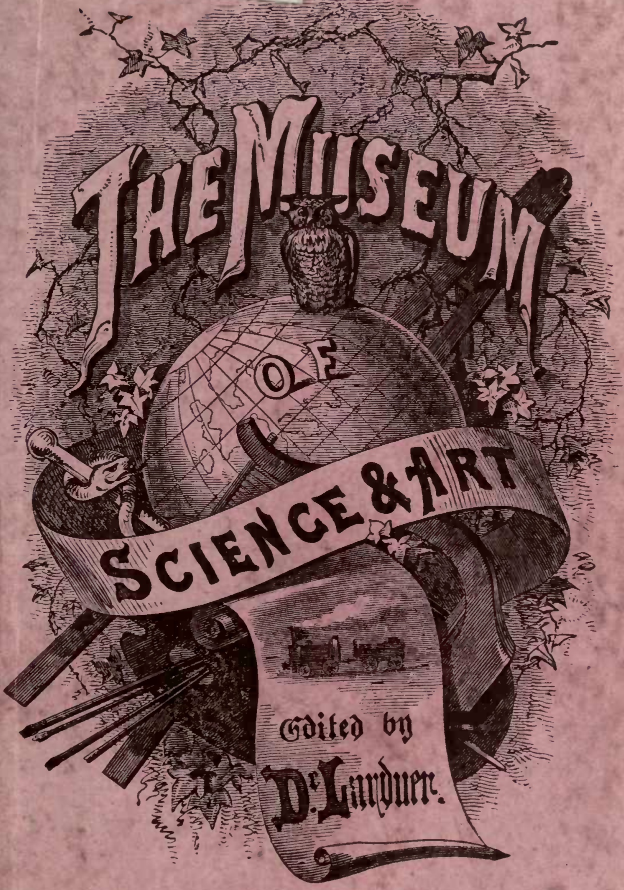


LONDON
WALTON AND MABERLY,
UPPER GOWER STREET & IVY LANE.

Price Eighteenpence.

EDITED BY

DIONYSIUS LARDNER, D.C.L.,

Formerly Professor of Natural Philosophy and Astronomy in University College, London.

ILLUSTRATED BY ENGRAVINGS ON WOOD.

VOL. IV.

LONDON:

WALTON AND MABERLY,

UPPER GOWER STREET AND IVY LANE, PATERNOSTER ROW.

1854.

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

CONTENTS.

THE ELECTRIC TELEGRAPH.

EARTHQUAKES AND VOLCANOES.

THE BAROMETER.

THE SAFETY LAMP.

STEAM.

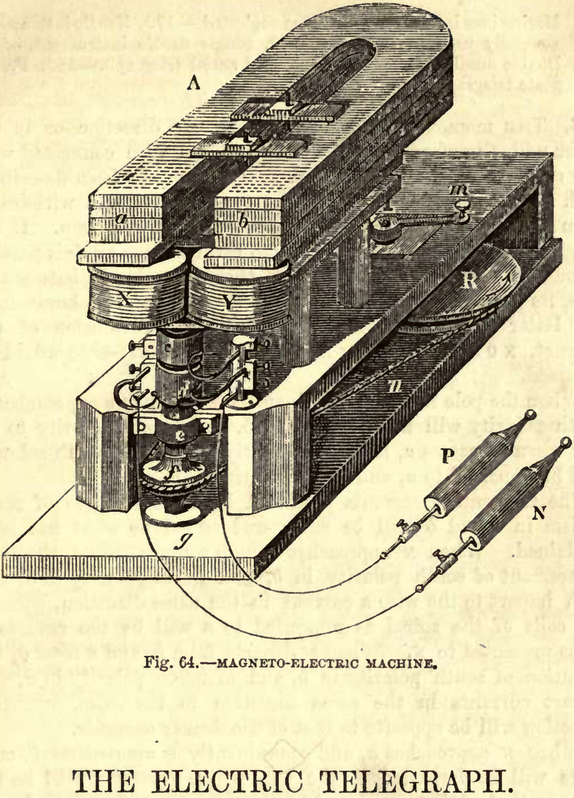


Fig. 64.—MAGNETO-ELECTRIC MACHINE.

THE ELECTRIC TELEGRAPH.

CHAPTER VII.

163. Momentary currents alternately in contrary directions.—164. Method of producing momentary currents all in the same direction.—165. Magneto-electric machine.—166. Its effects in producing shocks and currents.—167. Method of applying it to telegraphs.—168. Chemical property of the current.—169. Decomposition of water.—170. Application of this property to produce written characters at a distance.—171. Methods of moving the paper under the style.—172. Telegraphic characters marked upon it.—173. Use of relay magnets in cases of feeble currents.—174. Form and application of them.—175. Telegraphic lines constructed by companies in England and America, and chiefly by the state on the continent.—176. Various forms of instruments used.—177. Influence of national feeling.—178.

163. THE momentary currents in the one direction or in the other will, therefore, be produced upon the wire connected with the extremities of the coil, such as have already been described, each time the poles, N and S, are presented to and withdrawn from the ends, *a* and *b*, of the horse-shoe of soft iron. If the magnet, N O S, were mounted so as to revolve upon an axis passing through the centre of its bend, and therefore midway between its legs, its poles might be made to pass the ends of the horse-shoe, the latter being stationary. During each revolution of the magnet, N O S, the polarity imparted to the horse-shoe would be reversed.

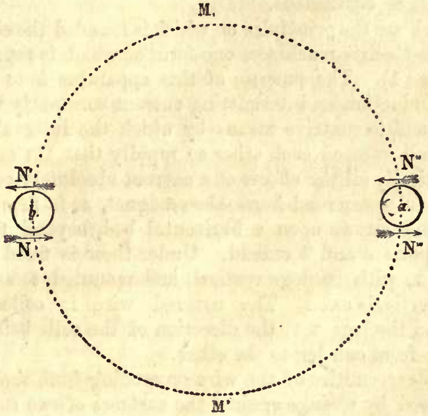
When the pole N approaches *b*, and consequently S approaches *a*, south polarity will be imparted to *b*, and north polarity to *a*; and when N passes *a*, and consequently S passes *b*, south polarity will be imparted to *a*, and north polarity to *b*.

The momentary currents produced by these changes of magnetism in *a* and *b* will be easily understood by what has been explained. When N approaches *b*, and S approaches *a*, the commencement of south polarity in *b*, and north polarity in *a*, will both impart to the wire a current in the same direction, because the coils of the spiral as presented to S will be the reverse of those presented to N. When N departs from *b*, and S from *a*, the cessation of south polarity in *b*, and of north polarity in *a*, will impart currents in the same direction to the wire, but this direction will be opposite to that of the former currents.

When N approaches *a*, and consequently S approaches *b*, currents will be imparted to the wire whose direction will be the same as that of those produced by the departure of N from *b*, and of S from *a*. When N departs from *a*, and S from *b*, currents will be produced in the same direction as when N approaches *b* and S approaches *a*.

If the direction of the currents produced when N approaches *b*, and S approaches *a*, be indicated by an arrow directed to the right, and that of those produced when N departs from *b*, and S from *a*, by an arrow directed to the left, the changes of direction which take place in each revolution of the magnet N O C, will be such as are indicated in fig. 63, where *b* and *a* represent the ends of the horse-shoe, *b a*; N the position of the pole in approaching, and N′ in departing from *b*, and N″ its position in approaching, and N‴ in departing from *a*. The arrows directed to the right express the direction of the two currents which are produced upon the conducting wire, while N makes the half revolution N‴ M′ N; and the arrows directed to

Fig. 63.



left express the direction of the two currents produced, while N makes the half revolution N′ M N″.

Thus it appears that in each revolution of the magnet, N O S, four momentary currents are produced in the wire, two in one direction during one semi-revolution, and two in the contrary direction during the other semi-revolution. In the intervals between these momentary currents there is a suspension of voltaic action.

164. It has been already shown how electric currents may be instantaneously suspended, re-established, and reversed in their direction by means of commutators (111). By such an expedient properly adapted, it is easy to understand that by suspending the currents in one of the two contrary directions, while the other is allowed to pass, an intermitting current always running in the same direction may be obtained. Or if the commutator be so adapted that while the momentary currents in one direction are allowed to run without interruption, those in the other direction shall be reversed, we shall then have in each revolution four momentary currents flowing in a common direction. The current thus produced will be intermitting, that is, it will pass upon the wire by a succession of pulsations or intervals of transmission and suspension, but since in each revolution of the magnet there are two pulsations,—that is, two intervals of transmission and two of

suspension,—and since the rotation of the magnet may be made with any desired rapidity, it follows that the pulsations will succeed each other with such celerity, and the intervals of suspension will be so brief that for all practical purposes the current will be continuous.

165. Such are the principles on which is founded the construction of magneto-electric machines, one form of which is represented in fig. 64 (page 1). The purpose of this apparatus is to produce by magnetic induction an intermitting current constantly in the same direction, and to contrive means by which the intervals of intermission shall succeed each other so rapidly that the current shall have practically all the effects of a current absolutely continuous.

A powerful compound horse-shoe magnet, A, is firmly attached by bolts and screws upon a horizontal bed, beyond the edge of which its poles *a* and *b* extend. Under these is fixed an electro-magnet X Y, with its legs vertical, and mounted so as to revolve upon a vertical axis. The covered wire is coiled in great quantity on the legs X Y, the direction of the coils being reversed in passing from one leg to the other.

The two extremities of the wire proceeding from the legs X and Y are pressed by springs against the surfaces of two rollers, *c* and *d*, fixed upon the axis of the electro-magnet. These rollers themselves are in metallic connection with a pair of handles P and N, to which the current evolved in the wire of the electro-magnet X Y will thus be conducted.

If the electro-magnet X Y be now put in rotation by the handle *m*, the handles P and N being connected by any continuous conductor, a system of intermitting and alternately contrary currents will be produced in the wire and in the conductor by which the handles P and N are connected. But if the rollers *c* and *d* are so contrived that the contact of the ends of the wire with them shall be only maintained during a semi-revolution in which the intermitting currents have a common direction, or so that the direction during the other semi-revolution shall be reversed, then the current transmitted through the conductor connecting the handles P and N will be intermitting, but not contrary; and by increasing the velocity of rotation of the electro-magnet X Y, the intervals of intermission may be made to succeed each other with indefinite celerity, and the current will thus acquire all the character of a continuous current.

The forms of commutators by which the rollers *c* and *d* are made to break the contact, and re-establish it with the necessary regularity and certainty, or to reverse it during the alternate semi-revolutions are various.

166. All the usual effects of voltaic currents may be produced

with this apparatus. If the handles P and N be held in the hands, the arms and body become the conductor through which the current passes from P to N. If X Y be made to revolve, shocks are felt, which become insupportable when the current has a certain intensity.

If it be desired to give local shocks to certain parts of the body, the hands of the operator, protected by non-conducting gloves, direct the knobs at the ends of the handles to the parts of the body between which it is desired to produce the voltaic shock.

167. For telegraphic purposes it will be sufficient to place the line wire in connection with one of the handles P or N, while the other handle is in connection with the earth. A current will then be transmitted on the line wire which will be intermitting, but which may be rendered continuous by a combination of magneto-electric machines.

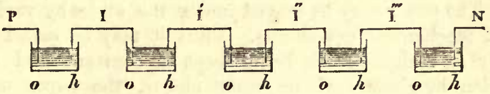
168. It remains, in fine, to show how the chemical properties of the electric current can be made to supply the means of transmitting signals between two distant stations.

When a current of adequate intensity is made to pass through certain chemical compounds it is found that these are decomposed, one of their constituents being carried away in the direction of the current, and the other in the contrary direction.

169. One of the most striking examples of the application of this principle is presented in the case of water, which, as is well known, is a compound of the gases called oxygen and hydrogen.

Let us suppose that a series of cups, *oh*, fig. 65, containing water are placed so that an electric current shall pass successively through them, commencing at the wire P and passing at *o* into the first

Fig. 65.



cup; thence through the water to *h*, and from *h* along the wire I to *o* in the second cup; thence in like manner through the water to *h*, and then along the wire I′, and so on to N, the wire P being supposed to be connected with the positive pole of a battery, and the wire N with its negative pole. The current will therefore flow from P to N passing through the water in each of the cups. Under such circumstances the water will be gradually decomposed in each of the cups the particles of oxygen moving against the course of the current, and those of hydrogen moving with it, the former are evolved at the points *o*, and the latter at the points *h*.

170. To show how this property of the current may be made to produce visible marks or signs, let us suppose a sheet of paper wetted with an acidulated solution of ferro-prussiate of potash to be laid upon a plate of metal, and let the point of a metallic style be applied to it so as to press it gently against the metallic plate without piercing it. Let the style be now put in metallic connection with the wire which leads to the positive pole of a voltaic battery, and let the metallic plate upon which the paper is laid be put in connection with the wire which leads to the negative pole. The current will, therefore, flow from the style through the moistened paper to the metallic plate, and it will decompose the prussiate, one of the constituents of which deposited on the paper will mark it with a bluish spot.

If the paper be moved under the style while the current flows, this decomposition being continued under the point of the style a bluish line will be traced upon the paper.

If while the paper is thus moved uniformly under the style, the current is permitted to flow only during intervals long or short, the paper will be marked by lines long or short, according to the intervals during which the current flows; and, since no decomposition takes place during the suspension of the current, the paper then passes under the style without receiving any mark. If the current be permitted to flow only for an instant, the paper will be marked by a dot. The long or short lines and dots, thus traced upon the paper, will be separated one from another by spaces more or less wide according to the lengths of the intervals of suspension of the current.

It is evident that the same effects will be produced, whether the style be at rest and the paper moved under it as is here supposed, or the paper be at rest and the style moved over it.

171. The paper may be moved under the style by various and obvious mechanical expedients. Thus it may be coiled upon a cylinder or roller, which being kept in constant and uniform revolution by clock-work or other means, the paper would be carried continually under the style, and unrolled from the cylinder after receiving the marks. Or the cylinder covered with paper might, while it revolves, receive a slow motion in the direction of its axis, so that the course of the style upon it would be that of the thread of a screw or helix. The paper might be cut into the form of a large circular disc, and laid upon a metallic disc of equal magnitude, to which a motion of revolution round its centre in its own plane might be imparted by clock-work; while the style might receive a slow motion directed from the

centre of the disc towards its edge. In this case the style would trace a spiral curve upon the paper, winding round it continually, and at the same time retiring constantly but slowly from its centre towards its edge.

172. Whichever method might be adopted, the paper would be marked with a continuous succession of combinations of lines of varying lengths and dots, separated by spaces more or less wide. These marks depending altogether on the succession of intervals of suspension and transmission of the current, which intervals can be varied and combined at will by an operator supplied with the means of controlling the current which have been already explained, it will be easily conceived that an agent at S can trace upon paper placed at S″ in the manner here described such a succession of characters composed of lines and dots as he may desire; and that an operator at S″, being supplied with a key, may interpret these characters, and thus translate the communication into ordinary language.

It is also easy to conceive that the agent at S can stop the clock-work which moves the paper at S″ or set it going at will, in the same manner as he can ring a bell or discharge a cannon.

173. It has been already explained that the intensity of the current transmitted by a given voltaic battery along a wire of given thickness must decrease in the same proportion as the wire increases in length. This loss of intensity due to the length of the wire is increased in the practical operation of the telegraphs by the loss of electricity arising from imperfect insulation and other inevitable causes. It has therefore become a matter of great practical importance to discover expedients by which the intensity of the current may be re-established, or by which the apparatus may be worked by a very feeble current.

It was obvious that the intensity might be maintained at the necessary degree of force by providing, as already stated, relay batteries at intermediate stations sufficiently near each other to prevent the current from being unduly enfeebled. But the maintenance of such numerous batteries in cases where great distances must be traversed is expensive, and it was desirable to discover some more economical expedient.

174. The properties of the electro-magnet have supplied the means of accomplishing this.

The lever *g h* (fig. 58) may be constructed so light and so free, that it will be capable of being moved by a current of extremely feeble intensity. But if this lever were charged with any of the functions by which it would become an instrument for giving signals, such as the ringing of a bell or the motion of a style or pencil, it would be necessary to impart to the electro-magnet and its other appendages much greater power. So long, however, as no more is required than to make it oscillate between the stops t and t', it may be constructed and mounted so as to be moved by the most feeble degree of magnetism imparted to m m' by a current of extremely low intensity.

Now let us suppose the axis o of the lever g h to be in metallic connection with a voltaic battery placed near to it at the station S′, and let the stop t' be in connection with the conducting wire which extends to another more distant station S″. When the end g of the lever is brought into contact with the stop t', the current produced by the battery at S′ will flow along the conducting wire to S″; and when the lever deserts the stop t', and is thrown upon t, the contact being broken, the current is suspended.

Now it is evident that by this means the original current flowing from the battery at the station S to the station S′ is the means of calling into action another current, which flows from the relay battery at the station S′ along the conducting wire to the station S″, and that the intensity of this current will not be affected in any way by that of the original current from S to S′, but will depend solely on the power of the relay battery at S′, and the length of the conducting wire from S′ to S″.

In the same manner another relay battery may be provided at S″, and so on.

In this succession of independent currents, those only which have signals to work need to have a greater intensity than that which is sufficient to give motion to a light lever, such as we have described above.

It will be evident also by what has been stated that the pulsations given to the original current at S, and the succession of intervals of transmission and suspension will be reproduced with the most absolute precision in all the succeeding currents, so that all signals which depend on these intervals of transmission and suspension will be made at the final station as promptly and exactly as if the original current from S to S′ had been continued throughout the entire line of communication with all the necessary intensity.

---

175. The lines of electric telegraph which have been constructed and brought into operation in different parts of the world, like the lines of railway, have been established in some by private companies, and in others by the state. In the United Kingdom and its dependencies and in the United States they have been in all cases established by the enterprise and capital of joint-stock

companies chartered or incorporated by the legislature, subject to certain conditions. On the continent of Europe generally they have been constructed and are exclusively worked by the state, but are placed under specified conditions and subject to regulated tariffs at the service of the public.

176. The forms of telegraphic instruments to which a preference has been given, in different countries are very various. In the United Kingdom and the United States, the several joint-stock companies by whom telegraphic lines have been constructed, have been generally formed by the friends and partisans of the inventors of particular telegraphic instruments, of which the companies have become severally the patentees. To these instruments they naturally have given a preference, in some cases irrespective of their merits, and as a necessary consequence every such company is more or less opposed, as well by interest as by prejudice, to other inventions and improvements. It has been a matter of complaint that such companies have sometimes become the purchasers of patented inventions for no other purpose than that of their suppression; and it is easily conceivable that a company having an extensive establishment in profitable operation may find it more advantageous to maintain their existing apparatus than to put them aside for others even of very superior efficiency. This is, after all, no more than what has occurred in the progress of all great inventions and improvements.

177. National feeling has, however, also had a considerable influence on the selection of the forms of telegraph adopted in different countries. Thus we find the telegraphs adopted in England exclusively English inventions; those generally adopted in France, French inventions; and those adopted in the United States, generally American inventions.

178. Amidst those conflicting motives directing the choice of companies and of governments, several inventions of great merit have necessarily been either wholly neglected, or bought up and wilfully suppressed, or in fine, brought into operation on a very limited scale.

The vast resources supplied by the discoveries by which physical science has been enriched since the beginning of the present century, and the fertility of genius directed to the application of these resources in all countries, has produced a swarm of inventions, even the least efficient of which possess great merits on the score of ingenuity and address in the application of physical principles. Our limits, the purposes to which this series is directed, and the large and various classes to which it is addressed, compel us to pass without notice many forms of telegraph which have been contrived and constructed. We shall therefore confine our observations to those apparatus which have been actually employed on the telegraphic lines established in different countries, and a very few others which appear to claim more especial attention.

On the claims of various projectors on the score of original invention, we must generally decline to enter. To discuss such questions so fully as to render justice to the claimants would require much more space than we can devote to the subject; and however interesting such a discussion might be to the inventors themselves and their partisans, it would offer but few attractions to the masses to whom our "Museum" is addressed.

We shall therefore first explain briefly the forms of telegraph generally applied in this country, and next those which are in operation elsewhere.

179. The telegraphic instruments used almost exclusively in this country are galvanometers (138), which make their signals by means of the deflections of magnetic needles, produced by the electric current.

These instruments are of two forms, the first, and most simple, consisting of one needle with its appendages and accessories, and the other of two independent needles, each accompanied by its own appendages.

THE SINGLE NEEDLE INSTRUMENT.

180. This instrument consists of a galvanometer and a commutator, mounted in a case resembling in form and size that of an ordinary table time-piece.

A front view of it is given in fig. 66 (vol. iii. p. 161). On the upper part is a dial, in the centre of which the indicating needle appears, like the hand of a clock, fixed upon an axis. Its play to the right and left is limited by two ivory studs inserted in the face of the dial, a short distance on each side of its upper arm.

The handle which works the commutator, also fixed upon an axis, is presented at the lower part of the case, under the dial.

Upon the dial are engraved the letters of the alphabet, the ten numerals, and one or two arbitrary symbols, under each of which is engraved a mark, indicating the motions of the needle, by which the letter or figure is expressed.

The galvanometer, constructed as already explained (140), is attached to the back of the dial, the axis of its magnetic needle passing through the dial and carrying the indicating needle in front.

The latter is also usually magnetic, its poles being reversed in their direction with relation to those of the interior needle, the effect of which is, that the current transmitted through the galvanometer has a tendency to deflect both needles in the same direction. The indicating needle, however, need not be magnetic. If it be sufficiently light, being free from magnetism, it will be carried by the axis to the right or left against the studs, by the deflections of the galvanometric needle which plays within the coils of the galvanometer, to which it is always parallel.

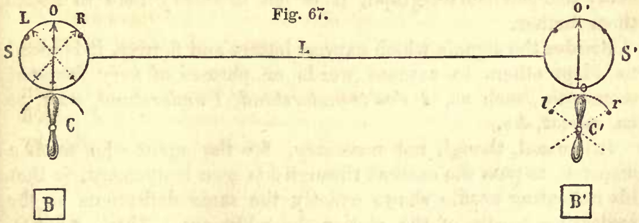
In connection with the instrument there are, as usual, an alarum and a galvanic battery.

By the commutator, the current produced by the battery may be transmitted upon the line-wire, or suspended or reversed in its direction, according to the position given to the handle. If the handle be vertical, as represented in the figure, the current is suspended, the arrangement of the commutator being then such as to cut off all communication between the battery and the line-wire. If the upper arm of the handle be turned to the right, the battery will be connected with the line-wire, on which accordingly the current will be transmitted. If the upper arm be turned to the left, the battery will still be connected with the line-wire, but with its poles reversed, so that the direction of the current on the line-wire will be reversed.

The mechanical form of the commutator, by which these changes of connection are made is different from that explained in (111), but the principle is the same, and the variation of the details are unimportant.

To comprehend the practical operation of the instrument, we are to consider that similar instruments, with similar accessories, are placed at each of the stations, between which dispatches are to be transmitted. To render the explanation more clear, let S and S′, fig. 67, be the two stations, O and O′ the dials, C and C′

Fig. 67.



the handles of the commutators, and B and B′ the galvanic batteries. If it be intended to send a dispatch from S′ to S, the arm of the commutator, C, is left in its vertical position, so that no current can pass from the battery, B, to the line-wire, L.

When the arm of C′ is vertical, no current can pass from B′ to L, and consequently the needle of O will remain in the vertical direction, without deflection. If the upper arm of C′ be turned to the right, *r*, the current from B′, passing along L, will flow through the coil of the galvanometer at S, and will deflect the indicating needle to the right, so that it will lean upon the right hand stud, R. If C′ be then turned back to the vertical direction, the current will be suspended, and the needle at S will return to the point O. If the upper arm of C′ be then turned to the left, *l*, the current will be again transmitted upon the line-wire, L, but in a direction contrary to its former course, and thus passing through the galvanometer at S, in a contrary direction, the needle, which was before deflected to the right hand stud, R, will now be deflected to the left hand stud, L.

Thus, it appears, that according as the upper arm of C′ is turned to the right or left, or placed in the vertical position, the needle on the dial at S, is also turned to the right or left, or placed in the vertical position.

In a word, whatever position is given to the handle of the commutator at S′, a corresponding position is assumed by the indicating needle at S, and these changes of position of the indicating needle at S, are absolutely simultaneous with the changes of position of the handle of the commutator at S′.

The manner of expressing the letters and figures, is by making repeated deflections of the needle right and left, making a short pause at the end of each letter signal. Thus two deflections to the left express A; three, B; four, C; while one expresses the completion of a word. One to the right expresses M; two, N; three, O; and four, P. In the same manner, L is expressed by four deflections, which are, successively, right, left, right, and left.

As these signs are purely arbitrary, and may be changed in every independent telegraph, it is not necessary here to notice them further.

Besides the signals which express letters and figures, it is usual to adopt others to express words or phrases of very frequent occurrence, such as, *I don't understand*, *I understand*, *wait*, *go on*, *repeat*, &c.

It is usual, though not necessary, for the agent who sends a dispatch, to pass the current through his own instrument, so that his indicating needle shows exactly the same deflections as the indicating needle of the station he addresses. Thus, when S′ addresses S, his own indicating needle, O′, speaks as well as the indicator, O, of the station, S.

All that has been stated in (111) *et seq.* of the transmission of the same despatch through a series of stations, of cutting off the transmission from all stations except that to which it is exclusively addressed, of the use of the alarum, &c., is applicable, without any important modification to this form of telegraphic instrument.

THE DOUBLE NEEDLE TELEGRAPH.

181. This is nothing more than two single needle telegraphs, such as has been just explained, mounted in the same case, their indicating needles playing side by side upon the same dial, and the handles of their commutators placed so that they can be conveniently worked at the same time, by the right and left hand of the telegraphic agent. Each instrument is altogether independent of the other, having separate accessories, and transmitting its current upon a separate line-wire.

The purpose of this form of instrument is merely to accelerate the transmission of dispatches, by enabling the agent to produce the signals expressing letters and figures in more rapid succession. In the single instrument there are only *two* signs made by one deflection of the needles, viz., a deflection to the right and one to the left. In the double instrument there are *eight* such signs, viz., two with each needle, as in the single instrument, and four obtained by combining the deflections of the two needles. Thus, if O express the position of the needle without deflection, *r*, a right hand, and *l* a left hand deflection, and R the right hand, and L the left hand needle, the following eight signals may be made in the time of a single motion of either needle.

L	R
r	0
l	0
0	*r*
0	*l*
r	*r*
l	*l*
r	*l*
l	*r*

With a single needle two deflections can only make four signals, viz., *r r*, *l l*, *r l*, *l r*. But with two needles, these being combined with single deflections and with each other, a greater number of different signals can be obtained than are sufficient to express the letters and numerals, each being made in the time necessary for two deflections of a single needle.

A front view of a double needle telegraph is given in fig. 68 (vol. iii. p. 177).

The small case at the top contains the alarum, and the small handle at the side of the large case is the commutator by which the current is turned on and off the alarum. The two large handles which appear in front are those of the commutators, which produce the changes of direction of the current, and when inclined to the right or left the needles acted on by the current assume a like position.

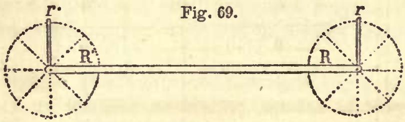
FRENCH STATE TELEGRAPH.

182. When the establishment of lines of electric telegraphs was proposed in France, the old aerial telegraph was, and had been for more than half a century, in operation, and formed a department in the public administration of considerable importance, employing an extensive body of agents, dispersed throughout the country, most of whom were specially instructed and qualified for the business.

The commission appointed by the government required that the electro-telegraphic instruments should exhibit the same signals as had been already used in the case of the former telegraph.

The old telegraph consisted of a long straight bar, R R′, fig. 69, called a regulator, to the extremities of which two shorter bars, $r\,r'$, called indicators, were attached by pins or pivots, so that each indicator was capable of turning on its pivot, so as to make any desired angle with the regulator.

Fig. 69.



If we suppose the circle described by each indicator to be divided into eight equal arcs of 45°, and that any convenient mechanism is provided, by which the agent who conveys the signals can at will give to each indicator any of these eight positions, each indicator would be capable of making eight signals, and by combining these in pairs, the two indicators worked together would be capable of giving sixty-four signals.

It is evident that even this large number of signals might be further multiplied, by giving to the regulator itself a motion round its centre, so that it might at will assume the horizontal or vertical position, or might take an intermediate direction.

In transferring this system of signals to the electric telegraph, the regulator is supposed to be placed permanently horizontal, and the two indicators to be capable of receiving any of the eight positions here explained.

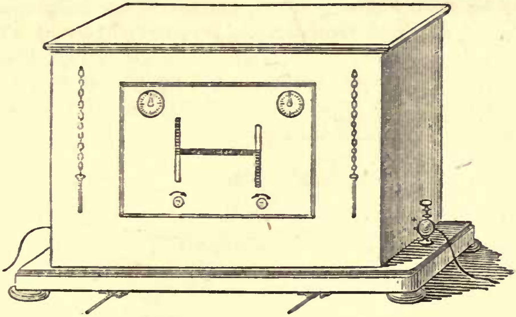
183. The telegraph contrived by M. Breguet, to exhibit such a system of signals, consists, like the double needle telegraph, of two distinct and perfectly similar instruments, one for each of the indicators. They are mounted side by side with their accessories in the same case, at a distance apart sufficient to allow the indicators to revolve without mutual obstruction, and sufficiently near each other to allow the same person to work both at the same time with his right and left hand.

Each instrument consists of an indicating apparatus and a commutator.

If s and s′ be two stations, between which dispatches are transmitted, the commutator at s moves the indicator at s′, and the commutator at s′ moves the indicator at s.

A view of the indicating apparatus is given in fig. 70. The two indicators are fixed upon axes placed in the same horizontal

Fig. 70.



line upon the dial. These axes, passing through the dial, carry behind it two escapement wheels, which are controlled by two anchors, as described in 151. These anchors are moved by the armatures of two electro-magnets, from which they receive vibrations, like those of a pendulum. The escapement wheels are impelled by the force of two main-springs, transmitted to them by two similar trains of clock-work.

Thus, for each swing of the anchor, the indicator makes one motion forward, and as the escapement wheels have each only four teeth at equal distances, one complete revolution of these wheels must cause the indicators to make a complete revolution by eight distinct motions, produced by the four swings of the anchor to the right, and the four swings to the left.

During a revolution of each of the escapement wheels, therefore, each of the indicators takes successively the eight positions required in the proposed system of signals, and since the motions of the indicators are governed by the anchors, those of the anchors by the armatures of the electro-magnets (154), and those of the electro-magnets by the successive pulsations of the electric current, it follows that if it can be contrived that commutators at one of the stations shall govern the pulsations of the current at the other, they will necessarily govern the motion of the indicators at that other station.

