Gunpowder - Spirit of Artillery

Col. C. B. Brackenbury

Gunpowder considered as the Spirit of Artillery

Col. C. B. Brackenbury RA

Paper read to Royal United Service Institute

29-2-1884

Friday, February 29, 1884.

ADMIRAL SIR FREDERICK W. E. NICOLSON, Bart., C.B., Vice-President, in the Chair.

GUNPOWDER CONSIDERED AS THE SPIRIT OF ARTILLERY, WITH THE RESULTS WHICH HAVE FOLLOWED AND WILL FOLLOW THIS VIEW OF ITS POSITION.

By Colonel C. B. BRACKENBURY, R.A., Superintendent Royal Gunpowder Factory, Waltham Abbey.

THE title of the paper which I have the honour to read to-day may appear to some of you a little fantastic, yet it represents exactly what needs to be said on this subject. You will perhaps say inwardly, though politeness will prevent the outward expression of your thought—"Of course, nothing like leather; the head of the Royal Gunpowder Factory will glorify gunpowder." In reply to this perhaps you will acquit me of egotism in stating the fact that many years ago, when I had no more idea of ever holding my present position than I had of becoming King of Madagascar, I wrote an article on gunpowder headed the "Soul of Artillery." My present views on the question are but developments of those which were then expressed, developments which naturally follow the progress of knowledge.

We constantly hear that a gun has been produced which will do this or that, yet it is not the gun which does it, but the gunpowder. The gun is only a tube to concentrate the action of the powder and guide the projectile. There is not a single gun actually adopted for service in any country which is not, by its weakness, a hindrance to the full action of the "Spirit of Artillery." When gun-makers say, as they frequently do, that their gun will produce a certain effect "provided that a suitable powder be found for it," they mean "provided that the strength of gunpowder be restrained, 'cribbed, cabined, and confined' to suit the weakness of the gun." We sometimes see in human life a great and strong spirit tear to pieces a feeble frame which contains it, and we do not say, "What a pity that the spirit is so strong," but rather, "How sad that the body is so weak." In the case of artillery we are always subduing and taming the spirit instead of strengthening the body. This may be necessary under existing circumstances, but, if so, the circumstances are

Royal United Service Institute. Feb. 1884 unfortunate, and stand in the way of getting the most value out of the Spirit of Artillery.

Yet, what a marvellous career this spirit has run. When it appeared in Europe, the most potent master existing was the Spirit of Chivalry. And what was this spirit? Glorified by poets and endued with prismatic hues by the mists of time, it began by protecting the weak against the strong, but degenerated and came at last to strengthening the strong and weakening the weak. If some knights went about the world redressing the grievances of ladies, that shows that ladies had terrible grievances to redress. There were good knights and bad knights at all times, and the power of the law was not sufficient to restrain the bad ones. For one Ivanhoe there were probably a good many Front-de-Bœufs. "O, but the knights were bound to obey the behests of their lady loves and run all sorts of dangers to please them." Yes, but if the tasks set were too hard and dangerous we read of knights slapping the ladies' faces when the deed was successfully achieved. And, as for fighting, the knights were at last so covered with heavy armour that the poorer foot soldiers had no fair chance in combat. At Crécy the French knights rode down their own archers because they were in the way. Finally the knight had to mount his horse before his armour was put on. He was then quite invulnerable unless his horse fell with him, and the difficulty of killing him on the ground was so great that there was plenty of time for his friends to succour him. Besides, he was generally treated with tenderness in view of a heavy ransom. The defensive armour of a knight was stronger in proportion to his wealth. James I said of later armour that "it was an admirable invention, which preserved a man from being injured, and made him incapable of injuring anybody else." This was the point to which chivalry, an admirable institution at first, had come.

Into a world so ordered was born the "Spirit of Artillery," weak and hesitating at first when the firearm was less powerful than the crossbow, and when a writer of the fifteenth century could say that an artilleryman more than anyone else should always have before his eyes the fear of God, because "the great strength and force" of gunpowder "constantly causes the cannon which they fire to burst." The spirit is recognized as a living agent "grievous and terrible through its desire to kill and destroy the artilleryman by means of the great ills, and mischiefs, and damages it does to him in its vocation and trade."[1]

Monluc, who fought under Francis I, speaks of the growing power of gunpowder, saying that the arquebus "discharged by cowardly and base knaves," which was the chivalrous way of describing foot soldiers too poor to afford armour, struck down many brave men with plenty of money. The Spirit of Artillery was at work levelling distinctions in the field, destroying the shams which had clustered round chivalry, and forcing every human being to stand on his own courage and prowess, instead of on invulnerability purchased by the rich and denied to the poor.

[1] "Arms and Armour." By Charles Boutell.

