On Her Majesty's Service

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BADDELEY F - PAMPHLET ON THE MANUFACTURE OF GP AT GOV FACTORY WA 1857

PAMPHLET

ON THE

MANUFACTURE OF GUNPOWDER,

AS CARRIED ON AT THE

GOVERNMENT FACTORY,

WALTHAM ABBEY:

BY MAJOR FRASER BADDELEY, ROYAL ARTILLERY.
CAPTAIN INSTRUCTOR.

WALTHAM ABBEY;
PRINTED FOR THE AUTHOR, BY E. LITTLER, SUN STREET.
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PREFACE.

Having been requested to write an Article on the Manufacture of Gunpowder for the Aide Memoire, to replace the present pages on this subject, which treats entirely of the old method pursued; I have thought that a pamphlet separately published, would be of service to those who might not wish the expense of such a large work.

The different processes employed, I have endeavoured to explain as clearly and simply as possible, without going into too minute detail, or entering into the cost, &c., &c. of Ingredients, and Manufacture, it having been considered for many reasons not advisable to do so.

Several Officers have visited this Establishment within the last year, and appeared to take an interest in the verbal descriptions given them by me, on witnessing the different stages of fabrication; should the perusal of this Pamphlet revive any interest they may have taken in the subject treated of, or give those who have not visited the Factory, some slight insight into the manufacture of this most important material of War, my object in writing these pages will have been more than gained.

J. FRASER BADDELEY

WALTHAM ABBEY, January, 1857.

CONTENTS

ON THE MANUFACTURE OF

GUNPOWDER.

GUNPOWDER, is an explosive propellent agent, being an intimate mixture of Saltpetre, Charcoal, and Sulphur, the proportions of which vary slightly in different countries, and according to the uses to which the Powder is applied. The propelling power of Gunpowder is dependant on the rapid decomposition of the nitre into its component parts; the oxygen forms carbonic acid with the Carbon in the Charcoal, and the heat thus generated by ignition changes both this and the Nitrogen into a large volume of heated gas: In a mixture of Nitre and Charcoal alone, the oxidation proceeds with comparative slowness: by the addition of Sulphur, an augmentation of combustibility is gained, in consequence of its igniting at a very low temperature; the Sulphur, also, by its presence, renders available for the oxidation of the Carbon an additional amount of Oxygen, viz., that which is united with the Potassium, the latter being at once converted into Sulphide upon ignition of the Powder. The advantages of Gunpowder, as a propelling agent, over every other explosive material, are—the comparative safety attending its manufacture and transport, and the gradual nature of its decomposition when compared with those materials such as Fulminating Gold, Silver, or Mercury, &c. &c. In Gunpowder, the force resulting from the rapid evolution of Gas in a confined space has sufficient time to overcome the inertia of the projectile, which is not the case with other explosive materials, the conversion of which into gaseous products is so instantaneous that nothing can resist the intensity of their explosive action. Other advantages suggest themselves in the use of Gunpowder, such as the comparative cheapness of the ingredients composing it, and the ease with which they may be obtained; for the Sulphur and Saltpetre are very abundant productions of nature, and the Charcoal can be manufactured cheaply and with great facility, and if care is taken in the process of the fabrication of Powder, little deterioration will take place on its exposure to heat or moisture.

Condensed Air and Steam have been used as propelling agents; but the great inconveniences attending their use quite preclude the possibility of adapting them to war purposes.

By long experience and practice, it is found that the Powder best adapted for the use of Artillery and Infantry is composed of the following proportions of the three ingredients, viz:—75 Nitre, 15 Charcoal, and 10 Sulphur in 100 parts, which proportion is closely adhered to in this country. The proportions indicated by theory for the production of Powder of the greatest intensity would be more nearly represented by the proportions—75 Nitre, 12·5 Sulphur, and 12·5 Charcoal; these proportions are adopted in some continental manufactories. Experience has, however, established real advantages as resulting from the employment of a somewhat larger proportion of Charcoal (15 parts) and a reduction of the Sulphur from 12·5 to 10.

BLASTING POWDER contains a greater proportion of Charcoal, and less Saltpetre; its action, consequently, is much slower—which makes it more efficacious than Gunpowder for this particular use, at a great reduction in price.

PURITY OF INGREDIENTS.

The greatest care is requisite in the purification of the ingredients composing Gunpowder. A short description of the different processes by which we arrive at this result may not be uninteresting.

SALTPETRE, OR NITRE,

The principal ingredient in Gunpowder, is an abundant production of nature, and is a combination of Nitric Acid with the vegetable alkali; it is never found pure, being always contaminated with other salts and earthy matter; it is principally found in the East Indies, Ceylon, and South America, and is sometimes produced from decayed animal and vegetable matter; it is totally unfit for Gunpowder until it has been refined; for, being combined with Muriates of Soda, Lime, Magnesia, and other Salts which absorb moisture, the close contact of the ingredients would be deranged by their presence—the strength of the Powder weakened, and the power of resisting the action of the atmosphere greatly lessened. As for the efflorescent salts it may contain, they are noxious only inasmuch as, possessing no particular useful property, they interpose their atoms between the more combustible ingredients, and impede the rapidity of deflagration.

There are two methods of refining Saltpetre at Waltham Abbey;—1st., the OLD method, of re-crystallizing three times—and 2nd., the NEW method, which has only just been adopted, both of which we shall here briefly describe.

OLD METHOD.

About 35 Cwt. of the Grough Saltpetre, as it is termed, viz., as it is imported in its impure state, is put into a Copper capable of holding 500 gallons, with 270 gallons of water, in the proportion of about 1½ lb. of Nitre to 1 lb. of water (which proportion varies with the quality of the Saltpetre) this is allowed to boil, and the impurities are skimmed off as they appear on the surface; cold water is occasionally thrown in to precipitate portions of the chloride which otherwise would remain on the top by the action of boiling: after being allowed to boil from 3½ to 4 hours, the furnace doors are thrown open, when the Chlorides and Salts fall to the bottom, In about two hours, a copper pump is lowered into the liquor, which is pumped out into a wooden trough, having four or five brass cocks, under which are suspended canvas filtering bags in the shape of a V; the solution is then filtered, and run off into pans containing about 36 gallons, and allowed to remain for 24 hours to crystallize, when they are set up on edge to drain off the liquor which remains uncrystallized, and which is called mother liquor. The Saltpetre thus obtained is called once refined and undergoes the same process twice again, the only difference being that there is a greater proportion to the Water each time, viz., 1¾ lb. to 1 lb. of Water the second time, and 2 lb. to one lb. of Water the third time: moreover, the third time, a small quantity of ground Charcoal is put into the solution, and it passes through double filters, which brings it to a very fine pure white colour when melted. The mother water which remains in the pans after each crystallization is conveyed away by gutters to cisterns under the building, it is then evaporated in iron pots to ¼ of its original bulk, filtered, and allowed to crystallize. The Saltpetre obtained from the first mother water is considered one stage inferior to Grough; that from the second equal to Grough; that from the treble refined equal to once refined Saltpetre. The water left from every stage is treated in the same way, so that actually nothing is lost of the pure material. Saltpetre treble refined by this process is perfectly pure, and fit for the manufacture of Gunpowder, and in order to free it from moisture, as well as for the convenience of storage and transport, it is melted in iron pots holding about four Cwt. by raising it to a temperature of 600 degrees Farenheit, and cast into gun-metal circular moulds holding about 38 lbs. each. It must be observed that it requires about two hours to bring the Saltpetre into a liquid state, and that, after this, the furnace doors are thrown open to lower the heat

to the proper temperature for casting into the moulds. When the cakes are cold, they are packed away in barrels containing 1 cwt. 1 qr. each, and put into store. Care must be taken, in melting the Saltpetre, not to raise it to too high a temperature, as this would reduce the quantity of oxygen, and form nitrate of potash, which would render it unfit as an ingredient in the composition of Gunpowder.

An exceedingly delicate test for the purity of Saltpetre is made as follows:—

Dissolve a small portion in a test tube or small phial with distilled water; add a few drops, first of Nitric Acid, then of Nitrate of Silver; if no discolourization takes place, the Nitre is pure. Should a milkiness appear, it indicates the presence of a Chloride (common Salt). To determine if the Saltpetre has been over-heated, and consequently if it contains Nitrite of Potash, add a drop or two of the Sulphate of Copper: if a green colour appears, it is a certain indication that it has been brought to too great a heat in the melting process.

NEW METHOD:

Forty Cwt. of the Grough Saltpetre is put into a copper with 270 gallons of water, and treated in precisely the same way as we have before described for the first refining; it is then filtered, and run off into large troughs about 10 feet long by 6 feet wide, and 9 inches deep, lined with sheet Copper; this liquor is then kept in a state of agitation by a wooden rake until nearly cold: by this process, a large quantity of very minute Crystals are formed, which are collected as they form by a wooden hoe, and shovelled with a spade on to a frame-work covered with Copper Sieving resting on the opposite sides of the trough, and allowed to drain: these fine white Crystals, which have exactly the appearance of Snow, when they have drained sufficiently, are raked over into a washing cistern adjoining, which is about 6 feet long, 4 feet wide, and 3 ft. 6 in. deep, and fitted with a false wooden bottom that can be removed at pleasure. Cold Water is allowed to run on to the Saltpetre in this cistern till it is nearly level with the top; after remaining for an hour, it is drained off, and filled again with fresh water, which is drained off after about another hour; the Saltpetre thus obtanied is perfectly pure, and equal in every respect to the treble-refined by the old method. The water remaining in the cisterns after agitation is left till the next morning, when a quantity of larger Crystals are formed on the bottom and sides; these are equal to once refined by the old method, and are used with Grough; the mother liquor is then drained off, and evaporated in the usual way: the water from each washing is conveyed into cisterns, and used with

Grough Saltpetre instead of Water; but, as it contains a small portion of Saltpetre in solution, a lesser quantity of Grough is used to make the proportions correct.

Drying.—The Saltpetre Flour, however, contains a certain degree of moisture, which has to be dried off in the following way; Two large copper trays, about 10 feet by 6 feet, with a 3-inch rim, are fixed over flues heated by a furnace, 4 inches of sand being between the flues and the bottom of the trays: the Saltpetre is spread about 2 inches deep all over, and raked about till dry; it is then barrelled up for use. It takes about 2 hours to dry 5 Cwt.

