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The Employment of Electricity in Military Operations

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LECTURE.

Friday, February 24th, 1865.

GENERAL SIR JOHN FOX BURGOYNE, Bart., G.C.B., R.E.,
Director of Works, in the Chair.

THE EMPLOYMENT OF ELECTRICITY IN MILITARY OPERATIONS.

By Captain H. SCHAW, R.E., Professor of Fortification and Artillery,
Royal Staff College, Sandhurst.

It is now nearly two years since I first undertook, at the request of the Council of this Institution, to give a lecture on Electricity as applied to Military purposes. Owing to various causes, the lecture has been deferred, and it is a proof of the rapid progress of the age that the facts which I shall now have to bring before you differ in some material points from those which I should have spoken of two years ago. New instruments have been invented, new discoveries made, and our knowledge of the subject has advanced so far, that electricity, which, but a few years since was looked upon as a philosopher's plaything, may now be fairly classed amongst the exact sciences.

So subtle is this force, however, so varied in its manifestations, so difficult to isolate from the influences of surrounding objects and forces, that some electrical phenomena are still but imperfectly understood, and an entirely satisfactory theory of electrical science has not yet appeared. Our instruments also, both for electrical measurements and for making use of electricity in practical operations, are in most instances still susceptible of improvement; and it is most essential that in the applications of electricity to military purposes, as in every other branch of military science, our army should keep pace with the discoveries and improvements of the day, and should be watchful, and ready to seize upon and weave into the web of that great and complicated fabric, the modern military system of civilised nations, every new scientific discovery which can be made to minister to the art of being the strongest.

The four special applications of electricity to war purposes to which I intend to draw your attention are—

1. The ignition of gunpowder.
2. The electric telegraph.
3. The electro-ballistic pendulum.
4. The electric light.

Electrical science has various other useful military applications, such as the *protection* of ships of war, and powder magazines, and other military buildings *from the effects of lightning* by means of the improved system of lightning conductors, for which the country is indebted chiefly to the researches of Sir Snow Harris; and the multiplication of copper plate engravings by an *electro-metallurgical* operation, which has been largely used on the Ordnance Survey. But such applications of electrical knowledge being in no way peculiar to the army, I will not allude to them further.

A safe, ready, and certain method of igniting gunpowder is of great value in numerous military operations. The circumstances under which it may be necessary to effect the ignition may be classed under two general heads. The ordinary service and proof of ordnance may be considered as one special branch; military mines as the other branch. Without alluding to small arms, we may be well satisfied with the friction-tube, as answering all the requirements of the artillerist, except in the case of the proof of ordnance, when for safety the operator must be at a distance, and electricity is advantageously employed. In this case there is a uniformity in the circumstances, and therefore a corresponding uniformity in the mode of operation, which may readily be reduced to a system.

The ordinary means of exploding mines, viz., "powder-hose" and "Bickford's fuze," cannot be considered as either safe or certain, and electricity may in most cases take their place with great advantage; but in mining operations the circumstances vary very widely, hence the adoption of one system becomes more difficult than in the former case.

For instance, *the powder* may be in one charge or divided into a number of charges. It may be buried deeply under ground or under the water, or it may be placed in blast holes, or with but slight covering in buildings, to be hastily destroyed.

It may be necessary to operate from a great distance, or the electrical apparatus and operator may be placed in safety within a comparatively short distance of the mines.

In some cases the *simultaneous* explosion of a number of mines is of importance; and sometimes in this case the failure of one or two charges may be of little detriment.

In other cases it may be most essential to the success of some operation that one or two, or, it may be, a larger number of charges, should explode *without fail*; and probably at a particular moment.

There are cases again in which the miner may choose his own time for the explosion, and others in which the exact moment of ignition must be dependent on the uncertain movements of the enemy against whom the mine is directed.

Numerous other variations in position, number, time of explosion, and comparative values of certainty and facility in the operation, will occur, and a method of igniting gunpowder which is perfectly satisfactory in

all cases has not been discovered up to this time. While admitting this however, I must claim for electricity (whatever defects may still exist in our methods of applying it) that it is generally the most safe, certain, and convenient mode of exploding mines; and the only method by which we can ensure the perfectly simultaneous explosion of a number of mines, or the ignition of gunpowder at a distance at any particular moment, more particularly under water or in wet situations.

