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Friday, April 30th, 1858.

GENERAL SIR J. F. BURGOYNE, BART., G.C.B., in the Chair.

GUNPOWDER AS A DISRUPTIVE AGENT.

By CAPTAIN SCHAW, R.E.

WHEN gunpowder was first applied to the service of mines, it was a decided improvement in the *economy* of war, if I may so speak. Previously to the end of the fifteenth century this powerful agent had only been used at a distance to project shot or large stones against the enemy's works, after the manner of the ancient balista or catapult, but now the full strength of the giant was employed in the most advantageous position to destroy their walls and ramparts. The besiegers, instead of employing their champion to pelt the enemy from a distance, now sought to place him in a position where he could give a fall at close quarters. In speaking thus I do not mean to disparage the value of artillery in breaching revetments, or destroying works under certain circumstances, for it often happens that guns can be got into a position whence they can breach a work in much less time than would be necessarily expended in mining and lodging charges of powder. As an instance of this, I need only mention the late victorious advance of Sir Colin Campbell through the town and suburbs of Lucknow; when his artillery breached the various fortified enclosures that opposed his progress, and opened a passage for the bayonets of his infantry, in a far shorter time than could have been done by mining, which would have been wholly inapplicable in such a case. I would, however, maintain that, when time is not so much an object as the economy of life and gunpowder, mines are to be preferred to artillery as a means of demolishing fortifications; and, in support of this statement, I may adduce the result of the experiments made by the French at Bapaume in 1847. From the records of their proceedings in the demolition of that old fortress, it appears that a breach 85 feet in length was formed in the face of one of the bastions by a battery of 24-pounders at point-blank range, after an

expenditure of 3,168lbs. of powder and 6,800lbs. of iron in shot, whilst a similar face was breached to the extent of 98 feet by the explosion of 1,736lbs. of powder disposed in three charges in rear of the revetment; or, in fact, a larger breach was produced with about half the quantity of powder, and with a saving of all the shot, by means of a mine. It must be observed also that the revetment was built of chalk rubble with a facing of brick, and this soft material was peculiarly favourable for the action of artillery. Had the masonry been of large blocks of granite, the ammunition required to effect a large artillery breach must have been enormously increased; while a very slight increase of the charges of the mines would have sufficed to overturn the revetment so constructed.

Before proceeding farther with our subject, it may be well to consider briefly the nature of the agent we employ in demolition by mining, and the degree of power we have at our disposal. Although there are many explosive compounds known to the chemists, and some of them much more powerful and violent in their action than gunpowder, yet none of them are so well adapted to the purposes of either artillery or mining. Of all the more dangerous and suddenly explosive compounds, such as chloride of potash and fulminating mercury, it may suffice to say that their action is too instantaneous for the purpose of artillery, as they burst the gun instead of propelling the shot, whilst they are both too expensive and too dangerous for employment in mining, and even there their instantaneous explosion produces a much less satisfactory result than the more gradually expansive force of gunpowder. Indeed the advantage of the slower action of gunpowder is so apparent, that some authors have recommended the admixture of sawdust with powder for mining purposes, with the idea that the effect would be increased by the slower ignition thus produced. The experiments made by Sir J. Burgoyne, however, have shown that this is a fallacious idea, and that gunpowder produces the greatest effect when used without admixture. There is one other explosive compound, which not long since made some stir in the world, and which I must briefly notice. Gun-cotton, or pyroxylic acid, discovered accidentally by Schönbein, appeared at first to have so many advantages over gunpowder, that it was supposed it would in a great measure supersede it. This substance results from

the saturation of clean cotton (or paper prepared without size, and chemically clean) in a mixture of equal parts of concentrated nitric and sulphuric acid, for about a quarter of an hour. It is then squeezed out, well washed in water, and dried carefully, when it is found to have entirely altered its nature, and to have become an explosive material, having about four times the force of gunpowder, weight for weight. There is little or no smoke when gun-cotton explodes, and the temperature at which it ignites is so low (356° Fah.), that it may be fired on the top of a small heap of gunpowder without igniting the latter. A heavy blow on an anvil ignites pyroxyline by the heat thus generated, but it cannot be fired by friction like the fulminates, and it does not appear to be injured by damp. There are many objections however to the use of this material:—for artillery its action is too sudden and the gases generated injure the metal of the gun, while its bulk and the uncertainty attending its manufacture (two samples seldom corresponding either in strength or the facility of ignition) have caused its abandonment by the miner also, and gunpowder still bears the palm amongst explosive agents. Pyroxyline, which is the same as gun-cotton, only that the proportions of the acids are slightly altered, is the substance now used so extensively in photography; it is dissolved in alcohol and ether, and is then called collodion.

