LONDON:

PRINTED BY RICHARD CLAY, BREAD STREET HILL,

CHEAPSIDE.

PREFACE.

THE following pages are submitted to the public with modesty. The writer of them has been absent from England seventeen years; and there may be improvements in the manufacture of the article he treats of that have not come to his knowledge.

He believes there is not a single work extant in the English language that discusses the manipulation of Gunpowder, and the best and most accurate methods of ascertaining its strength and quality. As much information as he could collect on those points is here submitted, and he hopes it will be found useful.

J. B.

MADRAS,

September, 1830.

LONDON:

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CHEAPSIDE.

To the Secretary to the Military Board, Fort St. George.

SIR,

I HAVE the honour to request you will be so obliging as to lay before the Military Board the following MEMOIR ON GUNPOWDER, which has been written at the suggestion of Colonel Conway, C. B., and printed, not to be made public, but for purposes of private convenience.

II. It will be in the recollection of the Board, that I was sent out by the Honourable the Court of Directors in 1813, in the gunpowder department, under the late Captain Fraser, of the Engineers.—Prior to my embarkation for this country, I had the opportunity of going through every branch of His Majesty's works at Waltham Abbey, for the purpose of learning the system of manipulation, and being taught the art of making gunpowder. To qualify myself, and to render every process thoroughly familiar, I engaged in the manual operations, in common with the workmen; I collected their opinions; I noted down such as were useful; added thereto my own remarks; and took plans, elevations, and sections of the utensils, implements, buildings and machinery of all the most important departments. The plans which Captain Fraser submitted to the Military Board in 1813-14, were either copies of the sketches I then took, or original designs of my own; and a reference to those plans will enable the Board to judge as to the degree of acquaintance I possess with regard to mechanism, machinery and common architecture, at least so far as they are connected with a gunpowder manufactory.

III. The Memoir I have now the honour to submit is upon a subject that possesses, unfortunately, but few attractions; and I fear that the voluminous documents on gunpowder which have passed the Board's consideration, since I came out to India, will not render the present paper in the least degree more attractive, or more interesting. The subject however is important; and I beg leave to observe, that, in the pages which follow, no controversy will be found; no undue preference given to any one particular method of manufacture; no system of my own to support; no practice of others to be reprobated;—but simply, a quiet, unobtrusive discussion of principles, which appeared to me to be what was required; because, in sundry papers that I have been obligingly favoured with the opportunity of seeing, some material points appear to have escaped observation, while much has been insisted on relative to questions of but little consequence.

IV. I have endeavoured to hold an equal balance in all the ensuing discussions. But, perhaps, it may be thought that a secret bias is discernible in favour of the English powder. If it should be so, I hope it will be found to rest on solid grounds, and not upon unsatisfactory assertions or unsupported dicta. I certainly do not think that any of the Indian gunpowders equal His Majesty's gunpowder, in strength and goodness;* but, lest it be imagined I have any prepossession on this subject, I beg leave to state, that, with reference to the Madras powder, in particular, my opinions have undergone much change. When I arrived in this country, sixteen years ago, it was, perhaps, but natural that I should feel a partiality for the British powder, and the system I had been taught; but a

* "The English powder is yet superior to ours, and to that of every other nation. I have often heard it said, the Indian powder is superior to the best English. I know not on what grounds this assertion has been made, for, in initial strength, I am certain of the contrary."—*Captain Bishop to Lieut.-Col. Frith*, March, 1824.

multiplicity of incontrovertible facts soon made it evident that the Madras powder was not so faulty as I had been told it was. Many trials, both in this country and in England, have since established the truth, that in a great number of cases it throws a shot or shell quite as far as the English powder, and sometimes further; therefore, so far as the quality or power of producing a high range is concerned, it is quite equal to all the requirements of actual service. It is another question, whether considerable additional expense ought to be incurred to obtain other qualities, which, with reference to the climate of Peninsular India, the Madras powder may probably be thought to possess in a sufficient degree: for I understand it to be a well established fact, that the whole of the Madras powder was kept under tarpaulins for three or more successive monsoons, during the Mahratta war under the Marquis of Wellesley, and that on a more recent occasion, some of it was similarly exposed for two or three campaigns, and was still found to range above proof. My opinion is, that no material improvement, according to the present system of manipulation, is attainable; and with reference to that system, I think it was very properly and truly characterized by a late Committee of the Military Board, as one that produced gunpowder of "a maximum of strength [practical effect] with a minimum of labour."

V. Such being my conviction, I hope I shall not be misunderstood in the remarks that I have made on parts of the Madras system in the ensuing pages. The design I had in view was, a free, unfettered discussion of the principles on which gunpowder should be and must be manufactured, in order to produce an article of the first quality. But while the discussion has been free, I hope it will be found also clear of undue bias or secret partiality. My determination was, to follow where truth, fact, and experiment, only might lead; and to advance nothing but what was substantiated, either by practical facts in my own knowledge, or by such as were

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VI. The Memoir now submitted is divided as follows, viz:

Sect. I. On the component parts of gunpowder.
II. Their purity.
III. Their proportions.
IV. Their manipulation.
V. On fired gunpowder.
VI. On the proof of gunpowder.
VII. Observations on the manufacture.
VIII. Observations on the proof of powder.
IX. Appendix.—On purifying the ingredients.

VII. Under these heads, or their subdivisions, the Board will find many points discussed which have engaged their attention: for instance, the spontaneous combustion of charcoal when in store;—whether fused nitre, or fire-dried nitre, is the best;—whether charcoal should be prepared in pits or cylinders;—and whether gunpowder should be pressed and glazed. This last question is a point so well understood, that no new experiment is now necessary to determine it. If gunpowder be pressed and glazed, it must be highly incorporated, or it cannot support those operations: they ruin it. Pressing and glazing are found to much deteriorate the Madras powder, particularly the L. G. or largest sized grain. Other points are also dwelt upon; but it does not appear requisite in this place to enumerate them.

VIII. One subject, however, I would particularly notice, not only because it is important, but because it has, probably, been the means of originating much misconception as to the true and absolute character and quality of the British and Indian gunpowders;—that subject is, the *method of proof.* In itself, it has more difficulty than is commonly supposed; and I have therefore dwelt on it rather largely. To ascertain the comparative quality of two gunpowders, it may be imagined, that nothing more is necessary than to take any like quantity of each, fire it from the same piece of ordnance, and compare the ranges. But this idea is at a most remote distance from truth; there are some such trials by which not the slightest knowledge of the quality of gunpowder can be acquired. It is an experimental fact, that of two powders A and B, the range of A was less than one-fourth the distance of B, in one trial; while in another, it ranged half the distance; in a third, an equal distance; in a fourth, superior, and all from the same piece of ordnance.

IX. Under the Section on the Proof of Gunpowder I have shewn that all the common methods of proof give fallacious results, if depended on singly; and in the Eighth Section, I have endeavoured to lay down a formula by which the true character and properties of gunpowder may be ascertained with facility.

X. This climate seems to include in it all that can be desired relative thereto, in the fabrication of gunpowder. It is the birthplace of the chief ingredient, nitre; very excellent wood for charcoal is obtainable; and the land-winds, coupled with solar heat, cannot fail to render perfect the last important operation in its manufacture. It is a curious circumstance, that gunpowder sent out by the Honourable the Court of Directors in 1819, ranged, in a pendulum éprouvette at St. Thomas's Mount, higher than it did in England. This can be attributable, I think, only to two causes—the climate, and the difference of latitude. The latter might influence the arc of recoil, and some allowance ought, *theoretically,* to be made for it; but as that allowance must again allow for the expansion of the suspending rods between the temperature of January in England, and September in the Carnatic, it is a nice point to say how far the practical range of the powder was influenced by locality of situation.

In January, 1819, two ounces of Waltham Abbey powder were proved at that place, and the medium ranges were	° ′ ° ′ 19 32 & 20 15
It was then, together with the two pendulum éprouvettes, in which it had been tried, sent out to Madras, and proved at St. Thomas's Mount in September, 1819, in the same éprouvettes, and ranged	20 28 & 21 31
The Madras powder ranged	22 51 & 23 11

But if it was the Honourable Court's intention to ascertain, by this experiment, the absolute quality of the English and Madras gunpowders, the experiment failed; for the pendulum éprouvette is an uncertain and fallacious method of proof, and one of the worst description for trying unpressed gunpowder against highly pressed and glazed powder.

XI. If what I have written, and have now the honour to submit, should be thought by the Board to be of any value; I beg leave to express a hope that, with their wonted liberality and condescension, they will be pleased to forward it, with their favourable notice, to Government.

I have the honour to be,

Sir,

Your most obedient humble Servant,

(Signed) J. Braddock.

Fort St. George,
July 1, 1829.

To Mr. BRADDOCK, *&c. &c. &c.*

SIR,

HAVING submitted to the Military Board your letter bearing date 1st July ultimo, with the "Memoir on Gunpowder" therewith forwarded, I have the honour, under the orders of the Military Board, to state that, viewing the work as one of great merit, and likely to prove of considerable utility to the Corps of Artillery, the Board recommended to Government that three hundred copies of the Memoir (with such modification or emendations as you might deem likely to enhance its utility) should be printed at the public expense, and under your superintendence. Government having been pleased to sanction the proposal, I am instructed to communicate the request of the Board that you will undertake the task of Superintendence.

(Signed) H. MOBERLY,
DEPUTY SECRETARY.

FORT ST. GEORGE,
Sept. 1, 1829.

I have accordingly revised the paper and made additions thereto: and I hope, in its present shape, it will be found a useful guide both to the gunpowder manufacturer, and the artillery officer.

EAST INDIA HOUSE,
March 10, 1831.

SIR,

YOUR letter of the 11th ultimo having been laid before the Court of Directors of the East India Company, I have their instructions to acquaint you that they have no objection to your printing a second edition of "The Memoir," by your son, Mr. John Braddock, on the Manufacture of Gunpowder.

I am,
SIR,
Your most obedient humble Servant,
P. AUBER,
SECRETARY.

MR. JOHN BRADDOCK, SEN.
Master Refiner of Saltpetre,
Royal Powder Mills,
Waltham Abbey.

ON GUNPOWDER.

SECTION I.—COMPONENT PARTS.

Gunpowder is an explosive propellent compound, consisting of saltpetre, charcoal, and sulphur. The terms explosive and propellent are not here used as synonymes; they are not convertible; for a chemical mixture may possess the explosive in a much higher degree than the propellent power. Fulminating gold, silver, and mercury are dreadfully explosive; but they have not the same projectile force as gunpowder, nor can they be used as substitutes for it.

2. Experiments made at Woolwich,* with fulminating mercury, shew that nothing can resist the exceeding intensity of its action, but that action is confined to a narrow space. A carronade was loaded with a charge of this powder and several cast-iron shot; the shot were not projected, as they would have been by gunpowder, but they were expelled in fragments, the extreme violence of the powder having shattered them to pieces.

3. Carbon and sulphur are both simple combustible substances; but nitre is a triple compound of oxygen, nitrogen, and potassium. The chemical action of these elements on one another, and the play of affinities between them, in a high temperature, occasion those awful results produced by gunpowder on the application of fire.

* See Nicholson's Journal, July, 1800.

4. By universal usage sulphur is included in the mixture; but it is not absolutely necessary for the production of the propellent power, for nitre and charcoal only will generate effects similar to the compound with sulphur. Gunpowder made without sulphur has, however, several bad qualities; it is not, on the whole, so powerful, nor so regular in its action; it is porous and friable; possesses neither firmness nor solidity; cannot bear the friction of carriage, and in transport crumbles into dust. The use of the sulphur, therefore, appears to be, not only to complete the mechanical combination of the other elements, but being a perfectly combustible substance, it increases the general effect, augments the propellent power, and is thought to render the powder less susceptible of injury from atmospheric influence.

5. " There is one good reason," says the Edinburgh Encyclopædia, "for the use of the sulphur, although it does not contribute to the production of any elastic fluid. The carbonic acid, which is generated, would doubtless combine with the potash, if it were not for the presence of the sulphur, and thus so much elastic fluid would be lost. That this is the case we know from the fact that carbonate of potash is always formed when nitre is decomposed by charcoal alone. This would be the case, to a certain extent, with gunpowder made without sulphur: some carbonate of potash would be formed."

6. It was ascertained, by experiments made at Essone, near Paris, in 1756, that the strongest mixture, without sulphur, consisted of,

Nitre	16 parts.
Charcoal	4 parts.

and they produced a power equal to 9; but with the addition of sulphur, a stronger mixture was made as follows:

Nitre	16 parts.
Charcoal	3 parts.
Sulphur	1 part.

and these produced a power equal to 17. None of the experiments gave a higher result than this: it equals the proportions of, saltpetre 80, charcoal 15, and sulphur 5, in 100 parts of gunpowder.

7. It thus appears, that the representative number of the powder made *with* sulphur is almost double that made without sulphur, viz. as 17 to 9; but, in another method of trial, the powder *without* sulphur produced a result equal to that made with it. Such, however, are the discrepancies that arise in researches instituted for the purpose of ascertaining the nature and constitution of gunpowder, and such the difficulties with which the subject is invested. This latter trial was made in the French mortar éprouvette, with a ball of 60 lbs. weight, as follows:

The foregoing Mixture.	Two Ounces.	Three Ounces.
Without Sulphur, ranged	213 Feet	475 Feet
With Sulphur	249 Feet	472 Feet

8. To this may be added the following extract: "Mr. Napier directed a small quantity of powder to be made of nitre and charcoal only, and was surprised to find that 15 lbs. of it projected a thirteen-inch shell as far as the best powder composed in the usual manner." *

9. "The advantage of using sulphur seems, from some late experiments in France, applicable for increasing the force of explosion only in small charges; but in quantities of some ounces, the explosive, or at least the projecting force of the powder without sulphur is as considerable as it is with it."† Under circumstances of absolute necessity, sulphur might therefore be dispensed with in the fabrication of gunpowder, but charcoal or nitre cannot.

* Gray's Operative Chemist, ed. 1828. † Rees's Encyclopædia.

10. Nitre is not the only salt that has been used for making gunpowder; its quantity or proportion in the mixture has been lessened, and the deficiency supplied by another elementary combination with the same base, potassium, viz. by chlorate of potassa, or the hyperoxymuriate of potash of the old nomenclature.

11. This salt has been tried in France, and fatal accidents have resulted from its admixture and incorporation with the common elements of gunpowder.* The French have, notwithstanding, succeeded in making gunpowder, of which it was one of the component parts; and the following extract from a work published in Paris in 1811, shews that it produced a range double that of war-powder of good quality. The composition of this powder seems to have been—

Nitrate of potash	25.0
Chlorate of potash	45.0
Sulphur	15.0
Charcoal	7.5
Lycopodium	7.5
Total	100 parts.

12. The extract runs thus:—" On se servit, pour en faire l'essai, à la dose de 92 grammes, (about 3 Troy ounces) d'un ancien mortier défectueux, auquel on ne pouvait obtenir, pour la poudre de guerre de bon qualité, qu'une portée moyenne de 187 mètres.—La poudre au muriate oxigéné fut introduite dans la chambre du mortier, et le globe placé dans l'ame, avec la plus grande circonspection; on mit le feu au moyen d'un assez long morceau d'amadou. Le coup partit très vivement, et le globe, qu'on put à peine suivre des yeux dans l'air, fut lancé à environ 381 mètres; et dans sa chute il s'enfonça si

* It would appear that gunpowder of this, or a similar kind, was proposed to the British Government in 1809; but its introduction into the service was very properly opposed by Lieutenant General Congreve, on account of the danger attending its use.

avant dans la terre, qu'on eut de la peine à l'y trouver et à l'en retirer."

13. This great superiority of range is attributable to the exceeding rapidity with which the chlorate suffers decomposition; but this advantage is more than counterbalanced by disadvantages. This salt, the basis of the percussion powder* of sportsmen, corrodes much more rapidly and deeply than common gunpowder, and renders fire-arms sooner unserviceable; and as it explodes by friction, both its use and manufacture are imminently dangerous.—Nor is this all. Such powder, kept for the purpose of chemical experiment, has been known to explode even spontaneously; it therefore forms too perilous a compound to be generally substituted for gunpowder, especially when employed for the purposes of war.

SECTION II.—PURITY OF INGREDIENTS.

SALTPETRE.

14. NITRATE of potash, nitre, or saltpetre, is a combination of nitric acid with the vegetable alkali. It is an abundant production of nature, but is never found pure, being always contaminated with other salts and earthy matter. The separation of the impurities from the nitre is called refining.

15. The late Captain Bishop, formerly Superintendent of the Gunpowder Manufactory at Madras, in his official memoir

* The elements of this powder are—

Chlorate of potassa	5 parts
Sulphur	2
Charcoal	1

made into a paste with weak gum-water. Great caution must be used. The nitrate of mercury forms a better percussion powder, which does not corrode like the chlorate of potassa.

on gunpowder, dated December, 1801, conceives that saltpetre may be both generated by nature, and produced by art in an imperfect and defective manner. He says, "defective nitre has, of late years, invariably been imported from Bengal." And, "when saltpetre of a defective quality is refined in a particular manner, and the nitric acid added to complete the saturation, it again becomes perfect nitre, and makes gunpowder stronger by a difference of 200 yards in the 10-inch range, than what can be made with imperfect nitre." He says also, "Saltpetre in this (perfect) state is very seldom obtained, and in any other it is unfit to incorporate with composition for gunpowder. Amongst the numerous samples which have been subjected to experiment, only one has been found to consist of perfect nitre. This was obtained from Doctor Heyne, and made, as he informed me, near Innaconda. Nitre of this kind will make gunpowder stronger by a difference of 200 yards in the usual proof range with a 10-inch mortar."

16. I notice this supposition of Captain Bishop's, because it seems to be supported by the strong authority of ascertained experiment; because it appears to be plausible, and because a curious and important question arises,—Does nature ever generate saltpetre in a defective and imperfect manner; and can variations in the strength of gunpowder be thereby accounted for?

17. In Captain Bishop's writings on gunpowder, there are, unquestionably, many valuable observations resulting from experimental research, and much sound practical knowledge; but his applications of theory, and his reasonings, are so mingled with the fanciful inductions of imagination, that they are extremely liable to lead the uninitiated into error, and are to be received with caution even by those who may be supposed to understand the subject.* There is no doubt that, in the

* Let not this be thought an invidious observation. It is no small praise, that Captain Bishop increased the proof range from 1,000 to 1,500 yards, in the 10-inch mortar.

present case, he made experimental powder with various samples of saltpetre, and found some of it range 200 yards further than other; but I see no solid grounds for his attributing it to defectiveness or imperfection in the nitre. Suppose the nitre deficient in oxygen,—it would then become nitrite of potash; but nitrite of potash is an artificial salt, and is not known to exist as a natural production. Suppose it to be mixed with a quantity of its base,—potash, this being soluble in water, would be got rid of in the process of refining, so that pure nitre would at last result. Suppose it to be deficient or redundant in any way whatever,—it would evidently be some other alkalescent compound, and not nitre, and would not therefore crystallize as nitre does.

18. But the following extract from one of the first chemical authorities of the day, will be more satisfactory than any reasoning of my own. "The same compound body is always of the same composition; no variation in the proportion of its elements can by any possibility take place. 48 parts of potassa combine with 54 parts of nitric acid to produce 102 parts of nitre: no method of putting the substances together, as by causing an excess of the one or the other, or abstracting one from a previous state of combination, or allowing other substances to be present, can cause any change in these proportions. Nor is this confined to the numbers 48, 54, and 102; but whatever may be the quantity of these elements in combination, or of the nitre produced, the proportions will be the same."*

19. Nitre is totally unfit for gunpowder until it be purified; for being combined with the muriates of soda, lime, magnesia, and with other salts which greedily absorb moisture, their deliquescent properties would be highly injurious, because they would derange the close contact and combination of the materials of which gunpowder is composed. As for the

* Faraday's Chemical Manipulation, p. 552, ed. 1827.—This extract appears to be conclusive on the point.

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 :—*quod non juvat obstat ;*" what helps not, hinders.

20. In the separation of these foreign admixtures, human skill could do little without the assistance of nature; but nature, with that exquisite beauty and order observable throughout creation, has imprinted upon every salt its own decided and uniform shape, from which it never varies. So also has she regulated and varied the temperature at which they are respectively soluble, that it requires only a knowledge of the laws of crystallization, to conduct the process to a successful issue, and to obtain nitre in a state of purity. For instance, by solution in boiling water the nitre is more soluble than in cold, but muriate of soda is not: the nitric solution is therefore drawn off at a high temperature, while the muriate, having first saturated the water, is deposited and left behind in substance. On the other hand, nitrate of lime, and the muriates of lime, of soda, and some other salts, are more soluble in cold water than nitre: hence the nitre crystallizes, while they are left dissolved in the cold liquid menstruum, or mother-water of crystallization. And it is on these different degrees of solubility of the various salts combined with the grough or impure nitre, that they are separated from it, and that the nitre is thereby purified.

21. With regard to the process, nitre is refined by solution and filtration; and two boilings are generally found to render it pure: but as in all manual arts, so in this, a knowledge of the best practical usages enables the operation to be conducted with greater certainty of success, ease, despatch, and economy. The use of bullocks' blood, eggs, &c., as recommended by some, is not efficacious: they have nothing whatever to do with the salt,—they produce no chemical action on it; they are intended solely to precipitate, or to raise to the surface, any impurity that may be held in suspension; but it is ques-

tionable if they do, and they are not in use in His Majesty's works. In my own opinion, cleanliness in the refinery, filters of a suitable nature, (there is some art in well filtering,) and practical knowledge, are to be held in much higher estimation than such expedients.*

22. It has been questioned, whether nitre, after having been refined, should be melted and then pulverized, or be at once reduced to powder, by drying the crystals, mixed with water, over a fire. By fusing, and being cast in moulds of convenient shapes, it becomes more portable, is extremely well adapted for the purpose of carriage, exportation, or commerce, and is less liable to contract impurity or dirt by long keeping in store. Before it becomes cold, it is soft and yielding, and will take an impression like wax, which is convenient for stamping on it the weight, or any other marks that may be considered expedient.—The advantages claimed for fire-dried nitre are, that, by the process it undergoes, it becomes at once reduced to a fine powder, at a small expense, and with but little labour; but the minuteness of the particles of fused nitre, reduced to powder by a process hereafter adverted to (88), is much greater, and therefore better adapted for the use of the manufactory. Besides, accidental impurity cannot be discovered in fire-dried nitre so well as it can be in nitre while in fusion; and the fire-drying process itself points out that no other water can or ought to be used than the "aqua distillata" of the shops, or its substitute, pure rain water. It has also been said, that gunpowder made with fire-dried nitre will not, when in barrel, become lumpy; but this is doubtful.

23. As to the fear of decomposing nitre by simple fusion, or driving off any portion of its oxygen, it is nothing more than apprehension. That no decomposition takes place, may be proved by fusing a small quantity in a glass retort over a spirit-lamp, and endeavouring to obtain oxygen gas by means of the pneumatic trough. At first, a number of air bubbles will escape, but not the least oxygen gas can be procured.

* See Appendix.

It is in this manner that oxygen is sometimes elegantly collected, for chemical experiments, from the chlorate of potash; but this salt suffers decomposition at a much lower temperature than nitre. In actual practice, however, fierce fires are of necessity used in fusing nitre; and it therefore requires some caution that the iron melting-pots do not become overheated: should they attain a red heat, the nitre would of course be subject to partial decomposition; but if the process be understood, and conducted with common care, this need never occur. I have seen many tons' weight of saltpetre fused, and do not recollect more than once having observed a melting-pot at a red heat; and this occurred through negligence. Nitre is not decomposed by fusion under a red heat: it melts at about, or under, 560 degrees of Fahrenheit's thermometer; whereas, the red heat of iron in twilight is, according to Henry, 1050°, and in daylight 1207°.

24. An exceedingly delicate test of the purity of nitre is made as follows. Dissolve a few grains, by weight, in a test-tube, or in a small phial three-quarters full of pure distilled water. Then add a drop or two of the solution of nitrate of silver. If no discoloration take place, if the water retain its transparency, the nitre is pure; but if any whitish turbidity or milkiness appear, it indicates the presence of muriatic acid or common salt; and the degree of opacity will be indicative of the degree of impurity. Accum states, that the delicacy of this test is astonishingly great; that the presence of the $\frac{1}{42250}$th part of common salt, or $\frac{1}{108333}$d of real muriatic acid, dissolved in pure water, may be discovered by it. There are other tests to discover the presence of other salts: but they are so very soluble in cold water, in the state in which they are commonly found combined with grough saltpetre, that purified nitre in crystals cannot be suspected to be contaminated with them.

25. At a high temperature, nitre is decomposed with great violence by charcoal; and it is this property that qualifies it to become the chief constituent principle in gunpowder. Pure

nitre does not deliquesce nor attract moisture as common salt does, nor does it contain any water of crystallization, as was formerly thought.