In confirmation of this, I may mention that at the commencement of the late demolition of the fortifications at Corfu, the electrical apparatus not having arrived from England, powder-hose was used for exploding the mines, and although every care was used, a number of the mines missed or lung fire; the latter description of failure being the more dangerous, as the fire sometimes smouldered for a quarter of an hour, and the mine exploded quite unexpectedly; moreover, perfectly simultaneous explosions could not be satisfactorily accomplished.

After the arrival of the electrical apparatus, the degree of certainty in the explosion of the mines was very greatly increased (amounting practically to perfect certainty in the case of the voltaic battery) the risk of hanging fire was entirely removed, and absolutely simultaneous explosions were effected without difficulty.

Before describing the apparatus by means of which sufficient heat for firing gunpowder may be produced by electricity, it will be necessary for me to put briefly before you the elementary principles of electrical science as now generally received. Electricity is now looked upon as one of the manifestations of the great force pervading all creation, which we call the attraction of gravitation, and of which mechanical force, heat, electricity, and chemical affinity, are but different modes of development, any one of which may be converted into any one of the others by proper treatment. Without attempting to define what this force with so many "*aliases*" may be, we know electricity, by certain accompanying phenomena, in two states, *at rest* and *in motion*, or static and dynamic electricity. A body statically electrified may be considered as having either more or less electricity than the earth, which is the electrical zero, just as with regard to heat the temperature of our bodies is our zero, and we speak of other bodies feeling cold or hot as they have less or more heat than our bodies, so a body is said to be positively or negatively electrified when it has more or less electricity than the earth.

And just as when two bodies at different temperatures are connected by a substance which will conduct heat, that which has most heat parts with its superfluity to that which has least. So if two bodies unequally electrified be connected by a substance which will conduct electricity, a flow or *current* of electricity passes from that which has most to that which has least, in the way which we call dynamic electricity.

The force compelling this transfer of electricity is generally known as *electro-motive force*, and it is greater or less in proportion to the amount of difference in the electrical states of the two bodies which are connected by the conductor.

All bodies with which we are acquainted, oppose resistance to this transfer of electricity, but the degrees of resistance offered by different

bodies are so very various that for convenience they are classed under two different heads—bodies which resist but feebly the electrical current, such as the metals, are termed conductors, while those possessing the property of resisting very strongly the passage of electricity, such as glass and resin, are termed insulators.

To understand rightly the action of electricity, we must have clear ideas of what are meant by the four terms—

Electro-motive force,
Electrical resistance,
Electric current, and
Quantity of electricity.

Electro-motive force is the active force tending to restore equilibrium when it has been disturbed, by causing the transfer of electricity, and overcoming the resistance opposed to this transfer.

Electrical resistance is what its name implies, the opposition or resistance offered by the substance through which the transfer of electricity takes place, diminishing the strength of the current, or the quantity of electricity which passes per second.

Electric current is the result of electro-motive force overcoming resistance, and we may generally reason about an electric current much in the same way as we do about a current of water.

We speak of *quantity of electricity* in the same way as of a quantity of heat stored in a body—*e.g.*, the heat stored in a red-hot 32-pounder shot is a definite quantity, which would do a definite amount of work, such as converting so much water into steam, and producing so much mechanical force. So a definite quantity of electricity stored in a Leyden jar will do a definite amount of work in passing out of it in the form of a current or of a spark, by decomposing so much water, or producing a definite amount of heat.

A committee appointed by the British Association has been engaged for some time past in deciding upon certain standards for electrical measurements.

The unit of resistance has now been decided upon, with reference to the acknowledged units of mass, time, and space, and material standards of resistance may be procured, taking the place of the yard measure of length, in all electrical measurements. Standards of *electro-motive force*, *current*, and *quantity*, have also been provisionally decided upon; so that electrical measurements may now be made by proper instruments with as much accuracy as measurements of heat, or of weight, or of length, breadth, and thickness.

Let us now pass in review the electrical effects which are practically useful in military operations.

1st. The earth is a magnet; a peculiar ore of iron known as the lodestone possesses the same property; soft iron brought in contact with the lodestone becomes temporarily a magnet, and steel permanently so. The north end of one magnet attracts the south end of another, and repels its north end, and *vice versa*, from which it will be evident that the end of a magnet which points towards the north pole of the earth is in itself a south pole, and not a north pole, as we are in the habit of calling it.

2nd. Soft iron may be temporarily, and steel permanently magnetized, by the action of a current of electricity. If a wire be insulated and wound round a bar of soft iron, a current of electricity passed through it will instantaneously convert the soft iron into a magnet, and it parts with its magnetism as instantly on the cessation of the current. Electro-magnets are used in the majority of electrical instruments.