The exact increase in bulk of gunpowder after ignition it is difficult to estimate; but it is supposed that when good powder is ignited the heat produced is about $2,000^{\circ}$ Fah., and assuming that the law which governs the expansion of gases holds good at such high temperatures, which we have no reason to doubt, one volume of gunpowder when ignited will produce 1,597 volumes of gas, exerting a pressure of 1,597 atmospheres, or nearly 10 tons on the square inch, or 1,440 tons on the square foot. This is but an approximation to the true force, as the great degree of heat evolved in the moment of combustion is so far beyond the range of experiment that we can only reason from analogy. We may judge, however, from these considerations, what a gigantic force is at our disposal in the convenient and portable form of gunpowder. Many attempts have been made to ascertain the force of gunpowder *by direct experiment*, but none of them have been very successful. In 1800, Count Rumford carried on a series of experiments

with this view at Munich. He procured a very massive gun, closed its muzzle with great weights, and fired the powder with which it was loaded by inserting the breech into a cavity prepared for it in a mass of red-hot iron, having a red-hot needle which protruded through the vent into the charge. His experiments, however, gave such widely different results, that no theory can be deduced from them.

This, however, was observed, that it is possible to ignite gunpowder under such a pressure that the gases cannot expand.

In the cases where the weights were heavy enough to retain the gases in the barrel, the products of combustion were found for the most part condensed inside it, in the form of a hard, coaly mass, which was inflammable with great difficulty.

Hence we learn, what other experiments have abundantly confirmed, that it is possible to tax the giant's strength too far—there is a limit to his power.

When the ingredients of gunpowder are not pure, or when the manufacture is imperfect, or when it has been injured by damp, the strength is very much diminished; in order therefore to be able to work with any degree of certainty in the use of gunpowder, we must have some practical test or standard of comparison by which we can estimate the strength of the particular powder at our disposal.

Various means have been employed for this purpose; and the three in most general use are the Eprouvette, the Balistic Pendulum, and the Gomar Mortar. The principle of the first is, the measurement of the recoil; which is effected in this manner:—a miniature cannon is suspended by a rod so as to swing freely; it is loaded with a fixed charge of the powder to be tested, and fired. The explosion produces an amount of recoil proportioned to the strength of the powder, and this amount is measured on a graduated arc of a circle beside which the gun swings.

The Balistic Pendulum is acted on by a shot out of a cannon, which is fired with a fixed charge of the powder to be tested; the shot strikes the pendulum, and buries itself in some soft material contained in a box at its extremity. The impact of the shot communicates a motion to the pendulum, which is measured on a graduated arc of a circle, and by a mathematical calculation the initial

velocity communicated to the shot by the powder can be determined, and from this initial velocity the strength of the powder is estimated. But the simplest and most satisfactory test, for mining purposes, is that in which a perfectly smooth and accurately-turned shot 68 lbs. in weight is projected at an angle of 45° from a mortar with a fixed charge of powder. The distance to which the shot is thrown is the measure of the strength of the powder: 2 oz. of good English cannon-powder project the shot 250 feet; musket-powder rather further.

When gunpowder is ignited in the open air, the gas evolved expands in all directions equally; and, wherever obstacles occur to hinder this expansion, the tendency is to blow them out of the way. When, however, gunpowder is exploded in a confined situation, the gas, though expanding equally in all directions as before, forces a passage for itself in whatever direction the resistance opposed to it is least; and it is plain that the whole of the gas being thus forced to act in one direction, exerts a much greater force in that direction than it did in any one direction when exploded in the open air.

This principle should be borne in mind in the application of gunpowder to the destruction of stockades, barrier-gates, walls of buildings, and in all cases where the charge is not lodged within the object to be destroyed, but merely applied outside it, a method of demolition which frequently has to be used on service, when there is not time to proceed in the more regular and economic manner by mining. Whenever powder is of necessity thus applied, every exertion should be made to heap as great a weight of earth, stones, or rubbish of any kind over it as can be obtained, which will confine the gas to a certain extent, and oblige it to exert much more force on the object to be destroyed. It sometimes happens that even this precaution cannot be taken, and a greatly increased charge of gunpowder is then necessary.

Thus, in 1839, the Cabul Gate of the fortress of Ghuznee was blown open by 300 lbs. of powder merely placed against it. The charge of powder in this case was considerably more than was necessary; 100 lbs. would have effectually destroyed the gate; but it was supposed that there was a second gate a short distance in rear of the front one; and, had there been a second gate so placed, experiments made at Chatham have shown that at least 200 lbs. of powder

would have been necessary to destroy both gates; and on service an excess of powder is always advisable, to make sure work. The late gallant exploit of the little party under Lieutenants Home and Salkeld, of the E.I.C. Engineers, who destroyed the Cashmere Gate at Delhi by the same means, is an illustration which will occur to all; but I am not able to state the exact quantity of powder used, nor the construction of the gates which were blown in.

When powder is plentiful, and there is no time for regular mining, a bridge is most easily destroyed by laying bare the keystones across the width of the bridge, and placing 300 or 400 lbs. of powder in sandbags or barrels along the trench so formed, as at A. figs. 1 and 2. After the powder is placed, and the train laid, any spare time may be advantageously employed in heaping paving-stones or any heavy material over the powder, but, even without this precaution, many ordinary stone arches were thus destroyed during the last Peninsular War.

Powder-magazines, or Bomb-proof buildings, may be hastily destroyed on this principle, by blocking up the doors and windows as far as possible, and placing several barrels of gunpowder in each compartment of the building, and exploding them simultaneously by powder-hose. An empirical rule for roughly estimating the charges in such a case, recommended by Sir Charles Pasley, is to divide the plan of the building into imaginary squares or rectangles as nearly square as possible, placing one charge in the centre of each compartment; the number of lbs. of powder in each charge being $\frac{1}{8}$ th the cube of the distance from the centre of the charge to the outside of the exterior wall ($\frac{1}{8} AC^3$, in fig. 3).