26. The chemical name of saltpetre is nitrate of potassa. When melted, it is called sal-prunella, and crystal mineral. Subjected to a red heat, it loses a portion of its oxygen: it is then termed nitrite of potass. If the heat be increased and continued, it ultimately loses, not only its oxygen, but its nitrogen also, and becomes reduced to its simple base, potassa. Its analysis is as follows:—

Equivalent number		102
viz.—nitric acid	1 proportional=54	102
potassa	1 proportional=48	

These again are reducible into 6 proportionals of oxygen,

viz.—5 in the acid, and 1 in the potassa .	=48	102
1 proportional of nitrogen	=14	
1 proportional of potassium . . .	=40	

Hence 100 parts of nitre are ultimately composed of—

Oxygen	47.06
Nitrogen	13.72
Potassium	39.22

27. By this analysis it is seen that saltpetre contains six atoms of oxygen, and one of nitrogen, condensed in one atom of its base, potassium. These two substances, oxygen and nitrogen, constitute the gaseous or elastic elements of the nitre; and it is to them, coupled with high temperature, that the explosive and propellent properties of gunpowder are to be ascribed. When gunpowder explodes, these gaseous elements become developed, being released from their combination with the potassium, and take the form of permanently elastic fluids. But no sooner is this first combination broken, than the ingredients generally enter into new affinities, which are exceedingly difficult to trace with precision; but they will be noticed in due course. (71, 72.)

CHARCOAL.

28. We are to consider this well-known substance, in this place, as vegetable matter changed from its original nature by a chemical process, by which it becomes applicable to a special purpose. It may be noticed, that charcoal results from the woody fibre of the vegetable only; and that the liquid and volatile parts are driven off in the operation, and form new combinations. For instance, vegetables are composed of carbon, oxygen, and hydrogen: these, in different proportions combined, produce vinegar, sugar, tar, resin, oil, and other products. Pyroligneous acid (or wood vinegar) and tar result from vegetable distillation: not that vinegar and tar existed prior to the process; but that the elements of which they are constituted, having been separated from the wood, combine in new proportions, and, being condensed, fall into new forms of matter. These products are collected, and are useful in the arts, and in domestic life; and the charcoal remains behind, an educt of the original woody fibre.

29. The good quality of gunpowder depends very much on the quality of the charcoal. Light but not spongy woods appear to be the fittest. In Europe, woods of this character are preferred, being found to make the best powder. At Madras, the gram-bush plant [cytisus cajan],* parkinsonia, and milk-hedge [euphorbia tiraculli],† have been found to answer well. The parkinsonia, by its fracture, looks very much like the best of the European woods; and, by proofs made at Purfleet in 1815, gunpowder made at Madras in 1814, of that wood, according to the English system of manufacture, ranged higher than that made with gram-bush, and exhibited a less decrease of range in a subsequent trial, after both powders had been exposed to the atmosphere for twenty-seven days.

30. I shall insert an extract from these proofs, and make one or two observations on them. All the barrels containing the Indian powders are noticed in the proof-report, as appearing to have been kept in a damp magazine.

* Extracted from Official Report, 1802. † Ibid.

NATURE OF THE POWDER.	MEDIUM RANGES.	
	Eight-inch iron mortar; 45° elevation; 2 oz. of powder; shot 68½ lbs.	After exposure to the air for 27 days.
	13th July, 1815.	9th August, 1815.
1. Gram-bush cannon-powder, made April, 1814, English system of manufacture . .	189 feet	177⅓ feet
2. Parkinsonia ditto ditto . .	227⅜ „	222 „
3. The King's Waltham Abbey cannon-powder: had been to sea in His Majesty's ship, Pylades	245⅓ „	233 „
4. Musketry powder, made April, 1814, according to the Madras system of manufacture	No trial	173⅜ „
5. Madras powder, made January, 1813	Ditto	157⅜ „
	Number of elm boards perforated by a steel ball fired with 4 drams of powder from a carbine.	After exposure to the atmosphere for 27 days.
1. Gram-bush musketry, of the same manufacture as the above cannon-powder . .	14 boards	12½ boards
2. Parkinsonia ditto ditto . .	13 „	12⅓ „
4. Musketry powder, as above	11½ „	11 „
5. Madras powder, as above .	11 „	10½ „
6. The King's Feversham powder, F. G.	15 „	13 „

31. By these trials, the parkinsonia charcoal, No. 2, appears to make decidedly better cannon powder, than the gram-bush,* and in the proof by musketry, its deterioration was in proportion smaller than the latter, after 27 days exposure to the air.—Compared with the King's powder in the mortar proof, I see no reason to be dissatisfied with it;† and both the powders, Nos. 1 and 2, which were made according to the British system of manufacture, gave an extremely good range in the carbine proof, compared with the Feversham powder, No. 6, which does not appear to have been exposed to the deteriorating influence of a sea voyage, as the other powders had been.

32. The powder, No. 4, was made according to the Madras system of manufacture, only it contained cylinder charcoal and fused nitre; in other respects it was the same as the powder No. 5, which was Madras powder, of the current manufacture, that had pit charcoal, and air-dried nitre in its composition. The result in both methods of trial appears in favour of the cylinder charcoal powder, and affords satisfactory evidence, that fusing the nitre, coupled with the use of cylinder charcoal, somewhat improves the quality of gunpowder, even upon the Madras system of manipulation. The Madras powder, No. 5, ranged the lowest of the whole; but its manufacture, and the quality of its ingredients, were precisely the same as No. 4, with the exceptions noticed. No improvement has been made in the Madras powder since that period.

ON CHARRING.

33. Opinions differ as to the best mode of charring.—The French disbelieve the assertion of Mr. Coleman,‡ that the

* "In whatever way it [gram-bush] may be carbonized, or in whatever proportions used, it is inferior to coal made from the parkinsonia, as has been amply demonstrated by many decisive experiments."—*Capt. Bishop.*

† The powder, Nos. 1, 2, and 4, were made under my own superintendence. The English practice could not be perfectly followed for the want of means.

‡ Phil. Trans. Vol. IX. p. 358.

King's powder was increased in strength one third, by being made with charcoal burned in cylinders. They made powder with cylinder charcoal; with charcoal that had been prepared in a stove or oven; and with a third kind made by distillation in a glass retort, and found that neither of those coals made stronger gunpowder than the charcoal which was burned in their customary manner, viz. in pits constructed of masonry. The following is their account of the experiment.

34. "Dès que l'administration eut connaissance de l'emploi de ces méthodes, [the process of cylinder burning] elle s'empressa de faire l'essai des charbons résultants de l'une et de l'autre. Elle fit brûler à l'arsenal de Paris du bois de bourdaine dans une cylindre de fonte placé dans le fourneau de l'une des chaudières de la raffinerie, dont le feu étant en activité depuis plusieurs jours; il en fut en même temps carbonisé une autre portion, par distillation dans un poële de fonte; enfin, on en distilla environ 30 kilogrammes dans une cornue de verre avec l'appareil pneumato-chimique. Des compositions de poudre de guerre et de chasse furent faites à Essone avec chacune de ces espèces de charbon, et à divers dosages. On essaya ces poudres au mortier et à l'éprouvette de M. Regnier, comparativement avec les poudres de guerre et de chasse de fabrication ordinaire. Au mortier, la portée de la poudre ordinaire, au dosage de 76 salpêtre, 14 charbon, 10 de soufre, fut supérieure de plusieurs mètres à celle des poudres faites avec les trois charbons, aux deux dosages différentes de 76 salpêtre, 14 charbon, 10 soufre: et 76 salpêtre, 15 charbon, 9 soufre; et cette infériorité fut la moins sensible pour la poudre faite avec le charbon de cylindre, et la plus considérable pour la poudre avec le charbon distillé à la cornue. A la petite éprouvette, les poudres de chasse avec les charbons au poële et à la cornue soutinrent la concurrence avec la poudre fine de fabrication courante; la poudre avec le charbon du cylindre fut seule plus faible."—Perhaps they overburned these charcoals. See 49.

35. "Les résultats de ces épreuves, sur les méthodes de carbonisation des Anglais, dûrent prouver à l'administration qu'elles

n'étaient pas préférable à celles usitées en France, et la confirmer surtout dans l'idée qu'elle avait eue de l'exaggération ridicule des prétendus avantages des modes de carbonisation employées en Angleterre; ces avantages ne tendaient à riėn moins, suivant Coleman, qu'à augmenter la force de la poudre, au point de permettre de diminuer d'un tiers la charge des bouches à feu."*

36. My design being the discussion of principles, only so far as they are supported by practical data, and having no experiments to oppose to the foregoing, I shall make no comment on these extracts, but simply observe that the results stated, coincide with experiments made at Madras under the superintendence of Capt. Balmain; for a set of cylinders such as are used in His Majesty's works at home, having been erected, and charcoal made in them, by one of the young men sent out by the Honourable the Court of Directors, in 1813, "it was found that burning the gram-plant in them did not improve the quality of the coal of that wood, and the cylinder coal of all other woods was inferior to the pit-coal of the gram-plant." But this enunciation concerning the quality of the charcoal applies only to the strength of gunpowder, not to its preservation or durability.

37. Here, however, two remarks may be offered;—the first is, that Captain Balmain's opinion, concerning the superior quality of the gram-plant charcoal, is directly opposite to Captain Bishop's; see note, (*) page 14: and the second, that

* The fact is, that the burning of charcoal in cylinders was coupled with other improvements to effect this end. Lieutenant General Congreve, in a tract published in 1811, shews, among other statements, a saving to the nation of £619,800 sterling, from 1797 to 1810, which he states was effected "in consequence of the improvements in the manufacture of new gunpowder, by which its strength [was] so much increased, that it was found necessary, in the year 1796, to reduce the charge of gunpowder for ordnance one-third in weight." And one of these improvements, was the bringing "to perfection a new description of gunpowder, called cylinder powder, from the form of the retort in which the process of charring [was] performed." "Powder made with charcoal so produced, greatly exceeds the strength of common powder."

conclusively as the French appear in the foregoing extracts to have decided the question against cylinder charring, more recent experiments made in France, seem to incline them to the adoption of the English system after all, in preference to their own. The Baron Dupin, in his " Force Militaire de la Grande Bretagne," gives an outline of some experiments made before a special committee, appointed in 1814, to examine the merits of powder made at Bouchet, with charcoal prepared in a close vessel, compared with Dartford powder that had been obtained specially for the occasion; and the results were a trifle in favour of the French powder. He quotes the following words: " Rien ne s'oppose, disent les commissaires, à ce que nous fassions de la poudre de guerre aussi bonne que la poudre de chasse qui vient d' être éprouvée. Nous y parvièndrons en préparant le charbon d'après le mode Anglais."* And then says, " Formons des vœux pour qu'on fasse, à cet égard, ce qu'on a démontré possible." And again, " une partie des qualités de la poudre Anglaise est due à cette carbonisation, disais-je en 1820; l'expérience du Bouchet a prouvé cette assertion. Esperons qu'on emploira ce procédé pour toutes nos poudres." I shall not attempt to reconcile these discrepant opinions of our continental neighbours. (35.)

CYLINDER CHARRING.

38. The charcoal used in making His Majesty's gunpowder is prepared by distillation in large cylindrical iron retorts.† In this process, the volatile products of the wood are driven off by the fire, and are condensed and collected in suitable receiving-vessels. This method is considered to be superior to the common method of charring in pits. It is stated in a report detailing the result of experiments made under the

* Note, pp. 144 and 145, second Paris edition, 1825.

† The idea of this method of charring originated with the late Bishop Watson. See his Memoirs, Vol. I. It was acted on in 1783 or 1784, during the administration of His Grace the late Duke of Richmond, then Master-General of the Ordnance.

sanction of the Honourable the Board of Ordnance, on Malborough Downs, in August, 1811, that "gunpowder which contains cylinder charcoal in its component parts, will retain its strength far better than that which is made with either common pit-coal, or that which hath been charred in pots, because the two last sorts have unavoidably more or less deliquescent salts therein."

39. If it be an object to procure charcoal of the greatest purity, there can be little doubt that distillation in proper vessels is the best way to obtain it;* for, in this case, as soon as the juices of the wood are driven off, they are separated from it; whereas, in pit burning, such of the resulting products as are inflammable are consumed by the fire, and such as are not, deposit their earthy and saline bases on the charcoal. As far as these bases are deliquescent, they are injurious: and of such as are not, the least that can be said is, that they are foreign admixtures, and unnecessary, if not detrimental.

40. I have met with no writer who offers an opinion why cylinder charcoal is superior to pit charcoal for making gunpowder, nor am I, myself, able to solve the question. The assertion has been made by one, and repeated by others, and experiment seems to confirm it as a fact. But from my own researches, I think there are grounds for concluding, that cylinders not only make a purer charcoal, *i. e.* a charcoal less contaminated with foreign mixtures, but that they also produce it free from alkali. Potash is found in almost all plants that grow at a distance from the sea. And we know, that by burning wood in the open air, collecting the ashes, lixiviating them, and evaporating the solution, the common potash of commerce may be obtained. The question therefore appears to resolve itself into this: as alkali is produced when wood is burned, having access to the atmosphere, is it, or is it not produced, when burned in close vessels where the atmosphere is

* See Parke's Chemical Essays, Vol. I. p. 398.

excluded? It is, I believe, a question among chemists, whether potash exist in the wood, or whether it be formed during the incineration;* if it exist in the wood, it appears to be a difficult point to decide how it is got rid of by the cylinder process, as it does not evaporate, but simply fuses on the application of powerful heat."† The decision, however, would not be difficult; a single experiment would, if properly conducted, be sufficient to prove the point, or disprove it. I do not possess the means, or opportunity of deciding the question by direct trial on a sufficient scale; but the following experiments, I think, bear very closely upon it.

41. One hundred parts of the gram-bush charcoal used at present at the Madras powder mills were incinerated. The ashes produced alkali in the proportion of 1.51 per cent. of the weight of the charcoal employed, and from 30 to 35 per cent. of their own weight. The charcoal itself was macerated in pure water, and on being tested, the water also discovered the presence of alkali. It may therefore be concluded, that pit-burned gram-bush charcoal is alkalescent.

42. Samples of nitre, purified at Madras in the years 1814 and 1828, were then examined; and on the application of the proper tests, neither of them discovered the presence of alkali. This experiment, though apparently unconnected with the subject, will presently be seen to bear upon it.

43. To ascertain whether the gram-bush charcoal contains alkali in consequence of its preparation in pits, as well likewise for the purpose of ascertaining whether the King's gunpowder was free from it, I weighed half an ounce of the King's rifle powder of 1813, containing cylinder-burnt dogwood charcoal, and half an ounce of Madras powder of 1828,

* See Parke's Chemical Essays, Vol. II. p. 17; and Note 6, p. 585.

† Ibid. Vol. II. p. 19.—It would appear that the alkali passes over with the pyroligneous acid, from which it is obtained, by a German process, for collecting potash.

made with pit-burnt gram-bush charcoal, and put them both with equal quantities of cold distilled water into two test glasses. When each powder had been dissolved, I put into each glass a slip of dry reddened litmus paper, and after letting each remain a few hours, I took them both out for examination.* That slip which had been in the solution of the Madras powder had its blue colour restored, thereby indicating the presence of alkali, as was to be expected from the fact just stated of the gram-bush charcoal containing potash: but the slip that had been in the solution of the King's powder indicated no trace of alkali, for the red colour of the test paper had not been in the remotest degree disturbed. I ascertained by another experiment that His Majesty's powder did not contain a free acid.

44. Again. I tested in the same way two samples of gunpowder made at Madras, in 1814,† with cylinder-burnt gram-bush charcoal, and cylinder-burnt parkinsonia charcoal, the powder being made according to the British system of manufacture; but there was not the slightest trace of alkali in either of these experiments: they were both quite as free from it as the King's powder.

45. To leave no doubt on this point, I made a third trial on Madras pit-burnt gram-bush charcoal powder of the year 1814, lest the lapse of fifteen years should have had any chemical action on the other powders of the same age, and have destroyed the intention of the experiment; but this trial also indicated the presence of alkali.

46. On these trials it may be necessary to make the following observations: His Majesty's powder was made from the charcoal of wood that had been exposed to the weather; it may therefore be thought that this circumstance might have

* From the small quantity of alkali in half an ounce of powder the test will not act immediately.

† Nos. 1 and 2 of Paragraphs 30, 31.

been the cause of its containing no potash, (See 51.) But the gram-bush and parkinsonia woods were fresh cut, and were charred while saturated with their own juices; the objection cannot therefore hold good with reference to them. Now we have shewn that the nitre contains no potash, (42,) and by trial I ascertained that the sulphur did not; the conclusion consequently must be, that the alkali in these experiments proceeded only from the charcoal. Hence, having shewn that the pit charcoal powder was alkalescent, and the cylinder charcoal powder was not, I apprehend we may legitimately draw the inference, that the cylinder process was the cause of the cylinder charcoal being produced uncontaminated with alkali, and for this cause, if for no other, that cylinder charring is the best method of making charcoal for gunpowder.

OBJECTIONS.

47. Close distillation has been objected to, from the danger of overburning the wood; but when the process is understood, the objection possesses no weight, because it does not exist in practice. Even where the operation is not understood, if the coal be withdrawn, or the fire put out, when the last portions of acid escape, and the gas assumes a "violet blue colour," the char will be perfect, and there will not be the remotest danger of super-carbonization. In this case, however, practice is the best guide.*

48. Charcoal may be made exceedingly hard by intense heat. The voltaic apparatus has imparted to it the ability to scratch glass, and even to resist the action of a moderate fire. "It is rendered so much less combustible, that it remains unaltered when ignited on an iron plate with free access of

* See Parke's Chemical Essays, Vol. I. p. 402, *et seq.* for a curious occurrence which took place in consequence of a slight alteration of the apparatus in which charcoal was burned in one of the English merchants' manufactories.

air."* In such a state as this, it is of course utterly unfit for gunpowder, and by parity of reason, all heat unnecessarily continued after the wood is duly charred, is detrimental.

49. In the year 1802, some experiments were made at Madras, on cylinder-burnt charcoal, by the late Captain Bishop, and Benj. Roebuck, Esq., and they found that gunpowder made with cylinder charcoal burned to excess, ranged 42 yards; while that which had been properly charred in cylinders ranged 157 yards, which plainly shews that gunpowder may be ruined if made with charcoal unskilfully prepared.

50. Against the use of cylinders has been objected the expensiveness of the process. At home, the liquid products of the wood are turned to good account, and it has been said, that they repay the cost of the fuel. The demand for them in this country not being the same, the most useful product here would be the tar, which, mixed with spirits of wine, makes a good black lacquer, and by itself is useful for many purposes to which common tar is applied. Indeed, for the preservation of timber,† and of iron work exposed to the weather, it is superior to common tar. Now if, in this country, the common process of burning charcoal could be so improved, as to free the coal from deliquescent salts without the use of cylinders, it would be an advantage with reference to economy of preparation, and an absolute improvement with reference to the quality of the gunpowder; for alkali is not simply a harmless foreign intermixture, but a most injurious one, from its deliquescent property, whereby it disarranges the elementary particles of the powder, and renders it ineffective in proportion to the degree of disintegration produced.

51. I think this improvement might in part, though not wholly, be effected. The wood used in the King's charcoal works at home is piled in stacks, and exposed to all changes

* Henry's Chemistry, Vol. I. p. 340.

† See Parke's Chemical Essays, Vol. I. p. 399.

of the weather; and if, in this country, the wood of the gram-plant were to be exposed to the heavy rains of but one monsoon before it was burned, the soluble salts would probably be washed out; the charcoal be deprived of one grand cause of its absorbing moisture, and the powder of losing its strength in damp climates. This idea is corroborated by the fact, that the incinerated leaves of hazel wood, which gave in one experiment so much as 26 per cent. of soluble salts, yielded only 8.20 per cent. when a portion of the same sample of leaves had, prior to another experiment, been simply washed in cold water;* and by the following extract from Parke's Chemical Catechism: "Dr. Peschier has shewn that potash exists ready formed in the juices of vegetables, sometimes free, and sometimes in combination with acids; and it has been found, *that if vegetables be soaked for some time in water, and then burnt, they will afford no potash.*"†

52. With regard to the opinion, that by overburning charcoal its hydrogen is driven off, it becomes hard, and is less fit for gunpowder; in the first place, it is doubtful if hydrogen exist in charcoal in any sufficient quantity to be useful, and in the next, it is not found to exist in carbon in an uncombined state; it may be there accidentally, because charcoal absorbs a portion of all the gases, and because hydrogen is one of the products of the wood. As to its being rendered harder, and less fit for gunpowder by overburning, the fact appears to be well established, though the cause of its unfitness is not so evident. The mere mechanical property of hardness may perhaps account for it; it is probably the extreme hardness of the diamond, which is pure carbon, that renders this gem so difficult of combustion. I am inclined, however, to think, that the nature and properties of *gunpowder charcoal* have not as yet been sufficiently investigated. The practical chemist, both for analysis and experiment, prefers, I believe, charcoal that has been very much burned; the more burned, the better;

* Thompson's Chemistry, Vol. IV. p. 192, ed. 1826.

† Note (e), p. 125, 12th edit. 1826.

but such charcoal, I should apprehend, differs in its properties materially from that used in making gunpowder.

PRACTICAL MEMORANDA.

53. Charcoal for gunpowder is deteriorated if it retain the bark of the wood or plant. The tree in Europe is cut when the sap is in full circulation, as the bark at that time, on being crushed, easily peels off. Gunpowder made with charcoal having the bark on, or with charcoal not enough burned, is what is technically termed lighty; that is, on explosion, a number of sparks fly off, which, under some circumstances in actual service, might be attended with danger.* Hence it is an established rule, that all wood which is but partially burned, pieces of stick, or straw, filiments of hemp from the sacks, and heterogeneous particles of matter of every description, should be carefully picked out of the charcoal before it is pulverized. Wood that is decayed should not be charred, but be at once rejected.

54. The goodness of charcoal may be judged of by the following indications. It should be light, and not too much burned. It should, however, be perfectly charred, which may be known by a handful, when in combustion, giving out no smoke. On being snapped, the fracture should exhibit the same appearance throughout, either a dead black, or a shining jet black, according to the nature of the wood. It should be so soft as not to scratch polished copper, and lastly and especially, it ought to exhibit no alkali on being treated with pure distilled water.

55. To ascertain if it contain alkali, add to one ounce of charcoal, in powder, three fluid ounces of boiling distilled water. Mix them well together in a clean marble mortar. Filter them. Reduce the filtered liquor by evaporation to one quarter its

* For instance, on ship-board or in battery.

volume. Apply to it litmus paper that has been reddened by vinegar, or by any weak acid. If the charcoal contain alkali, the natural blue colour of the litmus will be wholly or partially restored, but if it be free from alkali, the red colour of the paper will not be changed.

56. Various kinds of wood yield different proportions of charcoal. About 25 per cent. of charcoal is obtained from the several kinds of wood used for making His Majesty's gunpowder; but this, of course, depends very much on the age and dryness of the wood. The following experiment affords some information on this point.

	Wood before Charring.	Produce of Charcoal.	Weight of Sea Coal used.	Time occupied in Charring.	
	lbs.	*lbs.*	*lbs.*	*Hours*	*Min.*
One Set of Cylinders	577	162	246	8	40
Another ditto . . .	580	167	224	8	40

57. Charcoal is considered in chemistry to be a simple substance; but that which is used in the composition of gunpowder is not, in all probability, pure carbon. Charcoal absorbs $12\frac{1}{2}$ per cent. of moisture on being exposed to the air, independent of what it may absorb additionally, should it contain alkali. It has also the singular property of absorbing ammoniacal, muriatic, and other gases, to an extent many times exceeding its own bulk. In combustion, carbon combines with 2.66 parts of oxygen, and forms carbonic acid gas, which is one of the elastic products of fired gunpowder.

The chemical equivalent of this gas is 22
It consists of 1 atom of carbon . . . . = 6 }
2 atoms of oxygen . . . =16 } 22
The chemical equivalent of carbonic oxide is 14
Consisting of 1 atom of carbon . . . . = 6 }
1 atom of oxygen . . . . = 8 } 14

58. It is supposed that pyrophorous, a substance which ignites on exposure to the air, is sometimes produced in the preparation of charcoal, and that the occasional and apparently spontaneous combustion of charcoal, when in store, arises from that circumstance. Pyrophorous was originally discovered by submitting alum and the human fæces to a red heat; "but honey, flour, sugar, or any animal or vegetable matter may be substituted instead of the human fæces." As some kinds of clay contain alum, and as some one or other of the foregoing substances may meet with such clay among the wood of which charcoal is made, it is easy to conceive how pyrophorous may by accident be sometimes produced, though it may be difficult to account in a formal manner for its production in making charcoal by any direct union of its bases. It is a well-known fact, that accidents do occur, both in Europe and in this country, by charcoal taking fire when in store; and in some cases, after the closest scrutiny, it has resulted that there was no apparent external cause to excite combustion.* In India, clay and human excrement are substances very likely to meet together either among the wood for charcoal, or in the pits in which the wood is burned; and if so, pyrophorous may be formed, and accidents afterwards take place, as they have occurred sometimes at the Madras gunpowder manufactory, and that, too, without any known or apparent cause.

OF SULPHUR.

59. This mineral is a simple combustible substance, found in great quantities generally in the neighbourhood of volcanoes; it is obtainable also from metallic ores and from other sources. It readily fuses, and volatilizes. At 170° of Fahrenheit it begins to evaporate; an increase of 15 or 20 degrees of temperature causes it to melt, and at 220 it is completely fluid. If the heat be suddenly increased to 250° it loses its fluidity,† and becomes

* In the "Bulletin des Sciences Militaires," for January, 1831, there is a very interesting Report upon this phenomenon, by Colonel Aubert; and it has been further illustrated by Mr. Hadfield, in a paper read before the Literary and Philosophical Society of Manchester, November 4, 1831.

† Henry, Vol. I. p. 380, ed. 1826.

firm and of deeper colour, provided that the experiment be made in a close glass vessel. By reducing the temperature, it regains its fluidity, if the change of heat be rapid, otherwise it is volatilized. At 600° it sublimes, and may be collected in the form of flowers of sulphur.