3rd. A spiral of wire carrying a current of electricity is itself a magnet, and will act on a magnet balanced inside it, attracting and repelling its opposite poles, so as to cause it to deflect from its *normal position*. An instrument made on this principle is known as a galvanometer, and is used for detecting and measuring currents of electricity, and also for needle telegraphs.

4th. As currents of electricity produce magnetism, so from magnets (either permanent or electro-magnets) currents of electricity may be produced. From a permanent magnet it is most easily produced by an arrangement devised by Professor Wheatstone. Soft iron bars wound with insulated wire are fixed on the poles of a permanent magnet of a horse-shoe shape, a soft iron armature is pivoted so as to revolve in close proximity to the ends of the soft iron bars without touching them; at the instant when this armature recedes from the ends of the bars a momentary current of electricity passes through the coils of wire in one direction, and at the moment when it approaches the poles again, another instantaneous current circulates in the opposite direction. Thus by rapid rotation of the axis a constant succession of alternate currents is produced.

From an electro-magnet a similar succession of alternate currents might be produced in the same way by mechanical means. It is more usually obtained by a different arrangement: a bundle of soft iron wires is wound, first with a thick insulated wire, through which the current from a voltaic battery is made to pass, converting the system into a powerful magnet—a fine insulated wire is wound over the primary thick wire on the cylinder, and an ingenious arrangement of the circuit connecting the primary wire with the battery causes an alternate breaking and reforming of this connection with great rapidity. At each breaking and making of contact, a momentary current passes through the outer thin wire. Such an instrument is known as an induction coil. It is probable, however, that more powerful currents would be obtained by the mechanical arrangement than by the more usual and ingenious form of the instrument, in which the current does its own work, and uses part of its power in breaking and making contact.

This principle has been used in instruments for igniting gunpowder, for producing the electric light, and for telegraphing, as will be mentioned shortly.

5th. An electric current produces heat.

6th. An electric spark produces heat, or more properly, it is the manifestation of the heat produced by the sudden passage of a quantity of electricity through a highly resisting substance.

These two last effects are practically used in the ignition of gunpowder, we must therefore consider them first.

*Here is a voltaic battery, each cell of which has an electro-motive

* The lecturer exhibited a battery of Grove's construction, having ten cells.

force, equivalent to nearly two standard units. The accumulated electro-motive force of the 10 cells, we may call 20, *i.e.*, the platinum pole has an electro-motive force of 10+, or above the zero of the earth, and the zinc pole has an electro-motive force of 10—, or below the zero of the earth.

But each cell of the battery has also a certain resistance, which we may call $\frac{1}{10}$ of a unit of resistance, or the whole battery has a resistance equal to 1. When the poles of the battery are not connected, this electro-motive force does no work, being unable to overcome the resistance of the air between the poles; but if the poles are connected by a wire of metal, a constant current of electricity passes through it and the battery. If the wire be thick, and of a metal which has a low specific resistance, but little apparent effect will be produced on the wire, but there will be a large consumption of zinc in the battery. If the wire be thin, and of a metal which has a high specific resistance, the electro-motive force, in overcoming this resistance and forcing a certain quantity of electricity through the circuit, will raise the temperature of the wire, doing work in that part of the circuit; at the same time, consumption of zinc in the battery will be less. This principle is made use of for the explosion of gunpowder—a very thin platinum wire is introduced into the charge to be exploded; thick copper wires lead to the voltaic battery at the moment when the circuit is completed, the platinum wire is raised in temperature to the fusing point, and the gunpowder is ignited.

Now the exact force necessary to ignite the gunpowder in this way, can be readily determined; by a few simple experiments the electro-motive force and resistance of one cell of the voltaic battery can be found, and the electrical resistances of the conducting wire per yard, and of the platinum wire in the fuse can also be easily measured, as also the current required to fuse the platinum wire.

The celebrated law of the German philosopher Ohm, then enables us to determine how many cells of the battery will be necessary in any given case.

The law is $C = \frac{E}{R}$ or the current is proportional to the electro-motive force directly, and to the resistance inversely.

Suppose we find, by experiment, that our platinum wire is fused when the electro-motive force is 1, and the total resistance in the circuit is 1 unit, then $C = \frac{E}{1}$ represents our normal current. To produce this same current when the resistance is increased by the addition of conducting wire, or fuses, in the circuit, we must add more cells. For instance, let conducting wire of resistance equal to 2 units be added (about 200 yards)

$$\text{Then } \frac{E}{1} = \frac{N \times E}{N \times (\frac{1}{10} + 2 + 1)}$$

$$\text{Whence } n = 3\frac{1}{3}$$

That is three cells would not produce fusion, but four would do so. In practice we should use five or six to overcome accidental defects.

