BLASTING is the process by which portions of rock, or other hard substances, are disintegrated by means of an explosive agent, such as gunpowder. It is largely resorted to in quarrying, tunnelling, and mining operations.

Of late years there has been rapid advance in the art, through the discovery of new explosives, through improvements in appliances for firing, &c.; so that the older method of blasting has, in many instances, given place to a more complex system, with which much better results are obtained. The simpler process may be described thus. When a blast is to be made, a hole to receive powder is first bored in the rock; such holes vary in diameter from ½ inch to 2½ inches, in depth from a few inches to many feet, and in direction from the vertical to the horizontal. The borer, or jumper, with which the hole is made is a steel pointed drill; it is struck by a hammer, and is turned partly round after each blow, to make the hole cylindrical. One man may do all this alone, but generally, in the case of larger holes, a man, in sitting posture, directs the jumper, supplies the hole with water, and clears out the powdered stone at intervals with a scraper, while another man, or two, or three, are engaged in striking. A small rope of straw or hemp is twisted round the jumper at the orifice of the hole to prevent squirting up of the water. In the case of soft rock a loaded drill is sometimes used, which acts merely by its own weight. On the other hand, in substances like pyrites, or compact magnetic iron ore, which cannot be penetrated with steel drills, holes for blasting may be made by the gradual action of an acid (commonly muriatic) admitted through a vertical glass tube. When a sufficient depth is reached, the hole is cleaned and dried, and a charge of powder put in. A small taper rod of copper, the needle or nail, is inserted so as to reach to the bottom of the charge; then the rest of the hole is filled up with some such material as dry sand or tough clay, which forms the "tamping" or wadding, and which is firmly rammed down in small quantities successively by means of the tamping bar, a copper-faced punch of such thickness that it nearly fills the hole, and having a groove in it to receive the nail. This operation requires great care, because of the danger of eliciting sparks through collision. The hole being now fully charged, the nail is withdrawn, leaving a small vent hole, into which is then introduced an oaten straw filled with powder (or a series of such). To this is attached a slow match of paper steeped in saltpetre. The match is touched with fire; the alarm is given to retire to a safe distance; and presently the explosion takes place, the rock opening with a sharp report, and fragments of stone being often shot into the air in all directions. An improvement on this method of firing consists in the employment of Bickford's patent fuse, which may be described as a perforated rope or hose containing an inflammable composition. A suitable length of fuse is placed in contact with the charge before tamping, and carried up to the mouth of the hole. On being lighted it burns at the rate of 2 to 3 feet per minute, giving the miners an opportunity to escape before explosion. A water-tight form of the fuse is often used in submarine blasting,—the shot or charge being then made up in cartridge form.

Blasting, however, is often done on a much larger scale than that just indicated. As an example of the large blasts, or "mines," where great blocks of rock have to be removed at once, we might take some of the operations carried on at the Holyhead quarries a number of years ago for the harbour works. An entrance gallery, 5 feet 6 inches by 3 feet 6 inches was first driven from the face of the rock (hard quartzose schist), an extent of 34 feet, where a shaft, 3 feet 6 inches by 3 feet 6 inches, was sunk to a depth of 14 feet. From this, level galleries were driven some distance right and left, with four short headings, at intervals, returning towards the face of the rock and terminating in chambers for the charges. The four charges, amounting in all to 12,000 lb of powder, were enclosed in canvas bags coated with tar. They were calculated at the rate of 1 lb of powder to 3 tons of rock. For tamping a stiff red clay was used; it was well rammed up close to the bags of powder (leaving a small air space round these), and continued to the mouth of the gallery. The charges were fired simultaneously by means of platinum wire heated by a Grove's battery. The total quantity of rock removed was about 40,000 tons; it was separated into various sized blocks. Similarly, the Rounddown Cliff at Dover was overthrown in 1843 for railway purposes by 18,500 lb of powder, in three separate charges, fired simultaneously from a Voltaic battery; a saving of £7000 was thus effected by the South-Eastern Railway Company.

