of water, raise the temperature till disengagement of vapors which burn in the air. One or two hours after, raise the temperature 392°, then to 464°, and at last to 536°, and keep it at this point for ten days.

M. Coignet, of Lyons, has done away with the bath. He heats the phosphorus directly with the same care in a cast-iron vessel which holds 400 pounds. Five similar vessels, holding together 2000 pounds of phosphorus, or 4000 in one month can furnish enough for the entire consumption of the United States at the present time. After cooling, the phosphorus is found hardened. It is then broken with a hammer, and taken out, ground in a mill with water, passed through a sieve, and washed with sulphuret of carbon to dissolve the white phosphorus which has not been transformed.

Another method of separating the white phosphorus, consists in exposing the amorphous phosphorus to damp air, when the white phosphorus acidifies, and it is only necessary to wash with water to dissolve the acid.

The surest and most economical method of eliminating the white phosphorus is that followed by Mr. Coignet. It consists in submitting phosphorus to the action of a boiling solution of caustic soda, which attacks and dissolves the ordinary phosphorus, and forms a soluble hypophosphite, and disengages phosphuretted hydrogen. The ebullition is then continued, and the alkaline solution changes until all fetid odor has disappeared. It is then well-washed with water until all the soda is removed.

After the operation, the amorphous phosphorus is dried, and used as we shall hereafter indicate in the preparation of matches.

USES OF THE TWO VARIETIES OF PHOSPHORUS.

The principal uses of the two kinds of phosphorus consist in the manufacture of matches. For this purpose the annual consumption in France is about 72,000 pounds, while for all other uses the consumption is not more than 1,000 pounds.

CHAPTER III.

SULPHUR.

Formula S. *Equivalent* = 16.

PROPERTIES.

SULPHUR is a substance found abundantly in nature, sometimes isolated, and sometimes in combination with a great number of metals.

Sulphur may be obtained in three states. At the ordinary temperature it is solid; heated above 232° it melts, and furnishes a very limpid, canary-yellow fluid; heated at 750° it boils and distils.

Sulphur will crystallize at a low temperature by dissolving it in a volatile liquid. The sulphuret of carbon is its best solvent.

Melted sulphur is perfectly limpid, and of a clear, yellow color. Further heated, its color becomes deeper, and it loses its fluidity. At

320° it flows with difficulty, and its color becomes brown.

Sulphur burns with a bluish flame, giving out the well-known suffocating smell which needs no description. Sulphur combines with oxygen in various proportions, two of which are extensively used, the *sulphurous* and *sulphuric acids.*

Its fracture is light, its specific gravity = 1.99, and its equivalent = 16.

It combines with all metals and metalloids but nitrogen.

NATURAL STATE.

Sulphur is found native, and in combination with iron, lead, mercury, antimony, copper, and zinc.

It is met also in many sulphurous waters united with hydrogen, in several plants, and a few animal matters.

EXTRACTION.

Sulphur found in the trade is generally pure enough for the fabrication of matches.

CHAPTER IV.

RED OCHRE—MINIUM—BI-OXIDE OF LEAD—BI-OXIDE OF MANGANESE.

Red Ochre.

The *red ochre*, or sesquioxide of iron, is violet red, less easy to melt than iron, unalterable by heat, without action on oxygen or the air.

The sulphuric and hydrochloric acids dissolve it easily.

It exists very abundantly in nature; it is the sesquioxide of iron which colors the argilaceous earths. It can be obtained by different processes: 1st. By calcining iron in contact with the air; 2d. By decomposing the salts of sesquioxide of iron by ammonia; 3d. By decomposing the nitrate or carbonate of iron by heat. The cheapest process is to decompose the sulphate of sesquioxide by heat.

The sesquioxide of iron has several uses. In the fabrication of matches it is employed to color fancy matches.

The *yellow ochre*, or sub-sulphate of iron, is a natural product.

MINIUM.

Minium is an oxide of lead, pulverulent, yellowish-red; it is formed of two eq. protoxide of lead, and one bi-oxide, and is represented by $2(PbO)PbO_2$.

It is prepared in the following manner:—

Calcine the lead in a reverberatory furnace till converted into yellow oxide; the mass is well ground, and the powder submitted to the action of a current of water, which carries away the oxide. Collect it, and dry it, and in this state it is called MASSICOT. Have ready some sheet-iron vats, 4 to 5 inches deep, containing 50 pounds of massicot, and put them into the reverberatory furnace which has been used to prepare the massicot, and leave them over night. The oxide absorbs the oxygen, and passes at the state of red oxide or *minium*.

One fire is not sufficient, and the operation must be repeated several times.

The more thoroughly the oxide is divided, the more readily is it converted into minium.

As found in the trade, it is pure enough for the fabrication of matches. It is employed to color matches, and prepare the bi-oxide of lead.

BI-OXIDE OF LEAD.

This oxide has a flea color. Air and oxygen have no action on it. Heat transforms it first into minium, then into protoxide of lead.

Rubbed in a mortar with sulphur it takes fire, and produces sulphurous acid and sulphuret of lead. Hydrochloric acid decomposes it into water, chlorine, and chloride of lead.

The bi-oxide of lead does not exist in nature. It is represented by PbO_2.

It is better for the manufacturer of matches to prepare it himself, for it is rarely found in the trade, and generally it is not pure. It is prepared by treating the minium with nitric acid. For this purpose introduce 1 part of minium in a glass or earthen vessel, pour on it 5 to 6 parts of nitric acid diluted with its weight of water; raise the temperature by degrees to ebullition, shaking from time to time. The minium is decomposed; it gives its protoxide to the acid, and the bi-oxide is set free. When the decomposition is achieved, which does not take more than half an hour, fill the vessel with hot water, and let to settle, the bi-oxide deposits. Decant the clear liquor which contains the nitrate of lead, and substitute for it pure warm water; decant anew, and continue the same operation until the water has no taste. Collect the precipitate on a filter, and dry it at a gentle heat.

It can also be prepared in the following manner:—

Boil a solution of acetate of lead with an excess of chloride of lime in solution. Wash the precipitate on a filter to eliminate the salts, and dry it at a gentle heat.

This oxide is now largely used in the preparation of matches.

BINOXIDE OF MANGANESE.

The binoxide of manganese, such as found in the trade, is pure enough; but it is better to treat the commercial oxide by diluted hydrochloric acid until all effervescence has stopped. Let it settle, decant, and wash the residue with warm water until this water has no longer any taste. Collect the oxide on a filter, and dry it.

CHAPTER V.

SULPHIDE OF ANTIMONY — OXY-SULPHIDE OF ANTIMONY—SULPHURIDE OF MERCURY (VERMILION)—CYANIDE OF LEAD.

SULPHIDE OF ANTIMONY.

THIS sulphide (per-sulphide) Sb_2S_3 is orange yellow. Heat decomposes it into sulphur and proto-sulphide. Hydrochloric acid dissolves it with disengagement of sulphydric acid and precipitation of sulphur. It is obtained by mixing a solution of perchloride of antimony with tartaric acid, and passing a current of sulphydric acid through it. The precipitate is well washed, filtered, and dried at a gentle heat.

OXY-SULPHIDES OF ANTIMONY.

When the sulphide of antimony is reduced to powder, and roasted until it has lost its metallic brightness, then melted, it produces an opalescent product with a vitreous break. It is a mixture of oxide and sulphide of antimony, which takes the name of *crocus* or *liver of antimony*, according to the proportion of sulphur it contains.

The *crocus* contains ⅛ of its weight of sulphur, and the *liver of antimony* ⅓. But as the oxide and sulphide can combine together in many proportions, it is evident that the composition of these two products must vary. The first has a yellowish-red, and the second a brown and tarnish-red color.

SULPHIDE OF MERCURY.

The sulphide of mercury (vermilion), as found in the trade, is sufficiently pure for the fabrication of matches.

The sulphide of mercury (HgS) sometimes exhibits a red color, more beautiful than that of sublimed cinnabar. Heat decomposes it into sulphur and mercury. Hydrogen, carbon, and many metals also decompose it. Nitric acid and aqua regia rarely attack it. In the fabrication of matches it is used for coloring.

CYANIDE OF LEAD.

Cyanide of lead is obtained by adding a solution of cyanide of potassium to a solution of acetate of lead, and it forms a precipitate which is washed by decantation. The precipitate is then collected on a filter, and dried at a gentle heat.

CHAPTER VI.

CHLORATE OF POTASH—NITRATE OF POTASH—BICHROMATE OF POTASH—NITRATE OF LEAD.

Chlorate of Potash.

Chlorate of potash ($KOClO_5$) is an anhydrous salt, which crystallizes in the form of small spangles. They are larger when the crystallization is effected slowly. It is much more soluble in hot than in cold water.

100 parts	water	at 32°	dissolve	3.33	parts chlor.	of potash.
"	"	56°	"	5.60	"	"
"	"	$67\tfrac{2}{3}^\circ$	"	6.03	"	"
"	"	76°	"	8.44	"	"
"	"	95°	"	12.05	"	"
"	"	$120\tfrac{1}{3}^\circ$	"	18.96	"	"
"	"	$166\tfrac{3}{4}^\circ$	"	35.40	"	"
"	"	$220\tfrac{2}{3}^\circ$	"	60.24	"	"

Alcohol does not appreciably dissolve it. Chlorate of potash fuses at 750°; at a higher temperature it parts with its oxygen, and is ultimately reduced to chloride of potassium. On ignited coals it deflagrates vividly. It is one of the most active oxidizing agents, and forms explosive mixtures with the majority of combustible substances. Thus, an intimate mixture of it with sulphur, produces a violent detonation when placed on an anvil, and struck with a hammer. Those mixtures should be made with great care, and in small quantities to avoid accidents.

The detonating mixtures, formed of chlorate of potash, are much more powerful than the corresponding mixtures made with nitre. Gunpowder, much superior to that in ordinary use, has been made with chlorate of potash, but it was excessively *explosive*, and burst the fire-arms in which it was used. Its preparation and preservation being very dangerous, its manufacture has been abandoned.

A mixture of chlorate of potash and sulphur has also been used in the fabrication of percussion caps for guns, but *fulminating mercury* is now preferred.

If a drop of concentrated sulphuric acid be thrown on a mixture of sulphur and chlorate of potash, the sulphur takes fire. Advantage was taken of that property for producing fire, and the process was generally followed until it was superseded by the phosphoric matches.

Commercial chlorate of potash is sufficiently pure; but, before using it, the manufacturer must dry it completely.

NITRATE OF POTASH.

Nitrate of potash (NO_5,KO), commonly known in commerce by the name of *nitre* and *saltpetre*, is a natural production.

It has a cool, slightly bitter taste; its density = 1.933. Subjected to the action of heat it melts at about 662°, forming a mobile liquid, which congeals on cooling, with a vitreous appearance. Heat decomposes it into *nitrite of potash.*

It is more soluble in hot than in cold water.

100 parts water at 32° dissolve 13.32 parts nit. of potash.
" " 64°.4 " 29.00 " "
" " 113° " 74.60 " "
" " 206°.6 " 236.00 " "

Nitrate of potash is a powerful oxidizing agent; thrown on ignited coals it *fuses*, increasing the combustion of the coal at the point of contact. A mixture of it with sulphur, thrown into a heated crucible, produces a vivid combustion with great evolution of light, and forms sulphate of potash. It is one of the components of gunpowder.

Nitrate of potash, before using, must be perfectly dry.

BICHROMATE OF POTASH.

Bichromate of potash $KO2(Cr_2O_3)$ has a very intense red color; its taste is fresh, bitter, and metallic; it crystallizes in large rectangular tables, anhydrous, inalterable in the air, insoluble in very concentrated alcohol, soluble in ten times its weight of water at 68°. It destroys vegetable and animal colors. It is sufficiently pure as found in the trade.

NITRATE OF LEAD.

Nitrate of lead is prepared by dissolving litharge or white lead, or metallic lead, in an excess of nitric acid, taking care in the latter case to keep the acid in excess.

The hot solution, when saturated, deposits on cooling regular octahedron crystals of nitrate of lead, which are sometimes transparent, and sometimes opalescent, but in each case anhydrous. The manufacturer of matches can make it more easily when he prepares the bioxide of lead, by evaporating the acid solution; the nitrate of lead crystallizes on cooling. Cold water dissolves only about $\frac{1}{7}$ of its weight of nitrate of lead, while it is much more soluble in hot water. Crystals of nitrate of lead decrepitate on hot coals, and feed the combustion like all the nitrates. Nitrate of lead is decomposed by heat into hyponitric acid, which is disengaged, and protoxide of lead which remains. By boiling a solution of nitrate of lead with the oxide or carbonate of lead, a liquid is obtained, which deposits, on cooling, large crystals of a basic nitrate ($2PbO,NO+HO$).

A nitrate of lead, possessing still higher basic properties is obtained by treating the nitrate or bi-basic nitrate with ammonia, when a white precipitate of the formula $(4PbONO_5 + 3HO)$ is formed. A large excess of ammonia decomposes this precipitate, and leaves hydrated oxide of lead.

CHAPTER VII.

GUM—GELATINE.

GUM.

CERTAIN substances, as yet imperfectly understood, which issue from trees, are called *gums*. Their elementary composition is the same as that of amylaceous matter, but they differ from it in several of their chemical properties. Gum may be divided into three species.

1st. *Gum arabic.*

2d. *Indigenous gum.*

3d. *Gum tragacanth.*

Gum arabic issues in the form of a viscous solution, from certain species of acacia, and after some time the substance coagulates and dries on the tree. Large quantities are imported from Senegal.

Gum arabic is found in small round masses, having a conchoidal and vitreous fracture, and its taste is sweetish and nearly insipid. It dissolves into indefinite proportions in water, imparting to it a peculiar consistence called *gummy*. It dissolves slowly in cold, and rapidly in hot water.

The purest gum arabic has always a slightly yellowish tinge; but it may be made perfectly colorless by passing chlorine through a boiling solution of gum, and drying the substance.

Gum tragacanth flows from certain vegetables of the genus *Astragalus*, which are cultivated in the eastern part of Europe. It exudes in the shape of a very thick gummy juice, which by solidifying forms small contorted strips. This gum is the mixture of several substances. The essential principle of this gum is called *bassorin;* it does not dissolve in water, but it swells, and is converted into a gelatinous substance. It dissolves in alkalies.

Nitric acid converts gums into *mucic acid.* Gum in the fabrication of matches must be used in fine powder.

GELATIN.

Common glue answers the purpose in the fabrication of matches; it is manufactured from leather scraps, tendons, horns and hoofs of animals. When heated it melts, and congeals on cooling into a remarkably coherent mass. Cold water merely softens and swells without dissolving it, while boiling water dissolves it, and forms a viscid liquid which coagulates into a more or less consistent jelly on cooling. Alcohol precipitates gelatin from its aqueous solution. Prolonged ebullition with water destroys gelatin, and it no longer coagulates. When glue is used, it is better to soak it in tepid water for 24 hours before dissolving it.

CHAPTER VIII.

COLORING MATTERS USED IN THE PREPARATION OF MATCHES.

WE have already indicated two, the vermilion and the minium, and we shall now mention a few others extensively used.

PRUSSIAN BLUE.

To prepare it, dissolve in water some persulphate of iron; pour into this solution a sufficient quantity of yellow prussiate of potash. It forms a blue precipitate; let it settle; decant the clear liquid; wash the precipitate several times with water; collect it on a filter, and dry it. It is used to color blue.

CHROMATE OF LEAD

Is prepared by adding a filtered solution of acetate of lead to a like solution of bichromate of potash, as long as a precipitate forms. Wash it with water; collect on a filter, and dry it at a gentle heat.

It is employed to color yellow.

OTHER BLUE COLORS.

Instead of Prussian blue, the ultra-marine and smalt can be used.

GREEN.

Employ the green of copper, or a mixture of chrome yellow and Prussian blue.

VIOLET.

Use a mixture of Prussian blue and vermilion.

BLACK.

Use very divided lampblack.

WHITE.

Use a little white lead or chalk.

OTHER COLORS.

Several experiments have been made of employing colors of coal tar, and have so far succeeded. As their coloring power is very strong, very little is required to color large quantities of paste. They are used dissolved in alcohol. The powdered gum is colored with it, and dried afterwards.*

VARNISH FOR MATCHES.

Some fancy matches are covered with a light varnish, which is prepared by dissolving black shellac in alcohol. The solution must be very diluted, and is sufficient to give a brilliancy to the matches.

The proportions are—

Black shellac, 1 lb.
Alcohol, 1 qt.

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* For their preparation, see Treatise on the Preparation of Coal-tar Colors. Published by H. C. Baird, Philadelphia.

SECTION II.

FABRICATION OF MATCHES.

CHAPTER IX.

GENERAL REMARKS ON MATCHES.

Among the properties which characterize sulphur, its inflammability at 482° explains its earliest application in the fabrication of matches. That fabrication has received from chemistry various and important modifications, which facilitate the means of obtaining fire and light almost instantaneously.

When, for the first time, a match could be inflamed by dipping it in a bottle full of phosphoric mastic mixed with oxide of phosphorus, the result was fine, but was far from those now obtained. This primitive invention is due to

Cagniard de La Tour, and is the foundation of the actual industry of matches inflammable by friction.

The inflammation became more easy when the end of each sulphuretted match was provided with a paste called *oxygenated*, formed of powdered sulphur, 25; chlorate of potash, 30; lycopodium, 2; cinnabar, 1½; agglomerated by 5 or 6 parts of a solution, containing 4 of gum arabic, and 3 of gum tragacanth. This mixture once dried, could be effectively inflamed when the end of the match, thus prepared, was put into contact with asbestos imbibed with concentrated sulphuric acid. This acid decomposes the chlorate of potash; sets free the chloric acid which is immediately decomposed, and produces nascent oxygen which burns the combustible substances.

The following process was an improvement: Make a very thick solution with 50 parts of gum, and add to it 20 parts of phosphorus, which being mixed with 30 of chlorate of potash, and 0.5 of Prussian blue, gave an adhesive paste. That paste, dried at the end of the matches, took fire by friction. All these processes were very imperfect, and have been much modified.

Now the fabrication of matches is carried on in considerable establishments, which occupy several hundred men. It exists also in small factories, worked only by a single family. But, as generally those small factories do not work regularly, all the operations here indicated are done only in large establishments.*

The fabrication of matches is divided into a series of operations which we shall enumerate and describe rapidly in the following order:—

1. Fabrication of wooden matches.
2. Cutting and splitting of the wood.
3. Making of boxes.

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* In Germany there are very important manufacturers of matches, such as those of Mr. Romer, at Vienna, Levy, at Prague, Furtz, at Shuttenhofer. According to Mr. Peligot, Mr. Furtz manufactures yearly 600,000 cases of matches. He employs 400 men, and uses 800 pounds of phosphorus. The establishment of Messrs. Preschell and Pollack, at Vienna, is also very important, and well organized.

4. Laying in press the body of the matches.
5. Dipping into the sulphur.
6. Drying.
7. Taking down the presses.
8. Putting up into packages and boxes.
9. Preparation of the paste.

The first three operations are a special fabrication, generally done outside of the match factory, and it employs nearly as many men as all the other operations together.

The last six operations are carried on in the factory, and if the establishment is not considerable enough to have separate buildings for each one, all the hands are necessarily placed under the same hygienic conditions; but in a well organized establishment there are separate buildings for every operation.

CHAPTER X.

OPERATIONS FOLLOWED IN THE FABRICATION OF MATCHES.

THE wood of the white poplar (*Populus tremula* and *P. alba*) is generally used to prepare wooden matches. Birch wood is more costly, and less easy to split; the matches it produces burn longer. Pine wood is very good for the preparation of cylindrical matches.

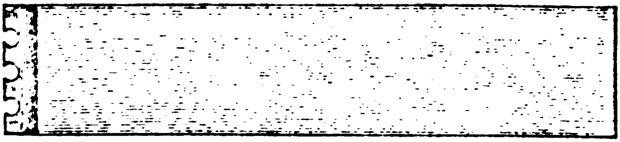
The first operation consists in drying the chunks of wood, in an oven, situated above a baker's furnace. The oven ought to be heated to 428°. When the greater part of the water has escaped in the form of steam, shut off all communication with the air, and leave the wood in it for 12 or 24 hours, open the oven, and begin another operation.

The dried chunks are cut into stumps from

2½ to 3½ inches long, according to the size of the matches. These cylinders are split square, then, with a knife, they are cut in the direction of the ligneous fibre, in shelves parallel to one of the sizes; cutting them in a perpendicular direction to the first section, all the shelves are subdivided in prisms, which adhere to each other if the knife stops at a few lines above the bearer; when the matches are to be isolated, the knife cuts the block in all its length.

It will interest the reader to know the apparatus used in Germany to manufacture wooden cylindrical matches. To prepare the wood, a plane is employed, the blade of which is represented below.

Fig. 7.



This little tool is very simple. The iron of the plane cousists of a little quadrangular and flat bar of steel. The bar is a little curved at one of its ends, which is filed, and has in it three cylindrical holes which are pierced with a drill, and which, being filed, become the punch which penetrates into the wood, and converts it into little cylindrical sticks. This iron is fixed into an ordinary plane.

The wood used is pine, without knots, in pieces from 2 feet 2 inches to 2 feet 5 inches long. The piece of wood, fixed on a table, is smoothed with an ordinary plane; every time the man planes, he draws from this piece of wood, thus prepared, three sticks the length of the wood. One man can produce every minute 180 sticks, then each stick giving 14 matches, he makes every hour 151,200 matches, or 1,512,000 in a day of ten hours. These sticks are fixed in bundles ready to be cut, and are tied together with strings conveniently placed.

When the large sticks are tied up they are cut with a knife, having the extremity of the blade moving around an axis. This operation is very rapid.

2. Laying in Press.

The pieces of wood which are to form the matches are brought into the factory in packages of 1500 to 2000; they are distributed to the hands who set them in the presses. They dispose a large number (800 to 1000) in a wooden frame, in which they are fixed in such a way as to be dipped at once into the chemical mastic. This operation occupies the most hands in the factory.

When the work is well divided, the number of hands employed in that operation would be equal to about the $\frac{4}{5}$* of the total number of persons employed in the factory.

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* This can be judged according to the personnel of some factories in Paris. At Mr. Morillon's, where 3 or 4 women are sufficient to dismount the presses, there are 150 employed to fill them. At Mr. Malbec's, they employ 150 fillers; 35 who dismount and fill the boxes, a dipper to the sulphur, one to the mastic, a grinder for the mastic, and a foreman. At Mr. Delacourcelle's, on 50 men, there are 44 fillers, 4 dismounters, 1 dipper, and 1 foreman.

This operation is done in the following manner: Each woman takes into her hand a certain number of pieces of wood, and spreads them rapidly on a shelf with notches, disposed in such a manner that each notch receives one body. The shelf being full, with the other hand, she takes another shelf similar to the above, and covers the first one. A second, a third, etc. shelves are placed in the following manner until the frame is full. When the frame contains 15, 20, and even 25 superposed shelves, they are fastened and fixed together with screws.

In Germany, where the fabrication of matches is the most advanced, they operate in the same manner, and it is the quickest process for the sulphuration. Mr. Peligot has ascertained that by this process a woman can fix in one day 200,000 matches.

In a well constructed factory, the above operation can be conducted, without in any way endangering the health of the operator.

3. SULPHURATION OR DIPPING IN THE SULPHUR.

The presses being filled, and laid up, are brought by women or children into the room intended for the dipping. The dipper takes the frame with both hands, and dips the ends of the bodies into sulphur melted in a square iron kettle, about 2 inches deep, with a flat bottom.

The sulphur must be at the temperature of 462°, and is kept at this point by a gentle heat, which can be limited by adding to it, from time to time, a piece of solid sulphur. Two flat kettles can also be used on the same fire, the first receives the solid sulphur, and when liquefied, it runs into the second. To be certain that the temperature does not raise above 482°, it is preferable to use a bath of boiling chloride of zinc.

4. DIPPING INTO THE CHEMICAL MASTIC.

The dipping of sulphuretted matches into the chemical mastic is always done in the same room as the sulphuration, and the two dippers work side by side. When the matches have been covered with sulphur at their extremity, the dipper deposits the presses on the floor near the other dipper, who takes them to complete their preparation by dipping the sulphuretted end into the chemical mastic. This operation is done in the same manner as the above, except that instead of a hollow kettle, a marble table is used, on which is spread a bed a quarter of an inch thick, of chemical mastic, half liquid. When the matches of one press have been dipped, the bed of mastic is smoothed again with a kind of trowel. He dips a second press, and so on throughout.

In Germany stone tables are used. In Paris, Mr. Malbec has adopted the use of a kind of trough, with a flat, copper bottom, square, and about 1½ inch deep; it is placed on a stone table. When we come to speak of the question of explosions in factories, it will be seen that it is not a matter of entire indifference what disposition is made for dipping, and that it is an advantage to use Mr. Malbec's apparatus.

