ON RECENT INVESTIGATIONS AND APPLICATIONS OF EXPLOSIVE AGENTS

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A LECTURE

DELIVERED TO THE MEMBERS OF THE BRITISH ASSOCIATION AT EDINBURGH, AUGUST 1871

BY

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ON

RECENT INVESTIGATIONS AND APPLICATIONS OF EXPLOSIVE AGENTS.

In submitting to the Members of the British Association some account of recent progress made in the production and application of explosive agents, I cannot attempt to give much more than an outline of the nature and results of important investigations which have been instituted, and are still being pursued, relating to the development and regulation of the explosive force of gunpowder, and to the application of some other explosive materials, which are already supplanting gunpowder in several of its important uses.

The manufacture of gunpowder, required for war-purposes, was carried on here and abroad for very many years without any important modification. The system pursued in this country in effecting the incorporation of the ingredients, and in converting the mixture into granulated gunpowder, of sufficient density and hardness to enable it to resist injury by transport and storage in all climates, furnished a product which was greatly superior to the generality of foreign gunpowders in regard to its keeping qualities, but which was also more violent in its action, because, in fact, the conditions essential to a rapid and complete transformation of the several constituents were more thoroughly fulfilled in its manufacture; and which hence earned on the Continent the name of "poudre brutale."

The comparatively small charges used even with the heaviest cast-iron smooth-bore guns, which until recently constituted our most powerful armaments by sea and land, were, however, regarded in this country as not unduly trying to the endurance of those guns; and although, about fourteen years ago, some attention was directed to the question of modifying the form or proportions of heavy guns with a view to increase their durability, in consequence mainly of some very instructive experiments instituted in America by Major Rodman, it was not until some little time after the first great stride was made in the increase of power of our

artillery (by the introduction of the 110-pounder Armstrong rifled wrought-iron gun), that attention became seriously directed to the importance of attempting to reduce the violence of action, or rapidity of explosion, of the gunpowder to be employed in the increased charges required to impart the requisite velocity and accuracy of flight to comparatively heavy projectiles. A comparison of the weight of shot and of the charges of powder used in the heavy guns of the present day, with those employed in the most formidable *cast-iron* siege and naval guns, will at once show how greatly the conditions must have become modified which attend the application of gunpowder to projectile purposes. Much has been written and said, especially of late, as to our having been far behind other nations in devoting attention to the modification of gunpowder, with a view to meet the altered conditions attending its application in the heavy guns of the present day; but the fact is, that not only were the first investigations into the action of fired gunpowder made in this country, but steps were also taken in England, almost as soon as in any other country, towards the production of a gunpowder, by employment of which the full powers of heavy guns may be developed with the least detriment to their durability.

In 1858 a small Committee was appointed to determine upon the best description of gunpowder to be used in the Enfield rifle, and not long afterwards this Committee was instructed to extend its inquiry to cannon powder—the most powerful gun of the service at that time being the 110-pounder Armstrong gun. One of the members, General (then Captain) Boxer, had, some few months previously, called attention officially to the desirability of modifying the action of the charges of powder used in the larger natures of guns, either by employing a weaker powder, or a larger grain and denser powder, the charge being increased in amount in order to obtain the same average pressure, and consequently the same initial velocity, as furnished by the quick powder then used. A careful consideration of the directions in which gunpowder was susceptible of modification, with a view to the reduction of the rapidity of its explosion, led the Committee to institute a series of experiments, which resulted, in the first instance, in the introduction into the service, in 1860, of the so-called rifle large-grain powder, for all rifled guns, and subsequently in the provisional introduction of pellet-powder for the heavier natures of ordnance. The means and appliances at the command of this Committee for carrying out their experimental investigations were small and imperfect; but the results at which they arrived not only served as the starting-

points of the successful results attained by the present Committee on Explosive Substances, but also became known to and aroused the attention of Continental Powers, through the agency of officers who visited this country at about the time of the Exhibition of 1862, at which date pellet-powder had already been experimented with for some little time. In America experiments on gunpowder were vigorously pursued at the same time as they were being slowly carried on, with comparatively imperfect means, in England, and the particular form of powder known as Prismatic, the production of which was developed in Russia a few years ago, and which has been to some extent adopted in Prussia, appears to have been of American origin, though it has not found favour in that country, where a gunpowder similar in form and size to the new powder known as *Pebble* is employed in guns of large calibre, under the name of *Mammoth powder*.