In reviewing recent developments of the art of blasting, the application of machinery in the boring of rocks naturally claims some attention. A good rock-boring machine, at least where used in connection with simultaneous firing by electricity, ensures considerable economy in time and labour over the old method of hand-boring. Of such machines, in which the jumper is repeatedly driven against the rock by compressed air or steam, being also made to rotate slightly at each blow, there are several varieties; the Burleigh rock drill is one of the best. It was used in the Hoosac tunnel in Massachusetts from 1869; and the last 5220 yards were completed with only eight of these machines. The rock was gneiss alternating with quartz. With hand-boring, the progress per minute was about 16 yards; with the Burleigh drill it was 48 yards, and the work was about one-third cheaper. According to *Engineering*, the cost of the Mont Cenis tunnel was £195 per linear yard; that of the Hoosac tunnel, notwithstanding much harder rock, only £180. In the recent large blastings at Hellgate, New York, the Burleigh machines also established their superiority, and came to be used exclusively. Among other boring-machines may be mentioned the "Diamond" drill, and the systems of Law, Ingersoll, M'Kean, Bergstroem, Sachs, Doering.

The general properties of ordinary blasting-powder are well known; it requires to be kept dry, and when dry, a spark of fire will cause it to explode. Various efforts have of late years been made towards the employment of more powerful explosive agents for blasting purposes. The violent oxidizing power of chlorate of potash marked it out as available for explosive mixtures; and sundry preparations containing this substance have been made (some of them highly dangerous). *Horsley's Blasting-Powder*, consisting of powdered nut galls and chlorate, may be taken as a type of these mixtures, and as the safest of them. It is both more violent and more rapid in explosion than ordinary blasting-powder, and does not give off any smoke or unpleasant smell when it explodes. It must be kept dry, and it is liable to explode through friction; the expensiveness of its ingredients is also a drawback. *Gun-cotton* was discovered by Schönbein in 1846, but owing to disastrous accidents occurring in the three years which followed, it was abandoned in this country and in France for sixteen years. Through the researches, meanwhile, of an Austrian, Baron von Lenk, it again came into notice in 1864, and a Government committee investigated the merits of the gun-cotton twist or rope made according to the Austrian system. For blasting hard rock its general superiority in effect to powder was recognized; and the absence of smoke, where the resistance opposed to the gun-cotton was sufficient to develop its full explosive force, was specially remarked upon. The want of rigidity of the material was objectionable; and several accidents

occurred, through violent friction of the twist, when miners had attempted to drive home a jammed charge. A considerable gain was secured by the invention of *compressed gun-cotton* by Professor Abel in 1868. In this form the explosive occupied less than half the space of the rope charges, and the smooth, hard exterior of the cylindrical charges rendered the operation of loading comparatively easy. The compressed charges, moreover, did not burn with the explosive violence of spun gun-cotton even when confined in the ordinary packing cases. Among further improvements may be noted the cheapening of the material by use of cotton waste, instead of the long staple cotton of high quality that was used in the Austrian manufacture. In 1868 Mr E. O. Brown discovered that (like nitroglycerine)[1] compressed gun-cotton was susceptible of violent explosion through the agency of a detonation, as well as in the ordinary way. This was important, especially for submarine operations and works of demolition; for the strong confinement which was always necessary in the other case could be dispensed with; indeed, with some waste of power, the substance might be exploded completely unconfined. Gun-cotton is not affected in its explosiveness by cold; and it can be kept any length of time without deterioration in the damp and perfectly unignitable state. The formula that has been assigned for the most explosive gun-cotton is $C_6H_7N_3O_{11}$.

In 1864 Mr Nobel's researches called attention to the application of *nitroglycerine* (discovered by Sobrero in 1846) as an explosive agent. He first showed that the effect of gunpowder was considerably increased through impregnation with it; and later, that the liquid itself, which burns slowly in the air on application of a flame with a common fuse, could be exploded by an initiative detonation,—confinement by tamping being then unnecessary. In its pure state it was soon proved to be the most powerful explosive yet known; its destructive force is about ten times that of gunpowder. Its liquid form, high specific gravity, and insolubility in water, are valuable properties in some cases, as in blasting under water or in wet holes. It freezes at a comparatively high temperature (40° Fahr.); but the opinion, formed from several grave accidents, that it was more susceptible of detonation in the frozen than in the liquid state, has been shown to be contrary to fact. When frozen it is more liable to recklessly rough usage. The liquid state of nitroglycerine, on the other hand, constitutes a very serious defect, owing to its tendency to leak from vessels in which it is carried, or from the blast-hole, through fissures in the rock,—resulting in unexpected explosions, it may be, through some slight concussion. Mr Nobel's ingenious device for rendering nitroglycerine temporarily inexplosive, by dissolving it, viz., in wood spirit, is only partially successful. Nitroglycerine has been extensively used in various mining districts, especially in California. After some terrible accidents, which occurred in 1866–7, its use in England was placed under severe restrictions.