At the upper corners, right and left of the front of the case, are two dials, in the centre of which are axes, which act, when turned, upon the springs which draw back the armatures of the two electro-magnets, and near them keys for their adjustment are suspended by chains. The springs are raised or relaxed, according as the keys are turned in the one direction or the other.

Under the indicating arms are two axes with square ends, by which the two systems of clock-work can be wound up, which is done by the same keys.

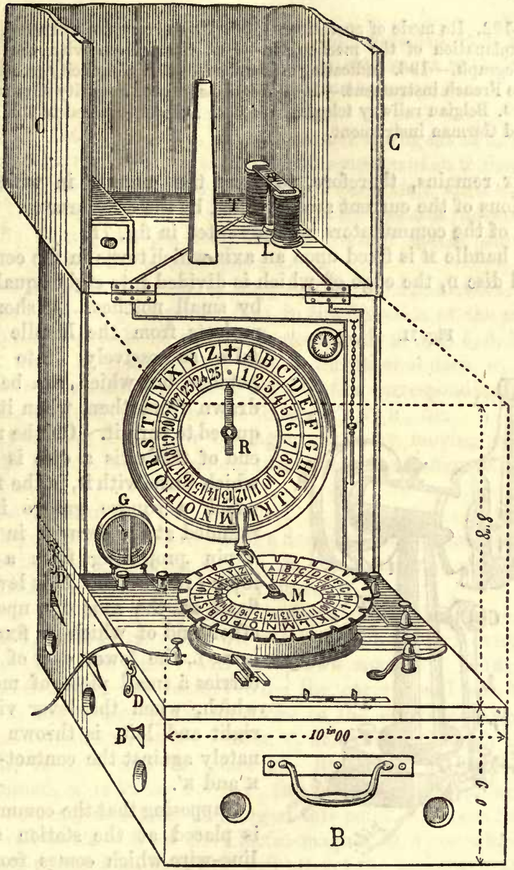


Fig. 74.—FRENCH RAILWAY TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER VIII.

184. Form of commutator of French state telegraph.—185. Its operation.—186. Method of sending and receiving a despatch.—187. Batteries.—188. French railway telegraph.—189. French railway portable telegraph.—190. German railway telegraph.—191. Siemens' instrument.

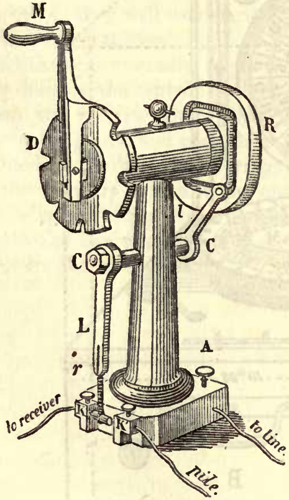
—192. Its mode of operation.—193. How errors are corrected.—194. Explanation of the mechanism.—195. Comparison with the French telegraph.—196. Indicating mechanism.—197. Simplicity greater than the French instrument.—198. Requires greater intensity of current.—199. Belgian railway telegraph.—200. Defects imputed to the French and German instrument.

184. It remains, therefore, to show the manner in which the pulsations of the current are governed by the commutator.

One of the commutators is represented in fig. 71.

The handle M is fixed upon an axis which turns in the centre of a fixed disc D, the edge of which is divided into eight equal parts by small notches. A short pin projects from the handle which falls successively into these notches, but which can be withdrawn from them when it is required to turn it. On the remote end of this axis a disc is fixed, which turns with it, in the face of which a square groove is cut, rounded at the corners, in which a pin projecting from a short lever *l* is moved. This lever *l* is fixed on the axis C C, upon the other end of which is fixed the lever L, the lower end of which carries a small piece of metal *r*, which, when the lever vibrates right and left, is thrown alternately against the contact-pieces K and K′.

Fig. 71.



Supposing that the commutator is placed at the station S, the line-wire which comes from the station S′ enters the foot, and is held there by a tightening screw A. This wire is in metallic connection, through the pillar, with the lever L, and consequently with the piece of metal at its lower end, which oscillates between the contact-pieces K and K′. This piece of metal, *r*, may therefore be considered as virtually the extremity of the conducting wire between the stations S and S′.

Attached in like manner, by tightening-screws, to the two contact-pieces K and K′ are two wires, one of which is connected with the battery, and the other with one end of the coil-wire of the electro-magnet, in the indicating instrument of the station S.

The other end of this coil-wire is either connected with the line-wire which proceeds to the succeeding station, or with the earth, at the option of the agent, a commutator being provided by which this change of direction may be made.

185. Let us see, then, in what manner the agent at S, provided with such a commutator, can govern the motion of an indicator at S′.

The arrangement of the apparatus is such, that when the handle M of the commutator is presented vertically upwards, as represented in the figure, the pin being in the highest notch, the lever L presses against the contact-piece K.

Let the highest notch be supposed to be numbered 1, and the others proceeding round the disc, in the direction of the motion of the hand of a clock, be numbered successively 2, 3, 4, 5, 6, 7, and 8.

It must be remembered, that at the other station, S′, there is another commutator precisely similar, the corresponding points of which we shall express by the letters M′, D′, R′, &c.

Let us see, then, how the agent at S, by moving round the handle M from notch to notch, can govern the motion of the indicator at S′.

The commutator and indicator at the station S′, when not employed in the transmission of a despatch, are placed respectively with the arm M′, having its pin in the notch 1′, and the hand of the indicator directed vertically upwards.

186. The arm M being, as represented in the figure, in the notch 1, let it be moved to the notch 2. The lever L being moved to the right, the piece *r* will be thrown upon K′. Being then in connection with the battery-wire, the current will pass by *r* and L to A, and thence by the line-wire to the corresponding point A′ of the commutator at the station S′, and thence through the pillar to the lever L′ and the piece *r*′. But since, as has been just explained, M′ is in the notch 1′, the piece *r*′ must rest against K. The current, therefore, arriving at this point, will pass from K by the wire to the coil of the electro-magnet at S′, to which it will impart magnetism, so that it will attract the armature, and move the anchor of the escapement, so as to make the indicator move from the vertical position 45° in the direction of the hand of a clock.

If the handle M be now moved from notch 2 to notch 3, the lever L will be thrown back to K, and the contact with K′ being broken, the current will be suspended, and the electro-magnet at S′ losing its power, the armature will recoil from it by the action of the spring (147) and the anchor of the escapement being again moved, the indicator will be advanced through another angle of 45°, and will be then in the horizontal position pointing to the right.

In like manner, it may be shown that when the arm M is moved from the notch 3 to the notch 4, the indicator at S′ will be moved from the horizontal position to one which will make an angle of 135°, with its original direction, or what is the same, 45°, with the position in which it would point directly downwards.

Without pursuing this explanation further, it will be easy to see that the successive positions assumed by the hand of the indicator at S′ correspond with those given to the arm M of the commutator at S.

We have here explained the action of one commutator at S upon one indicator at S′. The action of the other commutator at S upon the other indicator at S′ is precisely the same. It must be understood, that the two commutators at S are connected with separate and independent line-wires, are supplied with separate and independent batteries, and act upon separate and independent indicators at S′. The right-hand commutator at S is connected with the right-hand indicator at S′, and the left-hand commutator with the left-hand indicator.

From what has been explained, the process necessary, as well for receiving as for transmitting a despatch will be understood. In the reception of a despatch, the agent has only to place the handle of his commutator in notch 1, and to see that his indicator is vertical. After that he has only to observe the successive attitudes assumed by the two indicators upon the dial before him, and to write down the letters they successively express.

Since this form of telegraph gives 64 signs, while 26 are sufficient for the alphabet, and 10 for the numerals, there are 24 signs disposable for abridgements, such as syllables, words, and phrases of most frequent occurrence.

187. The battery employed in working these telegraphs is at present invariably that of Daniel (32). Formerly Bunsen's battery (34) was used at chief stations, where great power is often required, but this has now been discontinued.

Between the point K′ and the battery a commutator is placed, by means of which the agent can bring into action a greater or less number of the pairs composing the battery, so as to proportion the power to the distance to which the current is to be transmitted, or to the resistance it may have to overcome.

A perspective view of the telegraphic instrument, showing the two indicators and two commutators, in their respective positions, is given in fig. 72 (vol. iii. p. 193).

FRENCH RAILWAY TELEGRAPH.

188. The telegraphs which convey letters or words by conventional signals, like those described above, require a staff of agents

engaged in their management, who have been specially instructed and practised, as well in working the instruments as in interpreting their signs. That this is deemed a matter of great practical importance in telegraphic economy is manifested by the fact already mentioned, that the French government, before it resolved to establish the electric telegraph, caused instruments, on the new principle, to be constructed, by which the same system of symbols could be used as that which had been previously adopted in the semaphore.

Nevertheless, in cases like that of a system of telegraphs in which not only the business of the state, but that of the public, is to be transacted, and where, therefore, a permanent staff is employed exclusively in the management of the apparatus, no very serious difficulty can be encountered, even if the necessity of having a new telegraphic vocabulary is imposed upon these agents. For a short time the service will be slow, and less satisfactory, but the inconvenience is temporary, and constant practice in the manipulation of the apparatus, and in the interpretation of the signs, whatever they may be, renders the agents sufficiently expert.

The case is different with telegraphs used, not for state or commercial purposes, but exclusively for railway business. The telegraphs even of principal railway stations, and still less those of secondary stations, are not in that constant requisition, and consequently do not occupy a permanent and exclusive class of agents. They are managed by any persons who happen to be employed in the respective offices: by the station-masters, clerks, railway police, guards, or, in short, by any railway agent who may happen to be at hand. Now it is evident that telegraphic instruments, the use of which would require special instructions, and much previous practice, would not answer such a purpose.

These considerations have prevailed, with the administrations of the lines of railway in all parts of the continent, and have led them to adopt telegraphic instruments which satisfy the conditions explained above, more completely than do the apparatus which have been adopted for state and public communications.

In general the railway telegraphs are of the class called "letter or alphabetic telegraphs." The agent who transmits a message is supplied with a hand which moves upon a dial, round which the letters of the alphabet are engraved, as are the hours round the dial of a clock. At the station to which the message is sent, there is a similar dial, having upon it a similar hand, and the mechanism is so contrived that, when properly adjusted, the two hands must always point to the same letter. Thus, if the agent sending the message turns the hand to the letter M upon the dial before him, the hand upon the dial at the station to which the message is sent will also turn to the letter M, and in this way, by merely directing the hand successively to the letters of a word, pausing a little while at each letter the word will be spelled to the agent at the distant station.

All alphabetic telegraphs, whatever be their form or construction, convey the communications in this manner.

The French railway telegraph is in its principle identical with the state telegraph. The indicator in the latter makes a complete revolution by eight successive steps, moving in each step through an angle of 45°. If the alphabet consisted of only eight letters, this would at once become an alphabetic telegraph by fixing the indicator in the centre of a dial upon which, at equal distances asunder, the eight letters are engraved. But since the French alphabet consists of 25 letters, and since an additional sign is found convenient, the dial is divided into 26 equal arcs instead of eight, and the indicator makes a complete revolution by 26 equal motions, at the termination of these motions respectively pointing to the letters engraved upon the dial.

To accomplish this, the escapement wheel is constructed with 13 teeth instead of 4, the groove upon the moveable disc of the commutator has 13 sinuous undulations instead of 4 sides with rounded corners, and the fixed disc upon which the handle of the commutator moves, has 26 notches instead of 8.

The grooved disc, by the motion of which the oscillations right and left are imparted to the lever which makes and breaks the connection with the battery, is fixed immediately behind the notched disc, and the sinuous groove has the form represented in fig. 51, and acts upon the lever in the manner described in 133.

The commutator, with its appendages, is represented in fig. 73. The fixed disc has at its edge 26 notches, into which the pin projecting from the handle falls, as in the state telegraph. Engraved upon the face of the disc are, on the outside, the numbers from 0 to 25, and on the inside the 25 letters (W being omitted, not being generally used in the French language), the 26th place having the mark +.

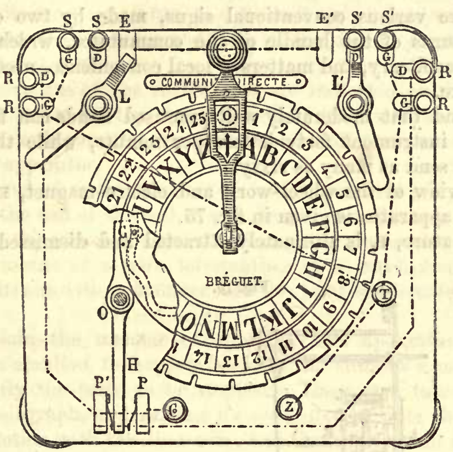
A part of the dial is broken away, to disclose the face of the moveable disc, with the sinuous groove behind the fixed disc. The lever G is visible, with its pin in the groove, and the oscillation of the end of the lower arm H between the contact-pieces, P and P′, is exactly the same as that described in 133 and in 184.

The handle of the commutator is keyed upon an axis which, passing through the centre of the fixed dial, is itself keyed into the centre of the moveable grooved dial behind it, so that when the handle is carried round the fixed dial, the moveable dial behind is carried round with it.

Upon the upper part of the board carrying the dial are placed two supplementary commutators, L and L′, the hands of which play upon the contact-pieces, S, S, E, and S′, S′, E′, as well as upon an oblong plate of metal, upon which the words "COMMUNICATION DIRECTE" are engraved.

The terminals C and Z communicate with the copper and zinc ends of the battery, or what is the same, with its positive and

Fig. 73.



negative poles; T communicates with the earth. The contact pieces S S′ are connected with alarums, R R with the indicators, and the axes of the arms L L′ with the line-wires. The dotted lines indicate the positions of slips of metal inlaid in the back of the frame, by which the several pieces are put in metallic connection one with another.

After the general explanation of the manner in which the course of the current is in all cases governed, it will not be necessary here to explain the application of these commutating apparatus, which are nothing more than particular applications of the general principle so fully developed in 111.

A perspective view of the commutator and indicating apparatus mounted in the same case, is given in fig. 74 (p. 17). The commutator is fixed upon a horizontal desk, that being the most convenient position for its easy manipulation. The indicator, which corresponds with it in form, is placed like the dial of a clock in front of a vertical case.

If we suppose the commutator (fig. 73) at the station S, and the indicator at S′, the arm of the commutator and that of the indicator being upon the mark +, any motion of the former made in the direction of the hand of a clock, will produce a corresponding motion of the hand of the latter, so that whatever letter or number the one points to, the other will at the same time point to.

By this means the agent at S may spell word after word to the agent at S′.

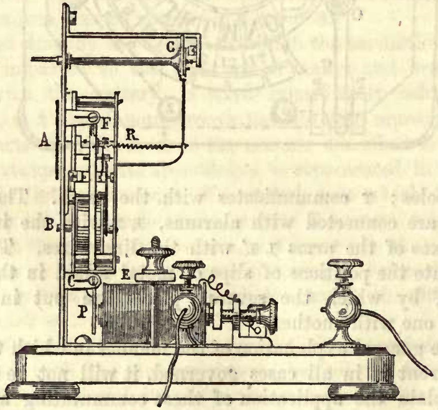
There are various conventional signs, made by two or more complete turns of the handle of the commutator, which, being altogether arbitrary, and matters of local convenience, need not be noticed here.

It is found that moderately well-practised hands can transmit with this instrument forty letters per minute, while the most expert can send as many as sixty.

A side view of the wheel-work and electro-magnet, E, of the indicating apparatus is given in fig. 75.

The armature, P, is alternately attracted and dismissed by the

Fig. 75.



magnet, acted on by the pulsations of the current, and imparts this motion to the escapement at F, by which the hand A of the indicator is advanced from letter to letter upon the dial, so that the motion of the hand A at the station S′ shall correspond exactly with that of the hand of the commutator at the station S.

189. The telegraph which is represented in fig. 74 is a portable telegraph constructed for the French railways by M. Breguet. This instrument, in size and arrangement, is adapted to be carried in the guard's van upon the train, so that, in case of accident, it may be immediately put in connection with the line-wires, and notice of the circumstance may be instantly transmitted to the two stations between which the accident has taken place.

Portable instruments for a like purpose have been constructed in England and elsewhere.

The apparatus consists of a stout oaken case, containing in the lower part, B B, a Daniel's battery of 18 pairs, a commutator, M, and an indicating apparatus, R. A small galvanometer is placed at G, to show the existence and force of the current, and a small electro-magnet, L T.

The dimensions of the instrument are indicated on the figure. When not in use the top, C C, attached by hinges to the case, can be turned down over the commutator and indicator, so as to close the entire apparatus.

A long rod of metal terminated in a copper hook, is provided, by which the end of the coil L can be put in connection with the line-wire; the end of the coil T being put in connection with the earth by means of a wire terminating in a small iron wedge, which is driven with a hammer into the joint between two of the rails.

To explain the manner of applying this apparatus, let us suppose an accident to happen between the stations S and S′, and consequently the train to be stopped. The guard takes out the portable telegraph, and raising its cover C C, he puts the wire of L in connection with the line-wire, and that of T within a joint of the rails, in the manner described above. He then makes one or two complete turns of the handle M of his commutator, observing whether the galvanometric needle G is deflected. If it is, he knows that he has transmitted a current to the line wires. This current divides itself at the hook, and a part goes to each of the stations S and S′, at each of which it rings the alarum. After a short interval a current is transmitted back from one or other of the stations, the arrival of which is indicated by the deflection of the galvanometric needle, G. The guard then informs the stations, one or both, of the accident, its place, the nature of the aid he requires, &c.

In comparing this with the state telegraph, it must not be forgotten that while this requires only one conducting wire, the state telegraph requires two. In fact, the French state telegraph, like the English double-needle telegraph, is in reality two independent telegraphs, whose signals are combined for the purpose of indicating hands, *n*, in all of them were placed upon the division of the dial marked +. The moment the arms, *a b*, or any of them, are placed against the stops T, the current transmitted upon the line-wire passing through the several indicating instruments, the indicating hands in all the instruments will commence simultaneously to move round the several dials. They will move from letter to letter with a starting and interrupted, but regular motion, like that of the seconds hands of a clock, but much more rapidly. The rate at which they are moved will depend on the force of the current, but, whatever be the rate, it will be common to all, all making successive revolutions of the dial precisely in the same time, and moving together from letter to letter with the most absolute simultaneity, and since they all started from the same point +, and move together from letter to letter, it follows that, whether their motion be quick or slow, they will all at each moment point to the same letter.

Now, it is important here to observe, that this common rotation of all the hands upon all the dials is produced and maintained by the current alone, without any manipulation whatever on the part of any agent at any station, and it would continue to be maintained indefinitely, provided that the battery were kept in action.

We have supposed the battery at the station S, from which the despatch is about to be transmitted, to be alone put into connection with the line-wire. But, in order to strengthen the current, each agent on the line, when he receives the signal, also puts his battery in like connection with the line-wire, so that the current acquires all the intensity which the combined action of all the batteries on the line is capable of producing.

The apparatus is so arranged that, in all cases, the galvanometer, *d*, is in connection with the line-wire, so as to indicate at all times at each station the state of the current.

It now remains to show how a despatch can be transmitted from any one station to all or any of the other stations on the line.

The apparatus is so constructed, that if the agent at any station presses down any one of the keys surrounding the dial, the indicating needle, upon arriving at that key, will be stopped; and at the same moment the current upon the line-wire will be suspended. This suspension of the current will also, at the same moment, stop the motion of all the indicating hands upon all the dials on the line. The agents at all the stations will therefore see and note the letter on which the transmitting agent has put his finger. The transmitting agent, after a sufficient pause, transfers his finger to the key of the next letter he desires to transmit. The moment he raises his finger from the first key the current is re-established on the line-wire, and all the indicating hands rotate as before, passing again simultaneously from letter to letter until they arrive at the second letter upon which the transmitting agent has put his finger, when they again stop, and so on.

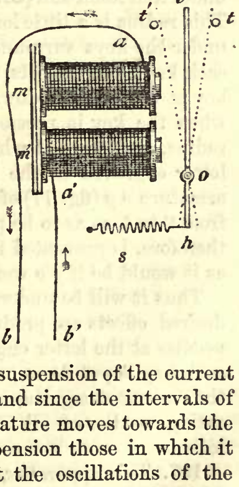
In this manner an agent at any station can stop the indicating needles at any or all the other stations successively, on their arrival at the letters of the words he desires to communicate.

193. If by reason of inattention or otherwise any letter or letters transmitted escape the attention of the agent at any of the stations to which the despatch is addressed, such agent immediately signifies the fact by putting his finger on one of the keys of his own instrument, by which he stops the hand upon the dial of the transmitting agent at a letter, which tells him to repeat the last letter or word as the case may be. This signal is understood at all the other stations, so that no confusion ensues.

194. Having thus shown how a despatch is transmitted and understood by those to whom it is addressed, I shall now explain the mechanism by which these effects are produced.

Beneath the dial of each instrument an electro-magnet, such as *m m′* (fig. 77) is placed, upon the coil of which the current transmitted from the batteries passes. This magnet, then, as usual, attracts its armature *g o*, which comes against the stop *t′*. Now the apparatus is so arranged, that when *g* strikes *t′*, the circuit of the current is broken, and consequently the current is stopped. This deprives the electro-magnet *m m′* of its magnetism; and *g* being no longer attracted, it is drawn back from the stop *t′* by the spring *s*, and it recoils upon the stop *t*. Here the connection with the line-wire is reproduced, and the current is re-established. The electro-magnet having thus recovered its magnetism, *g* is again attracted by it, and drawn into contact with *t′*, where the connexion is again broken, and *g* is drawn back to *t′* by the spring *s*, and so on.

Fig. 77.



Since the intervals of transmission and suspension of the current are the same throughout the entire line, and since the intervals of transmission are those in which the armature moves towards the electro-magnet, and the intervals of suspension those in which it recoils from the magnet, it follows that the oscillations of the armature of all the electro-magnets at all the stations are absolutely alike and simultaneous.

indicating hands, *n*, in all of them were placed upon the division of the dial marked +. The moment the arms, *a b*, or any of them, are placed against the stops T, the current transmitted upon the line-wire passing through the several indicating instruments, the indicating hands in all the instruments will commence simultaneously to move round the several dials. They will move from letter to letter with a starting and interrupted, but regular motion, like that of the seconds hands of a clock, but much more rapidly. The rate at which they are moved will depend on the force of the current, but, whatever be the rate, it will be common to all, all making successive revolutions of the dial precisely in the same time, and moving together from letter to letter with the most absolute simultaneity, and since they all started from the same point +, and move together from letter to letter, it follows that, whether their motion be quick or slow, they will all at each moment point to the same letter.

Now, it is important here to observe, that this common rotation of all the hands upon all the dials is produced and maintained by the current alone, without any manipulation whatever on the part of any agent at any station, and it would continue to be maintained indefinitely, provided that the battery were kept in action.

We have supposed the battery at the station S, from which the despatch is about to be transmitted, to be alone put into connection with the line-wire. But, in order to strengthen the current, each agent on the line, when he receives the signal, also puts his battery in like connection with the line-wire, so that the current acquires all the intensity which the combined action of all the batteries on the line is capable of producing.

The apparatus is so arranged that, in all cases, the galvanometer, *d*, is in connection with the line-wire, so as to indicate at all times at each station the state of the current.

It now remains to show how a despatch can be transmitted from any one station to all or any of the other stations on the line.

The apparatus is so constructed, that if the agent at any station presses down any one of the keys surrounding the dial, the indicating needle, upon arriving at that key, will be stopped; and at the same moment the current upon the line-wire will be suspended. This suspension of the current will also, at the same moment, stop the motion of all the indicating hands upon all the dials on the line. The agents at all the stations will therefore see and note the letter on which the transmitting agent has put his finger. The transmitting agent, after a sufficient pause, transfers his finger to the key of the next letter he desires to transmit. The moment he raises his finger from the first key the current is re-established on the line-wire, and all the indicating hands rotate as before, passing again simultaneously from letter to letter until they arrive at the second letter upon which the transmitting agent has put his finger, when they again stop, and so on.

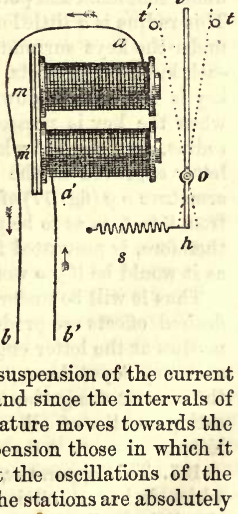
In this manner an agent at any station can stop the indicating needles at any or all the other stations successively, on their arrival at the letters of the words he desires to communicate.

193. If by reason of inattention or otherwise any letter or letters transmitted escape the attention of the agent at any of the stations to which the despatch is addressed, such agent immediately signifies the fact by putting his finger on one of the keys of his own instrument, by which he stops the hand upon the dial of the transmitting agent at a letter, which tells him to repeat the last letter or word as the case may be. This signal is understood at all the other stations, so that no confusion ensues.

194. Having thus shown how a despatch is transmitted and understood by those to whom it is addressed, I shall now explain the mechanism by which these effects are produced.

Beneath the dial of each instrument an electro-magnet, such as *m m′* (fig. 77) is placed, upon the coil of which the current transmitted from the batteries passes. This magnet, then, as usual, attracts its armature *g o*, which comes against the stop *t′*. Now the apparatus is so arranged, that when *g* strikes *t′*, the circuit of the current is broken, and consequently the current is stopped. This deprives the electro-magnet *m m′* of its magnetism; and *g* being no longer attracted, it is drawn back from the stop *t′* by the spring *s*, and it recoils upon the stop *t*. Here the connection with the line-wire is reproduced, and the current is re-established. The electro-magnet having thus recovered its magnetism, *g* is again attracted by it, and drawn into contact with *t′*, where the connexion is again broken, and *g* is drawn back to *t′* by the spring *s*, and so on.

Fig. 77.



Since the intervals of transmission and suspension of the current are the same throughout the entire line, and since the intervals of transmission are those in which the armature moves towards the electro-magnet, and the intervals of suspension those in which it recoils from the magnet, it follows that the oscillations of the armature of all the electro-magnets at all the stations are absolutely alike and simultaneous.

In each instrument the armature is in connection with a toothed wheel, upon the axis of which the hand *m n* (fig. 76) is keyed, so that each vibration of the armature puts forward one tooth of the wheel, and advances the hand *n* from one letter to another.

195. Upon comparing this arrangement with that of the French telegraph, it will be perceived that here the mainspring and wheel-work which moves the indicator are altogether omitted, and the armature of the electro-magnet, which in the French instrument only *regulates* the motion of the indicator, here both *moves* and *regulates* it. In fine, the armature here discharges at once the functions of the mainspring, and of the pendulum of a clock.

It will also be observed that the manipulation of the transmitting agent, by which he moves the indicators on the dials of the distant stations, is dispensed with, the current itself, through the intervention of the armature of the electro-magnet, imparting to the indicator a constant motion of rotation without any manipulation whatever.

That part only of the manipulation by which the indicator is stopped for a moment successively at the letters of the word intended to be transmitted, is retained, and that is effected by the action of the keys surrounding the dial.

196. Under the dial, a radius or arm is keyed upon the axis on which the indicating hand is fixed, so as to be always immediately under that hand and parallel to it, revolving simultaneously with it. This radius is a little longer than the indicating hand, and extends under the keys surrounding the dial. From the under-surface of each key a pin projects, the length of which is such that when the key is not pressed down, the radius passes freely under it; but when the key is pressed down, the pin comes in the way of the radius, and stops it when the indicating hand *n* arrives at the letter engraved on the key. By the action of the same pin the armature *o g* (fig. 77) of the electro-magnet is arrested in its return from *t′* to *t*, so as to be prevented from arriving at *t*. The current, therefore, is prevented from being re-established on the line-wire, as it would be if *g o* were permitted to come into contact with *t*.

Thus it will be understood how by putting down a key the two desired effects are produced. 1st, the stoppage of the indicating needles at the letter engraved on the key of the indicator on which such key is put down; and 2nd, the simultaneous suspension of the current along the entire telegraphic line, by which the indicating needles of all other instruments are stopped at the same letter.

197. This apparatus, compared with the French telegraph, to which it has an obvious analogy, has the advantage of greater simplicity. By dispensing with the mainspring and its necessary

train of wheel-work, and with the rather complicated commutator worked by the hand of the transmitting agent, many moving parts are rejected, and there are proportionately less chances of derangement and less causes of wear or fracture. But on the other hand the moving power which impels the indicator, being transferred from the mainspring to the current, a proportionately greater force of current is necessary. This force is, however, obtained without augmenting the magnitude of the batteries at any one station by the expedient of bringing the piles of both the terminal stations, and, if necessary, of any or all the intermediate stations, into the circuit.

198. In the batteries used with the French railway telegraph, the use of acid, as has been stated, is found altogether unnecessary. In the German telegraph, however, pure water does not give a sufficiently strong current, and it is acidulated with about one and a half per cent. of sulphuric acid. The battery at each station consists usually of from 15 to 20 pairs. The usual speed imparted to the indicator by the current is about 30 revolutions per minute.

M. Siemens invented mechanism by which the indicating apparatus was connected with one by which the letters of the despatch as they arrived were printed by ordinary type upon a band of paper. Since, however, this has not been brought into practical use, it will not be necessary to explain it.

When the electric telegraph was first opened to the general service of the public in Prussia, this apparatus of Siemens was generally used, but it has since been superseded by that of Morse, its speed of transmission being found insufficient for the public service.

BELGIAN RAILWAY TELEGRAPH.

199. When the electric telegraph was first brought into use on the Belgian railways, the French and German apparatus described above were tried in succession. In 1851 they were, however, both superseded by a form of telegraph invented and constructed by M. Lippens, mathematical instrument maker of Brussels.

200. M. Lippens attributes to the French and German railway telegraphs certain defects, which he claims to have removed. For the efficient performance of those telegraphs, it is evident that a certain relation must always be maintained between the force of the spring *s* (fig. 77), which produces the recoil of the armature *g o*, and the attractive force of the magnet, or what is the same, between the spring and the intensity of the current, with which the attraction of the magnet must vary. Now the intensity of the current is subject to variation, depending on the state of the battery, the number of pairs which are brought into operation, the length of

the line-wire upon which it is transmitted, the more or less perfect state of the insulators, and in fine on the weather.

If the current become so feeble that the attraction of the magnet is less than the force of the spring *s*, the armature *g o* will remain upon the stop *t*, from which the magnet is too feeble to remove it. If, on the other hand, the spring have not sufficient force to overcome the friction and inertia of the armature *g o*, and the small portion of magnetism which may be retained by the electro-magnet after the current has been suspended, the armature will remain upon the stop *t′*, the spring being unable to produce its recoil.