Without going further into such calculations, it may be stated briefly that the best mode of connecting any number of charges with a battery,

as well as the power necessary in any particular case, may readily be determined. There are three general methods of connecting a number of charges with a voltaic battery to produce simultaneous explosion.

Fig 1, the continuous circuit. Fig. 2, the divided circuit. The first is the simplest, and is suited to a large number of small cells, which is a troublesome battery; the second, the most certain, and is suited to a few large cells; but a large number of mines cannot be exploded thus. Fig. 3 shows a combination of the two systems, which is the best for a large number of mines. Twenty-one were thus fired simultaneously in the demolition of the Keep at Corfu.

If instead of ten cells of this battery I had some hundred cells, the electro-motive force would be so great that if I were to approach one pole incautiously I should receive a violent shock; or a spark would pass between a conductor connected with one pole and brought near to the other pole. A similar effect may be produced by other means, viz., by friction, or by magnetic induction. Both of these means have been tried, and friction, though until lately uncertain in its results, has now, through the wise adoption of a new material, viz., *hardened india-rubber* or *ebonite*, by Major Von Ebner, of the Austrian army, been found by far the most powerful and certain means of producing heat by electrical spark.

Formerly electrical machines were made of glass, which is a very hygrometric substance, and allows the deposition of a thin film of water over its surface very readily when the air is at all damp. Glass is a good insulator, but water is a conductor. Thus, machines for developing electricity by friction when made of glass, will not act in a damp atmosphere, as the electricity escapes over the surface as soon as it is developed. But ebonite, a more perfect insulator than glass, is also eminently non-hygrometric, and by substituting plates of this substance for the old glass plates, or cylinder, of the electrical machine, and sheets of vulcanized india-rubber and tin-foil rolled up into a cylinder for the old glass Leyden jar, a compact and portable instrument has been produced, which is perfectly efficient in the wettest weather.

By means of this instrument, and a very delicate fuse, invented by Professor Abel, as many as fifty mines may be exploded simultaneously, in one continuous circuit. I believe that the number of fuses successfully ignited at one discharge has even reached the high number of 150. The fuse is, however, a very important part of the apparatus. The electric spark will not generally ignite dry gunpowder, but simply knocks the grains away. It is necessary, therefore, to interpose in the circuit a substance offering a certain amount of resistance to the passage of electricity, not too much nor yet too little, and this substance should be readily inflammable. Fulminate of mercury has

been successfully used ; but the best material yet discovered is that used by Professor Abel, a mixture of subphosphide of copper, subsulphide of copper, and chlorate of potassa. This compound possesses all the necessary properties, when carefully prepared, and kept from atmospheric influences. Like all such chemical compositions, however, it is liable to deterioration.

A rapid succession of electric sparks may be obtained from electro-magnets arranged as induction coils, as before explained, or from permanent magnets, arranged on Professor Wheatstone's plan. Wheatstone's magnetic exploder is a very convenient and portable instrument, but not nearly so powerful as the frictional machine for the ignition of gunpowder.

The induction coil, if well made, is very powerful ; but it is more delicate, troublesome, and expensive than the frictional machine.

It will be seen, then, that there are two general methods of igniting gunpowder by electricity, viz., 1st by the direct current of a voltaic battery heating a thin platinum wire ; 2nd, by the electric spark obtained from a friction machine (or by induction from magnets), acting upon a chemically prepared fuse. It remains to compare these two systems, and to note their excellencies and defects.

1. *The Direct Current.*—Experience has shown that this method is very certain, as certain, in fact, as it is possible for anything human to be, if the proper precautions be taken in testing before hand, and during the operations of preparing the mines, every part of the circuit, including the battery. Such tests can readily be applied as will give perfect certainty, that the electrical circuits are perfect, and that the electric current is sufficient to do the work required of it. The only element of uncertainty is, in moist situations, the danger of the powder becoming wet. This is a mechanical difficulty which, by proper care, ought seldom to cause a failure.

The conducting wires require to be perfect as regards conductivity, *i.e.*, that the resistance of the circuit should not exceed its proper amount, but insulation is of comparatively small moment. Now resistance is easily tested, and a little care will ensure that its proper amount shall not be exceeded. But tests for insulation are more difficult and delicate, and it is by no means easy to repair defects in insulation, which are very liable to occur from rough usage, or from deterioration of the insulating material by exposure to heat, light, and air.

