WASC

Extracts from
Chambers Encyclopedia
1 - Gunpowder
2 - Guncotton

1-CHAMBERS'S ENCYCLOPEDIA VOL. 5 (FRE-HUM), PUB. BY WAVERLEY 1925

:. Finally, the pro-
ended, and 'proved'
GUNPOWDER.)
ford, *Nitro-Explosives*
e of Explosives (1909);

IAK.
iop and architect,
anfranc to England
Rochester (1077).
l, and was architect
ier buildings.
ısical composer and
k in Hungary. As
army, and as the
ie made many con-
composer of dance
e became director
(1849), in Austria

mission to carry a
n), the annual pur-
shillings is obliga-
n under the Gun
soldiers, territorial
or at practice, gun-
censes (see GAME-
occupiers of land or
s of license-holding
or killing vermin;
ing, nor are rabbits

CANNON.
enus of coast fishes
more elongate eel-
nies. The British
spotted gunnel or
ish coasts, lurking

army, is a private
. Master-gunners
, generally placed
.—In the navy the
ranks qualified in
rom the Admiralty.
ance stores on board
intendence for their
has a general over-
e weapons employed
ler a gunnery officer
ners are sometimes
enants for quarter-
torpedo-boats, &c.
officer promoted by
Gunner's-mate is a
l after examination
gunners. Warrant-
tswains, carpenters,
promotion to com-

hich governs by its
loyment of all fire-
cetry' is generally
small-arms. It in-
erties of metals, and
n gun-manufacture,
he strains to which
, the velocities of
them of the various
d in the bore of the
ugh the air.
d of by an Italian
glia, who in 1537
He also invented
other writers fol-
cipal was Galileo,

whose *Dialogues on Motion* were printed in 1638. But the real founder of the science was Benjamin Robins (q.v.), whose *New Principles of Gunnery* appeared in 1742, and treated of atmospheric resistance, the force of gunpowder, the effects of varying the length and weight of guns, &c. His invention, the ballistic pendulum, enabled the velocity of a cannon-ball to be measured, and was generally used for that purpose until superseded by Navez's electro-ballistic pendulum about 1862. Euler, Halton, and others added by their commentaries on Robins's work to the general knowledge of the subject which existed up to the end of the 18th century. In 1840 Professor Wheatstone invented an electric chronoscope for measuring velocities, which was followed by those of Navez-Leurs, Bashforth, Noble, and De Boulengé (see GUNPOWDER—*Proof*). In 1878–80 the Rev. F. Bashforth produced his chronograph for measuring the resistance of the air to the motion of elongated projectiles. By means of his tables and the various instruments now placed at their disposal, mathematicians are able to calculate the proper length, thickness of metal, size of chamber, charge, form of projectile and method of rotating it for a gun of given calibre, and also to determine the time of flight, penetration, height and velocity at any point, and elevation required for any range, &c. All this is most necessary in order that the gun may be skilfully handled, and each weapon has its 'range table' made out, giving these particulars.

In 1880 Major F. Siacci, of the Italian Artillery, put forward a method of solving trajectories and problems in ballistics, and his formulæ, sometimes slightly modified, have been used by artillerists of all nations with very satisfactory results.

Without explaining the intricate calculations and delicate instruments used, it may be interesting to give a few examples of gunnery problems. A shot was fired at Shoeburyness in 1887, and called the Jubilee shot, from a 9·2-inch wire-gun at an angle of 40° elevation, by which it was thought an extreme range would be obtained. The calculated range was 20,765·3 yards (say 12 miles); maximum height, 17,110·6 feet; time of flight, 63·787 seconds; angle of descent, 53° 50′. The actual range was 20,236 yards.

The necessary elevation for a 12-inch 45-ton gun, firing with a charge of 295 lb. and a muzzle velocity of 1910 feet per second at a point 3000 yards distant and 1270 feet above it, is found to be 2° 25′.

In designing a rifle of which the velocity is to be 800 feet per second at 1000 yards, and trajectory in no place higher than 32 feet, it is necessary to know the proportions of weight of bullet to calibre, which are found by Siacci's formulæ to be 358 grains for a calibre of ·38 inch, or 254 for ·32 inch.

From such examples it will be understood that gunnery has become one of the exact sciences. The excellence of modern machinery enables the manufacture of weapon, projectile, powder, and fuse to satisfy the demands of the theorists, while such inventions as position and range finders and telescopic sights put it in the power of the trained artilleryman to show equally good results in practice. In actual warfare the accuracy is still further enhanced in these days by the help of airmen, who, after observation of the effects of the first directed fire, are able to signal to the gunners instructions enabling them to correct their aim. See BREECH-LOADING, CANNON, RIFLE, ARTILLERY; also Ingersoll, *Text-book of Ordnance and Gunnery* (1899); Bruff, *Text-book of Ordnance and Gunnery* (1898); Cranz, *Compendium der Ballistik* (1898); *The Official Text-book of Gunnery*; Lissak, *Ordnance and Gunnery* (1907).

Gunny, a coarse jute fabric (see JUTE), very largely exported from India to various parts of the world. American cotton is largely packed in gunny-bags. About 1850 the peasant hand-looms of Lower Bengal met both the home and the foreign demand; but now the manufacture is mostly carried on in large factories. Cloth and bags of the same kind are made in Dundee.

Gunpowder is a well-known explosive mixture, composed of saltpetre, sulphur, and charcoal, mixed together in certain proportions, somewhat varying in different countries and in different descriptions of powder. The early history of gunpowder is very obscure, and has been rendered even more so perhaps owing to the claims for ancient, even prehistoric, knowledge possessed by the Greeks, Arabs, Chinese, and Hindus, advanced by early writers. These have been often based on statements in languages known to comparatively few, and those few not necessarily equipped with technical and historical knowledge and the critical faculty which would prevent them from making mistranslations, or being deceived by the spurious claims of documents to an antiquity which they do not possess. Moreover, the undoubted fact that combustible mixtures (not, however, containing saltpetre) had been known as early as 350 B.C., and the exaggerated descriptions of their effect when thrown by machines, have also tended to mislead. Happily there is now no longer any need to be doubtful as to precisely what we may accept as authentic in the matter, owing to the exhaustive researches of Colonel H. W. L. Hime (late Royal Artillery) which are set forth in chapters i. to viii. of his work, *The Origin of Artillery* (1915). He disposes effectually of the early claims, and proves conclusively that there is no really authentic mention of gunpowder until about the second quarter of the 13th century, when the first description of the refining of saltpetre and a recipe for a gunpowder mixture appear in the *De Secretis*, by Friar Bacon (1214–94), written before 1249. The process of refining and the proportion of the ingredients were concealed by Bacon by cryptogrammatic writing, and an anagram, which Colonel Hime has solved. The proportions given by Bacon are 'seven parts of saltpetre, five of young hazelwood (charcoal), and five of sulphur.' Were there any doubt of the correctness of Colonel Hime's solution (which, it may be remarked, was published as long ago as 1904 in his *Gunpowder and Ammunition*), it would be set at rest by the discovery in 1909 by Professor Pierre Duhem of the university of Bordeaux of a short manuscript in the Bibliothèque Nationale, Paris, which turned out to be part of a work by Roger Bacon, and has since been published under the title *Un Fragment Inédit de l'Opus Tertium de Roger Bacon*. The date assigned to this work is 1266–68. It clearly describes a powder which is made of saltpetre, sulphur, and charcoal, and states that the powder is known in *several places*, which would imply dissemination of the knowledge since the earlier mention. It does not, however, speak of its use as a propellant, though its explosive qualities are distinctly mentioned (*Proceedings of the Royal Artillery Institution*, vol. xxxviii., No. 4, July 1911).