Since therefore the forces against which the spring *s* acts, and which it ought to exceed, and those which act against it and which ought to exceed it, are variable, it is clear that the maintenance of the efficiency of the apparatus requires that the spring *s* shall from time to time be adjusted, so as to be kept in that relation to its antagonistic forces, which are necessary for the due performance of the telegraph.

It has been already shown that very sufficient and very simple means of adjustment for this purpose have been supplied in the French telegraphs. The hands which appear in the upper corners of the instrument (fig. 70) are intended for this purpose, and being turned by the key, the springs connected with them are increased or diminished in their force, according as the key applied to them is turned the one way or the other. Similar adjustments are provided in the German instruments.

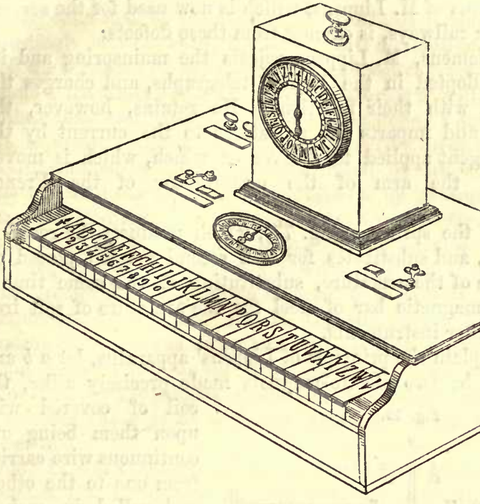


Fig. 81.—FROMENT'S ALPHABETICAL TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER IX.

201. Defects of the French and German instrument removed by Lippens' instrument.—202. Description of it.—203. Its wheel commutator.—204. Transmission of despatches by it.—205. Froment's alphabetic telegraph.—206. Morse's telegraph.—207. Froment's writing telegraph.—208. Bain's chemical telegraph.—209. Method of writing.—210. Electro-chemical pen.—211. Metallic desk.

201. M. Lippens and the Belgian railway and telegraph authorities by whom he has been supported, however contend, that although the permanent staff of the state and public telegraphs constantly occupied and practised in the manipulation of such apparatus may be relied upon for the due management of such adjustments, the agents of various grades employed on the railways, whose duties do not permanently connect them with the telegraph, and who are only called to it from time to time, cannot be depended on to perform adjustments requiring not only constant practice, but some address and some special knowledge of the principle and mechanism of the apparatus.

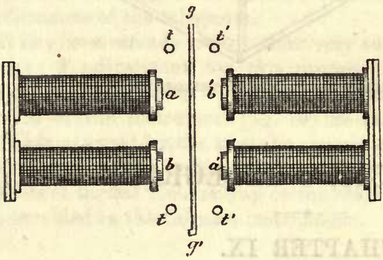
The apparatus of M. Lippens, which is now used for the service of the Belgian railways, is exempt from these defects.

Like M. Siemens, M. Lippens rejects the mainspring and its appendages adopted in the French telegraphs, and charges the current itself with their functions. He retains, however, the commutator, and imparts the pulsations to the current by the hand of the agent applied to a lever or winch, which is moved exactly like the arm of the commutator of the French instruments.

He rejects the spring *s* (fig. 77), which produces the recoil of the armature, and substitutes for it a second magnet placed on the other side of the armature, substituting at the same time a permanently magnetic bar of steel for the armature of soft iron used in the other instruments.

202. To explain the principle of Lippens' apparatus, let *a b* and *a′ b′* (fig. 78) be two electro-magnets made precisely alike, the coil of covered wire upon them being one continuous wire carried from one to the other, and rolled in such a manner that their polarity shall always have contrary positions in whichever direction the current may be transmitted on the wire. Thus, if *a* be a north pole, *b′* opposed to it will be a south pole, and in that case *a′* will be a north and *b* a south pole. If the current upon the coil be reversed, all these four poles will at once change their names—*a* becoming a south and *b′* a north pole, and *a′* a south and *b* a north pole.

Fig. 78.



Let *g g′* be a steel bar which is permanently magnetised, *g* being its north and *g′* its south pole, and let it be supported midway between the electro-magnets, having free play towards the one or the other until it encounters the stops *t t* or *t′ t′* by which it is arrested.

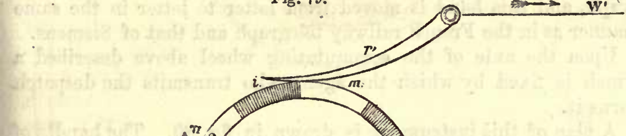
Now let a current be transmitted upon the wire, by which *a* will become a north pole, and consequently *b* and *b′* will be south poles, and *a′* a north pole. Since *g* is a north and *g′* a south pole, they will be attracted by *b′* and *a′*, and repelled by *a* and *b*, and consequently the armature *g g′* will be moved towards *b′ a′* until it is stopped by *t′ t′*. If the current be then reversed, *a* and *a′* will become south, and *b* and *b′* north poles; and the armature will be attracted by *a* and *b*, and repelled by *b′* and *a′*, and will accordingly move towards the latter until it is stopped by *t t*.

If the direction of the current be reversed rapidly, suppose, for example, ten times per second, the armature *g g′* will be made to oscillate ten times per second between the stops *t t* and *t′ t′*.

It is evident that the expedient adopted by Siemens, by which the transmission of the current is arrested by the contact of the armature with one stop and re-established by its contact with the other, might be easily modified so as to reverse the direction of the current by each contact with *t t* and *t′ t′*; and in that case the telegraph of Siemens would without other change be rendered exempt from the defects imputed to it, as well as the French instruments, by Lippens. But M. Lippens, either prevented from adopting this obvious expedient by the patent of Siemens, or giving a preference to the hand commutator for other reasons, has contrived an ingenious commutator worked by hand, by which he reverses the current with the greatest facility, rapidity, and precision.

203. This is a wheel commutator formed on the principle explained in 129, but there are two wheels such as are there described placed one upon the other upon a common axle, with a disc of gutta percha between them, so that one is insulated from the

Fig. 79.



other. The edges of both are divided into a series of conducting and non-conducting arcs, but the position of these relatively to each other is alternate, the conducting arcs of each disc corresponding in position with the non-conducting arcs of the other.

We may imagine the shaded arcs of fig. 79 to represent the conducting arcs of the upper, and the white arcs the conducting arcs of the lower disc, the one, however being separated from all contact with the other by the interposed disc of gutta percha.

When the wheel is made to revolve, the spring r' comes alternately into contact with the conducting arcs of the one and of the other disc. Another similar spring is applied to another part of the edge of the wheel, so as to be in contact with the conducting arcs of the upper disc, while the spring r' is in contact with those of the lower, and *vice versâ*.

One of the two discs is in connection with the copper, and the other with the zinc end of the battery, so that one may be considered as its positive and the other as its negative pole. One of the springs is in connection with one end, and the other with the other end of the conducting wire, which forms the coils, and which passes along the telegraphic line. By causing the wheel to revolve, therefore, the conducting wire will be alternately connected with contrary poles of the battery, and the current upon it will be reversed.

If the edge of the wheel be divided into ten equal parts by the conducting arcs, this reversion will take place ten times in each revolution, and if a revolution be imparted to the wheel in each second, the current will be reversed ten times per second.

In the apparatus of Lippens the oscillations thus imparted to the armature, $g\,g'$, fig. 78, are made to act by the intervention of toothed wheels upon the indicating hand which moves upon the dial around which the letters are engraved, as in the French telegraph, and this hand is moved from letter to letter in the same manner as in the French railway telegraph and that of Siemens.

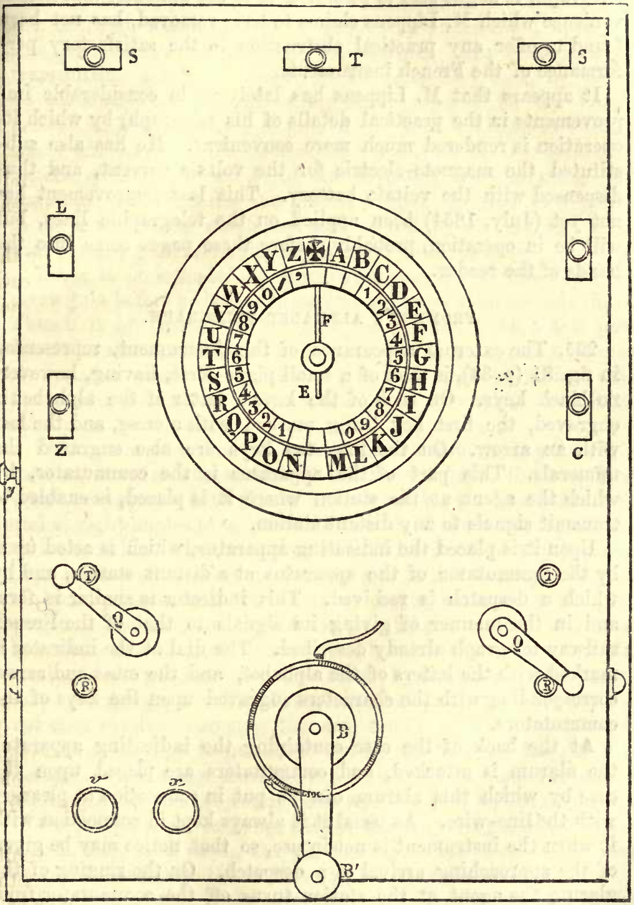
Upon the axle of the commutating wheel above described a winch is fixed by which the agent who transmits the despatch turns it.

A plan of this instrument is drawn in fig. 80. The handle of the commutator B B′ is keyed upon the axis of the wheel already described, which is under the table of the instrument. This wheel, and the springs which press upon it, are indicated in the figure. The handles Q Q are those by which the current is conducted from the up or down line through the indicating apparatus, or through the alarum, as already explained in the case of the German telegraph. Several other batteries are provided for establishing connections with the line wires, the battery poles, the alarums, and the earth, and differ in nothing essential from similar adjustments in other telegraphic instruments.

204. When the agent at any station, S, desires to transmit a despatch to any other station or stations, S′, he first, as in other telegraphs, calls the attention of the agents at S′ by means of the alarum. The current being then directed through the instruments severally by means of the adjustments provided for that purpose, the transmitting agent at S turns the handle B B′ of his

commutator, by which he produces the pulsations of the current, and puts the indicating hands upon the dials at S′, as well as upon his own in motion. These hands as usual, when properly

Fig. 80.



adjusted always point to the same letters. The transmitting agent stops the handle B B′ when he sees the hand F upon his dial point successively to the letters which spell the word he desires to transmit, and by continuing to operate thus, he transmits the entire despatch.

Such is the Belgian railway telegraph, and although it must be admitted that it supplies a certain improvement on the French telegraph, it ought also to be stated that the difficulty and inconvenience which M. Lippens claims to have removed, has not been found to offer any practical obstruction to the satisfactory performance of the French instruments.

It appears that M. Lippens has lately made considerable improvements in the practical details of his telegraph, by which its operation is rendered much more convenient. He has also substituted the magneto-electric for the voltaic current, and thus dispensed with the voltaic battery. This last improvement has not yet (July, 1854) been applied on the telegraphic lines, but will be in operation, probably, before these pages come into the hands of the reader.

FROMENT'S ALPHABET TELEGRAPH.

205. The external appearance of this instrument, represented in fig. 81 (p. 33), is that of a small piano-forte, having, however, no black keys. On each of the keys a letter of the alphabet is engraved, the first key being marked with a cross, and the last with an arrow. On the first ten keys are also engraved the numerals. This part of the apparatus is the commutator, by which the agent at the station where it is placed, is enabled to transmit signals to any distant station.

Upon it is placed the indicating apparatus, which is acted upon by the commutator of the apparatus at a distant station, and by which a despatch is received. This indicator is similar in form and in the manner of giving its signals to that of the French railway telegraph already described. The dial of the indicator is marked with the letters of the alphabet, and the cross and arrow corresponding with the characters engraved upon the keys of the commutators.

At the back of the case containing the indicating apparatus the alarum is attached, and commutators are placed upon the case by which this alarum can be put in connection at pleasure with the line-wire. As usual it is always kept in connection with it when the instrument is not in use, so that notice may be given of the approaching arrival of a despatch. On the ringing of the alarum the agent at the station turns off the commutator from the alarum and throws it into connection with the indicating apparatus.

To explain the tranmission of a despatch, let us suppose an apparatus, such as that represented in the figure, to be erected at two stations, S and S′, connected as usual by a conducting wire; the instrument, being unemployed, the line-wire at both is in connection with the alarum. Now let us suppose that S desires to transmit a despatch to S′. In that case S having first turned on the current, puts down any key whatever of his commutator, the effect of which is that a current is transmitted upon the line wire to S′, which rings the alarum; then S′ replies by transmitting a return current in the same way to S, by which S's alarum is rung. All being then prepared for the transmission of the despatch, S puts down with his fingers successively the keys of his commutator upon which the successive letters spelling the words of the despatch are engraved, and simultaneously with this the indicator upon the dial of S′ points to the same letters, which are taken down by S′. At the end of each word, S puts down the key marked with the cross.

When it is intended to transmit numerals, S puts down the arrow just before he begins them, and the cross when he ends them. Thus if it be desired to transmit the number 1854, S first puts down the arrow, and then the keys marked A, H, E, and D successively, after which he again puts down the cross to indicate that the number is finished. It remains now to explain how these effects are produced.

Within the case, and at some distance below the key-board, a steel rod is extended, parallel to the line of keys, the length of which corresponds with that of the row of keys. From this rod, and at right angles to it, proceeds a series of short steel arms, one under each key. In the bottom of each key, and at right angles to it, is inserted a short projecting pin, which corresponds precisely in position with the short steel arm just mentioned. The length of the arm, and that of the pin, taken together, is a little less than the distance between the bottom of the key and the steel rod when the key is not put down by the finger, the necessary consequence of which is that in that position of the key the rod may revolve, carrying the arm round with it unobstructed. But when the key is put down by the finger, the bottom of it is brought to a distance from the rod which is less than the sum of the lengths of the projecting arm and the pin, and consequently if the rod revolves, carrying with it the projecting arm while the key is thus held down, the pin coming in the way of the arm arrests it, and stops the further revolution of the steel rod.

It is evident that if the projecting arms were all inserted in the steel rod at the same side, or to speak with still more precision, if their points of insertion lay in a line along the side of the rod parallel to its axis, the pins of all the keys would arrest the revolution of the rod in exactly the same position, and, as it will presently appear, that the position in which the rod is stopped determines the signal transmitted, it would follow as a consequence that in such case all the keys would transmit the same signal, and the indicator at the station to which the dispatch is to be transmitted would always return to the same letter upon the dial.

To prevent this, and to vary the signal in the necessary manner, the projecting arms are inserted in the steel rod according to a spiral or heliacal line, surrounding it like the thread of a screw, so that if, for example, the rod be placed so that the first projecting arm corresponding to the key marked with the cross, points directly upwards, the fourteenth which corresponds to the key M, will point directly downwards, and the intermediate arms will point at angles more and more inclined from the upward direction, each being deflected from the upward direction more than the preceding one by the fourteenth part of the half circumference.

In like manner, in proceeding from the arm corresponding with the key M, which points downwards, each successive arm will be more and more deflected from the downward direction, each being more deflected from it than the preceding one by the fourteenth part of half the circumference.

Thus the twenty-eight projecting arms divide the circumference of the rod into twenty-eight equal parts, and consequently in a revolution of the rod, the arms come successively to the position in which they point upwards and in which they would encounter the pin projecting from the bottom of the key if that pin were thrown in their way by the key being pressed down by the finger.

It will be evident, therefore, that if from any cause the steel rod be made to revolve, its motion may be stopped at twenty-eight different points of its complete revolution by means of the depression of the twenty-eight keys. We shall now show how a motion of revolution is imparted to this rod.

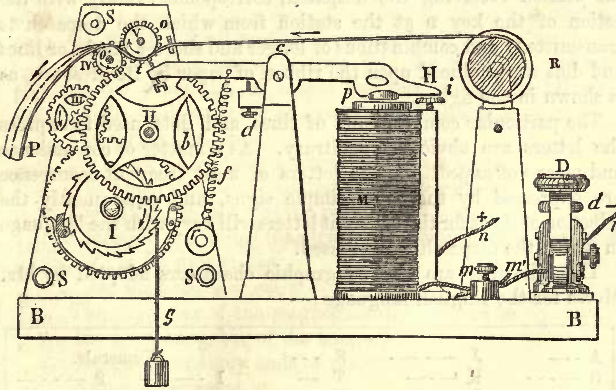
To its right-hand extremity is fixed a ratchet-wheel, which is in connection with a train of clockwork, moved in the usual manner by a mainspring. This clockwork is contained within the case of the apparatus. If it be wound up, and if nothing obstructs its action, a motion of continuous rotation will be imparted to the ratchet-wheel, and by it to the steel rod, and this motion will be more or less rapid according to the force of the mainspring, and the adjustment of a fly which is connected with it. They are so adjusted as to cause the rod to revolve two or three times in a second. But in the teeth of the ratchet-wheel, a catch is inserted, which counteracts the mainspring and prevents the motion, which can only take place when this catch is withdrawn. A bar is suspended parallel to the keys, and under them, by a contrivance called in mechanics a parallel motion, by means of which any of the keys when pressed by the finger will lower it. This bar rests upon the arm of the catch engaged in the teeth of the ratchet-wheel, so that whenever any key is put down by the finger, the bar is depressed, the catch disengaged, the wheel liberated, and a motion of revolution imparted.

On the left hand extremity of the steel rod is fixed a commutating wheel, similar in principle to that already described in the railway telegraph. This wheel, being fixed upon the rod, turns with it, moving when it moves, and stopping when it stops. Since the position in which the rod stops is determined by the key put down, the position in which the wheel thus fixed on the rod stops, is similarly determined. This wheel determines the pulsation of the current, and these pulsations determine the position of the indicator at the station to which the despatch is transmitted, in a manner which is substantially the same as that already described in the case of the railway telegraph.

MORSE'S TELEGRAPH.

206. This apparatus, which is applied on an extensive scale in America, and with some slight modifications in the Germanic States, is constructed upon the principle already explained in 153.

Fig. 82.



A general view of the instrument in its most usual form is given in fig. 82.

M is the electro-magnet; H is an armature working on the centre *c*; *i* an adjusting screw to limit the play of the armature, and prevent its contact with the electro-magnet at *p*; *d* another adjusting screw to limit its play in the other direction; *t* a metallic style which marks by pressure a band or ribbon of paper drawn from the roll R, and carried between the rollers *o* and *o′*; P the ribbon of paper discharged from the rollers *o o′*, after being impressed by *t* with the telegraphic characters; I, *b*, &c., clockwork from which the rollers *o o′* receive their motion, by which motion the ribbon of paper is drawn from the roller R; *f* the spring which draws the arm H of the electro-magnet from the armature; S S the upright pieces supporting the clockwork; B B the base supporting the instrument; D, the key commutator, by which the current transmitted along the line-wire is alternately transmitted and suspended; *m*, *n*, *m′*, *n′*, wires by which the coil of the electro-magnet and the poles of the station battery are put in connection with the line-wires.

The general principle of this and all similar apparatus has been already so fully expained in 153, *et seq.*, that little more need be said here to render it intelligible. If it be desired to transmit a despatch to a distant station, the battery at the transmitting station is put in communication with the line-wire, and by the action of the key D the current is alternately transmitted and suspended during longer and shorter intervals, which are determined by the conventional telegraphic letters. The action of the style *t* against the ribbon of paper which passes over it at the station receiving the despatch, corresponds exactly with the action of the key D at the station from which the despatch is transmitted; and combinations of longer and shorter marks or lines and dots are produced upon the ribbon of paper by its pressure, as is shown in the figure.

The particular combinations of lines and dots used to express the letters are obviously arbitrary. As a matter of convenience and means of expedition, the letters of most frequent occurrence are expressed by the most simple signs, and consequently the selection of signs for the different letters will vary with the language in which the dispatch is expressed.

The following are the telegraphic characters adopted by Mr. Morse for the English language:—

			Numerals.	
A · —	J — · — ·	S · · ·		
B — · · ·	K — · —	T —	1 · — — ·	9 — · · —
C · · ·	L ——	U · · —	2 · · — · ·	0 ———
D — · ·	M — —	V · · · —	3 · · · — ·	
E ·	N — ·	W · ——	4 · · · · —	
F · — ·	O · ·	X · — · ·	5 — — —	
G — — ·	P · · · · ·	Y · · — · ·	6 · · · · · ·	
H · · · ·	Q · · — ·	Z · · · ·	7 — — · ·	
I · ·	R · · ·	& · · · ·	8 — · · · ·	

This telegraphic apparatus being that which has been by far the most extensively brought into use, being not only adopted almost exclusively in the United States and contiguous countries, but also in all the German States, it may be useful here to present the instrument and its appendages in the form in which it has been most recently constructed in the United States, and which has been recommended by the American telegraphic confederation, as being that which it would be most advantageous to adopt generally, so that all the parts being manufactured of the same pattern and size no difficulty would be found in replacing any of them in case of fracture.

A perspective view of the instrument, omitting the paper roller and ribbon, is given in fig. 83 (p. 44).

Z. The wooden base upon which the instrument is screwed.

B. The brass base plate attached to the wooden base *z*.

A. The side frames supporting the mechanism.

h, *h*. Screws which secure the transverse bars connecting the side frames.

G. The key for winding up the drum containing the mainspring, or supporting the weight, according as the mechanism is impelled by one or the other power.

3, 4. Clock-work.

u. A lock or gauge to regulate the pressure of the rollers on the paper.

c. The pillar supporting the electro-magnet.

p. The adjusting screw passing into the pillar, *c*, projecting through the armature, to enable the telegraphist to adjust the sound of the back stroke of the armature at pleasure.

o. The spring bar, and

d, the screw to adjust the action of the pen lever.

D. The apparatus for adjusting the paper rollers.

f. The adjusting screw of the pen lever.

The form of the relay magnet recommended, is given in fig. 84 (p. 45), in its proper size.

A B, are the helices or coils.

C. The supporter of the magnet lightly screwed to

W, the connecting bar of the magnets.

Y. Rosewood or ivory ends of magnets.

D. Armature screwed to

E, an upright lever;

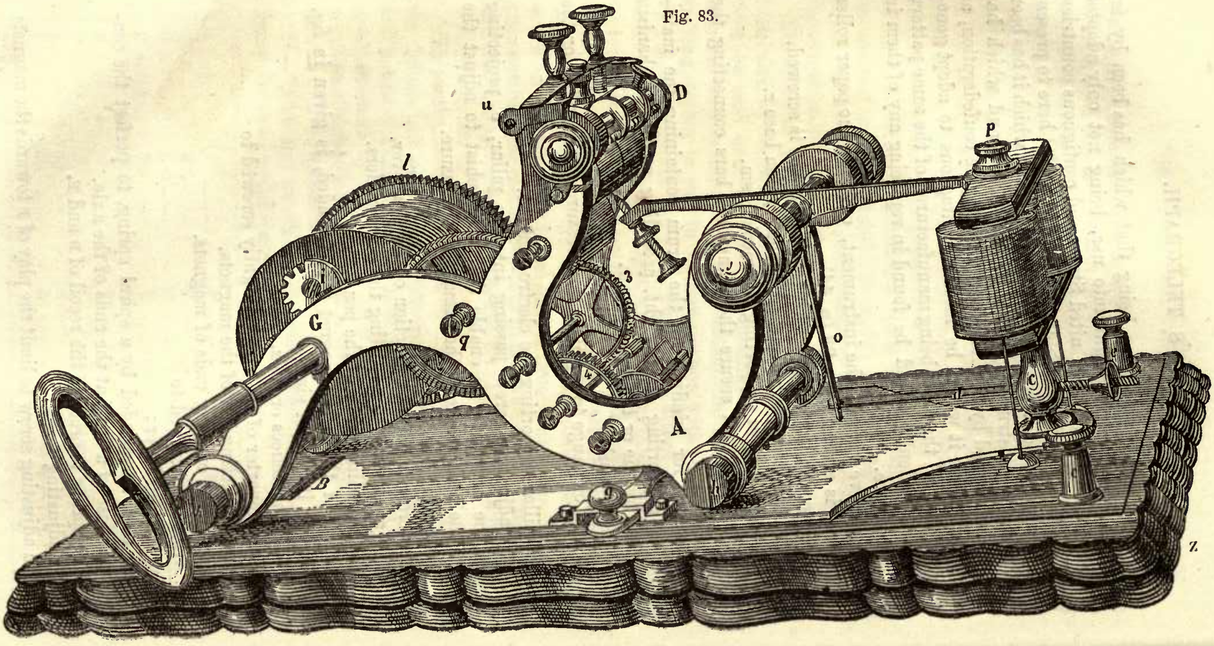
F, its axis, surrounded by a spiral spring, to perfect the connection in case of a fault at the ends of the axle.

M. The spring to produce the recoil of D and E.

L. Its adjusting screw.

H. An adjusting screw to limit the play of E towards the magnet;

Fig. 83.



R, its point of platinum.

S. An adjusting screw to limit the play of E from the magnet.

T. Its insulating point, in ivory.

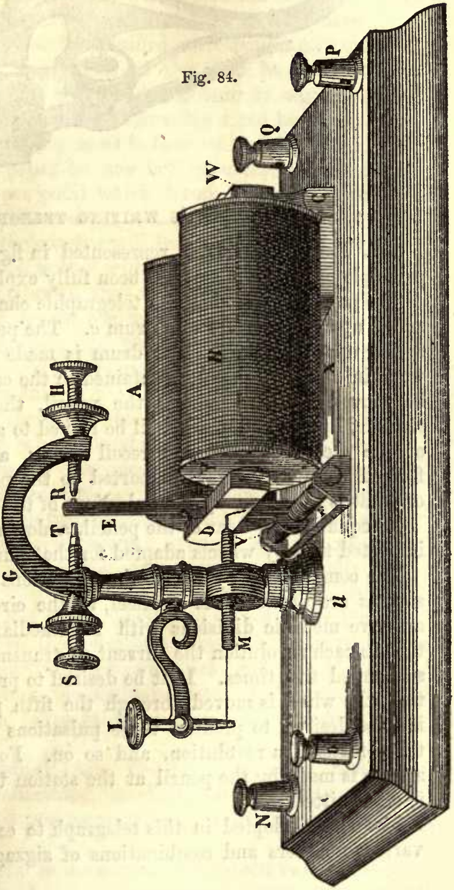
O N. Screws to connect with the wires of the station battery.

P Q. Screws to connect with the line wires.

X. The point where the coil wire passes through

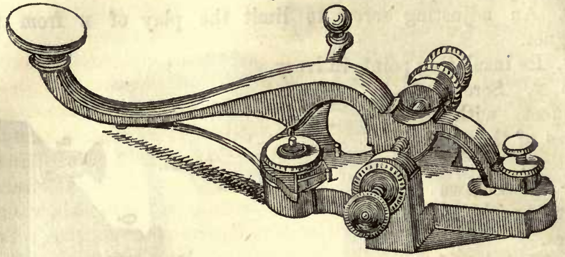
u, the base of the magnet.

Fig. 84.



The form recommended for the key commutator is represented in its proper magnitude in fig. 85 (p. 46). When the key is held down the circuit is perfect. It is not liable to wear and to produce a doubtful connection. The whole arrangement is designed to avoid the evils heretofore existing, and perfect every questionable part. The anvil of the key is well made, firm, and capable of hard wear, regardless of the adjustment of the key lever. The hammer of the key lever is also firm, and made of good platina wire, and securely made fast in the key lever. The adjusting screws of the axle are arranged according to the best mode, to secure the most perfect action. The elevation of the key lever can be adjusted to suit the operator, by elevating the key frame, or otherwise.

Fig. 85.



FROMENT'S WRITING TELEGRAPH.

207. This apparatus is represented in fig. 86 (p. 49), and the principle on which it acts has been fully explained in (153).

The paper upon which the telegraphic characters are written is rolled upon the surface of a drum *c*. The pencil *b* is pressed by a spring upon the paper. The drum is made to revolve by clock-work in the usual manner contained in the case *h*. If the paper be moved without moving the pencil, the latter will trace a straight line; but if the pencil be moved to and fro by the action of the electro-magnet and recoil spring, a zigzag line will be formed by the vibrations imparted to the pencil by the magnet, or what is the same, by the pulsations of the current.

To equalise the wear of the pencil, a slow motion of rotation is imparted to it by wheels adapted for that purpose.

The commutator by which the pulsations which determine the signals are produced, is a wheel, at the circumference of which are five metallic divisions with intermediate spaces vacant, so that in each revolution the current is transmitted five times, and suspended five times. If it be desired to produce a single pulsation, the wheel is moved through the fifth part of a revolution; if it be desired to produce three pulsations it is moved through three-fifths of a revolution, and so on. For each pulsation, one zigzag is made by the pencil at the station to which the despatch is transmitted.

The signs adopted in this telegraph to express the letters, are various numbers and combinations of zigzag forms.

BAIN'S ELECTRO-CHEMICAL TELEGRAPH.

208. The manner in which the decomposing power of the current is capable of producing written characters at a distance from the hand of the writer has been already explained (170).

Of the forms of telegraph in which this principle is brought into play, the only one which has been practically applied on an extensive scale is that projected by Mr. Alexander Bain.

209. To render this instrument understood, let us suppose a sheet of writing paper to be wetted with a solution of prussiate of potash, to which a little nitric and hydrochloric acid have been added. Let a metallic desk be provided corresponding in magnitude with the sheet of paper, and let this desk be put in communication with a galvanic battery so as to form its negative pole. Let a piece of steel or copper wire forming a pen be put in connection with the same battery so as to form its positive pole. Let the sheet of moistened paper be now laid upon the metallic desk, and let the steel or copper point which forms the positive pole of the battery be brought into contact with it. The galvanic circuit being thus completed, the current will be established, the solution with which the paper is wetted will be decomposed at the point of contact, and a blue or brown spot will appear. If the pen be now moved upon the paper, the continuous succession of spots will form a blue or brown line, and the pen being moved in any manner upon the paper, characters may be thus written upon it as it were in blue or brown ink.

An extremely feeble current is sufficient to produce this effect; but it will be necessary, when the strength of the current is very much reduced, to move the pen more slowly, so as to give the time necessary for the weakened current to produce the decomposition. In short, a relation exists between the greatest speed of the pen which is capable of leaving a mark, and the strength of the current; the stronger the current the more rapidly may the pen be moved. In this manner, any kind of writing may be inscribed upon the paper, and there is no other limit to the celerity with which the characters may be written, save the dexterity of the agent who moves the pen, and the sufficiency of the current to produce the decomposition of the solution in the time which the pen takes to move over a given space of the paper.

210. The electro-chemical pen, the prepared paper, and the metallic desk being understood, we shall now proceed to explain the manner in which a communication is written at the station where it arrives.

