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'Modern Gunpowder and Cordite'

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MODERN GUNPOWDER AND CORDITE.

(A Lecture delivered at the Royal Artillery Institution, January 23rd, 1893).[1]

BY

LIEUT.-COLONEL F. W. BARKER, R.A.

COLONEL C. TRENCH, R.A., IN THE CHAIR.

THE CHAIRMAN :—It is not necessary, gentlemen, to introduce the lecturer to you. I will call upon Colonel Barker at once to deliver the lecture which he has kindly prepared for us.

COLONEL TRENCH AND GENTLEMEN.—A most interesting lecture on explosives was delivered in this Hall, not many months ago, by a distinguished officer whose name is well known to us all, and whose services have been with the Royal Regiment of Artillery. The substances which he discussed in his lecture included, among many others, those whose manufacture and characteristics we are about to deal with this evening, namely, modern gunpowder and cordite. He, as Her Majesty's Chief Inspector of Explosives, treated (and, I submit, very properly treated) all the substances as explosives. I propose, however, to consider two of them, modern gunpowder and cordite, as propellants, and, as such, to discuss their manufacture, character and qualities, up to present date and recent experience.

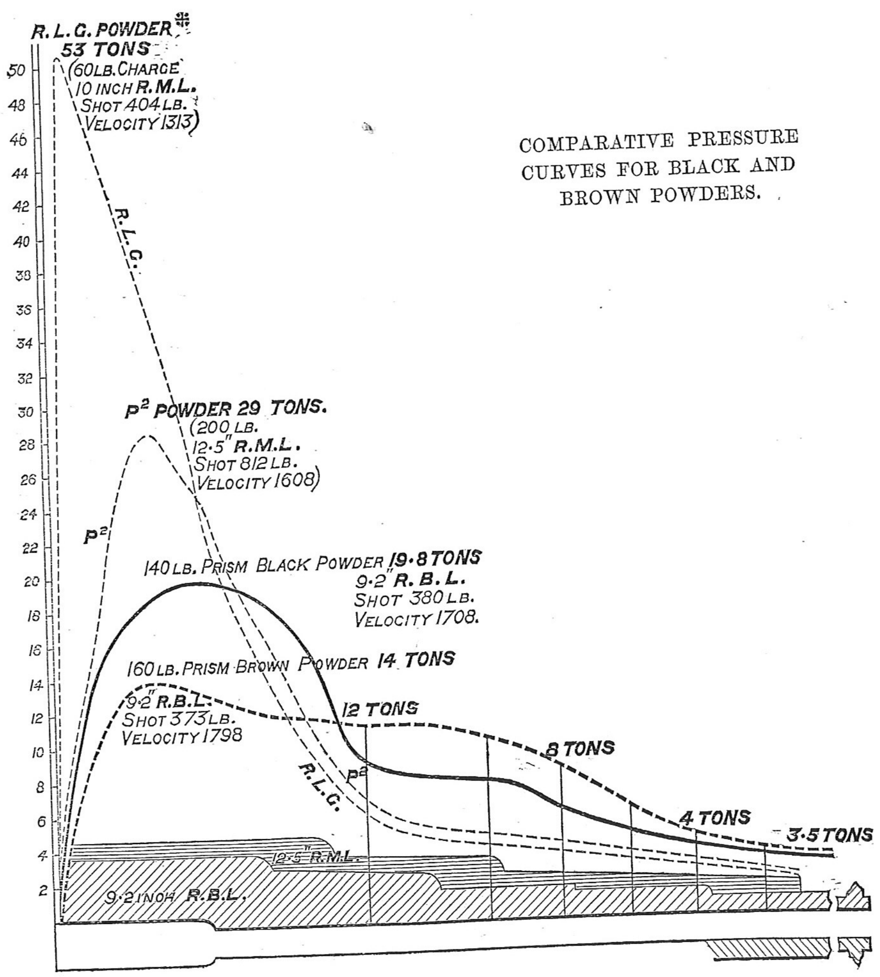
It is hoped, therefore, that what I submit to you this afternoon may prove a not unsatisfactory sequel to the interesting lecture to which I have already referred.

Modern gunpowder, as distinguished from that in use up to a comparatively recent date, may be classified as a "reliable propellant," whose powers are under control, and from which almost identical results may be expected under relatively similar circumstances or conditions. The older gunpowder was a powerful explosive whose violence was only conjectured, and whose characteristics were a bar to all progress in scientific gunnery. There are black powders now in existence and Gunpowder.

[1] Some of the diagrams, &c., connected with the Gunpowder portion of this lecture are taken from a paper read on "Modern Gunpowder as a Propellant," by the lecturer, in 1890, at R.U.S. Institution, and permission has been kindly granted to reproduce those required.

almost identical in appearance. With one class, the modern, the magnificent shooting of our prize rifle matches is obtained. The other, which represents the older gunpowder, is rejected as useless by civilised nations and, fortunately, (or unfortunately ?) relegated to the inhabitants of Darkest Africa and other simple folk who are easily satisfied with any compound containing a sufficiency of "villainous saltpetre." We can further emphasize the difference between old and modern gunpowders by comparing the manner in which pressures are developed by them; and I submit a sufficiently characteristic example in the diagrams Fig. 1 and Fig. 2 now before us. Even after the

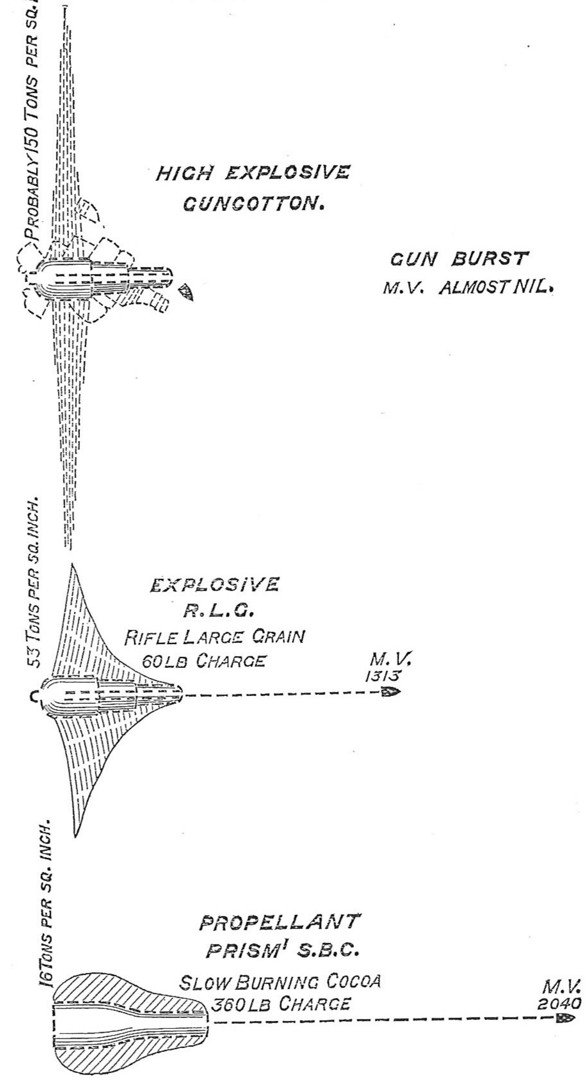
Fig. 1



COMPARATIVE PRESSURE CURVES FOR BLACK AND BROWN POWDERS.

Fig. 2.

EXPLOSIVE AND PROPELLANT EFFECT ON GUN AND PROJECTILE.



introduction of rifled guns we find a pressure recorded against R.L.G. powder of 53 tons; and only a few years ago, just before the manufacture of P² powder ceased, the pressures developed by it reached 29 tons, while the muzzle velocities in each case were comparatively low. On the other hand, the more recent gunpowders nearly fulfil the requirements of the artillerist, and give a high muzzle velocity with moderate and regular pressures properly distributed throughout the bore of the gun, and further, these powders, by their uniformity of action, ensure similarity of results. The diagrams here indicate what the pressures are with the old explosive R.L.G. The dark area represents the rapid increment of pressure and the equally rapid decrease which takes place when the charge is ignited.