The Russian towers of Presto and Nottick, at Bomarsund, were thus hastily destroyed by the French in the late war. These towers were circular, about 37 feet high, with a double tier of guns; there was an open court about 70 feet wide in the centre, with casemates 35 feet deep radiating all round it. The Presto tower, being in sight of both the armies and of the ships, was thoroughly destroyed by using all the powder found in it, amounting to 6,600 lbs., disposed in 6 charges of 1,100 lbs. each, placed in alternate casemates.

The Nottick Tower, being in a more secluded position, was not

Diagrams to illustrate
a Lecture on
GUNPOWDER AS A DISRUPTIVE AGENT.

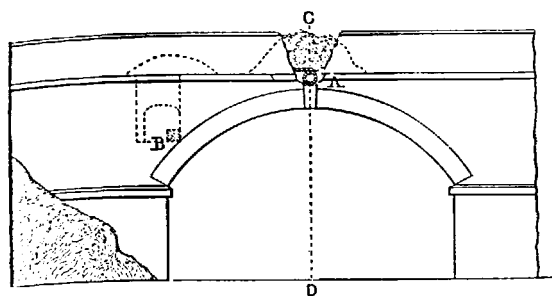


Fig. 1.

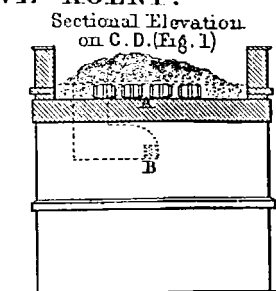


Fig. 2.

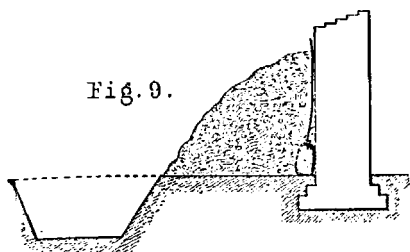


Fig. 9.

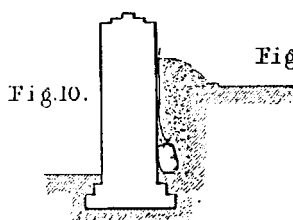


Fig. 10.

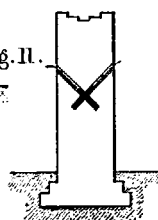


Fig. 11.

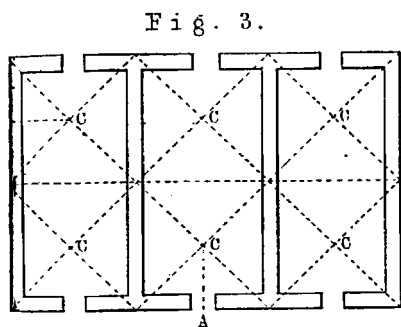


Fig. 3.

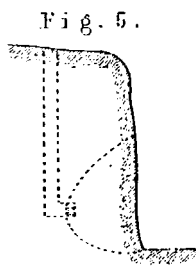


Fig. 5.

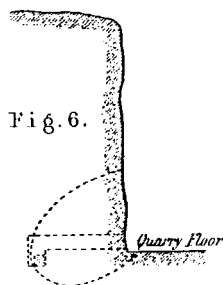


Fig. 6.

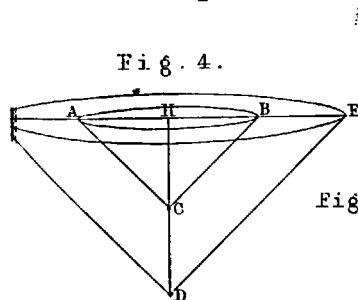


Fig. 4.

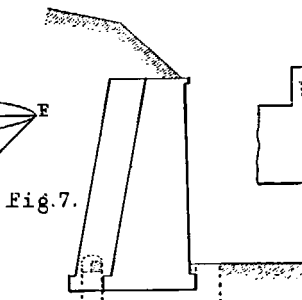


Fig. 7.

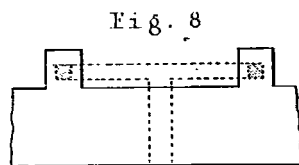


Fig. 8.

Plan of Revetment

Section of Revetment

H. Shaw Capt. R.E.

intended as a "*spectacle*," and only 3,700 lbs. of powder were used for its destruction, which was too little, a portion of the tower remaining uninjured. These quantities of gunpowder appear however to have been guessed at rather than estimated.

When fires occur in towns, it is often desirable to make a break in a row of houses, to stop the progress of the flames, and gunpowder may usefully be employed in such cases. If the powder be placed under a stone staircase, or where two walls meet, so as to confine its action as much as possible, 50 or 60 lbs. are generally sufficient to destroy an ordinary town dwelling-house. This system is frequently used at Montreal, in Canada, where the houses are chiefly of wood, and destructive fires are of constant occurrence.

The tottering ruins which remain after a fire, and which are often very dangerous and difficult to remove by ordinary means, may sometimes be thrown down very advantageously by small charges of powder placed against them on the end of a long pole, or secured by other means, and fired by a fuse.