211. The metallic desk is a circular disk, about twenty inches in diameter. It is fixed on a central axis, with which it is capable of revolving in its own plane. An uniform movement of rotation is imparted to it by means of a small roller, gently pressed against its under surface, and having sufficient adhesion with it to cause the movement of the disk by the revolution of

the roller. This roller is itself kept in uniform revolution by means of a train of wheel-work, deriving its motion either from a weight or main spring, and regulated by a governor or fly. The rate at which the disk revolves may be varied at the discretion of the superintendent, by shifting the position of the roller towards the centre; the nearer to the centre the roller is placed, the more rapid will be the motion of rotation. The moistened paper being placed on this disk, we have a circular sheet kept in uniform revolution.

The electro-chemical pen, already described, is placed on this paper at a certain distance from its centre. This pen is supported by a pen-holder, which is attached to a fine screw extending from the centre to the circumference of the desk in the direction of one of its radii.

On this screw is fixed a small roller, which presses on the surface of the desk, and has sufficient adhesion with it to receive from it a motion of revolution. This roller causes the screw to move with a slow motion in a direction from the centre to the circumference, carrying with it the electro-chemical pen. We have thus two motions, the circular motion carrying the moistened paper which passes under the pen, and the slow rectilinear motion of the pen itself directed from the centre to the circumference. By the combination of these two motions, it is evident that the pen will trace upon the paper a spiral curve, commencing at a certain distance from the centre, and gradually extending towards the circumference. The intervals between the successive coils of this spiral line will be determined by the relative velocities of the circular desk, and of the electro-chemical pen. The relation between these velocities may likewise be so regulated, that the coils of the spiral may be as close together as is consistent with the distinctness of the traces left upon the paper.

A view of the circular desk, the chemical pen, and the clockwork is given in fig. 87 (p. 65), which will render the preceding explanation more easily understood.

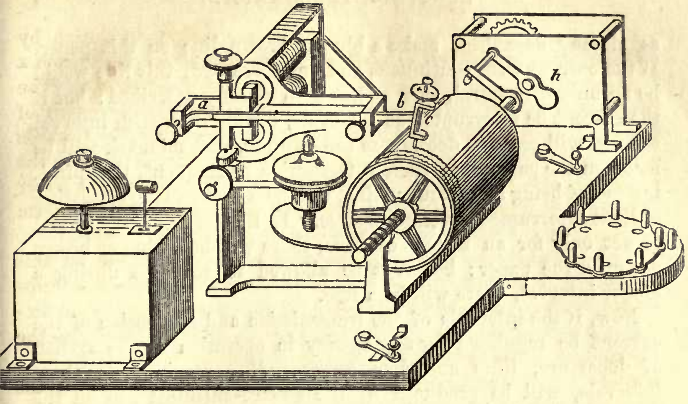


Fig. 86.—FROMENT'S WRITING TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER X.

212. Operation of Bain's telegraph.—213. Its commutator.—214. Its extraordinary speed of transmission.—215. Obstructions to its practical application.—216. Its prospects.—217. Autograph telegraph.—218. House's printing telegraph.—219. Its operation.—220. Henley's magnetic telegraph.—221. Brett's printing telegraph.—222. Celerity of telegraphic communication.—223. Circumstances which affect it.—224. Comparative ability of telegraphists.—225 Each telegraphist known by his manner of transmitting.—226. Easier to transmit than to receive.—227. Pauses in transmission.—228. Rate of transmission with double needle instruments worked by voltaic current.—229. Rate with magneto-electric current.

212. Now, let us suppose that the galvanic circuit is completed in the manner customary with the electric telegraph, that is to say, the wire which terminates at the point of the electro-chemical pen is carried from the station of arrival to the station of departure, where it is connected with the galvanic battery, and the returning current is formed in the usual way by the earth itself. When the communication between the wire and the galvanic battery at the station of departure is established, the current will pass through the wire, will be transmitted from the point of the electro-chemical pen to the moistened paper, and will,

as already described, make a blue or brown line on this paper. If the current were continuous and uninterrupted, this line would be an unbroken spiral, such as has been already described; but if the current be interrupted at intervals, during each such interval the pen will cease to decompose the solution, and no mark will be made on the paper. If such interruption be frequent, the spiral, instead of being a continuous line, will be a broken one, consisting of lines interrupted by blank spaces. If the current be allowed to act only for an instant of time, there will be a blue or brown dot upon the paper; but if it be allowed to continue during a longer interval, there will be a line.

Now, if the intervals of the transmission and suspension of the current be regulated by any agency in operation at the station of departure, lines and dots corresponding precisely to these intervals, will be produced by the electro-chemical pen on the paper, and will be continued regularly along the spiral line already described. It will be evident, without further explanation, that characters may thus be produced on the prepared paper corresponding to those of the telegraphic alphabet already described in the case of Morse's telegraph, and thus the language of the communication will be written in these conventional symbols.

There is no other limit to the celerity with which a message may be thus written, save the sufficiency of the current to effect the decomposition while the pen passes over the paper, and the power of the agency used at the station of departure to produce, in rapid succession, the proper intervals in the transmission and suspension of the current.

The succession of intervals of transmission and suspension of the current on which the production of the written characters on the prepared paper depends, may obviously be produced by the key commutator (128); and with that instrument at the station from which the dispatch is transmitted, an agent can convey in the same manner and with the same celerity as in the case of the telegraph of Morse, or that of Froment; and such is in fact the manner in which dispatches are usually transmitted with this apparatus.

213. But this form of commutator, though perfectly efficient so far as it goes, does not call into operation all that extraordinary celerity which forms the prominent feature of this invention, and of which a remarkable example has been already mentioned in the case of the experiments performed by M. Le Verrier and myself before the Committees of the Institute and the Legislative Assembly at Paris, which were made with these instruments, and, as we have stated, dispatches were

sent along a thousand miles of wire, at the rate of nearly 20000 words an hour.

We shall now explain the means by which this extraordinary feat is accomplished. The despatch must pass through the following preparatory process :—

A narrow ribbon of paper is wound on a roller, and placed on an axis on which it is capable of turning so as to be regularly unrolled. This ribbon of paper is passed between rollers under a small punch, which striking upon it makes a small hole at its centre. This punch is worked by a simple mechanism so rapidly, that when it is allowed to operate without interruption on the paper passing before it, the holes it produces are so close together as to leave no unperforated space between them, and thus is produced a continuous perforated line. Means, however, are provided by which the agent who superintends the process, can, by a touch of the finger, suspend the action of the punch on the paper, so as to allow a longer interval to elapse between its successive strokes upon the paper. In this manner a succession of holes are perforated in the ribbon of paper, separated by unperforated spaces. The manipulator, by allowing the action of the punch to continue uninterrupted for two or more successive strokes, can make a linear perforation of greater or less length on the ribbon, and by suspending the action of the punch these linear perforations may be separated by unperforated spaces.

Thus it is evident, that being provided with a preparatory apparatus of this kind, an expert agent will be able to produce on the ribbon of paper as it unrolls, a series of perforated dots and lines, and that these dots and lines may be made to correspond with those of the telegraphic alphabet already described.

Let us imagine, then, the agent at the station of departure preparing to despatch a message. Preparatory to doing so, it will be necessary to inscribe it in the perforated telegraphic characters on the ribbon of paper just described.

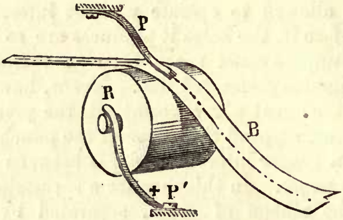
He places, for this purpose, before him the message in ordinary writing, and he transfers it to the ribbon in perforated characters by means of the punching apparatus. By practice he is enabled to execute this in less time than would be requisite for an expert compositor to set it up in common printing type.

The punching apparatus for inscribing in perforated characters the dispatches on ribbons of paper is so arranged, that several agents may simultaneously write in this manner different messages, so that the celerity with which the messages are inscribed on the perforated paper may be rendered commensurate with the rapidity of their transmission by merely multiplying the inscribing agents.

Let us now imagine the message thus completely inscribed on the perforated ribbon of paper. This ribbon is again rolled as at first upon a roller, and it is now placed on an axle attached to the machinery of the telegraph.

The extremity of the perforated ribbon at which the message commences is now carried over a metallic roller, which is in connexion with the positive pole of the galvanic battery. It is pressed upon this roller, as represented in fig. 88, by a small

Fig. 88.



metallic spring, terminating in points like the teeth of a comb, the breadth of which is less than that of the perforations in the paper. This metallic spring is connected with the conducting wire which passes from the station of departure to the stations of arrival. When the metallic spring falls into the perforations of the ribbon of paper as the latter passes over the roller, the galvanic circuit is completed by the metallic contact of the spring with the roller; but when those parts of the ribbon which are not perforated pass between the spring and the roller, the galvanic circuit is broken and the current is interrupted.

A motion of rotation, the speed of which can be regulated at discretion, is imparted to the metallic roller by clockwork or other means, so that the ribbon of paper is made to pass rapidly between it and the metallic spring, and, as it passes, this metallic spring falls successively into the perforations on the paper. By this means the galvanic circuit is alternately completed and broken, and the current passes during intervals corresponding precisely to the perforations in the paper. In this manner the successive intervals of the transmission of the current are made to correspond precisely with the perforated characters expressive of the message, and the same succession of intervals of transmission and suspension will affect the writing apparatus at the stations of arrival in the manner already described.

214. Now there is no limit to the speed with which this process can be executed, nor can there be an error, provided only that

the characters have been correctly marked on the perforated paper; but this correctness is secured by the ribbon of perforated paper being examined after the perforation is completed and deliberately compared with the written message. Absolute accuracy and unlimited celerity are thus attained at the station of departure. To the celerity with which the dispatch can be written at the station of arrival there is no other limit than the time which is necessary for the electric current to produce the decomposition of the chemical solution with which the prepared paper is saturated.

215. It may be asked then why this form of telegraph, affording as it does the means of obtaining a celerity of transmission so far exceeding any other that has been projected, has not been universally adopted?

To this it may be answered that the celerity here described can only be attained after the dispatch to be transmitted has been marked in the pierced telegraphic characters on the ribbon of paper, and that the process of so marking it would not be more rapid, however expert the operator might be, than that by which the same operator would transmit the same dispatch directly by the key commutator, either with this telegraph or those described in (191, 192). If, therefore, the time necessary to commit the dispatch in telegraphic characters to the perforated ribbon of paper, be included in the estimate of the time of its transmission from station to station, this form of telegraph is not only slower and consequently less efficient than either of those described in (191, 192), but it is slower than any other form of telegraph whatever.

It must therefore be admitted, that, so long as the demands upon the conducting wires do not exceed their powers of transmission by the operation of the ordinary methods now commonly practised, the contrivance of Mr. Bain can present no very strong claims for preference over the other systems. But if the demands of the public should be greatly multiplied, as they certainly would be by lowering the tariff, then the method above described would be presented under different conditions, and might become the only expedient of all those hitherto contrived, by which such augmented demands could be satisfied.

216. If for example the time should arrive when a much more considerable share of the demands now satisfied by the post-office should be transferred to the telegraph; if instead of short and unsatisfactory dispatches conveying political and general intelligence to the journals, fully detailed circumstantial statements and reports were required; if the same full reports of speeches and debates, on occasions of great public interest, or reports of any

proceedings or events of adequate importance, taking place at a distance, which are now transmitted through the post-office were required to be sent by telegraph, it is clear that the apparatus now in common use, of whatever form, would be utterly inadequate to the satisfaction of such demands.

But how, it will be asked, would the system of Bain be more efficient? The answer is obvious. Nothing more would be necessary than to engage a greater number of persons for the purpose of committing the dispatches to the perforated ribbons. If a great number of dispatches, short or long, be brought at once into the telegraphic office for transmission, let them be immediately distributed among a proportionate number of the persons engaged in the preparation of the ribbons. A long dispatch might be divided into several portions, and distributed among several, just as a manuscript report intended for publication in a journal is distributed among several compositors. When the despatches thus distributed should be committed to the ribbons, these ribbons might be connected together so as to form longer continuous ribbons, which being put into the telegraphic instruments would be sent to their destination at the rate of 20000 words an hour on each wire.

A mercantile firm, or the correspondent of a journal might, if they were so minded, have their own punching apparatus and their own telegraphic cipher, and instead of sending to the telegraphic-office a manuscript dispatch they would send a ribbon of paper containing the dispatch marked upon it, which being put directly into the instrument would be instantly transmitted to its destination. And this would be attended with the further advantage that the contents of the dispatch would be concealed from the agents themselves employed in its transmission. The party to whom the dispatch is addressed would in this case receive the sheet taken from the instrument written in the cipher of which he alone would possess the key.

It often happens, especially in the business of government or that of journalism, that the same dispatch is required to be transmitted to many different places in different directions. By the system of Bain this would be easily accomplished. The same ribbon which sends the dispatch in one direction may be transferred immediately to another instrument acting upon another line of wire, or even remaining in the same instrument the transmission may be repeated, changing the direction by a commutator.

If it were required no great difficulty would be presented by the process of perforating two or more ribbons at once with the same dispatch. The process would not be slower than that required for a single ribbon, and in that case the several ribbons might be at the same time sent to different telegraphic stations, and their contents transmitted in various directions.

In this view of the question, the system of Bain is to the common telegraph what the steam-engine is to the horse, the power to the hand-loom, the lace-frame to the cushion, the self-acting mule to the distaff, or the stocking-frame to the knitting-needle.

217. A modification of the electro-chemical telegraph has been contrived, by which a dispatch may be transmitted to any distant station, and then delivered in the handwriting of the person who transmits it.

By this method, a person at any station, as for example at London, may write a communication in characters used in common writing or printing on paper placed at another distant station, as for example at Trieste, and this writing shall be traced on the paper with as much precision as if the person writing held the pen in his hand.

We may imagine that the electro-chemical pen placed on the paper at Trieste is extended to London, and there held and directed by the hand of the writer, for this it is which almost literally takes place. The conducting wire, in connection with that part of the electro-chemical pen which is held in the hand, which extends from Trieste to London, may be considered as only forming part of this pen, and the end of such pen at London, held and directed by the hand of the writer, will communicate a motion to its point at Trieste, in exact correspondence with the characters formed by the hand of the writer.

Thus, if the writer at London move the extremity of the conducting wire so as to write a phrase or his usual autograph, the point at Trieste will there inscribe on the prepared paper the same phrase with the same signature annexed, and the writing of the phrase and the signature will be identical with that of the writer.

In the same manner a profile or portrait, or any other outline drawing may be produced at a distance. The methods of accomplishing this depend, like the other performances of electricity in this application of it, on the alternate transmission and suspension of the current, and on its decomposing power; but as they are at present more matters of curiosity than of practical utility, we shall not detain the reader here with any more detailed notice of them.

HOUSE'S TELEGRAPH.

218. This apparatus, which is in extensive use in the United States, is an example of the class of printing telegraphs, that is,

instruments which print in the ordinary letters the dispatch at the station to which it is addressed, by means of a power worked at the station from which it is transmitted. In a certain sense, this is accomplished by the three forms of telegraph described in (202, 203, and 204); but in these cases the dispatch is printed or written in cipher, which is attended with the inconvenience of being understood only by those who possess, and are sufficiently familiar with the key. The process of deciphering it, and writing it in common characters, occupying more or less time, for some purposes, such for example as that of journalism, this time must be taken into account in estimating the practical celerity of communications, inasmuch as the dispatch until so interpreted, is not available to the parties to whom it is addressed.

A telegraph which instead of impressing on paper characters in cipher, would impress the characters of common letter-press, even though these should be transmitted and impressed at a slower rate than that of the transmission of the characters in cipher, might nevertheless be, in effect, more expeditious, more time being saved by superseding the process of interpreting the cipher than is lost by the relative slowness of the transmission.

It is evident that these observations, being general, are applicable, not only to the instrument we are now about to describe, but to all others of the same class.

219. House's printing telegraph, like all other telegraphic instruments, consists of two distinct parts, a commutating apparatus to govern the transmission of the current, and a printing apparatus upon which the current arriving from a distant station operates.

The manner in which the transmission of the current is controlled by the keys of the finger-board, is substantially the same as in Froment's telegraph already described. The wheel, however, that produces by its revolution the pulsations of the current, is moved, not as in Froment's by clock-work, but by the foot of the operator, acting upon a treddle like that of a lathe which is seen under the case of the commutator in the fig. 89 (p. 81).

The rotation of this wheel is arrested at the point corresponding to any desired letter, by putting down with the finger the key upon which that letter is engraved, in exactly the same manner and by the same mechanical expedient as in Froment's telegraph.

The keys, upon the key-board of this instrument, govern by means of the pulsations of the current the motion and position of a dial or wheel at a distant station, inscribed with similar characters in the same manner as has been already explained in the case of the French railway telegraphs, and in that of the telegraph explained in (201).

Let us then suppose that by putting down any key, that inscribed with A for example at the station S, a certain dial or wheel at S′, having upon it letters corresponding with those of the key-board at S, is so moved that the letter A is brought into a certain position. The letters upon this wheel are formed in relief like type, and when successively brought into the necessary position by the action of the current, having previously passed in contact with an inking apparatus, a band or ribbon of paper is pressed against them by means provided at the station S′, and the impression of the letter is made upon the paper. By the next action of the current, the succeeding letter transmitted is brought to the same position, the ribbon of paper being meanwhile drawn forward, another impression takes place, and so on.

The apparatus by which the ribbon of paper is moved, the type inked, and the paper pressed against it is not worked by the current. That process is effected by mechanism put in operation by the agent at the station at which the dispatch is received.

In the figure, the ribbon of paper is represented at F, upon a roller from which it is gradually drawn, as letter by letter the words of the dispatch are impressed upon it. The black band which appears upon another roller is an endless strap by which the types are inked.

In the mechanism as well of the transmitting as of the receiving apparatus, there are many details showing much ingenuity of contrivance, and resources of invention, which, however, are too complicated to admit of any clear exposition without numerous plans and sections, and which we must pass over.

The printing apparatus, at the station at which the dispatch is received, is put in operation by the action upon the treddle, in the same manner as in the transmitting apparatus at the other station.

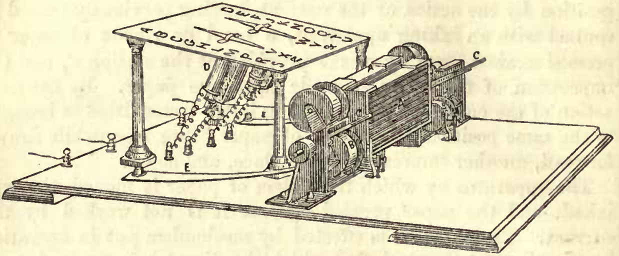
The galvanic apparatus, which supplies the current for working this apparatus, is the battery of Grove, described in (34). About thirty cylindrical pairs are necessary for a distance of 100 miles.

The first line operating with this apparatus was established between New York and Philadelphia in 1849.

MAGNETIC NEEDLE TELEGRAPH.

220. The Magnetic Telegraph Company, retaining the needle indicators generally used in England, have rejected the galvanic battery, and substituted the magneto-electric for the voltaic current. The instruments they have adopted are those which

Fig. 90.



were patented by Messrs. Henley and Forster, with some modifications.

This form of telegraph, enclosed in its case, is shown in fig. 91 (p. 97), and divested of its case in fig. 90.

The current is produced by electro-magnets, whose poles are moved in close proximity with those of strong compound permanent magnets. These latter are represented at A (fig. 90). At their poles a straight piece of soft iron is placed, by the inductive influence of which the magnetism of the several bars composing the compound magnet is collected and combined. The electro-magnets are formed in the usual way, and are mounted on centres on which they are turned by levers, which project from either side of the case, so that the agent can work one with each hand. When they have been pressed down by the hand they are raised to their former position by springs which are fixed on their axle.

When these levers are pressed down, the electro-magnets are reversed in the relation of their poles to those of the permanent magnets, and momentary currents are transmitted on the conducting wires, and when the levers are observed to rise to their former position, momentary currents are again transmitted, but in a contrary direction.

The currents thus transmitted on the line-wires are received at the station to which the dispatch is transmitted upon the coils of electro-magnets, which are placed under the desk upon which the indicating needles are placed, and they impart temporary magnetism to these. These electro-magnets act upon a small permanent magnet suspended under the desk, on the axis of the indicating needle, and parallel to it. They deflect this needle on the one side or the other, at the moment they receive the magnetism from the current, and their deflection is continued by the effect of the induced magnetism produced by the permanent magnet on the electro-magnet.

When the handle is raised, the momentary current being reproduced, but in the contrary direction, the polarity of the electro-magnet at the distant station is reversed, and the needle is deflected in the same manner to the other side.

BRETT'S PRINTING TELEGRAPH.

221. Mr. Brett, who has obtained such well-merited celebrity by his successful exertions in establishing electric communication by submarine cables between the United Kingdom and the continent of Europe, and more recently between the continents of Europe and Africa, took out, conjointly with Mr. House, a patent for a printing telegraph, the original form of which is represented in fig. 92 (p. 113).

The apparatus, like that of House's American telegraph, already described, consists of a key-board, which is the transmitting apparatus or commutator, and does not differ in any important particular from that already described. The receiving and pointing apparatus is also very similar, and stands upon the key-board. In front of it is an indicating dial, the hand upon which points successively to the letters printed upon the scroll of paper by the apparatus behind the dial. The printing apparatus, with some modifications, is similar to that of House.

This telegraph is, or was, lately exhibited at work in the Panopticon of Science, in Leicester Square.

The Messrs. Brett are understood, however, to be engaged upon the construction of an instrument which is expected to attain the same objects in a more satisfactory manner.

CELERITY OF TRANSMISSION.

222. Although it be true that the signals made at any one telegraphic station are rendered instantaneously apparent at another, no matter how distant, it must not therefore be inferred that the transmission of messages by the telegraph is equally instantaneous. Not only is this not the case, but the celerity with which messages are conveyed between station and station, so as to be rendered practically available for the purposes of intercommu-

nication, differs very much when one form of telegraphic instrument or one pair of operators is compared with another.

The profitable result of the operation of any telegraph is evidently measured by the number of words which it is capable of transmitting in such a shape as to be intelligible by the party to whom the message is addressed, in a given time. This, which we shall call the celerity of transmission, and which is quite distinct from the velocity with which electric signals are conveyed from station to station, is therefore a most important element in the estimation of the value of any telegraphic apparatus.

223. This celerity of transmission depends upon a great number of circumstances, several of which are independent of the telegraphic apparatus. The principal of these are :—

1. The skill and agility of the transmitting agent.
2. The quickness of eye, activity and attention of the receiving agent.
3. The instrument used for transmission.
4. The instrument used for reception.
5. The distance to which the dispatch is transmitted.
6. The insulation more or less perfect of the line wires.
7. The weather.

With all and each of these conditions and qualities the celerity with which the dispatches are received and rendered available at their place of destination, varies, and with some of them this variation extends to very wide limits.

224. Different telegraphists have very different powers as to celerity. These powers depend on practice as well as upon natural ability and aptitude, and on manual dexterity. Not only is it necessary to transmit the signals in quick succession, but to do so with such distinctness that they shall be readily interpreted, and such correctness as to render repetitions unnecessary. In this respect telegraphists having equal practice differ one from another as much as do clerks, some writing rapidly and legibly, some rapidly but not legibly, some legibly but not rapidly, and some neither rapidly nor legibly. The relative ability of telegraphists in this respect is partly mental and partly mechanical, depending as much upon quickness of intelligence, attention, and observation, as upon manual dexterity and address.

The great liability to delay, arising from the failure of the transmitter to render himself understood by the receiver, is rendered manifest by the fact that in all telegraphs conventional signs are established for the words, "wait," "repeat," "not understood," "understood," "proceed," and the like. When the transmitter is going on faster than the receiver can take down the words or understand them, then the latter remits the sign to "wait," and if this sign is several times repeated, the necessity of proceeding slower is apparent. If the receiver mistakes a sentence, word, or letter, he remits the sign to "repeat." At the end of each sentence, he remits the sign "understood," and so on. Now it will be easily conceived that this necessity for frequent interchange of signs between the receiver and transmitter must affect, in an important degree, the celerity of transmission, and that its frequency must depend, not only on the abilities of the telegraphic agents, but also on the character of the signs transmitted by the instruments, according as they are more or less obvious and unequivocal.

225. It is a remarkable and very curious circumstance, that, independently of the mere celerity, clearness, and correctness of transmission with certain telegraphic instruments each telegraphist has a manner and character, which is so peculiar to himself, that persons receiving his dispatch at a distant station, recognise his personality with as much certainty and facility as they would recognise the handwriting of a correspondent, or the voice and utterance of a friend or acquaintance, whom they might hear speak in an adjacent room. The agents habitually engaged at each of the telegraphic stations, in this way, soon become acquainted with those of all the other stations on the same line, so that, at the commencement of a dispatch, they immediately know who is transmitting it.

While the aptitude of the transmitter is partly manual or mechanical, that of the receiver of a dispatch is not at all so. In some telegraphic instruments, as we have seen, the presence of a receiving agent is unnecessary, the dispatch being written or printed by the apparatus itself. In all instruments, however, which merely exhibit arbitrary signals, expressing letters, numbers, or words, the celerity must depend on the skill, aptitude, and quickness of eye of the receiver, to catch and commit to paper the succession of letters or words, as fast as the signals expressing them are produced before him.

226. In general, it is much more easy to transmit rapidly than to receive rapidly. The transmitter knows beforehand what signs he is about to produce, while each of them comes upon the receiver altogether unawares, and if, in the celerity of their succession, one or more of them escape his eye, he is obliged either to guess at the missed letter or letters, which he can sometimes do with all the requisite clearness and certainty, or he must arrest the transmitter, which he does by giving the sign, "repeat," and so delay arises.

In telegraphs which work by a series of visible signs, whether they be deflections of the needle, as in the English instruments, attitudes of the arms, as in the French State instruments, or pointers directed to the letters or figures on a dial, as in the railway instruments, the celerity of the transmission must be determined by the power of the less able of the two agents, the transmitter and receiver. If the transmitter be able to send the letters more rapidly than the receiver can read and take them down, he must moderate his pace to the limit determined by the power of his correspondent. If the receiver be capable of reading and taking down faster than the transmitter is able to send the letters, his superior force is useless. He can only write the dispatch as fast as he receives it. To send dispatches with the greatest advantage of celerity, the agents yoked to corresponding instruments ought to be selected of as nearly equal ability as possible, since the slower of a pair necessarily neutralises the superior skill of his fellow, and the dispatch would proceed with equal celerity if he were yoked with a less able correspondent.

As quickness of hand is essential to the transmitter, quickness of eye is necessary to the receiver.

227. In all forms of telegraph which express the letters by signals, such as the needle telegraph, and the French State telegraph, a certain pause is necessary between letter and letter, to prevent the signals being confounded one with another. In the single needle instrument, the letters being expressed by from one to four deflections of the needle, and in the double needle, from one to two, the mean time of each letter is that of two and a half deflections in the one, and one and a half in the other, the intervals between letter and letter being the same in both. Owing to the slowness of transmission of the single needle instrument, it is only used between secondary stations, where there is but little business. It must, however, be remembered, in comparing the relative celerity of different instruments, that the double needle instrument, as well as the French State telegraph, is, in fact, two independent telegraphs, having not only separate and independent transmitting and indicating apparatus, with their respective accessories, batteries, &c., but separate and independent conducting wires. It is, in effect, as if two equally powerful and independent steam engines were united in the same work, in order to obtain double power.

228. In 1850, Mr. Walker made some calculations, with the view to determine the average celerity of transmission at that time with the double needle instrument in the hands of competent operators, and published the results in his work on electric telegraph manipulation. Eleven messages were timed, all of more than the usual length, the shortest consisting of 73 and the longest of 364 words. The total number of words was 2638, and,

consequently, their average length was 240 words. The total time of transmission was 162 minutes, and, consequently, the average number of words transmitted, per minute, was $16\frac{1}{4}$. The greatest speed of transmission was $20\frac{1}{2}$, and the least $8\frac{1}{4}$ words per minute.

As it might be considered probable that four or five years' general experience and practice might have improved the ability of the operators, I applied to the secretary of the Electric Telegraph Company, Mr. Foudrinier, requesting him to cause a sufficient number of messages, transmitted in the ordinary course of business with the double needle instrument, to be timed, which he was so obliging as to do, in June, 1854, and the following were the results:—

11 Messages.—Number of words in the addresses . . .	84
,, ,, ,, messages . . .	160
Total number of words transmitted .	244
Total time of transmission	689 seconds.
Average number of words transmitted per minute . .	$21\frac{1}{4}$

It appears, therefore, that the average celerity of transmission with this instrument has increased in the ratio of about 16 to 21.

The greatest celerity of transmission was, in this case, $24\frac{1}{2}$, and the least $16\frac{3}{4}$ words per minute.

229. The manner in which the magnetic electric current affects the needle in the arrangement adopted by the Magnetic Telegraph Company, being somewhat different from that produced in the common needle instruments, worked by the Electric Telegraph Company, although the systems of telegraphic signals are not essentially different, it appeared to me to be not impossible that the difference between the instruments might more or less affect the celerity of transmission. I therefore requested Mr. Bright, the Secretary of the Magnetic Company, to time a series of dispatches transmitted in the ordinary course of business. This was accordingly done on the 28th of June, 1854, and the following were the results:—

74 Messages.	Total number of words	2792
	Time of transmission . . .	$102^m\ 8^s$
	Average number of words per minute	$27\frac{1}{3}$

The greatest celerity of transmission attained in this series of messages was $37\frac{1}{6}$ words per minute.

The entire series consisted of messages transmitted from London to Liverpool, on a pair of double needle instruments, at different times of the day, and were carefully tabulated. In the series, several messages were included, the transmission of which was exceptionally slow, owing either to the difficult nature of the communications, consisting of long words in private cipher, or of the names of foreign towns, or, in fine, from the inaccuracy or slowness of the transmitting clerk in London. It would seem, therefore, that this series of messages includes fair conditions for an average result.

It would, therefore, appear that the needle instruments worked by the magneto-electric current used by this company are, *ceteris paribus*, susceptible of greater celerity of transmission than the instruments in which the needles are affected by the common voltaic current, in the ratio of about 27 to 21, or 9 to 7.

One of the causes which has been assigned to this increased efficiency, is the fact that the needles of the magnetic instruments have a *dead beat*, while those of the voltaic instruments, in striking the stops, have a recoil, and vibrate two or three times before they come to rest. Whether this be the real cause of the difference, further experience must prove, but it is difficult to imagine that it can be due to any cause independent of the instruments, seeing the large number of messages from which the average has been computed.