Impressed with the serious disadvantages of this explosive, Mr Nobel was led to the important observation that its readiness to explode by detonation is not diminished, but rather favoured, by mixture with solid substances, in themselves quite inert; and the dilution did not materially detract from the great superiority of nitroglycerine over gunpowder. In 1867 he brought before the public the substance appropriately called *dynamite*, which is one of the safest, most powerful, and most convenient explosives for industrial purposes. It consisted of seventy-five parts of nitroglycerine held absorbed by twenty-five parts of a porous, infusorial, silicious earth, known in Germany as "Kieselguhr." Other absorbents have been employed (precipitated kaolin, tripoli, precipitated alumina, sugar, &c.), but none of them are equal to kieselguhr in power of retaining oil. Dynamite is furnished to the trade in the form of small cylindrical cartridges, in which the material, consolidated by pressure, is enclosed in a single wrapping of parchment paper. It requires no tamping, and can be exploded by detonation under water. It is slow to catch fire, but burns rather fiercely when fired; and if the quantities are large, or under confinement, an explosion may finally ensue. The trade in it has developed rapidly; thus, while only 11 tons of it were sold in 1867, the quantity rose to 3120 tons in 1874.

In the preparation known as *lithofracteur*, which came into notice during the Franco-German War, nitroglycerine is used in considerably smaller proportions than in dynamite; and the kieselguhr of the latter is partly replaced by materials forming of themselves a feebly explosive mixture. Its properties are very similar to those of dynamite, but it is less powerful.

The less known ammonia powder, invented by Ohlson and Norbin, is much stronger than lithofracteur, and even surpasses dynamite. Its only drawback is the hygroscopic nature of its chief ingredient, which is nitrate of ammonium; but otherwise it is a very superior blasting agent. Numerous other explosives have been tried in blasting, but those we have named are amongst the most important.

In a recent paper to the Society of Arts, Mr Nobel has discussed the relative power of several blasting agents. He finds that when their ballistic power is compared bulk for bulk, the substances experimented with rank as follows:—Nitroglycerine, 100; ammonia powder, 80; dynamite (No. 1), 74; lithofracteur, 53; gun-cotton, 45; Curtis and Harvey's blasting-powder (fired by detonator), 17·5. While these figures show the great superiority of nitroglycerine, there are practical circumstances which bring it and dynamite nearly on an equality. Thus, to get the full benefit of a blast there should be no air-space round the charge. Now, from the danger (as we have seen) of nitroglycerine leaking through imperceptible fissures in a rock, rigid cartridges are required for it, and these always involve a considerable air chamber, whereas dynamite, being highly plastic, can be easily compressed so as to exclude all empty space. The cartridges of compressed gun-cotton are also liable, of course, to the objection just noticed.

Where rapid destruction is to be accomplished there is a saving of labour, of tools, and of time by use of the new explosive agents (such as dynamite or gun-cotton). Their shattering and splitting effect in hard rock is much greater; but in quarrying, the rock is generally not thrown out by them to the same extent. Where a moderate cleaving or splitting effect is desired, with as little local action as possible, gunpowder is best, as in raising large blocks of slate; also where great displacing action is required. In submarine blasting of soft rocks the violent explosives disintegrate the rock into a plastic mass within a limited area, but do not shatter or rend it to any great distance.