On comparing the two systems, there cannot for one moment be a doubt as to the immense advantages of the latter over the former. As an example in the refinery where this new process is carried on, the result (that is to say pure Saltpetre) is obtained in One Day instead of Six, with less than one-half the amount of labour and coals; the extraordinary saving in the expense of apparatus will be seen by perusing the following table:—

TO PRODUCE 23 CWT. A DAY:—

OLD METHOD:		NEW METHOD.	
Crystallizing Pans, 36 gallons (Copper)	375	Crystallizing Pans	50
Coppers, 500 Gallons	3	Coppers, 500 Gallons	1
Evaporating Pots	4	Evaporating Pots	2
Melting Pots	4	Cisterns Copper	2
Moulds, Gun Metal	20	Cisterns Wooden	1
		Drying Trays	2
Filtering Apparatus, Sets	2	Filtering Apparatus, Sets	1
Pumps, Copper	6	Pumps, Copper	2

In addition to this, there is ample room in the present building to erect two more sets of apparatus, which would then refine 69 Cwt. in a day, against 23 Cwt. by the old process.

On reflection, the reason of the great gain of time by this process will suggest itself; in the former method, when allowed to remain quiet, the crystals formed are very large, and the spaces left in them always contain a certain amount of mother water, which necessitates its being crystallized three times to perfectly free it from this liquor: in the latter, the crystals are so minute that there is practically no space for the mother water to collect; consequently, by careful washing, the Saltpetre is obtained perfectly pure.

CHARCOAL.

Charcoal is the next most important ingredient in Gunpowder; it is vegetable matter changed from its original nature by a chemical process, by which it becomes applicable to a special purpose. Wood Charcoal is the

woody fibre that remains after the liquid and more volatile parts have been driven off by the fire in the process of charring; the temperature resulting from the combustion of Charcoal is much higher than that from burning wood, in consequence of the absence of the large quantity of water which wood contains, amounting to between 50 and 60 per cent.; the object, therefore, of charring wood is the removal of moisture—and also, what is of great importance, the expulsion of those matters contained in it which become volatile before they are burned, thus rendering a large amount of heat latent. The woods generally used in this country in making Charcoal for Gunpowder are—the Alder, Willow, and Dogwood. Other woods are used sometimes by English and foreign manufacturers, but none produce a Powder of such quality as obtained from the above. It is usually considered that better Charcoal is distilled when the wood is allowed to season for a time: but recent experience has shown that wood only lately cut and peeled, after being dissicated in a hot chamber, will make equally good Charcoal with that which has been seasoning for three or four years.

All the wood which is cut in the Government Grounds, or purchased from merchants, is stripped of the bark, on account of its being impregnated with salts and gummy substances, cut into lengths of 3 feet for the convenience of loading the iron slips, which are a little above this length, and stacked in the wood yard. It is paid for by the cord, which is 14 feet long, 3 feet wide, and 3 feet high, containing 126 cubic feet. The method of charring is performed in the following way:—

Cylinder Charcoal.—Cylindrical cases of the required size, fitted with lids, are filled with wood: these cases are made to fit easily, and slide horizontally into iron retorts built in the wall, which admit of accurate regulation of heat (communicated to them by furnaces underneath), throughout the operation of charring; a great saving of time and heat is effected by their use, as when the wood has been properly charred, the case or slip containing it may be easily withdrawn, and another containing a fresh charge at once introduced into the retort without allowing the latter to cool down, as would otherwise be necessary. When it has been sufficiently charred, (which is known by experience in watching the burning of the Gas that is produced and is conducted into the fire), the slip is withdrawn by tackling, and at once lowered down into iron coolers or cases, which are immediately covered up with close-fitting lids, and then allowed to remain until all fire is extinguished; the goodness of Charcoal is an essential point in the manufacture of Gunpowder; about 25 to 30 per cent. is obtained; and one cord will produce about 4 Cwt. of Charcoal: if properly charred, it should have a jet black appearance, and when powdered, a lustre resembling velvet; it should be light and sonorous when gently dropped, and its fracture should exhibit the same appearance throughout; it should be so soft as not to scratch polished Copper, and ought not to exhibit any alkali when treated with pure distilled water. The Alder and Willow Charcoal are easily distinguished from each other—the former having a triangular pith most distinctly marked, and the latter a circular one. Dogwood is charred precisely in the same way as just described, and is purchased by the bundle of 27 lbs. weight, or thereabouts, each producing from 7 to 10 lbs. of Coal; it is very much smaller than the Alder or Willow, averaging the size of thick ozier; its pith is circular, and large in proportion to the size of the wood, exhibiting, when converted into Charcoal, a yellowish metallic appearance; it is considered by many that this Charcoal possesses peculiar properties which more particularly recommend it for the manufacture of Gunpowder: I have, however, tried every experiment on this point, and find no difference between it and carefully-picked small Alder or Willow—the strength and cleanness of the powder arising more from perfect incorporation, purity of the ingredients, and proper distillation of the Charcoal than from any other cause. Charcoal is very porous, and absorbs very greedily Gasses and moisture from the atmosphere; no large store, therefore, is ever kept, and particular care is taken to prepare it only in proportion as it is required for use. Before being used for Gunpowder, it should be carefully picked over, as portions of dense Coal are sometimes formed by the trickling down of tar which has condensed on the top of the retort. To ascertain if Charcoal contains alkali, powder a small portion, add some distilled water, boil and filter the solution, apply litmus paper that has been reddened by any weak acid—and, if it contains alkali, the original colour will be wholly or partially restored.

Pit Charcoal, which is used for pyrotechnic compositions, and also as an ingredient in Pit Powder,* is burned in the following way: from 3 to 4 cords of wood are built up in a circular mound about 10 feet in diameter, and 5 feet high, having a hole left in the centre, which acts as a chimney; this mound of wood is then covered with Stubble or Straw, about 3 or 4 inches deep, and over this a layer of Charcoal-Dust or Sand, about the same thickness; some lighted Charcoal is then put down the chimney, which is then closed up, and the process of charring commences; a shifting screen is always placed to windward, to regulate the draught, and small holes are left at intervals to allow the escape of the vapour; after 3 days and nights the operation is complete: the Charcoal thus produced contains more of the woody fibre, and burns slower than that made in cylinders; it consequently is heavier, has a very slight reddish tinge, a more metallic sound when dropped, and breaks with greater difficulty. Great attention and experience are required in burning this Charcoal, in consequence of which men from the forests are generally employed who are Charcoal-burners by trade.

* Pit Powder is an ingredient in Fuze Composition; it is preferred for this purpose, from the Fuzes being slower and more regular in burning than if made with common meal Powder.

SULPHUR.

This combustible elementary body is found generally in great quantities in the neighbourhood of Volcanoes; it is also obtainable from metallic ores, and readily fuzes. At 170 deg. of Farenheit it begins to evaporate; at 185 to 190 deg. it melts; at 220 deg. it is perfectly fluid: and at 600 deg. it sublimes. Sulphur is purified simply by melting: that which is supplied to this establishment has been once refined, and the following is a description of the apparatus, and method for purifying and rendering it fit as an ingredient in Gunpowder. A large iron pot is set about 3 feet off the ground, or about the height that an ordinary boiling copper is placed, having a furnace underneath. This pot has a moveable lid, which is fixed into the top of the pot with clay, and in which lid is an iron conical plug that can be removed at pleasure: from the pot lead two pipes, one to a large circular dome, and another to an iron retort rather below its level; the last-mentioned pipe has a casing or jacket round it, which can be filled with cold water; the communication of these pipes with the melting pot can be shut off or opened as occasion requires, by a mechanical arrangement. About $5\frac{1}{2}$ to 6 Cwt. of the once-refined Sulphur is broken up into small pieces, placed in the iron melting pot, and subjected to the action of the furnace: the plug in the lid, and the pipe leading to the dome are now left open, but the pipe to the retort closed; after about from two to three hours a pale yellow vapour rises, when the plug is put in, and the vapour conducted into the dome, where it condenses in the form of an impalpable powder, commonly called Flowers of Sulphur; a small pipe leads from the bottom of the dome on the opposite side into water, to allow the escape of the air, and Sulphuric Acid is taken up by this Water. In about $1\frac{1}{2}$ to 2 hours after, the vapour becomes a deep Iodine colour, when the communication with the dome is shut, and the one to the retort opened; at the same time, Cold Water from a tank above is allowed to pass into the jacket we have before mentioned surrounding this pipe; the vapour then distills over, is condensed in the pipe, and runs into the retort below in the form of a thick yellow fluid. When nearly all has distilled, which can be known by the jacket getting cold, the communication is again closed with the retort, and the fluid Sulphur left an hour to get sufficiently cool to ladle out into moulds, the furnace door and the communication with the dome at the same time are again thrown open, that the rest of the vapour may pass into the latter; the Flowers of Sulphur thus obtained are used for laboratory purposes, being unfit for the manufacture of Gunpowder, from the acid they contain, and the crystalline Sulphur, after being allowed to cool in the moulds, is barrelled up, and, used as the third ingredient in Gunpowder. To ascertain the purity of Sulphur, if a small portion is burned on a piece of porcelain, no residue should be left; also, if it is treated with distilled water, litmus paper should not be discoloured.

Having explained in a concise manner, which is all that is necessary in the present papers, the method of production and purification of the ingredients, the next thing to be considered is—their fabrication into Gunpowder.

PULVERIZING THE INGREDIENTS.

The three ingredients are now ground separately to a very fine powder: the mill which effects this and incorporates are so similar, that a description will be given under the head of "Incorporation." After being ground in this way, the Saltpetre is passed through a slope cylindrical reel, covered with Copper Sieving Wire of 24 and 28 meshes to the inch, which, as it revolves, sifts it to the required fineness, being then received in a box or bin underneath: the Charcoal and Sulphur are likewise passed through similar reels of 32-mesh wire respectively, and that which remains without passing through, is ground again under the runners. A very excellent machine has been invented by Mr. Hall, the engineer of Dartford, for grinding Charcoal, which makes a most useful addition to this establishment; it consists of a conical drum, working in a conical box, on the same principle as a coffee-grinding machine, the axis being vertical; the mill is fed with charcoal by a hopper, and, as it passes through in a fine powder, falls into a revolving reel, which sifts it in the same manner as before described, the whole being covered in, to prevent the great annoyance of dust which was felt until lately from the old Charcoal Mill. The three ingredients having been pulverized, are now fit for the mixing process.