Summing up the early history of the subject, we have from 350 B.C. to the 13th century many references to combustible mixtures which contain sulphur, pitch, naphtha, and various gums; but in no case is saltpetre mentioned, except in mistranslations, until it and its refining are described by Roger Bacon as a necessary preliminary to the manufacture of gunpowder. It may be asked why Bacon concealed his earlier knowledge of gunpowder, and never claimed to be its discoverer, if not actual inventor. The answer is that the church looked with small favour on friars who made chemical and physical experiments, and Friar Bacon had been suspected of practising the black art, his lectures at Oxford being interdicted by the general of the Franciscans in 1257, while he himself was ordered to Paris to place himself under the superintendence of the order. It was by the order of the pope, in 1266, for a treatise on science that he wrote the *Opus Tertium* (see BACON, ROGER).

It is doubtful whether Bacon was aware of the use of gunpowder for propulsion of a projectile; at any rate he makes no mention of it, and there is no certain knowledge as to who can claim its application for this purpose. It has been claimed traditionally for Berthold Schwarz, a monk of Freiburg, about 1313, as has also the invention of gunpowder; and the claim for the invention of the gun by a German monk is supported by an entry dated 1313 in a municipal MS. at Ghent. There is a statement in Barbour's *Bruce*, written in 1375, to the effect that Edward III. used 'crakys of war' against the Scots in Weardale in 1327; and in an illuminated Latin MS., dated 1326, belonging to Christ Church College, Oxford, there is a drawing of a bottle-shaped gun loaded with an arrow. In 1331 we have authentic record of the use of guns by the Germans at the siege of Cividale, and by the English at the battle of Crécy, 1346. After this the records of the use of gunpowder and cannon become frequent and reliable.

Gunpowder as used in early days, besides being of a weak composition (i.e. low in saltpetre), was often not carried made up ready for use, but its ingredients were mixed together as required. As the essence of good gunpowder lies in the intimate mixture of its ingredients, it need hardly be said that hand-mixing as required rendered the gunpowder produced uncertain in its action, and liable to give much fouling. The next step taken to improve it, therefore, was the mixture of the ingredients, slightly damped, in mortars or under rolls, and the breaking up of the cake so formed into grains (termed 'corning'), to which was subsequently added 'glazing.' 'Corning' is first mentioned about 1429, but was not probably regularly used until a century later. 'Glazing,' by which a bright surface is imparted to the grains by revolving them in a drum, is first mentioned in 1684, but was probably adopted earlier.

The regular manufacture of gunpowder in England dates from about 1412. Much of the saltpetre used was imported, but a certain amount was obtained from 'nitre heaps' and by digging in places where refuse had drained into the soil, and much discontent was caused by the high-handed proceedings of people with licences to dig for saltpetre. Importation of saltpetre from the East Indies direct into England by the East India Company commenced in 1626. Sulphur was, of course, and is still, wholly imported.

Of the gunpowder-works still in existence on their original sites, the government works at Waltham Abbey, the Chilworth Company's works at Chilworth, and Messrs Curtis & Harvey's works at Faversham are the most ancient—Waltham Abbey can certainly claim existence at least as early as 1561, while the other works mentioned date back traditionally to nearly as early a date. For a detail of the early history of the manufacture of gunpowder in England, the reader is referred to *The Rise and Progress of the British Explosives Industry* (1909). This work contains a mass of information on the subject, and an excellent bibliography.

Before the action of gunpowder can be properly understood, it will be necessary to give some explanation of the term 'explosion.' Explosion (as distinct from 'detonation') is simply very rapid burning; and burning is *broadly* the chemical combination of some element with oxygen to form an oxide. There can be explosions also in which oxygen is not involved. The rusting of iron, the burning of coal in a household fire, and the explosion of gunpowder are all oxidations which usually take place at very different rates; but it is only necessary that the iron shall be sufficiently finely divided and in intimate contact with pure oxygen, instead of the diluted oxygen of the air, for it to burn on ignition with great speed; while in the case of coal, if it be finely divided and diffused as dust in the air and then ignited strongly, explosion can easily occur, as is the not infrequent experience in coal-mines with coal-dust explosions. In the case of gunpowder, we have a store of *solid* oxygen in the saltpetre, and with this the combustibles, charcoal (carbon) and sulphur, are intimately mixed, so that every particle of the combustibles has close to it the oxygen necessary to burn it up as soon as ignition starts the action. In addition to the burning up of the charcoal and sulphur there are secondary reactions whereby the oxides of carbon and sulphur and the sulphur itself combine with the potassium of the saltpetre to form potassium carbonate (K_2CO_3), potassium sulphate (K_2SO_4), and potassium sulphide (K_2S_2). (Normal potassium sulphide is K_2S. K_2S_2 is formed at high temperatures.) These are all solids, and form approximately 57 per cent. of the products of explosion. The gaseous products are carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen (N). Assuming that the gunpowder under consideration is made up of the following parts by weight, viz. saltpetre (KNO_3) 75 per cent., charcoal 15 per cent., and sulphur (S) 10 per cent., and that the 15 parts of charcoal contain only about 11·5 parts of pure carbon (C), the remainder being ash, nitrogen (N), hydrogen (H), and oxygen (O), the final result on explosion is expressed very closely by the following equation :

$$16\ KNO_3+20{\cdot}7\ C+6{\cdot}8\ S=3{\cdot}885\ K_2CO_3+1{\cdot}428\ K_2SO_4+2{\cdot}686\ K_2S_2+13{\cdot}81\ CO_2+3\ CO+8\ N_2.$$

The volume of the permanent gases formed by the explosion after they have cooled down is about 280 times the volume of the original charge of gunpowder, but owing to the immense temperature due to the combustion of the powder, calculated from the heat given off, and the volume of gases evolved (which can be accurately measured) at about 4532° F. (2500° C.), this volume is enormously increased, and, assuming that the explosion takes place in a closed vessel in which the powder before firing fills the whole space available, the maximum pressure attainable is about 42 tons on the square inch.

From the accurately determined results obtained when gunpowder is fired, whether in a gun or in a closed vessel, mathematical expressions have been deduced for the work it is capable of doing in a gun, and tables made from which the charge needed in any gun, to give any required result, can be calculated, and the results of these calculations are in close agreement with those obtained in practice. The present knowledge of gunpowder is in the main based on the results of exhaustive experiments carried out by the late Sir Frederick Abel, chemist to the War Department, and Captain Sir Andrew Noble, late Royal Artillery, which were communicated by them to the Royal Society in two papers (1875–80) under the heading, 'Researches on Fired Gunpowder.'

Although saltpetre is almost exclusively used for the manufacture of gunpowder, there are two other nitrates—viz. sodium nitrate ($NaNO_3$) and ammonium nitrate (NH_4NO_3)—which possess some advantages over saltpetre. The first contains 56·47 per cent. of available oxygen, as compared with 47·48 per cent. in saltpetre, and a gunpowder one-third more powerful than that which can be formed with saltpetre can be made with it; the second, while it has only 20 per cent. of available oxygen, has the advantage that a gunpowder made with it leaves no solid residue on firing, as compared with the 57 per cent. approximately left by saltpetre gunpowders. Unfortunately, both produce very hygroscopic gunpowders; and, as a result, gunpowder made with sodium nitrate has only been used with advantage in very dry climates, and then immediately after manufacture—e.g. in the construction of the Suez Canal—while ammonium nitrate is only used, mixed with various combustibles or explosive compounds, for blasting or other disruptive purposes, the mixtures being contained in waterproof casings.