In the contest between gunpowder and armour the gunpowder won a long time ago. A similar contest is going on now. Rich nations build mighty ironclads, and put them on the sea like knights in heavy panoply. The Spirit of Artillery will win in the struggle as it did of old, and it is possible that the same result—the abolition of armour—may follow when the victory is clearly decided. Ironclad ships are now boxes containing a complicated mass of machinery, and comparatively but few men. First rate men-of-war used to cost 1,000*l.* per gun. Some late examples—the "Italia" for instance—cost something like 100,000*l.* per gun, and much more if we only count the big pieces able to pierce armour equal to that of their own ship. Fancy the value of 1,000,000*l.* going to the bottom as it may from the result of one blow, and then think how closely the Spirit of Artillery is following the same course as once resulted in the abolition of a degenerate chivalry, the excessive power of the strong over the weak, the rich over the poor.

We will now turn, if you please, to the examination of this spirit, and see how much we know about it, and how it is getting on with its growth.

And, first of all, what is its actual strength?

The difficulty of the subject, as treated from a philosophical point of view, has been illustrated by the extraordinary differences in the theoretical results arrived at by different investigators. Starting with the year 1702, De la Hire supposed that the force of fired gunpowder arose only from the expansion of the air lying within and between the grains, this expansion being caused by the heat developed in the action of combustion.

In 1743 Robins crushed this theory by showing that it would only account for about a 200th part of the force actually arrived at. Robins added the effect of the permanent gas developed from the powder which, raised by the heat, would give a force equal to 1,000 atmospheres.

Five-and-thirty years afterwards, in 1778, Dr. Hutton communicated to the Royal Society his researches on gunpowder, which showed a great advance over those of his predecessors. He calculated the force of fired gunpowder at about double the amount arrived at by Robins, and called it 2,000 atmospheres. But the laws of thermodynamics had not been discovered in his time, poor man, so his views are quite obsolete now.

Then, in 1797, Count Rumford attacked the subject again, and reported to the Royal Society a series of experiments in which he supposed himself to have proved that this tricksy spirit of fired gunpowder, when kept tightly bottled up, was capable of exerting a force equal to the pressure of no less than 101,021 atmospheres, that is, 662 tons on every square inch.

In 1823 Gay-Lussac reported his experiments, and decided that the permanent gases would, at the freezing point of temperature, occupy a space 450 times greater than the powder from which they were derived. Piobert, however, promptly demolished his figures, showing that by some error in calculation his results were double what they ought to be, and, indeed, in another place Gay-Lussac gives the amount as about 250 volumes.

Piobert himself, between 1831–36, gives various amounts, ranging from 200 to 650 volumes, but seems to have settled down to a theoretical estimate of about 350 volumes, with a maximum pressure of 23,000 atmospheres, that is, 151 tons at the time of greatest tension.

In 1843 General Cavalli (who, by-the-bye, invented a breech-loading cannon) experimented with small barrels, and considered that with violent powders he obtained actual tensions of 24,000 atmospheres (158 tons to the square inch), while in less inflammable powders the force was under 4,000 atmospheres (26 tons).

In 1854 a Prussian Artillery Committee came to the conclusion that the actual maximum pressures were, in their 6-pr. guns, 1,100 atmospheres (7·2 tons per square inch), and in the 12-prs., 1,300 atmospheres (8·5 tons per square inch).

Between 1857 and 1859 Major Rodman of the United States made some important experiments with apparatus very similar to that which is chiefly used now on the Continent for taking pressures. He obtained results for tightly-packed powder varying between 4,900 and 12,400 atmospheres.

In 1857 Bunsen and Schischkoff published results which credited gunpowder with developing permanent gases which occupy 193 times the space of the powder.

And at last, in 1875, two gentlemen, before whose scientific authority on this question one stands cap in hand—Captain Noble, of Elswick, and Sir Frederick Abel—laid down, after a series of careful experiments, in which the new power—electricity—was called to their aid, that the tension of the products of combustion, when the powder fills entirely the space in which it is fired, is about 6,400 atmospheres, or 42 tons to the square inch, the temperature being about 2,200° C., that is, about 4,000° F.

Such has been the disagreement among philosophers who, however, doubtless approach nearer and nearer to the truth. What an inestimable comfort it would be could we stop here, and feel sure we are right. All these great philosophers gaily tripped up the heels of their predecessors, and who is to guard us against the advent of some new philosopher of distinction who will find flaws in the reasoning of Noble and Abel? Perhaps even a new science with a long name may be invented, as thermodynamics were. These two gentlemen are well able to take care of themselves in a controversy, but it was with positive sinking of heart that I observed some of their conclusions criticized and challenged by a French Committee appointed to examine them. And, alas! even our two philosophers show in a second memoir that the amount of permanent gas and the heat developed may be quite different in the different sorts of powder. They have even found that the maximum tension of some fired powders is so much as 44 tons on the square inch, and in actual practice results have been given by crusher gauges professing to show even higher pressure than this.