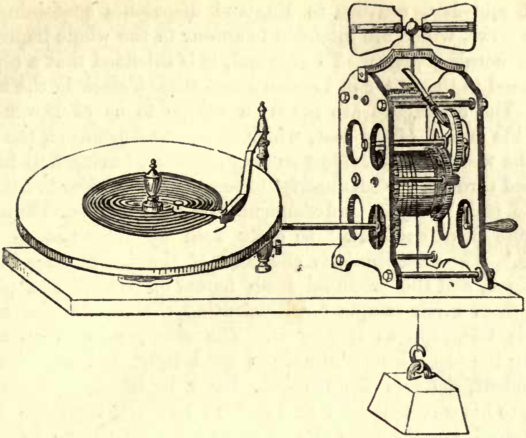


Fig. 87.—BAIN'S ELECTRO-CHEMICAL TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XI.

230. Illustration of the efficiency of the needle instruments.—231. Rate of transmission with the French state telegraphs.—232. With the French railway telegraphs.—233. With the Morse telegraph.—234. Discrepancy of reports.—235. Causes of its celerity.—236. Rate with Bain's telegraph.—237. Transmission of music.—238. Rate of transmission with House's telegraph.—239. Distance sometimes affects celerity.—240. Examples of distant transmissions in U. S.—241. Advantages of uniform organisation.—242. Uses of the electric telegraph.—243. Subject of dispatches.—244. Effect of the tariff.—245. Uses of the telegraph in railway business.—246. Portable railway telegraph.—247. Practical uses on railways.—248. Its economical advantages.

230. Mr. Walker, writing in 1850, gives the following illustration of the efficiency which has been attained in the working of the needle system, and in the management generally of the telegraphic business:—

"The rate at which newspaper dispatches are transmitted from Dover to London, is a good illustration of the perfect state to which the needle telegraph has attained, and of the apt manipulation of the officers in charge. The mail, which leaves Paris about mid-day, conveys to England dispatches containing the latest news, which are intended to appear in the whole impression of the morning paper. To this end, it is intended that a copy be delivered to the editor in London about three o'clock in the morning. The dispatches are given in charge to us at Dover soon after the arrival of the boat, which of course depends on the wind and the weather. The officer on duty at Dover, having first hastily glanced through the manuscript to see that all is clear to him and legible, calls 'London' and commences the transmission. The nature of these dispatches may be daily seen by reference to 'The Times.' The miscellaneous character of the intelligence therein contained, and the continual fresh names of persons and places, make them a fair sample for illustrating the capabilities of the electric telegraph as it now is. The clerk, who is all alone, placing the paper before him in a good light, and seated at the instrument, delivers the dispatch, letter by letter, and word by word, to his correspondent in London; and although the eye is transferred rapidly from the manuscript copy to the telegraph instrument, and both hands are occupied at the latter, he very rarely has cause to pause in his progress, and as rarely also does he commit an error. And, on account of the extremely limited time within which the whole operation must be compressed, he is not able, like the printer, to *correct his copy*.

"At London there are two clerks on duty, one to read the signals as they come, and the other to write. They have previously arranged their books and papers: and, as soon as the signal for preparation is given, the writer sits before his manifold book, and the reader gives him distinctly word for word as it arrives; meanwhile, a messenger has been dispatched for a cab, which now waits in readiness. When the dispatch is completed, the clerk who has received it reads through the manuscript of the other, in order to see that he has not misunderstood him in any word. The hours and minutes of commencing and ending are noted, and the copy being signed is sent under official seal to its destination, the manifold facsimile being retained as our office copy, to authenticate verbatim what we have delivered. This copy and the original meet together at the chief telegraph office at Tunbridge, early in the day, and are compared. When the work is over, and the dispatches have reached their destination, the clerks count over the number of words and the number of minutes, and find the rate per minute."

231. The signals adopted to express the letters in the French State telegraph being each made by a single motion of the arms, they necessarily are produced with greater celerity than the multiplied deflexions of the needle-instruments. Like the double needle-instrument, the French telegraph is composed in fact of two

completely independent telegraphic instruments, with two independent conducting wires, and its celerity of transmission is due to their combined powers.

It is stated by the directors of the administration that the average transmitting powers of these telegraphs is nearly 200 letters or signs per minute.

232. The alphabetical telegraphs, of which the French railway telegraph may be taken as an example, are much slower in their rate of transmission. M. Breguet, who has constructed those worked in France, and superintended and directed their operation, says, that their average rate of transmission, when fairly worked, is about 40 letters per minute.

233. The writing and printing telegraphs are independent of a receiving agent, the receiving apparatus in all these being automatic. All these instruments have an advantage over the English and French telegraphs, inasmuch as they employ only one conducting wire, and those who print the dispatch in the common letter-press characters, have the further advantage of being wholly independent of the skill of any agent to interpret or decipher them.

The celerity of transmission attainable with the Morse telegraph, which of all the forms of telegraphic apparatus hitherto invented is the most extensively used, is very considerable, but varies perhaps still more than the needle-instruments, with the skill of the telegraphist.

In this instrument, it will be remembered that the transmitting agent plays upon a key-commutator, the letters being severally expressed by repeated touches of the key succeeding each other, after longer or shorter intervals. At the station receiving the dispatch, the armature of the electro-magnet moves simultaneously with the transmitting key, and at each of its motions towards the magnet, it produces a distinctly audible click. The receiving agent acquires by practice such expertness and quickness of ear, that by listening to this clicking he is able to interpret the dispatch, and to write it down or dictate it to a clerk without using the apparatus for impressing it upon the paper ribbon.

Different telegraphists acquire this power of oral interpretation of the dispatches with different degrees of facility and precision; but all are more or less masters of it. So much so, that in most cases on the American lines, it is by the clicking of the magnet that the messages are taken down, being afterwards corrected, if necessary, by comparison with the indented paper ribbon.

The telegraphist is placed at a table, upon which the instrument stands, having before him the paper upon which the message is to be written, and at his left a provision of blacklead pencils ready cut and pointed, usually half a dozen. When the transmission of the message commences, the electro-magnet dictates it to him, letter by letter, at the same time indenting it upon the paper ribbon. He writes it down, and, in general, it is delivered by the magnet as fast as he can write it, availing himself of all such abbreviations as are intelligible to those who may have to read it. As the points of the pencils are successively worn he lays them on the table at his right hand. A person engaged exclusively in that process, visits his table from time to time, repoints the pencils lying on his right, and replaces them on his left. This person passes round the telegraph office, from table to table, keeping up a constant supply of properly pointed pencils at the hand of each telegraphist.

The most expert telegraphists are able to take down the messages in this manner by ear, without any reference to the ribbon, and so correctly that there is no need of subsequent verification. When the message is concluded, the sheet on which it is written is handed to another clerk, who is provided with a stock of envelopes, in one of which he encloses it; and, writing the address upon it, delivers it to a messenger, who forwards it to the party to whom it is addressed. Meanwhile the paper ribbon, on which the message has been indented in the telegraph ciphers, is cut off, folded up, and preserved for reference.

It is only, however, the most expert class of telegraphists that can operate in this way. Others, less able, are always obliged to verify and correct what they have taken down, by comparison with the indented ribbon, after the message has been concluded; while others less able still, cannot trust themselves to take down *by ear*, and sit before the ribbon as it is discharged from the roller, writing out the message from it *by eye*.

The salaries allowed to different agents vary according to the skill they attain in these operations. One who acquires the power of taking down rapidly and correctly *by ear* will receive twice the amount allowed to him who can only take down *by eye*, the latter being always much slower than the former.

It often happens that the power of interpreting easily and correctly *by ear* is very important, as in the case in which the mechanism of the instrument for moving and indenting the paper may have been accidentally deranged and disabled, or in which the office may be deficient in its supply of paper ribbon.

By the oral method of reception the entire receiving apparatus, except the electro-magnet and its armature, is dispensed with.

If a mistake is committed by the transmitting agent, in consequence of which a word or phrase is unintelligible, the receiving agent intercepts the current, and signifies that the word is to be repeated, and at the same time tears off the erroneous part of the ribbon. This, however, is a circumstance of rare occurrence.

When a very long dispatch is transmitted, and arrives with greater celerity than that with which an agent can transcribe it, the ribbon may be divided, and two agents put to work at once at its transcription. The reports of congress and public meetings transmitted to the journals, afford examples of this.

These reports may be, by one operation, transmitted to all the towns upon the same telegraphic line.

In some cases long dispatches, such as those addressed to the journals, are expedited by two or more instruments on different wires. The dispatch is, in this case, divided into two or more parts, marked 1, 2, 3, or A, B, C, &c., and these parts are simultaneously transmitted to their destination, being reunited there after their arrival. This expedient, however, can only be resorted to where there are two or more line wires, which is a rare case in the United States.

234. If the celerity of transmission of the Morse instrument be compared with that of the English and French telegraphs, it must not be forgotten that the latter require two wires, while the former requires but one. In the transmission and reception of a dispatch both, however, employ the same number of agents.

There is great discrepancy in the reported estimates of the celerity of transmission of the Morse telegraphs, owing probably to the varying skill of the telegraphists on whose performance such estimates have been based.

According to Mr. Turnbull, the average celerity of transmission of this telegraph is from 135 to 150 letters per minute.

In a report made by Mr. O'Reilly, the director of one of the most extensive of the New York Companies, it is stated that the average rate of transmission is from 20 to 23 words per minute. Since it is generally estimated that the average length of telegraphic words is five letters and a half, this would amount to 110 to 127 letters per minute.

Mr. O'Reilly adds, however, that a "higher rate of transmission could be obtained, but as nearly all operators copy from their instruments, and reduce the messages to ordinary writing as they arrive, the rate of 20 to 23 words is considered rapid enough, as an expert operator can indent his Morse characters faster than most men can write the words they express with a pen or pencil."

We may perhaps take 150 letters as a fair estimate of the rate of transmission, and it follows therefore that this telegraph is more rapid than the double needle-telegraph in the ratio of about 3 to 2, and since the latter employs two wires with their accessories, while the former employs only one, it follows that the transmitting power of each wire with the Morse telegraph is three times as great as with the double needle instrument.

235. The causes of this greater celerity are twofold: first, the greater celerity with which the ciphers are impressed upon the ribbon of paper, compared with that with which the visible signals are exhibited and succeed each other in the English and French telegraphs; and secondly, the removal of those delays of transmission which arise from the want of attention or quickness of eye on the part of the agent receiving the dispatch, rendering it necessary to repeat words which have been missed or misunderstood.

In the American offices of the Morse lines, it is stated in the published reports that "there are a number of attendants, each one of whom has his respective department; they are divided into 'copyists, book-keepers, battery-keepers, messengers, line inspectors, and repairers.' The usual charge of transmission is 25 cts., equal to a shilling, for ten words exclusive of the address and the signature sent 100 miles: the messages vary in price from 10 cts., or *5d.*, to 100 dols., or *20l.* The amount of business which a well-conducted office can perform, and the net proceeds arising therefrom, may well excite surprise; a single office in that country, with two wires, one 500, the other 200 miles in length, after spending three hours in the transmission of public news, telegraphed, in a single day, 450 private messages, averaging 25 words each, besides the address and signature, sixty of which were sent in rotation, without a word of repetition."

236. All that has been said above relating to Morse's telegraph may *mutatis mutandis* be applied to other telegraphic instruments, which write in cipher the dispatches by self-acting machinery, such as those described in 191, 192, and 193.

When dispatches are transmitted by means of a key-commutator, with Bain's telegraph, the operation being precisely similar to that of Morse, the celerity of transmission by operators of equal skill ought to be the same. Nevertheless, as these instruments of Bain's, with some modifications, are at present used on certain lines by the Electric Telegraph Company, Mr. Foudrinier has, at my request, caused a series of messages to be timed, of which the following is the summary of the results:—

63 Messages.—Total number of words in the addresses .	456
,, ,, ,, messages . .	991
Total number of words transmitted .	1447
Total time of transmission	4454 seconds.
Average number of words transmitted per minute . .	$19\frac{1}{2}$

It appears, therefore, that as this telegraph is worked in

England, its rate of transmission is slower than the double needle telegraph.

The advantage which attends its use is that it writes the dispatch in cipher, which is preserved in the telegraphic office, so that the labour of a clerk to copy the dispatch for reference is saved.

It would follow from the comparison of this result with the reports of the American telegraph, that the operators with Bain's system in England are not as expert as those of Morse's in America. But when the method of transmitting by a previously-prepared perforated ribbon, described in 194, is resorted to, the apparatus is rendered absolutely automatic, no agency being required either in the transmission or reception, save that required for the perforation of the transmitting ribbon, and the interpretation and transcription of the dispatch delivered in the telegraphic cipher.

Whatever may be thought of the practical difficulties which at present obstruct the application of this method of rapid telegraphic transmission, we cannot help thinking that it has before it a great future, and that when, like the steam-engine as improved by Watt, and the power-loom, it shall have had time to attain a greater degree of practical perfection, and to surmount prejudice and the opposing influence of counter-interests, it may be the means of transferring, to the telegraph, a large part of that business now done by the post-office.

237. It is an amusing fact, that music has actually been transmitted in this way by means of its rhythm. The following is related by an eye-witness of the experiment at New York:—

"We were in the Hanover Street office when there was a pause in business operations. Mr. W. Porter, of the office at Boston, asked what tune we would have. We replied 'Yankee Doodle,' and to our surprise he immediately complied with our request. The instrument commenced drumming the notes of the tune as perfectly and distinctly as a skilful drummer could have made them at the head of a regiment; and many will be astonished to hear that 'Yankee Doodle' can travel by lightning. We then asked for 'Hail, Columbia!' when the notes of that national air were distinctly beat off. We then asked for 'Auld lang syne,' which was given, and 'Old Dan Tucker,' when Mr. Porter also sent that tune, and, if possible, in a more perfect manner than the others. So perfectly and distinctly were the sounds of the tunes transmitted, that good instrumental performers could have had no difficulty in keeping time with the instruments at this end of the wires." *

That a pianist in London should execute a fantasia at Paris,

* Chambers's Papers for the People, vol. ix. No. 71.

Brussels, Berlin, and Vienna, at the same moment and with the same spirit, expression, and precision as if the instruments, at these distant places, were under his fingers, is not only within the limits of practicability, but really presents no other difficulty than may arise from the expense of the performances. From what has been just stated, it is clear that the *time* of music has been already transmitted, and the production of the sounds does not offer any more difficulty than the printing of the letters of a dispatch.

238. A great celerity of transmission is claimed for the printing telegraph of House, so great, that if the claim be well founded, it is a matter of surprise that it has not superseded the Morse telegraph in the United States, where competition is so sharp and action so free. According to Mr. Turnbull, who ought to be considered an impartial assessor, at least between inventors who are both American, the ordinary rate of transmission of the improved House instrument is from 30 to 35 words, printed in full, per minute, which would be from 165 to 200 letters. He adds, that business-messages are sent at the rate of 200 to 250 letters per minute, and that in one case 365 letters, transmitted from New York, have been printed at Utica, distant 240 miles, in one minute.

In a written estimate supplied by the directors of the House lines to Mr. Jones,* it is also stated that, accidents apart, the average number of words transmitted on a single wire per minute and printed in full by the telegraph at their place of destination, is from thirty to thirty-five; but when as in newspapers abbreviations are allowed, the rate is fifty. It is stated for example that the proceedings of the democratic state convention in the autumn of 1850, containing 7000 words, were transmitted from Syracuse to Buffalo in two hours and ten minutes, being at the rate of 54 words per minute. It is evident that in this telegraph, like others, much depends on the ability of the telegraphist, for it is stated that one telegraphist on the line has transmitted 365 letters in a minute, being at the rate of six per second.

When it is considered that this telegraph delivers its messages printed in the ordinary Roman characters, while all the others in practical operation deliver them either in visible signs or written ciphers, which must be interpreted and taken down in ordinary writing before they can serve any useful purpose, the vast superiority of this system of House must be conspicuously manifest, supposing of course that the reports and estimates above produced are verified by the actual performance of the instrument.

* Jones. Elec. Tel., New York, 1852, p. 112.

239. Although the distance to which the dispatch has to be sent cannot be said directly to affect the celerity of transmission, there are circumstances nevertheless which in practice render the transmission to great, slower than to lesser distances. In Europe, for example, stations separated by great distances, are generally in different countries, and the telegraphic line which connects them often passes through several different states in which different telegraphic systems are used, and where it is not practicable to put the wires proceeding from one direction in immediate connection with those which proceed in another. In such cases the messages which arrive must be taken down and retransmitted in the direction in which they are intended to be forwarded, and on this account alone, the time of transmission is augmented, at least in the ratio of the number of such repetitions which are necessary. But besides this, it rarely happens that a message on arriving at such intermediate station can be at once forwarded. It must wait its turn unless the wires happen to be unoccupied.

And even though it may be practicable to establish a direct communication between two distant stations by putting the wires in immediate connection, more or less delay must necessarily take place. The telegraphist who transmits, must first send a message along the line to all the intermediate stations to require the wires to be united for direct communication. At these intermediate stations, the wires may be employed, and the message must wait until they are free.

Thus, although it be true that so far as the electric fluid and the apparatus by which it is transmitted are concerned, they are capable of sending a message from pole to pole in an inappreciable interval, yet the machinery of telegraphy as practically constructed presents causes of delay which prevent in many cases this vast celerity from being called into action.

Until very recently, a message transmitted from Milan to Paris, being necessarily sent round by Trieste, Vienna, Berlin, and Brussels, was more than twenty-four hours in reaching its destination.

Besides these causes of delay, there are, however, others. It has been stated that the intensity of the current is diminished, *cæteris paribus*, as the distance is augmented. When transmission therefore to great distances is required, various expedients, at intermediate stations, such as relay batteries or relay magnets, or both, are required, and notice must be given to apply these even when they are provided.

The chances of interruption by reason of defective insulation or accidents to the wires, are also increased in proportion to the distance.

240. As may be naturally expected, the most frequent examples of direct telegraphic communication to great distances are supplied by the United States.

On the lines of the O'Reilly Company of New York,* messages are daily transmitted without any intermediate repetition to a distance of 1100 miles, that is from New York to Louisville in Kentucky.

"To do this, it is found necessary to place two batteries in the circuit at a distance of 400 miles apart, for the purpose of renewing the electric current, part of which escapes from defective insulation and atmospheric causes. There is no doubt but that, in a more advanced stage of telegraphing—which may be but a short time hence—New Orleans and New York will be placed in instantaneous communication with each other. To enable this to take place, requires, in the first place, a line substantially built and thoroughly insulated. It may be remarked, that it is but two years since, when to telegraph 300 miles on a single or unbroken circuit, was considered a feat; now, from improvements made since then in telegraphs, we can send over 1100 miles easier than we could 300 at that time. In our Cincinnati office, two years ago, and until very lately, they used a separate battery for each line. From a series of experiments made, one single battery, of no greater strength than those formerly used, now works eight distinct and separate lines, with no apparent diminution of strength, and at a great saving of expense to the office."†

A report of the directors of the New York Bain lines states that messages are transmitted by them, without being rewritten, from New York to Buffalo, a distance of 500 miles. This is done without any intermediate relay batteries or magnets.

The directors of the Morse lines at New York report that their telegraph messages have in some cases been actually transmitted without intermediate repetition to a distance of 1500 miles.

241. The promptitude with which dispatches are expedited, and the celerity with which they are transmitted, will be greatly promoted in all cases by an uniform system and organisation being established upon the lines over which they are transmitted. No greater cause of delay can exist than that which arises from diversity of telegraphic instruments and language. Much

* The American Telegraph Companies are subject to such constant changes, that it may be necessary to state here, once for all, that the names and denominations to which we refer are those which were current in 1853-4, but which may be changed before these sheets come into the hands of the reader.

† Report of Mr. O'Reilly. Jones's El. Tel., p. 101.

inconvenience, expense, and delay also arise even in cases where similar instruments and ciphers are used, from a want of uniformity in the various parts of the apparatus, and in the systems of abridgments which are adopted in the language. Where the instruments and the parts of apparatus have been constructed of varying patterns and sizes, they cannot be readily replaced in cases of wearing out or accidental fracture. By the adoption of one uniform size and pattern, depots of all the parts may be provided, from which any station which may be stopped by an accident can be immediately supplied with the part or parts which require to be replaced. Another advantage incidental to such uniformity is greater economy in the maintenance of the apparatus and lines.

Impressed with these considerations, a large majority of the American telegraph companies have formed themselves into a confederation, which meets annually at Washington, and which is permanently represented there by a permanent committee and secretary.

This body has published reports containing many important and interesting statistical facts, and has adopted measures with a view to the establishment of a central depôt for the supply of all articles necessary for the maintenance of the lines and stations, of good quality and at fair prices. The secretary of the convention, Mr. J. P. Shaffner, has commenced the publication of a monthly periodical devoted to subjects directly and indirectly connected with electric telegraphs; and as not less than nine-tenths of all the American lines, as well as those of contiguous states, are worked with Morse's instrument, it is proposed to reduce it as speedily as possible to one uniform pattern, so that its parts, as well as those of the batteries, may be always ready to be supplied in cases of failure or breakage, the like parts fitting indifferently all instruments and all apparatus.

The batteries invariably used by the American telegraphs are those of Grove, each element of which consists of a cup of unglazed earthenware, placed in a glass tumbler of equal height and greater diameter. A zinc cylinder is let down between the glass and the earthenware cup, and a platinum cylinder is let down into the earthenware cup. The space between the cups is then filled with acidulated water, and the earthenware cup is filled with pure nitric acid.

Such being the batteries, the articles of consumption in the working of the telegraphs are enumerated as follows by the secretary of the convention:—Nitric and sulphuric acids, zinc, quicksilver (for amalgamating the zinc, &c.), skeleton forms for messages, ink, envelopes, pencils, and pens.

From statistical data collected by the secretary, it was found that in 1853 the annual consumption and cost of these materials was as follows :—

	Quantities.	Cost.
Nitric acid	199680 lb.	£1105
Sulphuric acid	50000 lb.	500
Zinc cylinders	16500 lb.	400
Mercury	3000 lb.	600
Forms for messages . . .	10,000000	5000
Envelopes	6,000000	2680
Pens	576000	720
Pencils	50000	500

These returns, including only the results of the lines worked by the Morse instruments, about nine-tenths of the whole, would require to be increased by a ninth to obtain the total consumption.

It appears, therefore, that on the lines of the United States, the number of telegraphic messages transmitted in 1853 exceeded ELEVEN MILLIONS !

THE USES OF THE ELECTRIC TELEGRAPH.

242. To form an estimate of the uses to which the electric telegraph subserves, it would be necessary to obtain a report of the subjects of the messages classified, with the relative number of each class, which are transmitted from and received by the chief telegraphic stations. Although we have not been able to procure to any great extent such data, some notion may be collected as to the way in which this new social, commercial, and political agent is employed, from such scattered statements and notices as we have been enabled to collect from various sources.

It appears that the prevailing subjects of the dispatches vary according to the station from or to which they are sent. Thus, as might naturally be expected, in large commercial marts, such as Liverpool and Glasgow, they are chiefly engrossed by messages of mercantile firms and business. Their prevailing subjects also vary much with the season of the year. Thus, in summer, the messages of tradesmen are greatly multiplied in consequence of the number transmitted by dealers in perishable articles, such as fish, fruit, &c., which must be supplied in regulated quantities with the greatest promptitude.

We have obtained from the manager of the English and Irish magnetic telegraph company, the following classification of nearly 5000 dispatches which passed through the Liverpool office in the early part of the present year, 1854.

General merchants	1954
Stock and share transactions	1441
Ship insurers, brokers, &c.	339
Banking messages	315
Corn dealers	272
Betting	233
Personal and domestic	201
General brokers	117
Tradesmen	50
Cotton brokers, &c.	34
Law	31
Political	6
	4993

243. Mr. Walker gives the following list of the subjects of dispatches sent through the office of the Electric Telegraph Company, as a specimen of the uses which the public make of this mode of communication.

Accidents	Customs	Markets	Post-horses, &c.
Announcements	Deaths	Medical aid	Reporters
Appointments	Departures	Meteorology	Remittances
Arrivals	Dispatches	Missing trains	Respite
Arrests	Elections	Murders	Robberies
Bankers	Elopements	News	Royal movements
Beds	Expresses	Nurses	Sentences
Bills	Funds and Shares	Orders	Shipping news
Births	Government	Passengers	Ship-stores
Commotions	Health	Payments	Turf
Counsel	Hotels	Police	Witnesses
Couriers	Judgments	Political	Wrecks
Corps	Lost luggage		

It is obvious that the uses, whether personal or commercial, of the telegraph, are restricted by the tariff, and by the necessity of disclosing the contents of the dispatches to the telegraph agents. In England, the latter obstacle may in some cases be surmounted by the use of a cipher. The cipher must, however, always consist of a transposition of the letters, since the telegraphic signs only express letters, and besides this, it can never be used on sudden emergencies, inasmuch as it supposes a previous concert between the corresponding parties.

244. The obstacle to the extension of the uses of the telegraph, created by the tariff, has been of late greatly lessened by the considerable reduction of the prices of transmission, and it may be hoped that ere long the companies and the public will discover that the interest of the one and the convenience of the other will

be best promoted by a still further reduction of price, and a still larger use of this mode of intercommunication.

It is probable and desirable that something approaching to the uniform postage system may eventually be realised in the telegraph. Already a certain step towards such a system has been made, since for a fixed sum messages of a prescribed length can be transmitted to all distances exceeding a certain limit.

In the absence of exact statistical reports of telegraphic business, it may not be uninteresting to give some examples of the uses of this mode of communication.

245. In the management of railway business in all countries, but more especially upon our own ever crowded and over-worked lines, the telegraph has become an indispensable accessory, without which this mode of locomotion would be deprived not only of its efficiency but its safety. Consequently the railways in most countries have been provided with lines of telegraph expressly and exclusively for their own use, independently of those which are appropriated to the public service; and on the continent such telegraphs are usually alphabetic, that is, such as convey their messages by pointers, which are successively directed to the letters of the words, so that any of the railway officials who can read, may be able to interpret a message which arrives, or to transmit one to a distant station.

To illustrate the vast utility of the telegraph to the railway, Mr. Walker states that on the lines of the South Eastern Company, in the space of three months, upwards of 4000 messages have been occasionally transmitted, being at the average rate of nearly 50 per day. He gives the following as a rough classification of their subjects—

			Messages.
1.	Concerning	ordinary trains.	1468
2.	,,	Special trains	429
3.	,,	Carriages, trucks, goods, sheets, &c.	795
4.	,,	Company's servants	607
5.	,,	Engines	150
6.	,,	Miscellaneous matters . . .	162
7.	,,	Messages forwarded to other stations .	499
		Total . . .	4110

246. It has been already stated that portable telegraphs are provided in some parts of the continent, and in France in particular, with which the conductors are provided. Such telegraphs have also been contrived in this country, but we are not aware of their practical adoption. By these the conductor of a train can, whenever the train is stopped between stations, whether from accident or other

cause, give immediate notice to the preceding and succeeding stations, so as to prevent a collision by a following train overtaking that which is accidentally stopped, or if necessary he can call for an engine to carry on the train, or any other aid that may be required.

247. Notices of the passing, starting, and arrival of trains are however transmitted from station to station, quite independent of any accidents that may arise, so that all the station-masters, so far as relates to the movement upon the line, are endowed with a sort of omnipresence; so conscious are they of the possession of this power and its value, that their language is that of persons who actually *see* what is going on at vast distances from them. Thus, as Mr. Walker observes, they are in the common habit of saying—"I just saw the train pass such or such a station," fifty miles distant perhaps, when in reality all he saw was the deflection of the needle of their telegraph.

"If trains are late, the cause is known; if they are in distress, help is soon at hand: if they are heavy, and progress but slowly, they ask and have more locomotive power either sent to them or prepared against their arrival; if there is anything unusual on the line they are forewarned of it, and so forearmed; if overdue, the old plan of sending an engine to look after them has become obsolete—a few deflections of the needle obtain all the information that is required." *

The utility of special trains is well known. News of the utmost importance, or a government courier bearing dispatches of the greatest urgency arrives at one of our ports and demands a train *instantly* to convey him to London. Now in such cases it does not often happen that a disposable engine is found at the station where the demand is presented; but the telegraph sends a dispatch along the line, calling one from the nearest station at which one can be found, and when the engine has been obtained the special cannot start with safety unless the line is cleared for it.

The telegraph again interposes its aid, and sends a notice along the line of the moment of starting, from which, combined with the known speed of the train, the exact moment when it will pass every station upon the line is known, and of course the line is cleared for it, and all danger of collision removed. How frequent are the occasions for appealing to the telegraph for this aid without which special trains would not only be less rapid, but infinitely less safe, as well for themselves as others, may be seen by reference to the analysis of dispatches we have given above, from which it appears that in three months, upon the South-

* Walker, p. 84.

Eastern lines, there were not less than 429 messages respecting special trains, that is at the rate of about five per day.

248. In the general management of the traffic upon an active line of railway, an incalculable amount of capital and current expenditure is saved by the telegraph. Without it rolling stock would require to be provided in much greater quantity, and a far greater unprofitable wear and tear by useless trips, of what in railway language are called "empties," would take place. By the telegraph, as we have stated, each station-master is ubiquitous so far as the line is concerned. He knows where carriages, waggons, trucks, sheets, and engines are to be found, and how many of them, and he calls by the telegraph so many, and no more than he wants, and at the time he wants them, from the nearest or most convenient station where they are to be obtained.

Before the establishment of the telegraph, some of these objects were imperfectly attained by means of pilot engines, that is engines taking no vehicle, which habitually run along the line to carry messages from station to station. As an evidence of the immense saving effected by the telegraph in the practical working of railways, Mr. Walker states, that the cost of maintaining and working a single one of those pilot engines, (all of which have been superseded by the telegraph,) amounted to a greater sum than is now required to defray the expense of the entire staff of telegraph clerks, and the mechanics and labourers employed in cleaning and repairing the instruments and maintaining the integrity of the line wires.

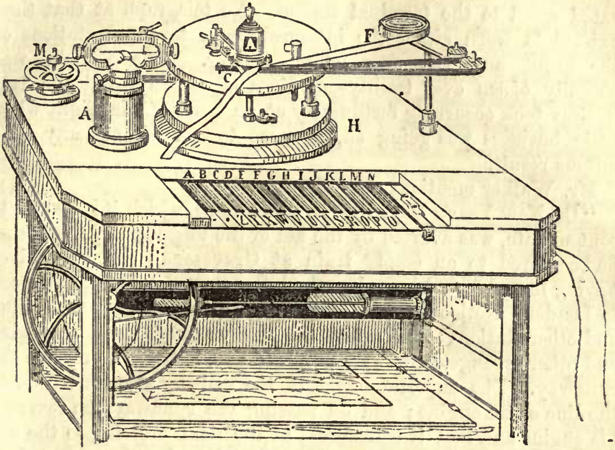


Fig. 89.—HOUSE'S TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XII.