There is another application of powder which I should mention here, as it holds a place between the cases we have just been considering and those where the expanding gas is solidly resisted on all sides. I mean, when powder is exploded under water. In this case the fluid offers so much greater a resistance than the air, that very good results are obtained by simply exploding the charge in contact with the object to be destroyed.

Reefs of rock which interfere with navigation may thus be removed with great facility. By the aid of a diving-bell, or diving-dress, a man goes down, and either prepares a cavity in the rock or finds a natural one, in which the charge of powder is lodged, well secured in a waterproof case; it is exploded by Bickford's fuse, or the voltaic battery, and the rock is shattered to pieces, and may easily be removed. The wreck of the Royal George, which obstructed the navigation at Spithead, was broken up and eventually removed in 1839, by the explosion of large charges of powder placed in contact with the wreck by means of diving-bells. The pressure of the water was so great at the depth at which the bottom of the wreck lay, that several failures occurred by the charges getting wet, although great care had been taken to make the cases waterproof.

The indomitable perseverance of Sir Charles Pasley, however, at length overcame all difficulties, and after the explosion of 4 large charges of 2,500 lbs. each, and a number of smaller ones, the wreck was thoroughly broken up and removed piecemeal.

In all such cases, however, the charge of powder necessary to effect demolition cannot be determined before-hand with any accuracy, and the powder is employed in a very uneconomical manner.

Where time and the nature of the case admit of it, it is always best to confine the charge of gunpowder in such a position that the gas in forcing its way out will effect the desired demolition; and in employing gunpowder in this manner a very important principle must be remembered, viz. that the resistance offered by the mass of earth, masonry, rock, or other material which is acted on by the powder, varies as the cube of the length of the line of least resistance. In other words, as the charge of powder is placed further from the face where the gas must escape, so the amount of the charge must be increased, not directly as the distance increases, but as that distance cubed, or multiplied twice by itself. The reason of this appears simple enough, and may be best shown by an example. Suppose $E A B F$, fig. 4, to represent the surface of the ground, and at C , 10 feet below the surface, a charge of powder to be lodged. Then the line $C H$, drawn from the centre of the charge of powder to the surface of the ground, in the direction which offers least resistance to the escape of the gas, is called the line of least resistance, and is written " $L L R$," and in this case the $L L R$ measures 10 feet. When this powder is ignited, it will throw out a mass of earth something in the shape of a cone; what the exact shape may be we need not stop to consider; some suppose it to be a paraboloid, some a frustum of a cone, but, for the sake of simplicity, we may consider it an inverted cone, the height of which ($C H$) corresponds with the distance of the charge from the surface, or the line of least resistance, while the size of the base will vary with the charge of powder.

Let us suppose that, with a certain charge, the diameter of this base ($A B$) is equal to twice ($H C$). Now let us suppose a charge to be placed 20 feet beneath the surface at D , then, if the quantity of powder be sufficient to produce a similar effect, a similar cone of earth $E F D$ will have to be raised. But the contents of similar

solids are to one another as the cubes of their similar dimensions; that is, if the height of two similar cones be 10 feet and 20 feet respectively, the content of the lesser cone is to the content of the greater cone (not as 10 : 20, but) as $10^3 : 20^3$, or as 1,000 to 8,000, which is the same as 1 : 8. And it is plain, that, if the cones are of the same material, the one will be 8 times as heavy as the other, and 8 times the force will be necessary to lift it; hence the charge of powder with the L L R of 20 feet, must be 8 times as great as the charge with an L L R of 10 feet; and so generally it may be shown that to produce similar results with varying L L R, the charges of powder must vary as LLR^3 . The direction and exact length of the L L R is therefore an all important consideration in mining, and I must explain that the L L R is not always the *shortest* line to the surface, though as a general rule it is so. For instance, when powder is lodged over the haunch of an arch as at B, figs. 1 and 2 (the weakest point, and therefore the most advantageous for applying the powder), the strength of the arch must be taken into consideration, as it offers a greater resistance than the spandril walls at the side; and, if the powder were placed at an equal distance from the soffit of the arch and from the face of the spandril wall, it would probably blow out at the sides, and leave the arch standing, or, if it were not placed deep enough down, it might merely make a crater in the roadway. Judgment and common sense must be exercised in such cases, but ordinarily the L L R is the shortest distance to the surface in any direction, be it upwards, downwards, or sideways from the centre of the charge; and the proper charges for mines in different cases are expressed in terms of the cube of the L L R, which is always measured in feet. Thus for an ordinary mine in earth to produce a 2-lined crater, or a hollow, the diameter of which at the top is equal to twice the L L R of the mine, $\frac{1}{10} LLR^3$ has been found to be the proper charge in lbs. of powder. To take an example—if the chamber be made 12 ft. below the surface of the ground, and it is required to load it with such a charge as will just throw out enough earth to leave a crater, the width of which at the top shall be 24 ft., we must take the cube of $12=1728$ and divide it by $10=172$, which is the number of lbs. of ordinary English cannon powder which will produce such a crater in ordinary soil (weighing about 100 lbs. to the CF).