It may be well now to discuss the methods by which gunpowder has been developed into a "reliable propellant," and, as briefly as possible, to deal with the outlines of its manufacture. Let us note the new features in the table before us :—

TABLE A.—*Gunpowders.*

	Old. *Black.*	Modern. *Brown.*
KNO_3	75 saltpetre	79 saltpetre.
S	10 sulphur	3 sulphur.
C	15 charcoal {willow, alder, dogwood}	18 charcoal (straw) {carbon. hydrogen. oxygen.}
		1·7 / 2·2 water {hydrogen. oxygen.}
		Black.
		75 saltpetre.
		10 sulphur.
		15 charcoal {carbon. hydrogen. oxygen.}
		1·0 / 1·3 water {hydrogen. oxygen.}

Water is no longer looked upon as an unavoidable evil ; its influence in reducing the pressure in the early stage of ignition, and the steam or gases produced from it hold a recognised position in the composition of the new propellant. These two vessels of water before you represent actually, the maximum quantity and the minimum quantity which should be present in each barrel containing 100 lbs. of service gunpowder. The larger quantity is 2·2 per cent, the maximum limit ; and the smaller 1 per cent., the minimum limit for ordinary powders.

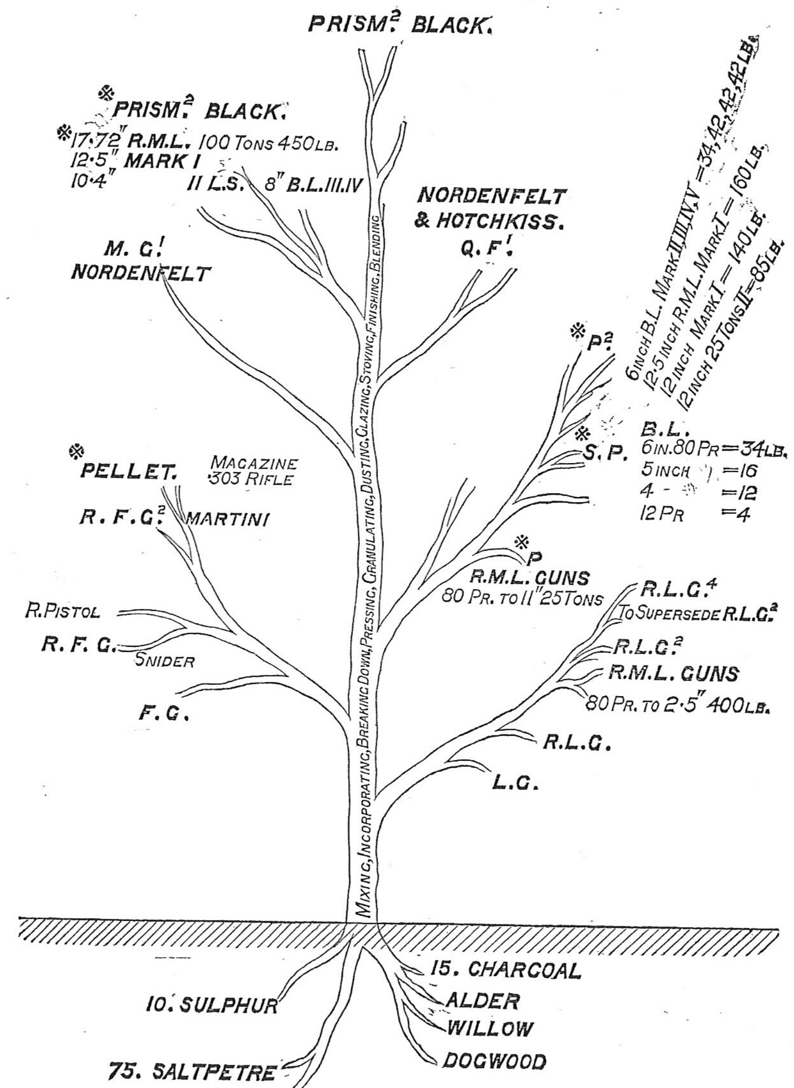
It is well to realise that the portion of the old maxim "keep your powder dry," must be considerably modified, and that, though modern gunpowder is designed to stand the ordinary changes of climate to which most of our war material is exposed, yet it may resent abnormal or artificial heating, or baking in magazines close to engine-rooms or boilers, as treatment unworthy of its dignity ! I might say in passing, that the quantity of water shown in the table (Table A) is the normal amount which gunpowder retains under ordinary conditions ; that is to say that it will not part with or absorb more than that quantity unless subjected to abnormal treatment. We may also observe that the charcoal has now fixed proportions of carbon, oxygen and hydrogen, which (when properly prepared) it should always contain. The old charcoal was merely burnt wood, and nobody knew anything about it. Now there is a careful analysis made of charcoal, and the proportions of carbon, oxygen and hydrogen are always adhered to.

As it is not proposed in this lecture to discuss the manufacture of gunpowder in detail, I shall only name the processes, each of which

has a considerable influence on the characteristics of the powder produced. They are exhibited along the stem of the tree diagrams, Figs. 3 and 4. In the roots the proportions of the different ingredients are

Fig. 3.

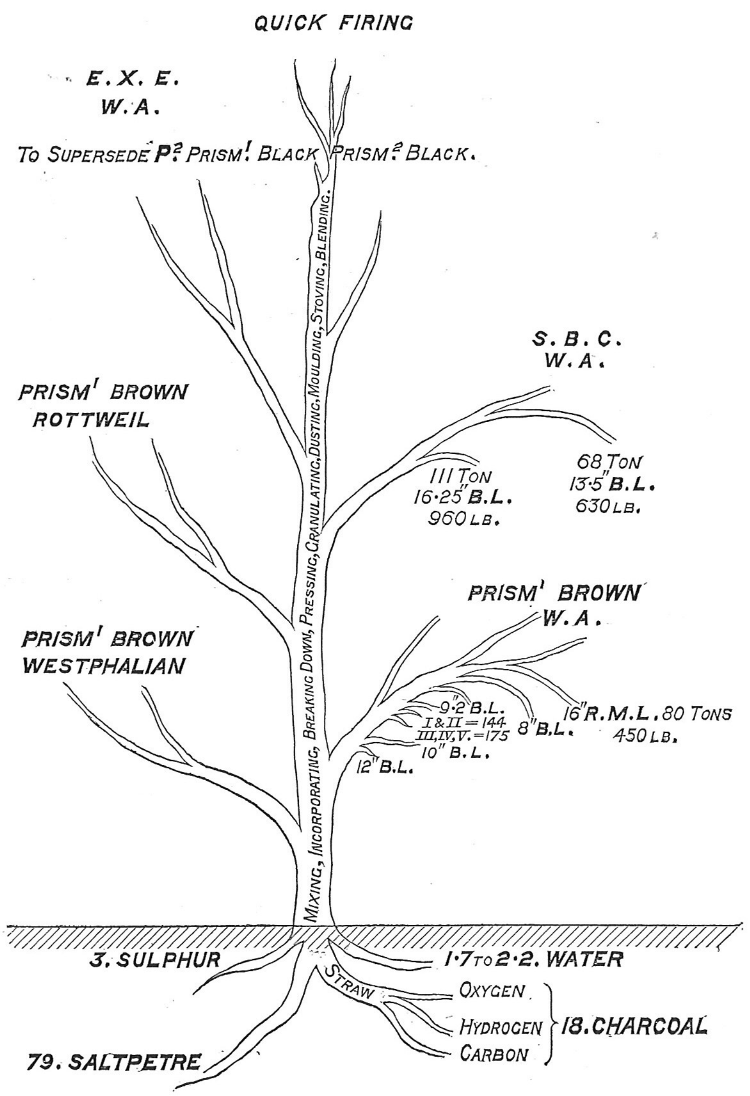
GUNPOWDER TREE.—*Black.*



* These charges are undergoing modification. *Vide* Brown Powder.

Fig. 4.

GUNPOWDER TREE.—*Brown.*



shewn, viz.: 3 of sulphur, 79 of saltpetre, 18 charcoal and water 1·7 and 2·2. The charcoal being composed of carbon, oxygen and hydrogen, straw being the material used for the new charcoal, and willow, dogwood or alder for the other. Along the stem of the tree the different operations are shewn, and the sketch is intended to present in an easily remembered form, the outlines of manufacture of gunpowder, and the

guns with which it is used in the services.

The story of the unsuitability of the early powders to arms of precision is a question of the past, outside the limits of time at our disposal, and more recent experience has shown that even the best black powders in very heavy muzzle-loading guns were found to strain the inner steel tubes, and had a tendency to split them.

We are now in a position to consider the various steps which, within the last few years, have completely altered the character of gunpowder. If we look at the diagram to which I invite your attention, it will help us to form an idea of the manner in which gunpowder has been gradually developed from an uncontrolable and uncertain explosive, into a reliable propellant and servant.

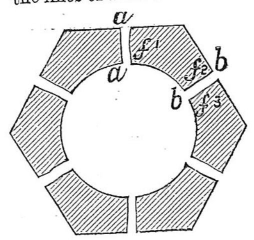
TABLE B.

Progressive Steps towards obtaining Gunpowders suitable for Modern Rifled Guns.