249. Prevention of accidents.—250. Its uses in the detection of crime.—251. Personal and domestic messages.—252. Electric news-rooms.—253. Telegraph extensively used in the United States.—254. Much used for commerce.—255. Sums paid for telegraphic despatches by mercantile firms.—256. Extensively used by American newspapers.—257. Illustration of the utility for political purposes.—258. Illustrations of its domestic and general use.—259. Secrecy of despatches not generally sought for.—260. Verbal ciphers of mercantile firms.—261. Ciphers for newspaper reports.—262. Association of New York journals.—263. Spirited enterprise of New York "Herald."—264. Use of electric telegraph in determining longitudes.—265. In producing horological uniformity.

249. Among the serious railway accidents which might have been, or actually were prevented by the telegraph, the following have been mentioned:—

In a storm, the wind blew a first-class railway carriage, which stood in an open shed at a second-class station, and putting it in motion upon a very level line, sent it flying with accelerated speed to the terminal station. No telegraph at that time existed to warn either the intermediate or terminal stations of the event and the approaching danger. The vehicle was actually *blown* over twenty-one lines of railway, but the trip it thus took occurring fortunately at an hour of the night when little business was going on, it came to rest without any calamitous result.

Mr. Walker mentions the following:—

"On New Year's Day, 1850, a catastrophe, which it is fearful to contemplate, was averted by the aid of the telegraph. A collision had occurred to an empty train at Gravesend; and the driver having leaped from his engine, the latter started alone at full speed to London. Notice was immediately given by telegraph to London and other stations; and while the line was kept clear, an engine and other arrangements were prepared as a buttress to receive the runaway. The superintendent of the railway also started down the line on an engine; and on passing the runaway, he reversed his engine and had it transferred at the next crossing to the up-line, so as to be in the rear of the fugitive; he then started in chase, and on overtaking the other, he ran into it at speed, and the driver of his engine took possession of the fugitive, and all danger was at an end. Twelve stations were passed in safety: it passed Woolwich at fifteen miles an hour: it was within a couple of miles of London before it was arrested. Had its approach been unknown, the mere money value of the damage it would have caused might have equalled the cost of the whole line of telegraphs. They have thus paid, or in a large part paid, for their erection.

"As a contrast to this, an engine, some months previously, started from New Cross toward London. The Brighton Company have no telegraphs; and its approach could not be made known. Providentially, the arrival platform was clear; it ran in, carrying the fixed buffer before it, and knocked down, with frightful violence, the wall of the parcels office."

250. Among the general uses of the telegraph to the public, many examples of the detection of crime are mentioned. It is generally known that the notorious Tawell, after the commission of the murder, started for London from Slough, by the Great Western Railway. Notice of the crime, and a description of his person, however, flew with the speed of light along the wires and arrived at Paddington so much earlier than the murderer himself, that upon his arrival he was recognised, tracked

from place to place, finally apprehended, tried, convicted, and executed.

One night at ten o'clock, the chief cashier of the bank received a notice from Liverpool, by electric telegraph, to stop certain notes. The next morning the descriptions were placed upon a card and given to the proper officer, to watch that no person exchanged them for gold. Within ten minutes they were presented at the counter by an apparent foreigner, who pretended not to speak a word of English. A clerk in the office who spoke German interrogated him, when he declared that he had received them on the Exchange at Antwerp six weeks before. Upon reference to the books, however, it appeared that the notes had only been issued from the bank about fourteen days, and therefore he was at once detected as the utterer of a falsehood. The terrible Forrester was sent for, who forthwith locked him up, and the notes were detained. A letter was at once written to Liverpool, and the real owner of the notes came up to town on Monday morning. He stated that he was about to sail for America, and that whilst at an hotel he had exhibited the notes. The person in custody advised him to stow the valuables in his portmanteau, as Liverpool was a very dangerous place for a man to walk about with so much money in his pocket. The owner of the property had no sooner left the house than his adviser broke open the portmanteau and stole the property. The thief was taken to the Mansion-House, and could not make any defence. The sessions were then going on at the Old Bailey. Though no one who attends that court can doubt that impartial justice and leniency are administered to the prisoners, yet there is no one who does not marvel at the truly railway-speed with which the trials are conducted. By a little after ten the next morning—such was the speed—not only was a true bill found, but the trial by petty-jury was concluded, and the thief sentenced to expiate his offence by ten years' exile from his native country.

I take the following illustration of this from a recent article on the subject which appeared in the "Quarterly Review."

The following is extracted from the telegraph book preserved at the Paddington station:—

"Paddington, 10.20 A.M.—'Mail train just started. It contains three thieves, named Sparrow, Burrell, and Spurgeon, in the first compartment of the fourth first-class carriage.'

"Slough, 10.48 A.M.—'Mail train arrived. *The officers have cautioned the three thieves.*'

"Paddington, 10.50 A.M.—'Special train just left. It contained two thieves: one named Oliver Martin, who is dressed in black, *crape on his hat;* the other named Fiddler Dick, in black trousers and light blouse. Both in the third compartment of the first second-class carriage."

"Slough, 11.16 A.M.—'Special train arrived. Officers have taken the two thieves into custody, a lady having lost her bag, containing a purse with two sovereigns and some silver in it; one of the sovereigns was sworn to by the lady as having been her property. It was found in Fiddler Dick's watch-fob.'

"It appears that, on the arrival of the train, a policeman opened the door of the 'third compartment of the first second-class carriage,' and asked the passengers if they had missed anything? A search in pockets and bags accordingly ensued, until one lady called out that her purse was gone. 'Fiddler Dick, you are wanted,' was the immediate demand of the police-officer beckoning to the culprit, who came out of the carriage thunderstruck at the discovery, and gave himself up, together with the booty, with the air of a completely beaten man. The effect of the capture so cleverly brought about is thus spoken of in the telegraph book:—

"Slough, 11.51 A.M.—'Several of the suspected persons who came by the various down-trains are lurking about Slough, uttering bitter invectives against the telegraph. Not one of those cautioned has ventured to proceed to the Montem.'

"Ever after this the light-fingered gentry avoided the railway and the *too* intelligent companion that ran beside it, and betook themselves again to the road—a retrograde step, to which on all great public occasions they continue to adhere." *

251. One of the consequences of the high price of transmission is that personal and domestic messages are most generally confined to cases of urgency, and often of distress, painful or ludicrous, as the case may be. Persons in easy circumstances, it is true, often resort to the telegraph to gratify a caprice or to obtain some object of gratification for which they are impatient. The mixture of subjects which the agents in rapid succession read from the needles, is most curious. "We have," says Mr. Walker, "ordered a turbot, and also a coffin; a dinner, and a physician; a monthly nurse, and a shooting-jacket; a special engine, and a chain-cable; an officer's uniform, and some Wenham-lake ice; a clergyman, and a counsellor's wig; a royal standard, and a hamper of wine; and so on. Passing over the black leather bag which some one every day appears to leave in some train, passengers have recovered luggage of most miscellaneous character by means of the telegraph.

* Quarterly Review, No. CLXXXIX., p. 129.

In the trains have been left a pair of spectacles, and a pig; an umbrella, and *Layard's Nineveh;* a purse, and a barrel of oysters; a great-coat, and a baby; and boxes and trunks, *et id genus omne*, without number."

252. Independently of the direct use made of the electric telegraph by the general public, for the transmission of private despatches, the several companies have established, in various principal places, news rooms, where intelligence is from hour to hour posted, as it arrives from all parts of the world.

The Electric Telegraph Company, soon after its establishment, opened subscription news rooms in the chief towns of England, especially those of the northern counties, in which intelligence of every description which could interest the general public was posted from hour to hour during the day, immediately on its transmission from London. These establishments did not, however, receive the necessary public support, and with one or two exceptions they have been discontinued. There is, however, in the Lothbury establishment, besides the private message department, a general intelligence office, in which the news published in the morning journals is condensed and transmitted to the exchanges of Liverpool, Bristol, Manchester, Glasgow, and other chief provincial centres of business.

On the evenings of Fridays, the London news is collected, condensed, and transmitted to the offices of upwards of 120 provincial Saturday papers, which thus receive during the night before their publication the most recent intelligence of every sort received by telegraph from all parts of Europe besides the current news of London to the latest moment. An example of the extraordinary efficiency of this department is given in the case of one of the Glasgow Saturday journals, which often receives as much as three columns of the debates, transmitted while the Houses are still sitting. A superintendent and four clerks are exclusively engaged in the business of this department, and in the latter days of the week their office presents all the appearances of the editor's room of a widely circulating journal. "At seven in the morning the clerks are to be seen deep in 'The Times' and other daily papers, just hot from the press, making extracts and condensing into short paragraphs all the most important news, which are immediately transmitted to the country papers to form second editions. Neither does the work cease here, for no sooner is a second edition published in London than its news, if of more than ordinary interest, is transmitted to the provinces." Arrived at the chief places in direct communication with London "swifter than a rocket could fly the distance, like a rocket it bursts and is again carried by diverging (branch) wires into a dozen neighbouring towns" of less magnitude and importance.*

Besides this organisation for the general transmission of despatches from one quarter of the great metropolis to another, there are some curious special arrangements made for the satisfaction of the wants of particular classes. Thus a wire is exclusively appropriated to communications between the Octagon Hall of the Houses of Parliament and the telegraphic station in St. James-street, the centre of the West-end clubs. This particular wire should be called the "'whipper-in' of the House, for it is nothing more than a call-wire for members. The company employ reporters during the sitting of Parliament to make an abstract from the gallery of the business of the two Houses as it proceeds, and this abstract is forwarded at very short intervals to the office in St. James's-street, where *it is set up and printed,* additions being made to the sheet issued as the MS. comes in. This flying sheet is sent half-hourly to the following clubs and establishments:—Arthur's; Carlton; Oxford and Cambridge; Brookes's; Conservative; United Service; Athenæum; Reform; Travellers'; United University; Union; and White's. Hourly to Boodle's Club and Prince's Club; and half-hourly to the Royal Italian Opera. The shortest possible abstract is of course supplied, just sufficient in fact to enable the after-dinner M.P. so to economise his proceedings as to be able to finish his claret and yet be in time for the ministerial statement, or to count in the division. The following, for instance, is a fac-simile of the printed abstract of the debate on the Address to her Majesty on the declaration of war:—

THE ELECTRIC TELEGRAPH COMPANY.

(INCORPORATED 1846.)

HOUSE OF COMMONS, FRIDAY, MARCH 31ST, 1854.

TIME.			REMARKS.
H.	M.		
4	0	House made.	HOUSE OF LORDS.
4	30	Private business and Petitions.	Lord Aberdeen stated, in reply to Lord Roden, that it was intended to appoint a day for solemn prayer for a blessing on Her Majesty's arms by sea and land.
4	40	Mr. Napier brought up report of Dungarvan Election Committee: Maguire duly elected, and attention called to state of law upon the withdrawal of Petitions.	
5	0	Notices.	
5	30	Lord John Russell moving reply to message of Her Majesty.	Earl of Clarendon moved

* Quarterly Review, No. CLXXXIX., p. 138.

TIME. H.	M.		REMARKS.
6	0	Stating various transactions and negotiations which have taken place with Russia.	the address in reply to the Queen's message. Earl of Derby : observations.
6	30	Mr. Layard approved of the sentiments expressed.	(7·30). Earl of Aberdeen replied to Lord Derby.
7	0	Still speaking.	
7	30	Compared the language and opinions of different Members of the Cabinet, and called attention to various articles in the "Times," which he maintained to be written with a full knowledge of the contents of the secret and confidential correspondence.	(7·45). Earl of Malmesbury regretted the tone taken by the Prime Minister. (8·20). Earl Granville : observations. Lord Brougham ditto.
8	0	Mr. Bright replied to Mr. Layard, adverse to policy of the Government.	Earl Grey ditto. (8·50). Earl of Hardwicke wished for a larger Naval Reserve.
8	30	Still speaking.	
9	0	Still speaking.	
9	30	Mr. J. Ball was prepared to support the war, though not agreeing in the reasons put forward to justify it.	(8·55). Marquis of Lansdowne said it was necessary to check Russia.
10	0	The Marquis of Granby expressed his regret at the language used by certain members of the Government with respect to the Emperor of Russia, whose conduct regarding Turkey he vindicated.	(9·5). Address agreed to, to be presented on Monday. LORDS ADJOURNED, 9·25.
		Lord Dudley Stuart.	
10	30	Still speaking.	
11	0	Lord Palmerston vindicating the policy of the Government.	
11	30	Mr. Disraeli supported the address, but severely criticised the conduct of different Members of the Cabinet.	
12	0	Analysing the secret and confidential correspondence to show that a plan for the partition of Turkey was assented to by the English Government in 1844, when the Earl of Aberdeen was Secretary for Foreign Affairs.	
12	30	Lord John Russell replying to Mr. Layard, and the observations of other speakers.	
12	40	Colonel Sibthorp : observations.	
		The Address to Her Majesty agreed to ; and on the motion of Lord John Russell, and seconded by Mr. Disraeli, to be presented by the whole House.	
1	0	HOUSE ADJOURNED.	

Saint James's Street Branch Station, No. 89, at the End of Pall Mall, opposite Saint James's Palace.

"The wire to the Opera is a still more curious example of the social services the new power is destined to perform. An abstract of the proceedings of Parliament similar to the above, but in *writing*, is posted during the performance in the Lobby, and Young England has only to lounge out between the acts to know if Disraeli or Lord John Russell is up, and whether he may sit out the piece, or must hasten down to Westminster. The Opera-house even communicates with the Strand-office, so that messages may be sent from thence to all parts of the kingdom. The government wires go from Somerset-house to the Admiralty, and thence to Portsmouth and Plymouth by the South-Western and Great Western Railways; and these two establishments will shortly be put in communication, by means of subterranean lines, with the naval establishments at Deptford, Woolwich, Chatham, Sheerness, and with the Cinque Ports of Deal and Dover. They are worked quite independently of the company, and the messages are sent in cipher, the meaning of which is unknown even to the telegraphic clerks employed in transmitting it. In addition to the wires already spoken of, street branches run from Buckingham Palace and Scotland Yard (the head police-office) to the station at Charing-cross, and thence on to Founder's-Court; whilst the Post-office, Lloyd's, Capel-court, and the Corn Exchange communicate directly with the central office." *

The Magnetic Telegraph Company have made arrangements by which the correspondents of the press are allowed to forward messages upon an entirely different basis; the charge for intelligence so transmitted, amounting to only one-tenth of the charge to the public, the matter being more voluminous, and passing through the wires at a time when they are not otherwise occupied.

The company also supplies the press and news-rooms in various parts of the United Kingdom, and especially throughout Ireland, with news by *contract;* at the rate of about one halfpenny per line of ten words; and are enabled to do so, by making manifold copies of the information (whatever be its nature) for the use of *all* the press, &c., in each town or district, through which such news passes.

Under such arrangements, intelligence to the amount of two closely printed newspaper columns, or more, daily, is transmitted between all the stations, conveying information of the various share, corn, cotton, coal, iron, cattle, provision, and produce [illegible] fairs, shipping arrivals, foreign and domestic informa- news, whatever its nature, obtained in *one* town [illegible] Each piece of

* Quarterly Review, No. CLXXXIX., pp. 139—141.

to *all* the rest; the arrival of vessels in Queenstown, the result of a market in Cork, or of a cattle fair at Ballinasloe, affording intelligence for the whole of the United Kingdom, and *vice versâ.*

In order to carry out this system, the company employs paid agents, news collectors, parliamentary reporters, &c.

253. It is a fact well known that the electric telegraph is much more extensively used for all purposes, political, commercial, and domestic, in the United States, than in this or any other part of Europe. Before the reductions which have within the last year or two taken place in the tariffs, this might fairly be explained by the comparatively small cost of transmission in America. But since those reductions were effected, it may be questioned whether there is any difference of cost sufficiently considerable to explain the vast difference in the extent to which the public, on different sides of the Atlantic, avail themselves of this mode of inter-communication.

We shall notice the question of the tariffs hereafter. Meanwhile, whatever be the cause, it is certain, that the practical use of the telegraph is much more extended among our transatlantic descendants.

The tariffs vary on different lines, but it has been estimated that the cost of a message of 10 words, exclusive of address and signature, sent 10 miles, is about 5*d.*, and for greater distances the cost may be taken at about 0·035*d.* per word per mile.

The classes of messages entitled to precedence, are government messages, and messages for the furtherance of justice in detection of criminals, &c.; then death messages, which includes cases of sickness when the presence of a party is sent for by the sick and dying. Important press-news comes next; if not of extraordinary interest, it takes its turn with the mercantile messages.

254. Commercial houses resort largely to the telegraph. For example: a person purchasing goods in New York, gives his reference to the merchant—such reference being perhaps 700 or 800 miles away from him. By the aid of the telegraph the merchant can learn the standing of his customer, even before the purchase is completed. There are bankers, brokers, &c., that receive and send, on an average, six to ten messages per day, throughout the year.

255. The manager of House's line at New York states that some commercial houses pay to the company as much as 200*l.* a-year, and that the average annual receipts from twenty mercantile houses amount to 100*l.* each.

The directors of Bain's New York lines report that the telegraph is used by commercial men to almost as great an extent as the mail. This can be better illustrated by the number of messages sent and received between cities whose commercial relations are intimate, during the hours from 10 A.M. to 5 P.M. For instance: there are transmitted daily, between the cities of New York and Boston, between 500 and 600 messages, two-thirds if not three-fourths of which are transmitted between the hours above named. Some houses pay from 12*l.* to 16*l.* per month to the telegraph. The amount paid by a commercial house is governed by the excitement there is in the market of the particular article they may be dealing in. If there are "ups and downs" in the market, money is lavished upon the telegraph freely.

The directors of the Morse New York lines, state that the annual telegraph outlay of several houses amounts to 600*l.*

It often happens that a party desires to "converse" with another 400 or 500 miles off. An hour is appointed to meet in the respective offices, and they converse through the operator. Cases may be mentioned of steamboats being sold over the wires —the one party being in Pittsburg, the other in Cincinnati. Each party wrote down what they had to say, higgled awhile, and finally concluded the sale. Their correspondence was filed away, like other messages, and kept for reference, if ever called in question. It is often used by parties, when from home, corresponding with their families. Sometimes it is the messenger of woe; and anon, that of pleasure. In the early part of 1852, the Astor House of New York, and the Burnet House of Cincinnati, had a series of telegraphic parties. An account of one of them was published in the "Cincinnati Gazette," the parties conversing being about 750 miles apart.

256. The following example of the activity of journalism is given by Mr. Jones, who was himself a telegraphic agent for the newspapers:—"Some time back the Asia arrived at Quarantine, near New York, about 8 P.M., was detained an hour by the health officer. The agent of the New York Associated Press and of the New Orleans Merchants' Exchange, Mr. Jones, to gain but a few minutes, had a boat in readiness when the Asia brought to. A small bag containing the latest news was handed over the steamer's side, to the small boat. By great exertions she gained New York half an hour ahead of the Asia. The bag was opened—a copy of her news was handed to us, addressed to the Merchants' Exchange, New Orleans, signed *Jones*—to work we went. It was being transmitted over the wires amid the thundering of the Asia's cannon, as she rounded the point; and a complete synopsis of her commercial and political news was received in Louisville, 1100 miles in the interior, before the ship had actually reached the city."

Th[illegible] line at New York state that, during the sittings of conventions, or elections, or the arrival of steamers, often from 2000 to 8000 words are reported. On some occasions of market excitement, the private messages are nearly doubled.

Debates of Congress are received at an average of about 4500 words per day, and transmitted at the rate of 1600 words per hour.

On the assembly of the Legislature of the State of New York at Albany, in 1847, the governor's message, consisting of 25000 letters, was transmitted to New York, 150 miles, and printed by the telegraph itself in two hours and a half.

257. In his reports to Congress, Mr. Morse has supplied various examples of the use made of the telegraph by all classes of persons. During the Philadelphia riots of 1844, the mayor of that city sent an express by railway, to the President of the United States at Washington. On the arrival of the train at Baltimore, the contents of the express transpired, and the telegraph, which was then just put in operation between Baltimore and Washington, not being yet established elsewhere in the States, sent on the substance of the despatch. The President held a cabinet council while the despatch itself was coming, and had his answer prepared and delivered to the messenger who brought the despatch at the moment of his arrival, who returned with it instantly to Philadelphia.

258. Nothing is more frequent in the United States than electric medical consultations. A patient in or near a country village desires to consult a leading medical practitioner in a chief city, such as New York or Philadelphia, at four or five hundred miles distant. With the aid of the local apothecary, or without it, he draws up a short statement of his case, sends it along the wires, and in an hour or two receives the advice he seeks, and a prescription. Cases are recorded in which electric marriages have been contracted between parties separated one from another by many degrees of latitude. A correspondent of the author of a paper in Chambers's Collection states, that in the United States, "The telegraph is used by all classes, except the very poorest—the same as the mail. A man leaves his family for a week or a month; he telegraphs them of his health and whereabouts from time to time. If returning home, on reaching Albany or Philadelphia, he sends word of the hour that he will arrive. In the towns about New York the most ordinary messages are sent in this way: a joke, an invitation to a party, an inquiry about health, &c. In our business we use it continually. The other day two different men from Montreal wanted credit, and had no references; we said: 'Very well; look out the goods, and we will see about it.' Meanwhile we asked our friends in Montreal—'Are Pump and Proser good for one hundred dollars each?' The

answer was immediately returned, and we acted accordingly; probably much to our customers' surprise. The charge was a dollar for each message, distance about 500 miles, but much further by telegraph, as it has to go a round to avoid water. If my brother goes to Philadelphia, he telegraphs, 'How is the family? What is doing?'—I answer, 'All well. Sales so much,' and so on." *

It has been contended by some, with much reason, that one of the most serious drawbacks to the general extension of the use of the electric telegraph is the impracticability of preserving that secrecy which the seal confers on written correspondence, the absence of which would utterly annihilate the utility of the post-office. The imperious necessity of guarding this secrecy inviolate is apparent in the heavy penalties attached to the rupture of the seal, which can only be effected with impunity by a special authorisation of a secretary of state. To confer on the electric telegraph all the public utility of which it is susceptible, means must be adopted, and will, no doubt, be ultimately adopted for the attainment of this object, the vital importance of which is implicitly acknowledged by the heavy penalties, the smallest of which is dismissal, imposed in all countries on the agents who disclose the contents of private telegraphic correspondence.

Such expedients must nevertheless be ineffectual, for it would contradict all the results of the common experience of life, if what must inevitably be communicated to half a dozen persons at least, and a copy of which is retained and filed in a public office, could remain secret from any parties who might have a sufficiently strong motive to come to the knowledge of it. But even though the disclosure of private communications to parties not employed in the telegraphic offices should be effectually prevented by the present expedient of swearing the clerks to secrecy, and inflicting the consequent penalties for the violation of their oath, still individuals communicating in private confidence one to another, wives to husbands, sisters to brothers, or children to parents, have things to say which it would be utterly intolerable, as is most justly observed by the reviewer already quoted even "to *see* strangers read before their eyes. This is a grievous fault in the telegraph, and it must sooner or later be remedied by some means or other."

The object might be accomplished by the use of any species of cipher, but this supposes that the parties corresponding have previously prepared the cipher, and are mutually possessed of its key. Such a condition could only be practically fulfilled by

* "Chambers's Papers for the People," vol. ix. No. 71.

correspondents having habitual need of intercommunication, such as mercantile establishments interchanging news of the markets, stocks, sales, and other commercial details; but for the occasional communications of domestic life it would be quite unavailable.

It is hinted by 'the Quarterly Reviewer,' that Mr. Wheatstone has invented a cipher which will be applicable to general purposes, and which will attain this object, and that it will be soon placed at the disposition of the public.

If the same privacy as is afforded by the post-office can be thus secured to telegraphic communications, and if by the multiplication of their wires, and the improved efficiency of their instruments, the companies are enabled to reduce their tariff to a still lower limit, and to base it on some uniform principle similar to the admirable penny postage system of Mr. Rowland Hill, it is difficult to foresee the extent of the revolution which this noble gift of science to mankind may effect. Great as the benefits have been which the post-office has conferred, they will sink to nothing compared with those of the telegraph. In estimating the importance of the part reserved for this vast agent of civilisation, it must not be forgotten that it is still in its early infancy, and that its most wondrous powers are not yet developed by time and growth.

259. The necessity of disclosing the contents of private despatches to the telegraphists is sometimes avoided in the United States by the adoption of a cipher, or by a conventional change of the signification of the letters of the alphabet. In some cases, with the telegraph of House, the manipulation of which is easy and simple, the party plays upon the keys of the instrument himself. It is, however, only in rare instances that these expedients are resorted to. The public confidence has been won by the general secrecy observed by the telegraphic agents, and in general no apprehension of disclosure prevents persons from sending the most private and confidential despatches in the usual manner. One of the directors, who for four years has had the superintendence of extensive lines, states, that in that interval he never heard of an instance of the contents of a despatch being divulged.

Another circumstance which experience has made manifest has given security to the public on this point. It appears that the agents who are for many hours labouring at the machine in the transmission of despatches, word by word, rarely are able to give that kind of attention to the sense and purport of the whole which would be necessary to the clear understanding of it. Their attention is engrossed exclusively in the manipulation necessary to transmit letter after letter, and they have neither time nor attention to spare for the subject of the whole despatch. The case is very analogous to that of compositors in a printing-office, who, as is well known, go through their work mechanically, without giving the least attention to the subject.

260. A sort of verbal ciphers, or abbreviations, are much in use, however, by mercantile houses. This is practised more for the sake of economy than secrecy, although the latter purpose is also attained. The firm and its correspondents have a key in which are tabulated a number of single words, each of which expresses a phrase or sentence, such as is of frequent occurrence in such communications. The following example of such a commercial despatch is given by Mr. Jones. The despatch to be sent consisted of 68 words, as follows:—

"*Flour Market for common and fair brands of western is lower, with moderate demand for home trade and export. Sales,* 8000 *bbls. Genesee at* 5 *dols.* 12. *Wheat, prime in fair demand, market firm, common description dull, with a downward tendency, sales,* 4000 *bushels at* 1 *dol.* 10. *Corn, foreign news unsettled the market; no sales of importance made. The only sale made was* 2500 *bushels at* 67 *c.*"

This despatch, when converted into the verbal cipher, was expressed in nine words, as follows:—

"Bad came aft keen dark ache lain fault adapt."

261. Complicated systems of cipher were invented for the transmission of parliamentary and law reports, and those of public meetings. When the tolls, however, were reduced by competition, this system was abandoned, and the reports were sent in full, or with such abbreviations only as are obvious.

262. The large quantity of telegraphic news which is published daily in the New York journals is explained by the fact, that seven of the principal journals of that city formed an association to telegraph in common, sharing the expense. Each journal was, however, at liberty to order for itself any extra intelligence, giving the others, or any of them, the option of sharing it.

263. Mr. Jones relates that one of the earliest telegraph feats, after the extension of the telegraph lines west to Cincinnati, was brought about by the agency of the "New York Herald," and before any regular association of the press was formed in New York.

"It became known that Mr. Clay would deliver a speech in Lexington (Ky.), on the Mexican war, which was then exciting much public attention. Mr. Bennett, editor and proprietor of the 'Herald,' desired us to have Mr. Clay's speech reported for the paper. We at once proceeded," says Mr. Jones, "to make arrangements to carry it into effect. We had a regular and efficient reporter already employed in Cincinnati, a Mr. G. Bennett; we also had a Mr. Thompson in Philadelphia in co-operation with us for some papers there, and which agreed, if the speech was first received, to share the expense with the 'Herald.' The 'Tribune' in New York, and the 'North American' in Philadelphia, agreed to start for a report of the speech, in opposition. From Lexington to Cincinnati was eighty miles, over which an express had to be run. Horses were placed at every ten miles by the Cincinnati agent. An expert rider was engaged, and a short-hand reporter or two stationed in Lexington. When they had prepared his speech it was then dark. The express-man, on receiving it, proceeded with it for Cincinnati. The night was dark and rainy, yet he accomplished the trip in eight hours, over a rough, hilly, country road. The whole speech was received at the 'Herald' office at an early hour the next morning, although the wires were interrupted for a short time in the night, near Pittsburg, in consequence of the limb of a tree having fallen across them. An enterprising operator in the Pittsburg office, finding communication suspended, procured a horse, and rode along the line amidst the darkness and rain, found the place, and the cause of the break, which he repaired; then returned to the office, and finished sending the speech."

The Philadelphia "North American," upon whom the "Tribune" chiefly depended, failed to get its report, and the latter purchased a copy from the "Herald."

The expense of securing the speech by express and telegraph, amounted to about 100*l.*

The telegraphs have derived a very large share of their revenue from the press. The whole expense, for telegraph reports of all kinds, have some years cost the New York Associated Press (six in number) probably about 1000*l.* each, or a total of 6000*l.* per annum. The average for the past five years probably has not been less than about 5000*l.* to 6000*l.* per annum. During long sessions of Congress it exceeded this amount.

Sometimes a single paper availed itself of the privilege of ordering long and expensive reports of meetings, speeches, conventions, &c., in which its associates participated or declined as best suited their estimate of the value of the news. In case the other papers refused to receive it, the whole expense was borne by it. The "Herald" is the only one of its associates which publishes a Sunday paper—hence it takes all the telegraph news which is received on Saturday afternoon and night, and pays the whole expense of the tolls.*

264. The electric telegraph, an offspring of science, has rendered to its parent great and important services.

From the moment that it was discovered that the pulsations of

* Jones, p. 138.

the electric current could, by means of the conducting wires, be transmitted to any distances, its use in the important problem of the determination of longitudes, became conspicuously apparent. By reference to our Tract on Latitudes and Longitudes, it will be seen that the difference of the longitudes of two places upon the earth's surface is nothing more nor less than the difference of the hour of the day or night, as shown by two well-regulated clocks at the two places. Thus, if while it is 3 o'clock at one place, it is 4 o'clock at the other, the latter is one hour of longitude east, and the former one hour west of the other; or if it be preferred to express the longitude in degrees, the one place is 15° east or west of the other.

Now since the machinery of the electric telegraph supplies the means of making all the time-pieces of whatever kind, or where-ever placed, which are brought into connection with the same system of wires, move in exact accordance, it is capable of making all the time-pieces in the United Kingdom move in exact accordance with the standard chronometer of Greenwich Observatory; or, to take a still larger view of the principle, it is capable of governing the movement of all the time-pieces of whatever sort, and wherever situated within the range of the vast net-work of telegraphic wires, which overspreads the European continent, so as to make them move in accordance with any standard time-piece, which may by common consent be adopted as the common regulator.