The fuse can be made by any tinsmith, if the platinum wire be obtainable ; and thin iron wire will supply its place on an emergency.

This method, then, is *certain* ; and the apparatus and stores connected with it are not liable to deterioration, and thus efficiency can always be tested and ensured.

On the other hand, the batteries are troublesome and not very portable, and mines cannot be exploded at any considerable distance from the battery, by this means, without using an inconveniently large number of cells, which would also be necessary to explode more than from twenty to twenty-four mines simultaneously.

2nd. *The Electric Spark.*—Of the methods of igniting gunpowder by the electric spark, the most satisfactory is the friction-machine. It may

be taken, then, as the type, and its excellencies and defects apply, more or less, to the other two instruments. Its advantages are simplicity and portability; it is always ready for use, requiring only occasional re-amalgamation of the cushions. It is efficient at great distances from the mines to be exploded, and the number of mines which can be exploded simultaneously is fully double that which the voltaic battery can conveniently command. It requires but one conducting wire, and the connections with the mines are always the same, and as simple as possible. On the other hand, the fuses which must be used with this instrument are delicate, and liable to deteriorate by keeping, and they cannot be extemporised or improved when defective, nor have we, at present, any satisfactory test which will discover whether a fuse is good or not. Professor Abel is now engaged in the endeavour to discover such a test; and should he succeed in doing so, of which he is very sanguine, the only serious objection to the exclusive use of this method will have been removed.

The necessity of perfectly insulating the conducting wire, although perfect insulation is a condition more difficult to ensure than perfect conductivity, is nevertheless a minor disadvantage; and the other advantages of this system over that of the direct current from the voltaic battery heating platinum wire are so great, that were the element of uncertainty which now is connected with the fuses, and the impossibility of testing removed, it would be so far superior to the other as to leave no room for comparison. As it is, however, the superior certainty of the voltaic battery and platinum wire fuse gives it a decided advantage in cases where certainty of explosion is of more importance than convenience. Under other circumstances, however, which are of frequent occurrence, when the occasional failure of a fuse is of slight importance, the frictional machine or magnetic exploder with Abel's fuse are much to be preferred to the old system. In the proof of ordnance this is eminently the case, and probably the magnetic exploder is the most suitable instrument for this purpose.

We will now pass on to consider the electric telegraph in its applications to war purposes.

Its first military application was a light submarine cable from Varna across the Black Sea, to complete the telegraphic communication between England and our army in the Crimea, and a system of telegraphic communication between Balaklava, Kasatch, and the different divisions of the British army there. During the Indian mutiny the electric telegraph was of essential service to our army. The late Lieut.-Colonel Stewart, of the Engineers, had charge of this department, and, with great energy, carried on the telegraphic wire always with the advance of the Commander-in-Chief, enabling him to keep up constant communication with the seat of government. The French made use of the telegraphs of the country in the late war in Italy, repairing them when destroyed by the Austrians, and using them to keep up communication along their line of operations with their base. In America, both North and South have used the electric telegraph largely, and some amusing anecdotes have reached us of tapping the enemy's telegraph wire, and so obtaining information which was not at all intended for the person who received it.

An electric telegraph equipment and a corps of telegraphists now form an integral part of nearly every European army, and of the American arm^{ies}. In our own service, the duties connected with the electric telegraph have hitherto been entrusted to the corps of Royal Engineers, and a provisional equipment is now in course of formation and trial at Aldershot. The officers of Engineers are taught at Chatham the principles and practice of electric telegraphy, and the various tests and electric measurements required in such operations. A certain proportion of non-commissioned officers and sappers are taught to manipulate the instruments, and to perform all the mechanical operations connected with repairing the instruments and batteries, and the construction and maintenance of telegraphic lines.

The electric telegraph in its military application has three general developments—

1. It may be stationary, connecting the various forts of a large fortified position, such as those at Portsmouth and Plymouth, or the various works of such fortresses as those of Malta and Gibraltar.

2. Or it may be moveable and of comparatively short length, to connect corps d'armée with head-quarters, and outposts during the marchings and manœuvres of a campaign.

3. Or it may be an extensive line of telegraph, maintaining the communications of an army with its base of operations during an advance, often consisting of the telegraphs of the country repaired, sometimes of a special line put up in a somewhat permanent manner as the army advances.

Intermediate between these is the case of the telegraphic communications in a standing camp, such as those at the siege of Sebastopol.