The principles laid down by the first Committee on Gunpowder, in 1858, as their guide in attempting to reduce the violence of action of powder when fired in large charges, have been, up to the present time, adhered to by those since entrusted with the continuance of these investigations. Before specifying them it may be instructive to glance briefly at some ways in which gunpowder may readily be modified, with the object of increasing or diminishing the rapidity and violence of its explosion, and at the reasons why they have not hitherto been selected.

As gunpowder is simply an intimate mechanical mixture of a powerful oxidising agent—saltpetre or potassium-nitrate, with two readily-oxidisable substances, sulphur and carbon or charcoal—it is obvious that the behaviour of this mixture, *i.e.* the rapidity with which it will explode, and the nature of the results furnished by its explosion, are susceptible of great modification by variations in the proportions of its ingredients.

According to the long-accepted chemical theory of the action of gunpowder, the function of the charcoal was to undergo conversion into gas by partial or complete oxidisation (*i.e.* by conversion into carbonic acid or carbonic oxide), according to the proportion which it bears to the saltpetre employed, while the sulphur was considered to act in two ways—firstly, in promoting the ready ignition of gunpowder by reason of its great inflammability; secondly, by uniting with the potassium in the saltpetre, and thus rendering available the whole of the oxygen for the oxidation of the carbon.

That this view is, to say the least, only a very imperfect explanation of the action of the ingredients in gunpowder, has long since

been demonstrated; but the broad facts are undoubted that the rapidity of explosion of a mixture of these three substances may readily be increased or diminished by modifications of the proportions of sulphur or charcoal, or of both, with which the saltpetre is mixed. A very notable difference may be observed in the rate at which two trains will burn, which consist of gunpowders in other respects alike, but differing, for example, in the proportion of charcoal which they contain.

A comparison of the composition of English and foreign gunpowders shows that some of them differ considerably from each other as regards the proportions of their ingredients; and there can be no doubt that these differences may exert a very decided influence upon the action of these gunpowders.

The extent to which the charcoal employed in their preparation has been burned (*i.e.* the duration of the carbonising process, or the temperature at which it has been effected), and its consequent composition, also vary considerably, and it has been abundantly demonstrated, by the more recent experiments conducted at Woolwich, that, the other characters of cannon powders, tried one against another, being alike, the violence of action increases in direct proportion to the amount of volatile constituents (as indicated by the proportions of hydrogen and oxygen) which have been allowed to remain in the charcoal. This result was observed many years ago in connection with powder for small arms, the French having found that a highly inflammable charcoal (*charbon roux*), produced by exposure of wood to a comparatively low temperature, furnished a very violent gunpowder, which, on account of its destructive action upon the firearm, was termed *poudre brisante*. It was, however, not known that apparently small differences in the composition, and consequently in the physical properties and ready inflammability of the charcoal, might be productive of very considerable differences in the action of gunpowder even when employed in large charges.

It need scarcely be pointed out, after what has been said regarding the influence exerted by certain variations of composition upon the rapidity of explosion and consequent violence of gunpowder, that different modifications in the composition of powder, which are opposed in the results they produce, may be made more or less completely to neutralise each other's effects. Thus, the reduction in rapidity of action of gunpowder, which may be effected by a diminution in the proportion of the inflammable ingredient sulphur, or of the oxidising ingredient saltpetre, may be counteracted by the employment of a slackly-burned and therefore highly in-

flammable charcoal; and in this way it may be possible that the composition hitherto fixed for gunpowder in this and some other countries may be susceptible of modification, with advantage in point of economy.