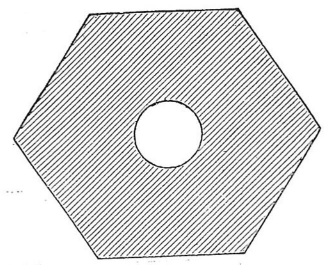
System or method adopted.	Powder.	Result.
Change of size (Increase in).	R.L.G., introduced 1866 P. ,, 1871 P.^{2} ,, 1876 R.L.G.^{4} ,, 1887	Diminution in rate of burning. Reduction of shock or blow given by the powder on ignition.
Change of density (increase in).	Pebble. Prism^1 Black. Prism Brown. Prism S.B.C.	Reduction of rate of burning. Reduction of initial strain in the bore of the gun.
Change of form and moulding.	Disc. Pellet. Sphere. Cylinder. Hollow cylinder. Cube. Perforated prism.	Regularity of ballistics in units of powders manufactured under the same conditions. Final break-up along the lines of least resistance, giving additional surface of combustion and production of gas as the projectile travels along the bore.
Change of texture, granulating and moulding.	Masses or conglomerate lumps formed of compressed grain. Progressive or Fossano Prism,^{1} black, 1881; ditto. brown, 1884; S.B.C, 1887; and E.X.E., 1887.	Regularity of density. ,, ,, pressures. ,, ,, velocities.
Change of composition.	Prism^1 brown. ,, S.B.C. ,, E.X.E. Water recognised as an ingredient.	Additional control over rate of burning pressures and velocities.
Blending.	P. and S.P. Prism^1 black. ,, brown. S.B.C. E.X.E.	Control over ballistics of lots or large batches. Regularity of results in batches, lots or charges of powder.

There are only two of the methods referred to in the table which our limited time will allow us to mention in detail. The first is change of form and moulding. It needs no explanation to demonstrate that a charge consisting of regularly shaped moulded powder of uniform size will give (other things being equal) more uniform results than could be obtained by an equal weight of irregular grains or lumps. But the modern shape, the perforated moulded prism, possesses further advantages over the other forms, which are worthy of consideration. If we take any of the old grain powders, or a mass or lump like P², we know that it burns from surface to centre. This being so, the surface of combustion decreases as the shot travels in the bore, or as the space behind the shot increases. That is to say, we find a reducing evolution of gas when you really most require an increasing one; and hence the speed or velocity of the projectile is not developed in the most satisfactory manner. On the other hand, if we now look at the perforated prism, we find that as the outside surface is diminished by combustion so the inside surface of the perforation is increased; thus we see a tendency to keep up a constant supply of speed producing gasses; and further, when the combustion reaches a certain point it is more than probable that the prisms break up across the lines of least resistance (they are marked in fig. *a*, *a*, *b*, *b*, and so on), thereby producing

Partly burned, and broken up across the lines of least resistance.



Unburned.



twelve new surfaces f^1, f^2, f^3, &c., for combustion; fully developing the progressive character of the powder, and helping the projectile along as its speed is accelerated.

The second detail of the diagram to be brought to notice is "Blending," upon which chiefly the uniformity of character of the powder depends, and few who have not practically studied the subject, can realise how difficult it is to obtain this uniformity. For example, a day's production represents about a unit or lot of 100 barrels, equal to 10,000 lbs. of gunpowder. This large quantity must be absolutely uniform in itself. That is to say, every charge from it, fired from the same gun, under similar circumstances, should give identical results as to speed and pressure. This batch of powder is, however, made in many machines, on the out-turn of which the weather and temperature exert considerable influence, and besides this, the machines are tended and worked by different men, each of whom has what may be termed

CONDITIONS OF ACCEPTANCE FOR SERVICE POWDERS.—TABLE C.

Nature.	Velocity.		Pressure.			Charge.	Size of Grain. Prism or Cordite.	Density.		Moisture.		Weight of Projectile.	Fired at Proof in	Used on Service with	Remarks.
	Min.	Max.	Min.	Max.	Mean.			Min.	Max.	Min.	Max.				
R. Pistol.	680	...	...	...	...	18 Grs.	$\frac{1}{20}$ to $\frac{1}{30}$								
R.F.G.	1250	1290	...	...	...	70 〃	$\frac{1}{12}$ 〃 $\frac{1}{20}$	1·58	1·62	·9	1·2	480 Grains.	Snider Rifle.	Snider Rifle.	
R.F.G.[2]	1300	1340	...	...	...	85 〃	$\frac{1}{12}$ 〃 $\frac{1}{20}$	1·7	1·75	·9	1·2	480 〃	M.H. Rifle.	M.H. 4″ Howitzer Jointed ·45 Machine Guns.	
M.G.[1]	1400	...	...	14·5	14·0	625	$\frac{1}{7}$ 〃 $\frac{1}{14}$	1·75	...	1·0	1·3	3170 〃	1″ Nordenfelt.	1″ Machine Guns.	
Q.F.[1]	1800 1820	1840 1860	...	14·5 13·5	14·0 13·0	$1\frac{15}{16}$ $1\frac{8}{16}$	$\frac{1}{2}$ 〃 $\frac{3}{10}$	1·75	...	1·0	1·3	6 lbs. 3 〃	6-pr. 3-pr. } Hotchkiss.	6-pr. and 3-pr. Q.F. Guns.	
R.L.G.	1385	1435	...	×	×	$1\frac{3}{4}$	$\frac{1}{4}$ 〃 $\frac{1}{8}$	1·67	...	×	×	9 〃	9-pr. R.M.L.	9-pr. R.M.L.	
R.L.G.[2]	1540	1590	...	16·5	16·0	$3\frac{2}{16}$	$\frac{1}{3}$ 〃 $\frac{1}{6}$	1·65	...	1·0	1·3	13 〃	13-pr. R.M.L.	M.L. 64, 40, 25, 16, 15, 13, 9, 2·5″, 12-pr. B.L. R.B.L. 7″, 40, 20, 12-prs., 8″, 6·6″, 6·3″ Howitzer.	
R.L.G.[4]	1380	1420	...	17·0	16·5	11	$\frac{1}{3}$ 〃 $\frac{1}{2}$	1·65	...	1·0	1·3	$67\frac{1}{2}$ 〃	64-pr. R.M.L.	R.M.L. 64-pr., 40, 25, 16, 13, 2·5″, B.L. 4″.	
P.	1890	1930	...	16·5	16·0	34	$\frac{3}{8}$ 〃 $\frac{3}{4}$	1·75	...	1·0	1·3	80 〃	80-pr. and 6″ B.L.	R.M.L. 12″, 11″, 10″, 9″, 8″, 7, 6·6″, 80-pr., 64-pr. of 64 cwt. B.L. 6″, 80-pr., 5″ and 4″.	
S.P.	1690	1730	...	15·0	14·0	4	$\frac{3}{8}$ 〃 $\frac{3}{4}$	1·75	...	1·0	1·3	$12\frac{1}{2}$ 〃	12-pr. B.L.	B.L. 20-pr. and 12-pr.	
P.[2]	1540	...	...	22·0	21·0	200	$1\frac{1}{2}$	1·75	...	1·0	1·3	812 〃	12·5″ R.M.L.	R.M.L. 12·5″, B.L. 6″ Mark II., III., IV. and VI.	
							Height. Diam. Hole.								
Prism[1], Black	1530	1570	...	20·0	19·0	210	·98 1·38 0·4	1·76	...	1·0	1·3	812 〃	12·5″ R·M.L.	R.M.L. 17·72″, 12·5″, 10·4″, B L. 8″ Mark III. and VII. 6″ Mark IV., V. and VI.	
E.X.E.	1940	1980	...	17·0	16·5	48	·976 〃 ·393	1·8	...	1·5	2·0	100 〃	6″ B.L.	R.M.L. 12·5″, B.L. 6″ Mark II., III., IV. and VI.	
Prism[1], Brown	1960	2000	...	16·5	16·0	55	〃 〃 〃	1·8	...	1·7	2·2	100 〃	do.	R.M.L. 16″ 80-ton, B.L. 12″, 10″, 9·2″, 8″ Marks IV. and VI.	
do.	1980	2020	...	18·5	18·0	295	〃 〃 〃	1·8	...	1·7	2·2	655 〃	11″ do.	Do. do. do.	
S.B.C.	2010	2050	...	16·5	16·0	360	...	1·85	...	1·7	2·2	655 〃	do.	B.L. 16·25″ and 13·5″.	
S.A. Pellet.	1830±40	...	...	19	18	70·5±3·5 Grs.	...	...	...	·9	1·3	215 〃	·303 Magazine Rifle.	·303 Magazine Rifle.	
SMOKELESS.							CORDITE. Diameter. Length.								
Cordite S.A.	2000±40	...	...	16	15	$30\frac{1}{2}$	·0375″	1·56	...	...	·5	215 Grs.±3	·303 Magazine Rifle.	·303 Magazine Rifle.	*Provisional.
do. 5	1690	1730	13	15	14	1 lb. $0\frac{1}{2}$ oz.*	·05″ 11″	1·56	...	...	·5	$12\frac{1}{2}$ lbs.	12-pr. B.L.	12-pr. B.L.	
do. 7·5	...	...	...	...	...	..	...	1·56	...	...	·5	...	...		
do. 20	2120	2170	18·5	15	14	5·7*	·2″ 14″	1·56	...	...	·5	45 〃	4·7″ Q.F.		
do. 30	2180	2220	11	14	13	15·8*	·3″ 14″	1·56	...	...	·5	100 〃	6″ Q.F.		