5. DRYING OF MATCHES.

Matches, saturated with the chemical mastic, are placed in the oven to dry. The presses are fixed on an open shelf where they will dry freely. The thermometer is used nowhere to graduate the temperature, so that the desiccation is operated more or less quickly. Generally the presses are left in the oven 24 hours. Hereafter we shall speak of imperfections in the disposition of the oven.

6. DISMOUNTING OF THE PRESSES—PUTTING UP IN PACKAGES AND BOXES.

When the matches are thoroughly dried, the presses are carried to the women who have charge of the dismounting of them; they undo the frames, empty the shelves, and collect the matches in bundles. This operation is done quickly, and in many manufactories, the persons who dismount the presses are the same who make up the packages and fill the boxes. The sequel of this work will show the importance of having the matches put up into boxes immediately after they are taken from the press. In many establishments matches are put up into packages of 1000 or 1500, and surrounded with paper. It is an imperfect method.

CHAPTER XI.

FRICTION MATCHES WITHOUT NOISE.

We give below several usual compositions of phosphoric mastic for ordinary matches.

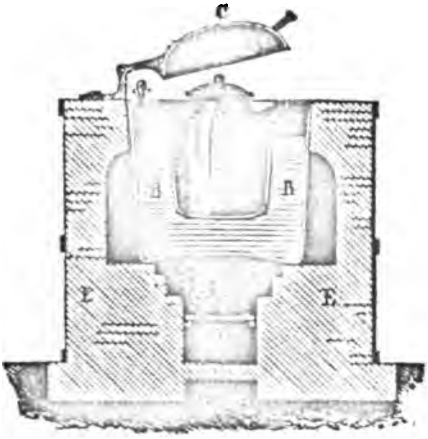
	Paste with Glue.	Paste with Gum.	Matches without Sulphur.
Phosphorus . . .	2.5 parts	2.5	3.
Glue	2 or gum	2.5	2.5
Water	4.5	3.0	3.0
Fine Sand . . .	2.0	2.0	2.0
Red Ochre . . .	0.5	0.5	0.0
Vermilion, or Prussian Blue . .	0.1	0.1	0.1 to 0.5
Chlorate of Potash .	"	"	3.0

Mr. Boetiger has given the two following compositions now in use:—

	I.		II.
Phosphorus . . .	4 parts		9 parts
Nitrate of Potash .	10 "		14 "
Minium	3 "	or Binox. Mangan.	14 "
Glue	6 "	or Gum	16 "

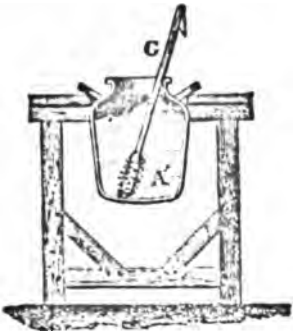
If glue is used, break it into small pieces; macerate it three hours in cold water, and afterwards melt it in a copper kettle, *A*, heated over a water bath, *B* (Fig. 8). When the glue is fluid, and at 212°, take the kettle out, and put it in the circular aperture of a table, *G* (Fig. 9), which will hold it firmly. Add to it by degrees the phosphorus, which melts immediately, and must always be covered by the aqueous liquid. Begin to stir, in turning the mass, with a wooden scovel covered with hair.

Fig. 8.



Stir all the time till cold, so as to have a well divided emulsion of phosphorus. Then incorporate the sand and the coloring matter.

Fig. 9.



This mixture is kept fluid by putting the dish which contains it over a sand bath, heated to about 97°. Spread that paste, with the help of a rule, over a marble or cast iron table, which is kept warm by means of a water bath placed under it. Renew that paste by successive additions every time you impregnate the matches.

When gum is used, the operation on the table must be performed while cold, in which case the gum is dissolved beforehand in water, so as to have a convenient provision. This solution thus prepared is used and weighed according to the different formulæ.

Put the gummy solution into the copper kettle (Fig. 8); heat it to 212° over a water bath; take out the kettle, fix it on the table (Fig. 9); put the phosphorus into it by degrees. It stays in the bottom *A'*. Beat well in emulsion till cold. This operation lasts about 1½ hour for 7 pounds of phosphorus.

That paste is used like the glue, with the exception that the table is kept cold.

When the matches have been saturated with the paste, the frames are put vertically, so as to dry in the air.

After two or three hours, carry the frames and place them in the oven. When glue is used, the desiccation is completed in one or two hours; with gum it requires 24 hours. This last preparation is the most costly.

The oven must be of incombustible materials, heated gradually and regularly by pipes disposed in the surrounding earth. Steam or water heated by a boiler outside circulates in these pipes.

To avoid having a general conflagration, in case of fire, separate the upright posts which support the frames by vertical plates of sheet iron.

It is desirable to keep on the floor a bed of sand, 4 to 5 inches thick, to avoid setting fire to the matches in walking on them, or when they are on fire, that they may be covered immediately.

When the desiccation is completed, withdraw the frames, and carry them into a room in which they are dismounted. The women who perform that operation must always have near them boxes full of sawdust, into which to dip the matches which may accidentally take fire.

In some of the following chapters we shall treat of the different precautions to be taken to avoid fire, and to prevent the accumulation of vapors in the rooms.

CHAPTER XII.

MATCHES WITHOUT SULPHUR.

To manufacture such matches the wood is prepared like other matches, only it should be very dry, particularly at the end of the operation.

When the matches have stayed in the frame, they are laid on cast iron plates, and heated to the point to acquire at their extremity a slightly brown color; these same ends, being very dry, are put, for a few seconds only, on the flat bottom of a dish, covered with from $\frac{1}{4}$ to $\frac{1}{2}$ an inch of stearic acid, melted by a water bath. A small quantity of the grease is absorbed by the wood, and ascends through the fibre. The end of the match is covered as usual with the phosphorous paste thus formed:—

Phosphorus	3	parts
Gum	0.5	"
Water	3	"
Sand	2	"
Bi-oxide of Lead	2	"
Coloring Matter	0.5	"

The stearic acid can be substituted by paraffine, spermaceti, wax, etc.

Matches with stearic acid produce light and fire more rapidly when wanted, the grease and the wood burning simultaneously, whilst with sulphuretted matches it is necessary to wait till all the sulphur has burned superficially before the wood begins to inflame. These last matches in burning exhale a disagreeable odor, whilst the former give a very slight smell of stearic candles.

There is but a trifling difference in the cost, for ten times as much sulphur is required as stearic acid. Indeed 1 pound of stearic acid costs at the most 27 cents, and 10 pounds of refined sulphur cost about the same. This improvement is of real importance.

We have examined the matches called Diamond State Parlor Matches, prepared by Messrs. Swift and Courtney, Wilmington, Del.

They are prepared as the above without any coloring matter, and they are, in our opinion, far superior to the German matches.

Mr. James R. Dey, 66 Cortland St., N. Y., prepares also the diamond matches, and the water-proof Vienna and Strella match, which realize as much as the German matches, and are of superior quality.

The matches we have indicated in the preparation above are colored blue, red, yellow, or green by adding 0.5 of the coloring matter in the mixture, and they are rendered waterproof and shining by coating them with the varnish of which we have indicated the composition; but in our opinion, the diamond matches owe their superiority to this fact, that they do not receive any coating of varnish.

CHAPTER XIII.

CANDLE MATCHES.

THIS kind of matches, invented by Messrs. Savaresse and Merckel in 1836, and improved in 1849, is prepared with a machine similar to a weaving loom, carrying a chain disposed for the weaving. Every wick of the match is composed of pieces of cotton, not twisted, and represents one thread of the chain, and 100 or 200 of these wicks rolled on a cylinder, and separated by a comb; pass through a bath of melted wax; they are drawn in a drawing frame which renders the wax smooth, cylindrical, and adhering around the wicks. A mechanical knife cuts, at one time, all the wicks according to the determined length, from 1 to 1¼ inch. The end of each match has the wax taken off, and the paste applied to it, 30 at a time. They are dried and put into boxes.

These candle matches are ignited by friction. They give immediately a fine light, which lasts one or two minutes, that is, four or eight times as long as the wooden matches.

The phosphoric mastic ought to be easily inflammable; for the cotton and the wax not having the solidity of the wooden matches, cannot resist powerful friction as well.

The paste is thus formed:—

Ordinary Phosphorus			12	parts
Gum			14	"
Sulphuret of Antimony			3	"
Minium	35	56 or bi-ox. lead	36	"
Nitric Acid	21			
Vermilion			0.1	"

We shall say but a few words of the tinder and paper match. A large sheet of tinder is cut into small squares, and at the end of each square is applied a little of the phosphoric mastic. To light them they are inflamed on a rubber prepared of paste-board, on which is applied a coating of glue and powdered glass, or emery.

The paper match consists of filtering paper, which has been macerated two or three hours in a solution of nitre, and when perfectly dried, it is cut into small bands, which are doubled, and at the end of each is applied some phosphoric mastic.

CHAPTER XIV.

MATCHES OF AMORPHOUS PHOSPHORUS.

THESE new matches can be prepared with gum or glue. In the first case, dispose beforehand a mixture of equal parts of gum arabic and water, so as to have a viscous solution.

In 2 ounces of that solution mix 1½ ounce of finely divided chlorate of potash, add the same quantity of powdered amorphous phosphorus, and 6½ drachms of powdered glass. This mixture is spread on a hollow marble about 1½ to 2 inches thick, so as to form a coating about 1 inch thick, which is kept at the same height, by adding some of the paste from time to time. Dip into it the end of the matches, which should have been sulphuretted beforehand.

If instead of gum you use gelatin, which adheres more strongly, and resists atmospheric influences better, take nice white gelatin, and let it macerate from two to four hours in twice its weight of water, and afterwards dissolve it over a water-bath heated to 122° for about 20 minutes. To 75 parts of that solution, add 40 parts of chlorate of potash in powder, 40 parts of amorphous phosphorus, and 20 parts of powdered glass. The mixture is spread on a marble, the temperature of which is kept at 105° by steam produced by a water-bath. Pour it on to the sulphuretted end of the match, and dry as usual.*

Some of these matches take fire only on being struck on a particular kind of rubber. Their paste is thus prepared:—

Amorphous Phosphorus	6	parts
Sulphuret of Antimony	2 to 3	"
Glue	1	part

---

* Amorphous phosphorus costing two dollars a pound, instead of ninety cents, the price of the ordinary phosphorus, renders these matches a little more costly, but they are not dangerous nor venomous.

The rubber is prepared by laying over one side of a paste-board the following composition:—

Amorphous Phosphorus	10	parts
Binox. Manganese, or Sulph. Antimony .	8	"
Glue	3 to 6	"

All those compositions must be well mixed, carefully avoiding pulverizing the chlorate of potash with the combustible substances.

CHAPTER XV.

MATCHES AND RUBBERS WITHOUT PHOSPHORUS.

We give below the different compositions used to prepare these matches:—

Chlorate of Potash	5 parts	6 parts	5 parts
Oxy-sulphuret of Antimony	½ “	“ “	“ “
Binoxide of Lead	3 “	“ “	“ “
Gum	2 “	2 “	2 “
Water	8 “	8 “	8 “
Sulphur	“ “	½ “	“ “
Cyanide of Lead	“ “	2 “	“ “
Glass	“ “	“ “	3 “
Bichromate of Potash	“ “	“ “	2 “

The following is very good:—

Chlorate of Potash	28½ parts
Glue	5½ “
Bichromate of Potash	3 “
Nitrate of Lead	2¾ “
Powdered Glass	10¾ “
Sulphur	85 “

These compositions applied to different kinds of wooden matches, take fire when they are rubbed on the ordinary rubbers, made with powdered sand, or glass and glue.

There are some other kinds which require a particular rubber:—

Composition for the Match.	Composition for the Rubber.
Chlorate of Potash, 7⅓ parts.	Chlorate of Potash, 6 parts.
Nitrate of Lead, 2⅓ parts.	Slags, 1 part.
Bichrom. of Potash, 2⅓ parts.	Emery, 1 part.
Sulphur, 1⅓ part.	Minium, 1 part.
Gum, 6⅓ parts.	Glue, q. s.
Water, 18 parts.	

The glue must lie in sufficient quantity to make a paste which will adhere to wood, etc.

Some new matches without phosphorus, inflammable by rubbing on a small *grate*, are made now by dividing into two parts the paste prepared in the following proportions:—

Chlorate of Potash	5 parts
Bichromate of Potash	2 “
Powdered Glass	5 “
Gum	15 “
Water	6 “

The first three substances are powdered together, and mixed afterwards with the gum previously dissolved in water. Half of this compound, diluted with a solution sufficiently adhesive, is used to cover the rubbing surface by adding to it 0.2 of its weight of emery.

If to the above mixture 0.8 of red sulphuretted antimony is added, you can make matches which will ignite by rubbing them on any polished or rough surface.

CHAPTER XVI.

NEW MATCHES CALLED SAFETY MATCHES.

LATELY new matches have been prepared by Messrs. Vaudaux and Poignon, which are free from white phosphorus, are without danger of poisoning, and diminish the chances of fire. The following is the composition of the chemical mastic:—

Chlorate of Potash	90 parts
Bichromate of Potash	45 "
Binoxide of Lead	25 "
Minium	20 "
Oxy-sulphuret of Antimony	20 "
Sulphuret of Antimony	15 "
Glass	15 "
Prussiate of Potash	5 "

All these substances, reduced to fine powder, are mixed together by adding to them 15 parts of gum previously dissolved in 55 of water.

It is sufficient to saturate the end of the match, and dry it as usual.

These matches take fire with more difficulty than the matches with white phosphorus, and are not so dangerous, particularly in the hands of children.

The following composition is better, for it will not ignite without the use of a special rubber:—

Chlorate of Potash	26 parts
Binoxide of Lead or Manganese . . .	25 "
Bichromate of Potash	20 "
Cyanide of Lead	20 "
Oxy-sulphuret of Antimony	20 "
Glass	4 "

These substances are mixed together with a solution of 5 of gum in 20 of water. A paste is made, into which the sulphuretted end of the match is dipped.

The special rubber is prepared with powdered sulphuret of antimony, mixed with a hot solution of glue, and spread on a piece of paste-board.

Mr. Bombes has invented a new match

which he calls *androgyne*, prepared in the following manner:—

The wood is cut into little cubic blocks, containing 300 or 400 matches not separated; they are sulphuretted as usual, and the sulphuretted ends are dipped into a paste composed of:—

Chlorate of Potash	2 parts
Charcoal	1 part
Terra Umbra	1 "

These three substances are pulverized separately, and then mixed with a viscous solution of glue kept warm, during the dipping, with a water-bath. When they are dried, or rather before the dipping, saturate the face of the block, which reunite the matches with a paste of amorphous phosphorus diluted in a solution of warm glue; and it is not until after this operation that the matches are separated.

To ignite one of these matches, break it into two unequal pieces, having in one hand the shorter piece; bear up the end covered with the chlorate paste on the end, saturated with the phosphoretted plastering; rub. A little deflagration takes place, the sulphuretted end takes fire immediately, and communicates it to the wood.

Below we give the report of Mr. Chevreul on that kind of match. This report was read before the Academy of Science of Paris.

EXAMINATION OF THE ANDROGYNE SAFETY MATCHES.

The matches of the Brothers Coignet are essentially formed: 1st, of a paste of chlorate of potash, sulphuret of antimony, and a glutinous substance applied to the sulphuretted end of the match; 2d, a *rubber or grate* covered with a thin coating of glutinous matter and amorphous phosphorus rendered rough by powdered glass.

A light friction of the priming of the match against the rubber is sufficient to ignite the match.

The *androgyne match* differs only from the hygienic match in this, that the amorphous phosphorus has been applied to the end of the match, which is not sulphuretted, instead of on a special rubber. It has then this advantage, that the match carries with it all that is requisite in producing the fire. Indeed, it is sufficient to rub one part of the match against the other.

The androgyne match, for hygiene, presents the same advantage in its use as the match of Coignet; and, it seems preferable to it as it is, in not necessitating the use of a separate rubber, which is important, as it has been remarked that a box of Coignet's contains more matches than can be ignited on the rubber annexed to the box, because the phosphorus of this rubber is much injured before all the matches are used.

For hygienic reasons, they both have a real advantage over the matches of white phosphorus, the use of which is not desirable in any matches intended for domestic purposes.

EXAMINATION OF MR. CANOUIL'S MATCHES WITHOUT PHOSPHORUS AND POISON.

The matches prepared by Mr. Canouil are not deleterious, and have the advantage of those of Coignet of containing neither white nor amorphous phosphorus.

The substances employed by Mr. Canouil are principally the chlorate of potash, the sulphuret of antimony, minium or another metallic oxide, gum, dextrine, or gelatine. This composition is similar to that of Coignet, but the substance applied on the rubber of Mr. Canouil's contains no red phosphorus nor deliquescent matter, and keeps as long as it adheres to the rubber.

The matches of Mr. Canouil require a rubber, but the rubbing must be stronger than is necessary with those of Mr. Coignet with amorphous phosphorus, and it is an unquestionable fact that children cannot light the matches of Mr. Canouil, while they can do so easily those of Mr. Coignet and the *Androgyne.* The amorphous phosphorus is prepared without danger to the health of the workmen, and the rubber, as prepared now, can be used to light a quantity of matches double that contained in the box.

CONCLUSIONS.

1st. For hygiene the androgyne matches have over ordinary matches the advantage of the matches of Mr. Coignet, of which the active and chemical principle of the rubber is the amorphous phosphorus.

2d. The matches without phosphorus or poison are without danger to the workmen employed in making them, and are good in use. We recommend their use.

CHAPTER XVII.

VARIOUS FORMULÆ.

I.

Take—

Gum Arabic	16	parts.
Phosphorus	9	"
Nitre	14	"
Vermilion or binox. Manganese	16	"
Water	q. s.	

II.

Take—

Glue	6	parts.
Phosphorus	4	"
Nitre	10	"
Minium	5	"
Smalt	2	"
Water	q. s.	

III.

Take—

Phosphorus . .	17 parts
Glue . . .	21 "
Red Lead . .	24 "
Nitre . . .	38 "

IV.

Take—

Gum Arabic . .	7 parts.
Phosphorus . .	4 "
Gelatine . . .	2 "
Chlorate of Potash .	2 "

V.

Put 4 parts of phosphorus into a wide mouthed phial, with enough oil of turpentine to cover it; add 1 part of flowers of sulphur and put the phial in hot water until the phosphorus is melted, then cork and shake until cold, when any supernatant spirit of turpentine must be poured off. Into this pulpy mass the extremities of the matches are dipped, and when dry, they are dipped again into the following mixture:—

Gum Arabic	3 parts.
Chlorate of Potash	2 "
Soot, Lampblack, Vermilion	1 part.

Dry cautiously.

All these formulæ can be varied indefinitely, but we would recommend the above as the best and the surest.

CHAPTER XVIII.

DANGERS—ACCIDENTS—DISEASES IN THE FABRICATION.

THE enumeration alone of the accidents which take place in the fabrication of matches, their transport, or their domestic use would require a volume. We shall direct attention only to the causes to which those accidents can be assigned, and we shall give but a few examples.

1. FIRES.

The danger of fire is the one which earliest occupied public attention on the appearance of this new branch of industry; and these fears have not been chimerical, for in every country dreadful examples have justified the distrust of the people, and rigorous measures have been taken by the several governments, and their fabrication has even been prohibited in some countries.

The English papers have given accounts of a violent fire which took place in London, in a manufactory of matches in Widegate Street, several houses were burnt, and seven persons lost their lives.

Explosions.—The explosion of the chemical mastic, before its application to the match, can present accidents as dreadful as the above, but happily they are now rare, thanks to the improvements which have been introduced in the process of fabrication.

In the beginning of the preparation of friction matches, the sulphur used to be melted with the phosphorus. This was the cause of violent explosions; not only the two bodies in contact combined to form sulphide of phosphorus, but the water is decomposed, and forms different gaseous products, which give place to dreadful explosions. This was, probably, the cause of the destruction of a factory near Paris; a violent explosion took place in the room where the dippers were working, the tables were broken to pieces, and the wall fell down.

The danger of the introduction of flowers of sulphur into the vessels in which the phosphorus is dissolved, struck Mr. Chevalier so forcibly, that he proposed, as late as 1840, to prohibit the manufacturing of matches with sulphide of phosphorus.

Not only the mixture of sulphur with phosphorus, but also the mixture of phosphorus with chlorate of potash, before the perfect division of these two substances in the glutinous solution, have been the cause of dangerous explosions, before the manufacturers dissolved those two bodies separately.

The imprudence of the men who work the mastic has been the cause of many accidents. Thus, when the dipper leaves the mastic to run, spread, and dry around the table he works on, the least friction will break the table to pieces. A drop of the mastic falling on the kettle of the dipper to the sulphur also produces violent explosions.

2. ACCIDENTS DURING THE TRANSPORT OF MATCHES.

Friction matches give rise to accidents, not so grave as the above, it is true; but their numbers are incalculable. To give a just idea of the number of accidents, and the fear of them, it is sufficient to say, that in Europe insurance companies refuse to insure express companies which carry matches.

Fire takes place very often in packages or boxes, contained in large boxes or barrels sent by freight, without communicating fire to other packages. Several manufacturers have given us a proof of it, by throwing on the floor packages of matches surrounded by a strong paper; we heard a crepitation indicating that the matches were taking fire, the paper was slightly burned, but, however, the flame was not visible outside. The want of air was the only obstacle to the combustion.

Sometimes the explosion of the mastic which surrounds the heads is so violent that, notwithstanding the thickest envelops, the flames pass through. Once, at Marseilles, the movement of a wagon containing 700 packages of matches, in passing up a high street, was cause sufficient for igniting the matches, which was accompanied by a strong explosion.

Similar accidents have occurred on railroads. Once, on the railroad from Vienna to Brunn, a car containing 12 barrels of matches took fire and was burned with two other cars. The loss was estimated at about $15,000.

3. ACCIDENTS OCCASIONED IN THE ORDINARY USE OF MATCHES.

There are few persons who have not witnessed some accidents occasioned by the explosion of a box or bundles of matches. These accidents are often without importance, but sometimes they have serious effects.

The examples of burns, particularly in the face, produced by the explosion of a match and the projection of a fragment of the incandescent mass, were very frequent a few years ago. Several cases were recorded, in which the eyesight was lost by this cause. Happily, since the great improvement introduced in this fabrication, these accidents are rare.

Children have been repeatedly the victims of their inexperience in the handling of matches. Without speaking of light burns, which we have often observed, we have seen accidents serious enough to produce death.

The too great *sensibility* of matches is the principal cause of these last accidents, the same that their too great *explosibility* is the ordinary cause of the burns in the face and eyes. This sensibility is such, that we have seen packages of matches take fire in the hands without knowing how it happens.

Burns produced by matches do not present any particularity.

4. DISEASES PRODUCED IN THE FABRICATION.*

By examining the accidents which destroyed the health of the workmen; by inquiring which

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* POISON BY PHOSPHORUS.—A correspondent of the Evening Post describes the case of a young girl, engaged in a friction match factory in New York, who having a tooth

are, in the fabrication of matches, the particular conditions capable of exercising a deleterious influence on the economy, we are led to attach the greatest importance to the emanation of the vapors containing phosphorus, which continually exhale, with a variable abundance, in all the rooms in which the mastic is worked, or matches are present already saturated with mastic.

It is necessary to examine the two following questions, viz:—

extracted, was poisoned by the fumes of phosphorus which entered the cavity. Disease called *necrosis* was induced, which extended to either side of the jaw-bone, points of discharge soon appearing upon the surface of the skin. This went on for two years, minor operations being made at times, to take away diseased portions of bone. At the end of these two years it was found necessary to resort to an extreme operation, and it was completed on Sunday, March 19th, at St. Vincent's Hospital. The entire jaw-bone, from side to side, was removed, and the tongue fastened down to prevent suffocation, until such times as the part should heal. This young girl is now terribly deformed, can take only liquids hereafter for subsistence —all the beauty of life destroyed to her. Twelve such cases have occurred within the last few years.

1st. Which are those parts of the work which expose the workmen to the phosphoric emanations?

2d. What are the nature and chemical composition of these emanations?

Operations which expose to the Phosphorous Emanations.—We have seen that all the wooden work, the making of boxes are generally completed outside of the factory. The operators are consequently strangers to the questions of hygiene and pathology, and as they occupy about half of the men employed in this fabrication, it results that half of the total number are out of the conditions of insalubrity of this kind of manufacture.

Inside of the factory, by allowing separate rooms for every operation, five-sixths of the men escape the influence of the noxious vapors. Thus, the filling of the presses, which takes four-fifths of the women, can be made in special rooms.

We have now to examine the room in which the mastic is made, the one in which they dip, the oven, and at last, the dismounting of the presses, and the packing or boxing.

The atmosphere of these rooms is more or less intensely altered by the vapors proceeding either from the paste intended for the dipping, or by the packs of matches already saturated with the chemical mastic.