As regards comparative safety, there is no doubt that modern explosives offer a relative immunity from the danger arising from fire, to which gunpowder is subject. Neither dynamite nor gun-cotton can be fired by a spark, and if accidentally fired by a flame, they allow reasonable chances of escape. On the other hand, accidents have often happened in the thawing of nitroglycerine preparations when frozen,—a process that requires great care, and for which suitable warming-pans are provided. But miners are slow to understand that a cartridge which firing does not set off cannot be slowly heated with the same impunity; hence they will roast the preparations near a

[1] It was found, in the course of these inquiries, that all explosive compounds, even including gunpowder, are susceptible of explosion through a detonation, though the nature and force of the detonation vary considerably with different explosive substances.

fire, or on hot cinders, or in other ways really dangerous. Gun-cotton and dynamite prove much safer than nitroglycerine as regards exploding through concussion. There is not, however (Mr Nobel thinks), that amount of difference between the sensitiveness of nitroglycerine and dynamite which the latter substance generally receives credit for. The main danger of nitroglycerine arose from the sensitiveness to concussion which it acquired through contact with a hard, metallic, strongly vibrating substance, such as the tin canisters in which it was contained. The main safety of dynamite is derived from the absence of any hard vibrating material in immediate contact with the nitroglycerine it contains.

As regards danger from concussion in manufacture and transit, gun-cotton ranks first; but in the hands of miners, the case is reversed, through the rough usage of gun-cotton charges, where, *e.g.*, they are found too large for a bore-hole, for gun-cotton is well known to explode with a blow. The danger most dreaded in modern explosives is from their supposed liability to chemical decomposition productive of heat, which sometimes leads to ignition and explosion. This decomposition is generally due to the presence of acid (chiefly nitric and hyponitric), which every nitrated compound has a strong tendency to retain. From the ease with which the acid can be washed out from nitroglycerine, both it and dynamite show much greater chemical stability than gun-cotton. Most cases of spontaneous combustion of the latter have probably arisen either from imperfect washing, or from drying at too high a temperature (by which hyponitric acid is set free).

Complaints have often been made of the poisonous fumes given off by the new explosives. Where this occurs, it is probably due to an injudicious use of the substance, resulting in imperfect explosion. If a dynamite cartridge partly burns instead of exploding, the temperature is much lower, and fumes of hyponitric acid are given off, which could not escape decomposition at the higher temperature of perfect explosion. The general mistake consists in not securing carefully the detonator cap to the fuse, and especially the fuse to the cartridge.

Blasting by Electricity.—It is known that electricity has a thermal effect on wire through which it passes; and the amount of heat produced in any part of the circuit is proportional to the resistance in that part. Thus a piece of wire of small section and conductivity may be made incandescent by a current. On this principle platinum is sometimes employed to fire blasting charges. In making a fuse of this sort, two insulated copper wires are twisted together for a length of about 6 inches, leaving the extremities free for about half an inch, and separated the same distance. A fine platinum (or iron) wire is stretched across this interval, metallic contact being established with the copper. The other ends of the fuse are connected with a battery. Platinum fuses are not much to be relied on for simultaneous blasting of several charges by one battery; for some of the fuses may take a little more time to reach the exploding temperature than others, and thus, as soon as one explodes, the connection between the others and the battery is broken. The batteries to be used with them are such as generate electricity of great quantity. The Bunsen and Leclanché batteries, in some of their varieties, are well suited for this. Twelve cells of Highton's battery will melt a piece of platinum wire over an inch long.

There is, however, another class of fuses, offering certain advantages over those just referred to, in which the spark produced by electricity of tension is the means used to effect the explosion. It might naturally be thought that an electric spark must inevitably cause explosion in a mass of powder or like substance through which it is made to pass; but this is not the case. The heating power of the spark is often insufficient for explosion. The duration of an induction spark is about the *millionth* of a second; whereas, to ignite powder, it is necessary that a spark should exist for at least the *three hundredth* part of a second. By interposing, however, a suitable priming composition in the interval which the spark is to cross, and in contact with the charge, explosion may be thus effected. In preparing such a composition, the properties of the ingredients as regards conductivity, inflammability, and explosiveness have to be nicely adjusted, according to the degree of tension of the electricity employed. The composition selected by Professor Abel for his fuses is an intimate mixture of subsulphide of copper, subphosphide of copper, and chlorate of potassium. It is a mixture which conducts, but conducts with difficulty, and the fuses made with it are very effective. There are several other varieties, *e.g.*, Ebner's fuse, where the priming consists of a mixture of sulphuret of antimony, chlorate of potash, and graphite.[1]

For generating electricity of tension with the Voltaic battery, Leclanché's battery is, again, one of the most suitable. The elements of this battery consist of a rod of carbon placed in a porous cell and tightly packed round with a mixture of peroxide of manganese and coke; the porous cell is placed in a vessel containing a plate of zinc, which forms the electro-positive element, and a solution of sal-ammoniac is used as the exciting liquid. There are some forms of battery for the same purpose so arranged that the contact of the elements with the liquid takes place only at the time of firing; such are those of Wollaston, Ruhmkorff, and Trouvé.