60. Sulphur is insoluble in water, and, by chemical authors, is said to remain unaltered by it; but the following extract from a report of a Committee of the Military Board in 1802, seems to speak a different language:—"An attempt made at the powder mills to levigate the sulphur in water, invariably ruined it for the purposes of the manufacture." When it is heated to 300° and poured into water, it becomes tenacious like wax, and is used to take impressions from engravings, seals, &c.

61. Sulphur is purified simply by melting; a gentle heat should be used, and to conduct the process skilfully, great care and attention must be paid to the degree of temperature, or state of the fire. The brimstone is first broken into small pieces, and during the time of fusion it must be kept constantly stirred with an iron instrument, which should be very slightly oiled, to prevent the adhesion of the sulphur, or rather, to facilitate its removement. Only a small shovelful should be thrown into the melting-pot at a time, and when that has become liquid, more should be added. After the refining or melting vessel is full, the sulphur should remain undisturbed until small needle-like crystals begin to form on its surface. It should be then *immediately* laded out into wooden tubs, with truss hoops, *i.e.* with hoops that may be loosened, and as soon as it is cold it may be removed, and carried through another similar process, which will, in all ordinary cases, prove a sufficient degree of purification. It will be observed on removing the mass from the tub, and breaking it in pieces, that the heaviest of the impurities have subsided, that the lightest have risen to the surface, and that the remainder have settled around the outside of the mass. These impurities should be removed, and the purer parts only be carried forward in process for the

second refining. The impure parts are to be considered as crude sulphur.

62. From a piece of sulphur picked up indiscriminately at the Madras powder mills from a heap of refuse, I collected a greater quantity of brimstone than I think ought to be included in what is considered as waste, and thrown aside as useless. My common-place book represents the experiment to stand thus:

By driving off the volatile substances and weighing the residuum—100 parts of sulphur gave—volatile products	68
Earthy residuum	32
	100

By collecting the products of 100 grains, I obtained brimstone, ...	62
Earthy residuum	32
Loss in the experiment	6
Total Grains	100

But it is proper to observe, that the residuum was a light earthy matter somewhat like pumice, so that it does not follow that the same proportion of sulphur should be obtained in the operations of the manufactory, because the residual matter may probably mingle with the sulphur, and neither rise to the top as scum, during the process of refining, nor sink to the bottom as sediment. A portion of it, however, might, by proper management, be assuredly obtained, and the whole might be collected by sublimation. The result of sublimation would be flowers of sulphur, which, from experiments that have been made, would appear not to make gunpowder so strong and good as common sulphur. It is however said, that flowers of sulphur become the same as common sulphur by fusion.

63. Sulphur has an affinity both for oxygen and potassa. Mr. Coleman represents one of the elastic fluids of fired gun-

powder to be sulphurous acid gas, a combination of sulphur with oxygen; but more recent authorities think that the sulphur in combustion unites with the base of the nitre, and forms one of the solid products or residua of fired gunpowder,—viz. sulphuret of potass.

64. The easiest test to discover the purity of sulphur is by burning it in a clean glass vessel over a chemical lamp. 100 grains, treated in this way, ought to leave too small a weight of residuum to be ascertained, except by scales capable of indicating minute fractions of a grain.

SECTION III.—PROPORTIONS.

65. This is both an interesting and difficult subject. It resolves itself into two parts,—scientific and practical; and in this order I shall consider it.*

66. Among the brilliant discoveries of modern chemistry may be classed the developement of the fact, that chemical combinations, to constitute the same compound, always take place in definite and unalterable ratios. To select one example out of multitudes, one atom of carbon combining with two of oxygen produces the gas carbonic acid; it can combine in no other proportion to produce the same gas, for if the quantity of oxygen be lessened, the union cannot take place; but it may be reduced to one proportional, and then one atom of carbon will seize it, enter into another combination, and generate carbonic oxide.—A perfectly correct analysis of the elastic and solid products

* With reference to the chemistry of this question, I have simply quoted the opinions of others. The subject appears to be one of some difficulty, and it has not to my knowledge been better treated of than in the quotations I have made.

resulting from the explosion of gunpowder, would therefore form an excellent datum to assist in deciding theoretically on the question of proportions; for, as nitre contains a given quantity of oxygen in a certain portion of its base, there should be a certain definite portion of carbon in combination with it, sufficient for its entire decomposition, but not more than requisite for such purpose, because more would answer no useful end. So with reference to the sulphur, if that enter into combination only with the potassa, the base of the nitre, it should be in that proportion which is proper to form the sulphuret, and there should be no superfluity, for that would only add to the weight of a charge of powder, and diminish its absolute and effective energy.

67. This view of the case supposes only two combinations: carbon with oxygen; and sulphur with potassa. Should there be a more diversified play of affinities, and the several elements of the powder enter into more complicated action, accurate analysis would still conduct us through the labyrinth, and point out what the proportions of the ingredients ought to be in order to sustain that action, and to produce a perfect ultimate result.—We thus perceive how analysis bears upon the case; we see that, *theoretically*, there can be but one set of proportions calculated to produce the best and strongest gunpowder; and that those proportions must be dependent upon the established and unerring laws of nature.

68. In Brewster's Encyclopædia, and in the Supplement to the Encyclopædia Britannica, (both recent works) there are good articles on gunpowder: they both take up the analysis of fired powder, and the former the question of proportions, which is thus stated:—"The proportions for gunpowder will be those in which the carbon will just consume the oxygen of the nitre, and the sulphur as much as will exactly saturate the potash. This will be effected by an atom each of nitre and sulphur, and three atoms of carbon; or nitre 95.5, charcoal 16.2, and sulphur 15. These will give in the 100, nitre 75.4, charcoal 12.8, and sulphur 11.8."

69. "In the present improved state of chemical science, when the nature of the bodies composing gunpowder is so well understood, as well as the compounds resulting from their action on each other, the proportions above given may be taken as the best for practice. The charcoal should, in particular, not be less in proportion to the nitre, as the smallest portion less than a whole atom, would be the same as to leave out the whole atom, in which case there would be no carbonic oxide formed. If, for instance, instead of the proportions, 95.5 nitre, 16.2 charcoal, and 15 sulphur, the carbon were 16, then there would be 4.2 of carbon left in the residuum, and no carbonic oxide would be formed; since bodies cannot unite but in definite proportions."

70. "The reason why carbonic oxide is formed during the decomposition of nitre by charcoal, will be obvious from nitric acid having five atoms of oxygen. Four of these unite with two of carbon to form two atoms of carbonic acid; while the odd atom of oxygen is compelled to take another atom of carbon to form carbonic oxide. The writer of this article found the presence of the latter substance a fatal objection to getting pure carbonic acid by deflagrating nitre with charcoal."

71. In speaking of the products of fired gunpowder, the same article says, "The bodies which result from the decomposition of this compound (nitre 95.5, charcoal 16.2, sulphur 15,) will be in 126.7 parts,—60 of sulphuret of potash, 40.8 of carbonic acid, 12.9 of carbonic oxide, and 13 of azote: the three latter are elastic fluids, equal to 66.7 out of 126.7."*

72. But the Supplement to the Encyclopædia Britannica gives a different account of the elastic products; it not only represents them to be more numerous, but varies a little as to their weight, and very much as to their bulk in cubic contents.

* Has the intense heat generated by deflagration any influence on these results? Has it any influence in disposing the elements of the gunpowder to enter into new affinities or combinations? Does the base of the nitre (potassium) become developed during combustion?

In order to attain facility of comparison, I have reduced the total 126.7 grains of Brewster's experiment to the proportion 100, and placed the two analyses in opposition in the following table. It is proper, however, to observe, that the gunpowder analyzed in the Encyclopædia Britannica contained nitre 75, charcoal 15, and sulphur 10, in the 100 parts; and that the solid residue was about 4½ per cent. in excess, which is supposed to have originated either in imperfect drying or from some unnoticed error in the experiment.

ANALYSIS OF 100 GRAINS OF GUNPOWDER.	ENCYCLOPÆDIA BRITANNICA.		EDINBURGH ENCYCLOPÆDIA.	
ELASTIC PRODUCTS.	*Grains*	*Cubic Inches.*	*Grains.*	*Cubic Inches.*
Azote or Nitrogen	13.24	42	10.37	32.4
Carbonic acid	28.77	30	32.06	68.3
Carbonic oxide	...	...	10.21	33.1
Carburetted hydrogen	2.70	9	...	...
Nitrous gas	3.25	6	...	...
Sulphuretted hydrogen	2.03	4	...	...
	49.99	91	52.64	133.8
SOLID PRODUCTS.				
Subcarbonate of potash	40.00	...	...	...
Sulphuret of potash	11.00	...	47.36	...
Charcoal	3.00	...	...	...
Sulphur	0.50	...	...	...
Total	104.49	91	100.00	133.8

73. The first analysis gives within a fraction of 50 per cent. or half the weight of the powder, as the elastic product generated in five different gases; while the second states it to be 52.64 per cent. in but three kinds of gas: but the greater and the most material variation is in the quantity or cubic measure of these aerial fluids, the former making it but 91 inches, while the other represents it to be 133, or nearly half as much again. There is also considerable discrepancy as to the nature of the solid residue, the former representing it to be subcarbonate of potash with a little unconsumed charcoal and sulphur; and the latter, sulphuret of potash only.

74. Other authors are not more happy in general coincidence.* Ure, in his Chemical Dictionary, ed. 1824, states from Berthollet, that these products consist of

Nitrogen gas....................	2 parts.
Carbonic acid	1 part.

While the British Gunner, ed. 1828, asserts that they are composed of

Carbonic acid gas	49 parts.
Azote, or nitrogen	34
Hydro-carbonate	10
Nitrous acid gas	5
Sulphurous acid gas	2
Total	100 parts.

75. From all of which we may draw these conclusions;—that charcoal and nitre are the two ingredients from which the propellent power is principally derived; that carbonic acid and nitrogen are the chief elastic products; and that, as the several authorities vary so much, they afford only an approximating guidance, but do not contain certain and specific data applicable, *à priori*, to the satisfactory decision of the question.

76. These scientific discrepancies throw us back again on practice and experiment; nor is it much to be regretted, because the operations of the manufactory are what must at last be depended on for strength and excellence in the quality of gunpowder. How accurate soever the accordances of theory may be on this point, there are circumstances in the manipulation by which they may be utterly subverted, and thereby possess not the smallest degree of value. For instance, the practical impulsive effect of gunpowder depends, not only on the chemical adjustment of its parts, but also on its lightness or density. Light and porous-grained powder explodes with greater rapidity than hard-pressed dense-grained powder; and *that* gunpowder which explodes with the greatest rapidity, will generate the greatest quantity of gas in the shortest time, and

* Dr. Ure has treated this subject more at large in the Journal of the Royal Institution, No. I. October, 1830.

in all ordinary cases produce the greatest effect. Perfect manipulation will produce a stronger and better powder with bad proportions, than imperfect manipulation will produce with good. When gunpowder is used in large quantities in heavy ordnance, its effects are dependent more on circumstances connected with its manufacture, than on the accurate adjustment of its primary elements: and lastly, experience has not only proved these several facts, but the singular fact also, that in high charges inferior gunpowder will range as far as the best. Hence we perceive that analytic chemistry is not of itself sufficient to decide the question of proportions; and hence it would appear, too, that the subject does not admit of a categorical decision.

77. The truth is, that theory stands in need of verification from practice: the two should go hand in hand together; and even thus united, they are barely adequate to set the question on a firm basis. The system of manufacture has a commanding influence over the quality of the article manufactured, and experiment has shewn that the same proportions yield different results, according to the manner in which they are made into gunpowder. The safest course, therefore, is to consult the determinations of practice; and with this view I shall here insert some experiments on proportions lately made at Madras, under the sanction of the Military Board. The proportions were as follow:—

No.		*Nitre.*	*Char.*	*Sul.*
1	Experimental powder (A. D. 1829)	66⅔	20	13⅓
2	Do. M. Champy ....do.	80	15	5
3	Do. English proportions ..do.	75	15	10
4	Do. No authority ....do.	78.5	12.5	9
5	Do. Brewster's Encyclopædia do.	75.4	11.8	12.8*
6	Do. Madras proportions....do.	75	13⅓	11⅔
7	His Majesty's cannon powder (1813) ..	75	15	10
8	Musket powder from the above, do.	75	15	10

* This is an oversight, occurring from an unnoticed misprint in Brewster's Encyclopædia. The proportions of the sulphur and charcoal ought to be reversed. The experimental powder was, however, made of these erroneous proportions.

78. Nos. 1 to 6 were musket powders, made according to the Madras system of manufacture, unpressed and unglazed. Nos. 7 and 8 were pressed and glazed powders, and therefore laboured under some disadvantages, in addition to their age, as will be hereafter shewn. The following table exhibits the results respectively produced by the whole, in medium ranges in yards.

ORDNANCE. Elevation 45°	WEIGHT OF THE SHELL.	WEIGHT OF THE POWDER.		THE FOREGOING PROPORTIONS.							
	lbs.	*lbs.*	*oz.*	1	2	3	4	5	6	7	8
13-inch iron mortar	200	9	..	2246	2395	2143	2235	2292	2328	2449	2386
10-inch do.	96	2	..	879	955	788	889	955	912	1003	1002
8-inch do.	64	1	..	589	662	533	578	668	651	671	738
8-inch mortar éprouvette	64	..	3	247	300	258	263	264	275	280	300
8-inch do.	64	..	2	166	162	159	158	159	171	160	187
8-inch iron mortar	64	..	2	43	48	44	39	51	46	58	58
Pendulum éprouvette	..	..	2	20°.95′	22°.87′	21°.35′	22°.92′	23°.15′	23°.50′	22°.25′	26°.8′5
Another do.........	..	..	2	29.50	31.00	28.50	29.00	30.50	30.00	,,	,,
Number of ¼-inch boards perforated by a steel ball fired from a musket....	..	..	¼	14	14	13⅛	14	13⅜	14	,,	15⅛

79. These trials are instructive. The proportions Nos. 1 and 2 are extremes as to the quantity of saltpetre and sulphur they contain; but were chemical data to be applied to them, it would probably be seen that a much greater deviation might have been expected in their comparative results than that which actually occurred. This seems to prove that the sulphur has no great active energy in generating the propellent power, (8.9.) or if it had, its quantity in the two powders being so disproportionate must have produced a greater discrepancy in the ranges.

80. Nos. 3 and 5 are of the same proportions as those constituting the analysis before alluded to (72). It is evident that No. 5 produces a better powder than No 3, the two powders being manipulated, as these were, according to the system obtaining at Madras; but the difference between them is not so remarkable as expectation would have been justified in supposing from the analysis of No. 5, which represents (72. 73.) the elastic fluids, or propellent power, to be half as much again as the other, No. 3: a result that is not verified by the experiment. To ascertain however the absolute merits of these two proportions, they ought both to be manipulated according to the English system of manufacture; for although No. 5 ranges higher than No. 3, yet No. 8 ranges higher than either of them, although the proportions of No. 8 and No. 3 are identical.*

81. The Madras powder, No. 6, maintains a good position among the experimental powders, which proves that its proportions are well adapted to the Madras system of manipulation. Nos. 2, 5, and 6, appear to be all good powders; but a more extensive and diversified set of experiments would be required before a judgment could be formed, or decision pronounced, as to the best of the three.

* I have not thought it necessary to expunge this paragraph; but the comparison instituted fails, in consequence of the oversight alluded to in the Note to paragraph 77.

82. But the most instructive lesson of the whole may be learned from the comparison of column No. 3 with No. 8; the wide difference observable in those two powders originating solely in the system of manufacture. This proves the high and predominating influence that manipulation possesses over the quality of gunpowder, independent of the question of proportions; and it brings the Madras and English manipulation into strong and immediate contrast. The difference in this case may be attributed to the different degrees of incorporation received by the ingredients, and the effect of it may be thus explained:—

83. Nitre produces no explosion except in contact with a combustible body: the application of great heat would effect a slow and silent decomposition of it; but if, during the process, charcoal were added, sudden combustion would be produced. A piece of red-hot charcoal thrown upon nitre while in fusion occasions rapid and brilliant combustion; but dry charcoal, in powder, thrown upon it produces sudden deflagration, which shews that the more numerous the points of contact are, the more violent and rapid are the effects. To apply this principle to the case in hand: His Majesty's powder, No. 8, having received a very high degree of incorporation, the minuteness of its particles is greater, and their contact closer and more intimate, than in the case of the same proportions, No. 3, in which the elementary atoms cannot be in such minute and intimate combination, because, by the Madras system of manufacture, the incorporation, as will be hereafter explained, (96 to 100,) is but a fraction of the quantity of incorporation received by the gunpowder made in His Majesty's works. The consequence is perceived in the difference of range of these two powders, and it should be borne in mind that this difference would have been still greater, had the powder, No. 3, been submitted to the operations of pressing and glazing, to the same degree and extent as the English powder, No. 8. (130 to 132.)

84. The whole of the powders, Nos. 1 to 6, having been made under circumstanccs alike common to all, there can be no error in asserting that the Madras proportions, No. 6, are better adapted to the Madras system of manufacture, than the British Government proportions, No. 3. We think this circumstance gives support to the idea that each peculiar system of manipulation has a set of proportions that agrees the best with it, and produces the best powder by it: but what those proportions are must be determined by experiment. These two facts are certain; that the Madras powder, No. 6, is better than the powder No. 3, and that His Majesty's powder, No. 8, is better than both. Chemistry lends no countenance to the supposition that purified nitre in different countries yields different quantities of oxygen, or that different charcoals combine with different ratios of oxygen to produce the same gaseous results.* No difference, then, occurring from the ingredients, I see no other method of explaining the dissimilar effects resulting from these three gunpowders, than that the difference between Nos. 3 and 6 is owing to the difference of their proportions; and that the variations of Nos. 3 and 8 are attributable chiefly, if not solely, to the different degrees of incorporation they received in making.†

85. Perhaps there would be no real utility in carrying the discussion of this subject to a greater length: it may therefore be observed, that if the nitre do but constitute about three-fourths of the whole mixture, the remainder is matter for practical experiment; and may, in some measure, be dependent on the system of manipulation. The following experiments, made on Malborough Downs in 1811, shew that for high charges there is not much choice between proportions that differ materially in the quantity of saltpetre employed.

* Different kinds of charcoals are, however, known to produce gunpowder of different qualities. This seems to imply that the chemical properties of charcoal made of different sorts of wood are not alike.

† It is proper, however, to bear in mind, that Nos. 3 and 6 were made of pit-burned, and No. 8 of cylinder-burned charcoal.

Of the proportions of the charcoal and sulphur I have no information.

Waltham Abbey Powder, 1809.	9 lbs. Charge.	10½ lbs. Charge.
80 lbs. proportion	4166 yards . .	4177 yards . . .
75 lbs. ditto	4242 „ . . .	4317 „ . . .
70 lbs. ditto	4168 „ . . .	4408 „ . . .

86. I shall conclude this section with a list of proportions, most of which, I have no doubt, constitute good gunpowder; but this could not be the case were chemical accuracy of as great importance as complete and perfect manipulation.

	Nitre.	*Char.*	*Sul.*
M. Champy	80	15	5
Poland	80	12	8
Dartford (French analysis) . . .	79.70	12.48	7.82
Bouchet (French)	78.	12.88	9.12
Shooting Powder	78	12	10
M. Champy	77	16	7
M. Chaptal	77	14	9
M. Champy	76	15	9
De Berne, Jun.	76	14	10
Poudre ronde (French)	76	14	10
Austria	76	13	11
Chinese	75.7	14.4	9.9
Brewster's Encyclopædia	75.4	12.8	11.8
Sweden	75	16	9
France (Macquer)	75	15.5	9.5
Do. resumed in 1808	75	12.5	12.5
British Government	75	15	10
Madras	75	13¼	11¾
Russia	70	18.5	11.5
For Mining	65	15	20

SECTION IV.—MANIPULATION.

87. Important as are the foregoing considerations with regard to the purity and proportions of the ingredients, the importance of manipulation is still greater; for whatever may be the perfection of the two former, if neglect, inattention, or unkilfulness occur in this branch of the manufactory, there can be not the shadow of a doubt but the resulting gunpowder will resolve itself into an article of inferior quality. We have just indeed had an illustration of this fact, where neither neglect or inattention existed, but where inferiority occurred merely through a different system of manipulation. (84. 130.)

PULVERIZING.

88. The saltpetre, charcoal, and sulphur are first to be reduced to a state of minute division: the more finely they are pulverized the better they are adapted for the purpose required; especially the sulphur. In His Majesty's works this is effected by cylinder mills and machinery, and the ingredients are reduced to the fineness of an impalpable powder; but if the end be obtained, it is a matter of small consequence how, the simplest and most economical means being the best. At Madras, the charcoal is crushed between metallic rollers, and falling thence into a reel enclosed in a case, is sifted at the same time. This method of pulverizing is simple, effective, and ingenious, and a thousand fold superior to the method formerly in use, viz. by pounding it in uncovered mortars. It is superior also to the cylinder mill.

MIXING.

89. Weighing and mixing the ingredients, in the King's works are done by the same men, in the same department; but at Madras, the two operations are entirely distinct. At Madras, the mixture is made very intimate and uniform, by each charge being worked by hand under a hard wooden roller, for four hours, in a mixing-trough. This process is not simply proper, but indispensable, according to the Madras system of manufacture. At home, the ingredients are merely mixed together by being stirred about in a tub. This operation, indeed, produces neither accuracy nor intimacy of mixture, but compensation is made for it in a subsequent process.

90. In Bengal, mixing is performed by shutting up the ingredients in barrels, which are turned either by hand or by machinery: each barrel contains 50 lbs. weight, or more, of small brass balls. They have ledges on the inside, which occasion the balls and composition to tumble about and mingle together, so that the intermixture of the ingredients, after the process has been gone through, cannot fail to be complete.—The operation is continued two or three hours; and I think it would be an improvement in His Majesty's system of manufacture if this method of mixing were adopted; but in such case, I should apprehend that half an hour's working would be sufficient. The end designed would be simply the attainment of perfect mixture.

INCORPORATION.

91. Whatever be the means employed to produce intimacy of mixture, a closer and more compact combination of the elementary particles is indispensable, in order to impart strength to the composition; in fact, to make it into gunpowder. This is effected by incorporation. The pilon mill is still used by some merchants in England for this purpose.—According to Rees's Encyclopædia, the best Battle shooting powder is still

made in pilon mills; but at Waltham Abbey, as well as at the Honourable Company's manufactories in India, the cylinder mill only is employed.

92. The French incorporate their powder in two ways; the first, by pilon mills, which make 55 strokes per minute, and complete the incorporation of 20 lbs. of ingredients in six hours; and the second, by means of strong barrels, each containing 90 lbs. of bell-metal balls.—The quantity of composition placed in one barrel is 75 lbs. and at from 35 to 40 revolutions per minute: the process is completed in two hours.*

93. At Madras, sufficient incorporation is held to be effected by one hundred revolutions of the mill; but in His Majesty's works, it is not completed under 1350, nor indeed could it be, as the ingredients are there simply mingled together, and not so intimately blended before their incorporation as at Madras. But after this part of the manipulation has been effected, the King's gunpowder is much better incorporated than the Madras; for in the former, there are then no bright particles of sulphur to be seen, on breaking a piece of mill-cake; and the whole mass will be perceived to be exceedingly close and intimate in its texture, and possessed of a fine homogeneous grey colour. This is not the case with the Madras powder. It has not the fine grey colour, but a deep black; and the composition, as well as the granulated powder, has, when compared with His Majesty's powder, an appearance of coarseness.

94. Freedom from specks, and from bright shining particles; greyness of appearance; and a liveliness of the composition during the latter stages of the process, (which last circumstance is perceptible by the powder endeavouring to escape, as if like quicksilver, from the pressure of the cylinders,) are the practical indications by which experienced workmen, at home, judge of the perfection and end of the process. The incorporation is continued until these indications occur, and then the process is

* Aide Mémoire, French ed. 1819, pp. 664, 665.

known to have been properly effected: till then, it is understood not to be complete. It follows, therefore, that the operation is not one of mere arithmetical accuracy, but of some tact: and it was well known, that some of the old mill-men in His Majesty's works made better gunpowder than men newly entertained.

95. In England, two or three pints of water are used for a 42 lb. charge: but the quantity is variable; both the temperature and the humidity of the atmosphere influence it. Sudden changes of the weather have also considerable effect upon the incorporation of gunpowder. The most experienced workmen retard or accelerate the motion of the mill* according to the state of the atmosphere. It is desirable that the exact quantity of water should be mingled with the charge at the commencement of the process; but it frequently requires a small sprinkling after about two hours' working: if the composition be too dry, it will not incorporate. Great attention is paid at home to the quantity of water used: it is considered to have material influence on the goodness and strength of the gunpowder. The rule is, to use as little as possible; but the precise quantity is subject to fluctuation, and can be determined only by experience and practical knowledge.