Let us accept a sort of rough round number for our practical manufacturing purposes and call the maximum pressure of any ordinary gunpowder, fired in a space that it fills, 45 tons on the square inch. Then, if the powder-makers fulfilled the old desire to make the strongest possible powder, and if we suppose the interior of the gun, where the powder lies, divided into a number of rings, each an inch wide, we should have for a 12-inch powder-chamber a pressure of no less than 1,696·4 tons on each ring seeking to tear it open; in fact, to burst the gun. Now, this is just what we powder-makers would like, and the artillerymen would like, because tremendous pressures would, other things being equal, mean immense velocities for the shot and more honour to the craft. But at this point the gun-maker and the carriage-maker step in and tell us that neither gun nor carriage would stand such enormous strains for long. They say that this spirit must be tamed and kept within bounds lest it should work more harm to the gunners than to the enemy; and it will not do to reply that they can use less of the powder. No, they must have great effect and small pressure at the same time. The gun-makers are running a race, which appears to me rather dangerous, in their efforts to procure great effects from light guns. For, unfortunately, the same powder will produce different effects in different climates. English-made powder has been proved to give higher velocities and pressures in India than at home, and Indian-made powder is too weak here to produce the effect required. The spirit becomes more lively in a hot climate. This would matter little if the pressure allowed were at all near the high limit of the action of gunpowder. But in all new guns, English or foreign, the pressure must be kept at about a third of that which is possible, and it is a grave question whether on the whole it would not be better to strengthen the gun even at the expense of more weight. However, the progress which has lately been made has been chiefly in the direction of taming this terrible agent, and making it do its spiriting gently.

Let us try to conceive what happens in the powder-chamber of a gun when the charge is ignited. Here all is supposition, for we cannot possibly see the burning of the powder, and even the philosophical and important experiments of Noble and Abel only tell us the *results* obtained in burning very small charges, not how the results are caused, still less the process in a gun of high calibre. If we compare the heat of a small fire with that of a great furnace, we know very well that it differs not only in size but in intensity. Probably a similar difference, though not so great, exists between the combustion of small and large charges of gunpowder. For our purposes at this moment we will neglect these fine distinctions, and lump all the guns together. How then does a charge burn in a gun?

First of all a small flash darts from the outer world by means of the tube, through the vent, and fires the charge at one spot. The first powder ignited produces a small quantity of heated gas, which penetrates wherever the way is easiest, that is, round the cartridge and through any holes there may be in it. Then the lumps of powder, whatever shape they may be, begin to burn all over, producing a quantity of gas which is proportionate to the size of the surface which is burning. In a single lump like that of the powder known as pebble, more gas is produced at first than later, because the burning surface is larger. Thus, supposing the usual theory is correct, namely, that each grain or lump burns regularly till all is consumed, we have much gas produced before the shot has time to start, and only a small increase afterwards to add to the velocity of the projectile, as it travels on through the gun. But if there be a hole through the lump as in the case of prismatic or the new cylindrical powder, it burns inside and outside at the same time, and, as the outer surface diminishes, the inner increases, so that we have an increase from the inside to compensate for the decrease of the outside, and thus the shot continues to receive a strong impulse up to the last, to quicken its speed through the bore. I shall show directly why I conceive that this theory is not altogether correct, but it is so up to a certain point.

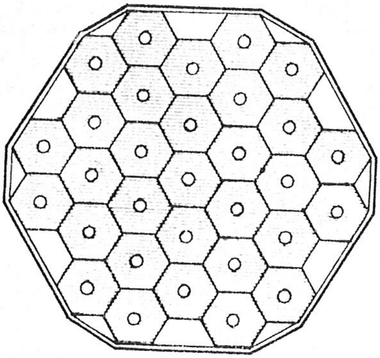
With regard to the shape of the lump, it is clear that as nothing is stronger than its weakest part, lumps of a spherical or cubical shape will take a time to burn away equal to that of burning from the outside to the centre taken anywhere we like. But long or flat pieces will only require the time necessary to burn through half their smallest dimensions. It matters not how much powder there might be. A cake a foot square and half-an-inch thick would require no longer to burn than a small sphere half-an-inch in diameter.

But the charge in a gun is composed not of one lump but of many, and we have to ignite every one of them if we wish to obtain the full effect of the powder. The more regularly we can ignite the charge, the more regular must be its action, and the more regular the velocity given to the projectile. To this end it is necessary that the first fiery spirit produced should get at each lump quickly and all over its surface. Suppose that we light the charge from behind. I take this as the simplest case. A portion of the gas will rush round the outside of the charge through the space which surrounds it and another portion will rush into any spaces there may be between the lumps. Now in the old powders the lumps, or pebbles as they were then called, in the powders for heavy guns, lay irregularly throughout the whole charge. Roughly speaking, opposite each space where the gas would enter there would be a lump which, though ignited, would receive an impulse forward, or sideways, according to where the gas entered. It would be driven forward, a similar effect would be produced on others, and we might, as an extreme case, suppose a large portion of the charge propelled onwards and dashed in a mass against the base of the shot. There would be a sudden check, a blow on the gun as well as the shot, a recoil wave assisted by the gas from the mass which would now burn, and, altogether, a great and irregular dashing about of gas waves (probably liquid at first, but we will call it gas), and so may arise what are called wave pressures. These would be uncertain and incalculable, and the same charge might one day give one pressure on the interior of the gun and another day another pressure. The velocity of the shot would be different, and therefore the shooting irregular.