* The larger sizes, ·4″, ·45″, and ·50″ are still in the experimental stage.

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a personal error, which is enough in each process to make a serious difference in the portions of the batch or lot made by those working at the same time. The consequence of this would be that, if unadjusted, the lot of 10,000 lbs., as a whole, would prove most irregular in its characteristics and unreliable in its shooting. To overcome this a constant systematic method of intermixing the various batches from each process is adopted; and this (which is termed blending) being carried out on scientific principles, gives a uniformity to each unit of 10,000lbs. which could not otherwise be obtained. We are thus provided with reliable and uniform batches or "lots" of the propellant under discussion.

Let us now examine the practical results which the development of modern powders has rendered possible. The table of conditions which must be fulfilled before these powders are accepted, sufficiently indicates what a very reliable propellant we have in modern gunpowder.

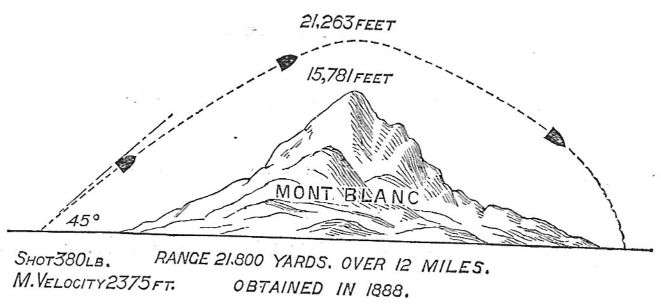
TABLE C.

You see here velocities ranging to above 1300 miles an hour, and the difference admissible between the maximum and minimum velocities of of the rounds fired is only about 40 feet a second, or little more than the speed of a quick runner; while the mean deviation from the mean is generally 10 feet or less, which is under seven miles in a velocity of over 1300 miles per hour. Again, as to pressures in the bore of the gun, it can be seen how restricted and low they are. If we examine Table C. it can be seen how very regular the powders must be in their ballistics before they are admitted into the service, and if they do not fulfil those conditions the powders are rejected.

I further submit some results of the lecturer's firing with pebble powder at Waltham Abbey. It was only an average sample of service powder made in 1886 and kept in a waterside magazine and used as our "standard," for comparison with current manufacture. Here are the results of firing carried out during one month. On the second day of the month we fired the first round for the standard, and it gave 1690 feet in the 12-pounder breech-loader. Then we fired six experimental powders, testing the ordinary manufacture, and the last round fired with the same standard as the first, gave 1690 feet with 12 tons pressure. On the 10th of the same month, the first round gave 1690 feet; then we fired four experimental powders, or rather current manufacture powders, in between, and the last round with the same standard gave 1695 feet, that is to say 5 feet difference, and the pressure was 12·4 tons. On the 22nd of the month, the last round gave 1694 feet. I submit, that all of us who desire good results with our field guns might very well rest satisfied if we could always get that kind of shooting. But the first round on the last day's firing was rejected, because the velocity was rather high. It was 1716 feet, that is to say, 26 feet higher velocity than ought to have been obtained. The reason was this: that we fired a friction tube which exploded but did not ignite the charge. It struck down on the seam of the cartridge, broke up some of the pebbles into smaller grains. The new friction tube fired the charge, and the slightly increased velocity, 1716, was the result. You see, therefore, how careful we must be, to have only one variable in experimental tests of this nature. Again, I may remind you that for all these experiments we have every shot weighed to the fraction of an ounce and the rotating bands gauged most carefully, to ensure that there is no other variable, when testing powder, than the powder itself.

There is still one other result which, although hardly within the scope of this lecture, ought not to pass without notice, as it shows, in an interesting manner, what modern guns with modern gunpowder are capable of doing. If we could imagine the highest mountain in Europe, Mont Blanc, placed between us and London, a shot which was fired not very long ago would have passed 5482 feet above its summit and lodged at the other side in London. This gives us some idea of what

Fig. 5.



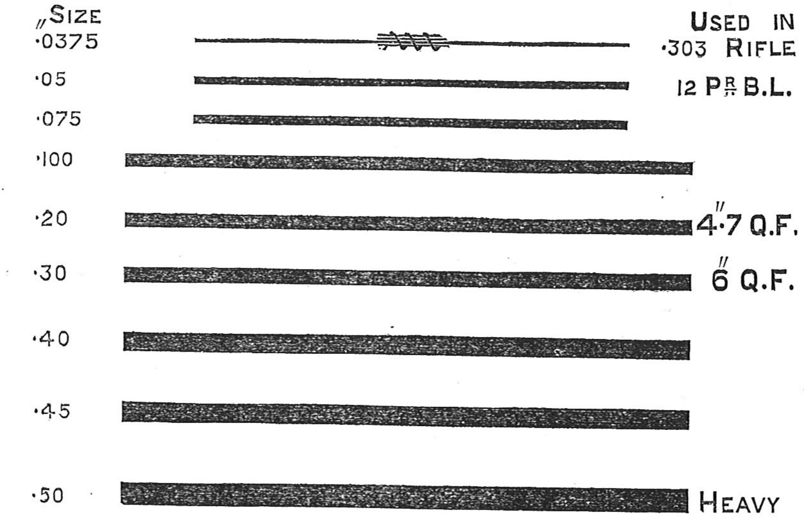
modern guns with modern gunpowder will accomplish. We cannot yet say what they will do when cordite comes to be used. I daresay this result suggests to some of us that we may possibly enable a projectile to leave the earth, as suggested in one of Jules Verne's stories, but practical gunnery has not yet approached to this. A velocity of between five and six miles a second would be required for the purpose, while about half-a-mile a second is our present maximum, possibly in the next few years we may do it, and attempt to disturb the equilibrium of the planetary system by sending messengers to the moon or elsewhere!

If the time at our disposal permitted, we could examine a long series of practical results which demonstrate that where properly handled and reasonably treated, modern gunpowder is a very reliable propellant. And further, until quite recently, when compared with any other, it might fairly claim to hold its own as a speed producer against all competitors. Quite recently, however, the high position which modern gunpowder has held, has been disputed by its youthful rival, cordite, and other smokeless powders whose characteristics we shall now discuss.

CORDITE.

Cordite.	Nitro-Glycerine,	58.
	Gun-cotton, ...	37.
	Mineral Jelly,	5.

Comparative Table showing dimensions of Cordite at present used.



The thicker cordite, size 20 and upwards, is cut into lengths of 14 inches, and used in bundles of the required weight for the charge.

Cordite for Field guns is 11 inches long, and the S.A. rifle charge is made up of 60 strands, or threads of suitable length for the cartridge.