As has been pointed out, the combustibles in gunpowder are charcoal and sulphur. Sulphur, however, also plays an important part in increasing the initial rate of ignition and burning of the gunpowder, owing to its volatility, whereby it gives off vapour, even below its comparatively low melting-point of 239° F. (115° C.), which is capable of readily penetrating into the grains or pieces of powder. Reducing the amount of sulphur, other conditions being the same, reduces the rate of burning of a gunpowder, especially on first ignition. Gunpowder ignites and explodes at about 600° F. (321 C.).

The following table of the compositions of English gunpowder at various dates is taken from Colonel Hime:

	About 1250.	About 1350.	1560.	1647.	1670.	1742.	1781 to Date.
Saltpetre..	41·2	66·6	50·0	66·6	71·4	75·0	75
Charcoal..	29·4	22·2	33·3	16·6	14·3	12·5	15
Sulphur ..	29·4	11·1	16·6	16·6	14·3	12·5	10

Colonel Hime considers that the 1350 composition was only a laboratory receipt, as it would have given a powder much too powerful for use in the weak guns of the period.

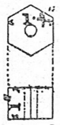
The following table of foreign gunpowders is compiled from the British official *Treatise on Service Explosives* (1907):

	Austria.	Belgium.	France.	Germany.	Italy.	Russia.	Spain.	United States.
Saltpetre........	75·5	75	75	74	75	75	75	76
Charcoal........	14·5	12·5	12·5	16	15	15	12·5	14
Sulphur.........	10·0	12·5	12·5	10	10	10	12·5	10

It will be noticed that there is some variation in the compositions. This is due to the fact that there does not appear to be any mixture which can be pronounced definitely to be the absolute best, and about equal results are obtained from any of the compositions given, since, as will be explained later, the mechanical treatment of the ingredients has an enormous effect on the behaviour of the resulting gunpowder.

The compositions given above are for 'black' gunpowders. About 1878 a different class of powder was introduced on the Continent, and in 1884 was adopted by Great Britain for heavy ordnance. It contained only small quantities of sulphur and a charcoal made from charred straw. The proportions of these powders were, in the British service, 79 saltpetre, 18 charcoal, and 3 sulphur in the case of 'Prism Brown' and 'Slow Burning Cocoa' (S.B.C.); and for 'Experimental E' (E.X.E.), 77·37 saltpetre, 17·62 charcoal, and 5 sulphur. These were termed 'brown' powders from their colour. The word 'cocoa' simply refers to the colour of the powder so named. These powders, which were prismatic in form, and the cubical powders are no longer made, having been superseded by the more efficient smokeless powders (see GUN-COTTON), but require some mention. Before, however, this is made it will be necessary to describe briefly the manufacture of gunpowder and the way that it behaves on ignition.

Process of Manufacture.—It is not possible to give in detail all the processes whereby the ingredients are obtained in as uniform and pure a condition as possible. These processes are absolutely essential, and will be found fully described in the official treatise already referred to, and in such works as *Explosives*, by Arthur Marshall (1917). Assuming the ingredients to have been purified, they are first reduced to a fine powder by grinding. They are then mixed by hand in the required proportions, and thoroughly incorporated in a wet state in a powder-mill into a cake called a mill-cake. This cake is then broken down between copper-plates into meal. From this meal-powder all granulated powders are made. The meal is compressed in a press-box, the amount of compression it undergoes being dependent on the density of powder required. After compression the press-cake is broken into pieces ready for granulating, which is done in the granulating-machine, the powder passing between gun-metal rollers till it is broken into grains of the required size, different powders being made to pass through sieves whose meshes are of the size of the grain required. The largest grain powder in the British service was 'Rifle Large Grain 4' (R.L.G.[4]), which would pass a square sieve-hole of about 0·5-inch side and be retained on one of 0·3-inch side; and the smallest was pistol powder, which passed a hole of 0·015-inch and was retained on one of 0·01-inch side. There is a considerable amount of dust formed by the granulating process, so that after granulating it is necessary to dust the powder previous to glazing it, which is the next operation. It is glazed in glazing-drums, which, revolving rapidly, impart a glaze to the powder simply by the friction set up. The powder is now stoved or dried in copper-trays in a drying-room, which is heated to a temperature of about 100° F., and the powder is left in this room from one to two hours according to the amount of moisture that it contains. At one time all powder was granulated, but the enormous increase in the size of guns necessitated the introduction of other descriptions of powder—viz. *cut* and *moulded* powders. With the cut powders, after the process of *pressing*, the press-cake, instead of being granulated, was first cut into strips, and these strips were then cut into cubes, and the powder so made, called cubical or pebble powder, was of two sizes—viz. ⅝-inch and 1½-inch cubes. In the moulded powders, as is implied in the name, each grain or piece of powder was moulded or pressed in a separate mould. This was done in a hydraulic or cam machine. The exact quantity of granulated powder required to form each prism was deposited in moulds; the powder in these moulds was then pressed by plungers exactly fitting the moulds till the required density was obtained. The moulds were hexagonal in form, and produced hexagonal prisms about 1·4 inch in diameter across the flats and 1 inch in height, with a hole 0·4 inch in diameter through the centre (see figure).



The processes of manufacture described above have for their object that the resulting gunpowders shall have uniform density, hardness, size, and shape, for on these the behaviour of the powder largely depends. A dense hard powder with a good glaze ignites less readily and burns more slowly than one of loose texture; moreover, the particles of such powder will burn layer by layer without breaking up and developing gases too rapidly. Consequently all gunpowders are pressed up to a considerable density, varying from about 1·6 in the small-grained sizes to 1·85 in the moulded powders. The size of grain profoundly affects the rate of burning, as can be readily seen by considering the case of two equal charges of powder, the one made up of one cube of 1-inch side, and the other of 1000 cubes of $\frac{1}{10}$-inch side. The cube of 1-inch side will ignite and burn from a surface, at the start, of 6 sq. inches, while the 1000 cubes of $\frac{1}{10}$-inch side will ignite and burn from a total surface of 60 sq. inches (i.e. $1000 \times 6 \times \frac{1}{10} \times \frac{1}{10}$ sq. inches), and will obviously burn away and give off all their gases enormously more rapidly than the 1-inch cube.

As to shape. It is desirable that the production of gas shall be uniform. It is clear that a regular form—say a cube—will burn from its largest surface and give off most gas at the start, and that as it burns away the surface and rate of production of gas (not considering for the moment the effect of the increasing heat on the rate of burning) must diminish. This is met to some extent by the hole in the centre of the prisms with prismatic powders, which enlarges as the exterior diminishes.

The object of getting a slow-burning powder is to distribute the work done over the whole bore of the gun instead of producing all the gas and developing all the pressure at the breech-end of the gun. Theoretically, with a powder exactly suited to a gun, all its particles would be just consumed as the projectile leaves the muzzle. Clearly, therefore, the size of grain needs to be very different for use in a rifle with a barrel, say, 2 feet 9 inches long and 0·45 inch in calibre, and in a gun with a bore, say, 30 feet long and 17·72 inches in calibre.

We are now in a position to consider the 'brown' powders. In the larger (and particularly the longer) guns introduced in the last quarter of the 19th century it was found that the large cubes or prisms of 'black' powder used in order to produce slow burning, however hard and dense they might be made, were apt to break up instead of burning layer by layer, owing to the great heat and pressure which they had to sustain for a considerably longer time than in the short guns of the early 'seventies.' Consequently a gunpowder of a slower-burning *composition* had to be sought, and this was found in the 'brown' powders.

Proof.—When a gunpowder, or a smokeless explosive, is to be used as a propellant, it is 'proved,' before acceptance, in a gun or a rifle, to test whether the given charge of it, prescribed for that gun or rifle, is capable of imparting to a projectile the velocity, without exceeding the pressure, laid down in the 'specification' for it.