In stationary military telegraphs the conductors are sometimes buried under ground, sometimes suspended in the air. The latter plan is generally preferable, because defects are easily discovered and easily repaired.

In special cases it may be necessary to bury the wire underground, and the depth should be sufficient to avoid risk of injury from shells (five feet probably would be sufficient). Such underground systems are very expensive, and very difficult to repair when accidental faults occur.

Moveable Electric Telegraph lines may either consist of an insulated wire laid along the fences by the roadside, as it is unwound from drums carried in a waggon—the system pursued in America, as I am informed by Captain Beaumont, R.E., who was for some time with General McClellan's army—or it may be a thin bare wire, supported on light poles or lances, carried by men at intervals of about 40 or 50 yards, which is the system adopted in the Austrian and Prussian services.

The former appears to be the best, as it requires fewer men. It would be desirable if the insulated conductor could be protected by an outer sheathing, so as to be secure against accidental injury from wheels or horses' hoofs; but the extra weight and expense of such a conductor are great objections to its use. An ordinary copper wire of several strands, equivalent altogether to one of 16 or 18 gauge, insulated with gutta-percha or india-rubber, and protected with tarred hemp, appears the most suitable upon the whole.

For the third class of military telegraphs a bare iron wire supported on poles must generally be adopted; for single lines of moderate length insulators are not essential, and were not used in India; but they are of advantage, especially during rains and fogs. Generally it would seem desirable to have a few hundred miles of No. 8 iron wire, with insulators and tools, and materials necessary for erecting a line of this sort on poles at the base of operations of an army, and a short ten miles of insulated wire with the head-quarters, to be used as a moveable conductor.

The electric telegraph instrument, which appears to me best suited for military telegraphs, is the ordinary single needle instrument, used very generally in England. It is cheap, portable, simple, easily repaired, it requires but feeble currents of electricity to work it, and ordinary clerks can transmit messages at the rate of about 12 words a minute by its means.

The Morse telegraph instrument is more perfect than the single needle. It records the messages sent, is less liable to error, and greater speed is attainable by its means. It is, however, more costly, less portable, requires more powerful currents of electricity, and is not so readily repaired as the single needle. I think, therefore, that it should be only used in special cases on long lines of comparative permanency.

These instruments both require voltaic batteries to set them in action, and probably the battery used at the Royal Engineer establishment at Chatham is the most convenient arrangement.

It is a modification of Daniel's constant battery, the metals being copper and zinc, the copper being placed below the zinc in each cell, instead of beside it. Gravity keeps the heavier salt—sulphate of copper—at the bottom, and the lighter—sulphate of zinc—floats at the top; each metal is, therefore, immersed in a solution of a salt itself. No acids nor porous earthenware cells are required for this battery. Dry crystals of sulphate of copper, and water, are sufficient to charge it for use, and it will remain in action with occasional addition of crystals for about a year. The sulphate of zinc is rapidly formed by the action of the battery.

Telegraph instruments are made, to be worked without voltaic batteries, by the induced currents obtained from permanent magnets. These have some advantages on the score of convenience and portability, and of efficiency out of doors in frosty weather, when batteries are liable to freeze. Instruments of this class are sometimes made to signal by means of needles; sometimes in the same manner as the Morse instrument, and sometimes as dial instruments, showing the letters of the alphabet by a pointer on a circular face, like a clock. The last form may be occasionally useful in military telegraphs, as it requires less carefully trained operators, and is very portable. Probably the form manufactured by Messrs. Siemens and Halske is the strongest and best suited to military telegraphs. It is used in the Prussian and Austrian services.

The operators should evidently, in most cases, be soldiers, and a certain proportion of the whole of them should be capable of repairing any part of the apparatus which may get out of order, and of tracing out the cause and position of any ordinary fault in the line.

A certain amount of training is necessary for this purpose, and it seems desirable that men so far trained should be thoroughly educated in all the different modes of telegraphing, whether by Captain Bolton's light—by flags—or other means alluded to in lectures given lately in this Institution by Captain Bolton, 12th Regiment, and Captain Colomb, R.N., and that they should be constantly practised in these various modes of telegraphing.