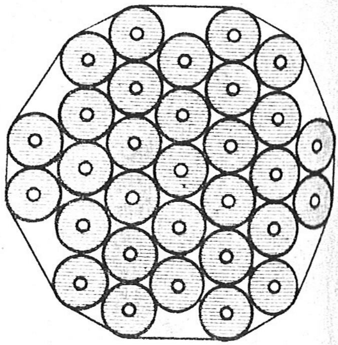
But now look at the back of a charge of prismatic powder. There

BASE OF CARTRIDGE MADE WITH P^2

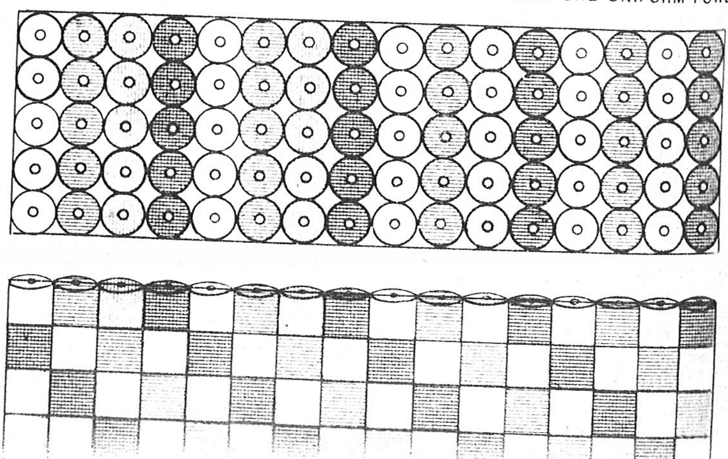
BASE OF CARTRIDGE MADE WITH PRISMS.



BASE OF CARTRIDGE MADE WITH CYLINDERS.



C^2 METHOD OF BLENDING 4 LOTS OF GUNPOWDER TO FORM ONE UNIFORM POWDER



are regular holes running right through the charge from end to end, and giving easy access to every prism in its interior at least. In a charge of cylindrical powder, not only the inside but the outside of each cylinder is freely exposed to the passage of the heated gas, and, other things being equal, we may expect less irregularity of action, as turns out to be the case. You see that the theory is in favour of the cylindrical powder, and this is one of the reasons why I designed it in that shape.

But, whatever be the shape, it is impossible for the ignited pieces, pebbles, prisms, or cylinders, to remain in their places. How do they move and what do they do? This is just what I wish somebody would tell me. Perhaps they are at first prevented from touching each other by the liquid or gas which surrounds them. Perhaps, on the other hand, they are crushed almost at first. This is certain that in a bottle of fragments of prismatic powder blown out of a gun and picked up extinguished, I found one fragment showing distinctly that it was part of the inside of a prism, which inside had never been ignited at all. At any rate it seems highly improbable that the lumps of powder burn regularly as has been supposed. It is a little dangerous to differ from received theories, but there seems to be good reason for supposing that, at some point in the burning, the original lumps are broken up along lines of least resistance and, after that, the powder, being in many more fragments than at first, burns more rapidly and fiercely in its volcano of molten fire.

There are at least two reasons why it would appear probable that the lumps must break up. First, because each prism or cylinder, burning both from inside and outside, must become a mere shell hurried along among other such shells in a raging torrent of liquid fire, striking the sides of the bore and the other similar shells. Secondly, because hard as a piece of gunpowder may seem, it is really a sponge with extremely small orifices, into which I believe the gas at the great pressure which prevails must penetrate.

There are many facts with regard to gunpowder which can, so far as I know, be explained in no other way; and it is found that, acting on this belief as a theory, practical results always turn out much as was to be expected. For instance, if the surfaces at first ignited are large enough to get up a considerable pressure, yet not so small as that all the powder shall disappear suddenly, the size of each piece makes no practical difference, other things being equal. Here are two prisms very different in size which give almost identical results. I am not aware of a single case in which there has been among the pieces of powder blown out of a gun and afterwards picked up, one solitary morsel retaining the shape of a cylinder or prism regularly burnt from outside and inside. And, to crown all, I have actually seen pieces of powder break up into three or four morsels even when ignited in the open air of a room. If this seems a heresy, it is one which will, I believe, in time become an article of faith.