The instrument generally used for taking velocities is a chronograph, the invention of Major De Boulengé of the Belgian Artillery. It consists of a brass column supporting two electro-magnets. No. 1 electro-magnet supports a long cylindrical rod, called the chronometer, covered by a zinc tube; No. 2 electro-magnet supports a shorter rod. Two screens of copper wire are placed at certain fixed distances in front of the muzzle of the gun. No. 1 electro-magnet is magnetised by the current passing through the screen nearest the gun, and No. 2 by the current passing through the farthest screen. As the shot passes through the first screen the current is broken, and the rod or chronometer suspended by No. 1 electro-magnet falls by gravity. Similarly, when the shot passes through the second screen, the shorter weight suspended by No. 2 electro-magnet falls on to a disc, which, pressing a spring, causes a knife to be released, and this, darting forward, strikes the chronometer in its fall, making an indent in the zinc tube. The distance of this indent from the zero point (which is the indent made when the currents through both screens are broken simultaneously) is that through which the chronometer-rod has fallen during the time taken by the projectile in passing from the first to the second screen. As the space between the screens is known, and a known law connects the distance on the chronometer-rod and the time of its fall, the velocity of the projectile can be readily calculated.

The pressures in the bore of the gun are calculated by means of a 'crusher gauge.' A small copper cylinder is inserted in the gauge, which is screwed into the gun at that part where it may be desired to measure the pressure, or for 'chamber' pressures is placed loose in the bore close to the breech. The copper cylinder is measured before and after the discharge of the gun, and the pressure, corresponding with the amount it has been shortened by the pressure of the gases of explosion, is given by a table. This table is prepared from the shortenings resulting from compressing copper cylinders with known pressures in a specially designed press.

Gunpowder is now practically obsolete as a propellant for war-like purposes in civilised countries, having been superseded by the smokeless powders (see under GUN-COTTON), which commenced to be introduced in 1885; but though smokeless powders are rapidly replacing it for sporting purposes also, there still is a market for certain high-class sporting gunpowders. For blasting purposes, however—except in fiery coal-mines, in which its use is forbidden by law (see 'Permitted Explosives,' under DYNAMITE)—it is still in enormous request; for, from the Annual Report by H.M. Inspectors of Explosives for 1914, out of a total of 33,661,940 lb. of explosives used in mines and quarries in the British Isles (not including that used in the making of railways, roads, docks, and other similar works, or exported), 17,060,874 lb. was gunpowder. If 'Bobbinite' (which is practically a gunpowder) be included, this amount must be increased by 1,453,475 lb. Blasting-powder varies considerably in quality; but the greater portion of it is of an inferior class, containing a reduced percentage of saltpetre, and manufactured and finished, especially in the time taken in the incorporation of the ingredients, with less care. No doubt the strongest gunpowder is not needed for many mining and quarrying operations, as a slow splitting action, rather than one tending to break the material displaced into many fragments, is often desirable; but a very potent factor in the matter is that miners and quarrymen generally provide their own explosives, and to them present cheapness appeals. A great deal of blasting-powder is sold in the form of compressed cartridges, ready for use in bore-holes (see BLASTING).

For war-like purposes gunpowder is still used in considerable quantities, and is indispensable for the charges of tubes, primers, and igniters used for firing the smokeless-powder charges of guns, and for the bursting-charges of certain shell. It is also used for blank cartridges for manœuvres, saluting, and signalling. In the Annual Report of H.M. Inspectors of Explosives for 1918 it is stated that, out of the total of 425,559 tons of all explosives made in licensed factories between the 4th August 1914 and 11th November 1918, no less than 66,094 tons were gunpowder. Not less than half (and probably more) of this would be for war-like purposes.

Gunpowder possesses the following advantages as compared with other explosives: If protected from damp, it keeps wonderfully well in all climates; the ingredients are comparatively cheap and easily obtained; with reasonable care, it is safe in transport or store; and, lastly, it needs no special detonator to fire it to obtain its maximum effect. Its disadvantages are that it is quickly rendered useless

if exposed to moistu
inert matter, and, a
half as powerful as
gives off much smo
objectionable when

Gunpowder P
Roman Catholics of
I. and the Houses
day of the opening
1605. The design o
(q.v.), irritated th
Catholics to expec
had put the pena
in 1604 Catesby co
Wright and Thoma
a brave soldier serv
brought over from
Percy was admitte
oath of secrecy. A
from the hands of
ever, was not info
24th May Percy
Parliament House
mine. The adjourn
to time caused sund
In December the c
culties were great
became expedient t
associates—John G
Thomas), and Bate
following March th
a convenient cellar
of Lords. The min
cellar was stored
with faggots.
All was ready by
to provide men, h
rection, which it wa
the midland counti
had congregated.
Catholics, Sir Ev
wood, and Francis
Tresham lacked th
fellows. Wishing
eagle, he wrote to
mysterious letter, w
bury and led to the
not otherwise been
of the conspirator
The government,
development of the
if casually by th
Monteagle at three
4th. Fawkes, wh
that the fuel and f
master, Percy. H
into execution, a
returned to the cel
night. He was me
Catesby hastened t
his friends. A few
several of the cons
killed, and others
mitted for trial.
plot was gradually
The government
suspicion that the
moted or approve
his confession im
society, especially
latter made good
a brother Jesuit,
nothing more than
companion, were
place at Hindlip,
Coughton, in the
rendezvous of th
cited the greatest

if exposed to moisture, contains some 57 per cent. of inert matter, and, as a result, is not only less than half as powerful as a good smokeless powder, but gives off much smoke. This last is only seriously objectionable when it is used as a propellant.

Gunpowder Plot, an attempt by certain Roman Catholics of England to destroy King James I. and the Houses of Lords and Commons on the day of the opening of parliament, November 5, 1605. The design originated with Robert Catesby (q.v.), irritated that James, who had led the Catholics to expect some measure of toleration, had put the penal laws in full force. Early in 1604 Catesby communicated his plan to John Wright and Thomas Winter. Guy Fawkes (q.v.), a brave soldier serving in the Spanish army, was brought over from Flanders, and together with Percy was admitted to the plot after taking an oath of secrecy. All five then received communion from the hands of the Jesuit Gerard, who, however, was not informed of the conspiracy. On 24th May Percy hired a room adjoining the Parliament House which they intended to undermine. The adjournment of parliament from time to time caused sundry postponements of the work. In December the digging was begun. The difficulties were greater than was expected, and it became expedient to call in the assistance of fresh associates—John Grant, Robert Winter (brother of Thomas), and Bates, a servant of Catesby. In the following March the conspirators were able to hire a convenient cellar immediately below the House of Lords. The mine was now abandoned, and the cellar was stored with casks of powder, covered with faggots.

All was ready by May. Money was now wanted to provide men, horses, and arms for the insurrection, which it was intended should break out in the midland counties, where the chief conspirators had congregated. So about Michaelmas some rich Catholics, Sir Everard Digby, Ambrose Rookwood, and Francis Tresham were induced to join. Tresham lacked the courage and fanaticism of his fellows. Wishing to save his friend Lord Monteagle, he wrote to him on Saturday, October 26, a mysterious letter, which was shown to Lord Salisbury and led to the discovery of the plot, if it had not otherwise been already betrayed. The names of the conspirators were, however, not disclosed. The government, therefore, waited for the fuller development of the plot. The cellar was visited as if casually by the Lord Chamberlain and Lord Monteagle at three o'clock on the afternoon of the 4th. Fawkes, who was found there, explained that the fuel and faggots were the property of his master, Percy. He still hoped to carry his design into execution, and a little before midnight he returned to the cellar to take up his post for the night. He was met and arrested at the doorway. Catesby hastened to Warwickshire, hoping to raise his friends. A few days later they were attacked; several of the conspirators, including Catesby, were killed, and others were taken prisoners and committed for trial. From their confessions the whole plot was gradually revealed.