Such a training is, as far as possible, given to the men of the Royal Engineers selected for this course at Chatham, and they are also instructed in the method of firing mines by electricity. Arrangements are also made to employ the trained men from time to time in this especial service. I fear, however, that the system is not as satisfactory as that pursued in most foreign armies, in which a special corps of telegraphists exists. It is one of the defects of a comparatively small army that men are too valuable to be given up entirely to one branch of what may be termed the scientific work of the army, and it follows that the scientific corps are as far as possible trained to perform a very great variety of duties. Now, excellence in every branch of industry has been obtained by division of labour, by giving each individual one definite work to do, when it may fairly be required that he shall do it thoroughly well. The contrary system has its advantages. It tends to give readiness of resource and fertility of invention. It expands the minds of those whose range of education is thus enlarged, and makes such soldiers less machines, more thinking men; but it is doubtful whether the work is so well performed under this system as under that of the division of labour.

I must pass on, however, to the two other applications of electricity I have mentioned.

The electro-ballistic pendulum, as now used at Shoeburyness, under the able management of Lieutenant Noble, R.A., is the invention of Major Navez, of the Belgian service, and it is a vast improvement on the cumbersome ballistic pendulum formerly in use. The object of the instruments being to ascertain the velocity of shot and shell at the moment of their leaving the mouth of the gun, and at different periods during their flight, and so to arrive at accurate conclusions with regard to the laws governing the motions of projectiles of various shapes, sizes, and weights, projected with different charges of powder, and at different angles of elevation, from ordnance of all descriptions. In these days of revolution in all artillery, such investigations have the highest practical value, and enable us to decide between competing systems of construction and service of ordnance, and to determine the direction in which experiment may be pursued advantageously with a degree of confidence otherwise unattainable. Without entering into the details of the construction and action of the apparatus, the principle of its action may be thus briefly described.

A small pendulum swings freely beside a graduated arc of a circle, carrying with it an index arm having a carrier on the end reading $\frac{1}{2}$ of a degree. The law of the motion of a pendulum is so exact that the time occupied by the pendulum in moving through the space of one of the smallest divisions of the arc is accurately known.

The pendulum is supported at one extremity of the arc by a straight electro-magnet, and the index can be clamped at any part of its path by a powerful horse-shoe electro-magnet.

Two open frame works of wood are erected in the range of the gun to be tried, at 40 feet apart, and a wire is wound backwards and forwards across each of them in such a manner that the shot in passing through each frame must cut the wires. The wire on this first frame is connected with a voltaic battery and the straight electro-magnet, so that while it is unbroken, the pendulum remains suspended at the upper zero point of the arc. When the gun is fired the shot cuts the wire and releases the pendulum, which instantly commences to travel down the graduated arc. The wire wound on the second frame is connected with another battery and electro-magnet, which latter, when it loses its power by the wire being severed by the shot's passage through the second frame, allows a weight to drop, and completes the circuit of the clamping horse-shoe magnet, and so arrests the index hand in its course. The number of degrees through which the pendulum has moved corresponds very nearly with the time occupied by the shot in moving through the 40 feet between the two frames. Various corrections are applied to this reading, by means of which the velocity of the shot can be determined within an extremely minute fraction of absolute exactness. It is evident that the frames may be placed at any point in the range at the proper height to allow the shot to pass through them in its flight, and so to record its own velocity at that particular part of its course.

There are two general applications of artificial light which are useful in war, *signalling* and *illuminating* an enemy's works. The first application has been ably treated of by Captains Colomb and Bolton, I will not, therefore, allude to it further. The power of illuminating an enemy's works at night is however an important auxiliary in war, whether offensive or defensive. In offensive warfare it has been successfully used by the Federal Americans. By means of the Drummond lime light, placed at a distance of nearly 1,000 yards from Fort Sumpter, they succeeded in illuminating the breach they had formed in the fort, so far as to enable them to discover working parties, and keep up a fire upon it at night and so prevent the Confederates from repairing it.

In the defence of a fortress such power of illuminating the besieger's works at night and discovering his working parties must retard the siege most materially, as it is chiefly at night that we can now hope to sap up towards a fortress well-garrisoned and armed with modern rifled small arms and ordnance.

There are two qualities necessary in a light to illuminate at a distance, *volume* and *penetrating power*. The electric light is very much more powerful than the lime light in the latter of these qualities, yet one of Serrin's ordinary electric lamps will not illuminate sufficiently to distinguish moving objects at a greater distance than about 400 or 500 yards.

It is probable, therefore, that a combination of a number of lime-light lamps was used by the Americans so as to produce a great volume of light, and that a combination of two or three ordinary electric lamps, or perhaps one having a greater volume of light than is usual, by means of

a more powerful current of electricity, might effect the purpose. Experiment is needed in this direction.