The grinding of the substances, and the preparation of the mastic do not require a continual attendance. One man can work it; besides, these operations are done in the open air, and it is about the same for the oven, near which the men do not remain. It is not the same for the dipping shop, and principally the rooms occupied by the women who dismount the presses, and those who box or pack the matches.

A stranger, who enters this part of the factory, is struck by the emanations which exhale. The air is often thick, principally in the room where the presses are dismounted, and if he remains for some time, he begins to cough. After a certain time, the system becomes accustomed to that particular atmosphere; and nearly all the women cough only during damp weather, and principally when the air is not renewed, the vapors accumulating, and becoming too thick.

Nature and Composition of the Vapors which exhale in the Manufacture of Matches.—The air of the rooms has not been analyzed yet, and theory alone can guide us. If we examine one after the other, each of the substances which enter in the composition of the mastic, if we put aside the sulphur which plays no part, we find phosphorus alone which can change the atmosphere. We have demonstrated (Chap. I.) the facility with which phosphorus absorbs the oxygen of the air. At the ordinary temperature, the action of the air, principally damp, on phosphorus is very appreciable. If the air is dry and the temperature low, the action is but slightly perceptible; but, if damp, we see the phosphorus immediately surrounded by a light white cloud. These vapors are called *hypophosphoric acid.*

In aerated water exposed to the light, phosphorus gives *phosphorous acid*, and hydrogen proto-phosphuretted, produced by the decomposition of water, and there is not the least doubt that in the rooms some phosphuretted hydrogen is mixed with the hypophosphoric acid.

Another interesting question is, to know if phosphorus itself exists in a gaseous state in the atmosphere of the factory. Some chemists admit its existence. M. P. Thenard does not believe that the slow combustion of the phosphorus in the air is perfect, and he thinks that there is much vapor carried away at the state of phosphorus. The following facts demonstrate this theory: 1st. If a piece of phosphorus is introduced for a few minutes into nitrogen, hydrogen, carbonic acid, etc., then taken out, and a little air introduced into the gas, it becomes luminous in obscurity; 2d. If we suspend to a thread a piece of phosphorus, and we introduce it into a bottle and leave it in for a few minutes, the bottle stays luminous for some time, while containing a large quantity of oxygen. Thus phosphorus, while cold, emits vapors in gases, and this vapor is not instantaneously burned by the air. It is very probable that in the factories the workmen breathe vapor of phosphorus mixed with hypophosphoric acid.

Let us examine now briefly the effects of these emanations on the health of the men.

The diseases are, 1st, more or less aggravated inflammation of the *bronchiæ;* 2d, *alterations of the teeth and maxillary bones*, etc.

1st. *Bronchitis.*—Coughing is the most frequent pathological phenomenon in the shops, but it is rare that the inflammation becomes great.

2d. *Diseases of the Jaws.*—It is not long since this disease has appeared amongst the men working in match factories. Dr. Strohl has pointed out in the following terms, the causes of this disease:—

"The vapors of phosphorus are transformed by its contact with oxygen into hypophosphoric acid, and this acid mixed with the air is dissolved in the saliva, and forms phosphoric acid. Often this latter acid is produced by the combustion of the phosphorus, for it sometimes occurs that the vessel in which the mass is heated, takes fire. This substance renders the saliva acid. We know the dissolving action of this acid; the gums are softened by the saliva, the liquid acid attacks the teeth, filters between them and the soft parts, reaches as far as the alveolus, and there exercises its dissolving and corroding action.

This theory has not been admitted by all physicians, for the reason that if the theory were correct it would seem that the teeth would be invariably in a bad state, and it has been observed that in the same room, while one man has all his teeth destroyed, another working near him has them in perfect order.

It would be interesting and important, as well for science as on the score of humanity, to discover and point out the real causes of these diseases, and the proper mode of treating and curing them.

CHAPTER XIX.

REFORMS IN THE FABRICATION OF MATCHES.

THESE measures of reform (unhappily those measures have not been taken yet in factories in this country) embrace, not only all the parts of the fabrication of matches, but also the cartage and the sale of these products. Their object is to prevent all accidents, and to look to the maintaining of the salubrity of the factories. We shall divide this matter under three heads:—

1st. The fabrication.
2d. The transport and sale.
3d. The salubrity of the shops.

1. FABRICATION.

1st. *Preparation of the Mastic.*—Notwithstanding the progress made in the fabrication of the mastic, it is important to require two capital precautions which have been indicated by Mr. Payen. The first consists in completely excluding the sulphur from the substances which enter into the composition of this mastic. The second consists in always dividing the phosphorus while alone, and mix it with the other substances when they are perfectly ground, and that the mixture is conveniently cooled. The precautions to be taken, we have indicated.

After taking measures against the too great *explosibility* of the mastic, it would be useful to provide against its too great *sensibility*. Mr. Malbec has invented an apparatus for determining with precision the degree of sensibility of the paste. This apparatus consists in a vessel conveniently disposed, and containing mercury, heated over a water bath, at about 186°. It is at this temperature that the paste ought to be tried. Saturate with it the end of a match, and dip it into the mercury; if it takes fire, it is a sign that it is too sensible; then increase the quantity of the substances, the object of which is to divide the molecules of phosphorus.

CHAPTER XX.

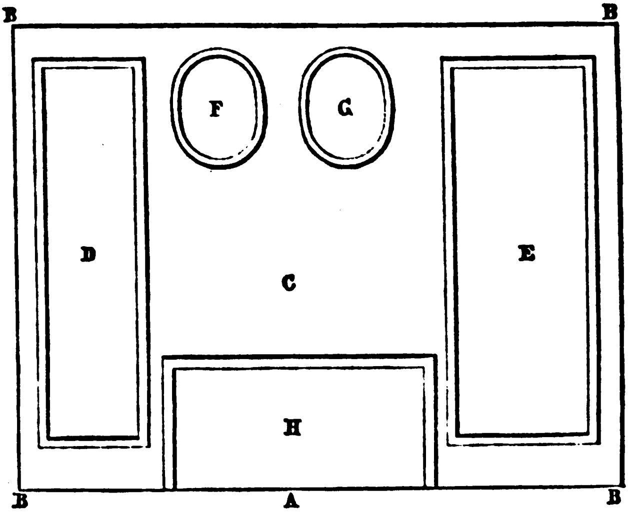
CONSTRUCTION OF THE FACTORY.

The complete separation of the rooms is the essential point in the construction of a match factory. It is not only an indispensable condition, in order to give to the shops the dispositions necessary for the health of the men, but it is also an important precaution against fire and explosions.

It is necessary, not only to establish a separate shop for each operation, but also to adopt certain rules in the position of each shop, its construction, etc. etc. This will be better understood by the following diagram, which indicates all the dispositions to be taken to decrease the dangers and inconveniences of this fabrication.

1st. The *grinding* of the substances, and the *preparation of the mastic* must be done in a little apartment *F*, composed of a single room on the first floor, and isolated all round.

Fig. 10.



2d. The *sulphuration* and the *dipping into the mastic* are done together in a room *G*, equally isolated, longer than the above. The roof will be half open all the time for the escape of the vapors, and that the air may be continually renewed.

3d. The *oven* occupies a building *D*, also isolated. All the materials of this room are of iron, and it must always have passing through it a current of dry air.

4th. *Laying and taking down of the Presses; Boxing.*—The most important rooms are those of the laying of the presses, taking down, and the boxing. These three operations occupy many hands. The first operation not exposing the operatives to the phosphorous emanations, it is only necessary to keep them separate. The two other being very noxious, the shop must be in the most advantageous condition. A building alone, *E*, is disposed in the following manner:—

This building has two stories, and is isolated. In the first floor the presses are laid. The upper part has no communication with the room below, but presents a single room, and the roof is pierced with several windows, which are opened at will to let the noxious vapors escape.

The *store rooms*, *habitation buildings* are isolated, as represented in *H*. The form and dimensions of this building may be arranged according to the taste of the manufacturer.

By following the above dispositions, great advantage will be realized; and, if to them we add the construction of a wall *B*, about 6 feet high, surrounding all the buildings, we see that match factories will be relieved of the inconveniences of being near to a public thoroughfare.

We are certain that this plan will present but little difficulty in its realization, and we hope that hygienists will be satisfied with its disposition.

The fabrication of matches, though commenced several years since, is still in its infancy.

Unhappily the savants have attached but little importance to this kind of manufacture, and it is only since the learned report of Mr. Chevreul that scientific bodies have given their attention to it. Let us hope that, before long, a match will be discovered, having all the properties of ordinary matches without their inconveniences.

SECTION III.

GUN COTTON.

CHAPTER XXI.

HISTORY—XYLOIDINE AND PYROXYLINE—PROPERTIES AND COMPOSITION.

HISTORY.

IN the course of 1833, a well known French chemist, Braconnot, having dissolved starch and some other organic matters in nitric acid, obtained by precipitating the dissolution by water, a new substance that he called *Xyloidine*. This substance was remarkable for its quick inflammability, but it did not fulminate with as much energy as gun cotton, and it left a residue of charcoal.

Five years after the publication of the researches of Braconnot, Mr. Pelouze, in an interesting paper, announced the discovery of a more simple and economical process to obtain the Xyloidine. This process consisted in substituting for the dissolution of the starch, the pure and simple impregnation of the paper, cotton, flax, etc. by concentrated nitric acid. Besides, Mr. Pelouze announced to the Academy of Sciences, that Xyloidine resulted from the union of the elements of nitric acid with those of starch, and explained by this decomposition, the excessive combustibility that he found in this substance.

We shall see, hereafter, if it was really the Xyloidine of Braconnot that Pelouze obtained.

For eight years the researches of the above chemists seem to have been forgotten, when in September, 1846, a great stir was made concerning a new discovery of Mr. Schoenbein, a Swiss chemist, who announced the transformation of the cotton into an explosive substance of a power superior to that of ordinary powder. Mr. Dumas was informed of this invention by a letter from the author, who appeared anxious to keep his process secret. But the opinion of Mr. Dumas was, that this invention was connected, without doubt, with the history of the Xyloidine of Braconnot and Pelouze. From that time, chemists made extensive researches upon this subject. Different recipes for preparing the *fulminating cotton* or *gun cotton* were published in Germany. In October of the same year, Mr. Dumas communicated to the Academy of Sciences the processes of Messrs. Otto, Dr. Knopp, Dr. Bley, etc. It resulted from the experiment of those chemists, that fuming nitric acid had the property of rendering explosive not only cotton, but also shavings and sawdust.

As we see, the German recipes were nothing more than Pelouze's process to prepare the Xyloidine. This latter chemist had only to prepare cotton and paper, as he had done eight years before, and introduce 1½ grain of this matter into a pistol, to obtain an explosive effect, such, that a board 9 inches thick was pierced by a bullet, at a distance of 76 feet. Other essays made by MM. Prelat, Sequier, Lassaigne, etc., with different fire-arms, have left no doubt on the ballistic properties of the nitric paper.

Two important questions were to be resolved, one purely scientific, the other practical. Was the explosive product obtained by Pelouze and the German chemists, the Xyloidine of Braconnot? Was this product susceptible of being substituted for the ordinary powder?

Nobody had thought to put the first question, and Messrs. Flores Demonte, and Menard seem to be the first who have considered the difference between the Xyloidine of Braconnot and the cellulose treated by nitric acid. As for Mr. Pelouze, who, with several other chemists, had not suspected the difference between the two products, he soon ascertained that ligneous substances take a larger quantity of nitric acid than starch; and he declared a short time after that the products were different in their properties and composition; that is the reason why this chemist proposed to call *pyroxyle* or *pyroxyline* the product of the action of nitric acid on cotton, paper, and other ligneous matter. He demonstrated in the following terms the difference between this product and the Xyloidine of Braconnot, obtained by precipitating with water the nitric dissolution of starch and ligneous matters:—

"The Xyloidine," says Mr. Pelouze, "is very soluble in nitric acid, and this dissolution is destroyed in twelve hours, the substance of Braconnot being then transformed into a deliquescent acid."

"The pyroxyline is insoluble even in an excess of nitric acid; it can remain in for several days without disappearing, and without losing any of its weight. The Xyloidine, while very inflammable and detonating by a shock, leaves, when heated in a retort, a residue of charcoal."

"The pyroxyline, heated at 347° to 366°, burns with violence, and its distillation in a retort is impossible."

"The Xyloidine has been analyzed with oxide of copper, as other organic substances, only the quantity of oxide of copper was increased."

"Pyroxyline, in the same circumstances,

bursts all the tubes, even by operating on very small quantities."

Such are the properties. As for the composition of the two substances, Mr. Pelouze adds: "I have concluded from my analysis, that the Xyloidine can be represented by one equivalent of starch, which has lost one equivalent of water, and gained one equivalent of nitric acid."

To obtain the formula of the pyroxyline, Mr. Pelouze has chosen a specimen of cotton and paper, leaving very little ashes by incineration. He dried them at 248°, and submitted them to the action of the mono-hydrated nitric acid, or a mixture of this acid and concentrated sulphuric acid.

In ten experiments, which have lasted from 10 minutes to 48 hours, the increase in weight has been the same, and ranges between 68 and 70 per cent. of the dry matter.

Admitting that the nitric cellulose is the only product which results from the proceeding reaction, the calcul indicates that it ought to result from the combination of two equivalents of mono-hydrated nitric acid, with one equivalent of cellulose, less one equivalent of water; and it has for its formula

$$C_{12}H_9O_9 2NO_5 HO$$

or without hypothesis

$$C_{12}H_{11}O_{22}N_2$$

The composition corresponds to the following numbers:—

Carbon	26.66
Hydrogen	3.70
Oxygen	59.28
Nitrogen	10.36
	100.00

The formula of the Xyloidine, deduced from the analysis, gives the following numbers:—

Carbon	34.80
Hydrogen	4.34
Oxygen	54.09
Nitrogen	6.77
	100.00

From the above, obtained, if not by direct analysis, at least by indirect means apparently unexceptionable, it results that when the amylaceous and ligneous matters lose their solid state, and pass, one at the ordinary temperature, the other at a higher temperature, in dissolution in concentrated nitric acid, the compound or compounds which result from the action of water in such dissolutions, essentially differ from the composition and properties of those which result from a simple impregnation of the cellulose.

Since the researches of Mr. Pelouze, the chemical study of pyroxyline has made great progress. Messrs. Fordos and Gelis, in the combustion of pyroxyline, have announced the formation of bi-oxide of nitrogen and a cyanic compound. Mr. Dumas, in a learned paper, has announced the formation of several other products. He speaks thus: "Until now, the analysis of the fulminating cotton has not been made, some are engaged on it, and may be exposed to useless dangers. This analysis is easily made by using the apparatus of Messrs. Gay Lussac and Thenard, which they employed fifty years ago."

"The combustion tube, being heated by an alcohol lamp, at from 392 to 572°, little parcels of gun cotton thrown into it burn quickly without any danger.

"It disengaged vapor of water, carbonic acid, oxide of carbon, nitrous vapors in large quantities, and bi-oxide of nitrogen. The raw gas contains enough inflammable products to burn when a candle is near by. The color of the flame indicates compounds of the cyanogen."

It is in this paper that Mr. Dumas has indicated the way to obtain a fulminating product with chlorate of potash. Cotton impregnated with this salt gives a fulminating product superior to the nitric cotton.

On the occasion of the reading of this paper, Mr. Pelouze differed from Mr. Dumas, in regard to the effects that the gaseous products produce on fire-arms, of which we shall speak hereafter.

This historical notice is sufficient for the present, only we shall state some facts announced by Messrs. Peligot and Pouillet. They have made many experiments on the products of the combustion of gun cotton placed in the same conditions as gun powder.

Mr. Peligot has analyzed gun cotton, dried in vacuum, at the ordinary temperature, and found the following results.

12 Carbon . . .	72	22.8 Carbon
9 Hydrogen . .	9	25.6 Water
9 Oxygen . . .	72	
3 Nitric Acid . .	162	51.6 Nitric Acid
	315	100.0

Thus, by representing by

$$C_{12}H_{10}O_{10}$$

the composition of the cotton, we see that in contact with nitric acid, it lost one equivalent of water, and takes three equivalents of nitric acid.

CHAPTER XXII.

FABRICATION OF GUN COTTON—NITRIC PAPER—PYROXAM—PROPERTIES.

Gun cotton and nitric paper, according to the analysis of Messrs. Pelouze, Payen, and Poinsot, can be considered as formed of two equivalents of cellulose which have lost three equivalents of water by combining with five equivalents of nitric acid, constituting a double compound:—

$$\begin{array}{rl} & C_{12}H_8O_8 3NO_5 \\ & \underline{C_{12}H_8O_5 HO 2NO_6} \\ \text{Pyroxyle} & C_{21}H_{17}O_{17} 5NO_5 \end{array}$$

This compound, as we have seen, can be completely transformed into a gas at the temperature which inflames it, that is, from 347° to 356°; the oxygen of the acid burning all the carbon of the organic matter. It forms in volume, 46 of oxide of carbon, 2 of carbonic acid, 10 of nitrogen, and 34 of vapor of water.[*] Some more complex and variable products are probably generated, but in all cases it does not deposit carbon or acid in the guns when the raw material is pure cotton, when the acids employed are perfectly free from foreign matters, and when the product has been purified of all free acids by washings.

Pure gun cotton is insoluble in water, alcohol, ether; soluble in the latter with the addition of a few hundredths of alcohol, soluble in weak proportions (½ to 2 per cent.) of acetic ether. Five times more soluble when prepared with nitric acid containing nitrous acid.[†] In this last case, the cotton is more or less disaggregated, and more slowly combustible. Gun cotton

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[*] Mr. Combes has avoided the formation of oxide of carbon, a deleterious gas, and substituted it by carbonic acid, by adding to the pyroxyle the eight-tenths of its weight of chlorate of potash.

[†] This acid is prepared by passing nitrous acid gas into the mixture until the total weight has increased from 1½ to 2 per cent.

has some other properties which possess but little interest, but it is important to observe that under the same denomination of *pyroxyle* or *pyroxyline* they confound products with very different properties of explosibility, while containing the same elementary principles in equal proportions; and a remarkable thing is that those which explode at the lower temperature, present the weakest ballistic power, and have the most destructive action on fire-arms, by the vapor of hyponitric acid they generate.

The causes of these great differences exist in the different degrees of cohesion of the organic substances employed. Thus, the cotton having a uniform cohesion, offering the maximum of surface to the action of the acid for the propagation of combustion, gives, when pure, the best product—the only one it is safe to use for fire-arms. The cotton from old cloth, old hemp, linen, and paper, which offer the most variation in their thickness, and in the alteration of the fibre which composes it, are sometimes inflammable at a lower temperature. Thus the thick nitric paper, newly prepared, and being a little acid after the washing, detonates at 212°. It is the product which has burst the most fire-arms, and sent the projectile the shortest distance, for the reason that its decomposition begins in the gun at a lower temperature, disengages at first vapors of hyponitric acid, and sometimes terminates immediately.

The *pyroxam* (nitric starch), more inflammable from 203° to 212° is so instable when completely saturated with nitric acid, that it is spontaneously decomposed at the ordinary temperature, giving abundant nitrous vapors, and even producing a detonation.

The pyroxam alters more rapidly in damp air, the disengagement of the gases raises the mass which becomes pasty, then syrupy, and gradually more acid and soluble in water; when dried it is not explosive, and dissolves in large proportions in anhydrous alcohol.

The different pyroxylic products are so much less stable, that they contain an excess of acid, on account of an insufficient washing.

Thus, the maximum of instability is met in the product (nitric starch) of which the organic basis has the least cohesion, and of which the aggregation is the most irregular, and each concentric bed of all the granules possesses several degrees of cohesion; indeed, the nitric starch, dissolves in its weight of acetic ether, and reduces by evaporation into diaphanous lamella, the cohesion of which is homogeneous. It is stable in the air, and does not inflame at 212°. The same ether dissolves only $\frac{3}{100}$ of its weight of nitric paper.

The preparation of nitric cotton is very simple, but requires many precautions, principally if the operation is with large quantities.

Prepare beforehand, in order to have it cold, a mixture of mono-hydrated nitric acid, 1 equivalent, 63, with 1 equivalent of concentrated sulphuric acid, 49. The liquid ought to present a sufficient volume to immerse in it all the cotton. If a certain quantity of the cotton impregnated with acid is left out of the mixture, the combination heats the fibre to the point of decomposing the nitric acid, and disengages nitrous vapors dangerous to breathe. It will even occasion a deflagration.

After 15 or 20 minutes, withdraw the cotton, press it well between glass, and wash it in a large excess of water. Press it and wash it in new water until it is no longer acid, to be sure of which, wash it with a very weak solution of carbonate of soda, and terminate by a washing with pure cold water. Press the cotton well and dry it. This cotton can be used immediately to load fire-arms; but it is better after a few days. One hundred parts produced from 170 to 175 parts of pyroxyle.

The preparation of the paper is the same as the cotton; but requires more care to avoid spoiling the sheets.

To obtain the *pyroxam* (nitric starch), the composition of which is similar to that of the cotton, dry the starch in vacuum at 257°, to evaporate the hydratation water. Leave the fecula to dry in a cool and dry place; dilute it in fifteen times its weight of the mixture of nitric and sulphuric acid. Leave to stand for six hours; wash it in an excess of water, and dry in a current of air at 104°. The pyroxyle can be decomposed, so as to set free the cellulose with all its chemical properties by the following process: Dip the pyroxyle in a concentrated boiling solution of chloride of iron. The deoxidizing action of this compound takes off the oxygen from the nitric acid, disengages hyponitric acid, and the cotton is covered with rust. This incrustation is taken up by diluted hydrochloric acid, and the cellulose is regenerated with all its primitive properties.

In the chapter on the application of gun cotton, we shall give another process of preparation.

CHAPTER XXIII.

BALLISTIC PROPERTIES OF GUN COTTON AND NITRIC PAPER.

The first essays tried by Messrs. Pelouze and Prelat, and those of Lassaigne have proved, without any contest, the remarkable energy of the new powder; but in these essays, the ballistic pendulum had not been used, and the substance employed was principally nitric paper. Messrs. Seguier and Clerget by using this paper have established the superiority of this new agent over hunting powder, and it has been admitted that at equal weight its force is about four times greater than that of the ordinary gunpowder. Soon this proportion was substituted by that of one to three, result of experiments made with the ballistic pendulum, and communicated by M. Arago.

However, the committee of artillery, established in France, was unfavorable to the new powder. Messrs. Piobert and Morin named inconveniences, which, in reality, were due only to defective process of preparation, such as the residues of water and charcoal; and those two savants came to the conclusion that this singular substance did not seem proper to substitute for gunpowder.

The discussion was animated on both sides, and in a communication made to the Academy of Sciences, Mr. Piobert insisted on the *bursting properties* of gun cotton, which he looks upon as a spring of dangers, and a cause of inferiority, relatively to gunpowder, in the use of fire-arms. He speaks of two proof mortars of cast iron, broken by small proportions of pyroxyline. On the other hand, Messrs. Seguier and Clerget, continuing their experiments, announced the following results:—

STANDARD.—*Ballistic effects of a charge of common hunting powder.*

Distance, 45 feet.
Load, 6 grains.
Target, cast-iron plate.
Effect, flattened half of the bullet.

1ST COMPARATIVE ESSAY.

Load of gun cotton, 6 grains.
Effect, dissemination of the bullet in lead spangles.

2D ESSAY.

Load, 3 grains.
Effect, flattening the bullet into the form of a sun to ⅜ of its original diameter.

3D ESSAY.

Load, 1 grain.
Effect, similar to the standard shot with 6 grains of ordinary powder.

We see, that with ⅙ of gun cotton, the results are the same as with ordinary gunpowder.

Struck by the inconveniences, and the

dreadful examples indicated by Mr. Piobert, Seguier tried if it could not be possible to avoid the effects of a too instantaneous production of gas. In his researches, he tried the experiments of Mr. Piobert himself, who ought to have known that in working a mass of powder into a spheroid form, the slowness of the combustion follows a certain law, and is in proportion to the diameter of the sphere.

It is this delay in the deflagration which suggested to Mr. Seguier the idea of studying the influence of the bringing together of the fibres of the gun cotton, on the duration of the combustion of this cotton in fire-arms, and consequently the difference of its ballistic effects. Having taken for a standard the ballistic results of one grain of cotton, given above, he loaded successively the gun, with the same weight of a kind of lint, proceeding from tissues of cotton of different thicknesses of threads. He ascertained that this lint furnished ballistic effects superior to cotton. Besides, he ascertained that the superiority of the effects was more marked with the barrel of a musket, 2 feet long, than with that of a pistol 9 inches long.

Numerous experiments have been made, but much is still left unachieved on this subject. Mr. Payen has demonstrated that the mode of preparation of the pyroxyline has a great influence on the ballistic properties of the effects obtained. Mr. Morin has tried with the ballistic pendulum two products of the same cotton, one prepared with pure sulphuric and nitric acids in the proportion of equal equivalents, the other with the same mixture containing gaseous hyponitric acid.