MIXING THE INGREDIENTS.

The ingredients are now weighed out very accurately in the proportion of 75 Nitre, 15 Charcoal, and 10 Sulphur in 42 lb. charges,* viz.—Nitre 31 lbs. 8oz.—Charcoal 6 lbs. 4 oz. 13 drs,—Sulphur 4 lbs. 3 oz. 3 drs., and thoroughly mixed in a machine, which consists of a cylindrical gun-metal or copper drum, about 2 feet in diameter, with an axle passing through its centre, on which there are metal flyers, like forks: the machinery is so arranged that the flyers and drum revolve in opposite directions when in motion at a rate of about 100 revolutions per minute: 5 minutes is sufficient for a thorough mixture; the composition is then drawn off by a slip into canvas bags the proper size to hold the 42 lb. charges, which are tightly tied, and taken to small magazines: these are called green charges, and are now ready for the next process, incorporation.

WET MIXING.

A plan has been patented by Mr. Drayson, of Maresfield, Sussex, for mixing the ingredients wet in the following way:—The proportion of Saltpetre is put into a pot with about 12 pints of distilled water, and brought to the boil, either by steam or an arrangement of flues; it becomes then a solution of Saltpetre: the Charcoal and Sulphur are next added, and the whole mixed together, so as to form a stiff paste; it is then turned out into bags, and goes through the ordinary process of manufacture: the Charcoal, by this means, appears actually to imbibe the Saltpetre, and the mixture must be far more intimate than by the former method. Should a quick and safe arrangement be matured which will enable this plan to be carried out, it will add greatly to the capability of an establishment, as from experiment on a small scale it has been fully proved that the ingredients mixed

* The Gunpowder Merchants always use 50 lbs. in each charge: this quantity of 42 lbs. was first fixed upon many years ago, and is considered by some to possess important virtues—which, however, I have never been able to discover; moreover, I have proved by experiment, that charges of 50 lbs. will make equal Powder in every respect—and, I consider, with great additional safety in the manufacture; for I am convinced that nine-tenths of the explosions which occur in this process proceed from there not being sufficient composition on the mill, whereby the surfaces of the runners and beds occasionally come in contact with each other, causing immense friction; there are many opinions as to the cause of these explosions in this particular stage of manufacture: no reason I have ever heard accounts for them so satisfactorily, or points so clearly to the remedy.

in this way require only half the time of incorporation, and produce a powder as strong and good in every respect as by the present process.

THE INCORPORATING MILL.

The Incorporating Mill consists of an iron or stone circular flat bed, about 7 feet in diameter, fixed very firmly in the floor of the building which covers it, whereon two iron or stone cylindrical runners from 5 to 7 feet in diameter, 14 to 18 inches wide, and each weighing from 3 to 4½ tons, revolve: they have a common axle, and a vertical shaft, passing through the centre of the bed, is connected with this axle, and to machinery above or below, which communicates the motion. These runners are not equidistant from the centre, by which arrangement in their revolution every part of the composition on the bed is subjected to their action, which is three-fold, viz:—crushing, grinding, and mixing; crushing, from the weight of the cylinders; grinding, from the twisting motion which they are forced into from so large a diameter revolving in so small a circle; and mixing, from a combination of the two former motions. To prevent the Powder from falling over the side of the bed, a wooden rim, about 2 feet in height, is placed at an angle of 45 degrees with it, like the side of a funnel, and fitted closely all round its circumference: this is called the "Curb;" and in the centre of the bed, a gun-metal ring, or "Cheese," as it is termed, about 2 feet in diameter, and 5 inches high, concentric with the bed, prevents the Powder working beyond in that direction; moreover, two scrapers or "Ploughs," connected by stays with the horizontal axle, revolve with the runners, one rubbing against the inner, and the other the outer circle; these ploughs are made of hard wood, shod with leather and felt, and their use is continually to disturb and rout about the composition, and keep it under the path of the runners, so that every part should get its share of incorporation. The houses or sheds which cover these buildings have hitherto been constructed of wood, with either corrugated iron or wooden roofing; the new incorporating mills in this factory, which are just completed, are built with three sides of strong 3-foot brickwork, and the fourth side and roof of corrugated iron and glass: they are also placed in a line contiguous to each other, the alternate ones only facing the same way, so that an explosion from one would probably communicate no further, and the lighter parts of the building would blow away, leaving the rest entire. Most of the machinery in the factory is driven by water wheels; the motive power of these Mills is

Steam:* a horizontal shaft worked by the engine passes underneath the entire length of the building in a cast-iron tank, and a bevel wheel on this shaft is geared into another one on the vertical shaft under the centre of each bed, which, communicating with the runners, gives the necessrry motion. A very perfect arrangement is made, by which each pair of runners may be stopped or set in motion independently of the others, and without any sudden or jerking movement, which would be likely to cause explosions: it is managed in the following way:—

An iron drum is cast in one with the bevel wheel, which is loose on the horizontal shaft; two segments, edged with copper, are keyed on to this shaft, which are made to expand or contract at pleasure inside this drum by the action of a lever. These segments being keyed to the shaft, always revolve with it, and when made to expand into the drum, the friction imparts the same motion to the bevel wheel, and consequently to the vertical shaft in connection with the runners.

In order, as much as possible, to guard against any explosion spreading, above each bed, placed so as just to clear the runners, is suspended or balanced a copper tank, holding about 40 gallons of water: on one side of the tank is fixed a small shaft, which communicates with similar cisterns over the beds of the mills on either side; the other end of the tank rests on a flat board, which is subjected to a great part of the force of an explosion; this consequently lifts, disengaging the support of the tank, the contents of which drenches the bed which has just exploded, thereby putting out all fire, and cooling the machinery, besides having a similar effect on the mills right and left—preventing, by this means, any extension of fire.

INCORPORATING THE INGREDIENTS.

The charge is spread pretty evenly over the surface of the bed, and moistened with from 4 to 6 pints of distilled water: the quantity varying according to the state of the atmosphere; the runners are then set in motion, and run from seven to eight† revolutions per minute for 3½ hours,

* Care has been taken in providing a chimney of sufficient height to the Boiler-house, which, with the further caution of using always Anthracite Coal, precludes the possibility of any accident from Sparks, &c. falling.

† In the new Steam Mills, the Engine is arranged so that from 8 to 14 revolutions can be given to the runners by merely altering, with a lever, the position of the friction wheel on the main shaft, which works the governor. I consider that, without going to either extreme, many advantages will be gained by fixing the speed at 10 revolutions, which will greatly reduce the time at present allowed for incorporation.

during which time the Powder is often routed up by a copper-shod spud, and watered slightly with a fine rose-watering pot, according to the experience of the millman; at the end of this time the mixture is thoroughly incorporated, possesses all the chemical properties of Gunpowder, and is taken off the bed in the form of cake, varying from $\frac{1}{4}$ to $\frac{1}{2}$ an inch in thickness, and of a blackish grey colour; this is called "Mill Cake," and when broken, the fracture should exhibit the same uniform appearance, without presenting any sparkling or yellow specks: should this, however, be the case, it is a sign of the ingredients not being sufficiently incorporated: in this stage, it undergoes certain proofs; samples of the cake are taken from every charge that is worked, dried in an oven, and granulated; half a dram of this is fired in a vertical eprouvette, which it ought to raise 3·5 inches; and $\frac{1}{2}$ an oz. is flashed on a glass plate; if very little residue or ash is left, it is an additional proof of its being well incorporated, and that the millman has done his work properly.

Incorporation is by far the most important process in the manufacture of Gunpowder; for, however carefully the other part of the fabrication is carried on, should there be a failing in this, the Powder will be worth nothing.

The great and ultimate object to be attained in the manufacture of Gunpowder is—to produce that which shall give equal results with equal charges: the greatest regularity should, therefore, be observed in this stage; the millman should have great experience; the runners and beds should be, as nearly as possible, the same size and weight, and driven at the same speed throughout the factory; at any rate, each charge should be worked to the same number of revolutions; the motion of the runners should also be as uniform as possible, which is very satisfactorily accomplished by each water wheel being regulated by a governor.

In one of the largest Gunpowder manufactories in England, a new method has been adopted in this process: the charge is constantly kept moist with boiling water by a self-acting apparatus; the bed of the mill is hollow, and made of iron, through which a constant supply of hot water or steam circulates from the engine boiler, which raises the temperature to about 170 deg. Farenheit; it is considered by the manufacturer that this plan succeeds well, producing as intimate a mixture of the ingredients, with a saving of about one-third of the time. The new mills just completed are constructed so as to admit of the application of this principle, should it ever be considered advisable to adopt it.

BREAKING DOWN THE MILL CAKE.

The Mill Cake, after it comes off the bed of the Incorporating Mill, is placed in wooden tubs, and taken to small-expense magazines, and from

there, in about 12 hours, to the breaking-down house: the object of the machine from which this takes its name, is to reduce the cake to a convenient size for the hydraulic-press box, and also that, by being crushed again to meal, it may get a more even pressure: it consists of a strong gun-metal frame work, in which are fixed two pairs of fine-toothed or plain rollers, which revolve towards each other, working in spring collars, so that, on any hard substance getting in by mistake, they would open, and allow it to pass through, thereby preventing the dangerous friction which would otherwise result. A hopper, or upright wooden funnel, capable of holding about 500 lbs., is fixed at one end of the machine, and an endless canvas band 2 ft. 6 in. wide, having strips of leather sewn across at intervals of 4 inches, passes over one roller at the bottom of the hopper, and one at the top of the machine: when set in motion, this conveys the cake from the hopper to the highest point of the band; it then falls through the first pair of rollers, and from thence through the second, passing in the form of meal into small wooden carriages underneath, which, as they are filled, move forward by a self-acting motion, making room for others. The Mill Cake thus broken down, is fit for the Press.

PRESSING THE MEAL BY THE HYDRAULIC PRESS.

The meal is now subjected to very powerful pressure; and, in order to explain the way in which this is effected, a short description of the apparatus must be given; the principle of the hydraulic press is so familiar to most, that it will be unnecessary to do more than shew how the power is applied.

A very strong oak box, 2 ft. 6 in. square, and 2 ft. 9 in. deep, is constructed so that two of the sides and lid will fall back on hinges, or form a compact solid box when screwed firmly together. Forty-six copper plates 2 ft. $5\frac{1}{2}$ in. square, slide vertically into this box, and are kept $\frac{5}{8}$ of an inch apart by two metal slips with corresponding grooves which can be removed when necessary.