The government was now much concerned with a suspicion that the murderous design had been promoted or approved by the Jesuits. Bates had in his confession implicated certain fathers of the society, especially Garnet (q.v.) and Greenway. The latter made good his escape abroad. Garnet and a brother Jesuit, Oldcorne, who was convicted of nothing more than aiding in the concealment of his companion, were discovered in a priest's hiding-place at Hindlip, whither Garnet had fled from Coughton, in the neighbourhood of the appointed rendezvous of the conspirators. Their trial excited the greatest interest. It soon became evident that Garnet's knowledge, such as it was, of the plot had been forced upon him by the conspirators, who were anxious to obtain from him some token of his approval for the satisfaction of their own doubtful consciences. He admitted that he had derived a general knowledge of some treasonable design against the government, in the first instance from Catesby, and that subsequently he had learnt the particulars from Father Greenway in confession. On further examination Garnet expressed some doubt whether the communication made by Greenway was strictly sacramental or under the seal of confession, or at least whether Greenway himself so considered it. It was, moreover, elicited from Garnet that he had frequent conversations with Greenway on the plot, though always 'in relation to confession.' Finally, when Catesby wished to give him full information out of confession—information which would have released Garnet from all shadow of scruple in taking measures to reveal or prevent the crime—the Jesuit refused to listen to him. Some of Garnet's actions, both before and after the 5th November, gave probability to the belief that he knew more than he admitted, and was not unwilling that the plot should succeed. He blamed himself, indeed, for not having done more to prevent the mischief, and declared that he should suffer, not as a martyr, but as a penitent thief. It is, however, clear that the clergy in general, whether secular or regular, and the entire Catholic community, with the exception of a score of fanatics, were innocent of all participation in the plot.

See the *Narrative of the Gunpowder Plot* by David Jardine (1857), which treats the facts in a masterly and impartial spirit; Gardiner's *History of England*, vol. i. chap. vi.; and Tierney's edition of Dodd's *Church History*, vol. ii. In 1896 Father Gerard, S.J., tried in *What was the Gunpowder Plot?* to show that the evidence of a real plot was slight, and that the plot was itself partly manufactured by government agents; in 1897 Gardiner traversed this theory in *What the Gunpowder Plot was.*

Güns (Magyar *Köszeg*), a frontier town of Hungary, 57 miles SSE. of Vienna, with a castle of Prince Esterházy: pop. 8000.

Gunter, EDMUND, mathematician, was born in Hertfordshire in 1581, and educated at Westminster and Christ Church, Oxford. Although he took orders and became a preacher in 1614, his mind was strongly bent towards mathematical studies, and in 1619 he obtained the professorship of Astronomy in Gresham College, London, a post which he held down to his death, 10th December 1626. His principal works are the *Canon Triangulorum* (Lond. 1620), a table of logarithmic sines and tangents to seven places of decimals, being the first table published in accordance with Briggs's system, and treatises on the *Sector, Cross-staff, and other Instruments* (1624). Gunter was the first to use the terms cosine, cotangent, and cosecant for the sine, tangent, and secant of the complement of an arc. To him are also due the invention of the surveying-chain (see CHAIN), a quadrant, and a scale, and the first observation of the variation of the compass.

The name of *Gunter's Scale*, or *Gunter's Lines*, is usually given to three lines to be seen on almost any sector, and marked N, S, T, meaning the lines of logarithmic *numbers*, of logarithmic *sines*, and of logarithmic *tangents*. To understand their construction and use requires a knowledge of logarithms; they are explained in every school-book of practical mathematics. The distances of the divisions marked 1, 2, 3, &c. on the line of log. numbers, represent the logarithms of those numbers—viz. 0, ·301, ·477, &c.—taken from a scale of equal parts. The other lines are constructed on an analogous plan. Calling

Z-CHAMBERS'S ENCYCLOPAEDIA, VOL. 5 (FRE-HUM) PUB. 1925

y breech-loading,
n' principle (see
facture of shot-
idustry, and one
-barrel-welding—
rrant descriptive
some eighteen or
the skill of the

hand-forged from
usually composed
, or of iron and
of the metals be
greater the pro-
l the harder the
etter will be the
ome varieties of
gun-iron con-
tain 70 per
cent. of steel;
in others a
good quality
and an in-
ferior quality
of iron are
used together,
and no steel
enters into
the composi-
tion. The
rod of gun-
iron is built
up of alter-
nate layers of
the hard and
soft metals,
and in the
manufacture
must be twisted
side by side to
a barrel. These
veen rolls into a
etal, the riband
, or more twisted
the barrel or the
Belgian welders
h in making the
as many as six
to form a single
not so hard as the
ered to be inferior
ded barrels. The
and received it
proper size, pro-
isting the riband
ald cover a whip-
er. This coil has
t a time, and the
esult being a tube
igh when finished
hich are the next
barrel must pass.
bes to form the
few inches at the
other and to the
ite them through-
reech actions are
ork and bolting-
n is ready for the
piece of walnut
by the 'screwer,'
nisher' to prepare
ich are comprised
ving, hardening,
rrels when finely
which rusts the
ey are composed,
ofter metal turns

it a darker colour. This process, termed 'browning,' occupies several days, and when successful shows clearly the damascening or curls of fibre obtained by twisting the gun-iron rods in the earliest stage. A barrel not showing such curls would be termed a 'scelp' barrel if it were a twisted welded barrel, but if of one uniform colour, unbroken by regular markings, it would probably be composed of plain iron or steel only.

For ordinary gun-barrels steel is used. Sir Joseph Whitworth's fluid-compressed metal was the first successfully employed, but later high-grade carbon, nickel, and vanadium steels have been found suitable for the bars out of which the barrel is drilled. In a sporting gun or rifle a quick second shot is more advantageous than continued rapid fire, so double-barrelled guns are still preferred, and some are now made to discharge by a single trigger. For repeating and magazine guns, see BREECH-LOADING, the mechanisms and general construction being identical for guns and rifles. The automatic gun (Browning) is a similar type, but the loading and firing mechanisms, instead of requiring manipulation, are actuated by utilising the recoil to perform the necessary movements, or to cramp springs which effect them, the trigger only requiring to be pulled to fire the weapon after each shot. The use of magazine weapons for sporting purposes is deprecated as tending to wasteful shooting, and in some states they may not be used for killing game. Cold drawn steel barrels proved too expensive. The standard size of the modern shot-gun is 12 bore; 8 and 4 bores are used only for wild-fowling; and *punt-guns*, guns of from 1-inch to 3-inch bore fitted into shooting punts, are employed for firing from ½ lb. to 4 lb. of shot at a time into flocks of sea-fowl.

With the exception of punt-guns, guns of all bores are made upon the same principle of breech-loading, and nearly all are more or less choked; i.e. the diameter of the barrel is suddenly lessened near the muzzle, forming a cone which causes the pellets of the charge to fly from the gun more compactly and at an increased velocity. A 7-lb. gun may now be expected to send on an average 220 pellets of a charge containing 305 pellets into a circle 30 inches in diameter (or 60 into a 10-inch square) at 40 yards distance, the pellets having an average velocity at the muzzle of 840 feet per second, and a striking force at impact (40 yards) of 1·90 oz. The last shot of the charge will not be more than 10 feet behind the first one that reaches the target at that distance. The killing range of the shot-gun is about 45 yards, of wild-fowl guns about 140 yards with swan-shot. After pulling the trigger until the shot reaches the muzzle ·007 of a second elapses, and ·13 before the shot, having passed the muzzle, reaches a target 40 yards distant. Shot-guns are now built very much lighter than when breech-loaders first came into general use (1865); shorter barrels are used without loss of shooting power or appreciable increase in the volume of the recoil. Smokeless explosives are in general use all the world over for shot-guns.