96. The incorporating-mills at Waltham Abbey are turned by water. They make seven and a half revolutions per minute. The quantity of ingredients laid on a mill at one time is called a charge: it weighs 42 lbs., and is worked for three hours. Hence, from 1300 to 1350 revolutions of the mill result as the regulated degree of incorporation for 42 lbs. of composition. The cylinders are of a dark grey limestone, bearing a good polish, not brittle, nor of easy fracture; they are six feet diameter, eighteen inches thick, and weigh about three tons each. The bed-stone is of the same kind, seven feet diameter, and eighteen inches thick. Calculating the weight of the two cylinders at six tons, it follows, that, in three hours, at seven and a half revolutions per minute, they subject the ingredients

* A water mill, of course, is here alluded to.

to the action of no less a pressure than 8,100 tons. It is this long-continued grinding, compounding, and blending together of the ingredients, that makes most ample compensation for their imperfect intermixture before incorporation, and produces those peculiar appearances spoken of in paragraphs 93 and 94.

97. The gun-metal cylinders at Madras weigh, as nearly as possible, 4½ tons each. The pair of cylinders, therefore, being 9 tons, and the number of revolutions 100, the pressure they exert on the composition is 900 tons. The charge laid on the Madras mill is 60 lbs., about half as much again as that at Waltham Abbey; and at the eightieth revolution of the mill, gunpowder dust from the corning-house is mingled with the composition, and the whole is then worked up and incorporated together during twenty more rotations, to complete the established number of 100; so that the Madras powder undergoes, finally, only about one-thirteenth part of the incorporation of the King's gunpowder.*

98. There is a certain point beyond which it is unnecessary to carry the process of incorporation, but where that point is to be fixed I think it difficult to say, having reason to believe that it differs in different systems of manufacture. The 94th and 96th paragraphs shew how a judgment may be formed as to the ascertainment of the point generally; but they shew also that it is not fixable to any precise arithmetical limit. It may therefore perhaps be thought, that the exact number of 100 revolutions, followed at the Madras manufactory, has more of fancy in it than of judicious practical adaptation; but that it may be known why that particular number was determined on,

* Suppose the 900 tons to be applied *solely* to the 60 lbs. of fresh composition: then, if 42 lbs. receive 8,100 tons of incorporation, 60 lbs. ought to receive 11,571, one-thirteenth of which is very near 900 tons, the degree of incorporative pressure established at Madras.—Perhaps this method of computing and comparing the effects of the cylinders may be objected to mathematically; but I prefer it, as a more popular and easy method of illustrating the position advanced.

I shall give the reason in the words of Captain Bishop, who was the author of the system.

99. "To determine the maximum effect of the cylinders at Fort St. George, 60 lbs. of composition were milled from the rising to the setting of the sun: it was made into powder, proved, and found greatly inferior to that which had only been milled with 100 rounds. The powder so made was kept apart some years, often proved, and as often found of the same inferiority. Let it not be supposed that any loss was sustained of any one, or of all the ingredients; for the composition was, during the whole time of milling and mixing, at that precise degree of humidity which prevented a particle from flying off. This was proceeding to the utmost extreme; this was passing far beyond the maximum; but such was the intention: for it was to begin at this extreme, and reduce the effect gradually to the discovery of that point which suggested the measure. Similar quantities were milled with 1000, 500, 400, 300, and 200 rounds, and found still, in corresponding proportion, inferior. 100 rounds seemed the maximum, though little difference could be perceived, either in the strength or quality, when only 75 rounds were applied. The same effect occurred at 150 and 120; and it being impossible to ascertain the precise quanta of milling required, the maximum was fixed at 100 rounds; and long experience has convinced us that this is as nearly the real one as can be arrived at."

100. The Madras powder, notwithstanding, is not sufficiently incorporated, as is evidenced when it is tried in the 8-inch mortar, with a charge of two ounces: in this method of proof, its inferiority to the English powder is very apparent; and when pressed and glazed, still more so. (130, 132.)

101. In the Aide Mémoire, p. 707, French edition, 1819, may be seen the results of some experiments made in France, in 1816, on the incorporation of powder in pilon mills, whereby it appears that seventeen hours' stamping produced a powder no

stronger than eight hours' stamping. The following were the ranges in metres.

8 hours	260.6
11 „	261.5
14 „	262.6
17 „	258.4

These experiments plainly shew that there is a certain point at which the process of incorporation has attained its maximum, and beyond which the powder derives from it no increase of strength.

102. The practice of mingling the dust of gunpowder with the fresh composition (97) is not in use at home. When there were horse mills at Waltham Abbey, (they have been pulled down since I left England,) they were generally employed in re-working the dust made in the different departments of the manufactory: and the time allowed for working a charge of such dust was one hour and a half. The gunpowder made from this re-worked dust, or meal powder, gains no strength by this additional incorporation; on the contrary, it is not so strong, nor so regular in its effects, as the powder which is made from the fresh ingredients. In favourable weather the dust is sometimes pressed into a solid state without re-working. This pressed dust-cake is harder than pressed mill-cake, and constitutes a very firm and durable grained gunpowder; but both this and the re-worked powder are somewhat inferior to powder made from the original ingredients, owing perhaps to a greater proportionate loss of charcoal, the most volatile of the ingredients, and the most likely to fly off and be lost in the several stages of the manufacture.

103. The forementioned horse mills may be estimated, as to effect, on a par with the bullock mills at Madras; but they were not generally employed for incorporating the fresh composition, being thought for that purpose inferior to the

water mills, although, by their working double the length of time, the number of revolutions made by them nearly equalled the number made by a water mill.

104. Connected with this subject, I subjoin a remark extracted from my memorandum book, made when I was going through His Majesty's works at Waltham Abbey. "I find that in about one hour and a half, a water mill incorporates the composition as effectually as six hours in a horse mill." In these respective periods, the water mill makes 675 revolutions; the horse mill 1080. The remark thus made was simply practical, and had no other observation connected with it, than that it appeared to be desirable for gunpowder mills to have a rapid motion. I am still of that opinion, and strongly impressed with the persuasion, that rapidity of incorporation is requisite, in order to produce gunpowder of the first quality: why, I cannot explain.

105. Pilon mills are said to make good powder; they produce 50 or 60 stampings per minute; their effect therefore assimilates a good deal to the effect of the quick motion of water cylinder mills. The pilon and the water cylinder mill have these properties in common: they compact, compress, blend, and incorporate the composition, the one by a ponderous grinding pressure, and the other by quick heavy collision; the means are different, but the effects produced assimilate. Whenever and wherever practicable, a quick incorporative motion ought to be introduced, and permanently established, in a gunpowder manufactory, for it possesses not only the advantage of effecting what is desired in a superior manner, but it becomes eventually a saving of expense; for less machinery, and fewer buildings for incorporation are required, whatever may be the system of manufacture followed. We think, with reference to incorporation, that the cylinder mill is preferable to the pilon mill, although the French prefer the latter. The following proof trial, made in Bengal last year (1828), shews that the French powder is superior in high practical effect to the gunpowders

made in India, and there is little doubt of its having been made in a pilon mill; for that method of incorporation is, I believe, chiefly followed in France. On referring to an official copy of the proof report, I see the French barrel was marked, P. C. If this mark mean "Poudre Champy," it was probably powder that had been incorporated in barrels; should it be so, it will still serve to illustrate the position advanced, for in that case also, the incorporation is effected by a quick collisive motion: though, unless convinced by experiment, I cannot think this method of incorporation calculated to produce so good a powder as incorporation in a water cylinder mill.

ORDNANCE. Elevation 45°	WEIGHT OF THE Powder. lbs.	Powder. oz.	Shell. lbs.	Shell. oz.	*French Cannon Powder.* yards.	*Ishapore Cannon Powder.* yards.	*Allahabad Cannon Powder.* yards.	*Madras Cannon Powder.* yards.
8-inch Gomer iron mortar .	..	2	68	8	75⅔	56⅔	76⅓	52½
Ditto ditto	1	..	41	11	681	318	557	419
10-inch ditto	1	..	85	13	381	255	354	253
8-inch ditto	1	12	41	11	1589	709	1168	1148
10-inch ditto	1	12	85	13	928	461	671	558

MADRAS MILLS.

106. Compared with the machinery and workmanship of the King's incorporating mills, the mills at Madras are far inferior. Inequalities both in the cylinders and beds would in a moment condemn them at home. They are not, indeed, recommendations anywhere, but they are defects which might progressively be remedied, and at no additional expense; for when a mill might require repair, or to have a new bed, or a new facing to the cylinders, if what had to be done were executed under competent superintendence, there is no insurmountable obstacle to the machinery being made to execute its office as well here as in England.

107. I should think that stone beds would be preferable to metal, even with the present gun-metal cylinders. The metallic beds which are in use at Madras are apt to wear hollow, and to lose their original horizontal position: the metal also, both in the cylinders and bed, wears unequally; I have observed that the softer parts retire, and leave the harder parts prominent. The stone used in gunpowder-mills has not these natural defects; and I have not known a stone bed, once properly fixed and imbedded in the masonry built to receive it, afterwards to deviate from its original position. The surfaces of the bed and of the cylinders ought to be smooth and free from risings and hollows: a gunpowder-mill must be considered to be in bad order if they are not.

108. The contrivance called a plough is an instrument that saves the expense of manual labour; and I see no objection to its employment in an incorporating mill. When well constructed, ploughs are perfectly safe in their use, and effective in performing the office required. At Madras, formerly four men, but now two men, are employed to do what the plough might be made to perform; *i. e.* prevent the composition from spreading to the sides of the bed, and push it towards the centre, so as to be placed in the track of the cylinders. In each mill, the labour of the men thus employed might be saved; but it would not be safe to add this instrument to the Madras mills as they are at present constructed.

109. Ploughs are to be preferred to manual labour, from the constancy and regularity of their operation. These points are of importance in the process; it being essential to its perfection that none of the composition escape the action of the cylinders. Indolence, inattention, negligence, and the want of dexterity, are contingencies that apply not to them; their operation is constant and certain: and in all departments of a gunpowder-manufactory, the less the variation in any of its processes, the greater likelihood there is of the gunpowder resulting of uniform quality, and producing regularity in practical effect.

110. After the incorporation of the ingredients, gunpowder is essentially made. If it be now granulated and dried, it possesses all the strength that the manufacture can impart.

111. The Madras gunpowder is used in this state; but in His Majesty's works, the mill cake is subjected to the operation of pressing prior to the process of granulation; and it is afterwards glazed.

GRANULATION.

112. The necessity of this process results from the inconvenience that would arise in practice from the use of mealed powder, and from the fact that gunpowder in a mass does not explode. If a solid piece of mill cake, or of press cake, be set on fire, it will not flash off in sudden explosion, as it would have done had it been previously reduced to grain,* but it burns with extreme fury. This fact may teach us, that the explosion of a heap of gunpowder is but the rapid combustion of all its parts; that where the fire first takes hold of it, there it begins to burn, and continues to burn until the whole is consumed. This action, however, as is well known, is so rapid, even in a large quantity of gunpowder, that it appears to be a sudden simultaneous burst of flame, though philosophically and truly it is not so. We shall, however, give further consideration to this point, under the section on fired gunpowder.

* The following results occurred in a three-ounce French mortar éprouvette, shell 6¾ lbs., on firing the following charges:

1 ounce of solid English press cake in one piece .	Shell not moved.
1 ounce of ditto in one piece, weight seven-eighths of an ounce, and 4 small pieces .	Shell just tilted out of the éprouvette.
1 ounce of ditto in 9 pieces, weighing 12½ drams, the remainder in small pieces, grain, & dust	Shell thrown 3½ yards.
1 ounce of ditto in 57 pieces	Ranged 10¾ yards.
1 ounce of English cannon powder	Ranged 57 yards.

Therefore, by analogy, we may conclude that different degrees of granulation or fineness of the grain would cause press-cake gunpowder to range all intermediate distances from nothing to 57 yards.

113. The question to be discussed with reference to granulation is this:—Ought the size of the grain to be large or small?

114. In all practical questions concerning the nature and effects of gunpowder, it appears to me that the system of manufacture is so closely connected and interwoven with the result of proof trials, that numberless observations, perfectly true with respect to the particular powder and experiments to which they apply, lose their force and become inapplicable as soon as they are disconnected from the particular view that gave rise to them, and are made universal in their application to all other sorts of powder tried under similar circumstances. Hence arises the difficulty of laying down general principles: and, no doubt, from this circumstance have arisen those frequent contradictions and incongruities which are to be met with among writers on gunpowder. These remarks apply to the present question; for there are experimental facts to support the assertion, that, while the different sizes of the grain make no material practical difference in some powders, they produce very unequal and dissimilar effects in others.

115. The size of the grain is thought by many to be of essential importance; and a writer in the "Bulletin des Sciences Militaires" spends twenty-eight pages of close print, to prove that the grain of gunpowder ought in all cases to be small. But of all useless writing, that on the subject of gunpowder, when disconnected from practice or diversified experiment, is the most profitless.—With reference to His Majesty's powder, the size of the grain appears to be immaterial when used in quantities of 2 lbs. and upwards; but in some instances, when used in smaller quantities, the fine grain ranges further than the large grain.—But neither large nor small sized grain appears to possess any advantage with reference to regularity of practical effect: in any given number of firings, the ranges of the one vary as much as those of the other.

116. The French employ or did employ only fine-grained

powder for all kinds of fire arms; but His Majesty's powder is of two sizes, cannon and musket; and the Baron Dupin says that they now imitate this practice.* Making fine-grained powder only is, according to English usage, more expensive than making large grain: and as with respect to His Majesty's powder no general advantage is derived from the grain of cannon powder being smaller than the established size, it would not be an instance of economy or of good sense to incur greater expense without an equivalent benefit.† How the size of the grain may affect other gunpowders when used in large quantities I have no data to enable me to state, further than what is shewn in the following table, which exhibits a number of ranges of cannon and musket powders of different manufactures, fired with different charges in different pieces of ordnance. It may be remarked, that in each trial the fine grain was fired from the same instrument as the large grain, and that where the mortars are different, though of the same calibre, the word *ditto* terminates, and the denomination of the ordnance is expressed in full.

* "Les Anglais emploient deux espèces de poudres: la grosse sert à lancer les plus pesants projectiles; la poudre fine est réservée pour les petites armes. Déjà nous imitons celle-ci."

† "Small-grained powder is stronger in small quantities, and therefore fitter for musketry; the large-grained powder is better for the charges of cannon, as has been ascertained by experiment."—*Lieut. General Congreve.*

	ORDNANCE.	WEIGHT OF				POWDER.	CANNON, or L. G.	MUSKET, or S. G.	RIFLE, or F. G.
		Powder.		Shell.					
		lbs.	*oz.*	*lbs.*	*oz.*		*yards.*	*yards.*	*yards.*
1	13-inch iron mortar	9	—	200	—	Waltham Abbey	2449	2386	—
2	10-inch ditto	2	—	96	—	Ditto	1003	1002	—
3	10-inch brass mortar	—	—	—	—	Ditto	1500	—	1513
4	Ditto	—	—	—	—	English system of manufacture	1402	1402	—
5	Ditto	—	—	—	—	Madras ditto	1413	1326	1324
6	Ditto	—	—	—	—	Ditto	1448	1460	1414
7	Ditto	—	—	—	—	Ditto	1376	1377	1397
8	Ditto	—	—	—	—	Ditto	1383	1431	1384
9	Ditto	—	—	—	—	Ditto, pressed and glazed	1033	1236	1345
10	8-inch iron mortar	1	—	64	—	Waltham Abbey	671	738	—
11	8-inch iron mortar	1	—	65	8	Ishapore	358	651	—
12	Ditto	—	—	—	—	Allahabad	501	665	—
13	Ditto	—	—	—	—	Madras	449	623	—
14	Ditto	—	—	—	—	Bombay	183	383	—
15	8-inch iron mortar	—	2	64	—	Waltham Abbey	58	58	—
16	Ditto	—	—	—	—	Madras	—	46	—
17	8-inch iron mortar	—	2	65	8	Ishapore	41	41	—
18	Ditto	—	—	—	—	Allahabad	56	42	—
19	Ditto	—	—	—	—	Madras	43	43	—
20	Ditto	—	—	—	—	Bombay	12	20	—
							° ′	° ′	
21	Pendulum éprouvette	—	2	—	—	Waltham Abbey	22.25	26.85	—
22	Ditto	—	—	—	—	Madras	—	23.50	—
23	Pendulum éprouvette	—	2	—	—	Ishapore (mean of 12 firings)	17.29	20.92	—
24	Ditto	—	—	—	—	Allahabad (ditto)	19.48	21.06	—
25	Ditto	—	—	—	—	Madras (ditto)	16.92	20.29	—
26	Ditto	—	—	—	—	Bombay (ditto)	15.22	18.14	—

117. An examination of the foregoing table will not be uninstructive. It shews that when His Majesty's powder is used in large charges the size of the grain makes no difference in the range. And that in smaller charges, for instance No. 10, although the fine grain ranges further than the coarse, yet the difference is but $\frac{1}{10}$th of its range, while in the other powders, Nos. 11 to 14, the variation is about $\frac{1}{3}$ to $\frac{1}{2}$ in favour of the fine grain. The Madras powder also in the higher charges gains nothing by the grain being smaller, except in the case of No. 9, which was an experimental powder. The number of trials here given is not sufficiently large nor diversified enough to draw general conclusions from; I therefore leave them for the reader to form on them his own judgment.—Further exemplification of the effect of coarse and fine-grained powders may be seen in the proof reports under the 6th section.

PRESSING AND GLAZING.

118. Bramah's hydrostatic press, or a very strong wooden press working with a powerful screw, lever, and windlass, constitutes the description of mechanism by which density is imparted to gunpowder. The incorporated or mill-cake powder is laid in the bed or chamber of the press, and separated at equal distances by sheets of copper, so that when the operation is over, it comes out in large thin solid cakes, or strata, distinguished by the term press-cake. The mill-cake powder at Waltham Abbey, in 1829, was submitted to a mean theoretic pressure of 70 to 75 tons per superficial foot. But the friction of the screw in mechanics being very great, uncertain, and variable, it is not easy to determine the absolute degree of power practically applied to the powder by this operation.

* The *slates*, or those pieces of mill-cake on which the cylinders rest while the mill is unloading, are not pressed; they are very hard and dense, and are broken up at once.

119. These cakes, layers, or strata, are broken to pieces by wooden mallets, and reduced to about the size of horsebeans. In this state the powder is taken to the corning-house, where the granulation is completed by throwing it into parchment sieves, arranged on a large frame suspended by ropes at its corners, and turned by means of a crank, which imparts to both the frame and the sieves a rotary shaking motion. Each sieve has in it two solid disks of lignum vitæ, which crush the powder between their edges and the inner surface of the sieve; and the parchment bottoms of the sieves being pierced with holes of the size of cannon powder, allows the grain to escape until the whole is reduced to the proper size.* These sieves fit into other sieves having bottoms of hair-cloth, and by this arrangement the grained powder is retained by the hair sieves, while the dust passes through, and is received in a trough or bin placed beneath the shaking frame.

120. The late Sir William Congreve invented a machine by which the press-cake is crushed between toothed rollers, and at once reduced to grain; so that the operation is both simply and expeditiously performed. I know not what practical objection exists against this piece of mechanism, but I understand it is not in general use at home. The principle is one that for many years I thought applicable to the granulation of gunpowder, and unless there be danger in the use, or it be too expensive, I see no reason why a machine properly constructed might not be made to perform its office both efficiently and satisfactorily.

121. By means of wire sieves of different degrees of fineness the grain is separated and classified. It is then glazed;—the cannon powder, by being shut up for one hour and a half in a long reel or cylinder, covered with strong close-wove canvass, and making 40 revolutions per minute; and the musket and rifle powder, by being enclosed in a large cask or glazing barrel,

* Some pieces, however, resist the action of the disks. These are broken smaller with wooden mallets.

perfectly smooth inside, and working with the same velocity as the reel or cylinder. In either case the abrasion of the grains against one another, and against the inner surfaces of the reel or barrel, breaks off the sharp points and angles, imparts to them more roundness, and finishes by adding a smoothness and polish to their surface.—Such are the operations of pressing, granulation, and glazing.

ADVANTAGES.

122. The susceptibility that even the best gunpowder possesses of absorbing moisture from the hygrometic property of the charcoal, renders pressing and glazing always desirable, and in some cases indispensable. It is essential that gunpowder should not only possess great impellent force when newly made, but that it should retain its force to remote periods.* No other means of effecting this is known at present, than by imparting density to the powder, and a gloss or polish to the surface of the grain.

123. The operations of pressing and glazing preserve the powder; they make it competent to withstand the shaking and friction of carriage, and render it less liable to deteriorate if kept long in store, or if subjected to the influence of humid atmospheres. This cannot be better illustrated than by an extract from the same report of experiments made on Marlborough Downs in 1811, as before quoted. (38.)

124. "Mill-cake gunpowder cannot retain its strength, because the grains are too soft and porous, and in consequence attract moisture like a sponge; mill-cake gunpowder made in the year 1789 ranged this year 3628 yards."

* Lieut.-General Congreve gives the following experiments in illustration of the durability of English government powder. The ranges are those of a 10-inch sea service mortar, loaded with a charge of 9 lbs. of powder.

Feversham Powder, made	1785,	ranged 4319 yards.
Ditto	1809, . . .	4360
Waltham Abbey . . .	1809, . . .	4430

125. "Gunpowder manufactured from hard-pressed cake has a firm close grain, and consequently is not liable to attract moisture: a charge of this powder similar to the charges which were used with unpressed cake powder ranged 4193 yards, although it had been made five years longer than the former."

126. "Moderately glazed powder is more durable than unglazed powder, because the grains are rendered firmer, and less liable to attract moisture."

127. Another advantage which is considered to result from pressing, is equality of projectile effect. When the composition is taken out of the incorporating mill, some of it is hard, like pieces of thick slate; some in pieces that easily crumble, and some in dust. Of course the density is not equal; and as density has a very influential operation in practical results, it is important that equal density, as far as attainable, should be possessed by every grain.—To secure this, the same weight or quantity of powder is, in His Majesty's works, always placed in the press at one time, and the distance that the press is screwed down is invariably the same. Thus equal density must follow as near as practice can effect it. And this is designed to secure the advantage just alluded to, viz. regularity of projectile force when the powder is used in actual service.

DETERIORATION.

128. The benefits of pressing and glazing are absolute: the disadvantage, if so it may be termed, is rather imaginary than real, unless the powder be of inferior quality. These operations interrupt the rapidity of combustion, and therefore in all ordinary cases they impair the propellent force of the powder.—This deterioration has been estimated as high as from $\frac{1}{5}$ to $\frac{1}{4}$ of the range; *i. e.* if a given charge of mill-cake powder ranges 1000 yards, the same charge of the same gunpowder, when pressed and glazed, will range but 750 or 800 yards. This refers to the powder only when newly made; we have just

shewn (125) that it does not apply when it is 20 or 30 years old, for then pressed powder will range further than unpressed.

129. It is a well-known fact, that pressed and glazed gunpowder does not range so far as mill-cake gunpowder. The Honourable Mr. Napier, while superintendent of the Royal Laboratory at Woolwich, found, "from a mean of 600 experiments, that (pressing and) glazing gunpowder reduced its strength about one-fifth, if the powder is good, and nearly a fourth, if of inferior quality." This ratio of deterioration corresponds exactly with an experiment I made on powder fabricated at Madras in 1813, according to the English system of manufacture. The loss of range was a little more than one-fifth, but less than a fourth. But the degree of density, as well as size of the grain, will very much modify the result of experiments made to ascertain the quantity of loss.

130. The following trials, made at St. Thomas's Mount in September, 1829, very fully exemplify the principle under discussion. The powder was of the same quality and manufacture, only one kind had been pressed and glazed, and the other had not. Some English powder was tried at the same time as a standard of comparison. The following are medium ranges.—

ORDNANCE.	WEIGHT OF THE Powder.		Shell.	English Cannon Powder, 1813.	Madras common Cannon, 1829.	Madras Cannon, pressed and glazed, 1829.
	lbs.	*oz.*	*lbs.*			
8-inch iron mortar. .	—	2	65½	124 feet	85 feet	67 feet
5½-inch brass ditto. .	—	2	16	184 yards	131 yards	92 yards
8-inch éprouvette . .	—	3	64	281 „	274 „	200 „
8-inch iron mortar .	—	8	44	294 „	225 „	159 „
Ditto	1	—	—	781 „	560 „	308 „
Ditto	2	—	—	1853 „	1728 „	1001 „

131. These results shew, that from 1-4th to 1-5th of the range is not, in all cases, a sufficient allowance for the loss occasioned by the operations under notice. The variations of

the pressed and glazed powder here, are from about 1-5th to 2-5ths below the range distance of the unpressed powder; but it is proper to remark that the Madras cannon powder is of a large-sized grain, somewhat larger than that of His Majesty's cannon powder, and as the size would no doubt materially affect the ranges of this particular powder, the foregoing deterioration is perhaps greater than what would occur, were the size of the grain reduced somewhat smaller.

132. The very great disparity between this pressed and glazed experimental powder and the English powder cannot fail to be remarked. I believe it is the first time that dense gunpowder of the manufacture of this Presidency * has been brought into immediate contrast with English powder. All the proof trials made in 1813 and 1814, between the powders of the manufactories of Madras and Waltham Abbey, involved the fallacy of opposing a light, porous, unpressed, and unglazed gunpowder, to a powder of great density, the grain of which was of high polish and indurated surface; and therefore the majority of those proofs could not fail to give other than delusive results. The short experiment here detailed will tend to place the characters of the two powders in their true light, and to dissipate the idea that has been so long prevalent of their near coincidence in quality. It cannot fail also to be noticed, how powerful and predominating an influence manipulative processes may exert on the practical effects of gunpowder; and how necessary a thorough knowledge of the subject is, when the quality of different gunpowders, and the relative merits of their system of manufacture, become matter of dispute, and the objects of critical examination.