The following table indicates the great difference in the properties of the two products:—

		Loads.		
		15½ grs.	31 grs.	
Velocity communicated to a bullet weighing 6½ drs.	Pure cotton and pure acids	234 yds.	356 yds.	
	Vapors of the mixture	...	113 yds. 78 yds.	
	Acids containing hyponitric acid	...	0	The bullet did not pass out of the cannon.

Thirty-one grains of pyroxyle prepared on a large scale, with cotton and ordinary acid, give to a bullet a mean velocity of 342 yards.

Such are the results of experiments made carefully by competent men. It is to be desired that this subject should be more fully investigated.

The following views touching it are from the anniversary address of the President of the Royal Society of Great Britain, for this year (1864), and are certainly entitled to respect and consideration.

"The advantages which are claimed for gun cotton over gunpowder for ordnance purposes and mining operations are so many and so important as to call for the fullest investigation. The absence of smoke and the entire freedom from the fouling of the gun, are points of great moment in promoting the rapidity of fire and the accuracy of aim of guns employed in casemates, or in the between-decks of ships of war. To these we must add the innocuous character of the products of combustion in comparison with those of gunpowder, and the far inferior heat imparted to the gun itself by repeated and rapid discharges. With equal projectile effects, the weight of the charge of gun cotton is but one-third of that of gunpowder; the recoil is stated to be reduced in the proportion of 2 to 3, and the length of the gun itself to admit of a diminution of nearly one-third. These conclusions are based on the evidence of long and apparently very carefully conducted courses of experiments in the imperial factory in the neighborhood of Vienna. The results appear to be especially deserving the attention of those who are engaged in the important problems of facilitating the employment of guns of large calibre and of great projectile force in the broadsides of our line-of-battle-ships, and in reducing, as far as may be possible, the ports. When the material was first introduced by Schoenbein, in 1846, its distinctive qualities in comparison with gunpowder were recognized. To the employment of gun cotton, as then known, there was, however, a fatal drawback in its liability to spontaneous combustion. The elaborate experiments of the Austrian

General Von Lenk have shown that this liability was due to imperfection in its preparation, and ceases altogether when suitable processes are adopted in its manufacture. Perfect gun cotton is a definite chemical compound; and certain processes for the removal of all extraneous matter and of every trace of free acid are absolutely indispensable. But, when thus prepared, it appears to be no longer liable to spontaneous combustion: it can be transported with perfect security, or be stored for any length of time without danger of deterioration. It is not impaired by damp, and may be submerged without injury, its original qualities returning unchanged on its being dried in the open air, and at ordinary temperatures.

"A scarcely less important point towards the utilization of gun cotton, and the safety with which it may be employed in gunnery, is the power of modifying and regulating its explosive energy at pleasure, by means of variations in the mechanical structure of the cartridge, and in the relative size of the chamber in which it is fired."

CHAPTER XXIV.

USES OF GUN COTTON IN MINING OPERATIONS—PYROTECHNIC EFFECTS—GENERAL APPLICATION.

If the appreciation of the ballistic effects of the pyroxyle is yet in doubt, it is not the case as to its power and advantages under some other circumstances, principally in the blasting of rocks. The first experiments were made by Messrs. Combes and Flandin, mining engineers.

These experiments were made in a quarry of coarse calcary. A horizontal hole one foot deep was driven into the rock. The hole was driven in such a way that the rock was free on two faces, the upper and lower. The hole was 2 feet 4 inches below the upper face. They introduced into it 1½ ounce of gun cotton, which, after being packed, left an empty space 2 feet long. It was lighted; the explosion took place with very little noise, and without any projection. An appreciable time elapsed between the time that the match inflamed the cotton, and that when the mass was raised a little by dividing itself into pieces of $\frac{1}{8}$ to $\frac{1}{4}$ of a cubic yard. The mass thus blasted and divided above the hole extended 2 yards, at least, from the lower face, 3 yards at the left, and 1½ yard from the right of the axis of the hole.

The total cube was about 7 cubic yards, the bed of the lower rock was fissured, as far as 2½ feet from the axis of the hole. To produce the same effect with mining powder would have required half a pound.

These essays do not give the exact measure of the effects of the pyroxyle, and it requires further experiments. However, they permit us to hope that the substance will be used for mining purposes in the same manner as ordinary powder, and without requiring difficult precautions. Its property of burning without smoke and smell will, we think, assure it the preference in all subterranean works.

We shall not speak, here, of the application of the pyroxyline in the preparation of fulminating powders, as in the sequel of this work we shall have a special article on that subject.

According to Messrs. Seguier and Clerget, there is no doubt that nitric paper will take an important place in pyrotechny. Paper prepared according to Mr. Pelouze's process, and dipped in solutions of nitrate of strontia, sulphate of copper, nitrate of baryta, have produced fine red, green, and white flames.

There is no doubt that trials will be made to apply to industry the expansive force of the pyroxyle, and Messrs. Lesseré and Valod have made several experiments in applying to the movement of machines, the expansion produced by the deflagration of nitric paper; but those savants have been stopped in their essays by the explosion of the machinery. Experiments and time can only resolve these difficulties.

To the probable astonishment of the reader, we shall speak of the *application of the pyroxyline in the alimentary use.* Mr. Pelouze at a meeting of the Academy of Sciences, speaks thus: "When we see nitric acid engages in organic combinations, in which it loses its ordinary properties, its odor, causticity, solubility, we ask if it is absolutely impossible one day to obtain alimentary substances by following a process, more or less directed in the sense I have indicated, that is, of introducing nitrogen into matters which do not contain it. For me, I am inclined to believe in the possibility of such a discovery."

Some years since, Messrs. Bernard and Bares experimented on the xyloidine as an alimentary substance. The results have been negative. Xyloidine has shown itself inalterable in the intestines; it has remained white, deflagrant, insoluble in water, soluble in acetic acid and alcohol.

CHAPTER XXV.

APPLICATIONS OF GUN COTTON—COLLODION—ITS USES IN SURGERY—PREPARATION OF ARTIFICIAL LEAVES AND FLOWERS.

COLLODION.

MR. MAYNARD, of Boston, has made a curious application of the pyroxyle obtained by Mr. Gaudin's process, by rendering it soluble in alcoholized ether. He designates this agglutinative solution by the name of *collodion*. He prepares it as follows:—

The cotton is dipped into a mixture of three parts of sulphuric acid and two parts of nitrate of potash. It is left to react for 15 minutes, washed and dried as usual.

According to Mr. Payen, the surest mode of preparation consists in mixing one part in weight of dried and powdered nitrate of potash, with three parts of concentrated sulphuric acid; he dips the cotton entirely into this mixture, and leaves it from 1 to 2 hours, washes and dries it.

The product dissolves incompletely in ether, containing $\frac{8}{100}$ of alcohol; it forms a syrupy liquid which is kept in close vessels. Spread several times on the skin, it forms by the evaporation of the ether a very adherent pellicle, resisting alcohol and water. It offers thus a means, now generally used, to cover or reunite wounds, and takes the place of the English plaster. The pellicle obtained on a glass plate can be taken, and burns less quickly than gun cotton.

Collodion can be used to render tissues water-proof. Tissues covered with collodion can be used to cover large wounds and keep them from the action of the air, as in drying it contracts and becomes hard. The solution used for this purpose is thus prepared:—

Ether	90
Alcohol	10
Pyroxyle	2 to 3
Castor oil and turpentine	1

For some time collodion has been a precious agent in surgery and medicine. It answers to a multitude of uses relative to certain wounds, ulcers, eye diseases, etc.

Thus, it is a remarkable circumstance, that a compound, the explosive properties of which seem destined to extend the list of the most terrible agents of destruction, presents in itself very little modified in its texture, one amongst the most efficient agents used in protecting the life of man.

APPLICATIONS OF COLLODION TO PREPARE ARTIFICIAL FLOWERS AND LEAVES.

M. Berard Touzelin has made several new applications of collodion, principally in the fabrication of artificial flowers and in book binding, and he has succeeded in economizing in these different applications two-thirds of the ether by concentrating the solution of pyroxyle and collecting the ether which becomes disengaged. He prepares his collodion in the following manner:—

Ether at 56° . . .	100
Gun cotton* . . .	6
New castor oil . .	5 to 8

The solution being prepared while cold, he distils it over a water bath, so as to collect ⅞ of the ether. He leaves it to settle 8 or 10 days; decants the clear liquid, and adds the castor oil.

Very finely powdered different mineral colors can then be mixed with the solution, or coal tar colors can be dissolved in it. The liquid thus colored is run on a glass perfectly level. The collodion solidifying it can be taken at once.

M. Berard obtains a perfect imitation of leaves of different plants, with the help of moulds taken from nature according to different processes, and principally by the help of the figuring while warm (about 200°). The moulds are prepared in the following manner:—

Put on a cloth plug a natural leaf, supported

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* The gun cotton is prepared with nitrate of potash and sulphuric acid.

on its inferior face, *i. e.*, the superior part of the limb outside, interpose carefully on it, plaster passed through a fine sieve, and mixed so as to take the stamp well. The lump of plaster having become of sufficient consistency, with a knife give it the form of a truncated cone, of which the extreme edges of the leaf represent the little basis; these edges are cut with a penknife to follow the denticulation of the leaf. The cone is dipped several times into a bath of melted wax ready to solidify (about 176°) till the thickness of the envelope is strong enough.

Dip it into cold water to increase the consistence of the wax, and diminish that of the plaster. Then strip the basin by taking out the conical mass of plaster.

This basin containing the leaf in the bottom is metallized with powdered plumbago. It is then put into a bath of sulphate of copper, and submitted, as usual, to the ordinary process of electro-metallizing, and in 8 or 10 days is deposited a bed of copper sufficiently thick; then take out the wax envelope and the leaf which covers the bottom of the copper mould. The mould is filled with melted bronze, and run into it while liquid, by engaging in it an iron rod which forms a handle; you obtain thus a matrice, of which you print under a strong pressure the embossments (nerves of the leaves) in a thick lead basin (alloyed with 0.2 of antimony).

It is between this matrice and the basin that are successively figured the leaves cut with the punch from the colored collodion. The figuring is effected by a quick pressure, the moulds being kept at the temperature of 212°. For the stalks adapt to the leaf an iron wire colored with green paper.

Recently, M. Berard has made a new application of the colored collodion spread on cloth or paper, and figured by pressure on surfaces representing hollow the projectures of the skins shagreened for book-binding. This figuring is effected between a copper cylinder and a cylinder in shields of paper, hardened by an energetic pressure that exercises a strong screw on the iron axis of this kind of paper cylinder.

CHAPTER XXVI.

APPLICATION OF COLLODION IN PHOTOGRAPHY.

A VERY happy application has been made of collodion in photography. We do not expect to give here a treatise on this art, but we think it of interest to the reader to be informed of that part which specially treats of the application of collodion to the art.

PURE COTTON.

Take wadding cotton, and treat it, 1st, with a solution of weak potash; 2d, with water; 3d, with hydrochloric acid; 4th, with boiling distilled water, and dry it.

GUN COTTON.

Take 10 ounces of dried nitrate of potash in fine powder, introduce it into a mortar, and pour on it 20 ounces of sulphuric acid. Mix well, and gradually immerse in the mixture 1½ ounce of pure cotton. Leave the cotton a quarter of an hour; remove it to a funnel, and wash it well with lukewarm water. When the cotton is free from acid, wash it well three or four times with distilled water. Dry it at a proper temperature, keeping it covered with paper to keep off the dust. If during the process red vapors are evolved, the operation has to be begun over again.

PREPARATION OF THE COLLODION.

It is better to prepare a large bottle at once, as it keeps well, and improves by settling.

In a ground stoppered bottle introduce—

Rectified ether . .	100	parts (weight).
Commercial alcohol .	20	" "
Gun cotton . . .	2 to 4*	"
Aq. ammonia . .	5	drops

---

* Use two parts in summer, and four in winter.

Shake occasionally, and when the cotton is dissolved, add—

Iodide of ammonium	1	part
Cyanide of potassium	$\frac{1}{10}$	"
Fluoride of potassium	$\frac{1}{10}$	"

When the salts are dissolved, filter through a cotton cloth into a bottle previously washed with ether. Instead of iodide of ammonium, you can use—

Iodide of potassium	1	part
Iodine	$\frac{2}{10}$	"

The collodion has a yellow color, which after a few days becomes light straw.

As the solution of the salts is difficult in ether and alcohol, dissolve the salts in a few drops of water, and then add it to the collodion. For immediate use it should be kept in bottles of three or four ounces.

CLEANING OF THE GLASS.

The glass, on which the collodion is applied, should be well cleaned with the following composition:—

Alcohol	10 ounces
Ammonia	2½ drms.
Rotten stone	1½ drm.

APPLICATION OF THE COLLODION ON THE GLASS.

Take the glass by one corner, in the left hand, and with the right hand pour the collodion on to the centre of the glass and let it flow over the glass by giving it a half rotary motion. When the whole surface of the glass is covered, pour off the excess of collodion by the opposite corner, to prevent streaks, as you must only pour upon the glass enough to cover it. Place it horizontally, and give it a gently inclining motion from side to side. When the collodion begins to dry, immerse the glass plate into the sensitive bath.

SENSITIVE BATH

Is prepared in the following manner:—

Distilled water	100 parts
Nitrate of silver	8 "

Dissolve the whole of the silver in distilled water, filter, and let it stand a few hours. For this purpose use a vertical bath of gutta percha.

Before using the bath, filter the solution; when the bath is nearly full, immerse the plate quickly, raise it after a minute to inspect it, when it will have a milky color, nearly white, as well as an oily appearance caused by ether.

When these phenomena have disappeared, and the glass has no marble appearance, remove it; allow it to drain before putting it into the frame.

The length of time for it to remain in the bath of silver varies from one to three minutes. Expose the glass plate in the camera to take the picture. When done develop the image.

DEVELOPING THE IMAGE.

There are two ways of developing—

(*a*) *By pyrogallic acid.*

(*b*) *By proto-sulphate of iron.*

(*a*) To develop by pyrogallic acid, prepare the following bath:—

Distilled water . . .	100 parts
Pyrogallic acid . . .	1 "
Glacial acetic acid . .	10 "

When the plate is removed from the frame, take it by one corner, cover it with the above solution, agitate well the fluid over the entire surface, being careful that the plate is entirely covered with the liquid. The image gradually appears, but it is not very distinct; it is rendered perfect by putting it into a bath of—

Nitrate of silver . . .	1 part
Distilled water . . .	100 parts

When the image is perfect in all its parts, wash the glass with distilled water, and fix it.

(*b*) To develop by the proto-sulphate of iron, prepare the following bath:—

Distilled water . . .	100 parts
Proto-sulphate of iron . .	10 "
Glacial acetic acid . .	2 "
Sulphuric acid . . .	2 drops

Filter, and pour it into a porcelain dish, and immediately plunge the glass in. In three or four seconds the image appears and is perfect. Wash and fix it.

Fixing the Proof.

There are two methods of fixing the proof:

(*a*) By sulphate of peroxide of iron.

(*b*) By hypo-sulphite of soda.

(*a*) To fix by the sulphate of peroxide of iron, prepare the following bath:—

Distilled water	1000	parts
Sulphate of peroxide of iron	2	"

Allow the proof to remain in this solution from 50 to 60 seconds, wash with distilled water, and dry.

(*b*) To fix by the hyposulphite of soda, prepare the following bath:—

Distilled water	1000	parts
Hyposulphite of soda	60	"

Operate as above.

Positives on Collodion.

The principal advantage positive pictures possess is, that they do not reflect like the silver plate, and they require less time to take than negative pictures. The preparation of the plate for pictures is precisely the same as for negatives, except it requires a much shorter exposure in the camera. The pictures are developed with pyrogallic acid, to which is added a drop or two of nitric acid, or with the proto-sulphate of iron and the same quantity of acid. The two solutions are thus prepared—

I.

Pyrogallic acid	10 grains
Acetic acid	65 minims
Nitric acid	1 minim
Distilled water	10 ounces

II.

Proto-sulphate of iron . .	26 grains
Acetic acid	80 minims
Nitric acid	2 "
Distilled water	640 "

What we have said above is sufficient to demonstrate the great utility of gun cotton in photography, and the reader who wishes to make himself acquainted with the full description of the manipulations of this art, can find them lengthily explained in Hardwick's "Manual of Photographic Chemistry."*

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* This volume will shortly appear from the Industrial Press of Henry Carey Baird, Philadelphia.

CHAPTER XXVII.

ACCIDENTS WHICH ARE LIABLE TO OCCUR DURING THE PREPARATION OF GUN COTTON—CAUSES OF THESE ACCIDENTS—PRECAUTIONS TO BE TAKEN.

IT is to Mr. Payen that we are indebted for a complete study of the very important question of the accidents which are liable to occur in the preparation and the drying of pyroxyline.

During the preparation, Mr. Payen has observed that when he pours the nitric acid or the mixture of nitrate of potash and sulphuric acid on the cotton, the temperature sometimes raises high enough to bring about the inflammation of the fibre, which is out of the liquid. Every chemist has observed that in operating by dipping the cotton into the acid, if the operation is done slowly, so that a part of the cotton is out of the acid, a particular reaction takes place, and gives a disengagement of nitrous vapors. Sometimes they have seen this reaction take place so rapidly that it provokes an effervescence, to such an extent, that the liquid is ejected more or less quickly from the vessel which contains it, and the cotton disaggregates, and is converted into a brown-reddish solution.

These two accidents are greatly to be apprehended, and can be stopped by throwing the whole into cold water, but it is better to avoid it by dipping the cotton completely into the liquor, in which it may stay more than 48 hours without inconvenience. These two accidents have not yet produced dangerous results; that is the reason why we only indicate them; but as all recorded accidents have occurred during the drying, we shall be more particular on the precautions to be taken in this operation. We have seen cotton explode at a temperature of 140°; how shall we explain such explosions when direct experiment shows that the pyroxyline, in order to fulminate, requires a more elevated temperature? Mr. Payen has examined this phenomenon, and he has demonstrated that currents of air, heated even moderately by stoves or furnaces, may produce explosions? Every one has remarked that if gun cotton is placed on ordinary paper, and if that paper is kept above lighted coals, at a distance, such that the paper is scarcely burnt, and that the hand very easily supports the temperature of the current of air, and the deflagration is not long in being produced—then, according to Mr. Payen, it is very probable that, under these circumstances, currents of air or gases resulting from the combustion, keeping a temperature above 212° and even 356°, may inflame some particles of the cotton where they do not sensibly affect the skin.

To ascertain the truth of his theory, Mr. Payen kept for a long time the pyroxyline in contact with fine sheets of metals or porcelain heated by steam, and in no case has he ever seen inflammation produced; and he has several times proved that currents of air, heated by the intermediary of metallic plates or masonry works, inflame the cotton at a temperature not above 186°.

The consequence of these observations is, that in the oven used to dry the pyroxyline, hot air, heated by furnaces, stoves, etc., ought to be excluded, even if it was mixed with cold air. On the contrary, an oven, with a current of air heated by steam, fulfils all the conditions of safety, and by using steam, the oven can be heated without danger nearly up to 212°.

Mr. Gaudin has proposed a very good method of drying small quantities of pyroxyline.

Through the room in which the cotton is, he passes a current of air, which has been desiccated by quicklime. This process is economical and perfectly safe, but is too tedious to operate on large masses. Mr. Payen has seen that the pyroxyline, prepared with raw cotton, heated on a mercury bath, requires a temperature higher than 392° to take fire.

When prepared with pure cellulose, it explodes at 329°. Nitric paper, according to this chemist, has an explosive property weaker than the cotton.

CHAPTER XXVIII.

METHOD OF DISTINGUISHING GUN COTTON FROM ORDINARY COTTON — SPONTANEOUS FORMATION OF PRODUCTS SIMILAR TO PYROXYLINE.

MANY processes have been proposed to distinguish gun cotton from ordinary cotton. One chemist has proposed to rub them in the dark; he says that gun cotton becomes luminous, whilst ordinary cotton does not give any emission of light; we have tried this process many times, and have never succeeded. The best method is the following:—

Make a mixture of 1 ounce of sulphuric ether, with ¼ of an ounce of alcohol, introduce into it 5 or 6 grains of the cotton to try; if it dissolves and forms a syrupy solution, it indicates gun cotton, if ordinary cotton it does not dissolve. This test is the surest and most easy.

Another very serious question worth attracting attention to, is the spontaneous production of matters similar to the pyroxyle, and, like it, capable of taking fire. Mr. Thenard first called the attention of chemists to this fact. For some time, in his house, they used to deposit in an open box the snuffings of lamps, when one night they spontaneously took fire, and he attributed this effect to the fact, that the snuffings impregnated with oils had absorbed the oxygen by degrees, and had become spontaneously inflammable.

It must also be remarked, in regard to gun paper, that the liquor may unite with the nitric acid, and become inflammable. It is in this way possible to explain the spontaneous combustion which has resulted from the breaking of bottles full of nitric acid, the acid running into organic matters.

SECTION IV.

COLORED FIRES.*

THE phenomena exhibiting colored flames may be distinguished into *non-illuminating* and *illuminating fires*. The former expression is certainly not to be taken in the strict sense of the word, since a flame without any light is clearly impossible; but the line of distinction between the two is so marked, that the meaning is readily understood. *Non-illuminating fires*, owing to that very peculiarity, are of but limited application compared with the colored or illuminating fires proper, which are those principally called into service by pyrotechnists. The medium of combustion in the former is

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* In this section we are indebted for many recipes to the "American Druggists' Circular."

almost exclusively alcohol, while that of the latter is either charcoal, or sulphur, or both together.

Before proceeding with a description of the various lights and their components, it will be necessary to give practical methods for the preparation of the ingredients, and it will be found advisable to adhere strictly to the rules laid down in the following chapter.

CHAPTER XXIX.

SUBSTANCES USED FOR PREPARING COLORED FIRES.

NITRATE OF POTASH.

IN Chapter VII. of this work, we have said all that is necessary of this substance. Before using, it must be perfectly dried. It colors the flame of alcohol *clear pink.*

SULPHURET OF SODIUM.

Dry the glauber salt, in an iron pan over a coal fire, as long as watery vapors arise from it; the white powder resulting is mixed with ⅓ its weight of powdered charcoal, placed in a crucible, covered, and exposed to the strongest heat of a stove. Sulphuret of sodium is produced, which fuses; when the crucible is taken from the fire it is allowed to cool, then broken, and the sulphuret powdered and preserved in well-stoppered bottles.

OXALATE OF SODA

Is prepared by neutralizing a concentrated hot solution of carbonate of soda, by slowly adding oxalic acid until it turns blue litmus paper into red. The salt is crystallized and dried in the usual manner, using cold water for washing, and no heat in drying.

NITRATE OF BARYTA.

The material to manufacture this salt is the native sulphate or carbonate of baryta, or the commercial chloride of barium. The mode of preparation for the two former is the same as that of the nitrate of strontia, as we shall see. From chloride of barium it is prepared as follows: Dissolve four parts of chloride of barium in eight of hot water, and three parts of nitrate of soda in three of hot water; mix the solution while hot, and stir till cold. Owing to chemical affinities, an exchange of acids and basis takes place, from which results a fine crystallization of nitrate of baryta and chloride of sodium.

The nitrate of baryta is drained in a glass funnel from the mother liquor, washed slightly with cold water, then dissolved in hot water, and recovered by a second crystallization. The mother liquor from this latter yields another though more impure supply of the salt. The crystals are treated in the same manner as nitrate of strontia.

CHLORATE OF BARYTA.

This salt is difficult to prepare sufficiently pure for the wants of the pyrotechnist. Its preparation is very circumstantial, and the best is as follows: Dissolve 15 parts of tartaric acid in 48 parts of water, and neutralize by adding gradually 14 parts of crystallized carbonate of soda. At the same time have 12 parts of chlorate of potash dissolved in 32 of boiling water. The hot solutions are mixed, stirred up, and set aside to cool. On cooling, there will be found a precipitate of bitartrate of potash and a solution of chlorate of soda.

This latter is filtered off, and to it are added 12 parts of oxalic acid dissolved in 36 parts of cold water, the mixed solutions being surrounded with a frigorific mixture in an ice freezer. It is necessary for the precipitation of the oxalate of soda that the solutions should be kept as cold as is practicable, since this salt is quite soluble at the ordinary temperature. The oxalic acid has disengaged the chloric acid, which latter is now contained in the supernatant liquor, and after filtering, is in its turn neutralized with freshly precipitated pulpy carbonate of baryta, by the aid of a slight elevation of temperature. The solution of chlorate of baryta is then evaporated *over a water bath,* and the salt as it forms removed from the liquor which is completely dried. For the purpose of a pyrotechnic display, this salt must not be deliquescent, nor exhale any acid, and when ignited on paper must show a purely emerald light; if this light has a reddish or yellowish hue, the salt is unfit for use. The carbonate of baryta called for in this formula is prepared by precipitating a solution of chloride of barium by one of carbonate of ammonia, to which some ammonia has been added.