METHOD OF LOADING THE BOX.

About 800 lbs. of the meal is put into this box while the plates are in the position we have described; when full, the slips are withdrawn, the plates being then only separated by the powder between them: the lid is now firmly screwed down, and the box turned over by an arrangement of pulleys, so that the plates, which were vertical, will now be horizontal; the present upper side is then unscrewed, and a travelling crane, moving on a rail over head, is lowered till the claws attached to it hook on to two trunnions fixed on the sides of the box; it is now hoisted by means of a hand wheel windlass—and the box being suspended, is pushed easily, by means of the rail, and deposited in this position on to the table of the ram under the press block. The pumps that work the hydraulic press are in a separate house, a high traverse intersecting them; the men, after placing the box in the position in which we left it, retire to a room adjoining the pump house, and are in comparative safety in the event of an explosion. The pumps are now set in motion by a water wheel,† and are allowed to work up to the required pressure, which is about 70 tons to the square foot; after this pressure has been obtained, (which is known by the safety-valve lifting, and the water making its escape) the box is allowed to remain under the press for ¼ of an hour, a cock is then opened, which allows the free passage of the water from the cylinder, and consequently the descent of the ram; it is then conveyed from under the block in the same manner, and very easily unloaded, it being constructed, as we have before explained, so as to allow the top and two sides to fall back on hinges. The Press Cake is then taken out in layers between each plate, resembling dark-pieces of slate, about ½ an inch in thickness: after a day or so, this hardens so much as to be difficult to break, and the appearance of the fracture resembles that of the finest earthenware; many important advantages are gained by this pressure, of which the following are the principal:—

First—The density of the Powder is increased, which prevents it falling to dust in transport, or by rough usage. Secondly—Its keeping qualities are improved, for it withstands the action of the atmosphere, and absorbs less moisture than a porous light Powder. Thirdly—it produces more grain in the manufacture than mill cake; and a less proportion, consequently, is lost in dust. Fourthly—a closer connection of the ingredients is obtained. Fifthly—a greater volume of inflammable gas is produced from a certain bulk, than from a corresponding bulk of lighter Powder.

The range, however, is lessened from a greater quantity being blown out of a gun unignited; but this small loss is more than counter-balanced by the former advantages, and actually it is only perceptible in newly-made Powder; for a light porous Powder soon loses its superior range from its absorption of moisture, while that of the dense Powder remains unaltered.

† There is also an arrangement of levers, by which they can be worked by hand, if necessary.

GRANULATING THE PRESS CAKE.

The next process is Granulation, or reducing this Press Cake into the the proper sized grain for cannon, musquet, or rifle Powder; the machine which effects this is very beautifully contrived, and is entirely self-acting, obviating the necessity of any one being in the building while it is in motion; it resembles, in appearance and action, the breaking-down machine, except that it is larger, and is fitted with three pair of toothed rollers of different degrees of fineness, working in the same kind of collars already mentioned, so that, on any hard substance passing through, they would open accordingly, and thus prevent friction. At one end of the machine is a wooden hopper or funnel, which is filled with the press cake; this is contrived so as to rise gradually by the motion of the machine, and constantly to supply an endless band, similar to the one described in the breaking-down house; when the cake arrives at the highest point of this band, it falls over, and is granulated between the first pair of gun-metal rollers; under each pair is a screen covered with 8-mesh wire; all that is not sufficiently small to pass through, is carried on to the next pair of rollers—and, in like manner, that which does not pass through the second screen is carried to the third pair; in addition to these screens, there are three oblong sieves covered with 8 and 16-mesh wire, and 56 cloth respectively, fixed under, and parallel to each other, each being separated by about four inches of space, running at an incline just below the three pairs of rollers; these all lead to little wooden carriages placed on the opposite side of the machine, which are divided so as to collect the different-sized grain as it passes down: to facilitate the separation and sifting of the Powder, and to prevent masses of it forming, and clogging up the wire, a shaking motion is imparted by a circular wheel attached to the frame-work of these sieves revolving against an octagonal one fixed to the machine. The grains which pass through each screen below the rollers fall on to the upper one of these three last-mentioned sieves; that portion which passes through this, and is retained on the 16-mesh wire—is cannon powder; that passing through the 16-mesh sieve, and retained on the 56 cloth, is fine grain; and a board running also parallel underneath retains the dust that passes through the cloth.

The "Chucks," as they are called, or those grains that are too large to pass through these different sieves, are collected in the same way as the grain, and undergo the process of granulation again.

The hopper, having arrived at a certain height, and discharged its contents, rings a bell, which is a signal for the machine to be stopped and recharged: the Powder thus obtained is by no means finished, as it contains a good deal of moisture and dust, which have to be expelled, and separated from it; it is called, in this state, "Foul-grain Powder."

DUSTING LARGE-GRAIN POWDER.

The keeping qualities of Powder are very much improved by removing the dust, which quickly absorbs moisture from the atmosphere; this operation for large-grain is performed by cylindrical reels about 8 ft. 6 in. long, and 3ft. 8 in. in diameter, clothed with 28-mesh canvas, which revolve at the rate of 38 times per minute; those for large-grain are called horizontal reels, in contra-distinction to those for fine-grain, that are called slope reels: each is enclosed by a wooden case, to prevent the dust flying about the house. When the powder has run its time, one end of the reel is lowered; it then runs out into barrels placed to receive it. This entirely separates the dust, and imparts a fine black gloss, which is sufficient glazing for the large-grain Powder; there, however, remains a certain degree of moisture; it has, therefore, to undergo a further process of being stove dried: before, however, describing this next essential part of the manufacture, we must follow the course fine-grain has to go through till it is also fit for this operation.

DUSTING FINE-GRAIN POWDER.

The Fine-grain Powder has a much greater proportion of dust when it leaves the granulating house than the large grain; and it is found necessary, on this account, to use a different kind of reel. They resemble those for the former Powder, except that they are covered with 44-mesh canvas instead of 28, and are placed at an incline which prevents their being choked up with the quantity of dust; each end is also open, and a continuous stream of Powder, fed by a hopper, passes through while they revolve, which pours out at the lower end into barrels: this process is repeated a second time, which sufficiently frees it from dust.

GLAZING FINE-GRAIN POWDER.

The Fine-grain Powder thus dusted, is then glazed for three hours in barrels capable of holding 300lbs., which are 3ft. 6in. in length, and 2ft. 8in. in diameter, revolving at the rate of 32 times in a minute. By the mere friction of the grains against each other and the inside of the barrel, a glaze is imparted, presenting a fine polished surface to the grain.

Powder glazed in this way withstands the action of moisture to a far greater extent than unglazed Powder, and in transport very little dust is formed.

An artificial glaze is sometimes given by the addition of a little lamp black or Graphite in the glazing barrels; this plan is not, however, adopted in the Government Works, as it is considered that these coatings might attract moisture. The small quantity of dust generated by this process, is removed by passing the Powder again through similar slope reels to those before mentioned; these are called slope-reels for glazed Powder, which are kept separate. The fine grain is now in a similar state to the large-grain in the stage in which we left it; they both contain moisture, which it is necessary to expel before they are fit for the service.

STOVING OR DRYING POWDER.

A drying-room, heated by steam pipes, is fitted with open frame-work shelves, on which rest small wooden trays about 3 feet long, 1 ft. 6 in. in breadth, and $2\frac{1}{2}$ in. deep, having canvas bottoms; on each is spread 8 lb. of Powder; this room holds about 40 barrels, or 4000 lbs.. which remains in it for 24 hours, and is subjected to a heat of 130 deg. of Farenheit for 16 hours, communicated by steam passing through pipes arranged horizontally on the floor of the room. The temperature is raised and lowered gradually, otherwise the too sudden change would be likely to destroy the texture of the grain. The ceiling and roof are fitted with ventilators, through which all the moisture escapes, so that there is a constant current of hot air circulating through the room. It is of the greatest importance that the vapour should be carried off; for, if this is not effectually done on the decrease of temperature, it would return to its liquid state, and form again on the Powder.

FINISHING DUSTING.

The action of heat, however, produces a small portion of dust; both these Powders, therefore, when they leave the stove, are reeled in horizontal reels, clothed with 28 and 44-mesh canvas respectively for 1½ hours: this perfectly separates any remaining dust, and gives the finishing glaze to the large-grain Powder. This is the final process, and the Powder thus finished is taken to the barrelling-up house, weighed out into barrels holding 100 lbs. each, marked L. G. (large grain), and F. G. (fine grain) as the case may be, and stored in magazines

The proportions of different Powders obtained in the manufacture are as nearly as possible seven-tenths large grain—two-tenths fine grain—and one-tenth dust: all that is separated in each operation is worked over again for one hour under the runners, and goes through the remaining different stages of manufacture, the same as the regular work. That which is separated in the last dusting of the fine-grain or musket Powder through the 44-mesh cloth, exhibits a beautiful uniformity of grain: after being reeled for 1½ hours in a 72-mesh silk, it is equal in appearance to the finest sporting Powder, and is used to fill Captain Boxer's diaphragm shells: About 8 per cent. is obtained.

THE POWDER BEST ADAPTED TO THE ENFIELD RIFLE.

A great many experiments have been made lately, and particular attention paid to ascertain the Powder best adapted to the Enfield Rifle; hitherto common fine-grain Powder, obtained by the method we have described, has been exclusively used; but it is a question whether one made with greater care, of more even grain, and pressed lighter, would not be better suited for rifle practice; the principal thing to be guarded against is the fouling of the piece, which prevents more than a limited number of rounds being fired without cleaning it. As far as experiments have been carried at present, it is considered that a Powder made from small-wood Charcoal, from ½ to ¾ of an inch in diameter, incorporated for 4 hours, slack pressed, and separated so as to obtain an even grain, between a 16 and 20, or 20 and 28-mesh wire sieve, will answer, in all respects, for this service better than any other.

EXAMINATION AND PROOF OF GUNPOWDER.