133. It does not appear necessary to investigate the causes why dense gunpowder ranges short of lighter powder of the same manufacture; it is sufficient that such is the fact. But if it be thought a question of curiosity worth examining into, I think it attributable not to loss of inherent strength, or the less

* Madras.

copious extrication of the elastic fluids, but simply to a delay in their developement. I think that gunpowder of light, specific gravity, ranges further than powder of greater density, only because it explodes with greater facility, for the same reason, to use a homely illustration, that shavings will burn faster than chips, and chips than billets of solid wood. Time, however, reverses this action; the porousness of the light powder makes it more susceptible of injury; it imbibes more humidity than the dense powder, and what it gains in immediate effect, it loses by age and long keeping.

DRYING.

134. The two last operations in the manufacture of gunpowder, are drying and barrelling.

135. Gunpowder should be thoroughly dried, but not by too high a degree of heat; 140° or 150° of Fahrenheit's thermometer is heat sufficient. It appears to be of no consequence whether it be dried by solar heat; by radiation from red-hot iron, as in the gloomstove; or by a temperature raised by means of steam. His Majesty's gunpowder is dried by the two last methods. The grain should not be suddenly exposed to the highest degree of heat, but gradually. The duration of the process will depend on the means employed to effect desiccation.

135 (*a*). Damaged gunpowder, if not too much injured, may be made serviceable by re-drying it, and separating the dust. Before it is dried, it should be passed through a sieve, to break all lumps and separate extraneous matter. When gunpowder is entirely spoiled, the saltpetre may be extracted by solution, by filtering, and by crystallization.

135 (*b*). I transcribe the following curious passages on the drying of gunpowder from official reports made to the Military Board at Madras, in 1801 and 1802. "Gunpowder explodes at exactly the 600° of heat of Fahrenheit's thermometer; at any

degree under this, it will not explode. When gunpowder is therefore exposed to 500 it alters its nature altogether; not only the whole of the moisture is driven off, but the saltpetre and sulphur are actually reduced to fusion. The powder, on cooling, is found to have changed its colour, from a grey to a deep black; the grain has become extremely indurated, and by exposure to even very moist air, it then suffers no alteration by imbibing humidity, [it will not then imbibe humidity.] Gunpowder, therefore, thus dealt with, if well made in other respects, is as near to a state of perfection, perhaps, as it can be brought; the process improves its strength; and by having the power to resist moisture, it will keep for any period of years without caking, or a diminution of its energy."

135 (*c*). "The daring process by which Lieutenant Bishop proposes to remedy the absorption of humidity, by subjecting the powder at its last stage in the manufacture to a heat of 500° of Fahrenheit, for the purpose of expelling all the moisture, and fusing the saltpetre and sulphur, is a bold and happy conception, of which he is entitled to the exclusive credit. We have reason to hope that this process, apparently so full of peril, will abridge the aggregate danger of the manufacture, as the complete moisture of the composition before it is put into the cylinder mill, will entirely remove the apprehension of danger from that part of the work where it has most frequently occurred." It would seem that the state of "complete moisture" is an indispensable condition in this proposed process of drying gunpowder: for if the composition be not very damp, the fusion will not succeed. The process, however, has never been carried into practical operation.

135 (*d*). The following experiment on a sample of gunpowder thus dried is sufficiently interesting to merit insertion. "100 grains of gunpowder, previously fused, were exposed on a sheet of writing-paper during the whole of the north-east monsoon in an open situation facing the north. 100 grains of the same gunpowder, not fused, were exposed in the same situation. The former gained no weight, and of course imbibed no

moisture. The latter was reduced by the moisture of the atmosphere, to nearly the state of paste."

BARRELLING.

136. After gunpowder has been thoroughly dried, it should be passed through sieves, or a screen, or be winnowed, in order both to clean it finally for barrelling, and to cool it. If barrelled while hot it becomes lumpy, and soon begins to adhere and cake together.

137. We may here notice, that the gunpowder made from the original ingredients is thus designated in His Majesty's works—

The cannon powder, as . . .	No. 1, 2.
The musket powder, as . . .	No. 3.
The finest grain, as	S. A.

Gunpowder made from the re-worked dust, or from dust press-cake, is termed—

The cannon powder	L. G.—S. G.
The musket powder	F. G.
The finest grain	S. A. blank.

The cannon powders are usually kept separate, and the barrels marked accordingly. But the musket powder is generally mixed, and the barrels marked thus—No. 3, F. G. S. A. The S. A. blank is an unglazed powder, used for the priming of large ordnance, and other purposes.

138. The best gunpowder being exceedingly susceptible of deterioration, it follows, of course, that gunpowder-barrels should be well made, and of perfectly dry and well-seasoned wood. It has been shewn what great care is requisite, in order to produce gunpowder of superior quality; it would be absurd indeed, if, after this end had been accomplished, the next step should be to destroy it; and this could not more effectually be done, than by finally disposing of the powder by putting it into bad barrels.

139. Having thus discussed the principles of manufacture, an important consideration still remains with reference to the means of ascertaining with certainty the character and quality of the article manufactured. To determine this point with precision involves greater difficulty than might at first be imagined; and as a preliminary step thereto, it will be necessary to consider the nature and action of fired gunpowder.

SECTION V.—ON FIRED GUNPOWDER.

140. Under this head I propose, first, in a few words, to state the force and effects of fired gunpowder; and, secondly, to consider sundry causes that modify its effects, and very much influence the range distances, both of proof trials and of actual practice.

141. The force of gunpowder results from the decomposition of its parts. The more minute those parts are, and the closer their contact, the more vivid their action, and the more powerful the combined effect of the whole. This remark refers to the elementary particles of the mixture, and not to the mere density of the powder, which being produced by pressure, merely brings those particles into closer contact without respect to their previous size. It is the exceedingly fine and minute division of the original ingredients that is here alluded to, their perfect intermixture and incorporation, and their being worked up, embodied, and compounded together into one perfect homogeneous mass. When this is the case, and the ingredients are pure, the gunpowder is as perfect as the present state of science and knowledge can make it.

142. The action of the elastic fluids generated by fired powder, is considered to be the same as the power of steam, or of common air of the same degree of density. The best

authorities represent the force of these elastic products to be proportionate to the space they occupy; that is, they possess only one-half the power, when they occupy a double space; one-third the power, when they expand into a treble space, and so on:—the ordinate ratio decreasing in proportion as the expansion increases; the temperature remaining the same.

143. Mr. Robins states, that gunpowder produces, on explosion, a permanently elastic fluid, occupying 244 times the bulk of the powder; and that its expansibility is increased by the heat of the explosion to about 1000 times the elasticity of common air. "But with far better opportunities," says Dr. Hutton, Tract 37, Vol. III. p. 211, "than fell to the lot of Mr. Robins, we have shewn that inflamed gunpowder is about double the strength that he has assigned to it; and that it expands itself with the velocity of about 5000 feet per second."

144. The explosion of gunpowder confined in a piece of ordnance is generally supposed to be instantaneous; so it is, but not simultaneous; for that portion of the charge nearest the vent explodes before the portion which is farthest from it, and nearest to the shot. This fact cannot fail to be evident from the following experiment. A charge of large-grained powder was fired from a fowling-piece at a skreen of paper ten paces distant, it was perforated by thirty-six grains; but at four paces distant it was pierced with innumerable holes, which could not have occurred, had the explosion of the powder been otherwise than progressive.

145. In theoretic gunnery it is assumed, "that all the powder of the charge is fired before the shot is sensibly removed from its place," but in all large charges this assumption must be false.—Explosion is progressive; for the quantity of power, generated even by a small quantity of powder, is so great, that the shot, as well as the outermost portion of the charge, must be removed before the whole is fired. The flash of a gun is, however, a decisive refutation of such a principle, for flame and light are but the media by which gunpowder passes from a

solid state into its aerial or gaseous elements, and as the flash is seen in large ordnance eight or ten feet distance from the original position of the charge, not only does the shot remove before the whole explodes, but the simple fact of the flash being seen,* proves also that a part of the charge explodes out of the bore of the piece.—I notice this circumstance because it will hereafter be shewn that large charges are unfit to be used in proof trials of gunpowder; and nothing can be a plainer reason why they are unfit, than the fact that a portion of such charges explodes to no useful end, and produces no effect upon the shell or shot.—I now proceed to consider those causes that influence the range both of proof and practice.

DENSITY.

146. The effect of different degrees of density has already been shewn (129, 130, 131); and it having been placed beyond doubt, that specific gravity and glazing have a large influence upon the range; it becomes of course a point of importance in all comparative proof trials to ascertain the respective densities of the powder as accurately and truly as possible.†

147. In order to effect this, the grain ought to be of the same size, and be equalized by being passed through sieves; and perhaps if fine grain were preferred, the real density would be more closely arrived at. But whether the size be large or small, the shape of the grain will modify the result of any experiment made with the view of ascertaining the specific gravity; if it be round, it will pack together closely, whereas, if it be oblong and angular, it will occupy more bulk, and weigh comparatively lighter, though it may probably be of greater absolute density. Thus, from examination, I have no doubt that the Ishapore and Allahabad powders are both denser powders than the Bombay, yet, upon trial, the Bombay powder

* In the experiment with ten grains of powder specified in paragraph 177, no flash was seen, and the solid residue of the powder was found adhering either to the plug of the éprouvette weight, or in the chamber of the éprouvette.

† The degree of gloss or polish imparted by glazing is not reducible to any measure or definable standard. It must be judged of by comparison.

is represented to shew greater specific gravity than either. The former are pressed and glazed powders of an angular-shaped grain; the Bombay powder is a dirty looking powder, of a round grain and irregular size.

148. I may here offer a remark which will be found very extensive in its application, viz. that on the repetition by one person of an experiment made by another, (although the directions how to perform it may have been scrupulously followed, and every minutiæ strictly attended to,) yet, if corresponding results do not follow, it must not be a matter of surprise.—Such failure is a thing of perpetual occurrence, and may in very many cases be with much greater reason expected than not. Such experiments require their results to be confirmed by repetition.

149. In order that as little variation as possible may occur in ascertaining the density of powder, I would recommend the following apparatus, which I think better calculated than the methods generally used for ascertaining that point, though I must acknowledge that neither this nor any other means that I know of is satisfactory in practice.

150. Prepare a conical vessel of the exact capacity of one cubic foot; place it below a frame containing a hopper, or funnel-shaped reservoir, holding somewhat more than a cubic foot, and having an opening at the bottom with a small slide or some other means of retaining the powder.—When the conical measure has been properly placed, open the slide and let the powder pour down quietly into the measure until it be full.—When full, shut the slide, equalize the powder at the aperture of the measure; take at least three several weighings, and let the medium of the whole be considered as the common density. The result may be expressed in avoirdupois ounces.

SIZE OF THE GRAIN.

151. We have before discussed this point, and need in this place only to refer to it. (114 to 117.) One remark, however,

it may be proper to make, which is, that as the size of the grain materially affects some powders, it seems to point out that at least all pressed and glazed cannon powder ought to be equalized before a proof trial, in order to make a fair experiment: I mean, that if one cannon powder be much larger than another, the larger should be reduced to the size of the smaller, or an adequate allowance made for it.

WINDAGE.

152. The high or low gauge of shot or shells,—the regularity or imperfections of their figure,—their want of sphericity,—their oxidation,—and other defects on their surface, may all be classed under the general idea of windage.

153. The almost incredible difference of effect produced by gunpowder when confined closely, and when suffered to escape by windage, or other means, is a circumstance too well known to all who understand practical gunnery to need any particular notice in this place. I will, however, state one instance of the effect produced by irregular figure in the shell, because it fell under my own notice, and because it powerfully illustrates the necessity of great circumspection being used in proving gunpowder, and the errors which may result from the want of it. The case in point was a proof made at St. Thomas's Mount, in January 1814. Two ounces of Madras powder fired in an 8-inch mortar, with a 48 lb. shell, gave the following ranges:

1st fire	85 feet
2d.	174
3d.	132

and the same quantity of fine-grained powder made at Madras, according to the English system of manufacture, gave,

1st fire	105 feet
2d.	183
3d.	216

In both which cases there occurs one range by the same powder more than double the distance of another range; although the same shell was used in all the firings, and the weight of the powder and all other circumstances were alike in each trial.

154. To this may be added the following experiments, which are not less remarkable, the variation in the ranges occurring simply from the use of shells of high and low gauge:

Two ounces of English cannon powder threw an old iron ball of 64 lbs. weight, from an 8-inch iron mortar	108 feet.
All circumstances the same, except using a new brass ball of 64 lbs. weight	308 feet.
One ounce of English rifle powder threw an old iron shell weighing 8 lbs. from a $4\frac{1}{2}$-inch mortar	117 yards.
All circumstances the same, except using a new brass shell of 8lbs. weight	346 yards.

The accuracy of these experiments may be depended on.

ON THE INSTRUMENT OF PROOF.

155. Observe its state, whether it be new or old; but little used or much worn. If it be of the same denomination as some other instrument in which a course of experiments has been carried on, and if it be intended to repeat those experiments with the expectation of arriving at the same results, see that the bore, calibre, weight, and every particular is exactly the same as in the instrument in which the original experiments were made. Every minutiæ ought to be attended to with a care and scrupulosity bordering on fastidiousness; and even then there are many probabilities against the results of the second experiment being the same as the first, particularly if the two trials be made by different persons with different instruments. It may be here observed, that the common expression of the strength or quality of gunpowder, by representing a certain weight of it to project a shell from a given sized mortar a certain number of feet or yards, is quite fallacious, and not in the least to be depended on. To fix the

proof range is a point of great difficulty; and in order to it, the most exact and careful description of the ordnance ought to be given. I shall exemplify some of these remarks by what follows. I have known two ounces of the same gunpowder to give the following results in different 8-inch mortars:

One medium trial (iron mortar)	150 feet.
Ditto. Ditto. Ditto.	220
Ditto. Ditto. (brass mortar)	353
Two ounces of English cannon powder ranged in a pendulum éprouvette at Waltham Abbey	20°.15′
The powder and instrument of proof were then sent to India, and two ounces of the same powder ranged in the same éprouvette at Madras .	21°.31′

In the experiments made in Bengal in 1828, and repeated at Madras in 1829, the following discrepancies occurred in like denominations of ordnance.

CANNON POWDER Fired in an 8-inch iron Gomer Mortar, with a ball weighing 65¼ lbs.	Ishapore	Allahabad	Madras.	Bombay.
In Bengal, 2 ounces ranged .	41 yds.	56 yds.	43 yds.	12 yds.
At Madras, ditto . . .	23 „	31 „	28 „	10 „
In Bengal, 1 pound ranged . .	358 „	501 „	449 „	183 „
At Madras, ditto	393 „	357 „	460 „	188 „
In Bengal, 1½ pound ranged .	721 „	1042 „	1135 „	407 „
At Madras, ditto	927 „	903 „	1204 „	513 „

These instances may suffice to shew, that even in the same denomination of ordnance and with an equal charge, the same gunpowder will not always give corresponding results. To say, therefore, that a given weight of gunpowder in any particular piece of ordnance will range a given distance, is not correct. See also paragraphs 154 and 168.

LOADING.

156. A difference of 10 per cent. in the range has been known to occur according as the powder was carelessly thrown into the chamber of a mortar, or carefully packed or piled up in it as close to the vent as possible. Nor should attention be observed in loading only, but after the proof instrument has been charged, it should be fired as quickly as possible. In some proof trials I have known the mortar to be washed out with water and wiped dry: but however dry it may be wiped, unless the piece be very warm, a dampness will remain; and should the charge be deposited only for a few seconds in a damp receptacle, it will be influenced by it. On the other hand, if the piece be much heated, the charge, if not soon fired, will derive considerable benefit from the heat, and so in either case there will arise a cause of irregularity.

POWDER.

157. If in comparative proof trials the hygrometic state of gunpowder could be ascertained by some common well-known hygroscopic standard, it would be highly desirable; but as this is not practicable in consequence of hygrometers being made in a great variety of ways, and having no common measure for zero or unity, the usual method of determining this point is to expose the powders under experiment to the sun, or to any degree of heat common to them all; and the difference of weight before and after exposure indicates the humidity of the powder. It is best, however, to expose a weight of 100 or 1000 equal parts, and to denote the difference in decimals, such a method of notation being the most convenient for comparison.

158. Humidity and dryness are well known to exert a great and opposite influence on gunpowder; and when it is heated by artificial means, and fired while it possesses a high temperature, the range is amazingly increased. As it may sometimes

occur in practice that a longer range may be required while any addition to the charge might not be made effectual to promote it, it may be useful to state an experiment which seems to point out that the same weight of powder will produce this result, if it be only allowed to acquire an increase of temperature before it be used.

One ounce troy of powder fired in a 4½-inch mortar, shell 8lbs, gave a medium range of . . . . 141 yards.*

One ounce of the same powder was heated in a copper pan to about 400° of Fahrenheit's thermometer, and then fired as before—it gave a medium range of. 242 yards.

159. I would not advise any of my readers, as practical men, to attempt heating gunpowder for any exigency of the service to the degree of 400° of Fahrenheit's thermometer; but they might with singular propriety practise the suggestion contained in the following judicious remarks made on this experiment by a Committee of the Military Board at Fort St. George, appointed in 1802 to report on Captain Bishop's Memoir.

160. "The astonishing effect of heat on the power of gunpowder to the extent of doubling its projectile force is correctly stated by Mr. Bishop.—After finishing our proofs of the various sorts which we examined, the powder being usually kept during the experiments in the ordinary temperature of a cocoa-leaf shed, at the same hour of the day; we have occasionally exposed a charge to the heat of the sun for a few minutes before being used, and the range has been invariably increased in a remarkable degree in proportion to the time of exposure and the heat acquired. In many cases of actual service, where the quality of gunpowder is defective, or the quantity insufficient, an officer may be enabled to prolong a defence, or to complete the operations of a siege, by a due attention to this interesting fact, and our president will take care that it shall be particularly impressed on the attention of the officers of the coast artillery."

* Captain Bishop's Memoir, 1801.

OBSERVATIONS.

161. I made experiments with the view of ascertaining whether good gunpowder on explosion always produces an equable power, and though I did not succeed in establishing the fact, yet I think the probability is in favour of the supposition, and that the variations which occur in practice are attributable more to the instruments made use of than to innate variableness in the power employed. The regularity of recoil, and the small difference in the arc of vibration in every successive trial of good powder in the pendulum éprouvette, would seem to indicate in gunpowder a very near approximation to equability of explosive power.

162. Suppose the question granted; allow the power generated to be constant and uniform, yet while there are so many disturbing causes to modify the projectile force of gunpowder, it is quite hopeless to expect constant and uniform results either in practice or experiment. We will collect these disturbing influences into one condensed view, in order to judge of the sum total of their power. We have already noticed, density—size of the grain—windage—particulars concerning the instrument of proof—loading—and the state of the powder. We may subjoin as collateral circumstances, occasional or accidental oversight in the manufactory; want of purity in the ingredients; irregular mixture; variable density in the same powder; imperfect incorporation; irregularity in the size of the grain; bounding of the shell or shot in the bore of the gun; its manner of rotation; influence of side or oblique winds; the influence of wind in other directions; and the resistance of the atmosphere, which may vary in different trials from the same instrument if the projectile be not a perfect sphere and free from asperities on its surface. All of these, and perhaps other circumstances added to them, may, in comparative proof trials, exert their single or united influence to disturb and modify practical results; and then is to be superadded the difficulty of ascertaining which of these disturbing causes acts most powerfully, and which not at all; and to crown the whole comes the

utter impossibility of apportioning the precise ratio of allowance to be made for all, or each of them, or for any combined number in any particular case.—If we attach to these considerations the importance that is really due to them, we shall see that those singular difficulties* in the proof of gunpowder which seem to constitute anomalies at variance with any known and acknowledged principle, and which are so discordant among themselves, as to appear beyond the reach of being satisfactorily accounted for, are not altogether so extraordinary as might be imagined, although they do frequently most completely baffle every attempt to apply to them any reasonable principle of explanation.

SECTION VI.—PROOF OF GUNPOWDER.

163. Gunpowder is invested with difficulties, from the earliest stage of its manufacture to the very last result obtained by trial for ascertaining its explosive powers. And the many methods that have been invented, and that are still in use for proving it, constitute a sufficient testimony of the difficulty attending this indispensable, final check upon its manufacture.

164. To conduct proof trials with skill, especially of gunpowder of different kinds, and of unknown systems of manufacture, a comprehensive knowledge of its nature and action is necessary, both in order to guide the experiments to results that are satisfactory, as well as to deduce from them conclusions that are substantial, and which may be with confidence depended on. In proving gunpowder, as has just been observed, extraordinary discrepancies sometimes take place that seem to defy reconciliation: and indeed the results are often so capricious, singular,

* See paragraphs 169 and 181.

and unexpected, as to make it sometimes altogether impossible to account for them. But though this be the case, I yet think there can be but little doubt that no apparent anomaly is an absolute departure from fixed principles, but rather an effect which results as harmoniously from established causes, as any phenomenon that occurs among the better known, and more widely diversified operations of nature. The difficulty lies in discovering the causes of irregularity;—to apply to them known and acknowledged laws adequate to their solution would not probably be difficult, were they but once discovered.

165. I am of opinion that the true principles on which gunpowder ought to be tested or tried, as to real strength and quality, have been much misunderstood, or, if known, the knowledge has been far from general. The French certainly do not appear to have hit upon the true method, by confining gunpowder closely, as in their mortar éprouvettes; for in these instruments there is not a very material difference of range between powder which is very good and that which is very bad. The English government method of proof approximates much more closely to true principles, and is certainly better adapted to shew the real quality of powder than the French éprouvette. I shall not however anticipate our subject; these relative methods will come in due course under consideration. It is nevertheless a matter of first-rate importance to determine what the particular manner of proof is which may be depended on, and I hope to establish that point in the course of the present section.

166. It would be a singular advantage if any single trial could be devised which, in itself, would be decisive and satisfactory; and calculated to shew accurately the real explosive force, as well as the practical and available effect of gunpowder; a method on which dependence could be placed, as being indicative of the general consequences that would result in practice, whatever might be the nature, quantity, or quality of the powder employed. But I know not of any one single experiment that possesses the property of exhibiting these points satisfactorily, or even in a manner approximating to truth. The general

objection against every single existing mode of trial is, that whatever be the result it may give when two powders of different systems of manufacture are compared together by it, accordant results do not follow if the same powders be tried, generally, with service charges, in the several denominations of ordnance used in war.

167. The practical artillerist, on whom usually devolves the office of ascertaining the proof range of gunpowder, will perhaps wish for simplicity, and for the specification of some single easy trial by which he may ascertain not only the actual range of powder, but judge of its quality or capability of producing any particular given effect he may require. I have just stated that I know of no such trial. Such knowledge can be ascertained only by actual experiment with the powder he has to make use of. Its range-distances must be determined from practice. And this remark, I apprehend, will hold good universally, whether good gunpowder be used or bad. To ascertain its range-distances the artillery officer must make the experiment for himself, and it is more than probable, it is almost an absolute certainty, that he will have to do this as often as he uses a different gunpowder and a different piece of ordnance. Gunpowders will not range alike, nor will different pieces of ordnance, though of the same denomination, range alike (155); and therefore the mere proof of gunpowder can afford no further criterion for the guidance of actual service, than as it gives the range-distance of the particular charge, in that particular piece of ordnance in which the proof was made.

168. Let me be allowed here to offer an especial caution.—Equal range has often been mistaken for equal quality.—This is a great error, if applied universally. I shall hereafter, as we come to them, specify the particular cases in which, if different gunpowders range equally, they may be regarded as equally good: but, to establish the position that the distance to which any powder may project a shot or shell is not a criterion of its quality,* unless under particular circumstances, I shall give the

* See also paragraphs 154, 155, 181, 184, 204.

comparative results of several experiments made between the English and the Bombay powders; the range of the English powder being taken in every case as unity, and the range of the Bombay powder reduced to its corresponding fraction; observing only that I commence with one trial in which the Bombay powder ranged equal to the English.

DESCRIPTION OF ORDNANCE.	WEIGHT OF				English cannon powder	Bombay cannon powder.
	Powder.		Shell.			
	lbs.	oz.	lbs.	oz.	Relative ranges.	
24-pounder iron gun	8	—	23	10	1.00	1.00
8-inch French éprouvette	—	3	64	—	1.00	.88
Pendulum éprouvette	—	2	—	—	1.00	.76
10-inch iron mortar	2	—	85	8	1.00	.49
8-inch ditto.	—	2	64	—	1.00	.28
Ditto ditto	1	—	41	10	1.00	.24
5½-inch mortar	—	2	16	—	1.00	.22
10-inch iron mortar	—	2	96	—	1.00	.13
8-inch French éprouvette	—	½	64	—	1.00	.09

169. In the course of this Section, the whole or the greater part of the actual ranges of the above trials will be alluded to and specified in illustration of certain positions. I have preferred the decimal notation of them here for the convenience of comparison, and to shew that though a bad powder, which in one case ranges as far as an acknowledged good powder, yet in another method of trial ranges not a half, or a quarter, or a tenth, but actually only an eleventh part (0.09) of the distance of the same powder to which it was equal when used in large quantity. I scarcely think it possible to give a more powerful or satisfactory confirmation of the point to be established; nor can there be any thing clearer than the inference to be drawn from it, viz. the circumspection required in deciding on the quality of different gunpowders from particular trials. It is evident that with a knowledge of this fact certain methods of proof could be selected, in which inferior gunpowder, especially if unpressed and unglazed, would give as high a range as the best, and with all the details of the experiment on either side conducted with perfect fairness; but the results of such a proof would be most delusive.