To Generals Sir C. Pasley and Sir J. Burgoyne we are indebted for nearly the whole of the practical knowledge we possess on the subject of the proper charges for mines in different cases. The researches of Sir J. Burgoyne have thrown much light on the subject of blasting and mining in rock, and, while Sir C. Pasley was Director of the R. E. Establishment at Chatham, he made a series of careful experiments in military mining, from which he deduced rules which have been generally found to give as satisfactory results as could be desired.

We may first consider mines in common earth, which are frequently used in the attack and defence of fortified places; the besiegers using them to form lodgments in advance, when the ordinary approach by sap becomes very dangerous, or when it is apprehended that the defenders have counter-mines, and in the latter case very large charges are sometimes used, placed very deep below the surface of the ground, and the mine is then called a globe of compression or an overcharged mine, as the force of the powder compresses the earth to a considerable distance below and around it, destroying any galleries of the enemy's mines which may be within the limits of its influence, and forming a large crater which can be converted into a lodgment. The object of the counter-mines in the defence, on the other hand, is to destroy the besiegers' mines with the least possible charges of powder, so as to have no available craters for them to take advantage of. Ordinary mines, however, are classified according to the size of the crater intended to be produced. When the width of this hollow, measured at the surface of the ground, is equal to the LLR , it is called a 1-lined mine; when it is equal to twice the LLR , it is called a 2-lined mine, and so on. $\frac{1}{2} LLR^3$, giving a 3-lined crater, is the proportional charge most frequently used in the demolition of earthenworks, when the earth is to be scattered and thrown out as much as possible, while $\frac{1}{25} LLR^3$ was found sufficient to throw down the chalk cliff at Seaford, near Dover, about 200 ft. in height, the LLR being in that case 70 ft, and the charges, of which there were two, each 12,000 lbs. $\frac{1}{80} LLR^3$ again was successfully used by Captain Larcom to throw down a perpendicular face of hard clay and gravel in the Phoenix Park, Dublin, which was thus transformed into a gradual slope, since made ornamental by planting. Very wide limits these certainly are, but the effects wished to be produced in

different cases, and the circumstances under which the powder acts, vary as widely. Where the powder has to act upwards it throws out a mass of earth, which by the action of gravity must fall to the surface again, and, if the force with which it is thrown out is not very great, a large proportion will fall back into the crater again, and no further effect is produced. Hence it is necessary to use very large charges in ordinary mines beneath the surface of the ground. This may serve to explain the extraordinary circumstances recorded by Mr. Rees in his History of the Siege of Lucknow, where he relates that in several instances Europeans were standing on the spot when the enemy's mines were exploded, and that they were simply lifted up and let fall again without injury. Their mines must have been under-charged, or what is more likely, their powder of very bad quality, and therefore the earth was merely raised slightly and dropped again. When full charges are used, the earth rises like a sheaf of corn, spreads out, and falls on all sides, leaving a crater where the powder had been.

When powder acts behind the face of a perpendicular cliff, the charge blows out a similar crater; but here, the force of gravity, instead of acting to destroy the effect of the powder, materially assists it, for the bottom of the cliff being suddenly blown away, and the whole mass violently shaken at the same time, the action of gravitation brings the portion acted on to the ground. It is true that, in some cases of very tenacious rock, such as that which is quarried at Holyhead for the new breakwater, the bottom of the cliff may be blown out by small charges into a series of caverns, and the upper portion will remain overhanging in a dangerous state. In this case, it is found necessary to lodge very large charges below the level of the floor of the quarry (fig. 6); and so, gaining increased resistance in front, the whole cliff is lifted, as far back as some natural fault or joint, and thrown down in a heap of broken stones.

The resistance to the escape of the gas when the powder is placed in a re-entering angle as here shown is very great; and, whenever a *free face* cannot be obtained, the charge must always be increased.*

There is another consideration in such operations which should be borne in mind; namely, that the height of the face acted on must

* A charge placed behind a free face is shown in fig. 5.

bear a certain proportion to the length of the L L R, otherwise, the whole mass will not be lifted, but there will be a crater thrown out, as before described, while the top may remain overhanging. The experience gained at the Holyhead quarries would seem to show that from four to five times the L L R is the greatest height of face which is admissible, if the lifting effect is to be produced.

The demolition of masonry in different positions is a very important branch of military mining.

When the besiegers approach the ditch of a fortification by systematic attack, they have generally two great difficulties to overcome; first, the counterscarp, or outer wall of the ditch, which prevents their descent into the ditch; and then the escarp, or retaining wall of the rampart, which presents a formidable obstacle to their ascent into the interior of the work. These two walls may be scaled; but this is a hazardous mode of operation, and generally one attended with great loss of life. The first may also be approached by a great gallery under ground, and broken through with picks and crowbars, while the other is breached by heavy artillery in a battery on the crest of the covered way; but, if mines be employed, as is often the case, the charges used are proportioned to the thickness of the wall near its base. The counterscarp is generally a simple retaining wall, and here $\frac{3}{20}$ th L L R³ is sufficient to throw it down, though a larger charge would be used in such a case to form an easy slope or ramp for the descent into the ditch. Having worked across the ditch by sap, a miner is attached to the revetment of the escarp, and he works either through or under the wall, and lodges his charges at the back of it. (figs. 7 and 8.) Escarp revetments have generally counterforts or buttresses of masonry projecting back into the earth; these serve to strengthen the revetment, and make breaching by artillery more difficult. The miner, therefore, lodges his charges in or behind the counter-forts, and here the minimum charge to throw the wall down must be $\frac{4}{20}$ or $\frac{1}{5}$, probably increased to $\frac{1}{4}$ to make a practicable breach.