See GUN-COTTON, GUNPOWDER, FIREARMS, RIFLE, &c.; Greener's *Gun and its Development* (1881; 9th ed. 1910), and his *Modern Shot Guns* (1888); books on guns and shooting by Hawker (1844), Payne-Gallwey (1882-86), Walsh (1884), Shaw (1902), Horace G. Hutchinson (1903), Buckell (1907); and *The Causes of Decay in a British Industry*, by 'Artifex' and 'Opifex' (1907).

Gunboat, a small boat or vessel armed with one or more guns of heavy calibre. From its small dimensions, it is capable of running close inshore or up rivers, and from the same cause it has little chance of being hit by a larger vessel at the long range which the carrying power of its guns enables it to maintain. At the outbreak of the Russian war, a large squadron of them was hastily constructed for the British navy for the first time. Their tonnage was small; and their armament usually consisted of one 8-inch gun and one 100-pounder Armstrong gun. Gunboats from 1870 to 1900 were small mastless vessels mounting one large gun in the bow, and propelled by an engine with single or twin screws. The gun was pointed by means of the helm or the screws; the gunboat was in fact a floating gun-carriage. In the British navy these gunboats carried an armour-piercing gun of 18 tons, on a draught of only 4 feet. But they have been designed to carry 35-ton guns, or heavier, and were intended for coast defence. In 1903 there were in the navy 33 torpedo-gunboats, the largest form of special torpedo-boats. But these gunboats are now obsolete, and the name is practically limited to a class of very light-draught vessels for use in rivers; these have 4-inch guns and searchlights, and some are propelled with stern wheels, others with screw propellers in tunnels. These were extensively used during the Great War, 1914-18, in Mesopotamia and Africa, and did excellent work. Most Continental navies are provided with gunboats of various size and construction.

Gun-carriage. See CANNON.

Gun-cotton (nitro-cellulose) is an explosive compound produced by the action of a mixture of strong nitric and sulphuric acids upon cotton (cellulose). So long ago as 1832 it was discovered by Braconnot that woody fibre and similar substances could be converted into highly combustible bodies by the action of concentrated nitric acid. Six years later Pélouze extended this discovery to cotton and other organic substances. He was followed by Dumas, who treated paper in a similar way, and he proposed to make cartridges with paper so treated, the idea being that no residue would be left in the barrel after firing such cartridges. But no practical result followed these discoveries until, in 1846, Schönbein (q.v.), having hit upon the proper mode of treating cotton with nitric and sulphuric acids, announced the discovery of gun-cotton, which he proposed as a substitute for gunpowder. He prepared it by immersing carded cotton-wool in a mixture of nitric and sulphuric acids, and the equation for its formation may be stated thus:

$$\underset{\text{Cellulose.}}{C_{12}H_{14}O_4(OH)_6} + \underset{\text{Nitric Acid.}}{6HNO_3} = \underset{\text{Gun-cotton.}}{C_{12}H_{14}O_4(ONO_2)_6} + \underset{\text{Water.}}{6H_2O}.$$

This equation is not, however, universally accepted. It treats cellulose as a hexatomic alcohol. In another equation the cellulose molecule is taken as $C_6H_7O_2(OH)_3$—i.e. as half that given above—and the gun-cotton molecule as $C_6H_7O_2(ONO_2)_3$, as follows:

$$C_6H_7O_2(OH)_3 + 3HNO_3 = C_6H_7O_2(ONO_2)_3 + 3H_2O.$$

The obscurity arises from the failure so far to ascertain quite definitely the molecular weight of cellulose or the constitution of the molecule, and the empirical formula $C_6H_{10}O_5$ is often used for lack of a better. It will be observed that no mention is made of sulphuric acid in these equations, the presence of which is, however, essential in the production of gun-cotton, for, although it takes no active chemical part in the action, it absorbs the water which is formed by the chemical transformation, and thus keeps the nitric acid up to its full strength. Whichever equation be accepted, the action indicated by it is never wholly obtained, as lower nitrated products are invariably present to a greater or less extent according to the strength of the nitric acid. These lower nitrated cottons, termed 'collodion cottons,' are soluble—that is, are converted into jelly, by a mixture of alcohol and ether, while true gun-cotton is insoluble. As the explosive force depends upon the degree of nitration, every effort is made to keep the latter as high as possible. Good gun-cotton will often contain as much as 12 per cent. of soluble cotton.

Schönbein's discovery led to experiments being made by many eminent chemists in nearly every country in Europe with the idea of utilising the new explosive for military purposes. It was first manufactured in England on a large scale in the year 1847 by Messrs Hall & Son of Faversham; but, in addition to minor accidents, a terrible explosion took place in their works, which created so much distrust that its manufacture in England was discontinued for some sixteen years, as the causes of the explosion—almost certainly imperfect cleansing of the cotton in the first place, and insufficient removal of all acid from the gun-cotton in the second—with the then imperfect knowledge possessed of the subject, could not be satisfactorily accounted for. The first country to turn Schönbein's discovery to practical account was Austria. General Von Lenk, an Austrian artillery officer, after extensive trials succeeded in considerably improving the method of manufacture and purification; while by using gun-cotton yarn plaited or tightly wound, he succeeded in moderating the rapidity and increasing the uniformity of its combustion when burnt in the *air;* and as a result, in 1862, several batteries of Austrian artillery were armed with gun-cotton cartridges. But it soon fell into disrepute, not only on account of its unstable nature, but also because it was found that Von Lenk's improvements were of no practical utility when the gun-cotton was confined in the bore of a gun; the great heat generated caused the inflamed gas to penetrate rapidly through the whole cartridge, so that there was little or no retardation in the rate of combustion, and the rapid combustion caused excessive pressure in the bore, besides giving very unequal results.

The probable advantages of gun-cotton as a disruptive explosive for military purposes had, however, never been lost sight of by Sir Frederick Abel, chemist to the British War Department (1854–88). Nothing daunted by the failure of the Austrian experiments, nor by the explosion at Messrs Hall's works, Sir Frederick Abel continued his experiments, and he ultimately discovered a method of manufacture whereby not only a complete purification from free acid is assured, but the material is converted into thoroughly compact homogeneous masses. His method of manufacture, adopted almost universally, may be briefly described as follows. The best white cotton waste alone is employed. This is first thoroughly cleansed from all grease by boiling with alkalies; it is then picked over by hand and all foreign substances removed, after which the fibre is separated and all knots and lumps opened out by passing the cotton waste through a 'teasing' machine; it is then cut into 2-inch lengths and again teased, thoroughly dried, and divided into charges weighing 1¼ lb. each, which are kept in airtight tin boxes till ready for dipping. The acids used in the manufacture of gun-cotton are nitric acid having a specific gravity 1·52, and sulphuric acid of 1·84 sp. gr.; these are mixed in the proportion of one part by weight of nitric acid to three of sulphuric acid, and allowed to cool down in iron tanks. The mixed acid is run off into the dipping-pans, surrounded by cold water, into which a 1¼-lb. charge of cotton is immersed and left in for about five minutes, in which time it will have absorbed about 14 lb. of acid. The charge is then transferred, with the acids it has absorbed, to an earthenware-covered pot which is placed in a cooling-pit, surrounded with water, where it remains for about eight hours. At the end of this time the cotton has been completely converted to gun-cotton, and the remaining processes are all devoted to the complete removal of every trace of acid. The charge removed from the earthenware pot is placed in a centrifugal wringing-machine, in which the bulk of the acids are removed, then immersed with other charges in a large bulk of running water in which it is well agitated until the water coming away shows no signs of acidity. It is then removed to a centrifugal wringing-machine, washed again, and then wrung free from excess of water. Transferred to a 'beating' machine, it is reduced to a very fine state of division by knives revolving in water, and any acid set free in this process neutralised with bicarbonate of soda. This beating is a highly important process. After beating, the gun-cotton is boiled for several hours, in which process soluble impurities are removed, and finally passed through grit-traps, in which foreign matter, such as sand, small stones, bits of metal, &c., is caught, into the 'poacher,' where it receives a final washing in a large volume of water, and is treated with sufficient alkaline matter to make it alkaline to the extent of from 1 to 2 per cent., and finally pressed in hydraulic presses into slabs or discs or any other form required. If the gun-cotton is to be subsequently mixed with other substances, explosive or otherwise, or to receive subsequent treatment, to form one of the numerous explosives into which it enters, the addition of alkali is omitted.