Now, if such an uniformity of chronometers were established, the longitudes of all places would be determined by ascertaining by observations on the sun, which are always easy and susceptible of great precision, the local time, that is to say the time which would be shown by a well-regulated clock on the present system. The difference of the two times, that shown by the common standard regulator and that shown by the local clock, would be the difference of longitude between the place in question and the place where the standard regulator would show local time.

265. In places at great distances asunder, and in different countries, such horological uniformity would, at first, for civil purposes be attended with some inconvenience, since the hour of noon would vary with the longitude. Thus, at a place 15° east of the standard station, the hour of noon would be one o'clock, and at a place 15° west it would be 11 o'clock. Such an inconvenience would, however, only be felt at the moment of the change of custom. It is obvious that it would be as easy and simple to mark the moment at which the sun passes the meridian by 11 or 1, as by 12.

Incidentally to such an horological uniformity would arise, however, the convenience that the hour of noon at all places would express their longitude with relation to the standard station.

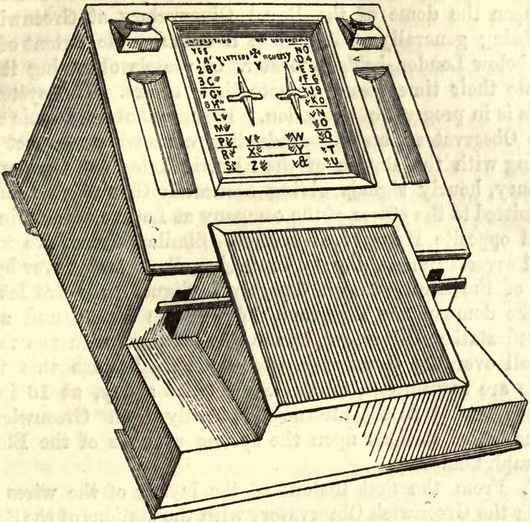


Fig. 91.—HENLEY'S MAGNETIC NEEDLE TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XIII.

266. Signal time balls.—267. Electric connection of observatories of Greenwich, Brussels, and Paris.—268. Uses of electric telegraph in astronomical observations.—269. In regulating the observatory clocks.—270. In fixing with precision the time of an astronomical phenomenon.—271. Telegraphic lines of the United Kingdom.—272. Their extent in 1854.—273. Electric Telegraph Company.—274. Table of its lines, stations, &c.—275. Present tariff (1854).

266. By concert between the Astronomer Royal and the several Electric Telegraph Companies, the Greenwich local time is announced at certain hours of the day, at conspicuous places in different parts of the country, so that navigators who happen to be in any of our ports, may avail themselves of these means of regulating their chronometers. We have already explained the

signal given daily at one in the afternoon, by the fall of a large ball upon the dome of the Royal Observatory at Greenwich.* This being generally visible from a considerable extent of the river below London-bridge, masters of vessels observing it can regulate their time-pieces or note their errors. This system of signals is in progress of extension. By means of a galvanic clock at the Observatory, and the conducting wires which connect that building with the station of the Electric Telegraph Company at Lothbury, hourly signals giving accurately Greenwich time are transmitted to the offices of the company at Lothbury, and in the Strand opposite Hungerford-market. Similar signals are transmitted several times a day to Tunbridge, Deal, and Dover by the wires of the South-eastern Company. Signal balls are let fall over the dome of the Telegraph Office in the Strand and at an elevated station, Liverpool, at the same instant with the fall of the ball over the Greenwich Observatory. Besides this time-signals are transmitted on the wires twice a day, at 10 in the forenoon, and 1 in the afternoon, directly from Greenwich to various chief stations upon the system of lines of the Electric Telegraph Company.

267. From the first instant of the laying of the wires connecting the Greenwich Observatory with the stations of the South-eastern Railway Company and the Electric Telegraph Company, it was evident that one of the earliest and most useful applications of them would be the determination of the longitudes of several of the principal observatories in the British Isles and on the Continent. During the year 1853, the earliest opportunities were accordingly taken for determining the longitudes of Cambridge, Edinburgh, and Brussels, which was accomplished with complete success, as far as regards the galvanic communications and the observations of the signals at all the observatories.

The observatories of Greenwich, Brussels, and Paris are now placed in direct electric connection by the submarine cables between Dover, Calais, and Ostend, to the great advantage and advancement of astronomical science.

268. In the routine of the business of an observatory, the astronomical clock is an instrument in never ceasing use. A part of almost every astronomical observation consists in noting with the last degree of precision the moments of time at which certain phenomena take place; and so great is the degree of perfection to which the art of observation has been carried, that well-practised observers are able, by the combination of a quick and observant eye and ear, to *bisect a second*, and even to approach to a still

* See Tract on Latitudes and Longitudes.

more minute division of that small interval. In order to enable the reader fully to appreciate the benefit which the telegraph has rendered to astronomy, it will be necessary here briefly to explain the manner in which this kind of observation has hitherto been made.

To determine the moment at which the visual ray proceeding from a celestial object has some definite direction, two things are necessary—1st, to ascertain the direction of such a ray; and, 2ndly, to observe the time when it has such direction. The telescope, with its accessories, supplies the means of accomplishing the former, and the astronomical clock the latter.

If T T′, fig. 93, represent the tube of a telescope, T the extremity in which the object-glass is fixed, and T′ the end where the

Fig. 93.

images of distant objects to which the tube is directed are formed, the visual direction of any object will be that of the line *s′ c* drawn from the image of such object formed in the *field of view* of the telescope to the centre *c* of the object-glass, for if this line be continued, it will pass through the object *s*.

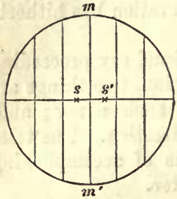
But since the field of view of the telescope is a circular space of definite extent, within which many objects in different directions may at the same time be visible, some expedient is necessary by which one or more fixed points in it may be permanently marked, or by which the entire field may be spaced out as a map is by the lines of latitude and longitude.

This is accomplished by a system of fibres or wires, so thin that even when magnified they will appear like hairs. These are extended in a frame fixed within the eye-piece of the telescope, so that they appear when seen through the eye-glass like fine lines drawn across the field of view.

The system consists commonly of five or seven equidistant wires, placed vertically at equal distances, and intersected at their middle points by a horizontal wire, as represented in fig. 94. When the instrument has been adjusted, the middle wire *m m′* will be in the plane of the meridian, and when an object is seen upon it, such object will be on the celestial meridian, and the wire itself may be regarded as a small arc of the meridian rendered visible.

The *eye* of the observer is occupied in watching the progress of the object moving over the wires in the field of view of the telescope. His *ear* is occupied in noting, and his mind in counting the successive beats of the pendulum, which in all astronomical clocks is so constructed as to produce a sufficiently loud and distinct sound, marking the close of each successive second. The practised observer is enabled with considerable precision in this way to subdivide a second, and determine the moment of the occurrence of a phenomenon within a small fraction of that interval. A star, for example, is seen to the left of the wire *m m′* at *s*, fig. 94, at one beat of the pendulum, and to the right of it at *s′* with the next. The observer estimates with great precision the proportion in which the wire divides the distance between the points *s* and *s′*, and can therefore determine the fraction of a second after being at *s*, at which it was upon the wire *m m′*.

Fig. 94.



The fixed stars appear in the telescope, no matter how high its magnifying power be, as mere lucid points, having no sensible magnitude. By the diurnal motion of the firmament, the star passes successively over all the wires, a short interval being interposed between its passages. The observer, just before the star approaching the meridian enters the field of view, notes and writes down the *hours* and *minutes* indicated by the clock, and he proceeds to count the *seconds* by his ear. He observes the instant at which the star crosses each of the wires; and taking a mean of all these times, he obtains, with a great degree of precision, the instant at which the star passed the middle wire, which is the time of the transit.

By this expedient the result has the advantage of as many independent observations as there are parallel wires. The errors of observation being distributed, are proportionately diminished.

When the sun, moon, or a planet, or, in general, any object which has a sensible disk, is observed, the time of the transit is the instant at which the centre of the disk is upon the middle wire. This is obtained by observing the instants which the western and eastern edges of the disk touch each of the wires. The middle of these intervals are the moments at which the centre of the disk is upon the wires respectively. Taking a mean of the contact of the western edges, the contact of the western edge with the middle wire will be obtained; and, in like manner, a mean of the contacts of the eastern edge will give the contact of that edge with the middle wire, and a mean of these two will give the moment of the transit of the centre of the disk, or a mean of all the contacts of both edges will give the same result.

By day the wires are visible, as fine black lines intersecting and spacing out the field of view. At night they are rendered visible by a lamp, by which the field of view is faintly illuminated.

These points being well understood, no difficulty will be found in understanding the manner in which the telegraph has conferred vastly increased facility and precision on such observations.

269. The first service which it has rendered is that of making all the clocks in the observatory absolutely synchronous. This has been already accomplished with regard to the solar clocks, that is, those which indicate mean or civil time. It may be, and no doubt will be, also accomplished, with still greater advantage to science, in the case of the astronomical clocks, that is, those which mark sidereal time. The several observers, occupied usually in different rooms, have each their own clock. Now, however perfect may have been the workmanship of these clocks, no two of them can be relied upon to go absolutely together for any length of time; therefore, one of the duties of the observer, and of the conditions of good observations, is to note the error of his clock—that is, its deviation from the standard chronometer of the observatory. These errors will be effaced by the expedient of putting all the clocks in the observatory in electrical connection, so that the pendulum of the standard chronometer shall regulate the pulsations of the current, and these pulsations again regulate the motion of all the other clocks.

We believe that the Astronomer Royal once contemplated this improvement, and most probably, when suitable opportunity shall be presented, he will carry it into practical effect.

270. The clocks being thus reduced to absolute accordance, the next service rendered by the telegraph to the astronomer consists in affording the means of ascertaining the instant of time at which any celestial object passes across the micrometer wires with greater facility and precision than were attainable by the use of the eye and ear in the method above described.

This improved method of observation, as it is now being prepared for the Greenwich Observatory, consists in a key-commutator placed under the hand of the observer, which governs a current transmitted to an electro-magnet, connected with a style placed over a cylinder coated with paper, upon which it leaves a puncture when it is driven down by the pulsation imparted to the current by the finger of the observer acting upon the key. The paper-covered cylinder is kept in uniform revolution at any desired rate by clock-work, and another style impelled by another current receiving its pulsations from the pendulum of the chronometer, is driven upon the paper with each beat of the pendulum, the interval between two successive marks made by this style representing one second of time.

Now let us suppose, for example, that by the motion imparted to the cylinder, an inch of the paper passes in each second under the style. The style moved by the clock will therefore leave a succession of marks upon the paper, at distances of an inch asunder. But the particular distance of these marks is unimportant, nor is it material that the cylinder should be moved with mathematical precision. If its motion for the short interval of a second be practically uniform, that will suffice.

When the object, a star for example, approaches the field of view, the observer, with his eye to the telescope, holds his finger over the key. He sees the star enter the field and approach the first wire. The moment it crosses the wire, he presses down the key, and the style gives a puncture to the paper on the cylinder. In the same manner, when the star crosses the second and succeeding wires, he again and again presses on the key, and thus leaves as many distinct marks on the paper as there are wires.

After the observation thus made has been concluded, the marks on the paper are examined, and their distances from the preceding and following marks made by the pendulum style are exactly measured, from which is inferred the fractional part of a second, between the moment at which the star crossed each of the wires, and the last beat of the pendulum.

In this way the time of the transit is ascertained to the hundredth part of a second.

The Astronomer Royal, noticing this method of observing in an address delivered before the Royal Astronomical Society, said, that "In ordinary transit observations, the observer listens to the beat of a clock while he views the heavenly bodies passing across the wires of the telescope; and he combines the two senses of hearing and sight (usually by noticing the place of the body at each beat of the clock) in such a manner as to be enabled to compute mentally the fraction of the second when the object passes each wire, and he then writes down the time in an observing-book. In these new methods he has no clock near him, or at least none to which he listens: he observes with his eye the appulse of the object to the wire, and at that instant he touches an index, or key, with his finger; and this touch makes, by means of a galvanic current, an impression upon some recording apparatus (perhaps at a great distance), by which the fact and the time of the observation are registered. He writes nothing, except perhaps the name of the object observed."

He further observed that it was expected that by this method the irregularities of observation would be greatly diminished, whether because the sympathy between the eye and the finger is more lively than between the eye and the ear, remains to be determined. The Astronomer Royal proposes to use the "centrifugal or conical-pendulum clock" as an instrument superior in every way to those used in America; and "considering the problem of smooth and accurate motion as being now much nearer to its solution than it had formerly been, it might be a question whether, supposing a sidereal clock made on these principles to be mounted at the Royal Observatory, it should be used in communicating motion to a solar clock."

It is worthy of remark also, that punctures can be made upon the *same* revolving barrel by observers employed at two or more instruments erected in different rooms, by means of keys or commutators, which complete the circuit from the same battery to the same puncturing-point. This is at present done with two instruments at Greenwich. All necessity for comparing clocks is, of course, avoided.

Some difficulties occurred at first in imparting to the cylinder a sufficiently smooth and equable motion, the motion given by common clock-work being always one made by starts like that of the seconds' hand of a pendulum. It was to surmount this difficulty that the Astronomer Royal proposed the substitution of the centrifugal pendulum (resembling the governor of a steam engine) for the ordinary oscillating pendulum. In the report of the Astronomical Society, published in February, 1854, it was announced that "The various difficulties which occurred from time to time in the mechanism of the barrel or smooth-motion clock, used for giving motion to the cylinder on which will ultimately be recorded the transits made with the transit-circle and altazimuth, according to the American method of self-registration, have been overcome. It now carries the cylinders put in connection with it with perfect regularity, its rate having all desirable steadiness."

TELEGRAPHIC LINES OF THE UNITED KINGDOM.

271. The telegraphic lines established throughout these countries have been constructed altogether by private companies, chartered or incorporated by the legislature. The total extent of lines in actual operation in the beginning of 1854, was a little more than 8000 miles, upon which about 40000 miles of conducting wire were laid, which would give an average number of five conducting wires over the entire telegraphic net-work.

272. This vast machinery of electric communication has been erected by five or six different companies, but the chief part of it by two—the Electric Telegraph Company, and the English and Irish Magnetic Telegraph Company: the former possesses nearly

4500 miles of line, and more than 24000 miles of wire; and the latter 2200 miles of line, and 13000 miles of wire.

The capital of the former is nearly 800000*l.*, and that of the latter 300000*l.*

It is estimated that the total amount of capital invested in the telegraphic lines of the United Kingdom may amount to about a million and a half sterling.

THE ELECTRIC TELEGRAPH COMPANY.

273. This company was the earliest established, and was in operation for four years without any rival whatever, and for six years without any real competition. These circumstances will explain the large proportion in which the extent of this company's lines exceed all others.

The consequence of the exclusive possession of this important machinery of intercommunication combined with the want of all experience as to the extent to which the public in general might be disposed to avail itself of the advantages offered to them, was naturally and very excusably the establishment of a high tariff. The use of the telegraph was regarded, so far as related to private individuals, as a luxury rather than a necessary of social life, and so far as related to men of business, as an expedient likely to be resorted to only in cases of the most pressing urgency: conceding the justice of these views, a high tariff was not only defensible, but absolutely necessary to the protection of the interests of those who had invested their capital in the enterprise.

Time, experience, and habit, on the one hand, rendered the public familiar with the uses of the telegraph, and created a greater disposition to profit by it for the ordinary purposes of life; and on the other, supplied to the Company that experience of which its managers stood in need, and enabled them, without imprudent risk, to develop liberal and enlightened views in the commercial management of the enterprise. Gradual reductions were made in the tariff, which were further stimulated by the establishment of competitors; and a standard of tariff has been established which, as will presently appear, can leave no reasonable ground of complaint as compared with those of other countries. Whether a still further reduction and a nearer approach to the principle of the uniform postage system would not benefit the companies as well as the public is a question that time and experience alone can solve.

274. The following table, for which we are indebted to the Board of Directors of this company, shows the extent of its lines.

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No of Magnets.
BANGOR AND CAERNARVON	$26\frac{1}{4}$	3	2	4		4	
BIRMINGHAM, SHREWSBURY, AND STOUR VALLEY RAILWAYS.							
Birmingham, Wolverhampton, and Shrewsbury	$138\frac{1}{2}$	4	12			1	
Birkenhead, Lancashire, and Cheshire Junction	$87\frac{1}{2}$	2	3				
Birkenhead Tunnel				2		2	
Sutton Tunnel				2		2	
CHESTER AND HOLYHEAD	$366\frac{1}{4}$	4	15				
EASTERN COUNTIES.							
London to Colchester	410	8	16				
Between Braintree and Maldon	36	3	3			3	3
London to Ely	$650\frac{1}{4}$	9	36			26	23
Ely to Norwich			15	4		9	4
Fakenham to Norwich			11	6		10	
Norwich to Yarmouth } Lowestoft }			13	29		13	
Chesterford to Bury			7				1
Chesterford to Newmarket			6				
Ely to Peterborough	$148\frac{3}{4}$	5	7			6	6
March to Wisbeach	27	3	2			2	2
Cambridge to St. Ives	$44\frac{1}{4}$	3	6			6	6
Broxbourne to Hertford	21	3	2			2	2
Waterlane to Enfield	6	2	2			2	
Shoreditch to Chatham				18		2	
Eccles to Attleborough	$3\frac{3}{4}$	1		2		2	
Audley End to Littlebury	4	2	2			2	
Shoreditch to Brick Lane	1	2	2			2	
Stratford to Woolwich	15	3	5			5	
Stratford to Clapton	$0\frac{1}{2}$	1				2	2
West Junction to Stratford Bridge	$2\frac{1}{4}$	3	5			7	
Coal-siding to Angel Lane	$0\frac{1}{4}$	1				2	
Forest Gate to Angel Lane	1	1				2	
Chobham Farm Line	1	1		6			
EASTERN UNION.							
Colchester to Ipswich	$86\frac{1}{4}$	9	6			6	5
Ipswich to Managers' office	1	2	2				
EXETER AND CREDITON	$83\frac{1}{2}$	2	4				
FURNESS LINE.							
Lindal to Dalton	$2\frac{1}{2}$	2	2				
Whitehaven Tunnel	$0\frac{3}{4}$	1		2		2	
GREAT NORTHERN.							
London to York	762	4	19		2		
London to York *via* Boston	421	2	8				
Peterborough to Grimsby	$156\frac{1}{2}$	2	7				
Boston to Retford	102	2	4				

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Lincoln to Gainsborough	$33\frac{1}{2}$	2	2				
Grimsby to Docks	1	4	2				
Knottingley to Leeds	16	2	5				
Bawtry to Rossington	7	2	2			2	
GREAT WESTERN RAILWAY.							
London to Bristol	$827\frac{3}{4}$	7	22		2		
London to Birmingham	$257\frac{1}{2}$	2	20				
London to Maidenhead	$67\frac{1}{2}$	3	9	9		9	
Slough to Windsor	12	4	1				
Reading to Basingstoke	31	2	2				
Oxford to Banbury	23	1				5	
Swindon to Gloucester *via* Cirencester	90	2	8				
Tetbury to Brimscombe	$8\frac{1}{4}$	1		2		2	
Box to Corsham	$3\frac{1}{2}$	1		2		2	
Bath to Bristol	23	2	4				
Bristol and Exeter Railway	531	6	13				
Yatton to Clevedon	8	2	2				
Tiverton Junction to Tiverton	20	4	2				
Taunton to Yeovil	50	2	6				
LANCASHIRE AND YORKSHIRE RAILWAY.							
Manchester to Normanton	$355\frac{1}{4}$	7	31			8	
Summit Tunnel	$3\frac{1}{2}$	2	2			2	
North Dean to Bradford	20	2	5				
Wakefield to Normanton	16	4	Included in G.N.R.				
Waterloo to Southport	$39\frac{3}{4}$	3	3			3	
Castleford to Methby	$1\frac{1}{2}$	2	Included in G.N.R.				
LANCASTER AND PRESTON, AND LANCASTER AND CARLISLE RAILWAY.							
Lancaster to Preston	42	2	2				
Lancaster to Carlisle	138	2	5				
Oxenholm to Kendal	8	4	2				
LONDON, BRIGHTON, AND SOUTH COAST RAILWAY.							
London to Brighton	202	4	17				
Brighton to Newhaven	$29\frac{1}{2}$	2	4				
London to Epsom	36	2	3				
London to Croydon	21	2	8				
Croydon to Epsom	$7\frac{1}{2}$	1		2			
Littlehampton to Ford	$3\frac{1}{2}$	2	2			2	
Bricklayers Arms to Deptford	$5\frac{1}{2}$	2	2				
Bricklayers Arms Junction to Forest Hill	5	2	5				
Balcombe Tunnel	$0\frac{3}{4}$	1		2		2	
Clayton Tunnel	$1\frac{1}{4}$	1		2		2	
Crystal Palace Extension	15	10	6			2	
LONDON AND NORTH-WESTERN RAILWAY.							
LONDON AND BLACKWALL	20	4	4			2	
London to Colwich	1012	8	3		2		

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Macclesfield to Liverpool	392	8	7		4		
London to Rugby	744¾	9	15		3		
Bletchley to Blisworth	65	4	8			2	2
Euston to Camden	2	2	2			2	2
Primrose Hill Tunnel	4½	6	4			4	4
Watford Tunnel	3	3	2			2	2
Bletchley to Windsor	30	4	4			2	
Winslow to Banbury	47½	2	4			4	
Winslow to Oxford	48	2	5			2	
Winslow to Junction	4	2					
Buckingham to Goodshed	0½	2		2		2	
Blisworth to Peterborough	141¾	3	10			7	7
Kilsby Tunnel	5¼	3	2			2	2
Rugby to Market Harborough	35½	2	5				
Rugby to Leamington	30	2	1				
Rugby to Birmingham	208¼	7	7				
Rugby to Tamworth	160½	6	2				
Tamworth to Colwich	68	4	2				
Birmingham to Manchester	595	7	17		1		
Crewe to Warrington	97	4	3				
Warrington to Newton Junction	28½	6	2				
Newton Junction to Liverpool	162¼	11	6		3		
Newton Junction to Preston	97	4	4				
Newton Junction to Manchester	150¾	9	3		1		
Macclesfield to Stockport	29½	2	3				
Stockport to Manchester	12	2	1				
Stockport to Guidebridge	10	2	Included above.				
Guidebridge to Eaton Lodge	217½	6	6				
Mirfield Junction to Leeds	40	4	4				
Saddleworth to Morsden	15	3	4			4	4
Huddersfield Tunnel	1½	3	3			3	3
Morley Tunnel	6	3	2			2	2
Manchester to Hardwick	4½	6	Included above.				
Warrington to Preston Brook Junction	19	4	Included above.				
Edge Hill to Lime-street	2½	2		2		2	
Edge Hill to Byron-street	2	2		2		2	2
Waterloo to Wapping	10½	3	4			4	4
Curzon-street to Bescot	19	2	2				
LONDON AND SOUTH-WESTERN RAILWAY.							
Waterloo to Portsmouth	378	4	12				
Waterloo to Southampton	78¾	1			2		
Bishopstoke to Southampton	33	6	4				
Fareham to Gosport	19	4	2				
Waterloo to Nine Elms	4	2	3				
Southampton to Dorchester	184½	3	8			8	
Poole Junction to Poole	7½	5	2			3	
Southampton to Brockenhurst	30½	2	1				

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Brockenhurst to Osborne	64	2	4				
MANCHESTER, SHEFFIELD, AND LINCOLNSHIRE RAILWAY.							
Manchester to Sheffield	165	4	10				
Denting to Glossop	4	4	1				
Sheffield to New Holland	131½	2	10				
Ulceby to Great Grimsby	19½	2	2				
Lincoln to Barnetby	59	2	6				
Woodhead to Dunford	6	2	2				
MARYPORT AND CARLISLE RAILWAY.							
Carlisle to Maryport	56	2	9			5	
MIDLAND RAILWAY.							
Derby to Rugby	246½	5	10			2	
Derby to Peterborough	363¾	5	9			6	
Peterborough to Leicester	159	3					
Melton Mowbray to Stamford	50½	2	2			2	
Derby to Lincoln	146¼	3	4			4	
Derby to Sawley	6¾	1				1	1
Derby to Normanton	442¾	7	15	14		21	1
Normanton to Leeds	75¼	7	7			3	
Leeds to Bradford	41¼	3	5			4	
Leeds to Skipton	78¾	3	7			6	
Apperley to Shipley Cabin	6½	2	2				
Skipton to Lancaster	78	2	1				
Hunslet to Hunslet Junction	0½	1				2	
Hunslet Junction to Waterlane	0¾	1		2		2	
Sheffield to Masbro'	15	3	2			2	
Derby to Willington	13	2				1	1
Derby to Birmingham	206¼	5	10			5	
Birmingham to Gloucester	371	7	14			6	
Lickey to Bromsgrove		2	2				
Gloucester to Bristol	150	4	8				
MONMOUTHSHIRE RAILWAY AND CANAL.							
Newport to Blaina	39	2	7				
Newport to Pontypool	17	2	3				
Risca to Nine Mile Point	2¾	1		2		2	
Aberbeeg to Ebbw Vale	5¼	1		2		2	
NORTH LONDON RAILWAY.							
Camden to Stepney	70	10					
Bow to Poplar	3	2	3				
NORTH STAFFORDSHIRE RAILWAY.							
Colwich to Macclesfield	308	8	Included above.				
Colwich to Stone	46	4	3				
Norton Bridge to Stone	11¼	3	2			2	
Stone to Stoke	49	7	3			1	
Stoke to Loco Works	1	2	2				
Stoke to Burton	88½	3	4			1	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Stoke to Newcastle-under-Lyne	3	2	2			2	
Stoke to Horecastle	50	8	4			2	
Stoke to Horecastle Tunnel	1	2	2				
Stoke to Crewe	$71\frac{1}{4}$	5	1			1	
Stoke to North Rode	27	3	Included above.				
North Rode to Macclesfield	$23\frac{3}{4}$	5	3			1	
North Rode to Uttoxeter	$54\frac{1}{2}$	2	4			3	
Rocester to Ashbourne	14	2	2			2	
OXFORD, WORCESTER, & WOLVERHAMPTON	115	2	13			2	
Worcester to Dudley	110	4	14				
Dudley to Wolverhampton	24	4	3				
SHREWSBURY AND BIRMINGHAM RAILWAY.							
Shrewsbury to Wolverhampton	118	4	9			1	
SHROPSHIRE UNION RAILWAY.							
Shrewsbury to Stafford	$58\frac{1}{2}$	2	3				
SHREWSBURY AND CHESTER RAILWAY.							
Chester to Shrewsbury	169	4	7			3	
Wheatsheaf Branch	4	4	1			1	
Oswestry Branch	9	4	1				
SHREWSBURY AND HEREFORD RAILWAY.							
Shrewsbury to Hereford	101	2	13			6	
Ludlow Race-course	1	4	1				
Ludlow Tunnel	$1\frac{1}{2}$	2					
Dinmore Tunnel	$0\frac{3}{4}$	4	2			2	
NEWPORT, ABERGAVENNY, AND HEREFORD RAILWAY.							
Hereford Junction to Hereford Station	82	2	3				
HEREFORD, ROSS, AND GLOUCESTER RAILWAY.							
Grange Court to Hopebrook	10	2	2				
SOUTH DEVON RAILWAY.							
Exeter to Plymouth	371	7	17			14	
Newton to Totness	$17\frac{1}{2}$	2	1				
Newton to Torquay	20	4	3				
Totness to Kingsbridge	9	1		3		3	
Plymouth to Kingsbridge	15	1		3		3	
WEST CORNWALL RAILWAY.							
Penzance to Truro	50	2	7				
SOUTH-EASTERN RAILWAY.							
London to Strood	124	4	26			23	
London to Greenwich	$7\frac{1}{2}$	2	4			4	
London to Observatory	$7\frac{1}{2}$	2	For time signals.				
London to Tunbridge	164	4	9			9	
Tunbridge to Paddock Wood	25	5	2			2	
Paddock Wood to Maidstone	30	3	4			4	
Paddock Wood to Dover	168	4	2	13		15	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Folkstone to Harbour	6	6	3			3	
Ashford to Margate	102	3	8			8	
Minster to Deal	27	3	3			3	
Ashford to Hastings	54	2	6			6	
Tunbridge to Robert's Bridge	84		10			8	
Robert's Bridge to Hastings	24	2	3			3	
Brighton Junction to Hastings	6	2	3			3	
Bricklayers' Arms to Junction	4	4	1			1	
Redhill to Shalford	76	4	4			2	
Shalford to Reading	54	2	7				
Merstham Tunnel to Redhill	7	2		4		4	
Redhill to Signal Pole	0½	1				2	
SOUTH STAFFORDSHIRE RAILWAY.							
Bescott to Walsall	7½	5	3			2	2
Bescott to Great Bridge	6	2	2				
Great Bridge to Dudley	6	3	2	2		3	1
Walsall to Brownhills	10½	2	2				
SOUTH WALES RAILWAY.							
Gloucester to Haverfordwest	647	4	35				
Landore to Llamsamlit	7	2		6		6	
Tunnel west of Landore	2	1		2		2	
S.N. wire from S.W. to Taff Vale Railway	0½	1		2		2	
Loop to Swansea	14	8	2				
Cardiff Docks	5	4	1				
Gloucester to Grange Court	15½	2	1				
TAFF VALE RAILWAY.							
Cardiff Docks to Merthyr	49	2	5				
Aberdare to Aberdare Junction	14½	2	2				
VALE OF NEATH RAILWAY.							
Neath to Merthyr	46	2	5				
Hirwain to Aberdare Junction	1	1	2			2	
Merthyr to end of Tunnel	2	1		2		2	
WHITEHAVEN JUNCTION.							
Maryport to Whitehaven	24	2	4			4	
YORK, NEWCASTLE, AND BERWICK RAILWAY.							
York to Newcastle	872½	10	18	13	1	19	1
Darlington to Newcastle	42¾	1				22	10
Darlington to Station on Stockton Line	1¾	1		2			
Dalton to Richmond	19½	2	2			1	
Dalton to Darlington	5¼	1					
Belmont to Durham	12	6	4				
Belmont to Fence Houses	3½	1				4	1
Brockley Whins to South Shields	24	8	2			3	
Newcastle to Brockley Whins	47½	5	Included below.				
Brockley Whins to Sunderland	35	7	3	2		3	
Newcastle to Berwick	399	6	8			7	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Newcastle to Benton	4	1					
Newcastle to Tynemouth	18	2	4				
Belton to Alnwick	12	4	2			1	
Fatfield to Washington	4	2		1		1	
Washington to Shields Drops	8	2		1		1	
Shields Drops to Sunderland Dock	16	2		1		1	
Sunderland Dock to Sunderland Statn.	8	2	Included above.				
YORK AND NORTH MIDLAND RAILWAY.							
Harrowgate to Church Fenton	48¾	3	2			2	
Hull to Milford Junction	77½	5	9			7	
Bridlington to Hull	30¾	3	5			5	
Scarborough to York	42¾	3	8			7	
Burton Salmon to Castleford	36	9	2			2	
Castleford to Normanton	33¾	9	2			1	
Milford Juncton to Burton Salmon	4	2					
Milford Junction to York	30	2	2				
York to Burton Salmon	217¾	13	10				8
EDINBURGH, PERTH, AND DUNDEE.							
Edinburgh to Tay Port	159	3	11			11	
Ladybank Junction to Perth	36	2					
Edinburgh to Scotland-street	1	2					
EDINBURGH AND GLASGOW RAILWAY.							
Edinburgh to Glasgow	332½	7	9		3	7	
Edinburgh to Greenhill	60	2	1				
Cowlairs to Hut Tunnel end	2½	2	2			2	
Haymarket to Edinburgh Tunnel end	3¾	2					
Edinburgh to Leith-street work	4	4	2				
DUNDEE AND ARBROATH RAILWAY.							
Dundee to Broughty	9	2	1				
Tay Port Submarine cable	4	4					
NORTH BRITISH RAILWAY.							
Berwick to Edinburgh	346½	6	10			10	
Portobello to Hut	6	2	2			2	
Tunnel	120 yds						
SCOTTISH CENTRAL RAILWAY.							
Greenhill to Perth	180	4	9			7	
METROPOLITAN STATIONS	500	52	71		5		

275. According to the tariff, as last arranged by the Electric Telegraph Company, all messages consisting of not more than 20 words are transmitted to distances not exceeding 50 miles for 1*s.*, to distances not exceeding 100 miles for 2*s.* 6*d.*, and to all

greater distances for 5*s.* For each additional ten words, or fraction of ten words proportionate charges are made.