Before explaining the application of this theory, permit me just to mention the principal operations in the manufacture of the older powders.

1st. The three ingredients, Saltpetre, Sulphur, and Charcoal, in a state of fine division, are well mixed in a revolving drum. The English proportions are by weight in dry powder—

75 Saltpetre.
10 Sulphur.
15 Charcoal.

2nd. The mixture, in a moist state, is incorporated under stone or iron "runners," heavy wheels which revolve on a bed, for some hours, and so mix and crush the ingredients as to bring them into a sort of softish cake, in which they are amalgamated and can no longer be distinguished one from another.

3rd. The cake so produced is broken down into meal between metal rollers.

4th. The meal is pressed between metal plates into a harder cake of the required density.

5th. The new cake is broken up into grain between toothed metal rollers and sifted to the size required, or, in the case of the pebble powders, is cut into the masses which we know as pebbles.

There are other processes of dusting, glazing, &c., not worth describing; but a very important one is—

6th, Drying. Up to this point there is always a considerable amount of moisture in the powder, and it has to be expelled, so as to leave only about 1 per cent., for reasons which need not be stated here. But I ask your attention to one point: the particles of moisture have to make their way out of the powder and must do so by channels between the particles of powder. Thus the mass becomes more or less spongy. If the moisture is driven out rapidly, the orifices will be comparatively large and the mass more spongy; if slowly, the sponginess will be less. As extreme cases, I have, by rapid drying, for experiment, largely increased the size of the mass and even blistered it. By very slow drying the mass has actually contracted and become more dense than it was when moist. Ignited in the open air, the fast dried pieces will burst like crackers, the slowly dried will burn slowly.

In order to get rid of the difficulty and the time spent in drying, we have tried making the grain of such a moisture only as will, when pressed, give a powder which requires no drying; and we have had considerable success with it. The best result yet given by a black powder in the 6-inch B.L. gun was obtained with a "dry-grain" powder, called—

	M.V.	Pressure.	Date.
L_8	1,963 f.s.	16·4 tons	25.10.82
Later, cocoa powder gave..	1,974 „	16·3 „	5.6.83
Still later „ ..	1,945 „	14·2 „	7.9.83

The newer powders, prismatic and cylindrical, pass through the same processes as the old until after granulation. The granulated powder is then simply pressed in moulds and dried. There are no other processes of manufacture, but a very important process of arrangement called "blending," of which more will be said shortly.

[illegible] moulds came to England

from America, was rather neglected here, but taken up in Russia, where the prismatic powder was first produced. The good qualities of prismatic powder were brought prominently into notice during the competition between the Armstrong and Krupp 9-inch guns at the Tegel practice ground, near Berlin; but even then it was not adopted here, mainly, I think, because the Russo-Prussian powder was, in its details, more suitable for breech-loading than for muzzle-loading guns. With details a little altered, it is now found much superior to pebble powder for even muzzle-loading guns. It was introduced at Waltham Abbey, on the recommendation of the Explosives Committee, in 1880. Besides the quality already explained of burning with better late effects, it is more regular, and has the advantage of making up into a better cartridge than the irregular lumps called pebble powder.

This prismatic powder was, therefore, a decided step in advance, but further progress was required. Hitherto short muzzle-loading guns had been used in this country, though Sir William Armstrong had produced long guns and proved their value as early as 1878, showing at the same time that breech-loaders and muzzle-loaders, made of the same internal dimensions and using similar ammunition, produce exactly the same effect. A high velocity with low maximum pressure on the gun was obtained by enlarging the powder-chamber, so as to leave an air-space. This was the best that could be done with the old powders, but Noble and Abel had already, in their second report to the Royal Society,[1] pointed out that, by detaining the projectile by a strongly resisting band, more value could be got out of the powder before the shot moved. Then the question arose whether a very slow-burning powder could not be used in this way to advantage by employing large charges which, burning slowly at first, would give little pressure, but would continue to develop a large amount of gas as long as the shot remained in the bore. In fact, the problem was to obtain the lowest attainable pressures at the breech and the highest at the muzzle. Colonel Maitland, the Superintendent of the Royal Gun Factories, asked if we at Waltham Abbey could break in the Spirit of Artillery to do this work, and we began to try our hands. I believe that this was the first instance, at least in England, when gun-maker and powder-maker agreed to work together, without the intervention of a Committee, and it was a recognition of gunpowder as the Spirit of Artillery, which must in time become universal.