DEFINITIONS.

170. Before we proceed further it may perhaps be necessary to define two or three terms hereafter to be used in a more particular and determinate sense. They relate to those points to which the attention should be expressly directed in proof trials of gunpowder, viz.

1 Its real inherent strength.
2. Its practical or available force.
3. Its manipulative quality.

171. The absolute inherent strength of gunpowder is not perhaps to be ascertained at all, by trial, in any instrument, or piece of ordnance in common use. Bad gunpowder, by exploding slowly, would require to be confined by an enormous superincumbent weight, in order that the whole might, if possible, be kindled before the resisting obstacle began to move. In a proof of this nature, a particular kind of instrument must be used; and there are grounds for belief, that in such a mode of trial, the results would depend more upon the chemical constitution of the powder, than on its manipulation, which is directly contrary to the usual results of practice. By ascertaining the real inherent strength of gunpowder is therefore intended, *that* mode of proof, or those methods of proof, by common ordnance, in which gunpowder of good quality will produce a much higher range with a small charge than bad gunpowder, although the latter may, and will in some particular cases, and under certain circumstances, range as far as the former, or further.

172. The practical or available force of gunpowder means, in other words, the absolute ranges it will give in ordnance and artillery of all sizes and denominations, with all the diversified multiplicity of charges used in actual service. The ascertainment of these range-distances belongs to the department of practical gunnery. The proof of gunpowder aims only at an approximation as to general effect. Actual range-distance may

therefore be considered synonymous to the term, practical or available force.

173. The manipulative quality of gunpowder is an expression employed to include several ideas, viz. the purity of the ingredients; the perfection or imperfection of their mixture; the degree of their incorporation; and the specific gravity of the powder. How the whole of these points are to be ascertained or judged of, will be shewn hereafter.

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174. We may now proceed to examine the merits or defects of the various instruments at present in use for proving gunpowder; and first,

OF VERTICAL EPROUVETTES.

175. In the common vertical éprouvette the powder acts by sudden blast and impulse: the superincumbent weight immediately rises, the flame escapes, and a great part of the strength of the powder is thereby lost. The established objection against this method of proof is, that the powder cannot act by its pressure, and that therefore the instrument is not adapted to exhibit accurate results. Four drams (109 grains) of powder, in the vertical éprouvette used daily in His Majesty's works at Waltham Abbey, raised the resisting weight, about 25 lbs., on an average 3 inches and a half high.

176. That fired powder might act by its pressure, and that the foregoing objection might be obviated, I constructed a vertical éprouvette on the principle of the common brass mortar, having a cylindric chamber sufficient to contain 100 grains weight of powder. The superincumbent weight, or resistance to be raised, was 500,000 grains, upwards of 71lbs avoirdupois. It was made to slide in upright guides, and had a plug below it that fitted the bore of the éprouvette as nearly air-tight as possible. The idea I had was, that by firing a charge of only 10 or 20 grains, this instrument would shew the absolute inherent force of any kind of gunpowder; and that, as the resistance exceeded

the weight of the powder in so very large a proportion, it would afford great accuracy of result. But my expectation was disappointed, for the results were in proportion as variable as in common trials, and the ranges such as could not be depended on. I therefore abandoned it.

177. This éprouvette, however, afforded convincing testimony of the immense increase of effect produced by closely confining gunpowder, as well as the loss of power occasioned by windage. We have seen (175) that 109 grains of His Majesty's powder ranged 3 inches and a half high: only 10 grains in this instrument raised a threefold greater weight more than 12 inches. But the experiment is perhaps worth being recorded.

HIS MAJESTY'S RIFLE POWDER.	Eprouvette as nearly air-tight as possible.	Eprouvette with $\frac{1}{100}$ part of an inch windage.	Proportion of the superincumbent weight to the powder.
1.	2.	3.	4.
10 grains . . .	12.70 inches	3.4 inches	as 50,000 to 1
20 ditto	31.48 ditto	19.15 ditto	as 25,000 to 1
30 ditto	46.07 ditto	27.80 ditto	as 16,667 to 1

178. The first column shews the weight of the powder; the second, the range of the éprouvette when air-tight; the third, the range when it had a little windage; and the fourth, the number of times the weight to be raised was greater than the weight of the powder. A comparison of the second and third columns, shews the great loss of power that arose from an alteration in the plug, which reduced it to the one-hundredth part of an inch smaller than the bore. The difference of effect produced by powder in this éprouvette, and by the 109 grains in the common éprouvette, is exceedingly disproportionate, and the loss of power, by a very trifling degree of windage, remarkable.

179. But the chief objection against this instrument, and I apprehend against all instruments constructed on the same

principle, is, that the results given are not to be depended on,* and the discrepancies are such as to form part and parcel of those discordancies which have before been alluded to (162, 164).—I think this representation is fully borne out by the following memorandum.

ORDNANCE.	WEIGHT OF		CANNON POWDERS.		
	Powder.	Shell.	English	Allahabad.	Bombay.
	grains.	*lbs.*			
Vertical* éprouvette, see par. 176	30	—	30. in.	34. in.	28.8 in.
	oz.				
8-inch mortar éprouvette .	3	64	288 yds.	217 yds.	255 yds.
5½-inch mortar	2	16	175 „	134 „	38 „

180. These are all the same opponent powders, but although the vertical éprouvette represents that of Allahabad to be superior to the English, the other two trials shew it to be inferior.—Observe also the high range of the Bombay powder in this, as well as in the mortar éprouvette; and again, notice how discordant the result is which it gives in the 5½-inch mortar.—I could multiply examples of these discrepancies, but let these suffice to shew that the vertical éprouvette exhibits fallacious results.

MORTAR EPROUVETTES.

181. French mortar éprouvettes are very much like the common eight-inch brass mortar, only that they have small chambers which contain no more than a given small quantity of powder; for instance, two or three ounces; and from the quantity which they contain comes their denomination, the two-ounce or three-ounce éprouvette. The shot is of brass,

* "Nothing could be more deceptive than the former mode [of proving gunpowder] by the vertieal éprouvette, in which a soft and rotten grained powder would produce a much greater effect than the hard and good serviceable powder."—*Lieut-Gen. Congreve.*

or of gun-metal, fashioned accurately to the shape of a sphere; it weighs sixty-four pounds,* and has one-tenth of an inch windage. These instruments produce a high range, on the principle that the force of gunpowder is proportionate to the space it occupies (142); but they are not adapted to ascertain the true strength of gunpowders of different modes of manipulation, as the following proofs testify, viz.

POWDER.	WEIGHT.	ORDNANCE.	RANGE.
	ounces.		
Bishop's rifle	2	2-oz. éprouvette	215 yards
English L. G.	—	64-lb. brass ball	208 "
Bishop's rifle	2	8-in. mortar	75 "
English L. G.	—	64-lb. brass ball	117 "
Bishop's rifle	2	5½-in. mortar	130 "
English L. G.	—	16-lb. shell	211 "

182. The first of these trials only was made in the mortar éprouvette; the others are inserted for comparison. The powders were the same in each trial. It will be seen how different the results of the mortar trials are, compared with that shewn by the éprouvette. It is not necessary here to offer any comment on this discrepancy, my object being merely to shew that these éprouvettes give results which cannot be depended on.

183. There appears, however, to be an exception to this remark; but the exception constitutes a departure from the original design of the instrument.—If a very small charge of powder be used, these éprouvettes may be employed to ascertain the real inherent force, as well as the practical effect of gunpowder. I speak without the support of direct experiment; but I think it probable that when these instruments are fired with their full charge, they may possibly exhibit the general effects of gunpowder, when it is used in actual service, in fieldpieces, and in large ordnance. I speak only from analogy, but I think it likely a full charge would pretty nearly indicate the relative

* This precise weight varies in different instruments, and so does the degree of windage.

practical ranges of different gunpowders in artillery—that with their chamber one-half or one-third filled, they would shew the relative ranges in large mortars with medium charges, and that fired with only half an ounce of powder, they might be very well used for ascertaining the absolute inherent force and explosive quality of gunpowder generally. It would be well worth the trouble of the experiment, to ascertain if these ideas be at all borne out by actual practice.

184. These éprouvettes constitute the national system of proof in France; and they are also used in different parts of the Continent of Europe. With the modifications just suggested, I think they may be usefully employed for ascertaining the quality of gunpowder; but in the manner they are always used, I have very substantial grounds for asserting that they give unsatisfactory and false results. In the instance of unpressed and unglazed powder tried against powder of greater density, they exhibit a range frequently in favour of the unpressed powder (181), while other trials, on which dependence may be placed, plainly testify its inferiority; nay, reduce but the charge to a low degree, and the same instrument will then bear the same testimony also. The following trials may be adduced in support of what has been stated in this paragraph, and I think that to reconcile their variations would be found extremely puzzling.

CANNON POWDER.	WEIGHT OF		ENGLISH, 1813.	MADRAS, 1825.	BOMBAY, 1825.
	Powder	Shell.			
	oz.	lbs.			
8-inch éprouvette .	3	64	288 yards	279 yards	255 yards
Ditto	1	—	57 „	50 „	23 „
Ditto	½	—	33 feet	15 feet	3 feet

THE PENDULUM EPROUVETTE.

185. Hutton's vibrating or pendulum éprouvette, is a small cannon, suspended from an axis on which it moves freely: it

indicates the force of gunpowder by the degee of recoil, which is measured by an arc of the circle attached to the instrument. It constitutes a good method of trial for a manufactory, when once the standard range has been fixed; but it fails, like all other modes of proof, to indicate a result which may be relied upon as to the absolute quality and general effect of gunpowder. Indeed, it fails to give the real force of gunpowder of the very same manufacture, in which the ingredients are the same, and every thing alike, except a difference in the size of the grain: for instance—

Two ounces of English cannon powder ranged . .	° ′ 22.25
While musket powder from the same cannon powder ranged	26.85

Again, with reference to powders of different manipulation, it gives a smaller result to the best powder, as is shewn by the undermentioned trial.

KIND OF POWDER.	Hutton's Eprouvette.	8-inch mortar, 2 oz. powder.	10-in iron mortar, 2 lbs. powder.
	° ′		
English cannon powder, 1813 .	22.25	58 yards	1003 yards
Experimental powder, 1829 . .	22.92	39 „	889 „

186. The English powder, in the first case, ranges a little below the experimental powder, though the two other trials establish its superiority; particularly as the experimental powder was new, and unpressed, and unglazed, and of a somewhat finer grain, while the English powder had undergone the operations of pressing and glazing, and was, besides, sixteen years old. The smaller size of the grain was indeed an advantage to the experimental powder, and perhaps the cause of its ranging so high; but an instrument, influenced so much as this éprouvette is by accidental causes, can never be considered a true indicator of the goodness and strength of gunpowder. Might not the position of the vent in this instrument be altered

with good effect? If the charge were to be fired in front, instead of in the rear, the whole of it must of necessity act upon the piece, and none would be blown out unconsumed;—a point of importance in the proof of gunpowder.

COMMON MORTARS.

187. The method of trial best adapted to shew the real inherent strength and goodness of gunpowder, appears to be an eight or ten-inch iron or brass mortar, with a truly spherical solid shot, having not more than one-tenth of an inch windage, and fired with a low charge. The eight-inch mortar, fired with two ounces of powder, is one of the established methods of proof at His Majesty's works. Gunpowders that range equally in this mode of trial may be depended on as being equally strong. Proof trials made in this manner, though necessarily affected in some degree, are not so much influenced as others, by the different sizes of the grain, or degrees of density of the powder, or other disturbing causes arising out of the system of manufacture. I have shewn in the last paragraph the variation that Hutton's éprouvette gave with gunpowder of the same manufacture, differing only in the size of the grain; but perfect similarity of strength in the same gunpowder was indicated by the mode now spoken of: thus,—

English cannon powder, two ounces, ranged .	58 yards
Musket powder from do. ranged also . .	58 do.

188. Large and small-grained gunpowders will not, however, by any means, constantly range with the perfect similarity indicated by the foregoing instance: but it appears to me that this method of proof for fine grain is not necessary; for as fine grained powder is not intended to be used in ordnance, there appears to be no good reason why it should be tried by it.

189. For cannon powder I think the eight or ten-inch mortar the best practical mode of proof at present known; and the reason is, that when used with a low charge; out of a great

multitude and diversity of experiments, I know not of a solitary instance in which it has failed to exhibit a superiority on the part of superior gunpowder, and an inferiority with respect to inferior gunpowder; although, as I have before shewn, this result is not a necessary consequence in all cases.

190. The propellent power of gunpowder being the result of the decomposition of its parts, it appears evident that no proof can be depended upon as a test of quality, unless it be one in which all the parts ignite before the projectile is moved. If the resisting obstacle commence its flight before the entire combustion of the charge, the quantity of space it passes through at the period of total deflagration will vary in different powders, and be dependent on the system of manipulation; and as the force or power of fired gunpowder is in proportion to the space it occupies (142), it might easily be demonstrated that in some methods of proof, especially that of the French mortar éprouvette, a small difference in the motion of the shell at the moment of the final explosion of the charge will make a great difference in the range; the results will therefore, in such case, be uncertain, and the proof, as a test of quality, fallacious.

191. In the mortar trial, with a small quantity of powder, I think it almost certain that the whole is in a state of ignition before the shot or shell is sensibly moved. The chamber of an eight-inch mortar is formed to contain two and a quarter pounds of powder: when, therefore, only two ounces are placed in it, there is left an unoccupied space equal to sixteen or seventeen times the bulk of the charge. Consequently, upon explosion, the sudden blast of the first portions that ignite displaces the remainder, which is blown about, dispersed, and scattered throughout the chamber of the mortar, and would escape were it not retained by the shell; but meeting with this opposition it receives a momentary check, while, at the same instant, being penetrated and enveloped on all sides by the flame already generated, it immediately kindles and explodes: and so the whole force of the charge acts simultaneously on the opposing obstacle, and propels it to

a distance proportionate to the absolute inherent strength of the powder. This illustration I think holds good whether the powder be pressed or unpressed, hard or soft, fine or coarse; so that the operations of pressing and glazing, and other disturbing causes, appear to be immaterial, or at least are of less consequence in this than in other modes of proof, as to the result. Sufficient space to explode in, appears to be the true principle on which cannon gunpowder should be tried as to its strength and quality.* Whether the powder be bad or good the test is equally fair, in either case, and therefore unobjectionable; and actual experiment most amply testifies that inferior gunpowder, so situated, invariably ranges below gunpowder of superior quality, which is, as I have just observed, a result that does not necessarily take place in other modes of trial.

192. It may, however, be objected against this test, that there is something in it not properly understood, which occasions gunpowder of a particular system of manufacture to give higher results than other powders, though service-charges shew them to be in no way its inferior; and that therefore service-charges constitute the true test of quality, and not any special or picked method of proof. I answer, it has already been proved that different operations in the manufacture make a wide difference in practical effect; therefore, in judging of the quality or goodness of different gunpowders, regard to the system of manufacture is imperatively required: it cannot be disregarded and put aside as a point of unimportance. But, if the one powder be in no way inferior to the other, of what consequence is the manner in which it be tried, whether by service-charges or by any other? Equal causes produce equal effects, and will do so in all cases and under all circumstances; but if causes supposed to be equal vary in some of their results, it may be considered certain that a fallacy exists in the supposition entertained respecting their equality. If, in any case, one gunpowder will

* Musket or fine-grained powder may also be proved in the same way; but the methods proposed in paragraph 264 appear to be preferable.

project a shell double or quadruple the distance of another, there is strong evidence of inferiority on the part of one of them; and if the inferiority should by chance appear to be on the side of the best powder, which seems paradoxical, I know only of two ways of accounting for it; viz., either by injury sustained, or by giving it such an excessive and unusual degree of density as is never likely to occur in practice.

193. I shall here adduce several examples of the relative inherent strength of the Indian powders as exhibited by the principle of trial now under discussion, and compared with His Majesty's powder as the standard of quality. I have only to remark, that I have no doubt if all the powders were to be tried in an 18 or 24-pounder gun, with a full-service charge, at an elevation of 1½ or 2 degrees, the difference of range between any of them would be hardly worth notice. Such has been the case with them heretofore, though not with the particular powders here experimented on.

ORDNANCE.	WEIGHT OF				CANNON POWDERS.				
	Powder.		Shell.		English, 1813.	Ishapore, 1825.	Allahabad, 1825.	Madras, 1825.	Bombay, 1825.
	lbs.	*oz.*	*lbs.*	*oz.*	*yards.*	*yards.*	*yards.*	*yards.*	*yards.*
8-in. iron mortar	—	2	64	—	62	33	37	43	18
10-in. ditto .	—	2	96	—	26	18	20	18	3½
8-in. ditto .	—	2	65	8	41	23	31	28	10
10-in. ditto .	1	—	87	—	425	287	286	295	84

The sixty-four pound shell was of brass; all the others were of iron.

194. Let it be understood that this method of trial (187) is a test only of what I have denominated the real inherent strength

of gunpowder, and not of general practical effect; for powders that range very differently in this proof may yet range alike with high-service charges. I know nothing more baffling or difficult than to determine in what the real inherent strength of gunpowder consists, or how it is to be ascertained (171); but I have preferred fixing it to the present test, thereby giving it locality, than to use the expression in a general and undefined sense, and making it consequently altogether unintelligible.

195. In a scientific examination of the quality and strength of gunpowder, there are other points to be attended to besides mere range-distance; but as actual range is, at last, the *sine quâ non*, the indispensable requisition of practice, it follows that trial by service-instruments is eventually the only final test to which gunpowder ought to be substantially submitted: for, however ingenious other instruments may be, if their indications are not to be depended on in actual service, the results they give must be considered but trifling and unsatisfactory, and of no real value. The established method of proof at St. Thomas's Mount, with a ten-inch mortar, ninety-six pound shell, and two pounds of powder, is therefore a very good test; but it must be borne in mind that it is not at all indicative of the absolute good quality of gunpowder. It answers well both for the purpose of ascertaining that no declension occurs in the manufacture, and to determine the practical effect of a large charge; but it by no means points out the real quality and goodness of the article manufactured. Captain Bishop appears to have established this proof in 1801, or to have confirmed the use of it; but his opinion of it, after he returned from Europe, where he had opportunities of acquiring more accurate information, was not what it had been, but is thus expressed in a letter to Lieutenant-Colonel Frith, dated March 2, 1824. "Our mode of proof is not dependable. It is rude and inaccurate. There are causes which may make very strong powder appear inferior to that which is weak. This, however, can never be ascertained with a ten-inch mortar and two pounds of powder. Some other time, perhaps, I will offer you an explanation of this paradox."

CARBINE PROOF.

196. A musket or carbine barrel is fitted up in a strong framing, loaded with four drams of powder and a steel ball, and fired against wet half-inch elm boards, or boards of any tough wood, sliding into grooves in a box, three quarters of an inch distant from one another, and the first thirty feet distant from the muzzle of the barrel. The usual range is the penetration of from fourteen to sixteen boards. This is a good method of proof for musketry and rifle powder; and I know of no practical objection against it.*

FLASHING.

197. Four drams of powder are laid in a small neat heap on a clean, polished, copper plate. The heap is fired at the apex by a red-hot iron. The explosion should be sharp and quick; not tardy nor lingering; it should produce a sudden concussion in the air; and the force and power of that concussion ought to be judged of by comparison with that produced by powder of known good quality. No sparks should fly off, nor should beads, or globules of alkaline residuum, be left on the copper. If the copper be left clean, *i. e.* without gross foulness, and no lights, *i. e.* sparks, be seen, the ingredients may be considered to have been carefully prepared, and the powder to have been well manipulated, particularly if pressed and glazed: but if the contrary be the result, there has been a want of skill or of carefulness manifested in the manufacture.

* I have said nothing, heretofore, of the common powder-triers, because they are not to be depended upon as indicating the real goodness of gunpowder. But if the sportsman should wish to ascertain the comparative strength of his powder by an instrument of this kind, as ingenious and useful a one as any I am acquainted with is made by " W. Moore, 78, Edgware Road, London." It is a steel spring in the shape of an octant, with a scale graduated in pounds, for measuring the force; so that it would answer as well for a weighing-machine as for proving gunpowder. It embodies a fine illustration of the philosophical axiom that action and reaction are in opposite directions and equal; and accordingly, when fixed, the instrument has no recoil. The charge is 10 grains; and this quantity of His Majesty's rifle powder I found gave a result of from 42 to 52 lbs.

198. I have heard it observed that this test is worth nothing; because, although large-grained powder may leave beads and foulness after explosion, yet small-grained powder of the same manipulation will exhibit none, but leave the plate clean; and that, therefore, no judgment can be formed of the quality of powder from it. But it has this advantage: if large grained-powder does exhibit foulness, it plainly shews that that powder is badly made; for His Majesty's cannon powder flashes off as rapidly as the rifle powder, leaving no such indication behind it. Even solid press-cake will leave no residuum. It may therefore be considered as certain, whenever such indications do occur in large-grained gunpowder, that it has been badly manufactured, and contains impure ingredients. And if such be the character of the cannon powder, the finer grain of the same manipulation must possess the same character also, although fewer indications of it, or none at all possibly, may be seen after the experiment.

REMARKS.

199. Having thus reviewed the several methods of proof which appeared to be the most deserving of notice, and having, I hope, established that the only principle on which gunpowder should be tried as to its true strength and quality, is that in which all the charge explodes before the projectile is sensibly acted on, I shall add but a word or two in correlative illustration of this point, as also with reference to the action of light and dense powder when fired in large quantity.

200. A charge of gunpowder, confined in a piece of ordnance, may be considered as a short bulky train. In a forty-two pounder, this train is nearly two feet long. Now it is obvious that if the powder be angular, soft, and porous, it will inflame with greater rapidity, and a larger part of the charge explode within the gun than when the powder is hard, and without sharp angles, and when the surface of the grain is polished. Hence, in probably all cases where the charge is closely confined, and the shot or shell touches it, unpressed gunpowder will range higher than

pressed and glazed gunpowder of equal quality; but the results may be variable, and not constant, should pressed and glazed gunpowder, although of superior quality, be tried against mill-cake powder, or powder of a soft friable grain, of a different system of manufacture. Sometimes gunpowder is pressed and not glazed. Unglazed, pressed powder, will give a higher range also than glazed powder, because the former retains its sharp angles and roughness of surface, which are both favourable to rapid combustion.

201. If, therefore, pressed and glazed gunpowder be tried with service-charges, against unpressed and unglazed powder, and their range prove equal, and the decision on their respective qualities be that they are equally strong and good, the decision, though founded on the actual results of practice, is not substantial; for the unpressed and unglazed powder ought to give a higher range than the pressed and glazed powder, and a proportionate allowance ought to be made. In pronouncing on the merits of different gunpowders, the artillery officer should bear this in remembrance. (130.)

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202. Let us now pass on, and ascertain how far the observations we have made are applicable to the results of actual experiments made in ordnance with service-charges.

203. We shall first notice certain trials made at Woolwich in 1826, at the request of the Honourable the Court of Directors, with Bengal, Madras, and Bombay powders, against the King's powder as the standard, which had been at sea three years, having been returned from His Majesty's ship Tribune. The deterioration it had suffered by this circumstance may be stated at ten per cent. as compared with other English powder that had been manufactured only five months before. The following have been selected out of a large number of trials which need not be specified.

	GUNPOWDER.	8-inch iron mortar 45° elevation. Shell 44 lbs. 10 oz. WEIGHT OF POWDER. 1 lb.	$1\frac{1}{4}$ lb.	$1\frac{1}{2}$ lb.	$1\frac{3}{4}$ lb.	10-inch iron mortar, 45° elevation, shell $85\frac{1}{2}$ lbs. powder 2 lbs.	24-pounder iron gun shot 23 lbs. 10 oz. powder 8lbs. P. B.	$1\frac{1}{2}$° elevation.
		yds.	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*
1	English Cannon . . .	589	750	1009	1221	836	516	993
2	Bombay, L. G. 1821 .	140	381	715	997	410	527	993
3	Allahabad L. G. 1821-22	149	450	717	966	401	585	1015
4	Ishapore L. G. 1822-23	401	621	830	1054	596	657	1097
5	Madras, L. G. 1823 . .	482	775	1087	1325	826	521	1132

204. We have here, at first glance, an exemplification of what has been so frequently asserted, viz., that bad gunpowder, under certain circumstances, will range as far as good. Here are two remarkable examples of gunpowder ranging, in one trial, only one quarter the distance of the standard powder, while, in another trial, they produce a range equal to the standard. I am not aware whether these powders, Nos. 2, 3, were pressed and glazed, or not, and therefore cannot speak of them so confidently as I otherwise might: but this may be safely asserted, that all the mortar proofs establish their inferiority; and if they were pressed and glazed, it may be inferred from the twenty-four pounder proof, that their specific gravity, and degree of gloss or polish, were not equal to those of the English powder.