The great and ultimate object to be attained in the manufacture of Gunpowder is, not so much to produce that which ranges the highest, as one that shall be durable in its texture, not easily deteriorated by atmospheric influence or transport, and one with which equal charges shall produce equal effects. It should present uniformity in the appearance of its grains,* which should be angular, crisp and sharp to the touch, not easily reduced to dust by pressure between the fingers, or dusty in handling: its specific gravity should not be under 55 lbs. to the cubic foot (that of Waltham Abbey is generally 58 lbs.) taking water at 1000 oz: its strength is tested by firing three rounds from an 8-inch mortar, throwing a 68-pounder solid shot with a charge of 2 oz.; this should give a range of from 270 to 300 feet: the distance, however, varies considerably, according to the state of the atmosphere, and the density of the Powder; for the greater the density, the less the range in small charges. Half an oz. flashed on a glass plate should leave little or no residuum; should white beads or globules appear, it is a sign of imperfect incorporation.

All these requirements are of paramount importance, particularly that which relates to the equal effect of given charges; for on this are based all calculations connected with Gunnery, and the accuracy of artillery practice is entirely dependent on it.

Many reasons have been advanced why the Government should be their own manufacturers to a certain extent—such as the great saving in the cost of Powder when compared to the price paid to the Merchants, which in seven years of the War from 1809 to 1815, from the Government having Waltham Abbey, Faversham, aud Ballincollig, amounted to upwards of £300,000; and, had there been greater capabilities, more than double that amount would have been saved: also, by exercising a control over the market, exorbitant demands are prevented, which might be made, were the Government not in a position to check this by their own establishments.

No reason, however, is so strong—or of such consequence as the above,

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* The proportion of different-sized grain in one Pound of Cannon Powder, has been fixed as under, viz :—

9 oz. that will pass through an 8 sieve, and be held on a 12
5 oz. .. .. a 12 16
2 oz. .. .. a 16.

viz.—the production of an equal Powder, it being next to an impossibility to obtain this result—indeed, it cannot be expected where the great bulk is supplied by half-a-dozen different contractors, none of whom pursue the same process.

The Government should therefore, I conceive, be in a position to manufacture for their utmost wants, at any rate all that does not come under the head of blank ammunition; the first outlay in buildings and machinery would be covered in a few years, and the service of artillery greatly benefitted by the use of a Powder that could at all times be depended upon. In the Government Factory every particular in the fabrication is most carefully attended to, the purity of the ingredients always tested, and great attention paid to the proper distillation of the Charcoal; they are always ground in the same way, and sifted to the same degree of fineness: in fact, every process is always carried on in precisely the same manner; the consequence is, that Waltham Abbey Powder is considered by all the best sample to work to: on this point, Major Mordecai, in his excellent work, says;—

"I would, therefore, propose the Waltham Abbey Powder as the type or standard to which our* Powder for military service should conform in nearly all respects. In this manufacture, the essential operations are—the separate pulverization of the ingredients, their incorporation by the cylinder mills alone, and the formation into cake by moderate pressure."

In addition to the above reasons of the advantages arising from Government Factories, are the experiments that can be carried on, and improvements made, in producing a Powder of superior quality. I cannot do better than quote a paragraph in the evidence of Lord Hardinge before the Finance Committee of the House of Commons in 1838: He says—

"At Waltham Abbey, in a very few years after it was constructed, the Powder was so improved, that the charge of Powder to the weight of shot was reduced from one-half to one-third; therefore two barrels were used instead of three, an advantage in stowing on board ship, as well as in the field."

From the above, it will appear that a great part of the Powder for H. M. Government has at present to be supplied by Merchants. The contracts are made out sometimes for them to supply their own Saltpetre,

* American.

and at others for the Government to furnish it pure at the rate of 77·5 lbs.† per barrel of 100 lbs., they finding the other materials and manufacture, a corresponding reduction in price being made: as, however, it has to come up, in nearly all respects, to the sample,‡ the requirements of which we have before stated, certain Proofs have to be undergone before being received for the different services.

PROOF OF MERCHANTS' POWDER.

The following are the different Proofs Merchants' Powder is subjected to:

Lots of 100 barrels are sent in, marked with the Number of the lot, and the maker's name on the head of each barrel: 25 per cent. of these are unheaded in the examining house: the Proof Officer then proceeds—

First, to take a bowl out of each barrel, and holding it about three feet above, pours it out quickly: should there be a good deal of dust, it is satisfactorily shown by this means.

Secondly, it is handled and pressed between the fingers, to test the firmness of its grain; and should there appear to be any great difference in the proportions of different sizes to that laid down as a standard, it is sifted and compared accordingly, being rejected should the quantities fall short or exceed the sample in any great degree.

Thirdly, a barrel or two are selected, and the Powder poured into a hopper, under which is placed a box very carefully constructed, so as to hold exactly a cubic foot: a slide is now withdrawn at the bottom of the hopper, and the Powder allowed to run into the box in a continuous even stream until it is piled up; the hopper is then removed, and the Powder struck off with a straight edge, level with the top of the box; the weight is now carefully taken, that of the latter being subtracted; should this not amount to 55 lbs., it is rejected, as not being of sufficient density.§

Fourthly, Samples are taken from every barrel and lot for the Firing Proof.

† This allowance of 2½ lbs. extra is given to make up for losses, &c. in the course of manufacture.

‡ The Merchants are provided annually with a Sample of Waltham Abbey Powder, to guide them in their manufacture.

§ A description will be given, in one of the following pages, of an Apparatus invented by Col. Mallet and M. Bianchi to test the Density of Powder.

Firing Proof. An average of 9 rounds of sample Waltham Abbey Powder is taken, 3 rounds being respectively fired, at the beginning, middle, and end of the Proof, from the same kind of mortar before mentioned, with a charge of 2 oz.; an average of 3 rounds, of each lot of the Merchants' Powder is also taken; should it fall short by more than 1 in 20, it is rejected.

Fifthly, To ascertain if any residuum or ash is left after ignition, about half an ounce is burned on a clean glass plate, and fired with a hot iron; the explosion should be sharp, and produce a sudden concussion in the air; and the force and power of this concussion should be judged by that of known good quality; few sparks should fly off, nor should white beads or globules appear, as it would be a sure indication, as we have explained before, of insufficient incorporation. It is also subjected to a second proof.

Second Proof.—A sample of 1 lb. from each lot, carefully weighed up, and a similar sample of the Comparison Powder, is exposed for 3 weeks in a box perforated with holes (called a damp chest) to the action of the atmosphere; this box is placed under cover, so that it is sheltered from the wet, but that the moisture can get to it; if, at the end of this time, there is a greater proportion of difference in range between them than one-twentieth, it is rejected; the pounds are also very carefully weighed up again, to ascertain the comparative absorption of moisture. This is called the hygrometric test.

The Saltpetre is also subjected to chemical analysis, both as to its quality and proportion, in the following way :—

First, as to its Purity. About a quarter of an ounce is pounded in a mortar with distilled water; this is put into a test tube, and boiled by a spirit lamp; the solution is then filtered, a few drops of Nitric Acid and Nitrate of Silver are added; if cloudiness appears, the Saltpetre is impure in proportion to the quantity and dirtiness in the appearance of the precipitate.

Secondly, as to its Proportion. A hundred grains of Powder, freed from moisture, and very accurately weighed, are put into a glass with sufficient distilled water to hold it in solution; this is boiled and filtered, the Charcoal and Sulphur being well washed until all Saltpetre is dissolved; the solution is then evaporated to dryness, and the weight of the residue represents the per-centage of Nitre.

It may also be arrived at indirectly, after the filtration, by drying the filter containing the Sulphur and Charcoal, subtracting the weight of the filter previously ascertained, thus getting their weight; the difference between this and the original weight of Powder being the proportion of Nitre.

The following is a description of the principles of an Apparatus called the "Densimetre à Mercure," which is used in the French Service, for determining the Specific Gravity of Powder.

"Appareil de Messrs. le Colonel d'Artillerie Mallet et Bathelemy Bianchi, pour déterminer la Pesanteur Spécifique des Grains de la Poudre. Appareil adopté par l'Administration de la Guerre.

"Parmi les épreuves réglementaires qui servent á constater qu'une Poudre est de bonne qualité se trouve la détermination de sa densité réelle. On est convenu d'appeller 'Densité réele' le rapport du Poids de la Poudre, au volume de ses Grains tels qu'ils sont constitués avec leurs pores entr'eux. Généralement cette densité s'obtient par l'immersion d'un poids donné de Poudre, dans un liquide dont la densité est connue, et qui remplirant complétement les interstices des Grains ne doit pas pénétrer dans leurs pores. C'est sur ce principe que reposent les instructions ministérielles du 5 Juin, 1835.

"Sur les épreuves des Poudres au moyen de l'immersion dans l'eau saturée de Salpêtre: mais l'expérience à demontré que cette méthode, simple et fagile en apparence, exige des précautions minatieuses et délicates, dont l'oubli ou la négligence peuvent alterer les resultats de manière à faire ressortir des anomalies telles, qu'il n'est plus possible d'avoir confiance dans un semblable procédé.

"Ces anomalies provienent des changemens de température qui peuvent soit occasionner un dépot de Salpêtre de l'eau saturée. Soit dissoudre une partie de Salpêtre de la Poudre; elles provienent aussi de la tendence de l'eau à pénétrer dans les Grains de la Poudre.

"Pour obvier à ces inconvénients on a proposé l'emploi d'autre liquides tels que l'essenges de térébenthine. l'alcool, l'huile....etc. enfin le Mercure pour y faire l'immersion de la Poudre. Le Mercure seul à paru propre à conduire à la solution du problème aussi c'est dans cette direction que des recherches ont été faites par des commissaires et inspecteurs des Pouderies, des officiers attachés à la direction centrale des Poudres et Salpêtre, et que divers appareils ont été successivement proposés et soumis à un examen approfondi par une commission déléguée par Mons. le Ministre de la Guerre depuis 1837, jusqu'a ce jour aucun des appareils proposé n'a resolu la question d'une manière assez satisfaisante et ont été sucgessivement rejetté.

"Enfin Méssrs. le Colonel d'Artillerie Mallet and Barthelemy Bianchi, Ingénieur Mécanigien du Service, de Poudre et Salpêtre, qui se sont occupé de cette question avec beaucoup de soin, ont proposé un appareil qui après de nombreux épreuves et un examen rigoreux a donné le resultat le plus satisfaisante, et a été adopté par Mons. le Ministre de la Guerre, qui en a ordonné l'emploi dans le Service de Poudre.

PRINCIPE DE L'APPAREIL.