The idea upon which I commenced work was, to use a shape which would be practically easy to make, would stand more rough usage than the angular prismatic powder, and would be ignited as regularly and uniformly as possible inside and out. As a first step, the angles were taken off the hexagonal prism so as to give it twelve sides. The result seemed promising, and the second step was to the cylindrical form. At the same time experiments were carried out to ascertain what was the greatest density which could be given to powder of the usual ingredients within fairly easy manufacturing limits. We found that 1·9 was almost more than we could do, and finally settled down to about 1·88. The first cylindrical powder made was of about the same

[1] [illegible]

size as Waltham Abbey prismatic powder; but as this required a long time to dry, we reached at a later period the size now before you, which has been adopted into the Service and is called C_2. Shortly after the larger-sized cylindrical powder had been made, the Ordnance Committee commenced their labours, and the powder was laid before them for trial. The trials have lasted a good deal longer than was pleasant to us impatient manufacturers at Waltham Abbey, but in the end the powder has been adopted, with the full approval of the Committee, and is now being manufactured for the Service. The chambers of all the new heavy breech-loading guns have been designed to fire this powder, on the same principle that makes men buy a saddle and bridle to fit the horse, not a horse to fit the saddle and bridle. The Spirit of Artillery has been given its fitting place, and the results are what you see on the table.

So far we have dealt only with the manufacture of powder with the usual materials in the usual proportions, but there is much to be done in modification of these. I happened once to be travelling in the same railway carriage with Sir W. Armstrong, and he asked whether, in view of getting rid of the eating away of the bores of guns by our unquiet spirit—erosion, as this "eating" is called—something might not be done by reducing the proportion of sulphur. On thinking over the question, it occurred to me that such a change might be advantageous in producing the slower powders now required. A few small experiments gave promising results, but the proposal found little favour, and it was left to a German firm to produce afterwards an excellent powder by this means and by the adoption of our new densities. This is the powder (Construction 82) the results of which are shown on the table. (See Table.) The composition of the powder is the same as that of the ordinary German prismatic, except in the proportion of the ingredients. The density is greater.

Another powder has been introduced in Germany, and is made there by two firms. It is called Cocoa Powder by one, and Brown Powder by the other. The proportion of sulphur is again small, and the charcoal, if so we may call it, is different from that generally made. It was only brought forward last year, and was at first irregular in action, but later samples have given very good results—about the same as Waltham Abbey C_2, and with a less amount of powder, which is an advantage. As it is supposed to be a great secret we must be silent about its details here, further than to say that we are able to make it at Waltham Abbey if its value is established. There are very different opinions about it: some people saying that it is too destructive to the interior of guns—in other words, that there is too much erosion. But it has two advantages over ordinary black powder, which, in my opinion, give it great claims to acceptance. It gives little smoke compared with black powder, and burns slowly in the open air, so that its manufacture is less dangerous. It contains more hydrogen, and produces, I believe, more permanent gas when fired in a confined space. There is reason to believe that it may be valuable in the old muzzle-loading guns as well as in the new breech-loaders.

Here is another powder, invented by the Italians, and called Fossano Powder, from the place where it is made. It is like our old P_2 powder, but larger, and the cake is differently made. First, a comparatively thin cake is made out of dense-grained powder; then this cake is again pressed between layers of lighter powder, and then the compound cake is broken up into lumps. The theory is that the outer layers will burn or break up first, and leave the denser grained interior to continue the action up to the muzzle of the gun. I venture to think that, though this was an improvement on the old powder, it will be superseded by the newer. Here are the results of some experiments lately made in the 100-ton Armstrong breech-loaders. They were carried out at Spezia by the Italian Committee. (See Table.) You will observe that the Waltham Abbey C_2 powder gave better ballistic results in the 43-ton B.L. gun than the cocoa powders, and we should expect even a greater difference in higher calibres. But the cocoa and brown powders have both beaten the Fossano powder. Still more would the C_2 be superior in ballistic effect.

A very wide field of progress has been opened by the use of grained powder pressed in moulds. The Spirit of Artillery has been bridled as it never was before, and rendered much more manageable. If we take a light-grained powder and press it together into a dense mass, we obtain lumps, of whatever shape, which will burn steadily for short muzzle-loaders. But if we take a powder of dense grain to begin with, and press it only so much as to make it hold together when first burning, but break up easily afterwards, we obtain in the later stages of combustion small pieces which will continue the production of gas as long as the projectile is in the gun. By this adjustment of means to the end we can meet any of the practical conditions which govern the dimensions of ordnance with reference to the places where the guns have to be worked.