When the white precipitate has settled, pour off the supernatant liquid, bring the precipitate on a filter, and wash it with pure water as long as the washings carry off any ammonia, which is the case if it colors a drop of a dilute solution of blue vitriol a deeper blue.

CHLORIDE OF STRONTIUM.

This is prepared in the same manner as the nitrate of strontia, substituting hydrochloric acid for nitric acid. Owing to its greater solubility in water, it is necessary to obtain the salt crystallized to evaporate the solution to a less bulk before a crop of crystals will form. These are drained in the same way as the nitrate, but dried at a higher temperature on bricks, and preserved in well-stoppered bottles.

NITRATE OF STRONTIA.

This salt is prepared from the native sulphate of strontia or its carbonate; the latter furnishes a solution of the nitrate when it is powdered, placed in a porcelain dish, and treated with commercial nitric acid as long as a violent effervescence is produced, then placing the dish on a sand bath, and heating it slowly, when a small portion of the mineral must remain behind, or otherwise it has to be added in order to prevent a loss of acid. The hot solution is then filtered and allowed to cool, when a second crop of crystals will result. Both crops are then drained on a glass funnel, folded in blotting paper, and pressed between two bricks. They are next ground into powder in a porcelain mortar, dried upon warm bricks, and finally preserved in well-stopped bottles. The sulphate of strontia requires another manipulation, which consists in first calcining the powdered mineral, embodied with about two-fifths of its weight of flour, and made into paste with some fatty oil, in crucibles or earthen pots, which are placed in a brick or potter's kiln. This yields an impure sulphuret of strontium, which is exhausted with hot water; the solution filtered and evaporated to the point of crystallization. The crystals, which are generally indistinct, may be separated, drained, and dried upon bricks, if it is desired to preserve them. To convert the concentrated solution into nitrate, it is treated with nitric acid diluted with an equal weight of water. This operation involves the disengagement of large quantities of sulphuretted hydrogen, and renders it necessary to perform it in the open air or under a good draught. When the effervescence has ceased, a small excess of sulphuret of strontium is added, the solution of the now nitrate of strontia is heated over a sand bath, filtered, and treated as above.

OXALATE OF STRONTIA.

Add to a solution of nitrate or chloride, a solution of oxalic acid as long as a white precipitate is formed. This is filtered off and repeatedly washed with water, then dried as usual. The acid liquor from the precipitation, as well as the washings, contains some strontia which ought to be recovered by precipitation with carbonate of ammonia, and the carbonate of strontia formed converted into nitrate or chloride.

SULPHURET OF TIN.

Tin is filed into a coarse powder, and mixed with an equal weight of flowers of sulphur. This mixture is deflagrated in a crucible brought to and kept at a red heat on a coal fire. Small portions are introduced at a time, when deflagration takes place, caused by the combustion of the excess of sulphur; no more is added until what is left in the crucible has assumed the temperature of the crucible, and is in a glow. When the crucible is about ¾ full, it is covered, heated somewhat stronger for a while, and then allowed to cool. The contents of the crucible are powdered in an iron mortar; if any of the metal should still be present in a free state, proved by the flattening of some of the coarsor grains, they must either be picked out, or the whole calcination must be renewed after adding some sulphur.

NITRATE OF COPPER.

Copper turnings or small slips of copper, together with a sufficient proportion of nitric acid in a porcelain dish, are placed in the open air and slightly heated. Should all the copper be dissolved, some more must be added until it ceases to dissolve, whereupon the solution is heated to boiling, then taken from the fire and allowed to cool slowly. The nitrate of copper will form in fine green crystals, which are freed from the mother liquor by pressing between filtering paper, and drying on bricks without heat. They are preserved in glass-stopped bottles.

CHLORIDE OF COPPER

Is prepared in the same manner with aqua regia instead of nitric acid. The solution is rapidly *boiled* down, and the blue crystals of chloride of copper which form on cooling when drained from the mother liquor, but still moist, are dissolved in alcohol, partly on account of their deliquescence, and because this preparation is only used in that condition.

IODIDE OF COPPER.

A solution of sulphate of copper, saturated in the cold, is added to a similar one of iodide of potassium until the liquid shows a blue color, when the precipitate has settled. The whole is then well stirred, filtered, and the precipitate on the filter washed, first with water, then with alcohol. The brownish white powder of iodide of copper is dried upon bricks at a low heat, and when dried preserved in stoppered bottles.

We have thus far enlarged upon the preparation of the rarer compounds required for pyrotechnic displays, all other ingredients are easily obtained in the trade, but they must always be of the best quality.

CHAPTER XXX.

NON-ILLUMINATING COLORED FIRES.

The usual modes of preparing these fires are as follows:—

Into a flat porcelain or tin cup pour alcohol, and add the coloring substance previously dissolved in hot water: Or cotton wadding is dusted with the preparation in a fine powder, then soaked in alcohol and lighted. The same ball of cotton may serve repeatedly by merely moistening it with alcohol: or take a common cylindrical tin box about 4 inches high and as many wide, and form it into a rude lamp after the manner of a spirit lamp by passing an inch of perforated tin or brass tube for the wick through the lid, then fill it with alcohol, to which a solution of the coloring substance has been added. The latter arrangement will be found preferable.

The following substances are used to produce the various colors.

Red.—Nitrate of strontia, chloride of strontium.

Yellow.—Chloride of sodium, nitrate of soda.

Green.—Nitrate and iodide of copper, boracic acid.

Green with Blue Streaks.—Chloride of copper.

Pink.—Saltpetre, pearlash, orange, chloride of calcium.

CHAPTER XXXI.

ILLUMINATING FIRES—BENGAL FIRES—OPEN LIGHTS—COLORED LIGHTS.

ILLUMINATING FIRES AND BENGAL FIRES.

THESE fires serve to illuminate objects of a small or larger compass; hence, intensity of light is principally to be aimed at, besides, there is a condition that there be but little smoke, and that the mixture burn off slowly and regularly. The mode of using the mixtures is either to place them open on a flat dish, or to put them into stiff paper capsules prepared in the manner of rockets, but of very thin paper. These two modes require different mixtures, and produce different effects. The former gives off a larger light, but, even in large quantities of short duration, while the latter, though smaller, burns longer and with more regularity.

OPEN FIRES.

Among the many recipes for these, but few deserve to be recommended, and these have been selected. The *white* and *red* fires only show a clear distinct color. The *green* is generally pale, and shows off easily when burnt after a red. A pure blue is very difficult to obtain.

The following should be observed as general rules: The ingredients for the fires are dried *singly* at a slightly elevated temperature, finely powdered, and preserved in well-stopped bottles until required for use. The mixing of the ingredients is best performed on a sheet of paper by means of a card, and should be done very carefully, so as to insure a complete mixture. Sifting is in most cases admissible, while triturating in a mortar is, above all, to be avoided.

After mixing, the powder is piled in small heaps in open vessels, for which purpose small flower-pot dishes are well adapted. On top of these several piles some gunpowder is placed to facilitate the lighting. The vessels should be arranged in such a manner that the flame may illuminate the intended object without being seen by the spectators. The distribution of the material into a greater or less number of dishes is governed by circumstances. A great number of small flames from a given quantity of mixture generally gives a more intense, but so much shorter lived light than the same quantity distributed in larger portions. Beyond a certain limit, however, even that intensity is not materially heightened by a few more lights. If the fire is to continue for some time, it must further be considered that large quantities of the mixture form a correspondingly greater amount of slags which greatly mar the effect. It is, therefore, best in such cases to burn off a number of small charges successively.

WHITE FIRE.

The following mixture is the best for white lights, being unsurpassed in brilliancy and power by any other.

I.

Take—

Saltpetre	18 ounces.
Sulphur	10 "
Black sulphuret of antimony	3 "
Burnt lime	4 "

The sulphur is used in the form of flowers previously dried; the lime is *not to be slaked*, but must be finely powdered; it must be fresh and be powdered immediately before use.

All other mixtures for white fires have either a blush tinge, or contain deleterious ingredients, which latter render them at least unsuitable for in-door use. Of this latter class we will mention only one.

II.

Take—

Saltpetre	12 ounces.
Sulphur	4 "
Sulphuret of tin	1 ounce.

Two other mixtures deserve mention, while not equal to No. 1.

III.

Take—

Saltpetre	24	ounces.
Sulphur	6½	"
Sulphuret of sodium	3½	"

IV.

Take—

Saltpetre	32	ounces.
Sulphur	10½	"
Gunpowder	7½	"

BLUE FIRES.

The only mixture to be relied on, though the light is not purely blue but bluish-white, is the following:—

Saltpetre	3	ounces.
Sulphur	1	ounce.
Black sulphuret of antimony	¼	"

RED FIRES.

The following mixture is the best in use; its composition may be altered by various admixtures.

I.

Take—

Nitrate of strontia	13 ounces.
Sulphur	1 ounce.
Powder dust	1 “

The latter ingredient is prepared from gunpowder, rubbed up carefully in a mortar, and then sifted through a hair sieve.

II.

Take—

Nitrate of strontia	12 ounces.
Chlorate of potash	8 “
Stearin	2 “
Powdered charcoal	½ ounce.

In using chlorate of potash, the precautions we have indicated in other chapters must be strictly observed, and all pounding and rubbing avoided.

III.

Take—

Nitrate of strontia	10	ounces.
Chlorate of potash	2	“
Sulphur	2½	“
Black sulphuret of antimony	1	ounce.
Powdered charcoal	½	“

This gives a very strong light.

The nitrate of strontia for these fires, as the ingredients for all others, must be well but carefully dried.

YELLOW FIRE.

This color, which is very little used, is produced by the following mixture:—

Nitrate of soda	3	lbs.
Sulphur	1	lb.
Black sulphuret of antimony	¼	“
Powdered charcoal	1	ounce.

GREEN FIRES.

The coloring ingredients for these lights are the salts of baryta; the color is generally not very deep.

I.

Take—

Nitrate of baryta . .	22½ ounces.
Sulphur	5 “
Chlorate of potash . .	10 “
Calomel	1 ounce.
Lampblack . . .	½ “

II.

Nitrate of baryta . .	30 ounces.
Chlorate of potash . .	9 “
Sulphur	11 “

III.

Chlorate of baryta .	3 ounces.
Sulphur . . .	1 ounce.

IV.

Chlorate of baryta .	1½ pound.
Stearin . . .	3 ounces.
Sugar of milk . .	1 ounce.

V.

Chlorate of baryta .	3 ounces.
Sugar of milk . .	1 ounce.

COLORED LIGHTS.

These are formed by filling cylinders of thin writing paper of about an inch in diameter with the mixtures. The length of the cylinder determines the duration of the light. The mixture may be moistened and pounded into the cylinder with a wooden rod. After drying, they will then be hard enough to allow of the removal of the paper, and may be further strengthened by being dipped or painted over with mucilage of gum arabic. The cylinders, when finished, are tied to the upper end of sticks fastened in the ground in a vertical position.

The mixtures vary essentially from those used for colored fires.

WHITE LIGHTS.

Saltpetre	4 ounces.
Sulphur	1 ounce.
Black sulphuret of antimony .	1 "

Yellow Light.

I.

Sulphuret of antimony	2 ounces.
Chlorate of potash	4 “
Sulphur	2 “
Oxalate of soda	1 ounce.

II.

Saltpetre	140 ounces.
Sulphur	45 “
Oxalate of soda	30 “
Lampblack	1 ounce.

Green Light.

I.

Chlorate of baryta	2 ounces.
Nitrate of baryta	3 “
Sulphur	1 ounce.

II.

Chlorate of potash	20 ounces.
Nitrate of baryta	21 “
Sulphur	11 “

RED LIGHT.

Nitrate of strontia	25 ounces.
Chlorate of potash	15 "
Sulphur	13 "
Black sulphuret of antimony	4 "
Mastic	1 ounce.

PINK LIGHT.

Chlorate of potash	12 ounces.
Saltpetre	5 "
Sugar of milk	4 "
Lycopodium	1 ounce.
Oxalate of strontia	1 "

BLUE LIGHT.

Chlorate of potash	3 ounces.
Sulphur	1 ounce.
Ammoniated copper	1 "

COLORED LIGHTS WITHOUT SULPHUR FOR INDOOR ILLUMINATIONS.

WHITE.

Chlorate of potash	12 ounces.
Saltpetre	4 "
Sugar of milk	4 "
Lycopodium	1 ounce.
Carbonate of baryta	1 "

YELLOW.

Chlorate of potash	6 ounces.
(or nitrate of baryta)	10 "
Saltpetre	6 "
Oxalate of soda	5 "
Powdered shellac	3 "

GREEN (*only after yellow or red lights*).

Chlorate of potash	2 ounces.
Nitrate of baryta	1 ounce.
Sugar of milk	1 "

RED.

Nitrate of strontia . . .	12 ounces.
Chlorate of potash . . .	8 "
Sugar of milk	1 ounce.
Stearin	2 ounces.

CHAPTER XXXII.

PHOSPHORIC LIGHTS.

PHOSPHORESCENCE.

A NUMBER of bodies have the peculiarity under certain circumstances of emitting light, the origin or cause of which has not as yet been fitly explained. Among such cases is the appearance of light *during the process of crystallization.* The transition of a substance from the non-crystallized, amorphous or liquid, to the crystallized condition, is accomplished by a simultaneous movement of its atoms, producing light in a manner which cannot be further accounted for.

In all cases to be mentioned, it will be found a very remarkable fact that when the substance has once shown this phenomenon, during its passage into the crystallized state, it will not show it again when redissolved and recrystallized. Evidently there is connected with it a positive change in the arrangement of the atoms, and the phenomenon of phosphorescence is only in so far coincident with the process of crystallization, as the latter is produced by a rearrangement of the atoms.

The amount of light developed is in all instances so small as to be observable only in the dark.

Arsenious Acid.—This substance, as it appears when freshly prepared, and partly even for some length of time afterwards, is in transparent, glassy, perfectly colorless lumps. It gradually passes, beginning on the outside first, into a semi-transparent porcelain like, and finally into a perfectly opaque state. This change is caused by the atoms assuming the form of crystals. It is reduced more rapidly and with the appearance of light when the crystallization of the acid takes place from a solution of it. For this purpose a piece of the transparent arsenic is powdered and dissolved in somewhat diluted and boiling hydrochloric acid to saturation, with due observance of the caution necessary to guard against accidental poisoning. The glass vessel containing the solution is then allowed to cool slowly, having been placed on some non-conducting substance, such as wood. As soon as the crystallization sets in, the formation of each crystal is observed in the dark by a brilliant glimmer of light.

Sulphate of Potash.—The neutral sulphate of potash, when freshly prepared, possesses the same property of phosphorescence while passing into the state of crystallization. It is necessary that the solution of this salt be not made by dissolving crystals of it in water, but that it be a solution of its components sulphuric acid and potash, or bisulphate of potash and potash. For, the once crystallized salt has already undergone the change in the atoms on which the success of the experiment depends, and its immediate formation, as it were, an amorphous condition, is indispensable. To a solution of purified pearlash or salt tartar in hot water, dilute sulphuric acid is added gradually, as long as effervescence takes place, or the liquid turns red litmus paper to blue, then filtered and evaporated to the point of which, a small portion of it on cooling deposits crystals. The solution is then allowed to cool slowly in an open dish, and it will show in the dark a constant succession of viscid flashes attending the formation of crystals.

Better results are sometimes obtained by neutralizing a solution of fused bisulphate of potash with pearlash in the same manner.

SULPHATE OF SODA AND POTASH.—A mixture of 11 parts of sulphate of potash and 9 of effloresced sulphate of soda is fused in a crucible, then allowed to cool, powdered, dissolved in just enough hot water, and quickly filtered. On cooling, the formation of crystals is accompanied by a similar phosphorescence as that above referred to. Within a few hours after their formation they will shine again when rubbed; but on being redissolved and again brought to crystallization, no light will be observed, nor would any be seen in the original solution if it were too dilute when first made, and had to be evaporated.

SULPHATE OF POTASH AND CARBONATE OF SODA.— A mixture of 8 parts of sulphate of potash and 3 of *effloresced* carbonate of soda, fused and treated in the same manner as the above, gives the same result.

CHROMATE OF POTASH AND SULPHATE OF SODA.—A mixture of 19 parts of neutral chromate of potash and 14 parts of *effloresced* sulphate of soda gives the same result as above.

CHROMATE OF POTASH AND SODA.—The following mixture behaves in the same manner: 2 parts of bichromate of potash and one of dry carbonate of soda. In this case the crucible must be large enough to allow for the effervescence caused by the disengagement of carbonic acid.

Benzoic Acid.—The sublimation of benzoic acid is attended by a brilliant exhibition of glimmering lights when properly conducted. An optional quantity of it is mixed with one-sixth of its weight of powdered charcoal, and put into a flat dish which is placed on a heated iron plate; the dish is covered by a large bell glass.

CHAPTER XXXIII.

PYROPHORS.

A SECOND class of self luminous substances are those in which this peculiarity is permanent and which are sometimes called *pyrophors* (FIRE BEARERS). Their phosphorescence consists in the diffusion of a pale light without manifestation of fire, the same as the well known appearance of phosphorus their prototype in the dark. In some of these substances the phosphorescence is caused by slow combustion; in others, such as some living and dead animals, and vegetable membranes, as well as some mineral substances, it depends upon causes not within our control, and therefore omitted from our selections; in others, again, it is produced by the illumination of the sun's rays by or during heating and other causes. Most of those which show a phosphorescence, after having been exposed to the sunlight, do the same upon being heated. The explanation of these peculiarities is beyond our limits, and more properly belongs to philosophy.

To produce phosphorescence by means of the sunlight it is only required to expose the substance for some minutes to the direct rays of the sun, and then exhibit it at once in the darkest place that can be selected. In some instances this state of illumination continues for several days; in others, it passes off after a few hours or even minutes. The latter peculiarity is dependent upon certain circumstances attending the preparation of the substances and upon the manner in which they are preserved, which should be in all cases complete seclusion from the air in well-stopped glass vessels.

The color of the light exhibited by these substances varies with their nature, and the degree of heat to which they have been exposed. A certain scale of light and color may, therefore, be produced by grouping together different substances or samples of the same substance, each having been heated at a different temperature.

Sulphuret of Barium.—Finely powdered sulphate of baryta, which must be free from iron, is formed into balls with mucilage of gum tragacanth; the balls are dried at a moderate temperature, then placed in common crucibles, and kept at a red heat for an hour. They are then allowed to cool slowly, and while still warm are transferred into flasks with well-fitting glass stoppers, which may be further secured with wax or tallow. The phosphorescence of this substance is much improved when the baryta has been mixed with three per cent. of magnesia.

Sulphuret of Strontium.—Sulphate of strontia, treated in the same manner as the above, produces the same effects.

Sulphuret of Calcium.—Oyster shells are calcined to perfect whiteness in a crucible, freed by dusting from the ashes, and then piled inside down in a crucible, with a layer of flowers of sulphur between each two. The crucible is then covered and exposed to a dull red heat for half an hour or more.

SULPHURET OF CALCIUM AND ANTIMONY.—Three parts of calcined oyster shells, treated with a mixture of 10 parts of flowers of sulphur and one of oxide of zinc, produce the same effects.

CHLORIDE OF CALCIUM.—Fuse chloride of calcium in a crucible, and pour it out on a bright iron surface or slab; break it into pieces when cold, and transfer it into well-stopped flasks. If no chloride of calcium is at hand, calcine a mixture of 7 parts of burnt lime, slacked to dry powder, with 15 parts of salt ammoniac.

NITRATE OF LIME.—Make a solution of chalk or marble in nitric acid, evaporate to dryness, and fuse in a porcelain crucible.

These substances may be made self-luminous also by other means besides the sunlight; for instance, by heating or pounding. A succession of experiments may be performed with them, after their phosphorescence from insulation has ceased, by first warming them in the hand, then in a water bath, and afterwards on a stone plate, each successive increase of temperature producing a fresh exhibition of light.

QUINIA AND SULPHATE OF QUINIA.—These two substances shine with remarkable intensity when slightly heated. Spread either of them over a sheet of paper, and warm it by holding it over a lamp. When this is withdrawn, a light will commence to spread from the edges to the centre, continuing sometimes for several minutes.

BORACIC ACID.—When boracic acid is fused, and is then allowed to cool, it will spontaneously, or rather by concentration, break into pieces, and along the cracks caused thereby a bright light will appear, strong enough to be visible even in daylight. Sulphate of potash, fused with cream of tartar and salts, shows the same phenomenon.

Phosphorus.—As this is one of the most dangerous substances to experiment on, we shall restrict ourselves to a few experiments which are accompanied by no particular danger, but are still to be performed with great care.

In the first chapter of this work we have given all the precautions necessary, in handling phosphorus, to avoid danger.

Phosphuretted oil is the best means of exhibiting the luminous properties of this substance. The phosphorus dissolves in olive oil to some extent when melted. A small dry piece, of the size of a pea, being placed in a test-tube with oil, is held in warm water, and when melted shaken until it no longer dissolves, and then poured off clear into a small vial which is to be well-stopped, and preserved in a dark place. When this vial is opened in the dark, its contents will shine with the same light as phosphorus itself. The light disappears upon closing the vial, but appears again on reopening it, and is intensified by shaking. It loses this property, however, after some time, when frequently opened. Characters written on paper with fresh phosphuretted oil appear in the dark with a bright glare.

Phosphuretted ether is prepared by digesting finely divided phosphorus in a closed vial with sulphuric ether for some weeks, with frequent shakings. A piece of sugar moistened with this ether and dropped into a vessel with tepid water will make the surface of the latter appear quite luminous in the dark.

The luminosity of phosphorus depends, for the greater part, upon its property of burning in contact with the air, by which a slight amount of light and heat is evolved, analogous to the strongly marked appearance of light and heat when it bursts violently into flame. Yet some of these phenomena, such as are evidently connected with any combustion, cannot thus be explained. Phosphorus is luminous, also, during its evaporation or sublimation, as is also sulphur. Most of these phenomena we are unable to deduce from any single one of these causes, but originate more generally in both.

SULPHUR.—Roll sulphur, drawn over a warm brick, shows its marks in the dark with a bright light.

CHAPTER XXXIV.

MILITARY FIREWORKS.*

BUILDINGS.—In a large establishment four separate buildings are required.

No. 1 should have a porch, and contain at least four rooms.

Cartridge room, for making paper and cartridges of all kinds.

Filling room, for filling cartridges.

Packing room, for putting up ammunition for transportation or storage.

Store room, for materials and tools.

No. 2. FURNACE or SMITH SHOP should have three rooms, two entirely cut off from the third by a partition wall.

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* For some portions of the information contained in this and subsequent chapters, we are indebted to "The Ordnance Manual."

Driving room, for driving rockets, fuses, etc.

Mixing room, for mixing compositions.

Furnace room, for casting fuses or bullets, and making compositions requiring the use of fire.

No. 3. CARPENTER'S SHOP.

No. 4. MAGAZINE for powder, fixed ammunitions, etc.

All these buildings should be at a distance from inhabited buildings, apart from each other, and protected by trees or traverses of earth placed between them.

The size of the rooms is regulated according to the number of men to be accommodated.

Precautions against Accidents.

Avoid, as much as possible, the use of iron in the construction of the buildings, fixtures, tables, benches, boxes, etc., of the laboratory; sink the heads of all iron nails if used, and fill over them with putty, or paste several thicknesses of paper over them. Before the men go to work, cover the floor with carpets or tarpaulins, which are taken up carefully after the men leave, and carried at least 50 yards from the building, and there shaken thoroughly and swept.

Place the stores in cloth bags in the windows, exposed to the sun. Prevent persons from entering with iron instruments or with matches about their person. All those who work where there is powder must wear moccasins or socks. The workmen should not drag their feet while walking.

The doors and windows must open and close easily, without friction, and they must be open whenever the weather permits.

Never keep more powder in the laboratory than is necessary, and have the ammunition and other products taken in the magazine as fast as finished.

Powder barrels ought to be carried on hand-barrows, made with leather, and the ammunition in boxes.

Never drive rockets, etc., in a room where there is any powder or composition, except that used at the time. Loading shells, driving rockets, pulverizing materials, etc., ought to be done in all cases in the open air, or under a tent far from the laboratory and magazine.

Never enter the laboratory at night, unless it is indispensable, and in that case use close lanterns.

Applications for burns.—Exclude the air by applying fresh lard to the burn; or bathe the part burned, and cover it with linen soaked in a mixture of 8 parts of sweet oil and 1 of ammonia well beaten together.

Materials.—As in different chapters of this work we have entered into explanations of the different materials used in fireworks, we think it unnecessary to recall them here. We would then refer the reader to those different chapters.