We have now examined the outlines of the methods employed in the manufacture of modern powders, and some of the processes which have been adopted to render them reliable propellants with the various guns in our service. The next step, or rather leap, in this manufacture to be considered, is the introduction of smokeless propellants. We are all aware how, for many years, this has been the ambition of the artillerist and the study of the chemist. It is hardly necessary to remind Officers of the Royal Artillery of the failures in this direction, which, for more than three decades, frustrated the efforts of those who tried to obtain a smokeless powder for rifled guns and small arms. Gun-cotton in every form, picric acid in various conditions, and many tri-nitro and di-nitro compounds were experimented with, confidently at first, then hopefully, and apparently finally abandoned in the face of what seemed to be insurmountable difficulties. At last, however, a sudden impetus was given to the whole question, about seven years ago, by recent discoveries in chemistry, and by the supreme importance which the introduction of quick-firing guns and magazine rifles gave to the production of a powder which would not, by its smoke, utterly neutralise the benefits to be obtained by rapidity of fire. Most of us

Cordite.

remember that many years ago smokeless powder was considered to be a possibility within reach, when the character of gun-cotton was first recognised, and it was thought that this substance might be utilised by being kept under control or "tamed" by some retarding agent. To the unscientific but practical man this seemed a matter not difficult to accomplish. On the one hand, we have a violent explosive of good gas producing powers and almost unlimited energy; on the other, an almost boundless range of dilutants, retarding agents, or "tamers," which, in greater or less quantities, should at any rate bring the violence of the explosion of gun-cotton to the same level as that of gunpowder. Here then, at first, was the problem to solve: To use with gun-cotton such a retarding agent as will "tame" the explosive, make it safe to handle, store and use, and at the same time leave it with sufficient energy for use in modern guns and rifles with certainty and regularity of propulsion. This problem, simple as it appears, baffled, for decades after gun-cotton was known, the energies and knowledge of the most scientific artillerists and chemists; and it is only within the last few years that any real approach to success has been made, and this success has been chiefly due to the use in the right direction of one of the properties which gun-cotton exhibits, namely its solubility in acetone.[1] The solubility of gun-cotton in acetone has been known for a considerable time; but how to utilise this property for artillery purposes has only recently been discovered, and is still the subject of careful investigation. Again, in January 1888, Messrs. Nobel & Co. registered a patent of the discovery that nitro-cellulose could be mixed with nitro-glycerine and that the two so combined, with or without the addition of a retarding agent, form a substance which can be relied upon for ballistic purposes. This, with other discoveries made about the same time, may be considered as practically the starting point for the most valuable of the smokeless powders, and those most largely used in the services, both in England and on the continent of Europe.

We shall now consider the composition and characteristics of the bases of smokeless powders which have been proposed or adopted. First on the list is gun-cotton. When we refer to the text-books we find that it is stated to be tri-nitro-cellulose, with the chemical composition and formula gun-cotton $= C_6\ H_7\ O_2\ 3\ (NO_3)$.[2] I therefore propose to adopt this nomenclature which has been accepted up to within the last couple of years. The table now before us gives what may, for practical purposes, be considered the basis of the principal smokeless powders. Modifications of:—

[1] Acetone, or "dimethyl-ketone," $CH_3\ CO\ CH_3$, or "pyro-acetic spirit," is obtained among the products of distillation of wood, and may be prepared by distilling the acetate of lead calcium or barium.

The crude distillate is shaken with a saturated solution of hydrosodium sulphate, which combines with acetone to form a crystalline compound $(CH_3)_2\ CO.\ HN_a\ SO_3$. This is freed from the mother liquor and distilled with sodium carbonate, when acetone distils over mixed with water, which is removed by fuzed calcium chloride.

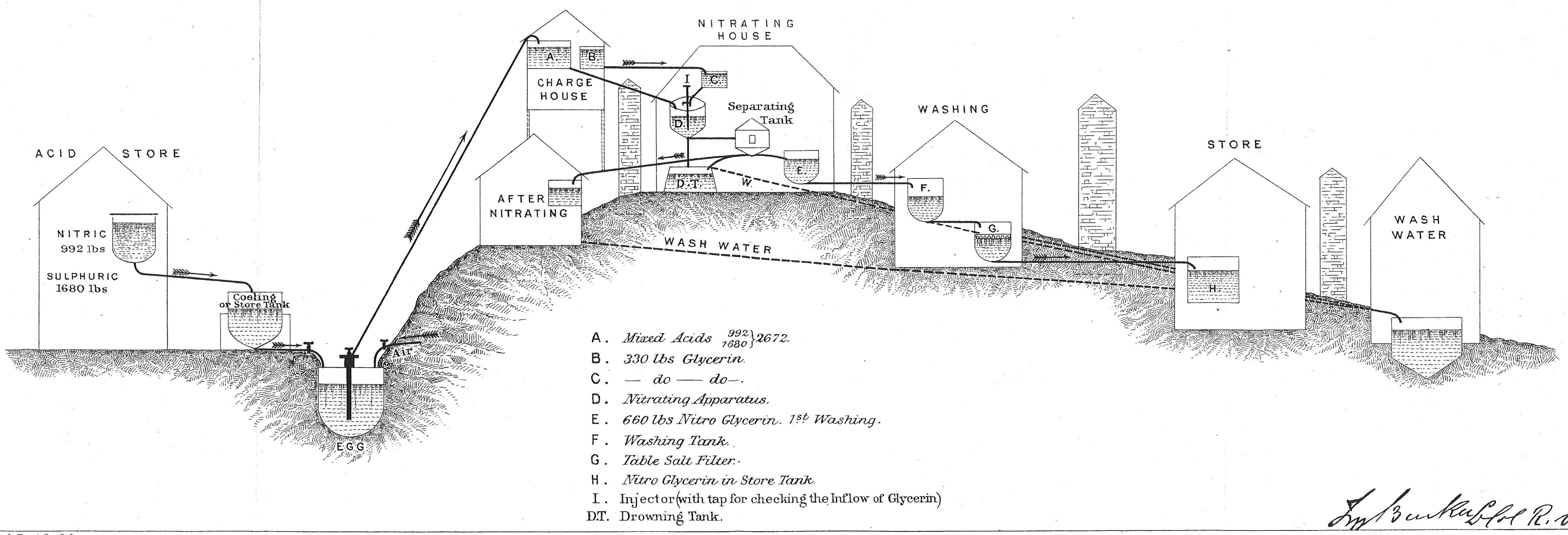
Acetone is a colorless fragrant liquid, Sp. gr. 0·81, and boiling at 56·3 C. = 133·3 Fahr.

It is inflammable, burning with a luminous flame. It mixes with water, alcohol and ether.—*Bloxam's Chemistry*.

[2] Some persons now hold the opinion that insoluable and soluable nitro-cellulose are the same substance under different "allotropic" conditions.

Plate II.

NITRO GLYCERIN FACTORY.



Vincent Brooks Day & Son, lith.

1st. *Gun-cotton.*—Trinitro-cellulose, $C_6H_7O_23(NO_3)$, obtained by the action of nitric acid upon cotton, viz. :—

$$\underbrace{C_6H_7O_23(HO)}_{\text{Cotton or Cellulose.}}+\underbrace{3(HNO_3)}_{\text{Nitric acid.}}=\underbrace{C_6H_7O_23(NO_3)}_{\text{Gun-cotton.}}+\underbrace{3H_2O}_{\text{Water.}}.$$

2nd. *Nitro-glycerin.*—$C_3H_53(NO_3)$ obtained by the action of nitric acid on glycerin.

3rd *Picric Acid.*—Trinitrophenole, $C_6H_33(NO_2)O$, formed by boiling "carbolic acid" or phenole with fuming nitric acid.

These may be taken as the parents of the majority of the smokeless powders which are deserving of consideration.

As most of us are acquainted with the manufacture of gun-cotton, and we need not follow up that of picric acid, I propose to only give a sketch of the processes of manufacture of nitro-glycerine now being made in tons weekly at Waltham Abbey. Nitro-Glycerin.

Before describing the processes I may as well tell you that it has been confidently stated, by a recent contributor to the daily press, that any tyro can make nitro-glycerine. This may possibly be the case; but if much nitro-glycerine be required, a large stock of tyros should be kept in hand to replace those who would undoubtedly be expended!

The manufacturing processes are exhibited on the diagram before you, and we may observe that in the preliminary operations the temperature must not be permitted to rise above a certain point, about 70·5° Fahr., and later on it must not be allowed to fall below a certain point, 50° Fahr. We have here the diagram (Pl. II) intended to show the construction and general arrangement of a nitro-glycerine factory. It is well to note that the various danger houses appear to be close together as shown in the diagram, whereas in reality they are hundreds of feet apart; and it would require paper of very inconvenient length to represent, in a satisfactory manner, the lateral extent of the various buildings.

The danger houses are separated not only by distance, but by heavy traverses, like walls of a fort, which isolate the buildings, and it is hoped that if an explosion took place, these traverses would confine the explosion to the exact locality where it occurs. The houses are lightly constructed of wood, and the traverses are very heavy solid masonry. The manufacture of nitro-glycerine is carried out as follows :—

The acids employed (nitric or sulphuric) are mixed, in a raised tank, in the acid store (Plate II) in the proportions of nitric acid 992 lbs., sulphuric acid 1680 lbs. The mixed acids are then allowed to run off into cooling or store tanks, where they remain until they lose the heat which has been generated by mixing.

The mixed acids, when ready for use, are passed into what is called the "egg." This is an iron vessel, egg-shaped at the bottom, and is an ingenious contrivance for dispensing with the use of pumps, the valves of which would be almost immediately destroyed by the corrosive action of the acids.