And now, with reference to the blending. An idea has lately been afloat that this process (which consists in mixing powders which, after manufacture, are found on proof to differ to some extent in results) can be got rid of, and powder made so regular that it will need no blending. No one can say what the future may bring, but up to this time there appears no prospect of any such consummation. You all know that there are people, and even plants, so organized that every change of weather affects them. This is precisely the case with the spirit we are imprisoning in gunpowder. It is such a nervous and sensitive spirit, that in almost every process of bottling it up—that is, in the manufacture of gunpowder—it changes under our hands as the weather changes. Sometimes we can detect its nervous sensibility and allow for it, as in the process of pressing into moulds, when we can by actual trial tell what densities we are getting, and give more or less pressure as is required. For instance, on the morning of the 13th June, 1882, the pressure had to be applied for 45 seconds to obtain the required density. Later in the day only 29 seconds were required to obtain the same density. So that in the morning of a June day half as much again time was required as in the afternoon. On the 30th June, 1882, during part of the day the time was as short as 26 seconds; on the 11th December the time varied between 98 and 84 seconds to produce the same density as was obtained in June with 26 seconds. That is nearly four times as long in the one case as in the other. In other stages of manufacture we have no such indications; but it is a fact that, not only the warmth of summer and the cold of winter affect it greatly, but the morning mists, the sunshine of mid-day, the dews of evening, nay, even a passing cloud, tell upon its nervous temperament. As a mitigation of the weather difficulty we are about to try warming a set of houses with hot water. By this means we hope to obtain a little more regularity, but it will not meet all the difficulties. The state of the weather during the process of drying is especially important, and as we dry 100 barrels or cases at a time, each "lot," as it is called, differs from other lots, as one child in a family differs from others; we know not why. So then, if we want uniformity of energy, we must put our children together in batches or teams like horses, putting the weak with the strong, so as to produce an average power and effect.

In the old powders the selected lots were put together and mixed in revolving barrels. But it is conceivable that when finished and subjected to that perpetual motion which is the fate of all things military belonging to England, there may occur in the shaking during a series of years a change of position in which the larger grains will come to the top and the smaller grains sink to the bottom, so that a charge taken out of the top of a barrel may give different results from one taken from the bottom. With the new powders there is no such danger. At Waltham Abbey we blend them with the greatest accuracy, as you see in the diagram, and they cannot shift their places, because their shape will not let them. (See Diagram.)

There is one feature in the manufacture of gunpowder to which I have not referred, as it is only an assistant, and does not in any way influence the character of the powder. I was amused at seeing a paragraph in a scientific paper the other day asserting that a certain gunpowder factory has just been provided with the electric light, and this was the first use of the light for such a purpose. We have had it at Waltham Abbey for two or three years past, and my ingenious friend, Major Watkin, has designed what I believe to be the safest possible light in existence. It may interest some of you to examine the arrangement with him presently. In the meantime I think you will admit its absolute safety. The incandescent lamp—anybody's will do—is plunged in a large glass vessel of water and hermetically sealed. The light can be used where we should fear to have any other known light, and thus are secured at once longer working for several houses, and brilliant illumination with perfect safety.

We have now run over the principal changes which have lately occurred in the manufacture of gunpowder—the production and breaking in of the Spirit of Artillery. And it all comes to this, that every step has opened up fresh possibilities, so that I, for one, feel that we are as yet only on the threshold of an immense subject. I forbear to lead you forward out of the region of facts into that of speculation.

But, certainly, much remains to be done. The force which abolished the shams of the old decaying chivalry has, by its influence on arms, called forth a larger chivalry, in which the private soldier may become and be recognized as a hero. It demands from him a courage capable of sustaining him in danger when there is no shock of battle to stir him, but a long waiting under a rain of death which comes to him from afar—unannounced, invisible. It demands also from him education and intelligence, not merely brute force. Whether, after having created the call for ironclads, it will abolish them again, remains for time to show; but if England keeps, as we all believe she will, her place in the first rank of human progress in arts, arms, and in the lofty courage which flourishes only where true liberty exists, we can only welcome the progress of the Spirit of Artillery.

TABLE I.—*Philosophers' Calculations.*

Date.	Authority.	Volume of gas.	Pressure.		Heat evolved. C.	
			Atmospheres.	Tons.	°	
1743	Robins........	244	1,000	6·7		
1778	Hutton........	250	2,000	13·5		
1797	Rumford......	..	101,021	662		
1823	Gay-Lussac....	450	2,137	14·3	1,000	
1831–6	Piobert........	350	23,000	151		
1843	Cavalli........	..	24,000	158	..	Violent powders.
			4,000	26	..	Less inflammable powders.
1854	Prussian Artillery Committee	..	1,100	7·2	..	In 6-pr. gun.
			1,300	8·5	..	,, 12-pr. gun.
1857–9	Rodman.......	..	From 4,900	32·1		
			To 12,400	81·3		
1857	Bunsen and Schischkoff	193	4,374	29	3,340	
1875	Noble and Abel	280	6,400	42	2,200	

TABLE II.—*Performances of different Guns and Gunpowders.*[1]

Gun.			Powder.		Shot.	Muzzle velocity.	Muzzle energy.	Mean pressure.	
Calibre.	Weight.	Loading.	Nature.	Weight.	Weight.				
ins.	tons.			lbs.	lbs.	ft. secs.	ft. tons.	tons.	
8·12	4·75	M	L.G.	16	66	1,580	1,142	..	68-pr. S.B.
7	4·1	B	R.L.G.	11	90	1,165	846	..	100-pr.