205. These trials appear to add confirmation to the view of the action of fired gunpowder before laid down (190, 191). The trial of one pound in the eight-inch mortar is favourable to the ignition of hard-grained, glazed, gunpowder. The charge is not very large; it occupies not more than half the cubic space of the chamber: the flame of that which explodes first has, therefore, opportunity to both penetrate into and envelope the

remainder, whereby the explosion of the whole is accelerated. And it appears still further corroborative of the view thus taken, that as these advantages decrease; as the charge becomes larger, and the chamber of the mortar affords less room for this particular action of the flame,—the difference of range decreases also, until these inferior powders, Nos. 2, 3, from one quarter mount up to five-sixths of the range of that of standard quality. I have little doubt that if the experiment had been followed up until the chamber of the eight-inch mortar was quite filled, the inequality of range would have been still further diminished.—We are of course aware, that by the supposition of the first generated portions of flame encircling and kindling the remainder of the charge, the trials in which such action takes place would be those particularly and specially favourable to bad gunpowder; but it must be borne in mind, that if they *are* favourable to it, they are equally favourable to good powder also, which, similarly circumstanced, will explode with a rapidity and power proportionate to its quality. In either case the advantages are the same, and the mode of proof therefore seems to be unobjectionable.

206. The experiment in the ten-inch mortar, with two pounds of powder, exhibits the operation of the same principle; but the quantity of powder being larger, the discrepancy is not so great: the inferior powders here range half the distance of that of standard quality.

207. The Ishapore powder was, there is reason to conclude, pressed and glazed; the results it gave were regular, assimilating to the uniformity of effect produced by the English powder; and though weaker, yet the regularity of its action is favourable, as it evinces that the manipulative operations of the manufactory had been properly attended to. This powder also produces a high range when used in large quantity: it is evidently a far superior powder to the two just noticed.

208. The Madras powder was mill-cake, granulated. Except in the first trial, it takes the lead of the whole in the eight-inch

mortar; and maintains a near equality with the English in the ten-inch; but in all these trials, a deduction should be made for its not being pressed and glazed. (130—132.)

209. In the 24-pounder iron gun with eight pounds of powder, a sudden reverse takes place. The English powder loses its superiority; it projects the shot no further than those powders that ranged but one quarter its distance in the first trial. How is this to be accounted for? It seems an easy way to get over the difficulty, by saying it would be a task of supererogation to attempt an explanation; and yet it certainly is true, for no dependence whatever is to be placed on a trial of this nature, as a criterion whereby to judge of the relative merits or quality of gunpowder. The best evidence of this fact is an examination of the foregoing trials themselves, which might prevent the necessity of further reasoning: but that we may not dismiss the point too abruptly, perhaps the following extract from the eighth edition of Adye's Pocket Gunner, p. 182, may elucidate it. The following trials were made in a twenty-four pounder brass gun at the several degrees of elevation specified. The range is taken to the first graze of the shot.

		yards.		yards.
Point blank	6 lbs. powder	480	10 lbs. powder	480
2° elevation	„	1100	„	1100
2¼ do.	„	1155	„	1158
2½ do.	„	1210	„	1216
3¾ do.	„	1496	„	1497
4 do.	„	1552	„	1552
4¼ do.	„	1599	„	1599
4½ do.	„	1646	„	1646
4¾ do.	„	1690	„	1693
5 do.	„	1746	„	1740

210. Here, there are too many coincidences to be the effect of accident; and, therefore, we may conclude that in every trial with ten pounds of powder, four pounds of it were blown out of

the gun, unconsumed. The inference to be drawn is, that a large portion of high charges explodes to no useful end; and therefore, that high charges are unfit to be used in comparative proof trials of gunpowder.

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211. Further remarks on the proof of powder may be founded on a long and laborious course of experiments made in Bengal in 1828, and repeated with great care at Madras in 1829, for the purpose of ascertaining the relative qualities of the gunpowder manufactured at the three Presidencies, viz. Bengal, Madras and Bombay. Some French gunpowder was tried in Bengal, and some of His Majesty's powder at Madras; these may serve as standards of comparison. All the Indian powders were of the manufacture of 1824-25; the French powder of 1820; and the English of 1813.—The whole course of the experiments contains more trials than those that are here inserted. I have selected and classified such of them only as I thought best adapted to exhibit the characters and qualities of the article experimented on.

BENGAL. 1828.

The medium range in yards is here given of the three nearest ranges out of five, the other two being rejected.

GOMER IRON MORTARS.	WEIGHT OF THE POWDER.		SHELL.		French Cannon Powder.	ISHAPORE.			ALLAHABAD.			MADRAS.			BOMBAY.			REMARKS.
	lbs.	*oz.*	*lbs.*	*oz.*		1	2	3	1	2	3	1	2	3	1	2	3	
8-inch ..	..	2	41	11	..	46	43	53	65	54	57	40	42	50	10	21	15	No. 1. Cannon Powder.
Do. ..	..	..	65	8	48	41	41	45	56	42	49	43	43	43	12	20	15	
Do. ..	..	..	68	8	76	57	59	59	76	64	63	53	59	51	14	20	14	No. 2. Musket Powder.
10-inch ..	..	2	85	13	..	33	28	32	40	26	40	28	27	34	5	15	9	No. 3. Cannon Powder that had been first dried for two hours in the sun; afterwards exposed to the atmosphere for 12 days; and then proved.
8-inch ..	1	..	41	11	681	318	604	415	557	685	440	419	668	474	97	311	129	
Do. ..	..	..	65	8	612	358	651	403	501	665	390	449	623	410	183	383	113	
10-inch ..	..	..	85	13	381	255	341	263	354	346	283	253	359	282	68	114	83	
8-inch ..	1	12	41	11	1589	709	1341	....	1168	1387	...	1148	1410	....	371	677	....	
Do. ..	..	..	65	8	1464	721	1354	....	1042	1363	....	1135	1348	....	407	610	....	
10-inch ..	..	..	85	13	928	461	779	....	671	804	....	558	827	....	154	373	....	

MADRAS. 1829.

The undermentioned results, in yards, are medium ranges of three firings each.

GOMER IRON MORTARS.	WEIGHT OF THE POWDER.		WEIGHT OF THE SHELL.		English Cannon Powder.	ISHAPORE.			ALLAHABAD.			MADRAS.			BOMBAY.			REMARKS.
	lbs.	*oz.*	*lbs.*	*oz.*		1	2	3	1	2	3	1	2	3	1	2	3	
8-inch .	..	2	44	..	....	40	34	33	44	45	33	32	47	32	14	19	8	No. 1. Cannon Powder.
Do.. .	..	..	65	8	41	26	32	29	31	36	33	28	31	28	10	16	9	
10-inch .	..	2	87	..	....	19	19	20	20	23	19	16	19	18	7	9	5	No. 2. Musket Powder.
8-inch .	1	..	44	..	781	459	620	407	396	665	395	528	664	522	128	330	119	No. 3. Cannon Powder that had been first dried for two hours in the sun; afterwards exposed to the atmosphere for 12 days; and then proved.
Do.. .	..	..	65	8	....	393	520	409	357	569	387	460	566	458	188	362	110	
10-inch .	1	..	87	..	425	287	324	273	286	404	236	294	341	300	84	122	80	
8-inch .	1	12	44	..	1499	1056	1412	....	1105	1428	....	1500	1382	....	731	800	....	
Do.. .	..	..	65	8	....	927	1210	....	903	1230	....	1204	1187	....	513	903	....	
10-inch .	1	12	87	..	902	581	786	....	535	808	....	700	823	....	207	416	....	

212. The relative densities of these powders are reported to stand thus:

	BENGAL REPORT.		MADRAS REPORT.	
	Cannon.	Musket.	Cannon.	Musket.
Bombay . . .	293	276	295½	280
Ishapore . . .	290	251	284	273½
Allahabad. . .	278	260	285½	273
Madras . . .	260	224	256	246

being the number of drams weight contained by a cylinder 3.5 inches in diameter, and 3.5 in height.

213. The relative degrees of hardness were judged of by "mealing" half a pound of each cannon powder of the same sized grain for five minutes. At Madras, the mealing was performed by passing a roller over the powder when spread out, and the powder that was the least crushed was considered to be the hardest. The experiment stands thus:

At Bengal.	At Madras.
Ishapore, the hardest.	Allahabad, the hardest.
Allahabad, ditto	Ishapore, ditto
Madras, ditto	Madras, ditto
Bombay, the softest.	Bombay, the softest.

214. The quantity of moisture contained in the powders was ascertained by exposing sixty pounds of each to the mid-day sun for two hours, and re-weighing them. The weights after this exposure are represented to be:—

	At Bengal			Loss.		At Madras.			Loss.	
	lbs.	*oz.*	*dr*	*oz*	*dr.*	*lbs.*	*oz.*	*dr.*	*oz.*	*dr.*
Ishapore Cannon Powder	59	8	12	7	4	59	11	8	4	8
Allahabad do.. . .	59	3	11	12	5	59	13	3	2	13
Madras do.. . .	59	6	10	9	6	59	10	14	5	2
Bombay do.. . .	59	1	0	15	0	59	12	11	3	5

The difference between these several weights and sixty pounds, represents the degree of moisture evaporated from each powder respectively, and is here specified as loss.

215. Twenty pounds of each of these partially sun-dried powders were then spread out on a plain surface, and freely exposed to the atmosphere for twelve days. Their weights after this exposure were as follows:—

	At Bengal.			Gained.		At Madras.			Lost.	
	lbs.	oz.	dr.	oz.	dr.	lbs.	oz.	dr.	oz.	dr.
Ishapore . . .	20	1	8	1	8	19	15	0	1	0
Allahabad. . .	20	1	14	1	14	19	14	14	1	2
Madras . . .	20	2	4	2	4	19	15	0	1	0
Bombay . . .	20	1	10	1	10	19	15	4	0	12

216. Before we proceed further, I may first notice how completely these experiments on density, hardness, and humidity, illustrate the remark made in paragraph 148.—The variations in the results between the two Presidencies throw a doubt upon them both, and make it hard to decide which of them approximates the nearest to truth, and which, consequently, is the one that may be the most safely depended on.

217. In density, the greatest difference between the two sets of trials amounts to about nine per cent.; the Madras experiment making the Ishapore and Madras musket-powders nine per cent. more dense than the Bengal experiment. In each case, however, the Bombay powder is shewn to possess the greatest specific gravity, Ishapore and Allahabad to be intermediate, and Madras to be the lightest.

218. The method employed for ascertaining the hardness of the powder must, from its nature, be imperfect.—One would think, that the powder possessing the greatest specific gravity

would of necessity have been the hardest, but both the trials represent it to be the softest.

219. The experiments to ascertain the degree of humidity are incomplete, from the want of hygroscopes, which could not be obtained at either Presidency. An examination of these trials will shew that the dryness or moisture of the atmosphere should have been previously ascertained, particularly in the experiment with twenty pounds of powder, which, at Bengal, exhibits an increase of weight after exposure, but at Madras, the reverse.—In the former case, the experiment turns out as might naturally have been anticipated; but the latter exhibits a result which, no doubt, is attributable to the superior dryness of the air of the Carnatic at the time the experiment was made.

220. Had the results of the foregoing experiments at Madras been corroborative of those made at Bengal, particularly those relative to the humidity and density of the powders, they would have been useful; but as they now stand, I fear the whole must be considered as affording very little guidance towards forming an opinion as to the respective qualities of the powders.

221. To these experiments, I shall take the liberty to add some of my own on the same powders, but different in their character. I extract them from my commonplace-book.

222. Memorandum of experiments made on the following cannon powders.—

English	A. D.	1813.
Allahabad	—	1825.
Ishapore	—	1825.
Madras	—	1825.
Bombay	—	1825.

223. In these experiments I used rain-water, which was not affected on being tested with the nitrate of silver or nitrate of baryta.

224. Half an ounce of each powder was weighed and thrown into a test-glass containing one fluid ounce of rain-water. Each powder remained in the water for twelve hours, being frequently stirred; it was then filtered, and the solution obtained transparent.

225. The transparent solutions were transferred to test-tubes, and first tested for alkali, by introducing into each tube a slip of reddened litmus paper. After twelve hours, the following changes had taken place:—

English, Ishapore	A slight tinge, hardly distinguishable from the red colour of the test paper.
Allahabad, Bombay	No change perceptible.
Madras .	Full bright purple.

226. The same solutions were then tested for free acid, by immersing in them slips of blue litmus paper. No action was produced by the English, Ishapore, and Madras solutions, but the Allahabad, in a few seconds, changed the paper to red, and so did the Bombay, but less decidedly.

227. It is therefore presumed that the English and Ishapore powders contained the slightest trace of alkali possible; that the Madras powder contained it in much larger quantity, and that the Allahabad and Bombay powders did not contain alkali, but contained a free acid.

228. The next step in the experiment was testing with nitrate of baryta. To the English, Ishapore, and Madras solutions, a few drops of pure nitric acid were added to neutralize any free or carbonated alkali they might contain. No acid was added to the Allahabad or Bombay powders, as the litmus test shewed it to be unnecessary. On adding six drops of nitrate of baryta to each solution, the appearances were:—

English .	Transparency barely tinged.
Ishapore .	Reddish opalescency.
Madras .	Opalescent.
Allahabad, Bombay	Both rendered turbid.

229. After standing eighteen hours, the quantity of precipitate in each solution was as follows:—

English	Very small; a slight deposit on the bottom of the test-tube.
Ishapore, Madras	About equal in quantity, but considerably more than the English powder.
Allahabad, Bombay	More copious than any of the other precipitates.

230. The whole of these precipitates were washed with the same rain-water, and on the addition of dilute muriatic acid were not dissolved.

231. From this test it would therefore appear that sulphuric acid, either free or in combination, or both, was present in all the powders, but in the Allahabad and Bombay powders to a greater extent than in the others.

232. Any alkali the solutions might contain having been saturated with nitric acid, and the sulphuric acid having been removed by the nitrate of baryta, I added to the same solutions a few drops of nitrate of silver, and the indications that occurred on the application of this test were as follow:—

English . . . . Slightly opaline.
Allahabad. . . . . . ditto
Ishapore . . . . ditto
Madras . . . . Turbid.
Bombay . . . . Turbid, with an immediate curdy precipitate on shaking the test-tube.

233. Being permitted to remain undisturbed until they were again limpid, the English solution had the smallest quantity

of precipitate, Allahabad and Ishapore somewhat more in quantity, the Madras still greater, and the Bombay most of any. The whole of these precipitates turned black on exposure to the sun. We may therefore conclude that they were caused by the presence of muriatic acid, and that they consisted of muriate or chloride of silver.

234. If we reduce the experiments into one view, they will stand as in the following table.

POWDERS.	ALKALI.	MURIATIC ACID.	SULPHURIC ACID.
English. . .	A faint trace	A trace	A trace
Allahabad .	None	A trace	Considerable
Ishapore . .	A slight trace	A trace	Somewhat more than the English, but less than the Allahabad or Bombay.
Madras. . .	Considerable	Somewhat more than the foregoing	
Bombay . .	None	Abounds	Considerable.

235. I would attach to these results no greater importance than they merit; but they may be considered as useful auxiliaries in forming an opinion as to the respective degrees of care with which the ingredients had been prepared, and in some measure also of the respective qualities of the powders with reference to their durability, and their competency to withstand the influence of damp climates.

236. Knowing the accuracy with which His Majesty's powder is manufactured, I was somewhat surprised to observe it contaminated as the tests indicate. The alkali is in so minute a quantity that it may be considered immaterial: other powder which I have tested from the same manufactory indicates none. And the sulphuric and muriatic acids I am disposed to consider as adventitious, and as having been introduced (most probably in combination with earths or alkalies,) with the water used in the incorporation of the powder. The water formerly used

for that purpose at Waltham Abbey was taken from the same stream as that by which the mills are turned; and as river waters are never pure,* but contain alkaline and earthy sulphates and muriates, the acids alluded to may, with reason, be supposed to have originated in that source. Of late years the mill-charges have been moistened with distilled water.

237. The same remarks may, in some measure, be applicable to all the other powders; but the Bombay powder indicating so large a quantity of muriatic acid, there appear to be very strong grounds for suspecting the imperfect purification of the saltpetre; and the free sulphuric or sulphurous acid in both that and the Allahabad powder may probably have arisen by using too great a heat in refining the sulphur.

238. I may add, that I dried one hundred grains' weight of each of the powders for half an hour in a heat of 175° Fahrenheit's thermometer, and on flashing them off at that temperature they all exploded with a sharp sudden concussion, except the Bombay powder, which exploded tardily, and generated a great number of minute globules of alkaline residuum. The other powders left nothing but streaks, or smoky traces behind them, and the number of these marks was in the following order,—English powder the fewest, then Ishapore, Allahabad, and Madras.—The Bombay powder very foul.

239. I shall now proceed to offer a few remarks on the foregoing experiments.

240. With reference to the proof reports, I think the trials, though good in themselves, are too laborious, in comparison with the degree of information to be derived from them. (See pages 96, 97.) Instead of four separate trials with two-ounce charges each, if one only had been judiciously selected, the results

* It is a singular fact, that specimens of water taken out of a lake on the Neilgherry hills and sent to Madras, were found so pure as not to be affected by any test that was applied to them.

given by it would have been as decisive as the whole of them: and so with reference to the higher charges: the number of trials might have been reduced, and the respective qualities of the powders judged of with equal certainty. In fact, a multiplicity of trials does but introduce embarrassment, and therefore a few firings are preferable to many.

241. It will be observed how great a variation occurs in the ranges between the coarse and the finer grained powders (116, 117). And how dissimilar some of the results of the Madras proofs are in comparison with those of Bengal (148—155). At Madras, the Ishapore, Madras and Bombay powders range higher than they did at Bengal, but the Allahabad powder ranges lower in the trials with charges of one pound and upwards. The Madras experiment represents the Allahabad powder to be of greater specific gravity than the Bengal experiment (212); taking for granted that each experiment was correctly made, the smaller range of the Allahabad powder may on this principle be accounted for.—In the two-ounce trials the Allahabad maintains a superiority in both the proof reports, as does the musket powder also with the larger charges, but the cannon powder falls off, which it would do if its density were greater.

242. It is both remarkable and curious that the ranges of the Allahabad musket powder in the two-ounce trials, should, according to the Bengal proof report, be lower than the ranges of the cannon powder of the same manufactory. That coarse and fine-grained gunpowders of the same ingredients and manufacture should preserve, in these proofs, an equality of range is perfectly explicable; but that they should exhibit much variance in cases where the manipulation may be considered to be good, is a discrepancy not before noticed or touched upon, and not easily to be accounted for. There seems to be no obvious reason for fine-grained powder in these particular trials ranging *below* the cannon powder; had it ranged a little above, perhaps the general principle of its quicker ignition might account for it; and it is still further worthy of notice that in the Madras

experiments, the same Allahabad musket powder regains its superiority, follows the general rule, and ranges further than the powder of a coarser grain.—I cannot account for it.

243. The results of the Bombay powder with two-ounce charges singularly differ, and seem to constitute an insuperable objection to the asserted excellence of proof-trials by the eight or ten-inch mortar, or, at least with reference to that part of the assertion which states that those trials are not so much influenced as others by the different sizes of the grain (187—192). The fine-grained Bombay powder ranges some of it double, some nearly double, and in one case treble the distance of the large grain. But I do not consider this any solid objection to the mode of trial; it rather bears on the powder itself, and seems to shew, that in the case of bad gunpowder no dependence can be placed on its results. The reason why badly manipulated powder ranges so low in these trials appears to be, that the tardiness of its explosion allows greater time for the escape of the elastic fluids round the sides of the shell, and at the vent, and occasions them a greater degree of condensation, or loss of elasticity by cold, which greatly diminishes the propellent power.—But although there are great discrepancies between the Bombay musket and cannon powders in these trials, yet their best and highest ranges are only half the distance of the other Indian powders, which is a difference amply sufficient to establish a discrimination of character, and by this may be determined the absolute strength and quality of the respective gunpowders without the possibility of error.

244. In speaking of the qualities of the Indian powders in my original memoir, I adjudged the superiority to the Allahabad manufactory, with only one reservation. The following is the original paragraph.—Allahabad powder the best. Its manipulation appears to be good, from the results yielded by it in the two-ounce trials. It possesses also the good quality of rapid ignition; and notwithstanding its density is greater than the Madras powder, it ranges generally superior. Great improvements must have taken place in the Allahabad

manufactory since that kind of powder was made, the proof of which is given in paragraph 203. There appears, however, to be one defect in the Allahabad powder; it does not retain its strength, but falls off materially on exposure to the air. The whole of the other powders, except in two cases, shew higher ranges after the twelve days' exposure than they did before; but the Allahabad exhibits a decrease of power equivalent to from one eighth to one sixth of the range. This may indicate some oversight in the manufactory, most likely one that has reference to the quality of the ingredients. These observations refer more particularly to the Bengal proof report.

245. In no researches ought the principles of inductive philosophy to be more rigidly followed than in researches into the nature, qualities, and effects of gunpowder. No fact ought to be stretched beyond its legitimate bearing; nor should any general inference be drawn from particular experiments. I could adduce many instances of error into which writers on gunpowder have fallen in consequence of not observing this necessary rule. But the thing itself is so evident, it is so plainly illogical to attach a general conclusion to particular premises, that the case needs no illustration; and I would wish the reader to correct any fault of this kind if he should observe that I have fallen into it in any part of the present Essay.

246. I make these observations partly with reference to my opinion on the Allahabad powder, not that my opinion is materially changed, but rather qualified, from facts that have subsequently come to my knowledge; for instance, the experiment detailed in paragraph 226, by which it is shewn that the Allahabad powder contains free sulphuric acid, which may possibly be the cause of its reduced range after exposure to a humid atmosphere; but more particularly from my having since seen the report of Colonel Galloway, written in 1822, wherein it would appear that the Ishapore powder is made to a degree of hardness which, before reading that report, I had no conception of. The following is an extract from Colonel Galloway's report.

247. "Since the powder has been so much better incorporated, and the new mode of pressing in thin cakes has been adopted, the corning frame and sieve (119) are unable to make the smallest impression upon the composition."—"I found that the powder cut and tore the parchment to pieces."—"I therefore made the sieves with strong parchment without holes. We put six pounds of powder into each sieve with the disk over the grains, and instead of their falling through and escaping the action of the disk as before, they are all kept under it, till the prominent angles are broken off by the weight and violence of the friction and motion of the disk." The operation continues twenty minutes; and the press cake is broken up with "lignum vitæ mallets," on slabs made of an alloy of tin and zinc, because wood was found not to be hard enough.

248. After having read Colonel Galloway's report, which the Honourable the Court of Directors have with great truth and justice pronounced to be "able, candid, and satisfactory," and having observed the even supererogatory care with which the operations of the Ishapore manufactory are conducted, I cannot but think it a great pity the powder should be made of such extraordinary hardness; for it must of necessity impair its propellent force, and deprive it of a part of its legitimate efficiency. The operation of pressing appears here to be carried to excess. His Majesty's gunpowder is firm enough to bear all the rough usage and accidents of usual service; but it is broken up in beech wood troughs, and not on metallic slabs,—with beech wood mallets, not with instruments of lignum vitæ,—and does not cut and tear the granulating sieves, as the Ishapore powder is represented to do. It appears then from this fact rather too hasty to say that the Allahabad powder is absolutely superior to the Ishapore, unless the same system be adopted at Allahabad also; but of the operations of that manufactory I am ignorant. What has been stated may therefore serve to explain the necessity of knowing the manipulative history of gunpowder, as well as being acquainted with its practical effect, before a judgment can be

properly pronounced, either upon its absolute or its relative character and quality.

249. The Madras powder produces, in comparison with the other powders, a good range at both Presidencies; which, as it is well mixed and unpressed, is what may be expected of it. But of the Bombay powder I still retain my former opinion, and say it cannot be denominated other than barbarous.—I hope the present official document may be the means of improving it.

250. Both the French and the English powders range with the higher charges superior to the cannon powder of the Honourable Company: the ranges of the French powder are particularly brilliant (see the proof, paragraph 211). It would have been satisfactory had the proof report noticed the size of the grain of this powder; but it was described simply as cannon powder, from which I conclude the grain was large; and I should apprehend, from the high ranges it gave, that it was an unpressed powder. It was obtained from a French ship of war, then lying in the Hoogly, off Calcutta: it may therefore be presumed to have been French Government powder, and as good as any manufactured in France. I am inclined, however, to consider it inferior to the British powder, from a comparison of its effects as detailed in the report under examination. From this we find, that with a charge of two ounces it ranged in one case below, and in another only equal to the Allahabad powder; whereas in the same kind of trial, the English powder ranged one third above the Allahabad powder, as the following statement will explain.

GOMER IRON MORTAR.	WEIGHT OF				French powder.	Allahabad powder.	English powder.
	Powder.		Shell.				
	lbs.	*oz.*	*lbs.*	*oz.*	*yards.*	*yards.*	*yards.*
8-inch	—	2	65	8	—	31	41 actual range.
Ditto	—	—	65	8	48	56	74 } *proportionate range.*
Ditto	—	—	68	8	76	76	100 }

The trials being made in different eight-inch mortars, and in different places, the French and English powders can be compared only through the intervention of the Allahabad powder: this, indeed, is not so satisfactory as if they had been directly opposed to each other, and their comparative quality had been deduced from trials out of the same mortar; yet as this particular instance embodies that mode of proof which appears to be the best adapted to exhibit the real inherent strength of gunpowder, I think we cannot greatly err if we adjudge the English powder to be superior to the French. Let it be observed that I place no stress on the two trials in which the *proportionate range* of the English powder is shewn, but on the first trial only: I cannot, however, divest myself of the opinion that our continental neighbours, the French, can have no ground for boasting* of their gunpowder, until they bring its range in the eight-inch mortar (187) with a charge of two ounces, to an equality with the range of the English Government powder, fired from the same proof instrument, each powder being also equal as to density, smoothness, and size of grain.