When the charge is ready to be transferred to the tank, A, in the charge house (*vide* Plate II), air is driven into the "egg" from an air engine, and the pressure of air on the surface of the acids forces them up to the charge house through the pipe which connects the bottom of the acid charge in the "egg," with the tank A, in the charge house. The acids are then run by gravitation into the nitrating apparatus, a large cylindrical lead vessel, D, fitted internally with coils of lead pipes, through which a circulation of cold water can be kept up without letting any water mingle with the charge, and then the 330 lb. charge of glycerine is passed into a little tank, C, above the nitrating apparatus. The nitrating operation takes place as soon as the acids are in, and they are kept in a state of effervescence by air, which is pumped through perforated tubes at the bottom of the apparatus. The glycerine is allowed to pass through an injector, which can absolutely control the rate of supply of the glycerine to the acids. The temperature is most carefully observed and regulated during this process, and as any abnormal rise immediately indicates danger, an elaborate system of control is maintained. The maximum temperature permissible is 70° Fahr.

The uniformity of temperature throughout the charge, and also intimate mixture of the glycerine with the acids, is ensured by a constant inflow of air through perforated lead pipes in the apparatus. The air so injected keeps the charge in a constant state of effervescence.

The temperature of the charge is regulated, in the first instance, by the rate at which the glycerine is allowed to flow into the acids.

2nd.—By the cooling influence of the water passed through the lead coils.

3rd.—By injecting carbonic acid, which is kept, for emergencies, under pressure, in an iron cylinder close to the apparatus.

If the temperature still rises and gets out of control, the whole charge is immediately run off into the drowning tank (D.T. in Plate II), which contains about 10,000 gallons of cold water.

If the nitration proves satisfactory the operation is completed in about an hour, and the 330 lbs. of glycerine are converted into 660 lbs. of nitro-glycerine, mixed up in a sort of foaming liquid with the acid in the nitrating apparatus. It is then passed away to the separating tank where it is allowed to stand for about an hour. There is a little glass window in the separating tank, through which the layer of nitro-glycerine, a few inches thick, can be seen floating on the top of the acids like an oily liquid. When the separation is completed the acids are allowed to run off to the waste house or "After-nitrating house" as it is called, from the nitrating house, and the nitro-glycerine is run into the first washing apparatus and washed with a solution of soda in water, in a large tank which is also kept in a state of effervescence by injected air. Then from the first washing it goes on to the second washing in another house, passed on by pipes, and is there washed with hot water and soda for about four hours. The nitro-glycerine is now at the bottom of the tank. Water floats on nitro-glycerine and nitro-glycerine floats on acid, and the houses, tanks, &c., are so arranged as to levels, that gravitation can be used as much as possible, in all shifting or transfer operations, to avoid pumping, striking, or using violence with nitro-glycerine. Then the nitro-glycerine is filtered off through a bag of table salt, sodium chloride, and is passed on to the store tanks, where it is kept in sufficient quantities for use in the manufacture of cordite. When finished, the nitro-glycerine is subjected to the "heat test," similarly to gun-cotton, and it should stand the test at 160° Fahr. for 15 minutes.

As cordite is composed of two "high explosives," gun-cotton and nitro-glycerine, the means adopted for converting them into a reliable propellant have now to be considered.

"High explosives" have all, more or less, the characteristics to which they owe their title. These are, great sensitiveness under certain conditions, and liability to violent explosiveness or detonation in their ordinary or "untamed" condition. This is exhibited in a graphic form in the diagram (Fig. 2).

One can well understand that none of these substances untamed are suitable for use with arms of precision. Under certain circumstances they might give fair shooting and satisfactory results; and under others their violence might be productive of the most serious consequences. A reliable retarding or "taming" agent was therefore absolutely necessary, and by using a solvent, such as acetone, and reducing gun-cotton to a plastic mass and then adding an inert or "slowing" substance, either a resin, grease, or other material, this violent explosive has been tamed down to any degree of rapidity of combustion required.

Gun-cotton has, however, one serious drawback, and that is that even with the highest degree of explosiveness which can be permitted for safety, it does not produce a satisfactory proportion of permanent gases during combustion, and the pressures developed are too high in comparison for the velocities obtained with the projectiles. We are therefore obliged to introduce some other ingredient which, while not producing smoke, will evolve the necessary gases for propulsion of the projectile, without increasing the rapidity of combustion or involving the risk of detonation. All manner of inert substances have been tried for this purpose with more or less success, but none as yet have been perfectly satisfactory. I may say, however, that a near approach to a gun-cotton smokeless powder was made at Waltham Abbey some years ago, when a grained powder was produced which, while smokeless, gave the best shooting obtained up to that time. Just at this period, however, the discoveries previously referred to were developed, namely, that an *active* agent could be used with gun-cotton, and nitro-glycerine combinations rapidly took the field.

The strange anomaly of two of the most violent explosives known, nitro-glycerine and gun-cotton, when combined in nearly equal proportions, producing a moderate explosive under control was, as I have already said, the starting point of a new era in smokeless powders. Nitro-glycerine is, as we know, about the most violent explosive yet discovered, gun-cotton is also noted in the list of "high explosives." Both when separate are very sensitive and easily detonated; but when combined they burn with great regularity.

I have now briefly mentioned the two great classes of smokeless powders; first gun-cotton and its kindred chemical compositions with a retarding agent, and, second, gun-cotton combined with nitro-glycerine where nitro-glycerine takes the place of the retarding agent which was formerly used with gun-cotton. The first has not been so successful for the reasons already given, while the latter (gun-cotton with nitro-glycerine) gives most excellent ballistics but very high temperatures. The excessively high temperature which is produced by the use of nitro-glycerine has contributed towards the continuation of investigations on the Continent, as to the possibility of obtaining a gun-cotton or other smokeless powder; but hitherto we have not heard of any marked success.

I think that we are now in a position to discuss the manufacture of the smokeless powder, cordite, which promises so favourably, and which has been made so successfully in large quantities for over a year at Waltham Abbey.

Cordite is a smokeless propellant of the combined nitro-cellulose (or gun-cotton) and nitro-glycerine type. Its composition was determined by a Committee (The Explosives Committee) of most distinguished chemists, with Sir Frederick Abel as president. They decided that the proportion of the ingredients should be gun-cotton, 37 per cent.; nitro-glycerine, 58 per cent.; and mineral jelly, 5 per cent. The gun-cotton is first dried (in the form of 9 ounce primers) down to about 1 per cent. moisture. Then a portion (27¾ lbs.) is placed in a brass-lined box, and 43½ lbs. nitro-glycerine are carefully poured over it. These ingredients are then carefully mixed by hand and taken to the incorporating machines, and the whole is brought into a gelatinous condition by the addition of about 15 10/16 lbs. of acetone, which is poured over the charge in the incorporating machine, and worked up into a kind of dough. 3¾ lbs. of "mineral jelly"[1] are afterwards added, and the material is incorporated or mixed for seven hours. When it has been sufficiently incorporated and is ready, the charge is taken to the press house where it is squeezed in a cylinder, one end of which has a small hole of the required size for the cordite, which is squirted through by means of a plunger or piston pressing on the other end of the cylinder. The cylinder is filled with composition and the plunger pushes or squirts the soft material in the form of cord or string of the thickness required. The sizes are ·0375 in., which is used for the rifle, up to ·5 in., which has been experimentally used with a heavy B.L. gun with satisfactory results. This string is wound on reels for the smaller, or cut into lengths for the larger natures. It is then placed in a stove and is dried, to get rid of the acetone at 100 degrees Fahr., from three to nine days, according to the thickness of the cordite. It is afterwards blended in the rifle cordite, by taking the production of ten presses which are on "one strand" reels and winding these on to one "ten strand" reel. Then the cordite on six "ten strand" reels is wound on to one drum, which make up a rope or cord of 60 strands, which in short lengths form the 30½ grain charge of the magazine rifle. The larger natures of cordite are blended on the same principles as gunpowder. Cordite has proved itself to be very safe to manufacture

[1] Mineral jelly (vaselin) is the liquid which distils over from petroleum at temperatures above 200 C. It is a hydrocarbon, richer in carbon than petroleum, and it boils about 278 C. Formula $C_{16}H_{34}$.

in its later stages, *i.e.*, *after* incorporation, and although we have had slight ignitions, I am glad to say that no explosion of any consequence has occurred.

Having now briefly sketched the outline of the manufacture of cordite, we will turn to what is doubtless the more interesting portion of the subject to practical gunners, namely, what are its shooting properties, its keeping qualities, and what is the effect of using it in the guns and small arms with which it is employed.

SHOOTING QUALITIES.