Sufficient has been said on this head to show that the explosive action of gunpowder is susceptible of very extensive modification by variation of its composition. But inasmuch as the force exerted by gunpowder is due not simply to the actual amount of gaseous products resulting from the explosion, but also, and in the largest proportion, to the heat developed by the chemical action, it follows that there must be particular proportions of ingredients which, leaving other conditions out of consideration, would appear the best, as furnishing the largest amount of gaseous matter compatible with the development of the highest temperature.

There can be no doubt that the proportions of saltpetre, sulphur, and carbon, fixed upon in the earlier days of gunpowder manufacture (and which have hitherto undergone no *very* considerable modification, and indeed *none* made with any definite design), were not fixed upon by any theoretical considerations, but were purely the result of tentative experiments; but they very nearly correspond to those required for the development of the most energetic action of the saltpetre upon the carbon (regarding the charcoal for a time as pure carbon), though they are not calculated to furnish the largest amount of gas from a given weight of the mixture. The latter result would necessitate the employment of the carbon in the proportion to produce carbon monoxide, or carbonic oxide; while the amount actually used in gunpowder is approximately that required to produce only carbon dioxide or carbonic acid, assuming the sulphur only to exercise the function above indicated, and not to take to itself any of the oxygen of the saltpetre. It has now been long established that the sulphur does at any rate undergo partial oxidation; but it is also admitted that the employment of the proportions of saltpetre, carbon, and sulphur, indicated by the old theory, which provided for the full oxidation, or conversion into carbonic acid, of the greater part of the carbon, furnished a mixture by the explosion of which a comparatively very great amount of chemical energy, and consequently of heat, is developed (or of pressure, when the charge is confined).

It is upon such considerations as these that the late Committee on Gunpowder came to the conclusion that, in attempting to moderate the explosive violence of gunpowder when used in large charges, it was inadvisable to make any change in the estab-

lished composition of gunpowder which might be productive of a diminution of the total pressure developed by a charge, unless the desired results were unattainable by modifying the mechanical and physical characters of powder—in other words, by introducing changes in the *preparation* of gunpowder, and in the *form* in which it is employed. It required but few experiments to demonstrate that the rapidity of explosion of gunpowder was readily susceptible of great reduction by simple mechanical means, and hence those means have been adhered to by the present Committee on Explosive Substances, in elaborating the powder now manufactured for naval and siege guns.

The degree of perfection to which the ingredients of powder are prepared by grinding, and afterwards mixing or incorporating, affords an obvious means of modifying the rapidity of explosion of the mixture, but it would also evidently be both unphilosophical and unpractical to reduce the rapidity of burning of powder by diminishing the degree of completeness to which the ingredients would react upon each other, and thus employing them wastefully, which would be the case if they were not converted into as intimate a mixture as is attainable by known means and appliances. But, starting with as perfect a mixture as can be prepared of the ingredients in the proportions calculated to furnish the maximum attainable change of volume (and consequently of total pressure at the time of explosion), there are *five* different directions in which gunpowder may be modified as regards its physical and mechanical characters, and the means thereby presented of regulating the rapidity of explosion, have, up to the present time, proved quite sufficient for all requirements. These variable points are—*the size* of individual masses composing the charge of powder; *the form* of these masses, and the *mechanical condition* of their *exterior;* the *density* or compactness of the masses, and their *hardness.* The size and form of the masses are readily modified by moulding the mealed powder into forms of a particular size and shape, as in the case of pellet-powder, prismatic, cubical, or spherical powder; or by breaking up, to a greater or less extent, and in a symmetrical or irregular manner, cakes of compressed powder of different thicknesses, thus producing what is called granulated powder, which ranges in size from fine sporting powder to pebble powder. The surfaces of these masses may be left in their original rough condition, or they may be more or less smoothed and deprived of sharp angles and edges by means of attrition and subsequent glazing or coating with graphite; and their ready inflammability may be