Frictional electricity is the kind generally adopted by military authorities in firing charges,—the machines for generating it being easily made, simple, portable, and powerful. Bornhardt's frictional machine has found extensive use in Austria in ordinary blasting operations. It is contained in a small metallic case, and consists of a disc of ebonite, which can be rotated between two cushions, charging a small Leyden jar placed near it. On pressing a little button from the outside, connection is made between the two coatings of the jar in such a way that the charge is sent through two wires by which the box is connected with the fuse, or fuses, at a distance. Some absorbent of moisture is kept within the box, and it is necessary to see that the machine be kept as warm and dry as possible.

Experiments were made by Messrs Wheatstone and Abel, a number of years ago, with Armstrong's hydroelectric machine, as a source of electricity for exploding charges of powder. They state that in very extensive mining operations, where a great many charges have to be fired simultaneously, and provided all the necessary appliances for success are at hand, the machine could be used very effec tively. It is a powerful source of electricity of high tension. There are serious objections, however, to its general use.

Electro-magnetic induction currents (such as are developed in Ruhmkorff's coil) were first applied, and successfully, by Colonel Verdu, a Spanish officer, in 1853. The induction discharge, unlike that of a Leyden battery, is much enfeebled by successive solutions of continuity, so that not more than four mines in a single circuit could certainly be exploded on this system. But M. Savare made an improvement by interposing the fuses in branches of the principal circuit. The mine nearest the apparatus explodes first; and, owing to the abrupt separation of the wires, the current can no longer pass through this branch; thus the electric action is augmented in the other branches, and in a similar manner the explosions necessarily take

[1] In one form of fuse employed with dynamite, there is connected with the priming just mentioned some mercuric fulminate and loose gun-cotton.

place in them, and that with a rapidity almost instantaneous. This is also a more efficient plan than that of employing a rheotome for changing the direction of the current, so as to bring wires connected with one or more charges successively into the circuit. The Ruhmkorff coil is, however, objectionable for its delicacy and the maintenance of batteries in connection with it. In experiments made by Messrs Wheatstone and Abel, a powerful magneto-electric machine was found very limited in its power of igniting several charges arranged in succession in one circuit (it only ignited three at most, with certainty); but on M. Savare's plan of arranging the charges in divided circuits, the simultaneous ignition of twenty-five charges was repeatedly effected; on several occasions as many as forty By this plan each charge was connected with a separate branch attached to the main line, and their connection with earth established by means of uncovered copper wire wound round an iron stake driven in the ground. Another form of instrument, devised by Wheatstone, consists of six small magnets, to the poles of which are fixed soft iron bars surrounded by coils of insulated wire; the coils of all the magnets are united together, so as to form, with the external conducting wire and the earth, a single circuit. An axis carries six soft iron armatures, in succession, before each of the coils. With this apparatus twenty-five charges were frequently fired in divided circuit, so rapidly that the effect on the ear was as of one explosion, only of slightly longer duration than when the large magnet was employed The Markus apparatus, largely used in Germany, is on the same principle.

Siemens's dynamo-electric machine, in which electro-magnets are employed, is a very useful machine for simultaneous firing It is found that the residual magnetism left in the coils of electro-magnets, after a current from even a single Voltaic cell has been once sent through them, is always sufficient to have the necessary inductive action on the armature. This inductive action, though very weak at first, generates slight alternating currents in the armature, which are by means of a commutator caused to flow always in one direction through the coils of the electro-magnet, thus increasin the magnetism in the core, which, in its turn, increases the inductive action, causing stronger and stronger currents to be generated in the armature. This action and reaction goes on till the limit of magnetic capacity of the core is reached, and if the coil of the armature be then suddenly connected with the line leading to a fuse, a very powerful current is transmitted. In Breguet's exploder (in which a bar of soft iron is suddenly separated from the armature of a magnet bearing two induction coils) a special arrangement gives rise to an extra-current, and considerably increases the intensity of the current. M. Breguet has lately utilized in this apparatus the new and powerful laminated magnets constructed by M. Jamin. Gramme's machines are also effective in exploding charges, but their volume and high price are against a large use of them industrially.