First, as to its shooting qualities, we can best judge of them by actual results obtained, and by comparison with our old friend black powder in the same weapon. These results, which are shown in the table before us, speak for themselves. I owe the latest results to the kindness of the Director-General, Dr. Anderson, and to our friends at Waltham Abbey. I have here sketched a comparative table (Table D)

TABLE D.—COMPARATIVE RESULTS.
Cordite and Black.

Nature.	Charge.	Velocity.	Pressure.
Magazine Rifle	70 grs.	1830±40	18
do.	**30 grs.**	**2000±40**	**15**
12-pr. B.L.	4 lbs.	1710±20	15
do.	**1 lb. 0½ ozs.**	**1710±20**	**15**
4·7 in. Q.F.	12 lbs.	1830±30	16 to 17·6
do.	**5 lbs. 7 ozs.**	**2145±25**	**15**
6 in. Q.F.	29 lbs. 12 ozs.	1890	15
do.	**14 lbs. 3 ozs.**	**2274**	**15·2**

showing the results obtained by black powder and smokeless powder. The black powder is in Roman type and the smokeless powder in black type, and I think that, without any further demonstration, we can see for ourselves the great advantages to be obtained if the smokeless powder always does what that table before us indicates. First we have 30 grains of the smokeless powder giving a 2000 feet velocity, as against 70 grains of the best of the modern black powders giving 1830 feet velocity, + or − 40. Then, in the field gun (which most of us here are interested in) one pound and half-an-ounce of smokeless powder (cordite) must give, as a condition of acceptance for service, 1710 feet + or − 20, as compared with 4 lbs. S.P. (selected pebble), which gives 1710 f.s. Then quick-firing gun, the 4·7-inch, gives, with 12 lbs. black pebble, 1880 feet + or − 30, while with 5 lbs. 7 ozs. of smokeless powder it gives 2145 feet + or −25. I think those results speak for themselves. Then again, in the 6-inch gun 29 lbs. 12 ozs. of black powder giving 1890 feet muzzle velocity with 15 tons pressure. The results in the table are based upon actual shooting, and the conditions of acceptance are framed upon practical experience, and these conditions must be complied with by all powders before they are allowed to pass into the service. It may here be interesting to quote some of the actual shooting within the last few months of our own experience, and for these, the latest results, I have again to thank our friends at Waltham Abbey and also the Director General, who has kindly permitted me to have them. With lot 8, size 5[1] (that is field gun size) in the 12-pr., 1 lb. 0½ oz. charge, from the actual results fired in July last we obtained 1732 feet as the muzzle velocity with 13·84 pressure. The results which were forwarded to me last month were 1726 feet velocity with the same lot, and 13·45 pressure. The temperature of the air when the firing took place in December being quite sufficient to account for the slightly lower results as compared with those obtained in July. It is easy to understand the favourable impression that results of this nature make upon those who watch them carefully. Then there are other difficulties which had to be contended with, and one was technically termed "sweating," which frequently causes strained relations between employers and employed (or unemployed?) Our "sweating," however, had nothing to do with workmen, but it was a curious propensity which some batches of cordite exhibited in exuding the nitro-glycerine on the surface. There are various causes which produce this exudation, one of which is water in the nitro-glycerine before incorporation; there are also several others which we need not enter into here, but I believe that the difficulty has been completely overcome, by arrangements during manufacture.

Climatic Trials.

Secondly, as to climatic trials or keeping qualities. Climatic trials have been carried out all over the world, and they have so far proved eminently satisfactory. The arctic cold of the winter in Canada with the temperature below zero, and the tropical heat of India have as yet failed to shake the stability of the composition, or abnormally injure its shooting properties. The Director General kindly wrote to me the other day and said that cordite returned from Canada has been analysed, and has been quite unchanged. I have myself had under my own observation 100 lbs. in an open case exposed, in an open porch, to all the vicissitudes of a Waltham winter—snow and rain—and also to an English summer—rain without the snow—and the results again showed that there was hardly any perceptible difference in shooting due to this severe test. If our old friend pebble or prismatic powder

[1] Size 5, lot 8, fired at Woolwich 7 July, 1892, in 12-pr. B.L. gun, charge 1 lb. 0½ oz.

M.V.	Mean.	Pressure.	Mean.
1734		13·3	
1731		14·2	
1733	1732	14·1	13·84
1733		13·8	
1728		13·8	

had half this ill-treatment one would have wished for a sea range, and a clear one, to fire over, and should certainly have protested against ordinary proof within twelve miles of London.

Thirdly, the effect on the weapon.[1] This may perhaps, and indeed is likely to prove the weakest point in the use of cordite under certain conditions. The small-arm magazine rifle undoubtedly suffers in the bore from the great heat evolved and the high velocity imparted to the projectile. On the other hand, we have at Waltham Abbey a 4·7 inch quick-firing gun which has fired, up to September last, over 40 rounds of black and 249 rounds of cordite, and yet the bore shows no abnormal erosion or scoring. We have also a 12-pr. B.L. constantly used, up to the same date, for firing pebble and cordite, and the bore is as smooth as could be expected.

In conclusion, we must all remember that, although smokeless powders have developed so rapidly, and have shown such great suitability for the guns with which they have been used, they are still in their infancy, and have not yet been subjected, on any large scale, to the stress of active operations in the field, engagements at sea, or lengthened storage in average magazines. So far as our experience goes, however, the results have been eminently satisfactory with our own smokeless powder, CORDITE.

DISCUSSION.

The Chairman—I may say that Colonel Barker will be very pleased to answer any questions that any gentleman may wish to put to him.

As regards the effect of temperature. Does not heating the cordite disturb its shooting qualities, and would you not expect abnormal results if it were fired hot? Say at 110° Fhr.

Colonel Barker—Heating cordite and firing it hot undoubtedly does disturb its shooting qualities, but as far as we can see not much more than gunpowder. I fear that we must always expect abnormal results with heated propellants—either gunpowder or cordite; and when fired hot the increase in pressures and velocities will depend upon the heat above the normal or average temperatures at which firing takes place.

Captain Orde Browne—Is it not true, as I think Captain Andrew Noble told me, that in some experiments in Spain they had a low velocity from their powder wherever they had been keeping it, and he recommended them to keep it in the sun, and they were astonished at the way the pressure went up?

Colonel Barker—That is so, I believe.

Captain Orde Browne—Would that be due to the temperature, or to the moisture that had been absorbed and got rid of; and would not cordite have a great advantage in that respect?

Colonel Barker—Cordite ought to have an advantage, because, if you subject gunpowder to a heating and cooling process, combined with the effect of

[1] Since writing the above, the lecturer has been informed that in the ·303 magazine rifle, this difficulty has been almost overcome by the use of a suitable wad. As regards the erosion in guns, *vide* the information given by D.G.O.F. in his remarks during the discussion.

moisture, it may get a little porous in its character, consequent on the absorbtion and ejection of water, while cordite has practically no moisure to part with.

CAPTAIN ORDE BROWNE—Then, so far as you know, if you did the same thing to powder at a comparatively low temperature, which might have moisture in it, and then to cordite, and put them in the sun and fired them, the cordite would stand at least as well?

COLONEL BARKER—I think so; our experience inclines us to believe that it would.

CAPTAIN ORDE BROWNE—Then as regards the pressure, is it at all due to its being slower? May we suppose that there is a higher pressure forward in the gun, or is it entirely due to the absence of liquid and solid products of combustion?

COLONEL BARKER—There must be pressure somewhere to get up the velocity.

CAPTAIN ORDE BROWNE—I thought the absolute pressure was reduced because there was no products of combustion except gasses—that there was not the same necessity for re-action: that the common powder was discharging the projectile in a quantity of liquid and solid combustion, and the cordite was discharging nothing but the projectile?

COLONEL BARKER—I think that is very probable.

CAPTAIN ORDE BROWNE—Is not that the reason, that where you have no projectile in front you have a noise with black powder because you have liquid and solid products of combustion,[1] and you have no noise with cordite because you have nothing but the gas in front?

COLONEL BARKER—I do not think that; that is a complete explanation.

GENERAL GOODENOUGH—The lecturer, Sir, is one and we are many; but I hope on some future day the subject may be again considered when we may have the pleasure of hearing him again lecture, because a temperature of 110° is a mere nothing, and I feel convinced that if in India you put a cartridge down on the ground it would rise to 110° in a very short time. I think that the subject is an interesting one to pursue, to see what would emanate and what the remedy would be.

There is a question that I want to ask, and that is this: We have heard that in France they have had great apprehensions as regards the keeping qualities of their high explosives, and we were told that they were prepared to renew the stock at at short notice, and so forth; and I should be glad if you could explain why it is that nothing of the sort appears to be requisite with us; and then, when you answer me, if you would kindly help this humble and ignorant individual by saying what acetone is and what mineral jelly is.