251. From a review and consideration of all that has been advanced in this and the last section, it may safely be decided, that many variations and irregularities which take place in experiments on gunpowder, may be traced to those disturbing, secondary, or accidental causes (162), some of which influence the results of proof trials, without any reference to the quality of the powder itself. All these accidental circumstances ought, therefore, to be taken into consideration, in reporting upon experiments made with powder in artillery; and, although it may possibly be thought, that what has been written has tended to throw doubt and embarrassment over the proof of gunpowder, yet, it appeared to be indispensable to enter into the detail and

* "Depuis plusieurs années, les procédés qui servent à la fabrication de la poudre se sont perfectionnés en Angleterre; cependant ces procédés semblent en général inférieurs à ceux qu'on suit maintenant en France, et qui réunissent, à la science des théories chimiques, la simplicité des appareils méchaniques les plus efficaces."—Baron Dupin.

minutiæ of the question, in order to arrive at some satisfactory and substantial conclusion. I shall endeavour to dispel both doubt and embarrassment, and to shew, when I arrive at the Eighth Section, containing observations on the proof of gunpowder, that its quality may nevertheless be satisfactorily ascertained.

SECTION VII.

REMARKS ON THE MANUFACTURE.

252. No addition to the common ingredients of gunpowder tends to improve it permanently.* Urine, and spirits of wine have by some been extolled; but the former contains too many deliquescent salts to be efficacious, and the latter is not adapted for the purpose of incorporation.

253. It seems to be immaterial whether nitre be fused or not, so far as the quality of the gunpowder is thereon dependent. Fusing makes it not more pure. The only advantage fused nitre possesses appears to be, that no moisture can, by possibility, be contained in it after the operation; therefore, the quantity weighed in the manufactory as the proper proportion to mix with the charcoal and sulphur, must contain the quantity of oxygen contemplated to be given out in combustion, whether the proportions were determined by scientific data or had been fixed on as the result of practical experiment. Dried crystals of nitre may frequently contain 3, 4, or 6 per cent. of moisture; and this could not be conveniently ascertainable in the bustling

* Good gunpowder is too strong for blasting and mining. The effect produced is much greater, particularly in blasting rocks, when the explosion is comparatively tardy. Charcoal in powder, or fine sawdust, may therefore be mingled with good powder for either of these purposes. The quantity to be added will be best ascertained (for blasting) by experiment. The hole above the powder should be filled up with dry loose sand.

operations of a large manufactory. However, if the crystals can, by solar heat in this country, be perfectly dried, the labour and expense of fusing might be saved; the operation being one of conveniency rather than of necessity, and the quality of the gunpowder would remain, in either case, unaltered.

254. In the preparation of charcoal, two points should be attended to—not to char too much, yet sufficiently; and to produce a char free from alkali. The most economical manner in which these ends can be perfectly attained, may be considered as the best. But charring in cylinders must not be decided to be the most expensive, unless the liquid products of the wood are thrown away; because in England there are manufactories established that supply the London market with wood vinegar, and concentrated acetic acid, which could not be, if the liquid products were not adequate to repay the cost of the fuel and incidental expenses.

[Pyroligneous acid is a most admirable antiseptic. Applied to fresh meat, it preserves it a great length of time. At home, I have known the common empyreumatic acid in a charcoal manufactory to have been used for curing hams, beef, herrings, salmon,—to all of which, if they are not overdosed, it is said to impart an excellent flavour. There is great probability that it might be used with success in this country,* where antiseptics are a thousand-fold more required than in England, and the difficulty of preserving fresh provisions is so much greater.]

255. The ingredients should be pure. Impure ingredients produce injury in two ways: they interpose extraneous matter between the atoms of the combustible substances, and thereby impede rapidity of explosion; they are usually deliquescent; they therefore imbibe moisture. Moisture induces an incipient crystallization of the nitre; and thus gunpowder of impure elementary parts includes within itself the germ of its own destruction.

* India.

256. Extremely minute comminution facilitates incorporation. Perfect incorporation constitutes the grand art and secret in making gunpowder: pure ingredients, and the best proportions are inefficacious without it. Most particular attention ought to be paid to this branch of the manufactory, though of course it must not monopolize all, to the exclusion of other departments. Rain water should be used in this process. An incorporating mill ought always to be in good order: the machinery should work smoothly and steadily, and the cylinders ought to travel upon the bed in a perfectly perpendicular position. I prefer stone to metal cylinders. Those formerly in use at the King's powder mills were always brought from the black-marble quarries in the neighbourhood of Namur;—but of late years, beds and runners have been obtained of much better quality from a marble quarry near Kidwelly, in Carmarthenshire. The stone of which they are formed is a black limestone, or marble of the transition formation—the stinkstein of Werner, (see Jameson's Mineralogy, Vol. I. p. 521.) It is distinguished by the peculiar fœtid odour emitted when two pieces are rubbed together; and for gunpowder mills it should be perfectly free from any admixture or specks of quartz.

257. Homogeneity of appearance characterizes well manipulated gunpowder. On snapping a piece of mill cake it ought to exhibit a fine ashen-grey colour throughout; and the grain or texture should be exceedingly close; it should not appear granular, nor even look coarse. No white specks are admissible. It is difficult to describe the appearance; but insufficiently incorporated gunpowder looks very differently from that which has been well mixed and perfectly incorporated.

258. Daily checks are in use in His Majesty's works. At Waltham Abbey every *mill-charge* is proved separately, so that negligence or accident cannot escape detection. This check is commendable, and one easy to be adopted. The instrument used is a good vertical éprouvette; and, with two smart lads, fifty or sixty trials may be made in an hour.

259. In this country,* where every thing depends on the officer in charge of a gunpowder manufactory, a constant and vigilant superintendence over every department is necessary: but some departments are more important than others. The saltpetre refinery should not be neglected. Frequent testing of the nitre should be resorted to: it constitutes a check at once easy and efficacious. The charcoal should engage much attention both with reference to the alkali it may contain, and with regard to its selection, and the careful examination of it before it be pulverized. We have already spoken of mixture and incorporation. If pressing and glazing constitute a part of the system of manufacture, they should not be carried to excess; but be regulated according to the nature of the service for which the powder is required, and the climate it may be used in. Superintendence, to be efficient, should of course include a knowledge both of the *rationale* and *practice* of the several operations, with an ability to rectify what is faulty.

260. To say of any gunpowder that its grain is as hard and as durable as flint, would be to me no recommendation of its quality; on the contrary, I should marvel why such extraordinary hardness had been imparted to it. With reference both to high practical effect, and to economy in use, the softer a gunpowder is, the better; but moderate density is very properly given it, to obviate the inconveniences which attach to a soft and porous-grained powder. As a gunpowder maker I should never think of imparting a higher degree of hardness or density to press-cake than what His Majesty's gunpowder receives; and for this climate, even less than that would probably be sufficient. If the ingredients be pure, I should have no apprehension of glazed gunpowder of moderate firmness keeping quite as well for any number of years as powder of greater density. The only ingredient susceptible of attracting moisture is the charcoal, and to prevent injury from this source, the powder ought to be kept, if possible, in air-tight packages.

261. An ounce phial full of water in one experiment, of spirits

* India.

of wine in a second, and of ether in a third, was placed in the chamber of a ten-inch mortar, with a charge of two pounds of powder, but on firing each respectively, there was neither increase nor decrease observable in the range: a charge of plain powder ranged an equal distance.

SECTION VIII.

OBSERVATIONS ON THE PROOF OF GUNPOWDER.

262. Under this head I propose speaking of what appear to me to be the best methods of proving gunpowder: First, at the manufactory; Secondly, at the artillery range, as a check upon the manufacture; and Thirdly, upon any special occasion, for the purpose of ascertaining and comparing the qualities of different gunpowders, either experimental or otherwise.

263. For the manufactory it does not occur to me that any better system can be adopted than that established in His Majesty's works, viz. the daily check mentioned in paragraph 258; daily flashing (197); and a monthly or weekly trial in the eight-inch mortar (187), for the cannon powder; and in the carbine or musket (196) for rifle and fine-grained powder, together with the test by flashing for all powder tried by these two methods.

264. Supposing the foregoing trials to be made merely for the personal satisfaction of the officer in charge of the manufactory, the tests to which it would appear desirable to submit the powders at the artillery range are the following:

For Cannon Powder.

		shell.	*powder.*
8-inch gomer iron mortar.		68 lbs.	2 ounces.
Ditto	ditto	42 lbs.	1 pound.
Ditto	ditto	42 lbs.	2 pounds.

For Musket Powder.

	shell.	*powder.*
$4\frac{2}{5}$ inch mortar	8 lbs. .	. 2 ounces.

Or by trial in the carbine (196), and examination by flashing for both cannon and musket powders.

265. The same instruments ought to be always used for these trials, and be used for no other purpose; the range distance should be fixed by ascertaining the actual range of the best powder that can be procured, (and that we conceive to be, for purposes of war, His Majesty's powder); and the quality of the powder under examination may then be judged of by comparison with the range of the powder chosen for the standard. I know of no better or more simple practical means of fixing the range distance than this, for I have before shewn the uncertainty that attaches to specifying any precise limit for it, without regard to the nature or state of the ordnance in which trials may be made (152 to 155). Once or twice a year an experiment should take place with the standard powder, to ascertain that no accidental variation occurs in the proof instrument. And if the standard powder were to be exposed to the sun a day or two before comparative trials, it would give it no other advantage than what is fair and proper; for it will always have to sustain comparison with powder newly manufactured.

266. For any special and minute examination of different gunpowders I would recommend attention to the following particulars.

1 Proof instruments.	4 Flashing.	7 Humidity.
2 Trials.	5 Density.	8 Testing, and
3 Proof report.	6 Size of grain.	9 Manufacture.

267. With reference to the instruments of proof, select them with care, both the ordnance and the shells. The gauge of the shells is of great importance (152 to 155). The only

instruments required I think are the eight-inch mortar, the $4\frac{2}{5}$-inch mortar, and the carbine or musket (196).

268. The trials to which the powder should be submitted in these instruments, are

For Cannon Powder.

8-inch gomer iron mortar.	Ball 68 lbs.*.	Powder 1 ounce.
Do. . . . . . do.	„	„ . 2 ounces.
Do. . . . . . do.	Shell 42 lbs.*	„ . 8 ounces.
Do. . . . . . do.	„	„ . 1 pound.
Do. . . . . . do.	„	„ . $1\frac{1}{2}$ pound.
Do. . . . . . do.	„	„ . 2 pounds.

For Musket Powder.

$4\frac{2}{5}$ inch mortar	Shell 8 lbs.*	Powder 2 ounces.
Carbine (196).	Steel ball	do. 4 drams.

269. From an attentive consideration of all the facts and experiments to which I have at any time had access relative to the proof of gunpowder, I am inclined to think the above trials constitute as satisfactory a test as any at present known. And the above number of firings appear to be sufficient; for if the scope and compass of the experiments be increased, it is more than probable that difficulty and embarrassment will be increased in the same proportion. Three firings of each charge would be enough; but in case of any unusual discrepancy occurring, the range that varies should be set aside, and another made in substitution.

270. I apprehend that the results from the lower charges may be depended on as indicative of the real strength and quality of cannon gunpowder, and those from the higher charges, as exhibiting (but not with precision) its practical force or available effects with service-charges.

* The weight of the shells I should consider to be of much less importance than their gauge and sphericity. The gauge should be as high as possible: the less windage the better: and the shells should also be perfectly globular.

271. With reference to the trials recommended for the musket powder, I have simply to remark, that inferior gunpowder will always be found to range below that which is good in either of them. They are both good trials for fine-grained gunpowder.

272. The whole of the foregoing trials should be repeated after exposing samples of each gunpowder to a damp atmosphere for twenty days. Exposure in this part of India, *i. e.* in the Carnatic, during the land wind season, is not the kind of exposure intended. The atmosphere should be humid; and the degree of its humidity should be noted by some hygroscopic measure, which, as hygrometers differ, should be described.

273. The proof report of these trials ought to contain intelligence of every particular that may appear requisite to be known with reference to the piece of ordnance used, the manner of loading, the appearance of the powder, and the state of the shells. It does not appear to be supererogatory that even the gauge and shape of every shell should be noticed in the proof report: it would by no means be unnecessary, were a column opened for that purpose, and remarks made as to the globosity, oxidation, asperities, or inequalities on the surface of each shell. And if irregularity be found to occur in the roundness of a shell in that part of it which touches the bore when the mortar is loaded, it should be especially noticed, because it occasions a variable degree of windage, which probably constitutes one of the main causes of discrepant range in practice. If all the shells are selected with great care, and as nearly alike as practicable, a simple remark in the report to that effect would be sufficient. The length of the bore of the piece and of the chamber should be inserted; their horizontal and vertical diameters, and whether the bore be larger at the seat of the shell than at the mouth. Mortars that have been used are sometimes larger in the bore just above the chamber than in any other part. The weight of the mortar should be given; and perhaps the nature, strength, and condition of the mortar-bed, and of the platform on which the mortar is placed. Such

nicety I fear may appear needless to some of my readers, and it may be said that I have not observed it myself; but my object all along has been simply to give comparative results from the same piece of ordnance, so that the advantages or disadvantages were equal on either side. But in proof reports, which may perchance have to be repeated elsewhere, or from which a third party is to judge of the quality of gunpowder, attention to the particulars that have been suggested, as well as to any other, however minute, that may occur to the officer making the proof trial, is by no means unnecessary, but proper.

274. Flashing. I consider this to be a good auxiliary test. If no beads or globules of alkaline residuum be seen after explosion, compare the appearance and number of smoky marks or traces that each powder may leave; observe the sparks that may fly off; and the relative sharpness of explosion (53, 197, 198).

275. Density. Hardness would appear to be dependent on density; but I believe that exposure to the sun will make both mill-cake and press-cake harder, and the grain of the resulting powder firmer, than that produced from the same mill-cake or press-cake, if granulated, without having been so exposed. For further guidance, see paragraphs 146 to 150. Specify the number of meshes to the square inch of the sieves by which the grains of the powder may be sized prior to the experiment for ascertaining its density. Two sieves of course will be required; one to prevent the larger grain from passing, and the other to allow the fine grain to escape, so that a medium size may be retained.

276. Nothing further appears necessary to be added with reference to the shape and size of the grain than what is contained in paragraph 151, and the paragraphs therein referred to. But I do not recommend the equalization of the grain of cannon powder as I have there seemed to intimate (151); for I consider the powder to be now under trial as it is issued from the manufactory, and to stand or fall by its own merits.

277. Humidity. Vide paragraphs 157, 158. A neat and satisfactory method of ascertaining the dampness of gunpowder is to expose a thousand grains weight of it in a common white plate for two hours to the heat of a sand bath kept as nearly as practicable at the temperature of from 140° to 150° of Fahrenheit's thermometer. The loss after drying indicates the degree of dampness. I have observed gunpowder of different manufactures to lose by this experiment from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent. The powder should be covered during the operation. A sheet of paper rolled up conically will answer for this purpose. It ought to have a small hole at the apex to allow the escape of vapour.

278. The examination of gunpowder auxiliary to proof trials may here terminate; and a knowledge of its relative qualities and adaptability for the requirements of actual service may, by the foregoing means, be satisfactorily acquired. The actual comparative ranges it may give, in connexion with a just regard to the manner in which those ranges may be qualified or affected by secondary causes, will constitute a safe criterion by which a judgment may be formed as to its practical and useful effect.

279. But where conveniences are at command, I would also recommend trial by the tests detailed in paragraphs 228 to 238, as well as attention to the system of manufacture (246 to 248). The whole of these points combined together appear to include all that can reasonably be required in any familiar, practicable examination of the quality, efficiency, and goodness of gunpowder.

280. To report judiciously and ably on an experimental comparative proof trial requires sound discrimination, arising from that particular acquaintance with gunpowder derivable only from a knowledge of principles; from familiarity with its manipulative history; from observation of the general effect produced by bad and good gunpowder when fired in large and small quantities in different ordnance, and from diversified

experiments made with the design of fixing the system of manufacture on the surest and most approved data, as well as of ascertaining in what cases deviation is of no material consequence, and where departure from principles, or failure in following them, would prove fatal to the quality of the article manufactured. I make no pretension to such perfect and intimate knowledge myself; the means and opportunities of acquiring it have not fallen to my lot. The opinion I express, is simply the conviction of twenty years' acquaintance with the subject of gunpowder generally, and of its manipulation in particular; coupled with the persuasion I feel, that much misapprehension has existed in India with reference to the true principles, both of its manufacture and proof; and that none of the papers or documents that I have seen, voluminous as they are, have set the matter on a firm basis. If, what has been advanced in the foregoing paragraphs, shall have tended to place the subject in a fairer light, and on a firmer foundation, the design I had in view has been fulfilled, and the task suggested to me, accomplished.

SECTION IX.—APPENDIX.

TO REFINE SALTPETRE.

281. Place a false bottom of wood, pierced with holes, in the copper boiler. Throw in twenty-eight hundred weight of grough saltpetre; add three hundred and ninety-two gallons of the purest spring or river water that can be obtained.* Raise quickly to a boiling heat. Boil three, four, or five hours, or until free from scum. At intervals, during the boiling, throw in small quantities of cold water; they are supposed to assist in separating the impurities. Skim off the impurities that rise to the surface. After sufficient boiling, let the fire decrease, and allow the solution to remain quiet, to cool and subside for two hours more.

* The proportion is a pound of water to a pound of nitre.

282. Then pump or lade it out gently into the filtering trough *a*, (see the annexed sketch). The filtering bags *c* are of close wove canvass, doubled. Before the cocks *b* are turned to let the solution into the filters *c*, a handful of pure, fine, dry, river sand should be sprinkled round their insides, to assist in filling up the meshes and pores of the canvass, and thereby forming a more perfect filter. On turning the cocks *b*, the first filtered portions of the solution will be received in the carrying pans *d*, foul and not transparent; these must be returned into the trough *a*, until the liquid filters through clear. When this occurs, the filtered liquid is to be carried to the crystallizing-pans, in which it should be suffered to remain about thirty-six hours to crystallize. These pans are of copper, and of about two feet six inches diameter, and twelve inches deep. They stand on stills or broad wooden troughs, having at one end an opening in the bottom, through which the mother-water escapes when poured off; and falling thence into proper channels, is conveyed into a general reservoir sunk below the floor of the refinery. Crystallizing-pans of this size are preferable to larger pans, because they are more convenient, and better adapted for the purposes to be accomplished.

283. At the end of thirty-six hours pour off the water of crystallization by raising the pans on edge,—the liquid will escape as before mentioned; lower the pans again, and, with a common gardener's watering-pot, sprinkle the crystals, but not too copiously, with water. Then set every two adjoining pans on edge again, face to face to drain, block them up with pieces of wood, and let them remain an hour or two, or until wanted to be carried on in further process.

284. The nitre will require a second purification. This is precisely similar to the first, only the proportion of water to be used is three hundred gallons to thirty hundred weight of crystals of the first refining. The filtering bags in this second purification are used double, that is, one bag is placed in another, so that the canvass is fourfold, for each single filter is made of double cloth. After the mother-water is poured off,

the nitre should be rinced or sprinkled as before, while in the crystallizing-pans, (but with rain water,) and then the pans may be set on edge to drain for six hours, or as much longer as may be convenient.

285. After each process the filtering bags should be washed clean, and be kept in that state ready for use. Wooden covers should be placed over the pans during crystallization: the design is simply to preserve the solution from accidental contamination. A little verdigris will be seen around the sides of the crystallizing-pans at the surface where the crystals touch the copper. It should be removed before the mother-liquor is poured off.

286. In manufactories where much greater labour and trouble are bestowed on the purification of saltpetre than the foregoing, it may perhaps be thought that the manual operations here detailed can never effect the complete purification of nitre. It is a fact, however, if they are properly performed, that they do; and that nitre so purified will be delicately white in appearance, and not indicate the slightest trace of muriatic acid on the application of the proper test.* The filters unquestionably constitute a most important feature of the process; and some dexterity and experience are required in the art of using them before the solution can be "run off well," as the workmen term it, thereby meaning that the liquid should be obtained perfectly clear and transparent. And though it may be not limpid like water, but somewhat coloured, in the first purification, it will flow as clear as crystal in the second.

287. To assist in making the filters properly, I have given in the sketch a figure *x*, shewing the shape of the canvass before it be sewed together to form the bag. The scale of feet and inches at the bottom of the plate will indicate the proper size. Each bag is suspended by four loops of strong twine, or small cord sewed on its upper edge at equal distances.

* I suppose the nitre to yield 80 per cent. of pure crystals, and not to be less clean than that.

288. If the purified nitre is required to be fused instead of being sun-dried, let the water be well drained off before it be thrown into the melting-pot, which should not be suffered to acquire a red heat. As for the remainder, the process is so simple that it requires no explanation. If the fused nitre be laded into close moulds with covers, it should be allowed to remain cooling before it is laded out of the melting-pot, until a small icy-like ring be formed round the inside of the vessel on the surface of the nitre;—lose no time in then removing it, or it will become solid, and the whole will have to be melted over again.

ON BURNING WOOD FOR CHARCOAL.

289. Sundry useful remarks relative to charcoal may be found in paragraphs 47, 49, 53, and 54.

290. The cylinders used for charring wood in His Majesty's works are of cast iron, about six feet long, and two feet six inches in diameter, fitted up in brick work, and accompanied with conducting-pipes, and having reservoirs for the reception of the liquid products of the wood. Such cylinders for the purposes of a manufactory are the best, and perhaps the most economical eventually: good charcoal may, however, be made by a much more simple apparatus.

291. The powder alluded to in paragraphs 31 and 44 was made of charcoal prepared in earthenware pipes about nine inches in diameter, and two feet long, arranged in a small furnace built with clay and a few bricks. The gas as it escaped was set on fire, merely to get rid of its offensive pungency, and it continued to burn like a gas-light, which in fact it was, as long as the wood supplied what was necessary for supporting combustion. When this ceased, the fire was allowed to go out, and the atmosphere was prevented from having access to the charcoal. When the pipes had cooled, the char was withdrawn, and the process repeated until coal enough for the experiment had been prepared.

292. In charring in the large way, the only points to be attended to are to keep the wood clean, to strip it of its bark, and remove all decayed parts, not to overburn it, but to check the process as soon as the last portions of the acid cease to drip, or of gas to escape. After the cylinders have in some degree cooled, and the charcoal is withdrawn, it should be placed in air-tight iron receivers, in which it ought to remain two or three days, or until it has become perfectly cold. One or two repetitions of the process will, with what has already been advanced on the subject, be sufficient to enable any intelligent individual to conduct the operation satisfactorily.

ON REFINING SULPHUR.

293. A gun-metal or bell-metal melting-pot, two feet six inches diameter, and one foot eight inches deep, is used in the King's works for this process. It is desirable either not to exceed this size, or to refine at one time no more sulphur when melted than is equal to the cubic contents of this vessel, if a larger melting pot should be already in use in a manufactory. The reason is, that with a larger quantity of brimstone, the fire is not so easily governed. Suppose a melting-pot of double the capacity of the foregoing to be employed, it would evidently, when nearly filled, require a higher temperature to conduct the process: this higher temperature would either have an injurious effect on the sulphur, by perhaps causing the production of sulphurous acid, or occasioning waste by evaporation. There is also more danger of the sulphur igniting.

294. I shall now describe the refining process; but paragraph 61 may also be consulted. The brimstone is first coarsely pounded, the impurest parts being rejected, and thrown aside for another operation. Use a gentle fire, and add only small quantities of sulphur at a time; and before more is added, let what has been previously thrown into the melting-pot be completely fused. In His Majesty's works, four hours are occupied in melting as much sulphur as the fusing vessel will contain; and when this has been effected, the fire is suffered to go out,

and the sulphur to remain undisturbed to cool and subside for about three hours longer. The scum or dross that arises during the operation must of course be removed. How the sulphur is then treated may be seen in paragraph 61. The appearance on its surface at the time it should be laded out of the melting-pot, is perhaps more like the appearance of dust upon water than regular crystallization (61), though that appearance, if closely examined, will be found to consist of minute incipient crystals.

295. The bottom part of the brimstone of the first purification is generally very impure. The upper portions are therefore to be gently and carefully laded out of the melting-pot; the subsidence or dross being stirred up and well mixed together and put into a tub by itself; the purer portions of it, when cold, are considered to be equal in quality to crude or unrefined brimstone, and are to be carried forward in process with it.

296. The sulphur must be refined a second time, but the operation is exactly similar to the first, except that there will be found no impurities like those just noticed at the bottom of the melting vessel.

297. The foul scum and subsidence of the first purification, and the very impure portions of the original sulphur, are thrown together, and after being coarsely pounded are submitted to fusion, which, in the technicality of the manufactory, is termed "The black pot." A considerable quantity of brimstone is obtainable from it. The manual operations are the same as before, until the melting-pot be full, when the filth and scum will rise and bubble up in frothy incrustations, which are to be removed with a gridiron skimmer, and piled up round the pot to prevent the liquid sulphur from flowing over. By constantly stirring the brimstone, the ebullition will eventually cease, and a foul scum arise, which must be removed and thrown aside; but the embankment of skimmings may gradually be remelted. This

operation occupies about eight hours, and when no further scum arises, the whole of it may be stirred about and mixed up together and laded out into the cooling tubs.

298. The purer part of this brimstone may be considered as impure sulphur: but the subsidence and the foul skimmings may be preserved for the process of sublimation, if it should be thought necessary to continue the operation to that extent.

THE END.

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