CHAPTER XXXV.

MATCHES—FUSES—ROCK-FIRE—BLUE LIGHTS—SIGNAL ROCKETS.

SLOW MATCH.

SLOW match is prepared rope, which is used to keep and carry fire; it burns slowly, with a firm, hard coal, and is not easily extinguished.

Materials.—Hemp or *flax* raps of 3 strands, slightly twisted, about 25 yards long, and of a uniform diameter of 0.6 inch—*acetate of lead, water.*

Preparation I.—Boil the rope for ten minutes in water, holding in solution $\frac{1}{25}$ of its weight of acetate of lead; remove it with spatulas into the tub, or let it remain in the cold solution until it is thoroughly saturated. First, twist it over the kettle, and then by attaching one end to the hook of a twisting winch, twist it hard, keeping it stretched by means of a stick passed through a loop at the other end; at the same time rubbing it smartly, always in the same direction from the hook, with coarse mats until the diameter of the match is reduced 0.1 inch, and it has a uniform twist and hardness.

Matches thus prepared burn 4 inches in an hour.

II.—If sugar of lead cannot be procured, the rope may be simply leached; for this purpose, it is put into a leach tub, and steeped in pure water for twelve hours; this water is then drawn off and replaced by lye prepared in a boiler with a quantity of ashes equal to half the weight of the rope, to which 5 per cent. of quicklime is added. When the rope is well leached, twist it with sticks, steep it 5 minutes in hot water, and terminate as above.

This match burns 5 inches in an hour.

A slow match may be made of strong paper by immersing it in a warm solution of nitre, one pound to two gallons of water. A half sheet thus prepared keeps fire for three hours.

QUICK MATCH.

Quick match is cotton yarn of several strands, saturated and covered over with an inflammable composition; it is used for communicating fire from point to point in fireworks.

The material required to make it is mealed powder, cotton yarn, gummed brandy or whiskey, in the proportion of 1 ounce of gum to ½ gallon of spirits. 1000 yards of quick-match require 1 pound of cotton yarn, 8 pounds of mealed powder, 1½ gallon of spirits, and 2½ ounces of gum. When dried it weighs 9 pounds.

Preparation.—Steep the cotton in the gummy whiskey until thoroughly saturated.

Make a paste of mealed powder by mixing 1 quart of gummed whiskey to 2 pounds of powder, and put a layer of it about ½ an inch deep in a bowl; on this spread a coil of the cotton by unrolling the ball, and distributing it equally on the surface of the paste until there are 5 or 6 yards over one another; put another layer of the paste, and continue until the bowl is full. After the cotton has been 3 or four hours in the bowl wind it on a reel. Before it is dried, dredge it with mealed powder; let it dry slowly, cut it off from the reel, and put it in bundles. One yard in the open air burns 13 seconds.

If to the above composition you add ⅙ of sulphur, 1 yard burns in 22 seconds, with ⅕, 33, with ⅓, 53, with ½, 162 seconds.

Fuses for Mortar Shells.

The hard, close grained woods are best adapted for making fuses. Beach or ash is generally used. It should be dried, sound, free from knots, worm holes, etc.

The composition is the following:—

For eight and ten inch light Mortar Fuses.

Nitre	2 parts.
Sulphur	1 part.
Mealed powder . .	3 parts.

For ten and thirteen inch heavy Mortars.

Nitre	2 parts.
Sulphur . . .	1 part.
Mealed powder . .	2½ parts.

Fuses for heavy Guns.

The composition of the mixture is the following:—

No. 1.	Nitre, 26.	Sulphur, 9.	Mealed powder, 14.
No. 2.	" 26.	" 9.	" 12.
No. 3.	" 26.	" 9.	" 10.

Rock Fires.

Rock fire is a composition which burns slowly, is difficult to extinguish, and is used to set fire to buildings, ships, etc. That which is put into shells is cast in cylindrical cases of paper, having a priming in their axis.

Composition:—

Rosin	3 parts.
Sulphur . . .	4 "
Nitre	10 "
Regulus of antimony .	1 part.
Mutton tallow . .	1 "
Turpentine . . .	1 "

Pulverize the sulphur, nitre, and antimony separately, mix them with the hands, and pass through a sieve. Melt the tallow first, then the rosin, stirring the mixture with spatulas, add the turpentine, and next the other materials, in small quantities at a time, stirring the whole constantly with large spatulas.

Let one portion of the composition be melted before more is added. When the composition becomes of a brown color, and white vapors are disengaged, the fire is permitted to go down, and when the composition is sufficiently fluid, the cases are filled not more than ¾ full.

FIRE BALLS.

Composition:—

Saltpetre	8 parts.
Sulphur	2 "
Antimony . . .	1 part.

BLUE LIGHTS.

Composition:—

For 100 lights take—

Saltpetre . . .	9 lbs.	10 ozs.
Sulphur . . .	2 "	6½ "
Red orpiment . .		11 "

The materials should be pure, well pulverized, thoroughly incorporated, and passed through a hair sieve.

Fill a wooden cup with the composition, and press it firmly in. Prime the cup with a quick match.

SIGNAL ROCKETS.

Rockets for signals are composed of a paper case charged with composition, a pot filled with ornaments, and a light stick to give direction.

Composition:—

Nitre	26	parts.
Sulphur . . .	5½	"
Charcoal . . .	19	"

CHAPTER XXXVI.

DECORATIONS FOR ROCKETS—WAR ROCKETS—ORNAMENTAL FIREWORKS.

Stars.—The composition to prepare stars is as follows:—

	White.	Yellow.	Red.	Blue.	Green.	5 points.
Nitre	16	"	"	"	"	"
Sulphur	8	1	"	"	64	7
Mealed powder	4	"	"	"	"	10
Charcoal	"	1	"	"	"	"
Nitrate of soda	"	6	"	"	"	"
Chlor. of potash	"	"	5	8	96	"
Nit. of strontia	"	"	20	"	"	"
Gum dammar	"	"	4	4	"	"
Sulph. of copper	"	"	"	4	"	"
Nit. of baryta	"	"	"	"	192	"

The material is reduced to fine powder, and mixed with the hands. The composition is moistened with whiskey in which gum has been dissolved.

Serpents are very small rocket cases charged with composition.

Streamers are small paper cases from 2 to 4 inches diameter, and from 2 to 4 inches long, made of four turns of paper, one end is closed, and the case is charged and primed like that of a lance.

Gold rain is made of small stars all the same size; the stars are cubes, the length of whose sides is 5 inches.

Marrons are small cubic boxes made of pasteboard, filled with powder, and wrapped with strong twine. They are used to give a loud report or the effect of cannonading.

War Rocket.—It consists, 1st, of a sheet-iron case lined with paper, and charged with rocket composition; 2d, of a cast-iron cylindro-conoidal head, with a small cavity communicating with the bone of the rocket and pierced with three holes, oblique to the surface for the escape of gas; 3d, of a wrought iron plug welded into the rear end of the case, and having a hole in its axis for the escape of gas.

The composition to make the rocket is thus formed:—

Nitre	10 parts.
Sulphur . . .	2 "
Charcoal . . .	3 "

Petard is a wooden box filled with powder, used to blow down doors, gates, barriers, etc.

ORNAMENTAL FIREWORKS.

Lances are small paper cases, 2 to 4 inches diameter, filled with one or more compositions each burning with a flame of a particular color. They are used to mark the outlines of figures, and are attached to light frames of wood on sticks of bamboo.

Their composition is as follows:—

	White.	Yellow.	Red.	Blue.	Green.
Nitre	26	"	16	8	96
Sulphur	9	4	10	2	64
Mealed powder	5	4	7½	"	"
Nitrate of soda	"	16	"	"	"
Lampblack	"	2	"	"	8
Nitrate of strontia	"	"	30	"	"
Sulphate of copper	"	"	"	4	"
Nitrate of baryta	"	"	"	"	192

Sun Cases are strong cases made like those for rockets, and filled with a composition which burns more slowly than the rocket composition; they are attached to wooden frames to give long rays of sparkling light.

The sunlight is thus formed:—

Nitre	1
Sulphur	1
Mealed powder	16
Charcoal	4

Lights are made by pressing lances or similar compositions in a shallow vessel, or in cases of large diameter; the burning surface being large, the light attains a great intensity.

Their composition is the following:—

	White.	Yellow.	Red.	Blue.	Green.	Bengal.
Nitre	16	2	5	8	24	"
Sulphur	8	4	6	2	16	4
Mealed powder	4	"	"	"	"	4
Nitrate of soda	"	20	"	"	"	16
Lampblack	"	1	1	"	1	"
Nitrate strontia	"	"	20	"	"	"
Sulphate copper	"	"	"	4	"	"
Nitrate baryta	"	"	"	"	48	"
Antimony	"	"	"	"	"	2

Petards are small paper cases filled with powder; one end is entirely closed, and the other has only a small hole left for a piece of quick match to communicate fire to the powder.

Wheels are made and driven like sun cases; they are used to give a rotary motion to pieces mounted on an axis, and to produce at the same time a brilliant fire.

The wheel fires have the following composition:—

	Common.	Brilliant.	Chinese.	White.
Nitre	6	1	1	6
Sulphur	1	1	1	7
Mealed powder	16	16	7	16
Charcoal	6	"	"	"
Steel filings	"	7	"	"
Cast iron filings	"	"	7	"

Roman candle is a long and strong tube, charged with stars which are thrown out successively by a charge of powder placed under each star.

Their composition is the following:—

Nitre	6
Sulphur	2
Mealed powder	16
Charcoal	6

Leaders are long paper tubes of small diameter, inclosing a strand of quick match. They are used to communicate fire rapidly from one point to another.

Streamers are composed of—

Nitre	2
Sulphur	1
Mealed powder	16
Charcoal	4

Serpents are formed of—

Charcoal	2
Mealed powder	16

Gold rain is composed of—

Nitre	16
Sulphur	10
Mealed powder	4
Lampblack	3
Flowers of zinc	1
Gum Arabic	1

SECTION V.

FULMINATING POWDERS AND PERCUSSION CAPS.

CHAPTER XXXVII.

HISTORY.

AMONGST the industries of new creation worth the attention of the science, is the fabrication of fulminating and percussion powders. The universal adoption of percussion arms for war purposes is the origin of the rapid development of this new fabrication. Then, if we consider that there exists a small number of manufactures more *unhealthful* than that of the fulminating powders, and none more dangerous, we shall see the utility of a work, the object of which is to indicate all the peculiarities of this fabrication, all its inconveniences and dangers, and at last the improvements to be applied in the different processes.

In 1810, a gunmaker of Paris, Mr. Prelat, introduced in France a lock-plate constructed on an English model, and in which the powder, composed by Berthollet, was used for a primer, that is a composition in which the chlorate of potash took the place of ordinary powder. This powder took fire by the shock of a piston, on which fell the piece performing the functions of a hammer.

At the same time Lepage began to distinguish himself amongst those who were trying to surmount the difficulties connected with the use of primers inflammable by shock.

Deboubert constructed also an ingenious gun; and in 1812 Pauly took out a patent for a similar fire-arm which could be loaded at the breech, and among several advantages it presented was that of not being liable to injury from rain or dampness.

The following year these fire-arms were improved, and in 1814 Brillat-Savarin announced that Pauly's guns could be advantageously used in the army.

However, notwithstanding the real advantages that the fulminating powders seem to have as percussion powders, advantages proclaimed by all the savants, the sum of the inconveniences outweighed the advantages.

The bad effects of the chlorate of potash were indicated in 1812 by Regnier, relatively to a new rifle invented by Gosset: Regnier declares that before this new gun could be of any use it would be necessary that the percussion powders should combine several essential qualities: 1st. Easy transportation without danger; 2d. That they do not oxidize fire-arms, as was the case with chlorate of potash; 3d. That they do not absorb the dampness of the air, as was the case with *fulminate of silver.*

Its previsions are now realized. In 1818 Lepage invented a new fowling-piece in which the prime was not chlorate of potash nor fulminate of silver, but *fulminate of mercury*, and it is to the use of this compound that is due the revolution operated in the fabrication of fire-arms. From all the fulminates, that of mercury is the only one now used.

CHAPTER XXXVIII.

FULMINATING COMPOUNDS.

FULMINATING compounds are compositions which detonate with great force by a blow or by friction.

Many metals form such compounds which are not used in the fabrication of percussion powders, but we think it will interest the reader to know how they are made.

FULMINATING ANTIMONY.

I.

Take—

Tartar emetic . .	100 parts.
Powdered charcoal .	3 "

Triturate together, put the mixture into a crucible filling it ¾ full, cover with a layer of charcoal, lute on the cover, expose three hours to a strong heat in a reverberatory furnace, and let it cool six or seven hours. Transfer the solid contents as quickly as possible to a wide-mouth stoppered bottle, where after some time it will spontaneously crumble down into a powder.

II.

Take—

Antimony . . .	100 parts.
Carburetted cream tartar	75 "
Lampblack . . .	12 "

Operate the calcination as above.

When the above processes are properly conducted, the resulting powder contains potassium and fulminates violently in contact with water. A piece the size of a pea introduced into a mass of gunpowder, explodes on being thrown into water, or its being moistened in any other manner.

FULMINATING BISMUTH.

Take—

Bismuth	120 parts.
Carburetted cream tartar	60 "
Nitre	1 part.

Operate as above.

It is very rich in potassium, and very explosive.

FULMINATING COPPER.

Digest precipitated copper with fulminate of mercury or silver, and a little water. It forms solid green crystals that explode with a great flame.

FULMINATING GOLD.

1st. Take: Recently precipitated peroxide of gold, and digest it for 24 hours in strong ammonia. Dry the resulting fulminate in the open air, or at a temperature below 180°, care being taken to avoid the slightest friction, lest it should explode. It is a deep olive-colored powder.

2d. Digest the terchloride of gold in an excess of ammonia. It is a brownish-yellow powder.

3d. Dissolve gold in the following: aqua regia, sal ammoniac, 4 parts; nitric acid 12 to 16 parts, and precipitate with a solution of carbonate of potash.

This compound can be safely made only in very small quantities at a time. Without great care it explodes with violence. This is caused by the slightest friction on sudden increase of heat Its fulminating properties may be destroyed by boiling it in pearlash, lye, or weak sulphuric acid; and by heating the residue after washing it in water pure gold will be obtained.

FULMINATING PLATINUM.

Treat the sulphate of platina with an excess of ammonia. It is similar to the gold salt.

FULMINATING ZINC.

Operate as for the fulminating copper; digest together fulminate of silver, zinc filings, and a little water.

Fulminating Silver.

1. Digest oxide of silver (recently precipitated and dried by pressure between bibulous paper) in concentrated ammonia for 12 or 15 hours; pour off the liquid, and cautiously dry the black powder in the air in divided portions. The decanted ammoniacal liquor when gently heated yields on cooling small crystals, which possess a still more formidable power of detonation than the black powder, and will scarcely bear touching, even while under the liquid.

2. Dissolve chloride of silver in strong ammonia, cautiously add pure potash in fragments, and when effervescence ceases decant the fluid portion, and wash and dry the powder as before. It is slightly less powerful than the last.

3. Pour one ounce of alcohol on 100 grains of powdered nitrate of silver, previously placed in a capacious flask or beaker glass, and shortly afterwards add one ounce of strong nitric acid. As soon as all the powdered nitrate assumes

the form of white clouds, add cold distilled water enough to suspend the ebullition. Collect the powder on a filter, and proceed as before.

4. Take 50 grains of metallic silver, dissolve it in ¾ ounce of nitric acid at a specific gravity 1.37, and add to the solution still hot, 2 ounces of alcohol, and apply heat until reaction commences; the fulminate slowly separates from the hot liquid under the form of small, brilliant, white, crystalline plates, which after being slightly washed with a little cold distilled water, are distributed upon separate pieces of filtering paper, in portions not exceeding 1 or 2 grains, and left to dry in the air. When dried, the papers are carefully folded, and preserved in boxes or bottles.

5. Take 1 part silver, and dissolve it in 10 parts of nitric acid at a spec. grav. 1.37, add the solution to 20 parts of alcohol at 85°, apply gentle heat till the liquid begins to boil, remove from the fire and set aside to cool. The fulminate of silver deposits in lustrous snow white, acicular crystals, and when washed and

dried, equals in weight that of the silver employed.

The fulminate of silver occurs either in the form of a dark colored powder, or small brilliant, acicular crystals or crystalline plates, according to the mode of preparation. It dissolves in 36 parts of boiling water, but the solution deposits the greater portion of the fulminate as it cools. It is one of the most dangerous substances for which we are indebted to chemistry. It explodes with unparallelled violence by the slightest friction or percussion, or when touched by sulphuric acid. This occurs even when it is moist, if it is pressed by a hard body, and when dried, the touch of a feather is often sufficient to explode it. Its explosive tendency is so great that it can hardly be made, handled, or kept with safety.

CHAPTER XXXIX.

FULMINATE OF MERCURY.

PREPARATION.

THE following process has been indicated by Mr. Gaultier de Claubry.

The mercury is dissolved by nitric acid in a glass flask with a short neck; the liquid must fill it quite ⅔ds, as it disengages a great quantity of nitrous vapors. The flask is placed under a chimney with a good draught. If there be no chimney the operation is performed in the open air, and a weak elevation of temperature is necessary. The proportions used are generally 1½ pounds of mercury and 18 pounds of acid.

The dissolution is divided into 5 glass flasks to operate the mixture with alcohol. For this purpose, when the dissolution has a yellowish shade, the mercury having disappeared, leave it to cool for 8 or 10 minutes, and pour it into the flasks. In the 5 flasks distribute 8 or 10 quarts of alcohol at 95°; often a very quick reaction is produced, and the fulminate deposits. The operation is achieved when it does not disengage any vapor, and when the liquid becomes limpid. In many cases it is necessary to put a little fire under the flask in order to determine the reaction. In both cases there is a great disengagement of vapor, the action of which on the animal economy is very strong. It can, however, be condensed with a receiver, into which will be found a certain quantity of mercury, alcohol, a kind of ether, and several other products.

When the fulminate is well deposited, separate the mother water, and reunite it in two flasks in which a new quantity separates.

Pour the fulminate into a wooden bowl, and after decantation wash it with about ¼ of its volume of cold water.

The most convenient process is the one adopted in England, and indicated by Dr. Ure. It gives the largest proportion of fulminate.

Dissolve at a gentle heat 100 parts in weight of mercury in 1000 parts of nitric acid at a spec. grav. 1.40; pour the dissolution, previously carried to 131°, into 830 parts of alcohol of a density of 0.83. By measuring it takes one vol. of mercury, 7½ of nitric acid, and 10 of alcohol.

Dissolve the mercury in the acid in a tubulated glass retort, the neck of which communicates with a glass receiver surrounded by cold water, to collect the distilled vapors.

The condensed liquid is poured back into the retort. When all the mercury is dissolved, and the temperature is at 131°, pour slowly the solution into the alcohol contained in a glass flask, the volume of which must be at least six times as great as the liquor it has to contain. A few minutes after there begins, from the bottom of the flask, a light disengagement of gas, the quantity increases by degrees till it produces a quick ebullition; it disengages by the neck of the flask a thick and whitish vapor forms, the greater part of nitrous ether, easy to inflame.

Some have tried to condense the part of the mercury mechanically carried away by this vapor; for this purpose they passed the vapor through a solution of subcarbonate of soda; but as this process rendered the formation of the fulminate more difficult, and altered its quality, it has been abandoned.

When the ebullition and disengagement of vapors have stopped, throw the whole on a filter, and wash the precipitate with pure and cold water until the washing water has no action on litmus paper. Take the filter, spread it upon a plate of copper heated by steam below 212°. Divide the dry precipitate into portions of 1¼ to 1½ drachms; shut it up in a paper, and afterwards in a large glass bottle.

By the above process Ure obtains from 100 parts in weight of mercury, 130 parts of fulminate; then as 100 parts of mercury corresponds to 142 of fulminate, the loss is of 8½ per cent. of the mercury employed.

On a warm, clear day, one man with two assistants can make, and partially wash, one hundred pounds of fulminate in 10 hours.

CHAPTER XL.

PHYSICAL AND CHEMICAL PROPERTIES OF THE FULMINATE OF MERCURY—CONDITIONS OF EXPLOSIBILITY.

THE well prepared fulminate of mercury is in the form of bright, little crystals of a brownish-gray color; they appear transparent when placed on a glass watch-crystal and humected with a few drops of water. They dissolve without residue in 130 parts of boiling water, and the solution deposits crystals by cooling.

The fulminate of mercury decomposes with flame and explosion, by a shock, or when heated at 370°. It disengages nitrogen, carbonic acid, and vapors of water and mercury.

The conditions of explosibility in the fulminate of mercury are very important to study from the point of view of the salubrity. Thus we would remark that the explosion is much more easy under the influence of the shock, when the striking bodies are harder. The shock of wood against wood, or even iron against wood does not determine the explosion. It occurs very rarely between iron and lead; oftener, but with difficulty, between glass and glass, marble and marble. It is always produced between iron and iron, less easily between iron and bronze, iron and copper; on the contrary, by rubbing, it is easily determined between two wooden plates, less easily between two iron or two marble plates.

The largest crystals are those which detonate the most easily. When the fulminate of mercury is humected with 5 per cent. of water, the part which is stricken alone detonates, and the inflammation is not spread to all the mass.

When you add 30 per cent. of water, you can rub the fulminate, without any danger, on a marble plate.

All these circumstances are important, and ought to be known by every manufacturer, foreman, workman, etc., for they furnish useful information, and diminish the dangers of the fabrication of the fulminating powders.

CHAPTER XLI.

EXPLOSIONS—FIRES AND OTHER ACCIDENTS PRODUCED BY ETHEREAL FLUIDS OBTAINED IN THE FABRICATION OF FULMINATES—TREATMENT OF THE WOUNDED.

WHEN the necessary quantity of mercury is dissolved in the nitric acid, and the alcohol is added, we have seen the production of a lively reaction. The whole mass is strongly agitated, it disengages very abundant ethereal vapors, very inflammable, and have been often the cause of violent fires. At the moment that the mixture of nitrate of mercury, and alcohol produces the fulminate of mercury, the glass flask, in which the operation is conducted, may be broken, and the liquid fall into the fire; however, we think that this accident cannot result in any dangerous consequences, because the considerable quantity of dissolution will extinguish the fire, and the flame of alcohol inflame the powder with difficulty. But there are other dangers, more serious for the men, and which have their cause in the ethereal vapors. It is very important to give some details on this subject. Mr. Gaulthier de Claubry has devoted to it a long paper in the "Annales d'Hygiène Publique."*

This chemist has added to his paper an account of the accidents which he has himself passed through while preparing the fulminate. "For the past three years," says Mr. Gaulthier de Claubry, "the fulminates have been prepared in open retorts, the volatile products spread in the atmosphere, and the men engaged in that work have often complained of serious pains."

In the instructions annexed to his report, Mr. De Claubry observes that when the alcohol acts on the nitrate of mercury, it disengages a great quantity of vapor. The effect is

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* October 8, 1839.

very decided on the animal economy, but, at this epoch this action had not been studied, it was later that some dreadful accidents led to begin its examination. Indeed the volatile products we have spoken of, were then without use, but some manufacturers, to increase their profits, tried to employ them, and one of them obtained a patent to extract the alcohol from the ethereal fluids. This extraction has furnished alcohol in a quantity sufficiently large to introduce it in the trade. The process consisted in saturating with chalk the condensed liquid, and distilling the liquor separated from that product.

Mr. Gaulthier de Claubry, while visiting the establishment in which this operation was practised, learned from the manufacturer himself, that a man, while saturating the liquor with chalk, had been suffocated, and another trying to take him away had been nearly suffocated himself. The first had caused a great deal of uneasiness, on account of the violent nervous accidents which were manifested a short time after fainting away, and he was sick several hours. "I interrogated this man," says Mr. Gaulthier de Claubry, "to know the kind of pain that he experienced. He could not tell me anything but that he was taken immediately with a violent headache; that his strength left him; he cannot characterize the odor of the vapors.

"While there I made a saturation. The ethereal liquid was in a pan, the chalk was thrown into it and stirred with a long pole. The men kept away from the vapors, and advised me not to go near by. I examined carefully the odor disengaged, and that of hydrocyanic acid was very manifest. I was immediately taken with a violent headache, which dissipated only after a night's rest."

These observations caused Mr. de Claubry to study more attentively the ethereal vapors we speak of. He ascertained that the products of the condensation on which they operate with chalk, have an agreeable smell of nitrous acid, and when they are inhaled for some time they occasion a painful sensation and headache.

Having treated with water the liquid product of the condensation, it separates a more or less considerable quantity of a yellowish liquid, having a strong odor of nitrous ether. Having tried to reunite a certain quantity with a little pipette, after two or three operations he experienced a whirling and a painful sensation of tightening in the head and the breast. "A drop of the liquid having touched my tongue," says he, "the pains became very strong, and the surrounding objects appeared to me as through a fog; a tingling in the ear added to these effects. After a few seconds a shivering of the limbs was manifested, and I experienced the beginning of fainting. A bottle full of ammonia was near me; I had strength enough to open it and smell it, which revived me.