At present our means of illuminating enemies' works are light balls thrown by mortars, which, falling on the ground, illuminate the surrounding objects to a certain extent; their range of illumination is, however, very limited, especially if they fall into trenches or hollows in the ground into which they have a natural tendency to roll. Colonel Boxer has invented a very ingenious apparatus called the parachute light; it is enclosed in a paper case like a 13-inch shell which, when it is projected from a mortar, and has attained its full height, is made to burst open by a small charge of powder, exploded by a fuze. The light, which is very powerful, is ignited at the same moment and remains suspended in the air for some time by a sort of parachute which is folded up in the paper case and which opens out as the vessel containing the light-composition begins to fall.

There is some uncertainty connected with the use of either of these arrangements, and a light so powerful that, by means of proper moveable reflectors, the whole neighbourhood of a fortress may be swept by rays of light to a distance of from 500 to 1,000 yards, and all the night arrangements of an enemy detected, is a most valuable auxiliary to the defence. Such an arrangement is quite practicable though it has not yet been experimentally used. The necessary electric currents may be obtained either by voltaic batteries or from permanent magnets.

About fifty cells of a large voltaic battery of Bunsen's or Groves' pattern are required to produce a good light. To obtain a sufficiently powerful current from permanent magnets a small steam-engine would probably be required, although for signalling purposes a sufficient volume of light might be produced by a machine worked by manual labour.

The voltaic battery appears the most hopeful source of electricity in the defence or attack of fortresses, being more portable than the steam-engine and magnetic apparatus.

Until lately there was a great difficulty experienced in producing a steady electric light, but this difficulty was most ingeniously overcome by M. Foucault, and his ideas have been improved upon by Mr. Holmes in England, and by Messrs. Serrin and Dubosc in France.

The light is produced by a powerful current of electricity between two points of pure carbon, which at first are made to touch and are then separated to a short distance, when a brilliant arc of flame, consisting of minute particles of ignited carbon, is sustained between them. The carbon points are both gradually consumed, but the consumption of the point connected with one pole of the battery is more rapid than that of the other, and the steady brilliancy of the light is contingent upon the exact distance at which the maximum light is obtained, being preserved between the charcoal points. The problem to be solved therefore was to preserve the centre of the space between the points always opposite the centre of the reflector, while the points were kept at a constant distance from one another.

The details of the mechanism by which this has been effected differ

slightly in different electric lamps, but the general principle of their action is this—

An electro-magnet forms a part of the circuit of the current of electricity producing the light. The strength of a current, you will remember, is inversely proportional to the resistance opposed to it. In this case the resistance in the circuit increases as the charcoal points are consumed and the space between them increases. When from this cause the current is reduced below a certain point the electro-magnet so far loses its force that a spring, always acting in opposition to the magnet, withdraws a soft iron armature from it, and in so doing releases clockwork which is arranged so as to move the two points towards each other, but one more rapidly than the other. As they approach the resistance is diminished, the current becomes stronger, and the magnet again attracts its armature and stops the clockwork, and so on. This arrangement with various adjustments has now been rendered so perfect that the variations in the light due to the alternations in the strength of the current are imperceptible, and its brilliancy is practically constant.

The rays are all gathered and thrown in any desired direction by a reflector, which may be made paraboloidal if the rays are to be thrown parallel to one another, or hyperboloidal if they are to be slightly dispersed. For the defence of fortresses such lamps would no doubt be disposed behind iron shields, or in cupolas, throwing their rays of light through a small orifice, which it would be very difficult for an enemy to hit by his distant fire.

I have now brought before you, as fully as time would permit, the four principal military applications of electricity, viz., the ignition of gunpowder by electricity, the electric telegraph, the electro-ballistic pendulum, and the electric light; illustrating the conversion of the electric force into heat and light and mechanical force, and thus exemplifying the wonderful unity of the works of God in creation, and the immense variety in the modes of his working.

The peculiar advantage of this form of force is that it produces the required effects at a distance from the source, and instantaneously. Electricity cannot be economically employed to produce heat or mechanical forces near at hand; other more simple and ordinary means are in such cases either great in amount, or almost invariably superior to it; but when time and distance are to be overcome rather than great effects produced, the value of electricity is fully developed.

CAIL'S RIFLED PROJECTILES, FOR SMOOTH BORE GUNS

Front & Rear.

Section in Centre.

1

Front.

Rear.

2

Rear.

Centre

3

End View.

4

Section at A.B.

5

E. Steel or Iron Point and Stalk.
D. Iron or Oak Pin through Stalk or Point.

C. Cap over Touch Hole or Neck of Shell.
F. Screw Plug for Liquid.