In military operations it often happens that buildings with massive walls, such as magazines, casemates, &c., have to be destroyed. The engineer may then pursue several different courses, varying according to the time, powder, and labour at his disposal. The

quickest and most wasteful method is that before spoken of, viz., placing a few large heaps of powder inside the building, blocking up the doors and windows, and firing the charges by powder-hose, or other means; but, where time is not so great an object, and powder is less plentiful, a much smaller quantity of powder will effect the desired result.

A series of charges may be placed in small pits sunk close to the wall, on the inside of the building, if the floor be higher than the ground outside (fig. 10), and the earth dug out (with more rubbish if procurable) piled over the charges; or the powder may simply be laid against the foot of the wall, and a trench dug a short distance from it, and the earth piled over the powder to the depth of twice the thickness of the wall (fig. 9); but a still more economical method is to lodge the charges in the centres of the walls themselves, either by forming small galleries in the walls with chambers at the end, which must be done when the walls are very massive, or, if they be rather thinner, a quicker process may be resorted to by boring holes into the wall, sloping downwards at an angle of 45° , with the borer or jumper, which is a bar of round iron, having a chisel-edge at one end, and which being struck with a hammer, or churned up and down by hand and constantly turned, forms a cylindrical hole somewhat larger than the bit used; at the bottom of this hole the charge is placed by pouring it in through a funnel, or loading with a cartridge, which is sometimes done when the hole is damp, or in an awkward position for pouring powder into it. The remainder of the hole is solidly filled up with clay or broken bricks, a piece of Bickford's fuse having been placed in the powder, and carried up to the top of the hole. The charge lodged in this manner is not in a very compact form, and it is best if the size of the hole in inches can be made equal to the thickness of the wall in feet; *e. g.*, for a six-ft. wall a six-inch bit should be used, but, as it is difficult to obtain, and still more difficult to work such large bits, a smaller one is generally used, and pairs of holes made opposite to each other in the wall, crossing in its middle thickness, as shown in fig. 11. These are called X holes, and by this means the powder is lodged in a more compact shape in the wall. It is not often that these holes can be bored so accurately opposite to each other, and in the same vertical

plane, as to ensure their meeting in the wall. When they do not meet, it is necessary to fire both holes as simultaneously as possible.

This mode of operation was employed in the demolition of a portion of the large barracks at Sebastopol, known as the "White Buildings." A few hours' work sufficed to sink the jumper-holes, and to load and tamp them; the charges used being about $\frac{1}{3}$ L L R³, or from 2 to 4 lbs. of powder in each hole, according to the character of the masonry.

Thus, with about 100 lbs. of powder, nearly 200 feet in length of a well-built three-story barrack was demolished. The effect of this demolition was very striking; the bottom of the wall being knocked away, the whole building sunk down and subsided quietly into a heap of rubbish, and seemed to fade away from the sight.

The principle of blasting may sometimes be advantageously used in the demolition of bridges, especially when the span is considerable and the arch rather flat. If a number of blast-holes be prepared in the keystones of the arch, and loaded with charges equal to about $\frac{1}{2}$ L L R³, and exploded simultaneously, the keystones will be blown out, and the greater part of the arch will probably fall. In the late series of operations at Rochester Old Bridge, some experiments were tried on this mode of demolition, and it was found that the peculiar arches of that old bridge could not be thrown down by blasts in the keystones alone, but that a combination of blasts both in the keystones and haunches of the arches, exploded simultaneously, effectually destroyed them. When powder is lodged in the centre of an extended line of masonry (as in these instances), the force acting equally in both directions, larger charges become necessary, and $\frac{1}{3}$ L L R³ is the usual proportion. It is a curious fact, however, that if the masonry to be destroyed, instead of presenting a considerable length which has to be torn in half, as it were, by the powder (as in the case of a wall), is of a polygonal or circular shape on plan, a much smaller charge, even $\frac{1}{16}$ L L R³, will suffice to destroy it.

I will not further multiply cases of the adaptation of powder to the demolition of walls, buildings, stockades, &c. under particular circumstances, but pass on to say a few words on the method of placing the powder in the required position, and that of exploding it at the moment wished for. As regards the placing of the charges, it is

plain that some means of access to the spot where the powder is to be lodged must be provided in the first place, and this is usually done by sinking a shaft, or driving a gallery, or a combination of both operations.