"Cet Appareil est destiné a être d'abord pesé plein de Mercure seul, puis après y avoir introduit un poid donné de Poudre et l'avoir de nouveau rempli de Mercure mélé á la Poudre; la différence des deux poids est evidement la même que la différence entre le poids de Mercure deplaçé et le poids de la poudre.

Ainsi soit—

$P =$ le poids du vase plein du Mercure.
$P' =$ le poids du vase plein avec mélange de poudre et mercure.
$A =$ le poids connu de la poudre.
$B =$ le poids cherché de mercure deplaçé par la poudre.

On a

$$P - P' = B - A;\ \text{d'ou}\ B = P - P' + A.$$

Ainsi la différençe des deux pesées de l'Appareil augmenté du poids de la poudre, représente le poids de Mercure deplaçé. Ce dernier poids divisé par la densité de Mercure (qui doit être déterminé à priori) donne le volume de ce Mercure deplaçé, volume égal à celui occupé dans la vase par les grains de la Poudre.

Soit $D =$ la densite connue de Mercure.
$V =$ le volume de Mercure deplaçé, ou le volume occupé par la Poudre.

$$V = \frac{B}{D}$$

Soit D' densité cherché de la Poudre—

$$D' = \frac{A}{V} = \frac{AD}{B} = \frac{AD}{P - P' + A}$$

"La densité réelle de la Poudre est égale á la densité du Mercure multiplié par le poids de la Poudre, et divisé par la différence des deux pesées augmenté du poids de la Poudre."

Major MORDECAI has entered very fully into the subject of the PROOF OF GUNPOWDER, and his remarks relating to the Eprouvette, Balistic, and Gun Pendulum will be found very interesting and instructive:—

REMARKS ON THE PROOF OF POWDER BY THE EPROUVETTES.

"By comparing the results of the proofs by the eprouvettes with those furnished by the cannon pendulum, it will appear that the eprouvettes are entirely useless as instruments for testing the relative projectile force of different kinds of powder, when employed in large charges in a cannon. Powders of little density, or of fine grain, which burn most rapidly, give the highest proof with the eprouvettes, whilst the reverse is nearly true with the cannon. Thus, all the eprouvettes concur in assigning the first rank among the cannon powders to the powder F, which is the lowest on the scale by the cannon; whilst the powder A, which is the strongest in the gun, is one of the weakest by the eprouvettes. Nor do these instruments assign any superiority to powder which is well incorporated, over powder of the same kind in other respects, which has been very imperfectly worked; on the contrary, they all give results with the powder incorporated by 15 minutes' work under the rollers, equal or superior to those furnished by the same powder worked 90 minutes.

"The only real use of these eprouvettes is to check and verify the uniformity of a current manufacture of powder, where a certain course of operations is intended to be regularly pursued, and where the strength, tested by means of any instrument, should therefore be uniform; but as a means of proving gunpowder received (as it is in our service) from manufactories pursuing entirely different processes, these eprouvettes may be pronounced worse than useless, since they may lead to erroneous results. By the French mortar eprouvette, scarcely any of the powders which we have found to be the strongest in the cannon, could be received as having given the required proof range of 246 yards.

The results by these eprouvettes correspond generally with those given by the 8-inch mortar, with a charge of 12 oz., by the 1-pounder gun pendulum, and by the musket pendulum, in which, as in all cases where small quantities of powder are used, rapidity of inflammation is the most influential element of strength.

EXPERIMENTS WITH THE 1-POUNDER GUN PENDULUM.

"Having ascertained that there is no correspondence between the indications of the force of cannon powder, which are furnished by the gun itself, and those given by the eprouvettes in common use, and also that no accurate indication of the relative force of different kinds of powder can be expected from the use of blank charges, even with large quantities of powder, I determined to try whether such an indication would be furnished by firing with balls from a gun of so small a calibre that its use would be attended with little difficulty or expense, and that the apparatus might even be susceptible of removal, if necessary, from place to place. For this purpose, I constructed a pendulum apparatus for a 1-pounder gun, to be fired with balls, with a charge of ¼ lb.; the velocity of the ball to be computed from the recoil of the gun pendulum alone, in order to dispense with the costly and slow process of using the ballistic pendulum.

The results of the experiments with this pendulum are exhibited in the following table:—

SUMMARY OF EXPERIMENTS WITH ONE-POUNDER GUN PENDULUM.

Charge of Powder one Quarter Pound; Windage of Ball 0·0475 *in.*

Kind of Powder.	Initial Velocity of Ball.	Relative Force of Powder.	Kind of Powder.	Initial Velocity of Ball.	Relative Force of Powder.
	Feet.			Feet.	
A.	1407	843	F.	1490	890
A. 1	1370	821	F. 1	1459	875
A. 3	1467	880	F. 0	1476	885
A. 0	1463	877	G. 1	1406	843
A. 4	1574	944	G. 6	1668	1000
B.	1446	866			
B: 1	1381	828	K. 1. r.	1392	835
B. 3	1481	888	K. 1. g.	1366	819
C.	1452	870	R. 15'	1460	875
D.	1376	825	R. 90'	1502	900
E.	1161	692	X. p.	1489	893
E. 1	1110	665	X. p. 4.	1534	919
E. 3	1263	757	X. p. 5.	1635	980
E. 5	1429	857			

"From these results, it appears that the indications given by the 1-pounder gun, with respect to the relative force of different kinds of powder, conform much more nearly to those of the eprouvettes and the musket, in

which small charges are used, than to those of the cannon with large charges. Thus, again, the powder F, which is among the weakest of the cannon powders in the 24-pounder gun, occupies nearly the highest rank in the 1-pounder gun; and the powder A, which is the strongest of all the cannon powders in the former gun, stands almost at the foot of the list in point of strength when tried by the latter; a similar remark may be made with respect to the powders D and K. In short, it appears that low density and fineness of grain, which are the qualities most favourable to the quickness of powder, exercise, in general, the greatest influence on the force of small charges; whilst, in large charges, (unless the powder is EXCESSIVELY dense, as the sample E) the slower development of force, which would be caused by the less rapid combustion of the coarse grains of dense powder, seems to be more than compensated by the greater intensity of the flame produced by such powder; so that, in the combustion of large charges, the whole force of the powder is actually developed in a smaller compass, and therefore with greater effect, when the powder is dense.

This remark may be illustrated by a comparison of the initial velocities of balls fired with similar charges from a large and a small gun, of nearly the same relative length of bore: thus, with a charge of one-fourth the weight of the ball, we have:—

WITH POWDER A:

In the 24-pounder gun, a velocity of ..	1702	feet.
In the 1-pounder gun	1407	"
Difference	295	

WITH POWDER F:—

In the 24-pounder gun, a velocity of ..	1552	feet.
In the 1-pounder gun	1470	"
Difference	82	

The following conclusion with regard to the proof of gunpowder has been arrived at by Major Mordecai:—

"The only reliable mode of proving the strength of gunpowder is to test it with service charges in the arms for which it is designed; for which purpose the ballistic pendulums are perfectly adapted.

"Although the present tendency to the use of cannon of very large calibre would make the proof by means of a 32-pounder or 24-pounder gun more satisfactory than by using a piece of smaller calibre, it does not seem to be necessary to resort to those heavy guns for obtaining a correct indication of the relative force of different kinds of powder. We have seen, indeed, that such an indication is not given by a 1-pounder gun; but the experiments at Metz have shewn that the 12-pounder gun classes the powders in the same order of strength as the 24-pounder; and further experiments may, perhaps, prove that a long gun of yet smaller calibre, a 9-pounder or a 6-pounder, will give corresponding results. As the use of the large ballistic pendulum is difficult, slow, and expensive—and as the indications furnished by the recoil of the cannon pendulum correspond with those given by the ballistic pendulum, I should propose, for the usual proof of gunpowder, to make use of the cannon pendulum alone, employing a gun of the smallest calibre which will give correct results, and firing the balls into a bank of earth, which would not make them unfit for ordinary service.

"An apparatus of this kind would not be costly, and might, therefore, be erected at several of the Arsenals, where powder may be conveniently received for inspection; the 24-pounder pendulum at Washington Arsenal being used occasionally for verification.

"In the 24-pounder gun, new cannon powder should give, with a charge of one-fourth, an initial velocity of not less than 1600 feet, to a ball of medium weight and windage.

"For the proof of powder for small arms, the small ballistic pendulum is a simple, convenient, and accurate instrument. The cost of the apparatus might be very much reduced, without impairing the accuracy of the results, by dispensing, in most cases, with the musket pendulum, which is the most costly part of it, and simply firing the ball into the ballistic pendulum block, from a barrel set in a permanent frame.

"The common eprouvettes are of no value as instruments for determining the relative force of different kinds of Gunpowder."

OF THE SIZE OF GRAIN FOR GUNPOWDER.

With regard to the particular size of grain for Gunpowder, I am confident great improvements might be made, both in obtaining greater regularity of effect and propelling force, by the adoption of a more uniform even

grain: there are at present half-a-dozen different sizes in our cannon and musket powder; and I think it stands to reason, that the more equal the size, the more uniform will be the ignition of all the grains, and consequently the effect of the same charges will be much more regular.

I have made many experiments on a small scale, all of which go to prove the correctness of this assertion; they, however, require to be made with service charges, to decide the particular size that would be most advantageous. Major Mordecai does not think any change is necessary in the grain for cannon powder; should, however, it not be deemed incompatible with the convenience of service to multiply the varieties of powder for special purposes, he considers that there would probably be an advantage in using very large grained powder for 13-inch mortars and heavy sea-coast howitzers, where enormous charges are used: by this means, the strain on the gun would be diminished, and the velocity of the ball perhaps increased.

DAMAGED POWDER.

Gunpowder that may have become too much damaged in transport to re-dust, is often worked over again, in the same way as a dust charge, provided the Nitre is found to be pure; should, however, the grains not be very much broken up—by reeling it for $1\frac{1}{2}$ hours, it will be perfectly freed from dust, and its original appearance and glaze nearly restored.

Powder, also, that may have imbibed an undue amount of moisture from damp magazines or exposure, can be re-stoved and dusted, which partially restores it: it would, however, be advisable generally, to use this Powder for bursting shells, or for blank ammunition salutes, &c. &c.—as little dependence can be placed on its regularity of effect, and I consider it most desirable that the best Powder should always be used for actual practice and service.

EXTRACTING SALTPETRE FROM DAMAGED POWDER.