A recent improvement on the above is nitration of the gun-cotton by the 'displacement process,' invented by Messrs J. M. & W. Thomson of the Royal Gunpowder Factory at Waltham Abbey. By this process the cotton is nitrated and then sufficiently purified from acid in one apparatus to pass at once to the boiling process.

Gun-cotton weighs about 70 per cent. more than the cotton from which it is made, but, apart from the mechanical treatment which it usually undergoes, is not altered in appearance by nitration. It is, however, rendered somewhat rougher to the touch and highly electric. It ignites at about 300° F. (150° C.), and if in small quantity and unconfined will burn away, leaving practically no residue. It is not, however, to be trusted, and may explode instead of burning. It is easily detonated by a blow or by friction, especially when warm. The term 'detonation' implies an extraordinarily rapid break up of the substance detonated into its elements, generally with a combination into other compounds, usually gaseous, this recombination giving rise to an enormous generation of heat. It differs only from explosion (see GUNPOWDER) in the degree of rapidity with which it takes place. The wave of detonation will traverse a charge of gun-cotton at the rate of about 20,000 feet per second, as compared with about 800 in the case of gunpowder. It is this rapidity of explosion which renders detonating explosives capable of producing such enormous effects, even when quite unconfined; for the weight of the superincumbent air—which it must not be forgotten is about 2000 lb. to the square foot—forms quite an efficient tamping, owing to its inertia, in such circumstances. A railway rail can easily be cut in half by the detonation of a charge of slabs of *wet* gun-cotton (see below), weighing about 1½ lb., simply tied to it by string. Detonation is usually started by a 'detonator,' which is a small metal tube containing, according to circumstances, from 12 to 70 grains of fulminate of mercury (one of the most violent explosives known, and one which usually needs ignition only to enable it to give out its full explosive force). The detonator (see BLASTING) is inserted in a 'primer' of dry gun-cotton, and the latter is embedded in or placed in the closest contact with the wet gun-cotton charge. (See in this connection a highly interesting paper, read by Professor Hopkinson, F.R.S., at the Royal Institution on 26th January 1912, on 'The Pressure of a Blow.')

The complete detonation of gun-cotton results in the formation of carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), and nitrogen (N), approximately according to the following equation:

$$C_{12}H_{14}O_4(ONO_2)_6 = 9CO + 3CO_2 + 7H_2O + N_6.$$

One volume of gun-cotton, at the density of water (which is very closely that of ordinary compressed gun-cotton), will produce theoretically 1140 volumes of gases. The calculated temperature (see GUNPOWDER) of detonated gun-cotton is about 2700° C., and the gases evolved are therefore enormously expanded by heat. The power of gun-cotton is about $2\frac{1}{2}$ times that of gunpowder when the latter is thoroughly well tamped and capable of exerting its full effect. Gunpowder untamped cannot practically be compared with gun-cotton. It will be noticed that the percentage of carbon monoxide (CO) is very high, showing the deficiency in available oxygen (O).

Dry gun-cotton, however well made and purified, is not an absolutely stable body, but decomposes slowly if exposed to temperatures much above 80° F.; and is not, as has been pointed out, very safe to handle. Owing, however, to the discovery in 1869 by the late Mr E. O. Brown of the Chemical Department, Royal Arsenal, that it could be detonated when containing some 20 per cent. of water by the detonation of a 'primer' of dry gun-cotton embedded in it, the heavy charges of Mines and Torpedoes (q.v.), and generally the stock of gun-cotton, are stored wetted with about $17\frac{1}{2}$ per cent. of water; in which condition it will keep indefinitely, is quite uninflammable, and cannot be detonated by the blow from a projectile. It is therefore very well suited for naval and military purposes, as for these it is comparatively rarely used in small charges; but it is but little employed for civil purposes for which small charges for bore-holes, &c., are usually required. Certain difficulties, however, which arise from the constant inspection necessary to see that the correct moisture is maintained, and the necessity of a heavy primer of dry gun-cotton or other less inert explosive to communicate detonation from the original fulminate detonator, have led to its abandonment for mines and torpedoes in favour of trinitrotoluene or amatol. Insoluble gun-cotton mixed with barium nitrate alone, or with the addition of charcoal or di-nitro-benzene, forms the explosive 'tonite.' Soluble gun-cotton mixed with nitro-glycerine forms the very powerful disruptive explosive 'blasting gelatine.' Otherwise it is not much used in mixtures to form disruptive explosives. (See DYNAMITE.)

Gun-cotton as a Propellant.—As stated previously, the early attempts to use gun-cotton as a propellant ended in failure, the cause being that the physical condition of the explosive rendered it impossible by mechanical means, such as tight-plaiting, to keep down the rapidity of its combustion. As early, however, as 1847 the solution of the difficulty by a chemical method was known, for Dr Hartig of Brunswick described the gelatinisation of gun-cotton by acetic ether, such gelatinisation converting the gun-cotton into a substance like horn. Colonel Schultze in 1866 produced his now well-known powder, made of nitrated wood mixed with barium or potassium nitrate, and in 1868 formed a company (which exists at the present time) in England to produce it. In its early form it was not gelatinised by a solvent, though the present productions of the company are so treated. It is a bulky powder, intended exclusively for use in shot-guns. At about the same period Abel and Kellner, of the Chemical Department, Royal Arsenal, both produced gelatinised powders; and in 1870 Volkmann, an Austrian, patented and made a gelatinised nitro-lignin powder, which was ultimately suppressed by the Austrian government as interfering with the government gunpowder monopoly. In 1882 Reid produced the well-known E.C. sporting powder, also a true gelatinised powder; and in 1885 France adopted for her army a smokeless powder, invented by Vielle, which was a mixture of soluble and insoluble gun-cotton gelatinised by ether alcohol. This procedure by a first-rate power led to immediate action by all the powers, and to an immense activity in the invention and production of smokeless powders.

In 1888 Nobel produced his 'ballistite,' which consisted of nitro-glycerine absorbed in soluble gun-cotton, with an addition of about 7 per cent. of camphor to promote the intimate union of the two explosives and to reduce the rapidity of explosion. Benzol was also used as a solvent, and evaporated out by heat. The percentage of nitro-glycerine in this powder varied from about 36 to 66 per cent., but the percentage used at present is about 50 per cent., the remainder being soluble gun-cotton. Camphor is no longer used, since it slowly volatilised out of the powder and altered its character. In 1889 Hiram Maxim patented his powder made of insoluble gun-cotton, nitro-glycerine, and an oil (preferably castor-oil), incorporated by partial solution in acetone—the last a volatile liquid, in which both gun-cotton and nitro-glycerine are soluble. In 1892 the British government adopted 'cordite,' made of the same ingredients as Maxim's powder, except that vaseline (mineral jelly) was substituted for oil. The proportions of cordite were 58 per cent. nitro-glycerine, 37 per cent. gun-cotton (insoluble), and 5 per cent. vaseline. Both Nobel and Maxim brought actions against the government for infringement of their patents, but were unsuccessful. The form of cordite used at present, termed 'Cordite M.D.,' and adopted in 1901, contains 30 per cent. nitro-glycerine, 65 per cent. of insoluble gun-cotton, and 5 per cent. of vaseline. During the war of 1914–18 a cordite made with soluble gun-cotton was used very largely owing to difficulty in obtaining sufficient supplies of acetone.