"The pain in the breast was then very violent, that in the head insupportable; I perceived the surrounding objects, and I breathed with difficulty. I then left the laboratory. The cephalalgy continued for 24 hours, and I was well again after three days."

Strictly speaking, we can assimilate to those effects only those produced by the gaseous hydrocyanic acid. While, however, there are some differences in all the poisoning cases we have observed, we have never seen that pain at the posterior part of the head on which Mr. Gaulthier de Claubry insists.

The cephalalgy is often noticed, but the seat is not indicated. It is an important question to study.

Since the attention of the scientific world has been called to the effects produced by the inhalation of *ether*, it is very probable that the effects, observed in the manufacture of fulminates, are produced independently of the hydrocyanic acid, by vapors of ether.

Without doubt, nitrous ether, the odor of which predominates in those vapors, plays an important part in the production of the phenomena, for nearly all the effects mentioned by Mr. Gaulthier de Claubry have been observed as a sequel of the action of sulphuric ether.

What is the treatment to which the workmen, who experience the above accidents, are to be subjected?

It is evident that the precepts established by Orfila in cases of poisoning by hydrocyanic acid* must be followed. He says that the inspiration of a slightly ammoniacal water cures poisoning by this acid by stimulating the nervous system.

Mr. Simon has proposed chlorine as an antidote of hydrocyanic acid, and Orfila has shown that chlorinated water administered, even five minutes after poisoning, revives life.

In every case the action of fresh air is useful; it is then necessary to carry the person immediately to the open air, and far from the place of operation.

Happily, those accidents are now very rare, or rather are without examples. Nevertheless the dangers to which the workmen are exposed have attracted the attention of chemists, and we owe to Mr. Chaudelon the construction of an apparatus destined to avoid them.†

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* Annales d'Hygiène, vol. i.

† Annales d'Hygiène, January, 1847, page 216.

This apparatus, represented below, is composed:—

Fig. 11.

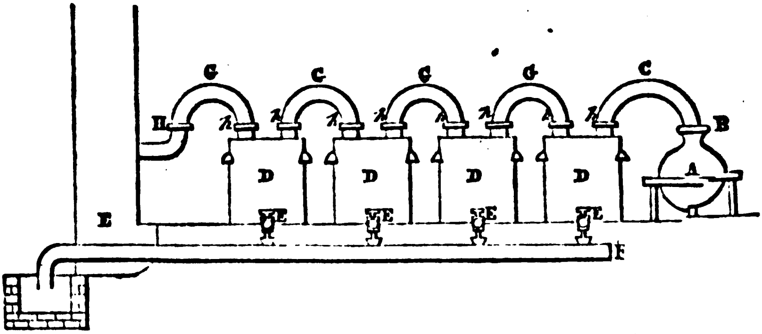
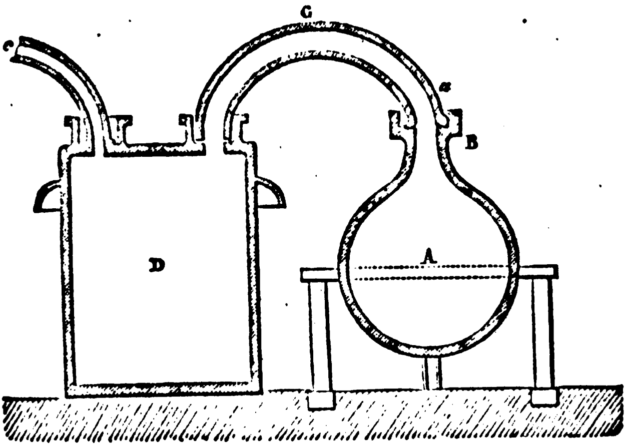


Fig. 12.



1st. Of two glass balloons, *A* of 10 gallons capacity resting on a frame, and in which are introduced the matters proper to prepare the fulminate of mercury. Each of these balloons has on the upper part of its neck a wooden collar *B*, covered with a sheet of lead, and adapting very tightly the collar by its circular groove *a*, forming a hydraulic fastening with the pipes *C*,*C*, which join the balloon to the apparatus of condensation. These tubes are supported by iron rods fixed in the floor of the room.

2d. Of a series of four earthen demijohns, *D*,*D*,*D*,*D*, provided at their lower part with a cork *E*, and carrying at their upper part tubulatings, *h*,*h*,*h*,*h*, with hydraulic fastenings, in which adapt the earthen tubes *G*, *G*, *G*, *G*, which put all the demijohns in communication. Each demijohn has a capacity of about 22 gallons. The first has three tubulatings, the others have only two.

3d. Of an earthen pipe *H*, fixed in the wall, and carrying the deleterious vapors in the chimney.

4th. Of an earthen pipe *F*, fixed in the floor of the shop, and receiving from each cork the liquids condensed in the demijohns to conduct them in the *saturating pan,* which is outside of the room in the open air.

The apparatus being ready to work, pour in each tubulating *h* the necessary water to fasten; take out the pipe *C*, and introduce in one of the balloons 1¼ gallon of alcohol at 95°. Dissolve separately 12 ounces of mercury in 8¼ pounds of warm nitric acid at 36°, when the dissolution is achieved, and the temperature is at 176°, pour it into the balloon containing the alcohol. The pipe *C* being put back to its proper place, fill with water the groove of the collar, and leave the operation to itself. A few minutes after the reaction begins, and the vapors pass through the demijohns in which they condense. The portions which escape the condensation are carried away through the chimney.

During the operation the assistant has to pour from time to time cold water into each tubulating, to take the place of that which has grown warm. When the reaction is achieved, take out the pipe *C*, being careful to shut immediately with a glass bell the tubulating left open, and proceed with the second balloon to the next operation. With the above proportions you obtain 20 ounces of damp fulminate, or 15 ounces when dry, and 3½ quarts of condensed liquor.

CHAPTER XLII.

PRESERVATION OF THE FULMINATE OF MERCURY.

THE fulminate of mercury prepared, as we have said above, is put away, and can be kept any length of time. This preservation requires great care. Generally the fulminate is deposited in a wooden tube, and kept under water. The tube must be covered with a black oil cloth covercle fixed on a barrel hoop larger than the tub, the edges being well fixed by means of little nails in the inside of the hoop. It is the oil cloth itself which must rest on the edges of the tub. In this way it covers it uniformly, and if any particles of fulminate become attached to it, it is very easy to take it out by using a damp sponge. The tub is thus not liable to many of the chances of accident which might proceed from the use of a wooden covercle, or the fall into the fulminate of some foreign matters. It is principally during the cleaning of the room that the tub must be covered. A few grains of a hard matter would cause the detonation of the whole.

We cannot insist too much on the necessity of keeping the fulminate always covered with sufficient water, and when any is taken out, be careful not to have any part adhering to the edges of the tub.

CHAPTER XLIII.

PREPARATION OF PERCUSSION POWDER.

To make the mixture of the fulminate of mercury with the nitre, they generally take the latter one into small pieces, and grind it with the fulminate. To manufacture in such a manner is very dangerous, also it is very important to observe all the directions previously given, and which consist in the use of the *nitre previously reduced to a fine powder*, and being careful to slightly humect it after having spread it on a large surface. This done, throw on it the fulminate, which is mixed with a wooden or horn spatula. The grinding is effected on a polished marble table, three feet by six. Black marble is preferable to white, because the powder remaining on some places can be more easily distinguished.

To effect the grinding, begin to raise the substances with the spatula, and terminate the operation with a wooden roller. The best wood to use is the boxwood. This operation must be done very carefully, and the grinding must be slightly and carefully done to avoid detonations, which are, of course, more dreadful as the quantities are more considerable. The marble and the paste must always be damp, for after a certain degree of desiccation, the explosion will be unavoidable, even with a very light pressure. It is well understood that it is necessary to operate on small masses at a time, and divide into small fractions the prepared fulminate. The quantity of nitre is half that of the fulminate, the mixture thus consisting: 2 parts of fulminate for 1 of nitre.

The mixture being made, take the paste with the spatula, but whatever be the care taken, it is impossible not to leave on the table a little fulminating matter that the desiccation will render explosive. We shall repeat here what we have said about matches. The table must be immediately washed with a sponge, and as the sponge itself will have adhering to it fulminating matters, wash it well in a pail of water. It will be dangerous to crush directly the little grains obtained during the above operation. By thus operating, accidents can be avoided. The following is the way to treat those grains without any danger. Wet with a sponge a varnished jar, throw into it the damp powder, some mist of the same operation, then the grains that you cover with some damp powder.

Leave the mixture all night, and the next day, raise the matter with the hand, and with a spatula carefully operate the mixture.

That paste is divided on blotting paper, and carried to the drier.

CHAPTER XLIV.

CORNING OF THE POWDER — DESICCATION — SEPARATION OF THE POWDER FROM THE MIST—PRESERVATION OF THE POWDER.

Corning of the Powder.

When the fulminating matter has been sufficiently *drained* in the dryer, corn it on a hair sieve fixed above a wooden table, by pressing it slightly with the fingers. This dangerous operation requires as much precaution as above. Too great a friction, especially if it be in the mass some parts too dry, will produce an explosion.

Thus, notwithstanding every care, the mass, which is sifted, can easily arrive at a degree of desiccation which renders it dangerous; it is very important to put on the sieve but very little powder; and, after each operation, dip the sieve into water, and before sifting, when there has been a certain interval between the two operations.

We have said that the corning is done on a wooden table. We think it will be better to cover that table with a black oil cloth well spread, which permits observation of the small quantities of powder which can be taken out easily with a damp sponge. The operation will be less dangerous by spreading under the oil cloth two or three thick woollen sheets, on which the shock of the sieve or other hard body will be without inconvenience.

The corned powder, mixed with mist, is poured into a sheet iron box of 12 to 14 inches, the angles are covered with wood to avoid the particles of powder penetrating into the corners. Shake this powder to give it a little consistency, and it is good to cover the inside of the box with sheet-tin to render the cleaning more easy. At last, to avoid explosions which might be produced by grains of powder interposed between the covercle and the box, it is essential to cover the edges with a lamina of lead ⅛ of an inch thick.

DESICCATION.

To dry the corned powder, put it on sheets of gray paper, in boxes made of white wood, which are carried into the oven, and disposed on shelves.

SEPARATION OF THE POWDER AND THE MIST.

When the powder is sufficiently dried, it is carried back into the corning shop, where it is poured on a hair sieve which separates the mist.

PRESERVATION OF THE POWDER IN THE MAGAZINE.

When the separation of the powder and the mist is effected, put the powder into bottles which must not contain more than 10 pounds. These bottles must be surrounded by braids of cane covered with a skin, and placed on shelves conveniently disposed.

When you want to use the powder to prepare the caps, begin to transvase it; pour it with a paste-board funnel from the bottles which contain it into small bottles of varnished leather. They are carried into the shop, and placed in a box covered with leather, near each woman who uses it according to wants.

CHAPTER XLV.

FABRICATION OF PERCUSSION CAPS.

The cap for small arms is made of copper. It is very slightly conical, with a rim or flange at the open end. It has four slits extending about half the height of the cap.

The cap is charged with the above percussion powder. To protect the powder from moisture, and also to secure it from falling out, it is covered over, in each cap, with a drop of pure shellac varnish.

The copper for making the caps is obtained in sheets, 4 feet long and 14 inches wide, weighing 3 pounds; a variation of 4 ounces, more or less, is allowed. The copper should be pure, free from seams, holes, or blisters, well annealed, and as evenly rolled as possible, with straight and smooth edges.

The copper is cleaned by immersion in a pickle, made of 1 part in measure of sulphuric acid, and 40 parts of water; it is scoured with fine sand and a hand-brush, and washed clean in running water, after which it is well dried in clean sawdust, and rubbed over with a cloth slightly oiled, when it is ready for the machine.

MAKING AND FILLING THE CAPS.

Both of these operations are performed by the same machine. The sheet of copper is adjusted on the table of the machine. The hopper is filled with the percussion powder, and the machine put in motion.

The *star* or blank is cut by a punch, and transferred to a die where it is formed into a cap by a second punch. The cap is caught in the notches of the revolving horizontal plate, and carried, first under the hopper containing the percussion powder, where it receives its charge of ½ a grain, and then under a punch which drives the charge firmly into the cap, and lastly, to the drop hole, where it falls into the receiving drawer.

The hopper is supplied, from time to time, from the ½ pound box, while the machine is at rest, using a small copper scoop for the purpose, and the box returned to its special closet, at least one yard from the machine and above its level, before the machine is put in motion.

As a cap is occasionally exploded under the punch in charging, all dust of percussion powder should be frequently removed, and only a small quantity of percussion powder kept in the hopper. The receiving drawer should be emptied after each sheet of copper is completed. 2314 caps are made from each sheet 48 inches long and 14 wide.

The average work of ten hours, including all necessary stoppages, is 31,000 caps for each machine.

PREPARATION OF THE VARNISH.

Dissolve 1 pound of the best gum shellac in 1 quart of rectified alcohol at 95°. The solution is made most readily at a temperature of about 120°. It must be stirred frequently till all the gum is dissolved. It is made and fit for use in four hours.

The varnish is best made and kept in glass vessels. 1 quart of alcohol and 1 pound of shellac make 1.46 quart of varnish; a small quantity of alcohol is occasionally added to thin the varnish when it is used.

Eighteen quarts of varnish are required for 1,000,000 caps. Two quarts of alcohol are required for thinning the varnish.

VARNISHING THE CAPS.

The caps are put into holes in counting plates, made of sheet brass, 15 inches by 12 inches, 0.5 inch thick, held in a frame of brass rods .35 inch square. This is quickly done by taking a parcel of caps on the plate, and shaking it sideways; the caps settle themselves on the holes. When the plate is filled, the defective caps and those which have lost their charge are easily detected by the eye, and are replaced by perfect ones. The plate is placed on its bed in the varnishing machine, which is worked by hand, and each row of caps is brought in turn under a row of wires, which are alternately dipped into a pan of varnish, and then into the caps, leaving in each a drop of varnish.

The quantity of varnish placed in each cap can be regulated by the size of the wires, or by the depth to which they enter the varnish. The caps remain in the plate thirty to forty minutes, when the varnish is sufficiently set to allow of their being turned into a tray for drying. These trays are of wood, 1½ foot long, 1 foot wide, and 1 inch deep, and contain 2500 caps. The caps remain in the trays for three days, in a room heated to about 100°. They are then put into bags, and kept at the same temperature for ten days longer before they are packed in boxes.

One boy can count and varnish 7000 caps in an hour.

MATERIALS REQUIRED FOR 1,000,000 CAPS.[*]

For the Caps.

1300 pounds of sheet copper, of which about ⅓ is returned in scraps.

For the Powder.

Mercury . . .	42 lbs.
Nitric acid . .	336 "
Alcohol . . .	382 "
Nitre . . .	24 "

For the Varnish.

Gum shellac . .	10 lbs.
Alcohol . . .	12 quarts.

For Bags.

31 yards of cotton duck, .75 yard wide.

For Boxes.

150 feet of white pine board.

Experience has shown that it is not safe to try to wash the percussion powder from partly filled

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[*] Ordnance Manual, 1861.

caps. A lot of unvarnished caps, imperfectly filled, being soaked in water for several days, became coated with a substance much more explosive than the original fulminate. The percussion powder must be burned, and the cap polished by rolling in a dust barrel.

FRICTION PRIMER FOR CANNONS.

The friction primer for cannons is a small brass tube filled with gunpowder, which is ignited by drawing a rough wire briskly through friction composition, contained in a smaller tube inserted into the first near the top, and soldered at right angle to it. A *lanyard* with a hook attached is used to ignite the primer.

The friction composition is made of—

Sulphuret of antimony . . .	2 parts.
Chlorate of potash . . .	1 part.

Moistened with gum water, 50 grains of gum Arabic in 2 ounces of water to 1 pound of composition.

The materials are first pulverized separately, mixed together dry, moistened with the gum water, and ground in an iron mill, such as is used for grinding paints.

The friction primer is composed of 1 *large tube*, 1 *short tube*, 1 *wire rubber*, *friction composition*, *musket powder* and *wax*.

The long tube is made from a circular disk of No. 19 sheet brass, 0.62 inch in diameter, by means of a series of five punches and dies, gradually diminishing in size to the last which is of the required size with the tube. The brass must be annealed before each punching.

The tube is cut to the prescribed length, measuring from the closed end by means of a circular saw, and the holes for the short tube and wire rubber are drilled, and the burrs removed. Length of the long tube 1.75 inch; exterior diameter 0.19 inch; interior diameter 1.75 inch; diameter of holes 0.15 inch, and 0.06 inch.

The *short tube* is formed from the long one by using two additional punches and dies, reducing the size each time. It is cut to the proper length by circular saws placed at the required distance apart, and the burr removed by rolling in a barrel. Length of the short tube 0.44 inch, exterior diameter 0.15 inch, interior diameter 0.133.

One end of the short tube is dipped into a solution of chloride of zinc, inserted in the hole drilled in the long tube, heated to redness in the flame of a spirit lamp, and soldered with soft solder; it is then washed and dried.

The *wire rubber* is made of No. 16 brass wire annealed, cut to the proper length, and pressed flat at one end by a machine for that purpose. The flat end is trimmed by a punch and die with dentated edges, and the tip is annealed in the flame of a spirit lamp. Length of wire 3.4 inches, length of flattened end 0.65 inch.

CHARGING AND VARNISHING.

The small tube is charged by pressing the open end in the friction composition spread on a flat piece of iron, and brought to the consistency of soft putty, the long tube being closed its whole length with a wooden or metal plug.

A conical hole is made in the composition while yet moist, with a conical drift, and the surplus composition removed; the wire rubber is passed through the short tube and through the small hole in the long tube, the round end first, leaving the annealed tip projecting out of the open end, which is then closed by pressing the top and bottom together firmly with pincers, and bending the tip against the bottom.

The end of the wire rubber is doubled on itself and twisted, leaving a loop 0.2 inch diameter, and then bent alongside the long tube for packing.

The head of the long tube, including the short tube and the joint, is dipped into shellac varnish colored with lampblack.

When dry, the long tube is filled with musket powder, and cleared with beeswax mixed with one-third its weight of pitch.

Both ends are touched with varnish, and the tube thoroughly dried.

MATERIALS REQUIRED FOR 10,000 FRICTION PRIMERS.

66 lbs. sheet brass No. 19. }
20 lbs. brass wire No. 16. } about 36⅓ lbs. returned in scraps.
1.25 lb. solder.
2.33 lbs. chlorate of potash.
2.66 lbs. sulphuret of antimony.
0.65 lb. beeswax and pitch.
11.00 lbs. musket powder.

1.25 quart varnish (0.75 lb. shellac, 1 quart of alcohol, 0.25 ounce lampblack).

44 sheets of common tin are required for 100 tin boxes.

CHAPTER XLVI.

APPLICATION OF GUN COTTON AND PAPER TO THE FABRICATION OF CAPS.

SINCE the discovery of pyroxylic products, the question relative to the fabrication of caps can be considered in a new aspect.

Will it not be possible to supersede the use of the fulminate of mercury in the fabrication of caps?

If the facts are not numerous yet, and if the experiment is not sufficient enough to answer this question, the experiments of Mr. Pelouze deserve great attention.

At a meeting of the *Académie des Sciences*, this savant speaks thus: —

"If we put a small quantity of nitric paper or gun cotton on an anvil, and strike it with a hammer, a detonation is heard; a great part of the matter has not been burned, and to have a complete inflammation the percussion must be repeated several times. The same thing occurs when the pyroxyline is introduced into a *cap* and tried in a gun. The greater part of the substance is not destroyed, and obstructs the chimney. The inflammation thus stopped is rarely communicated to the powder, principally when it is ordinary powder.

"It is probable that by modifying the chimney this defect could be avoided, and it could be possible to overcome the disadvantages connected with the pyroxyline in the stage of disaggregation in which it is found in the cotton or paper. In either case this matter was used alone to prepare percussion powder. By substituting for the paper or cotton the pyroxyline prepared with very fine tissues of hemp, linen, and introducing these substances into the caps, a detonation as strong as with the fulminate of mercury is produced."

The opinion of Mr. Pelouze was not adopted by every chemist, and Mr. Dumas again called attention to the fact that the pyroxyline by burning in the open air gives nitrous vapors. He observed that this powder used in the percussion powder will inevitably form nitrous acid; and he was disposed to believe that fire-arms cannot resist, that they will be quickly oxidized if the fire is communicated by the pyroxyline.

Mr. Pelouze made some new experiments. He studied the action of the new powder on fire-arms, and his essays were repeated by several manufacturers and a gunsmith, and the result was shown to be that the pyroxyline has no more destructive action than the fulminate of mercury and the nitre, and this result, says Mr. Pelouze, has nothing extraordinary. Why nitrous vapors, by supposing some formed during the combustion of the pyroxyline, which is doubtful, be more destructive to fire-arms than the sulphuret of potassium, the formation of which in barrels and chimney is consistent with ordinary powder? *A priori* it is more logical that the presence of an adhering solid body ought to be more noxious than a gas.

Mr. Pelouze maintains that the difference established by Mr. Dumas between the combustion in the barrel of a gun and that of the cap could not exist.

New experiments, confirming those of Mr. Pelouze, have demonstrated that if gun cotton, used alone as percussion powder, has badly succeeded, this cotton pressed with a few grains of ordinary powder in new caps answers very well; that the powder determines the combustion of the totality of the pyroxyline, and the inflammation is communicated easily to the charge. Charcoal and sulphur associated with the pyroxyline have given very good results.

Mr. Vrij, professor of chemistry at Amsterdam, has ascertained that starch treated by monohydrated nitric acid, swells, and is transformed into xyloidine. As pyroxyline is soluble in monohydrated nitric acid, if concentrated sulphuric acid is added to this solution, all the pyroxyline is precipitated into a white powder, which has all the primitive properties except the form. The question which has not been answered yet, is, whether this powder can be utilized in the preparation of percussion powder.

More could be said on this subject, but we think it of no use to do so in advance of actual experiment. A time will come, we have no doubt, at which this product will take the place of metallic fulminates.

CHAPTER XLVII.

DISPOSITION OF FACTORIES—PRESERVATION AND TRANSPORTATION OF PERCUSSION POWDER AND CAPS.

As in the fabrication of matches, every room must be isolated, indeed each one be a small building composed of a single room, without stairs, and of wood.

The room in which the fulminate is prepared must not only be isolated, but also situated at a great distance from the others, so that the ethereal products, in case they take fire, cannot communicate it to the other parts of the establishment.

The *barrels of alcohol* must be kept separate. The *magazine* is constructed as far as possible from the shop. The *dryer* and the room for sieving are the parts of the establishment which require the most complete isolation. Above all things the factory must be distant from any other buildings.

It is very important to have no fire in the rooms, and the light must be good enough not to be under the necessity of using any artificial light.

Oven.—It is necessary to have the shelves, which receive the powder very slightly elevated, so that the boxes can be taken with the hand without using a ladder. No work must be done in the oven; the papers used to cover the boxes are thrown into water acidulated with hydrochloric acid, in case it be needed to collect the mercury.

Sifting.—It is dangerous to use metallic sieves, and they must be covered with a lead band on their lower edge.

Magazine.—This part of the establishment must have a double door with an interval between, and it must be provided with a lightning rod.

The powder contained in the magazine is kept in wood or leather bottles, but green glass bottles are better if they are surrounded by cane braids, which present resistance enough not to break in case of receiving a fall. The rule must be established that one person alone has admittance into the magazine.

Decantation.—This is one of the operations which require the most care, and it must be done far from the magazine and in the open air.

With the precautions above indicated it is easy to prevent those accidents which occur during the different operations, principally the *grinding, sifting*, and *decantation.*

The face of the man must be covered with a light shield to prevent its being hurt in case of explosions.

TRANSPORTATION OF PERCUSSION POWDER.

It is very important to have the percussion powder prepared near the cap factory, because with all precautions, the damp fulminate may produce very violent explosions, and be the cause of serious accidents. Then we insist on this point, that the percussion powder ought to be manufactured near to the factory where it is to be used.

We have said above that some manufacturers have tried to utilize the volatile product resulting from the preparation of the fulminate. This alcohol does not contain hydrocyanic acid, but it requires great care and attention to have none pass at the distillation.

This alcohol, according to Mr. Gaulthier de Claubry, can be used over again in the preparation of the fulminates for making varnishes and a few chemicals, but it is dangerous to to use it to manufacture liquors, for without doubt it acts as a deadly poison.

PACKING OF FRICTION PRIMERS FOR CANNON.

The tubes are first put up in bundles of ten each, wrapped in water-proof paper; ten bundles are packed in a tin box painted or japanned. 100 tin boxes are packed in a box made of 1 inch white pine boards, dovetailed.