However useless Gunpowder may have become as a propelling agent, whether arising from immersion in the sea, exposure to weather, or being dangerous to re-work, or store in magazines, from grit, &c. having got amongst it, upwards of one-third, in fact nearly one-half its original value, can always be regained by the extraction of the Saltpetre, 96·5 per cent. of which can generally be obtained by the following operation.—

"Eight barrels, or 800 lbs., is put into a copper with from 200 to 240 gallons of water, and brought to the boil: the solution is then pumped out into troughs, and passed through double filters, in the same way as before described for refining Saltpetre, and received into crystallizing cisterns, where it is agitated till the flour is formed; the Charcoal and Sulphur remain behind in the copper and filters, and are of no further service.

REMARKS ON THE MOST ADVANTAGEOUS SITE FOR A GUNPOWDER FACTORY, AND THE GENERAL POSITION AND CONSTRUCTION OF BUILDINGS CONNECTED THEREWITH.

In making a few remarks on the above subject, there are two or three points to be considered, of which, perhaps, the following are the chief:—

FIRST, the safest and cheapest motive power for the machinery.

SECONDLY, the conveyance of the Powder from each stage of manufacture to the next.

THIRDLY, the general safety of the buildings, in their construction and position with regard to each other.

Water seems at once to suggest itself as best calculated to fulfil some of these conditions, and the banks of a river or head where there is sufficient fall and water supply would undoubtedly be the most advantageous position, both as regards economy and safety, for a manufactory of this description. Such a position would also present great facilities for the conveyance of the Powder from one stage of manufacture to another, rendering accident less likely; for the covered boats which are used for this purpose can be brought alongside each building to be loaded, and the Powder transferred from one to the other without the risk that other means might entail.

They should be so situated that each process follows next in succession to the previous one, thereby preventing a great deal of unnecessary labour, besides lessening the likelihood of danger, from Powder passing backwards and forwards in front of the various buildings. The magazine for the finished Powder should be as far away as possible from the neighbourhood of the manufactory, and situated so as to be quite out of the way of farm buildings, or traffic of any sort.

All sheds or coverings of the machinery ought to be separated as much as possible, and every operation carried on in detached buildings, so that any explosion or fire in one should not affect the rest; this should be particularly attended to in the more dangerous part of the manufacture, such as granulating, pressing, and dusting, where large quantities of Powder are generally going through these particular stages. Where space is limited, this object can, to a certain extent, be attained, by placing high traverses of earth or brick-work between each, and rows of poplar and other trees should be cultivated, and planted so as to intersect the buildings, being found materially to assist these artificial means.

The Incorporating Mills, where there is not more than from 40 to 50 lbs. working at a time, are found safe with merely a corrugated iron division between them, extending rather higher and wider than the Mills themselves. As a general rule, the floors of all buildings are covered with leather tacked to the wood, copper nails being invariably used; all projections and ledges inside should be avoided as much as possible, as they harbour the powder dust which floats in the air.

Every precaution should be taken against accident by explosion, or fire extending. In the Government Factory, engines are always kept with hose fixed, and everything ready for an emergency—some in floating barges, and others in sheds in different parts of the works, and the whole of the workmen are divided into detachments, and told off to their respective engines, each one having two foremen, who are responsible for its being kept in good working order, and who drill their detachments twice a month.

To prevent friction from grit getting on the floors, and that which might arise from nails in boots, no one is allowed to enter any building in those that have been worn out of doors, and leather slippers are provided to supply their place: in consequence of these precautions, very few accidents occur in this country, particularly those of a serious character; for the small explosions which do happen occasionally, are confined entirely to the incorporating process, a remedy for which, in some slight degree, I have pointed out in a former chapter.

In nearly all the private establishments abroad that I have visited, there appears to be a total neglect of any of the above precautions; all the processes are carried on in adjoining buildings, some in rooms one above another: grit, sand, and nails in boots never seem to be thought of; and in a manufactory in Prussia, where I proceeded to inspect some Powder for the British Government, the examining house or magazine, where there were upwards of 500 barrels collected, was merely a slight wooden building close to the stamping mills, Powder in it being so thick on the floor that it crumpled under one's feet like frozen snow. One manufacturer told me he had once an explosion that blew up a great part of his factory, the effect of which was still visible, though many years had elapsed; the same unconcern, however appears to prevail, and it can only be ascribed to the interference of a merciful Providence that these accidents are not of more frequent occurrence.

OBSERVATIONS ON THE MANUFACTURE OF GUNPOWDER ON THE CONTINENT.

It is not my intention to enter into any detail of the method employed on the Continent for the production of Gunpowder; but it may not be uninteresting to have a slight knowledge of it, particularly as it will shew the advantage of our own plan of manufacture producing, as it does, a Powder acknowledged by all to be of the best quality, in durability, strength, and equality of range.

The proportions of the three ingredients vary slightly all over the Continent, being as follows:—

	SALTPETRE.	CHARCOAL.	SULSHUR.
France .. } Belgium.. }	75	12·5	12·5
Russia	73·78	13·59	12·63
Prussia	75	13·5	11·5
Austria	75·5	13·2	11·3
Spain	76·47	10.78	12·75
United States	76	14	10

PRODUCTION AND PURIFICATION OF THE INGREDIENTS.

The Nitre is purified in a similar way to the new method employed at Waltham Abbey, though it is seldom obtained with so faint a trace of Chlorides, owing probably to its being of an inferior quality, and of higher refraction when it is imported.

The Sulphur is supplied to the manufactories in the form of Roll Sulphur, from Marseilles and Bordeaux, where there are very large refineries.

The Charcoal is prepared from dogwood, alder, willow, hazel, and poplar, sometimes in pits, and occasionally in cylinders, as at Waltham Abbey; at Wetteren, and in some parts of France, it is distilled by the action of steam. The "Charbon Roux," taking its name from its brownish red tinge from being only partially burned, was used formerly more than now, as the Powder made from it was found to injure, and exert very pernicious effects upon fire-arms.

PULVERIZING AND MIXING THE INGREDIENTS.

The ingredients are generally pulverized in copper drums capable of holding 224 kilograms: part of the Charcoal is mixed with the Saltpetre, and part with the Sulphur; they are then put into separate drums, which revolve about 25 times per minute for three hours, and in which are about 500 gun-metal or bronze balls the size of good large marbles: the ingredients are brought to the most minute state of division by these means, and are then mixed altogether for one hour in similar drums covered with leather, containing wooden balls.

INCORPORATING PROCESS.

The fine Powder thus obtained is sometimes merely moistened, so as to form a stiff paste, and passed through rollers, the cake formed being dried and granulated. The incorporating cylinders are used occasionally, but the more usual plan adopted on the Continent to effect this operation is the stamping mill, which requires a short description. It is nothing more or less than the pestle-and-mortar principle, each mill consisting of from six to twelve bronze or wooden mortars bedded in the floor of the building; they are the shape of the frustrum of a cone, the mouth being much narrower than the base; the pestles, or stampers as they are called, are made of wood, shod with either very hard wood or bronze, on which project wooden teeth about 12 inches long; a vertical movement is imparted to them by a shaft worked by the water wheel having similar teeth attached; in its revolution it raises the stamper about 18 inches, which falls again as the projection is disengaged, 25 times in a minute; this operation is carried on for 12 hours, during which period the charge (about 15 lbs.) is moistened at intervals, and routed up with a copper-shod spud; at the end of this time, the cake is taken out, and left to dry and harden; it seldom receives any pressure—though, in some manufactories, presses are being erected.

GRANULATING.

The cake is then granulated in sets of sieves fitting one into the other, having perforated zinc bottoms of different degrees of fineness, which are suspended from the ceiling of the room by ropes, an ash spring being attached to each box holding the sieves; the cake, is put into the uppermost one with some gun-metal balls, and shaken backwards and forwards, which motion the spring facilitates; it is thus broken-up into different-sized grain, being separated by passing through the several meshes.

The grain formed is then dusted in bags or shaking frames covered with canvas, and then glazed in barrels.

STOVING OR DRYING.

In Summer, the process of drying is often performed in the sun, and in Winter by the steam stove, in the following way: the Powder is spread about three or four inches thick on a large canvas tray, under which is an arrangement of pipes, which convey the hot air, forced by a fan through a cylinder heated by steam: it is considered to be sufficiently dried in from three to four hours, during which time it is occasionally raked about. In some manufactories it undergoes a further operation of being dusted, and is then barrelled up for use. Generally the great failing in the foreign manufacture is the neglect of the principal stage of the fabrication, viz. Incorporation; with the old stamping mill, it is quite impossible that the process can be carried out to the necessary extent: the continental powder is usually very soft in its grain, dusty, and quickly absorbs moisture from the atmosphere; its density is below the English powder, on account of its never being subjected to pressure; consequently it is not so durable, and forms a good deal of dust in transport; a great amount of residue is generally left in the gun, and its strength, as a propelling agent, is far inferior to our powders. On being flashed on a glass plate, instead of

producing a sudden concussion, like the sharp rap of a hammer, it burns more like composition, throwing off a quantity of sparks.

I have tried many experiments with all kinds of foreign powder, and find invariably, if the ingredients are pure, that, on subjecting it to an hour and a half's incorporation, and passing it through the remaining different processes, in fact re-manufacturing it, that its range will be increased by from 80 to 100 feet, its appearance and goodness in all respects equalling the Waltham Abbey Powder, shewing clearly the advantage of our system.

ON THE PURCHASE AND REFRACTION OF SALTPETRE.

We have seen that Saltpetre, in its grough state as it is imported, is combined with different deliquescent Salts, some samples being more impure than others, it becomes, therefore, necessary that there should be some means of guiding the purchaser in going into the market, in order that he may obtain the proper proportion of the pure material for the price paid; the difference between the original weight of a certain bulk and that which is left after refining being termed the refraction.

In the trade, the allowed refraction is 5 lbs. per cwt.—that is to say, if Saltpetre was at 30 shillings per cwt., and a purchaser wished to buy some at 5 per cwt. refraction, 30 shillings would have to be paid; but, on the other hand, if the refraction was below 5 per cwt., more than this sum would have to be paid, as a greater proportion of pure Nitre would be obtained in the process of refining, making it consequently more valuable; and if above 5 per cwt., for the same reason, less would be paid, being of an inferior description.