Modern military smokeless powders may be divided into two classes—viz. those made of mixtures of soluble and insoluble nitro-cellulose only, and those containing nitro-cellulose mixed with nitro-glycerine. In a few instances nitro-cellulose powders have nitrates, such as potassium nitrate, mixed with them to make up for the deficiency in oxygen of gun-cotton. The nitro-glycerine powders are much the more powerful if the nitro-glycerine and gun-cotton be proportioned so that the amount of gas produced on explosion when expanded by the heat of explosion shall give the highest possible energy; but the erosion of the bores of guns, due to the high temperature of combustion, has led to the reduction of the nitro-glycerine considerably below the theoretical limit, as in cordite M.D. Even so, powders with nitro-glycerine in them are more erosive than those of nitro-cellulose only. On the other hand, experience has shown them to be considerably more stable on exposure to high temperatures—a property of supreme importance in an explosive used by the British army and navy, which serve in every climate.

In stability all smokeless powders are, and, as far as can be seen, always must be, greatly inferior to gunpowder; but the full knowledge of this lack of stability, which has been proved by the disastrous explosions in the French and Japanese navies, attributed to decomposition of smokeless powder, has naturally led to precautions, in the way of provision of artificial cooling for magazines to maintain their temperature below 80° F. and close supervision of the condition of all cartridges, which will render the risk of such occurrences in the future exceedingly remote. It speaks well for the stability of cordite that the British navy has, in spite of world-wide service, been spared any disaster since its adoption which could be attributed quite definitely to its use. Further, they are, class for class, about 50 to 100 per cent. more expensive than gunpowder. On the other hand, smokeless powders have the following, and easily preponderating, advantages over gunpowder. Firstly, they are rather more than twice as efficient ballistically; secondly, they give very little fouling, and are practically smokeless in small-arms, and in guns give quite 75 per cent. less smoke—this smoke being due to the combustion or comminution of the materials of the cartridge-bag, wads, &c., to the smoke from the gunpowder igniter, but very largely to the comminuted copper dust due to the abrasion of the copper driving-band; and, lastly, they are not spoilt immediately by wetting, cordite standing wet remarkably well; but too much cannot practically be made of this, at any rate in the case of made-up cartridges with gunpowder igniters, as the ruin of the latter would be complete and the cartridges useless unless dried and the igniters replaced.

The influence of the size and shape of the grains on ballistics has been discussed in the article on Gunpowder. Precisely the same conditions hold with smokeless powders; and in the case of cordite, the cylindrical sticks, of which cordite charges are made up, vary in diameter from half an inch for the heaviest guns to $\frac{1}{10}$th inch in the cordite for the Webley revolver. A tubular form of this explosive is used for the charges of certain guns and for the cartridge for the ·303 rifle. The tubular form has undoubtedly two considerable advantages over the simple cord: firstly, on ignition it gives a very regular evolution of gas, in that, as it burns both from the interior as well as the exterior, the total area of burning surface is more constant; secondly, a bundle of it presents an exceedingly regular aggregate of surface for ignition from one end, and regular ignition is one of the first requisites for good ballistics. Regular evolution of gas can also obviously be obtained from thin strips, but these form a bad bundle for ignition from any point. Owing to their horny surface, smokeless powders, except in the very small charges for rifles, need, in order to avoid 'hang-fire,' an igniter of ordinary gunpowder to reinforce the flash of the cap or tube used to fire them (see CARTRIDGE). Many attempts have been made to use igniters made of smokeless powder for the purpose, but so far unsuccessfully. Such igniters must necessarily be made of finely divided explosive so as to ignite instantly, and the flame given by smokeless powder in such conditions, though immensely hot, is of very short duration, and of course quite deficient in the hot residue given by gunpowder. A minimum of delay between the firing of the cap or tube and that of the main charge is of first importance for naval guns, which are often fired from a constantly moving platform.

The manufacture of smokeless powders consists in the gelatinisation of the nitro-cellulose, or of the mixture of nitro-cellulose and nitro-glycerine while the latter are being intimately mixed; the pressing of the 'dough' while still wet with the solvent through dies to form cords or tubes, or the rolling of it into sheet to be cut up into grains or flakes; the drying out of the solvent, which often takes several weeks, and is the most lengthy, and, since it involves spacious drying accommodation artificially heated, one of the most expensive of the manufacturing operations. Finally, the productions of several periods are blended, and 'proved' for velocity and pressure. (See GUNPOWDER.)

See *Service Explosives* (1907); Sanford, *Nitro-Explosives* (1906); Guttmann, *The Manufacture of Explosives* (1909); and A. Marshall, *Explosives* (1917).

Gundamuk. See GANDAMAK.

Gundulf (1024–1108), bishop and architect, born in Normandy, followed Lanfranc to England (1070), and became bishop of Rochester (1077). He rebuilt Rochester Cathedral, and was architect of the Tower of London and other buildings.

Gungl, JOSEF (1810–89), musical composer and conductor, was born at Zsambek in Hungary. As a bandmaster in the Austrian army, and as the leader of his Berlin orchestra, he made many concert tours, gaining fame as a composer of dance music, especially waltzes. He became director of royal concerts in Prussia (1849), in Austria (1858).

Gun License, official permission to carry a gun (any description of firearm), the annual purchase of which for a sum of ten shillings is obligatory (penalty £10) in Britain under the Gun Licenses Act of 1870. Sailors, soldiers, territorial soldiers, or constables on duty or at practice, gunsmiths, and holders of game-licenses (see GAME-LAWS) are exempt, as are also occupiers of land or persons acting under the orders of license-holding occupiers when scaring birds or killing vermin; 'scaring' does not include killing, nor are rabbits counted as 'vermin.'

Gun-metal. See BRONZE, CANNON.

Gunnel (*Centronotus*), a genus of coast fishes in the Blenny family, but with more elongate eel-like form than the true blennies. The British species (*C. gunnellus*), the spotted gunnel or butterfish, is common on British coasts, lurking under stones in tidal pools.

Gunner, in the British army, is a private soldier of the Royal Artillery. Master-gunners are warrant-officers of artillery, generally placed in charge of one or more forts.—In the navy the gunner is an officer from the ranks qualified in gunnery, appointed by warrant from the Admiralty. He takes charge of all the ordnance stores on board ship, is responsible under superintendence for their expenditure and account, and has a general oversight of everything relating to the weapons employed and their proper use, either under a gunnery officer or where there is none. Gunners are sometimes appointed in place of sub-lieutenants for quarter-deck duties and to command torpedo-boats, &c. Chief-gunner is a commissioned officer promoted by selection from the gunners. Gunner's-mate is a first-class petty-officer, selected after examination from men qualified as seamen-gunners. Warrant-officers, including gunners, boatswains, carpenters, and engineers, are eligible for promotion to commissioned rank.

Gunnery is the science which governs by its laws the construction and employment of all fire-arms, though the term 'musketry' is generally applied to the scientific use of small-arms. It involves a knowledge of the properties of metals, and details of their manipulation in gun-manufacture, as well as the calculation of the strains to which the weapon will be subjected, the velocities of projectiles, and the effect upon them of the various forces to which they are exposed in the bore of the gun and during their flight through the air.

This subject was first treated of by an Italian mathematician, Nicolas Tartaglia, who in 1537 published *La Nuova Scientia*. He also invented the gunner's *quadrant*. Many other writers followed him, of whom the principal was Galileo,