And I must just express the pleasure I have had in being at an interesting and valuable lecture of this kind, and how much I congratulate the Committee upon getting the lecturer to come here—all the more so on account of the great dearth that many of you have felt and suffered from of information on professional subjects in our professional papers, which has been felt by a great many people, and

[1] I was reluctant to open the question of recoil and pressures which depend upon so many variables, each of which require careful consideration and discussion. For instance, recoil with blank depends, as Captain Orde Browne states, partly upon "the products of combustion" and partly upon the *rate* of combustion and other variables. Recoil with a projectile introduces another set of variables, dependant on the weight of the projectile. resistance of rifling, rotating bands, &c., and also on the rate of combustion and manner in which the charge is ignited. It is doubtless very interesting and useful to follow up this question fully in the light of all the practical experience and published information now at our disposal, but I submit that the outside fringe of the question could only be touched in one afternoon's discussion, and that erroneous conclusions could therefore probably follow.—*F.W.J.B.*

which is difficult to overcome. But this is a means of overcoming it by lectures, by which I think we ought to be able to keep pace with the times.

COLONEL SCOTT—I should like to say with regard to the keeping qualities that in India I saw cordite which was in the limbers at Meean Meer. They had the two limbers—the service limber and the experimental limber; the service limber was the ordinary limber, and the experimental limber was white colour with holes for ventilation; and they found in the experimental limber they had a temperature of about 122°, and in the service limber they went up to 132°. The boxes were opened and I saw them, and there was really no difference whatever in the cordite—there was just a mere faint odour of acetone. This cordite has now been sent down to Calcutta and Kirkee, and has been tried every month, and the results have been sent home to the Ordnance Committee, and they are most satisfactory so far. This is cordite that has been in boxes heated up to 122° and 132°. It was not fired at that temperature, but it was heated to that temperature, and the cordite did not suffer in any way. I took that same cordite with me three years ago to Burmah and every place I went to, and I brought it back, and it is just as good as ever. The cordite from India has not been analyzed, but it is going to be very shortly; but I do not think anything is likely to be found deteriorated. However, the great point for gunners of course is whether this stuff will shoot in India, and so far it has been shown that it does shoot.

COLONEL BARKER—May I thank Colonel Scott for answering in so practical a manner a large and important portion of the question that has been put by General Goodenough; and might I suggest in addition that if the experiments are to be carried out, which I have no doubt will be made, that gunpowder should at the same time be subjected to the same firing conditions? I am quite sure that cordite will come out very satisfactorily under the trial.

GENERAL GOODENOUGH—I should like to explain that at practice (and I am sure a great many gentlemen will confirm me) we always used to think that as you went on firing you generally got a longer range—that is to say, a higher velocity with the old black powder; and I always believed that that arose from the heating of the powder in the bore after the bore had been heated. If that was true, that the cordite would give a greater velocity when it was heated, I can only say that it is very likely to be heated, because, if you kept the gun loaded for a few moments after the firing was going on, the temperature in the bore would be very high and the pressure would be greatly increased. Black powder has often been subjected to that test and the increase has not been considerable; but if the increase is likely to be what Colonel Scott suggested just now, that ought to be considered. That point ought to be worked out. The point was not the keeping.

COLONEL BARKER—I meant merely the keeping. But with regard to the other point the experiments have not been concluded yet.

As regards General Goodenough's questions relative to the composition of acetone and also of mineral jelly—

Acetone is a colorless fragrant liquid Sp. gr. O. 81 and boiling at 56·3° C. Its chemical title is "Di-mithyl-ketone," and its formula CH_3, $COCH_3$. It is also called "pyro-acetic spirit" and is obtained among the products of distillation of wood.

Mineral jelly (vaselin) is the liquid which distils over from petroleum at a temperature above 200 C. It is a hydro-carbon richer in carbon than petroleum, and its formula C_{16} H_{34}. It boils at 278°.

Captain Abdy—There is a question, Sir, which has been sent to me by an officer who is unable to attend which, with your permission, I will now put on his behalf:—(1) Allowing that cordite supersedes gunpowder for cartridges of 12-pr. guns, what would the gain be in space saved in an ammunition box? (Naturally any space saved would be a gain, as likely to admit of more rounds being carried per box); and (2) will cordite, if used with the 12-pr., be likely to lessen the recoil sufficiently to enable the present gun-carriage to be lightened, or rather lighter in make? *i.e.*, will it do away with breaks, or reduce their weight, or that of any part of the gun-carriage?

Colonel Barker—The question, I understand, is by Colonel Brough. The first question is with regard to the capacity of limbers—what gain in space there is. That is very easily answered. There is not a great difference between the specific gravity, the density of cordite and gunpowder, so that you can see the space would be as 1 to 4. It is not quite so much for reasons which come in during the manufacture, such as the arrangement of the cartridge; but there would be an enormous saving of space if the present cartridge is finally adopted; and it is for those who manufacture the limbers and the limber-boxes and who have the arrangement of the cartridges to say whether the space will be gained.

With regard to the recoil,[1] it is a very difficult question and one that I should like to have had notice about; because it does not do to answer straight off a question that is put on the moment. One's inclination is to do so; but I think a lecturer is more discreet upon a large question of that kind if he waits until he can give something that is thoroughly authentic.

The Director-General—I am afraid I shall be travelling outside the subject of the paper in talking of the possible recoil of the new carriages, but there is no doubt, for the reason which has been already stated, I think by Captain Orde Browne, that as there is less to expel out of the gun, because there is nothing else in cordite, naturally the re-action is less and the recoil of the same velocity is less with cordite considerably than it is with black powder. And with regard to the capacity, we are hoping very shortly to produce an equipment for the Horse Artillery with a wire gun and pole draught and a limber to hold 42 rounds, which will be just 30 cwt. behind the team. That has not been attained yet anywhere. In that case there will be no brakes; there will be simply drag-shoes for stopping the recoil—that is found to be the simplest thing of all. And, by the way they are suspended, they do not require to be put under the wheels—they put themselves under the wheels and give no trouble whatever in working.

With repect to the effect of heat upon cordite, there is no doubt that cordite suffers from change of temperature more than black powder. Black powder on the other hand suffers a great deal more from change of moisture; but if the gravimetric density of cordite is not made too high, if it is kept below 50 cubic inches to the lb., the effect of temperature is not so great. But if the density is high, as in the 4·7-inch gun that Colonel Trench alluded to, and you take an extreme temperature of 110°, the pressure rises considerably. That raises the question whether we have got hold of the right size of cordite for the gun; just as with black powder, a great deal depends upon making the size of the explosive suitable for the nature of the gun. That matter, and many others connected with cordite, are still under discussion and experiment, and will no doubt be brought right. It is only this year that we have produced what may be called a service cordite—a cordite that does not vary in its quality; and the experiments now being carried on by the Ordnance Committee will show more and more what are the necessary precautions to be adopted in it. But the temperature is certainly one. And this has a very important bearing on the ship's magazines. For some reason, best known to themselves, the Navy put their magazines near their boilers to get them as hot as possible. That will not suit cordite at all—they will have either to shift their magazines, or to stick to black powder. But the change in velocity is very small—the reason being that the density is only 110 cubic inches to the lb. There is much more chamber room in the gun, and therefore the variation in pressure and velocity is not so great as it is when cordite is packed in a comparatively small space.

[1] *Vide* foot-note, p. 288.

I may mention (to show what great things we may hope from cordite) that the new Naval 12-inch gun, 35 calibres long, will have an 850 lbs. projectile against the service projectile of 714 lbs.; it will have a muzzle velocity of 2400 feet at least (2500 I had hoped for) against the present velocity of 1800 feet, or something like that; and the breaching mechanism of this 12-inch gun will be only very little larger than the breaching mechanism of the 8-inch gun—the reason being that the charge of cordite is so small comparatively that the gun can be made much smaller; and the breach-screw will only be, if I remember rightly, 12½ inches diameter—that is just the size it is for the 8-inch gun. So you see that the direct advantage we shall get in a gun specially made for cordite will be that all the breaching mechanism will be lighter.

With regard to erosion we do not know much yet; but a 4·7-inch gun has fired over 1200 rounds and is still serviceable; whereas the same gun fired with a much lower muzzle velocity with black powder becomes unserviceable after 800 or 900 rounds. I think it extremely probable that, from the absence of any liquid or solid matter mixed up with the gasses produced by the explosion, our larger guns will suffer much less in proportion than the smaller ones; but that is of course a matter that has still to be proved by actual experiments.

The Chairman—I think there is nothing left for us to do but to thank Colonel Barker for his most interesting lecture.

7

1893 Moden

Gunpowder and Cordite