To make the method of purchasing perfectly clear, I will annex a table of 5 tons refracted Saltpetre from 1 to 15 lbs. per cwt., and a Broker's Invoice: from this, it will appear that, according as the refraction is above or below the standard 5, so must the difference be subtracted from, or added to the gross weight, to arrive at the quantity to be paid for, tare &c. being taken into due consideration.

SCALE FOR FIVE TONS REFRACTED SALTPETRE, FROM ONE TO FIFTEEN POUNDS PER CWT.

	Cwt.	*qrs.*	*lbs.*
1..	103	2	27
2..	102	3	6
3..	101	3	13
4..	100	3	21
5..	100	0	0
6..	99	0	7*
7..	98	0	15
8..	97	0	22
9..	96	1	1
10..	95	1	9
11..	94	1	16
12..	93	1	23
13..	92	2	3
14..	91	2	10
15..	90	2	17

Illustration, at the Refraction of 6 Lbs. per Cwt.

112 : 100 : 112
5 6
107 106
100
107) 10600 (99 0 7*
963
970
963
7
112
107) 784 (7
749
35

BROKER'S INVOICE AT THE REFRACTION OF 2¼ PER CWT.

	Cwt.	*qr.*	*lbs.*
232 Bags Gross Weight.	398	2	26
Tare 7 lbs. per Bag, Draft 1 lb. per Bag........	16	2	8
Cwt.	382	0	18
Add the Refraction of 2¼* per Cwt.	9	3	8
Cwt.	391	3	26

232
7

	Cwt.	qr.	lb.
1624 lbs.	14	2	0
232 lbs.	2	0	8
	16	2	8

	£	s.	d.
at 40s. per Cwt.	783	19	3
Brokerage 1 per Cent...	7	16	9
	£791	16	0

* It is called 2¼, but it is really the difference between 2¾ and 5, or 2¼ per Cwt.

INVOICE AT THE REFRACTION OF 5¾ PER CWT.

	Cwt.	*qr.*	*lbs.*
240 Bags Gross Weight	348	3	21
Tare 9 lbs. per Bag; Draft 1 lb. per Bag	21	1	20
Cwt.	327	2	1
Deduct the Refraction of 5¾ lbs. per Cwt.* ..	2	1	5
Cwt.	325	0	24

240
9

	Cwt.	qr.	lbs.
2160 lbs.	19	1	4
240 lbs.	2	0	16
Cwt.	21	1	20

	£.	s.	d.
at 38s. per Cwt. ..	617	18	1
Brokerage 1 per Cent.	6	3	6
	£624	1	7

The means usually adopted by merchants to test for the refraction is—by melting a portion in a small mould, breaking the cake, and examining the fracture: should it present a fibrous radiated appearance, without any small lumps, it is considered to be of low refraction; on the contrary, if these appear, it indicates the presence of Salts; it requires, however, a practised hand to form any correct judgment by this method. Brokers and merchants, who are in the habit of examining it, can judge pretty accurately of its purity by the colour, size of its crystals, and general appearance.

Gay Lussac's method of examining Nitre consists in mixing about 20 grains (accurately weighed) of the dried specimen, with about 10 grains of charcoal powder, and 80 grains of chloride of sodium; this mixture is introduced by small portions into an iron crucible heated to redness; the fused mass is dissolved in water, the solution coloured with litmus, and dilute sulphuric acid of known strength added from a graduated glass until a slight excess has been employed, which is known by the peculiar bright red tint assumed by the solution. The number of measures of acid employed is then observed, and the amount of nitrate of potassa to which they correspond, calculated. Forty parts (1 eq.) of Sulphuric acid (SO_3) correspond to 101 parts (1 eq.) of nitrate of potassa, as may be seen by the following equation, which exhibits the action of the carbon upon the nitrate of potassa :—

$$2(KO.NO_5) + C_5 = 2(KO.CO_2) + N_2 + 3\ CO_2;$$

* Which is really ¾ per Cwt.

where it will be seen that every equivalent of nitrate of potassa produces an equivalent of carbonate, which requires also one equivalent of sulphuric acid for its neutralization. The chloride of sodium is merely added to the mixture to moderate the violence of the deflagration.

A fallacious result will be obtained by this method, if the specimen examined contain sulphates, as they are reduced to sulphides by fusion with charcoal; these being decomposed by sulphuric acid (with disengagement of hydrosulphuric acid) their presence will involve the use of an excess of the test acid, and a consequent excess in the calculated per-centage of nitre. If hydrosulphuric acid is, therefore, detected on the first addition of acid to the solution of the fused mass, recourse must be had to some one of the other methods.

In a former part of this Pamphlet, under the head of "Proof of Merchants' Powder," I have described shortly the method of determining the proportion of nitre in samples of Gunpowder. To ascertain the amount of the other two ingredients, however, requires some delicate manipulation; and, as it may interest some who may be chemically inclined, to try samples of Powder, I will transcribe Abel and Bloxam's method, from page 678 of their excellent work, "Hand-book of Chemistry," in order that those who have not the advantage of this book may be able to subject Gunpowder to chemical analysis.

ANALYSIS OF GUNPOWDER.

"I. Determination of Moisture.—About 20 grains of the powder, very finely pulverized, are exposed over sulphuric acid, *in vacuo*, until a constant weight is obtained.

"For ordinary purposes, the moisture may be determined by exposing the powder to the temperature of the water-oven, until it ceases to lose weight. A slight excess is generally obtained by this method, since a small portion of the sulphur in the powder is expelled, together with the moisture.

"II. Determination of Nitre.—The dried powder is transferred to a small beaker, in which it is drenched with about three ounces of hot water, and allowed to digest for some time upon a sand bath at a moderate heat. It is then thrown upon a filter of known weight, previously moistened, and is washed with hot water until a drop of the filtrate, which must be carefully collected, leaves no residue when evaporated upon platinum foil. The filter and residue are then dried in the water-oven (or, still better, *in vacuo*) until their weight is constant. The difference in weight

between the residue (*minus* the weight of the filter) and the powder employed, will represent the amount of nitre.

"To control this result, the filtrate and washings, obtained as above directed, are carefully concentrated in a porcelain dish, at a moderate heat upon a sand or air-bath, and afterwards transferred to a weighed platinum (or porcelain) capsule, and evaporated to dryness on a water bath; the residue is then exposed to a temperature of 300 degrees of Farenheit, (149 deg. C) in an air-bath, until it ceases to lose weight. The quantity of Nitre is thus determined directly.

"III. Determination of Sulphur.—This ingredient may either be determined directly, or by the loss of weight sustained by dry powder upon its removal.

Direct Determination.—1. About 20 grains of the dried powder are mixed with an equal weight of pure carbonate of soda, (or of potassa) about 20 grains of nitre, and 80 grains of pure chloride of sodium are then added, the whole intimately mixed, and then submitted to fusion in a platinum crucible, the operation being conducted, and the sulphuric acid determined in the fused mass, in the manner directed at p. 653.

"2. A tube of hard glass provided with two bulbs, is accurately weighed; about 20 grains of dried powder are introduced into one of the bulbs, and the weight of the tube and powder noted; the difference between the two weights will represent the amount of powder employed. The extremity of the tube nearest to the bulb containing the powder is then attached to an apparatus in which dry hydrogen is disengaged. A slow current of gas is allowed to pass through the tube; as soon as the atmospheric air is completely expelled, the bulb containing the powder is moderately heated by means of a spirit lamp, when the sulphur will vaporise, and pass over into the second bulb, where it will again condense; the space of tube between the two bulbs must be warmed with the spirit lamp from time to time, to prevent any sulphur from condensing there. When no more sulphur is expelled from the powder, which is finally exposed to a temperature approaching dull redness, the tube is allowed to become nearly cool; it is then carefully cut with a very sharp file between the two bulbs, and each part is afterwards weighed, cleaned out, and re-weighed. The amount of sulphur found in the second bulb should correspond, within the limits of error, 0·5 per cent. loss, to the difference between the first and the final weight of the powder.

"A slight loss of sulphur by this method is unavoidable, small portions being carried off mechanically by the current of hydrogen, if ever so slow, while a small quantity is also converted into hydrosulphuric acid.

"By adopting the following modification of this method, very accurate results may, however, be arrived at:—

"Instead of a tube with two bulbs, one of rather wider bore, about 8 inches in length, is employed, provided with only one bulb, at about 2 inches from one extremity of the tube. A small plug of dry asbestos having been introduced into the long arm of the tube, about ½ an inch distant from the bulb, the former is filled with thin filaments of dry bright copper, or of the finely-divided metal reduced from the oxide by hydrogen. The tube is then accurately weighed, the dried powder, from which the nitre has been removed, introduced into the bulb, and the weight again ascertained—the difference will give the amount of powder employed. The operation is then conducted as before, with this difference, that the copper is first raised to a red heat, and maintained at that temperature, before the sulphur is expelled from the powder. The sulphur-vapour, coming in contact with the heated metal, will at once combine with it, and no loss whatever is sustained. When the operation is completed, and the tube is cooled down sufficiently to be handled without inconvenience, it is carefully cut between the asbestos-plug and the bulb; the latter, containing the charcoal, is then placed on the balance while warm, and rapidly weighed; the loss of weight expresses the amount of sulphur, which may also be directly inferred from the increase of weight of the tube containing the copper.

"Indirect Determination. A weighed portion of the dry residue of carbon and sulphur left on extracting the powder with water, is introduced into a small flask, and boiled for some time with a solution of sulphide of potassium or of sodium, or of sulphite of potassa or soda, until the whole of the sulphur is removed. The carbon is then collected upon a weighed filter, well washed, dried in a water-oven, and weighed; the difference between this weight and that of the original residue of carbon and sulphur indicates the amount of the latter, which must now be calculated for so much of this residue as would be furnished by 100 parts of gunpowder; the result is the per-centage of sulphur.

"The alkaline sulphides or sulphites employed to dissolve the sulphur must be perfectly free from caustic alkali, since the latter is capable of attacking charcoal which has not been very thoroughly charred. A mixture of the bisulphide of carbon and alcohol may also be employed to extract the sulphur.

"The results obtained by the indirect method are invariably too low, since the extraction of the sulphur is never complete.

"IV.—Determination of Carbon. The amount of this constituent will have been ascertained by difference, and controlled by direct weighing in the preceding determinations. It is sometimes necessary, especially when charbon roux has been employed, to determine the amount of hydrogen contained in the charcoal; this is effected by burning a weighed quantity with oxide of copper in the manner to be described in a future part of the work, under the head of Organic Analysis."