A shaft is a well, excavated perpendicularly down into the ground (figs. 1, 2, and 5). A gallery is a horizontal or slightly inclined excavation running underneath the surface (figs. 7 and 8). In most soils, both of these excavations must be lined with planks, kept up by frames to prevent the earth from falling in. A shaft is generally $4\frac{1}{2} \times 3\frac{1}{2}$ square, that being the most convenient shape for working. Galleries vary in size; some, called great galleries, are $6\frac{1}{2}$ feet wide \times $7\frac{1}{2}$ feet high; these are used only for the descent into the ditch in attacking fortifications, or for the main galleries in a system of counter-mines; branch galleries are about $2\frac{1}{2}$ feet by 3 feet high. In easy soil a shaft may be sunk at the rate of 2 feet an hour, and a branch gallery driven $1\frac{1}{2}$ foot an hour; but in hard masonry, or rock, where blasting has to be used to break away the material and enable the miner to work it out with hammer and crowbar, the rate of progress is sometimes not more than 1 or 2 inches an hour. If powder is to be lodged at the bottom of a shaft, as is often the case in destroying piers of bridges, revetments, retaining walls, &c. the charge is always placed in a return formed at one side, never merely in the bottom of the shaft; and in the same way a return or chamber is always made at the end of a gallery for the charge; the object being to give a greater resistance to the elastic force of the gas in the direction of the tamping: if this precaution were not used, the tamping, if not blown out altogether, would probably be greatly compressed, and much of the effective force of the powder lost.

I have used the word tamping, which I must now explain. When the charge has been lodged in a mine, and the arrangements for igniting it completed, the galleries or shafts by which the chamber has been reached are carefully filled with any solid material at hand, such as filled sandbags, stones, clay, earth, &c. well rammed, and made as solid as possible, and strengthened often by pieces of timber placed across the opening and wedged in firmly. This process is termed *Tamping*, and upon its effectual execution depends in a great measure the success of the mine. The tamping should be carried to

a length of about $1\frac{1}{2}$ time the length of the L L R, to oppose a sufficient obstacle to the escape of the gas. Tamping is a much quicker process than forming the shafts and galleries; a shaft can be tamped generally at the rate of five feet an hour, and galleries at three feet an hour.

The galleries must be surveyed very accurately when they are long or tortuous, and in every case the exact position of the chamber with reference to the face to be operated on carefully ascertained, as a foot or two more or less of L L R makes a considerable difference in the amount of powder necessary.

The powder is placed in the chamber either in boxes, or large tarred bags, or in sand-bags, built up in a heap, as the case may be. It was at one time considered advisable to leave a space all round the powder in the mine, the idea being that the whole charge would be more likely to ignite by this arrangement; but practically this has been found a useless precaution. Where the mine is damp, every precaution must be taken to keep the powder perfectly dry; and, if there be actually water in the mine, it is best to put the powder in waterproof tin cases, enclosed in wooden boxes to preserve them from injury. In the demolition of the docks at Sebastopol, our engineers had great difficulties to contend with, owing to the water which percolated into the shafts and galleries. Powerful pumps were kept going day and night by parties of infantry, (the 18th and 48th Regts. I think), whilst the mining, loading, and tamping proceeded, and every precaution was used to preserve the charges from damp, by placing the powder in English and Russian metal powder-cases, and in water-casks obtained from the fleet.

The last point to which I would draw your attention, is the method of effecting the ignition of the powder in mines. Before the introduction of the voltaic battery, powder-hose was universally employed as the means of firing the charges of mines, and it still is frequently employed when the shafts and galleries are dry.

A powder-hose is a long linen bag (called a *sausage*, by the French *saucisson*), about 1 inch in diameter, and filled with powder. One end of this long bag or tube full of powder is secured in the charge to be exploded, and it is led along the shafts and galleries, in which it is protected from injury by being encased in a wooden trough.

A piece of portfire or Bickford's fuse is secured to the end of the hose, which gives the miner time to escape to a place of safety after he has ignited it. Powder-hose burns with great rapidity; but, if it is desired that several mines should explode at the same instant, it is necessary that the pieces of hose connected with each of the mines should be exactly of the same length, as the rate at which the flame travels along the hose is quite appreciable, and if the lengths were different the mines would explode in succession instead of simultaneously, and possibly the shock from the first explosion might injure the connection of the hose with one of the other mines, and so it might fail entirely. Bickford's fuse is a patent article, which is invaluable to the quarry-man for blasting in rock, and it burns so well under water that it is also frequently used for subaqueous explosions; but as its rate of burning is slow, about 2 ft. a minute, it is not suitable for firing mines which are communicated with by any considerable length of galleries and shafts.

The most scientific and perfect means of exploding mines is by electricity, as it is equally applicable to all situations wet or dry, and the ignition of any number of mines can by this means be effected simultaneously, at the exact instant that is desired. The principle which is ordinarily employed in the explosion of charges by electricity is this:—Different metals have different capacities for conducting a current of electricity, *why*, is as yet I believe unknown, but the fact is undeniable. Copper is one of the best conductors we know, and platinum, iron, and lead are amongst the worst.

When a current of electricity is forced through a piece of metal, it raises its temperature in inverse proportion to the sectional area of the piece of metal and to its powers of conducting electricity; thus, a thick wire would not be heated by the current so much as a thin one of the same metal, while a wire of a metal which is a bad conductor would be heated more than one of the same size of a metal which is a better conductor. Hence it will appear plain that we may so apportion our power of battery, and thickness, and material of conducting-wires, that the electricity may circulate through the main conducting-wires without sensibly raising their temperature, while at any point we please in the circuit the main conductor may be broken, and a very thin wire of a worse conduct-

ing metal introduced, which will thus be heated to such an extent by the passage of the electric fluid as to ignite powder at that spot.