[1] The object sought is to obtain the highest muzzle velocity with the lowest pressure.

Gun.			Powder.		Shot.	Muzzle velocity.	Muzzle energy.	Mean pressure.	
Calibre.	Weight.	Loading.	Nature.	Weight.	Weight.				
ins.	tons.			lbs.	lbs.	ft. secs.	ft. tons.	tons.	
9	12	M	P.	50	258	1,420	3,607	.	
10	18	,,	,,	70	410	1,364	5,288		
12	35	,,	P^2	140	714	1,390	9,125		
12·5	38	,,	,,	160	818	1,445	11,842	..	Unchambered.
,,	,,	,,	C/82	210	,,	1,591	14,352	16·7	
,,	,,	,,	Prism.	,,	,,	1,615	14,790	19·0	
16	80	,,	,,	450	1,700	1,604	30,329		
17·72	100	,,	,,	,,	2,000	1,548	33,233		
,,	,,	,,	Fossano.	551	,,	1,706	40,000	20·0	
9·2	18	B	C/82	150	320	1,976	8,661	15·1	
,,	,,	,,	C^2	200	,,	2,075	9,551	15·0	
,,	,,	,,	Prism.	150	,,	1,960	8,521	16·5	
,,	,,	,,	Brn. ,,	160	,,	2,011	8,971	15·4	
10·4	26	,,	C/82	220	462	2,001	12,823	15·9	
,,	,,	,,	Prism.	205	,,	1,868	11,175	15·6	
,,	,,	,,	Brn. ,,	220	,,	1,923	11,843	15·2	
12	43	,,	C^2	350	714	1,996	19,719	16·3	
,,	,,	,,	,,	340	,,	1,910	18,056	13·8	
,,	,,	,,	Prism.	260	,,	1,770	15,506	15·0	
,,	,,	,,	Brn. ,,	300	,,	1,978	19,365	17·4	
17	100	,,	Fossano.	772	2,002	1,833	46,629	16·5	
,,	,,	,,	Düneberg Brn. prism.	,,	,,	1,841	47,036	14·6	
,,	,,	,,	Cologne Brn. prism.	,,	,,	1,795	44,715	13·3	

Mr. Kraftmeier: Colonel Brackenbury in his lecture seems to have a strong preference for the larger prisms and larger cylinders. Now he mentions that, in drying out the moisture, small channels are formed in the prisms. Of course, in constructing larger prisms and larger cylinders there is much more moisture to be driven out, and therefore I should think there is much more chance of irregularity in the larger prisms by a larger quantity of channels being formed, and I should think that this would rather destroy the regularity which is expected to be attained from the more regular form and process of combustion of these larger cylinders. I have quite recently received news from Spezia that the 100-ton Armstrong breech-loading gun has also been fired with a charge of 375 kilos. of brown prismatic powder—about 825 lbs.—and that the pressure has not been very much higher than with the 350 lb. charge. I am sorry that I have not the actual results here.

Colonel Brackenbury: Mr. Kraftmeier [illegible] when he says that I strongly advocate any particular size of gunpowder; on the contrary, I think I am about the only person in Christendom who says it does not matter one way or another for ballistic purposes what the size of the powder is, or scarcely at all. I am perfectly prepared to accept either size, and will engage to get by other manipulations of the powder almost identical results, whatever the size may be, within reasonable limits. Drying the cylindrical powder takes a very much shorter time now than it used to do, and not only so, but by a process which we are working out, we shall, I believe, get rid of drying altogether. Drying has been looked upon as a process in the manufacture of gunpowder which has given the utmost trouble, and has altered the constitution and effects of powder to a very large extent; but by the process which we see our way to adopting, when we have worked out the details thoroughly, we shall get rid entirely of this troublesome process. I have had no information with regard to the experiment which Mr. Kraftmeier mentions as having taken place at Spezia; but I may say that some of the results at Spezia, shown on the table which hangs before you, were kindly communicated to me by him as agent of one of the great German firms, and the other results by the other agents. I may also say, and I am very glad to acknowledge it, that we are indebted to German manufacturers of gunpowder for having brought to the notice of this country the prismatic powder which they have worked out with a great deal of trouble, and also for kindly communicating to me on more than one occasion details which I was very glad to have. I have to thank Mr. Kraftmeier and the firm he represents for having given me valuable information on very important questions.

The Chairman: I have only one more duty to perform in reference to this lecture, and that is to ask you to thank Colonel Brackenbury most cordially for having brought this subject before us. It is manifest it is one of considerable intricacy, and, as he says, he, with all the knowledge he has brought before you, is only on the threshold of it, I think we may look forward to further lectures in this theatre; and I hope, perhaps, Colonel Brackenbury himself, when he has passed the gateway of which he is only on the threshold, will be able at some future time to follow up the subject. I beg to offer, in the name of the meeting, our cordial thanks to Colonel Brackenbury for the lecture he has given us.