The contents of the tin box, place and year of fabrication, are stamped on the lid, and the number of the box marked on the front side. The contents of the wooden box are marked on each end.

Dimensions of the tin box, length 4.5 inches, width 2.35 inches, depth 2.35 inches.

Dimensions (interior) wooden box, length 20.5 inches, width 12.00 inches, depth 9.5 inches.

Weight of the box containing 100 primers, .8347 pound.

Weight of wooden box containing 10,000 primers, 105 pounds.

PACKING OF PERCUSSION CAPS.

The caps are put into bags of strong cotton duck, 10,000 in a bag, and ten bags are packed in a wooden box. The box is lined with thick paper, the bags are packed in tow, and the cover is fastened with six 2 inch wood screws.

Bags and Packing Boxes.—The bags are 6 inches in diameter, and 13.5 inches deep. They are made with circular buttons, like cartridge bags for field service.

They are marked with the number of the bag, the contents, the place, and date of fabrication.

The *packing boxes* are made of 1 inch white pine, dovetailed; they have brackets for rope handles on the ends, are painted olive color, and marked on the ends with the number and kinds of contents, and on the inside of the corner with the place and date of fabrication.

Interior Dimensions.—Length 28.75 inches, width 12 inches, depth 8.5 inches.

Weights of 1,000,000 caps, 944 lbs.; bags with 10,000 caps, 9.625 lbs; packing box, 25 lbs; box packed with 100,000 caps, 127 lbs.

TRANSPORTATION OF CAPS.

The boxes are carried into the store room, and from there distributed for the consumption. The transport from the shop to the store does not present much danger. It is a well known fact, that in a box a cap may explode without communicating fire to the others. But, if the accidents are rare, this transport must be done carefully, and all we have said about matches can be applied in this case.

The avoidance of accidents in their preservation is worthy of much serious attention, and the retailer must act with them, at least, as carefully as with gunpowder. They must be kept separate, and in places where there is no danger of their falling down.

APPENDIX.

RECENT IMPROVEMENTS IN GUN COTTON.

At the British Association meetings of 1862, a committee of chemists and physicists was appointed to inquire and report on the so-called *Austrian gun cotton.* The report was published in the last meeting by Dr. Gladstone and Mr. J. Scott Russell; and we think it will be interesting to our readers to be acquainted with the principal parts of this paper.*

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* We are mainly indebted for the following pages to an abstract of this report, given in the "Annual of Scientific Discovery," 1864, p. 47, and to an able and interesting article on gun cotton in the "United States Service Magazine," April, 1864, p. 345.

CHEMICAL REPORT.

Since the discovery of gun cotton by Schonbein its application to war purposes has been frequently thought of, and many experiments, with a view of using it, have been made, especially by the French. Such serious difficulties have, however, presented themselves that the idea gradually came to be abandoned everywhere but in Austria. Here experimenting was kept up, and it having been reported on good authority that the experimenters had succeeded in overcoming many of the difficulties encountered elsewhere, the committee of the association applied to the Austrian Government for information, which was furnished to them. The following is a summary of the more important facts elicited. In the first place, the gun cotton prepared by Baron Von Lenk, the inventor of the Austrian system, differs from the gun cotton generally made in its complete conversion into a uniform chemical compound. It is well known to chemists that, if cotton is treated with mixtures of strong nitric and sulphuric acids, compounds may be obtained varying considerably in composition. Though they all contain the elements of nitric acid, and are all explosive.

There is one part of the process not yet alluded to, and the value of which is more open to doubt. The treatment of the gun cotton with a solution of silicate of potash, commonly called water-glass. Some Austrian chemists think lightly of it; but Von Lenk considers that the amount of silica set free on the cotton by the carbonic acid of the atmosphere is really of service in retarding the combustion. He adds that some of the gun cotton, made at the imperial factory, has not been silicated at all, and some imperfectly; but when the process has been thoroughly performed, he finds that the gun cotton has increased permanently about three per cent. in weight.

It seems a disadvantage of this material as compared with gunpowder that it explodes at a temperature of 277°; but, against the greater liability to accidents from this cause may be set the almost impossibility of explosion during the process of manufacture, since the gun cotton is always immersed in liquid, except in the final drying.* Again, if it should be considered advisable at any time, it may be stored in water, and only dried in small quantities as required for use. The fact that gun cotton is not injured by dampness like gunpowder, is indeed one of the recommendations, while a still more important chemical advantage, which it possesses, arises from its being perfectly resolved into gases on explosion, so that there is no smoke to obscure the sight of the soldier who is firing, or to point out his position to the enemy, and no residuum left in the gun to be got rid of before another charge can be introduced.

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* In ten years' experience it is proved that this temperature is sufficiently high to insure safety of manipulation: 277° is an artificial temperature; and artificial temperatures, accidentally produced, are generally high enough to ignite gunpowder. The greater liability to accident from this cause can, therefore, scarcely be admitted.

PHYSICAL REPORT.

Mr. Russell stated that greater effects are produced by gases generated from gun cotton than by gases from gunpowder, and it was only after long and careful examination that the committee were able to reconcile this fact with the low temperature at which the mechanical force is obtained. The great waste of force in gunpowder constitutes an important difference between it and gun cotton, in which there is no waste. The waste in gunpowder is 68 per cent. of its own weight, and only 32 per cent. is useful. This 68 per cent. is not only waste in itself, but it wastes the power of the remaining 32 per cent. It wastes it mechanically by using up a large portion of the mechanical force of the useful gases. The waste of gunpowder issues from the gun with much higher velocity than the projectile, and if it be remembered that in 100 pounds of useful powder this is 68 pounds, it will appear that 32 pounds of useful gunpowder gas is wasted in impelling a 68 pound shot composed of the refused gunpowder itself.

There is yet another peculiar feature of gun cotton. It can be exploded in any quantity instantaneously. This was once considered its great fault, but it was only a fault when we were ignorant of the means to make that velocity anything we pleased. Baron Von Lenk has discovered the means of giving gun cotton any velocity of explosion that is required, by merely the mechanical arrangement under which it is used. Gun cotton, in his hands, has any speed of explosion, from one foot per second to one foot in $\frac{1}{1000}$ of a second, or to instantaneity. The instantaneous explosion of a large quantity of gun cotton is made use of when it is required to produce destructive effects on the surrounding material. The slow combustion is made use of when it is required to produce manageable power, as in the case of gunnery. It is plain, therefore, that if we can explode a large mass instantaneously, we get out of the gases so exploded the greatest possible power, because all the gas is generated before motion commences, and this is the condition of maximum effect. It is found that the condition necessary to produce instantaneous and complete explosion is the absolute perfection of closeness of the chamber containing the gun cotton. The reason of it is that, the first ignited gases must penetrate the whole mass of the cotton, and this they do, and create complete ignition throughout only under pressure. This pressure need not be great. For example, a barrel of gun cotton will produce very little effect and very slow combustion when out of the barrel, but instantaneous and powerful explosion when shut up within it. On the other hand, if we desire gun cotton to produce mechanical work, and not destruction of materials, we must provide for its slower combustion. It must be distributed and opened out mechanically, so as to occupy a larger space, and in this state, it can be made to act even more slowly than gunpowder, and the exact limit for purposes of artillery Von Lenk has found by critical experiments. In general it is found that the proportion of 11 pounds of gun cotton, occupying one cubic foot of space, produce a greater force than gunpowder, of which from 50 to 60 pounds occupy the same space, and a force of the nature required for ordinary artillery. But each gun and each kind of projectile requires a certain density of cartridge. Practically, gun cotton is most effective in guns when used as $\frac{1}{4}$ to $\frac{1}{3}$ weight of powder, and occupying a space of $1\frac{1}{10}$ of the length of the powder cartridge. The mechanical structure of the cartridge is of importance as affecting its ignition. The cartridge is formed of a mechanical arrangement of spin cords, and the distribution of these, the manner and place of ignition, the form and proportion of the cartridges, all affect the time of complete ignition. It is by the complete mastery he has gained over all these minute points that Von Lenk is enabled to give to the action of gun cotton on the projectile any law of forces he pleases.

Gun cotton is used for artillery in the form of a gun cotton thread or spun yarn. In this simple form it will conduct combustion slowly in the open air, at the rate of not more than one foot per second. This thread is woven into a texture or circular web. These webs are made of various diameters, and it is out of these webs that common rifle cartridges are made, merely by cutting them into the proper lengths, and inclosing them in stiff cylinders of pasteboard, which form the cartridges.

In these cylindrical webs it is also used to fill explosive shells, as it can be conveniently employed in this shape to pass in through the neck of the shell. Gun cotton thread is spun into ropes in the usual way up to two inches diameter, hollow in the centre. This is the form used for blasting and mining purposes; it combines great density with speedy explosion.

The gun cotton yarn is used directly to form cartridges for large guns by being wound round a bobbin, so as to form a spindle like that used in spinning mills. The bobbin is a hollow tube of paper or wood; the object of the wooden rod is to secure, in all cases, the necessary length of chamber in the gun required for the most effective explosion. The gun cotton circular web is inclosed in close tubes of India-rubber cloth to form a match line, in which form it is most convenient, and travels with speed and certainty. In large quantities, for the explosion of mines, it is used in the form of ropes, and in this form it is conveniently coiled in casks and stowed in boxes.

As regards conveyance and storage of gun cotton, it results from the foregoing facts, that one pound of gun cotton produces an effect exceeding three pounds of gunpowder in artillery. This is a material advantage, whether it be carried by men, horses, or in wagons. It may be placed in store, and preserved with great safety. The danger of explosion does not arise until it is confined. It may become damp, and even perfectly wet, without injury, and may be dried by mere exposure to the air. This is of great value in ships of war, and, in case of danger from fire, the magazine may be submerged without injury. As regards its practical use in artillery, it is easy to gather from the foregoing general facts how gun cotton keeps the gun clean and requires less windage, and therefore performs much better in continuous firing. In gunpowder there is 68 per cent. of refuse, or the matter of fouling. In gun cotton there is no residuum, and therefore no fouling. Experiments made by the Austrian committee proved that 100 rounds could be fired with gun cotton against 30 rounds of gunpowder. From the low temperature produced by gun cotton, the gun does not heat. Experiments showed that 100 rounds were fired from a six-pounder in 34 minutes, and the gun was raised by gun cotton to only 120° F, whilst 100 rounds with gunpowder took 100 minutes, and raised the temperature to such a degree that the water was instantly evaporated. The firing with the gunpowder was, therefore, discontinued; but the rapid firing with the gun cotton was continued up to 180 rounds without any inconvenience. The absence of fouling allows all the mechanism of a gun to have much more exactness than where allowance is made for fouling. The absence of smoke promotes rapid firing and exact aim. There are no poisonous gases, and the men suffer less inconveniences from firing in casemates, under hatches, or in closed chambers. The fact of smaller recoil from a gun charged with gun cotton is established by direct experiment. Its value is ⅔ of the recoil from gunpowder, projectile effect being equal.

To understand this may not be easy. The waste of the solids of gunpowder accounts for one part of the saving, as in 100 pounds of gunpowder 68 pounds have to be projected in addition to the shot, and at much higher speed. The remainder Von Lenk attributed to the different law of combustion; but the fact is established.

The comparative advantages of gun cotton and gunpowder for producing high velocities are shown us in the following experiment with a Krupp's cast-steel gun—six-pounder. With ordinary charge, 30 ounces of powder produced 1338 feet per second; with charge of 13½ ounces gun cotton produced 1563 feet. The comparative advantages in shortness of gun are shown in the following experiments—twelve-pounder:—

Calibre.	Charge.	Velocity, feet per second.
Cotton length 10	15.9 ounces	1426
Powder length 13½	49.0 (normal powder charge)	1400
Cotton length 9	17	1402

As to advantage in weight of gun, the fact of the recoil being less in the ratio of 2 to 3, enables a less weight of gun to be employed, as well as a shorter gun, without the disadvantage to practice, arising from lightness of gun. As regards durance of gun, bronze and cast iron guns have been fired 1000 rounds without in the least affecting the endurance of the gun. As regards its practical application to destructive explosions of shells, it appears that from a difference in the law of expansion, arising probably from the pressure of water in intensely heated steam, there is an extraordinary difference of result, namely, that the same shell is exploded by the same volume of gas into more than double the number of pieces. This is to be accounted for by the greater velocity of explosion when the gun cotton is confined very closely in very small spaces. It is also a peculiarity that the stronger the shell the smaller the fragments into which it is broken.

As regards mining uses, the fact that the action of gun cotton is violent and rapid in exact proportion to the resistance it encounters tells us the secret of its far higher efficiency in mining than gunpowder. The stronger the rock the less gun cotton, comparatively with gunpowder, is necessary for the effect; so much so, that while gun cotton is stronger than powder as 3 to 1 in artillery, it is stronger in the proportion of 6.274 to 1 in a strong and solid rock, weight for weight. It is the hollow rope form which is used for blasting. Its power of splitting up the material is regulated exactly as wished.

As regards military and submarine explosions, it is a well known fact that a bag of gunpowder nailed on the gates of a city will blow them open. In this case gun cotton will fail. A bag of gun cotton exploded in the same way is powerless. If one ounce of gunpowder is exploded on scales the balance is thrown down; with an equal force of gun cotton nothing happens. To blow up the gates of a city, a very few pounds of gun cotton, carried in the hands of a single man, will be sufficient, only he must know its nature. In a bag it is harmless; exploded in a box it will shatter the gates to atoms.

Against the palisades of a fortification, a small square box, containing 25 pounds, merely flung down close to it, will open a passage for troops. In actual experience on palisades, a foot diameter and eight feet high, piled in the ground, backed by a second row of eight inches diameter, a box of 25 pounds cut a clean opening 9 feet wide. To this, three times the weight of gunpowder produced no effect whatever, except to blacken the piles.

Against bridges, a strong bridge of oak, 24 feet span, was shattered to atoms by a small box of 25 pounds laid on its centre; the bridge was not broken, it was shivered.

As to its effects under water, in the case of two tiers of piles in water, 13 feet deep, 10 inches apart, with stones between them, a barrel of 100 pounds of gun cotton, placed 3 feet from the face and 8 feet under water, made a clean sweep through a radius of 15 feet, and raised the water 200 feet. In Venice, a barrel of 400 pounds placed near a sloop, in 10 feet water, at 18 feet distance, threw it in atoms to a height of 400 feet.

All experiments made by the Austrian committee are conducted on a grand scale, thirty-six batteries, six and twelve-pounders, having been constructed, and practised with gun cotton.

The reports of the Austrian commissioners are all based on trials with ordnance, from six-pounders to forty-eight pounders, smooth bore and rifled cannon. The trials with small fire-arms have been comparatively few, and are not reported on. The trials for blasting and mining purposes were also made on a large scale by the Imperial Engineers' Committee.

The writer of the article in the *U. S. Service Journal*, already referred to, says:—

"A change in the strength of the acids, in the condition of their mingling, in the duration of the chemical action, in the temperature, and in the removal of the free acid from the cotton, will each effect a marked change in the product. Advantage is now taken of this fact, and gun cotton is prepared with reference to the special use for which it is intended just as gunpowder should be, and is to some extent.

"The gun cotton made at Hirtenberg, after the manner prescribed by General Lenk, differs, as might have been expected, very materially from that made elsewhere. The process of manufacture is different, and the details are so arranged as to insure much greater uniformity in the results.

"The cotton is immersed in a mixture of one part strong nitric acid, and three parts concentrated sulphuric acid. It is permitted to remain in this bath for 48 hours; it is then washed in a stream of running water for four to eight weeks, so as to lose every trace of free acid; it is then carefully dried. Analysis shows that this gun cotton is of a uniform and fixed composition, and is almost wholly trinitro-cellulose, represented by the Austrian chemists by the formula:—

$$C_{12}H_7(3NO_4)O_{10}$$

"It explodes at a temperature between 340° and 390° F., never below that, as was the case with gun cotton prepared after other formulæ. It does not deteriorate in quality when subjected to all the changes of temperature to which it is liable in service, nor when exposed to the various influences of dew, rain, and sun if afterwards dried.

"The gravest charge made against this new explosive material was, that it was liable to spontaneous combustion, as was known to be the case with gun cotton made in the ordinary way. It was of the utmost importance that this vital question should be thoroughly investigated, and for this purpose a committee of the three first Austrian chemists was appointed to report upon this and other objections urged against the adoption of gun cotton for war purposes.

"The results of this investigation, made with great ability and extreme care, are highly satisfactory, and furnish proofs, both theoretical and practical, that General Lenk's gun cotton is not liable to this fatal objection.

"The commission, after weighing maturely all that could be said in opposition to General Lenk's gun cotton, and its adoption for war purposes, closed their report with the following unqualified commendation: '*According to our experience up to the present time, June,* 1863, *we recognize in gun cotton from Hirtenberg an improved explosive compound, having many and great advantages, several of which gunpowder from its very nature can never possess.*'

"It has been urged that the gases of gun cotton were more poisonous than those of gunpowder, and on that account it could not be safely used in mines. The following table gives the analyses of the gases of combustion of General Lenk's gun cotton, as determined by Lieutenant Von Karoly, in the chemical laboratory of the engineer corps committee, and those of gunpowder by Bunsen.

Gases of Combustion, Volume per cent.	Bunsen.			Karoly.
	Sport'g.	Rifle.	Cannon Powder.	Gun Cotton.
Nitrogen	41.1	35.3	37.6	12.7
Carbonic acid	52.7	48.9	42.7	20.8
Carbonic oxide	3.9	5.2	10.2	29.0
Hydrogen	1.2	6.9	5.9	3.2
Sulphuretted hydrogen	0.6	0.67	0.86	Carbon 1.8
Oxygen	0.5	......	......	Water 25.37
Light carburetted hydrogen gas	0.0	3.02	2.7	7.2

"A comparison of the results, as above given, will show that the products of the combustion of either of the two materials contain gases which are irrespirable, and in this particular belong to the same class of gases. The relative quantities of some of those evolved from gun cotton are different from those produced from gunpowder, but they are both of such a nature as to require, that after an explosion of a mine with either gunpowder or gun cotton, the air should be renewed by ventilation before the place of the explosion can be approached without danger. The gases from the latter will be removed more quickly by ventilation than those from the former, as they contain in the latter case much solid matter which alone would suffice to make respiration almost impossible.

"The English Government has recently made experiments with the new explosive material, Baron Von Lenk having visited England, by invitation, for the purpose of assisting at the trials. More recently the French Government has taken up the subject, and is now engaged in an investigation into the merits of this new gun cotton.

"General Lenk is, at the request of the Emperor Napoleon, in France, to be present at these experiments. The attention of the United States Government was drawn to the success attending the experiments with gun cotton in Austria, by Mr. T. Carrisius, U. S. Consul at Vienna, and the Secretary of War has directed experiments to be made to determine whether its merits are such as to warrant its introduction into our service, in whole or in part. These experiments will soon be commenced.

"There are many considerations which make it important for us that the subject should recive a full, fair, and impartial investigation.

"We are now dependent upon India for our supply of saltpetre. By the introduction of gun cotton, we shall be enabled to substitute for saltpetre, the nitrate of soda, found in South America, much nearer home, and more easy to be obtained, and from a supply of which we are not so liable to be cut off.

"We have a long extended coast to defend against new and most formidable modes of attack. Our large sea-coast guns will require the assistance of the most destructive explosive for their shells, and the most powerful submarine batteries that we can devise, to protect our sea-board cities from the attacks of hostile iron-clads.

"Gun cotton will not, probably, supersede the use of gunpowder; it may prove a valuable co-adjutant."

BARON VON LENK'S GUN COTTON PATENTED IN THE UNITED STATES.

The *Scientific American* for July 9, 1864, contains the following:—

"On the 4th of June, 1864, Baron Von Lenk procured a patent, through the Scientific American Patent Agency, for the manufacture of gun cotton by his process in the United States. The assignees of the patent in this country are Messrs. Rawson & Richmond, of Detroit, Mich., who announce their purpose to proceed at once to erect a large manufactory, and to embark in the production of the article. Their establishment will be under the charge of a practical and competent person sent over from Austria by General Von Lenk.

"Our readers will remember that the commission of Austrian chemists came to the conclusion that 'gun cotton is far superior to gunpowder for all explosive power; that its use is less dangerous; that for artillery and small-arms one pound of gun cotton will give greater result than three pounds of gunpowder, and for blasting and mining purposes one pound of the former is equal to six pounds of the latter; that damp does not affect it; that it is not liable to decomposition; that it will not explode short of 277° Fahr.; that there is no smoke; that there is no fouling or refuse matter; that the recoil of the gun is but two-thirds of that from gunpowder; that lighter and shorter guns can be used; that the velocity of the projectile is greater and, more accurate; that the heating of the gun is much less; and that there is no danger in its manufacture.'

"The statement that the velocity imparted to the shot is greater, while the recoil of the gun is less, we should hardly believe except on further evidence than the report of one commission, however eminent.

"In consequence of the general interest in this improvement, we publish the patent in full. It contains a complete description of the process in as few words as possible.

"'IMPROVED GUN COTTON.

"'*To all whom it may concern:*

"'Be it known that I, Baron W. Lenk, of the city of Vienna, in the Empire of Austria, have invented a new and improved mode of making an explosive material out of cotton and other vegetable fibres; and that I do hereby declare that the following statement is a full and accurate description of the articles used, and the mode and manner of manufacturing the same into an article which is termed "Baron Lenk's Improved Gun Cotton."

"'*First.* The cotton or other vegetable fibre is first taken and spun into loose threads of sufficient strength to be easily handled.

"'*Second.* The cotton must then be thoroughly boiled in a solution of potash or of soda, in order to remove all greasy substances which the cotton may contain, and after thus boiled it may be exposed to the sun or wind, or in a heated room, to dry the same.

"'*Third.* The cotton must now be taken into a room heated to 100° Fahr., in order to make it perfectly dry.

"'*Fourth.* A mixture is now made containing one part weight of nitric acid of $1\frac{18}{100}$ to $1\frac{50}{100}$ specific gravity, and three parts weight of common sulphuric acid. This mixture must stand in closed earthen or glass jars for several days, or until the two acids become fully mixed and cooled.

"'*Fifth.* This mixture of acids is now put into an apparatus containing three apartments, one for the main bulk of the acids, one for the immersion of the cotton, and one for receiving the cotton after being immersed. This apparatus may be made of cast-iron.

"'*Sixth.* The cotton is now taken and dipped in the acid bath, in said apparatus, in such a manner that every three ounces of the cotton must come in contact with sixty pounds of the mixture of acids, or, in other words, the bath must contain fully sixty pounds of the mixture while parcels of three ounces of cotton are being dipped. The parcels thus dipped must be gently pressed, and the acids allowed to flow back into the acid bath, and the parcels are then put into the third apartment of the apparatus, where for every one pound of cotton there must be ten and a half pounds of said mixture of the acids. The cotton must remain in this state subject to the action of the acids for forty-eight hours, and the mixture must always have an equally strong concentration, and must be kept under a uniform temperature by a cooling process.

"'*Seventh.* The cotton is now taken out from the acids and pressed, and then put into a centrifugal machine to remove all surplus acids.

"'*Eighth.* The cotton is again put into another centrifugal machine, into which a constant stream of fresh water is admitted. This process is intended to remove the last particles of adhesive acids.

"'*Ninth.* The cotton is now taken and put into a flume or trough, and secured in such a manner that a running stream of fresh water may pass through and over it; and the same must remain in this situation for at least fourteen days. To lessen the time for this operation, the cotton may be immersed or saturated in alcohol for the space of twenty-four hours. This process is also intended to extract all and the last particles of acids that may possibly adhere to the cotton.

" '*Tenth.* The cotton is now taken from the stream of water, or if from the alcohol it must be washed, and then boiled in a solution of common soap and again dried. This process is intended to restore the cotton to its original softness and appearance.

" '*Eleventh.* The cotton is now taken and immersed in a solution of water-glass of one pound to two pounds of soft water, which must be $1\frac{9}{100}$ specific gravity of concentration. To one pound of cotton $\frac{195}{1000}$th of a pound of this solution of 46° Beaumè is required. The cotton is then taken out of this solution and exposed to the action of the atmosphere for at least four days. This process has the tendency to preserve the material, and also to make its explosive qualities less rapid.

" '*Twelfth.* The gun cotton is again washed in soft water free of lime, dried, and can then be packed in wood or metal boxes for storage or exportation; and may be used for artillery, torpedoes, shells, mining, blasting, small-arms, and for all purposes where explosive power is required.

" '*Thirteenth.* All other vegetable fibres may be treated and manufactured as herein stated, which process will make the same explosive like the gun cotton, and adapted to the same purposes.

" 'I claim as my invention an explosive improved gun cotton made substantially as herein described.

" 'BARON W. LENK.

" 'CITY OF VIENNA, AUSTRIA, *Dec.* 1, 1862.' "

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