The main conducting wires generally used are of copper about $\frac{1}{16}$ in. diameter, and to insulate them, or prevent the escape of the electricity into the earth or water through which they may pass, they are usually covered with gutta-percha. The thin wire, which is to be heated, is ordinarily of platinum, exceedingly fine; it is arranged in connection with a bursting charge of fine powder, and sometimes surrounded with gun-cotton to ensure the ignition of the powder, even should the platinum wire only attain a dull red heat. A thin iron wire is sometimes used for economy instead of the platinum, but, as it is liable to rust and deteriorate, and cannot be drawn so fine as platinum, the latter is much preferable.

There are many forms of battery which may be used for developing the current of electricity, but the most powerful, and the one in every way best adapted for the ignition of powder, is that known as Grove's, where the two metals used are zinc and platinum; the former being immersed in diluted sulphuric acid, and the latter in pure nitric acid, which is contained in a porous earthenware jar, to prevent it from mixing with the diluted sulphuric acid, as it would too quickly destroy the zinc. The platinum is almost indestructible, and the nitric acid in which it is immersed is only useful to remove the bubbles of hydrogen, which would otherwise collect on its surface as the water was decomposed by the electric current, and these bubbles being bad conductors would diminish the power of the battery considerably. In all other forms of battery they much weaken its power.

The hydrogen combines with the oxygen in the nitric acid to form water.

The zinc is gradually eaten away by the sulphuric acid, and has to be renewed from time to time.

When several charges are to be exploded simultaneously, there are various ways in which this can be effected; first, a pair of wires may be brought from each charge to the battery, the electric current generated in which will then be equally divided amongst all the charges, and a great *quantity* of electricity is therefore required for this system. This quantity must be obtained either by using very large plates or by

arranging the cells of a smaller battery abreast. A much more economical method, both as regards the power of battery required and the quantity of conducting medium necessary for the operation, is to connect one pole of the battery with one wire from the first charge, the other wire from the same charge being connected with one wire from the next charge, and so on till the second wire of the last charge is connected with the other pole of the battery, when the electric current, passing through all the charges at the same moment, fuses all the platinum wires, and the mines are simultaneously exploded. In this mode of arrangement, the *quantity* of electricity required to fuse one wire is sufficient to fuse them all; but a much greater *intensity* is needed to force the current through the greater resistance opposed to its passage by the great length of conducting wire and all the platinum wires, each platinum wire $\frac{3}{8}$ in. long offering as great a resistance to the passage of the electric current as 100 yards of the ordinary copper wire. The battery must in this case be arranged with the cells in *series* to obtain the required intensity, and the number of cells necessary may be at all times found by a simple calculation, when the power of each cell, the number of charges to be fired, and the length of conducting wire, are known.

A third, and still more economical, arrangement, as regards electricity, is to explode the charges in rapid succession by a mechanical arrangement which causes the whole force of electricity to pass through each charge in succession.

I have not attempted to explain the principle of the voltaic battery, as to do so would require a lecture in itself. I have merely indicated the mode of its application to mining operations. There are other modes of applying the force of electricity to the ignition of powder, by magnetic electricity, and by Rumkorff's induction coil; but, as they have neither of them attained to the same perfection as the one I have described, I will not allude further to them.

Since this Lecture was delivered magnetic electricity has been successfully employed for the simultaneous explosion of large numbers of charges of gunpowder, in experiments carried on by the Select Committee at Woolwich; and it seems probable that this method will supersede that in which voltaic electricity is the agent,

as the annoyance and expense of acids and voltaic batteries are done away with, and the exciting power is always ready at a moment's notice.—II. S.

Wednesday, May 5th, 1858.

THE RIGHT HON. LORD PANMURE, K.T. G.C.B. &c. in the Chair.

COAST DEFENCES.

By COL. E. WILFORD, R.A.

COLONEL WILFORD, after thanking the Chairman for the manner in which he had introduced him to the Meeting, proceeded as follows:—Before I attempt to enter upon the subject, I will take the liberty of remarking, that I think every Member of this Institution is highly indebted to the Council for the efforts they have made to organise these Meetings—every individual Member being encouraged to come forward and state his particular views and ideas relative to subjects which circumstances, or his peculiar line of thought, have led him to consider. Such opinions, of course, have no authority whatever; they are merely individual opinions. But, being here to say a few things as they occur to me, I am about to contribute my mite to this general subject.

My intention is not to pass in review our existing coast defences. I have not a knowledge of the facts sufficient to enable me to do so, nor do I feel authorised, as the matter is in the proper official hands. I may, however, make some allusion to the coast defences of England, but merely in illustration of the general subject; for it is assuredly a question that comes home to every Englishman's fire-side. Without referring to ancient history, I may mention a few incidents of more modern times to show, that, although we hold an insular position, still we have not escaped altogether scathless. I will advert, for instance, to the appearance of the Dutch at Chatham, in 1667, in the reign of Charles II., when they burnt our ships; and to the landing, in 1688, of the Stadtholder, William of Orange, from a large fleet at Torbay. On another occasion great alarm and apprehension were felt of a French invasion; so much so,