For more detailed information on the recent developments of blasting, reference may be made to Spon's *Dictionary of Engineering*, art. "Boring and Blasting;" *Professional Papers of the Corps of Royal Engineers*, vols. vii., x., xxii.; *Transactions of the Society of Engineers*, 1869 and 1871; *Proceedings of South Wales Institute of Mining Engineers*, vol. viii., No. 5, vol. ix., Nos. 1 and 2; Dingler's *Polytechnisches Journal*, Oct. 1, 1874; *Annales de Chimie et de Physique*, May 1875; *Journal of the Society of Arts*, May 28, 1875. (A. B. M.)

BLEACHING

BLEACHING is the process of whitening or depriving objects of colour, an operation incessantly in activity in nature by the influence of light, air, and moisture. The art of bleaching, of which we have here to treat, consists in inducing the rapid operation of whitening agencies, and as an industry it is mostly directed to cotton, linen, silk, wool, and other textile fibres, but it is also applied to the whitening of paper-pulp, bees'-wax, and some oils and other substances The term bleaching is derived from the Anglo-Saxon *blæcan* to bleach, or to fade, from which also comes the cognate German word *bleichen*, to whiten or render pale. Bleachers, down to the end of last century, were known in England as "whitsters," a name obviously derived from the nature of their calling.

The operation of bleaching must from its very nature be of the same antiquity as the work of washing textures of linen, cotton, or other vegetable fibres. Clothing repeatedly washed, and exposed in the open air to dry, gradually assumes a whiter and whiter hue, and our ancestors cannot have failed to notice and take advantage of this fact. Scarcely anything is known with certainty of the art of bleaching as practised by the nations of antiquity. Egypt in early ages was the great centre of textile manufactures, and her white and coloured linens were in high repute among contemporary nations. As a uniformly well bleached basis is necessary for the production of a satisfactory dye on cloth, it may be assumed that the Egyptians were fairly proficient in bleaching, and that still more so were the Phœnicians with their brilliant and famous purple dyes. We learn, from Pliny, that different plants, and likewise the ashes of plants, which no doubt contained alkali, were employed as detergents. He mentions particularly the *Struthium* as much used for bleaching in Greece, a plant which has been identified by some with *Gypsophila Struthium.* But as it does not appear from Sibthorp's *Flora Græca*, published by Sir James Smith, that this species is a native of Greece, Dr Sibthorp's conjecture that the *Struthium* of the ancients was the *Saponaria officinalis*, a plant common in Greece, is certainly more probable.

In modern times, down to the middle of the 18th century, the Dutch possessed almost a monopoly of the bleaching trade, although we find mention of bleach-works at Southwark near London as early as the middle of the 17th century. It was customary to send all the brown linen, then largely manufactured in Scotland, to Holland to be bleached. It was sent away in the month of March, and not returned till the end of October, being thus out of the hands of the merchant more than half a year.

The Dutch mode of bleaching, which was mostly conducted in the neighbourhood of Haarlem, was to steep the linen first in a waste lye, and then for about a week in a potash lye poured over it boiling hot. The cloth being taken out of this lye, and washed, was next put into wooden vessels containing butter-milk, in which it lay under a pressure for five or six days. After this it was spread upon the grass, and kept wet for several months, exposed to the sunshine of summer.

In 1728 James Adair from Belfast proposed to the Scotch Board of Manufactures to establish a bleachfield in Galloway; this proposal the board approved of, and in the same year resolved to devote £2000 as premiums for the establishment of bleachfields throughout the country. In 1732 a method of bleaching with kelp, introduced by R. Holden, also from Ireland, was submitted to the board; and with their assistance Holden established a bleachfield for prosecuting his process at Pitkerro, near Dundee.