In certain exceptional cases the shilling charge is extended to much greater distances than 50 miles, and the half-crown charge to much greater distances than 100 miles. These exceptions include towns of the highest commercial and manufacturing importance, with which a large telegraphic business must always be transacted. Thus, between London and Birmingham (112 miles) the charge is only 1*s.*, and between London and Liverpool (210 miles), London and Manchester (180 miles), London and Carlisle (309 miles), the charge is only 2*s.* 6*d.*

The charge for transmission is of course increased in proportion to the length of the message, but the daily experience of the telegraphic offices demonstrates that, with the exception of reports transmitted to the newspapers, the average length of the messages does not much exceed twenty words. I have obtained a return of the lengths of 74 messages transmitted, without any particular selection of subject, the total length of which, exclusive of the address, is 1151 words. The total length of the addresses is 540 words. This gives for the average length of the messages $15\frac{1}{2}$ words, and of the addresses $7\frac{1}{3}$ words, the average length of the messages, including the addresses, being therefore a little under 23 words.

Besides the convenience offered to the public by the transmission of messages to the various stations throughout the country, this Company has established a system of metropolitan intercommunication by means of seventeen branch stations in connection with each other and with the principal station at Lothbury. These stations are dispersed through the metropolis at points which have been found to be the most active centres of intercourse. They include the eight railway stations, the London Docks, Mincing Lane, General Post-office, St. Dunstan's Church, West Strand, Great George Street Westminster, St. James's Palace, Knightsbridge, and the Marble Arch, Hyde-park. Of these the stations on the West Strand, and the Eastern Counties Railway, Shoreditch, are open day and night.

Messages of 20 words are transmitted between any two of these metropolitan stations for 1*s.*

In all cases the charge for the telegraphic message includes its delivery at the place of address, provided that such place be within a radius of half a mile round the station, 6*d.* being charged for each mile additional, and no charge is made for the addresses of the sender or receiver.

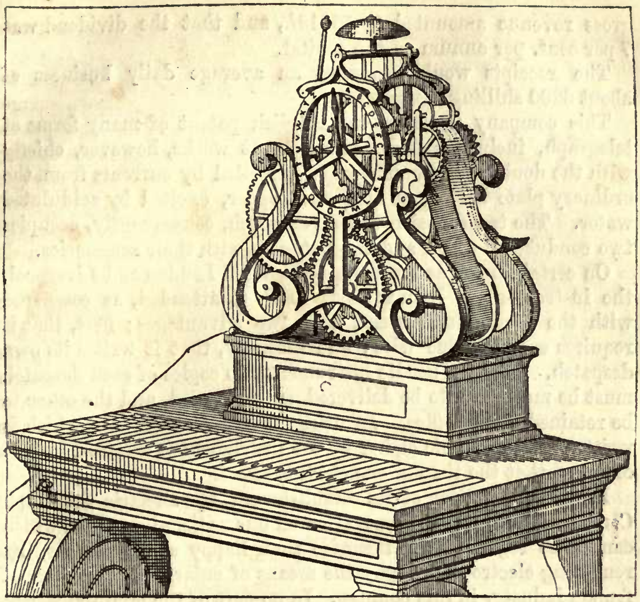


Fig. 92.—BRETT'S PRINTING TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XIV.

Electric Telegraph Company's present tariff (continued).—276. Magnetic Telegraph Company.—277. Chartered Submarine Company.—278. The Submarine Telegraph Company. between France and England.—279. European and American Telegraph Company.—280. Origin of the submarine companies' enterprises.—281. Wonderful celerity of international correspondence.—282. Organisation of electric communications with the Continent.—283. Mediterranean Electric Telegraph Company. —284. General table showing the places on the continent of Europe, which are in electric connection with each other, and with England, and the cost of despatches sent between them severally and London.—285. Telegraphic lines in the United States.—286. Vast projects in progress or contemplation.

According to the half yearly balance sheet of the company it appears that in the six months ending December 31, 1853, the gross revenue amounted to 56919*l.*, and that the dividend was 7 per cent. per annum on the capital.

The receipts would represent an average daily business of about 6200 shilling messages.

This company possesses the English patent of many forms of telegraph, including those of Bain. It works, however, chiefly with the double needle telegraph, impelled by currents from the ordinary plate battery of zinc and copper, excited by acidulated water. The transmission of each despatch, consequently, occupies two conducting wires, and two batteries with their accessories.

On certain lines, as for example between London and Liverpool, the instrument of Bain is used. This is attended, as compared with the needle instrument, with two advantages; first, that it requires only one line wire; and secondly, that it writes its own despatch. With the needle instrument two copies of each despatch must be made, one to be delivered as addressed, and the other to be retained by the office. In using Bain's method, that which is written in telegraphic cipher by the instrument is retained by the office, so that the time of one clerk is saved.

In the organisation of its establishment, the Electric Telegraph Company have made an innovation on our national customs, which cannot be regarded as otherwise than happy and judicious, by rendering electro-telegraphy the means of enlarging the sphere of female industry in this country. In no part of the civilised world, —except perhaps the United States, where our customs have been retained,—are females excluded from so many employments suited to them, as in England. In France they are extensively employed as clerks in various branches of commercial business. As money-takers or ticket-sellers in railway offices, theatres, concert-rooms, and in short in all public exhibitions they are engaged, to the entire exclusion of the other sex. As box-keepers and box-openers in all the theatres, and in numberless other occupations in which no bodily labour is needed, they are preferred to men.

Now the working of telegraphic instruments, and the general business of telegraphic offices is precisely the kind of occupation for which they are best fitted, and we notice with great pleasure the independent and enlightened step taken by the Electric Telegraph Company in their employment, which it may be hoped will prove only the commencement of a general movement, having a tendency to improve the condition of that portion of the sex who are obliged to seek the means of living by their industry.

The battery department is not one of the least interesting objects presented in the Lothbury establishment. The cellars of the building are appropriated to this generator of electric currents.

They consist of two long narrow vaults, in which upwards of 300 batteries are arranged, consisting of various numbers of pairs of plates, six, twelve, and twenty-four, adapted to carry smaller and greater distances.

The entire amount of voltaic power employed by this company throughout the country consists of 96000 cells composed of 1,500000 square inches of copper, and an equal surface of zinc. These are kept in action by the consumption of six tons of acid annually.

In the half year ending 31st December, 1851, the paid up capital of the company was augmented, and the tariff for the transmission of messages was reduced in the large proportion of 50 per cent. upon its original rate. The extent of the line was increased 8 per cent., and that of the conducting wires nearly 35 per cent. The average number of wires upon the lines was augmented by this change from 4 to 5. The effect of this, and the gradual increase from month to month in the next half year was an increase of above 60 per cent. in the amount of business, and nearly 13 per cent. in the receipts, the dividends having been augmented from 4 to 6 per cent.

Among the more recent improvements in the transaction of telegraphic business which have been made by this company, the following may be mentioned.

"Franked message papers," pre-paid, are now issued, procurable at any stationer's. These, with the message filled in, can be dispatched to the office when and how the sender likes; and the company intend very quickly to sell electric stamps, like Queen's heads, which may be stuck on to any piece of paper, and frank its contents without any further trouble. Another very important arrangement for mercantile men is the sending of "remittance messages," by means of which money can be paid in at the central office in London, and, within a few minutes, paid out at Liverpool or Manchester, or by the same means sent up to town with the like dispatch from Liverpool, Manchester, Bristol, Birmingham, Leeds, Glasgow, Edinburgh, Newcastle-on-Tyne, Hull, York, Plymouth, and Exeter. There is a money-order office in the Lothbury establishment to manage this department, which will, no doubt, in all emergencies speedily supersede the government money-order office which works through the slower medium of the post-office.*

* Quarterly Review, No. CLXXXIX., p. 149.

The effect of the gradual reduction of the tariff upon the business, and the profits of the company, will be apparent from the following table:—

Half Year Ending	Miles in operation.	Increase per cent.	Miles of line wire.	Increase per cent.	Mean Number of Wires.	Number of Messages.	Increase per cent.	Total Receipts. £	s.	d.	Increase per cent.	Average Receipts per Message. s.	d.	Average Receipts per Mile of Wire. £	Dividends paid per cent. per annum.
June 30, 1850 .	1684	...	6730	...	4	29245	...	20436	10	0	...	13	$11\frac{3}{4}$	5·04	4
Dec. 31, 1850 .	1786	6·06	7200	6·98	4	37389	27·84	23087	13	9	12·97	12	4	3·20	4
June 30, 1851 .	1965	10·02	7900	9·72	4	47259	26·39	25529	12	4	10·56	10	$9\frac{1}{2}$	3·23	6 and 2 per cent. bonus.
Dec. 31, 1851 .	2122	99	10650	34·81	5	53957	14·17	24336	8	10	−4·67	90	$\frac{1}{4}$	2·29	6
June 30, 1852 .	2502	17·91	12500	17·37	5	87150	61·52	27437	4	8	12·74	6	$3\frac{1}{2}$	2·19	6
Dec. 31, 1852 .	3709	48·24	19560	56·48	$5\frac{1}{5}$	127987	46·86	40087	18	2	46·11	6	$3\frac{1}{4}$	2·05	$6\frac{1}{2}$
June 30, 1853 .	4008	8·06	20800	6·34	$5\frac{2}{3}$	138060	7·87	47265	16	3	17·90	6	10	2·27	$6\frac{1}{2}$
Dec. 31, 1853 .	4409	10·00	24340	17·02	$5\frac{1}{2}$	212440	53·87	56919	0	1	20·42	5	$4\frac{1}{4}$	2·34	7
June 30, 1854 .	4652	5·51	25233	3·67	$5\frac{1}{2}$	235867	11·03	62435	0	0	9·69	5	$3\frac{1}{2}$	2·47	......

THE MAGNETIC TELEGRAPH COMPANY.

276. This Company has constructed lines connecting the following principal places by means of the submarine cable, extended between Donaghadee and Port Patrick:—

London.	Portpatrick.	Kildare.
Birmingham.	Donaghadee.	Carlow.
Manchester.	Belfast.	Thurles.
Liverpool.	Armagh.	Tipperary.
Preston.	Drogheda.	Limerick.
Carlisle.	Navan.	Waterford.
Glasgow.	Dublin.	Mallow.
Greenock.	Athlone.	Killarney.
Edinburgh.	Ballinasloe.	Cork.
Stranraer.	Galway.	Queenstown.

This company has established an underground line of ten wires from London to Liverpool, by Manchester, and one of six wires from Liverpool to Portpatrick, and from thence to Belfast. The line from Belfast to Dublin, and from thence to Cork, with branches, is overground on poles. The underground system is again adopted from Cork to Queenstown.

Lines are in progress of construction along the Waterford and Limerick Railway, and six additional wires are being laid between Dublin and Belfast.

The instruments used are the needle-telegraph, and chiefly the double needle instruments, the current being produced not by galvanic batteries, but by magneto-electric machines, on the principle patented by Messrs. Henley and Forster (220) improved in various details by the Messrs. Bright, the secretary and engineer of the company.

The speech delivered by the Queen on opening the parliamentary session of 1854, was supplied verbatim to the Belfast journals at 2 h. 25 m., to those of Dublin at 2 h. 40 m., and to those of Cork at 3 h. 20 m. on the afternoon of its delivery.

The tariff is regulated upon principles similar to that of the Electric Telegraph Company.

Although this company was not incorporated until the middle of 1852, it has now (July, 1854) upwards of 2000 miles of telegraphic lines, and 13000 miles of wire in active operation, and from the rapid progress it has hitherto made, and its power to extend its capital of 300000*l.* to 600000*l.*, it is probable that ere long its scale of operation will be much further extended, to the great benefit of the public.

SUBMARINE COMPANIES.

277. The Chartered Submarine Telegraph Company between Great Britain and the Continent has been formed with a nominal share capital of 150000*l.*, of which the half has been for the present reserved, the actual amount of the subscribed capital being only 75000*l.*

The operations of this company have hitherto (1854) been limited to the establishment of electric communication with Belgium, by means of the cable already described, connecting Dover with Ostend.

This company has recently coalesced with the Submarine Telegraph Company.

278. The Submarine Telegraph Company between France and England has a nominal share capital of 100000*l.*, of which about 75000*l.* have been subscribed and expended, the shares representing the remainder being still unallotted. The operations of this company have been limited to the establishment of electric communication between France and England, by means of the submarine cable laid between Dover and Calais.

279. The European and American Electric Telegraph Company has been established to form a link between the cables of the two submarine companies, and London, Manchester, and Liverpool, and intermediate places. This company has laid underground wires from Dover to London, and from London by Birmingham and Manchester to Liverpool. Of this line, the first section between Dover and London was opened for public correspondence on 1st November, 1852, and has since been in constant operation. Of the remainder, 190 miles were completed on 1st March, 1854, passing through Birmingham, Wolverhampton, Stafford, and Macclesfield, to Manchester. The remaining 30 miles to Liverpool has been since completed, and the entire line is now in operation. The total cost of this line, with its accessories, has been 100000*l.*

By an arrangement between this and the Submarine Company, all despatches between the offices of the latter from the Continent are transmitted upon the lines of the former, being delivered and received at the offices of the latter. In fact, so far as the public are concerned, the continental correspondence going or coming by France or Belgium is transmitted by these three companies, acting in common and as a single administration. Offices for correspondence between England and the Continent are established in London, Birmingham, Manchester, Liverpool, Gravesend, Chatham, Canterbury, Deal, Dover, Calais, Paris, Brussels, and Antwerp; despatches, however, being forwarded to England from all continental stations.

The tariff for all single messages between London and the Continent is 8*s.*, in addition to the Continental charge for transmission between the Continental station to or from which the message is transmitted, and Calais or Ostend. If the message is sent to or from any provincial town (except Dover), there is an additional charge for its transmission between London and such town.

280. The originators of the novel and bold project of submarine electric communication are stated to be the Messrs. Jacob and J. W. Brett, brothers, of Hanover-square, London. Their first propositions were addressed to the English government, and were directed to the deposition of a submarine cable between Holyhead and Dublin, which they offered to undertake if the government would make them a grant of 20000*l.*, for which, of course, the State would have for public purposes the free use of the line. This offer was declined.

The next propositions, addressed to the French and Belgian governments, were attended with more success. An exclusive privilege was granted by both governments, to which the English government acceded for the use of such submarine conductors as the parties should succeed in depositing, and in consequence of this, the companies were formed, by which the project has since been realised, and the cables already described between the English coast near Dover and the coasts of France and Belgium, near Calais and Ostend, were laid, by which London, Paris, and Brussels have been brought into and now are in instantaneous electric communication; and through these capitals the whole Continent, wherever telegraphic wires have been established, has been put in connection with the United Kingdom.

281. The actual celerity with which correspondence can be transmitted between London and parts of Europe more or less remote, may be judged from the fact that the Queen's speech, delivered at the opening of the parliamentary session of 1854, was delivered verbatim and circulated in Paris and in Berlin before her Majesty had left the House of Lords.

Messages have been sent from the office in Cornhill to Hamburg, Vienna, and, on certain occasions, to Lemberg, in Gallicia, being a distance of 1800 miles, their reception being acknowledged by an instantaneous reply.

282. It is satisfactory to be able to state that measures are being taken by many of the most important continental states to extend the benefits of telegraphic communication by multiplying the

stations, by increasing the number of conducting wires, and by lowering the tariff.

The electric communications with the continent may now be considered as secure from all chance of interruption. Accidents from the dragging of anchors may occur, by which any one of the submarine cables may be disabled for a time, but in that case the communication with the continent will be maintained by either or both of the others, such a coincidence as the simultaneous disabling of all the three not being within the bounds of moral possibility.

MEDITERRANEAN ELECTRIC TELEGRAPH COMPANY.

283. Another company has been formed by the spirit and enterprise of the Messrs. Brett, under the auspices of the governments of France and Piedmont, for connecting the coasts of Europe and Africa by electric wires, in the manner already explained (84). This company is formed with a share capital of 300000*l.* An exclusive privilege for fifty years has been granted to it by the two governments, and a guarantee of interest of four per cent. on 180000*l.* is given by the French, and 5 per cent. on 120000*l.* by the Sardinian Government.

This enterprise is now (1854) in rapid progress of realisation, several hundred men being occupied in constructing the lines across the islands of Sardinia and Corsica. It is expected that the lines to the coast of Africa will be completed and in operation soon after these pages will be in the hands of our readers.

While we write these lines (June, 1854) we learn that the cable has been laid between Spezzia and Corsica, and between Corsica and Sardinia, and is already in successful operation.

The condition and form of the bottom between coast and coast has been ascertained by soundings, and is found to present no obstacles, being free from any considerable inequalities of depth. The conducting wires within this cable have received a special form, the advantage of which is, that in case of the cable being bent by any accidental inequalities of the bottom, or accidents in the process of its deposition, the wires will not be strained, but will easily yield as a spiral spring would. In the cables already laid, it has been found that some of the wires have been more or less injured from this cause, so as to render their performance unsatisfactory.

The weight of this cable is at the rate of 8 tons per mile. It contains six conducting wires, each of which is covered with a coating of gutta percha, and the whole is surrounded with hemp, properly tarred, so as to form a compact rope, which is finally enclosed like those already described in a compound heliacal armour of twelve galvanised iron wires.

Until the cable and wires destined ultimately to connect Alexandria with Sardinia can be completed, it is intended to establish a special line of steamers between Malta and Sardinia, so as to be enabled to transmit intelligence instantaneously from the centre of the Mediterranean to London, Paris, and all parts of Europe. Two mercantile houses, Messrs. Rubattino and Co., of Genoa, and Messrs. Antonio Galea and Co., of Malta, have undertaken conjointly to place two steamers to run between Malta and Sardinia, to take the despatches coming from the East, to be transmitted to Paris and London.

It is intended, however, meanwhile, to connect Malta by a cable with the nearest point of the African coast, and by this, and an underground line of wires to Bona, to establish an electric communication with Sardinia, and thence with London.

284. In the following table, collected from the most recent reports, are shown the telegraphic stations established in various countries of Europe in July, 1854. Annexed to each place is the charge at which a single message is transmitted between it and London. Of this charge 8s. is the part applicable to the transit between London and Calais or Ostend, the remainder being the cost of transmission between one or other of these places, and the continental station. A single message cannot exceed 20 words if transmitted by Calais, or 25 words if transmitted by Ostend. The charge is increased in a two-fold ratio for messages which exceed this number of words, but which do not exceed 50, and in a three-fold proportion for such as exceed 50, but do not exceed 100. In general, messages exceeding 100 words are not transmitted.

In some cases a message may be transmitted by different routes at the option of the person sending it. Thus, for example, a message to Vicenza may be sent *viâ* Baden, *viâ* Bavaria, *viâ* Switzerland, *viâ* Sardinia, or *viâ* Belgium. The cost of transmission in such cases varies with the route chosen. In all such cases the charge given in the Table is the lowest of those at which it can be sent.

The tariff by way of the Hague is not included in this Table.

FRENCH STATIONS, *viz.*	s.	d.
To Abbeville	10	6
,, Agen	17	0
,, Amiens	11	0
,, Angers	14	0
,, Angoulême	15	6
,, Arras	10	6
,, Auch	17	6
,, Auxerre	13	6
,, Avignon	17	6
,, Bar-le-Duc	13	0
,, Bayonne	18	0
,, Beauvais	11	6
,, Behobie	18	6
,, Besançon	15	0
,, Bezières	18	0
,, Blois	13	6
,, Bordeaux	16	6
,, Boulogne-sur-Mer	10	0
,, Bourges	14	0
,, Brest	15	0
,, Caen	13	0
,, Cahors	16	6
,, Calais	8	0
,, Carcassone	18	0
,, Cette	18	0
,, Chalons-sur-Marne	12	6
,, Chalons-sur-Saone	15	0
,, Chartres (Eure et Loir)	12	6
,, Chateauroux	14	0
,, Chaumont	13	6
,, Cherbourg	12	6
,, Clermont Ferrand	15	6
,, Colmar (Alsace)	14	6
,, Creil	11	6
,, Dieppe	11	0
,, Dijon	14	6
,, Douai	11	0
,, Draguignan	18	6
,, Dunkirk	10	0
,, Evreux	12	0
,, Foix	18	6
,, Grenoble	16	6
,, Havre	12	0
,, Laon	12	0
,, La Rochelle	15	6
,, Lille	10	6
,, Limoges	15	6

FRENCH STATIONS, *viz.*	s.	d.
To Lorient	15	0
,, Lyons	16	0
,, Macon	15	0
,, Mans (le)	13	0
,, Marseilles	18	6
,, Melun	12	6
,, Metz	13	6
,, Mont-de-Marsan	17	6
,, Montpellier	18	0
,, Montauban	17	0
,, Montbrison	15	0
,, Moulins	14	6
,, Mulhouse	15	0
,, Nantes	14	6
,, Nancy	13	6
,, Narbonne	18	0
,, Nevers	14	0
,, Nimes	17	6
,, Niort	15	0
,, Orleans	13	0
,, Paris	12	0
,, Pau	18	0
,, Perigueux	16	0
,, Perpignan	18	6
,, Poictiers	14	6
,, Privas	16	6
,, Quimper	15	0
,, Rennes	14	0
,, Rochefort	15	6
,, Roubaix	10	6
,, Rouen	11	6
,, Saint Quentin	11	6
,, St. Etienne	16	0
,, St. Lo	12	6
,, St. Omer	10	0
,, Strasbourg	14	6
,, Tarbes	18	0
,, Tonnerre	13	6
,, Toulon	19	0
,, Toulouse	17	6
,, Tours	14	0
,, Troyes	13	0
,, Valenciennes	11	0
,, Valence	16	6
,, Vannes	14	6
,, Versailles	12	0
,, Vesoul	14	6

TO	s.	d.	TO	s.	d.	TO	s.	d.
Arau	20	0	Brunswick	20	0	Ghent	10	0
Aarbourg	20	0	Brussels	12	0	Giessen	18	0
Adelsberg	22	0	Bühler	22	0	Glaris	22	0
Aeltre	10	0	Carlsruhe	14	0	Glognitz	22	0
Agram	22	0	Casale	24	0	Gorlitz	22	0
Airolo	22	0	Cassel	18	0	Gospich	22	0
Aix-la-Chapelle	16	0	Charleroi	12	0	Gotha	18	0
Alexandria (Sar.)	24	0	Chaux de Fonds	22	0	Goritz	22	0
Alstätten	22	0	Chemnitz	20	0	Gratz	22	0
Altenbourg	20	0	Chiasso	24	0	Haarlem	16	0
Altona	24	6	Cilly	22	0	Hagenau	22	0
Altorf	22	0	Coire	22	0	Hague	14	0
Amsterdam	16	0	Come	18	0	Halle	20	0
Andermatt	22	0	Courtrai	10	0	Ham	18	0
Ansbach	18	0	Coblentz	18	0	Hamburg	22	0
Antwerp	12	0	Cologne	16	0	Hanau	18	0
Arnheim	16	0	Copenhagen	24	6	Hanover	20	0
Appenweier	18	6	Cracow	24	0	Harburg	22	0
Aschaffenburg	16	0	Dantzig	24	0	Hasselt	12	0
Asti	22	0	Darmstadt	15	0	Hattingen	14	0
Ath	12	0	Delemont	20	0	Heidelberg	14	0
Augsburg	18	0	Delft	16	0	Heilbronn	16	0
Baden, Baden	14	0	Dessau	20	0	Herisau	22	0
Baden (Swiss)	20	0	Deutz	16	0	Hermanstadt	26	0
Bale	20	0	Dirschaw	24	0	Herzogenbuchsee	20	0
Bamburg	18	0	Dordrecht	14	0	Hof	20	0
Bautzen	22	0	Dresden	20	0	Hohenschwangau	18	0
Bellinzona	22	0	Dinglingen	14	0	Horgen	22	0
Bergamo	20	0	Duisbourg	18	0	Inspruck	18	0
Berlin	22	0	Dusseldorf	18	0	Ischl	24	0
Berne	20	0	Empoli	35	0	Jurbise	12	0
Berthoud	20	0	Eisenach	18	0	Karlstadt	22	0
Beyreuth	18	0	Elberfeld	18	0	Kempten	18	0
Bielitz	26	0	Elbing	26	0	Kell	14	0
Bienne	20	0	Elsineur	24	6	Kissengen	18	0
Bodenbach	20	0	Erfurt	20	0	Klagenfurt	22	0
Bologna	26	0	Essek	28	0	Klausenberg	30	0
Borgoforto	24	0	Feldkirk	18	0	Kohlfurt	24	0
Botzen (in Tyrol)	20	0	Flawyl	22	0	Konigsberg	26	0
Brain-le-Compte	12	0	Flensburg	24	6	Korsör	24	6
Breda	14	0	Fleurier	22	0	Kosel	24	0
Bregenz	18	0	Florence	36	6	Kothen	20	0
Bremen	20	0	Fossano	22	0	Kreutz	24	0
Brescia	20	0	Frankfort on M.	15	6	Kufstein	20	0
Breslau	22	0	Frankfort on O.	22	0	Laibach	22	0
Brigg	22	0	Frauenfeld	22	0	Landau	14	0
Brixen	20	0	Fredericia	24	6	Landen	12	0
Bromberg	26	0	Fribourg (Swiss)	22	0	Landshut	18	0
Bruchsal	14	0	Friburg (Baden)	14	0	Langenthal	20	0
Brugelette	12	0	Friedrichshafen	16	0	Lans-le-bourg	20	0
Bruges	10	0	Geneva	22	0	Lausanne	22	0
Brugg	20	0	Genoa	24	0	Leghorn	34	6
Brunn	22	0	Germersheim	14	0	Leipzig	20	0

TO	s. d.	TO	s. d.	TO	s. d.
Lemburg ...	26 0	Offenburg ...	14 0	Saint Imier ...	20 0
Lenzbourg ...	20 0	Olmutz ...	22 0	Saint Trond ...	12 0
Leyden ...	16 0	Olten ...	20 0	St. Jean de Mau-	
Lichtensteig ...	22 0	Oos ...	14 0	rienne ...	20 0
Liege ...	12 0	Oppeln ...	24 0	Salzburg ...	20 0
Liegnitz ...	22 0	Orsowa ...	26 0	Samaden ...	24 0
Liestall ...	20 0	Oschersleben ...	20 0	Sarrebrück ...	16 0
Lindau ...	16 0	Ostend ...	8 0	Schiedam ...	16 0
Linz ...	20 0	PADERBORN ...	20 0	Schaffhausen ...	22 0
Locarno ...	22 0	Padua ...	20 0	Schweinfurt ...	18 0
Locle (le) ...	22 0	Parma ...	24 0	Schwyz ...	22 0
Louvain ...	12 0	Passau ...	20 0	Semlin ...	26 0
Lubeck ...	22 0	Pays Bas Frr. ...	12 0	Sion ...	22 0
Lucca ...	34 6	Pepinster ...	14 0	Sienna ...	28 6
Lucerne ...	22 0	Pescia ...	35 0	Soleure ...	20 0
Ludwigschafen	16 0	Pesth-Bude ...	24 0	Sonceboz ...	20 0
Lugano ...	24 0	Peterwardin ...	24 0	Spires ...	16 0
MAGDEBURG ...	20 0	Pietra Santa ...	32 6	Splügen ...	22 0
Malines ...	12 0	Pirano ...	22 0	Stettin ...	22 0
Manage ...	12 0	Pisa ...	32 6	Stuttgard ...	16 0
Mannheim ...	14 0	Pistoja ...	37 0	Süssen ...	22 0
Mantua ...	20 0	Plaisance ...	26 0	Swinnemunde ...	22 0
Marburg ...	18 0	Plauen ...	20 0	Szegedin ...	24 0
Massa ...	26 0	Poggebonsi ...	37 0	Szolnock ...	24 0
Mestre ...	20 0	Pola ...	22 0	TAMINES ...	12 0
Milan ...	20 0	Pontadera ...	33 0	Tarnow ...	24 0
Minden ...	20 0	Posen ...	24 0	Temeswar ...	26 0
Misocco ...	22 0	Potsdam ...	22 0	Termonde ...	12 0
Modena ...	24 0	Prague ...	20 0	Teufen ...	22 0
Mogadino ...	22 0	Prato ...	37 0	Thalwyl ...	...
Mons ...	12 0	Presburg ...	22 0	Thusis ...	22 0
Monza ...	20 0	Przmysl ...	26 0	Tirlemont ...	12 0
Morat ...	22 0	QUIEVRAIN ...	12 0	Tournay ...	10 0
Morgiers ...	22 0	RACCONIGI ...	22 0	Trento ...	20 0
Motiers ...	22 0	Ragaz ...	22 0	Treves ...	16 0
Mouscron ...	10 0	Rapperschwyl ...	22 0	Treviglio ...	24 0
Mulheim ...	14 0	Rastadt ...	14 0	Trevisa ...	20 0
Munich ...	18 0	Ratibor ...	24 0	Trieste ...	22 0
Munster ...	18 0	Ratisbon ...	18 0	Trogen ...	22 0
Murzzuschlag ...	22 0	Reggio ...	22 0	Troppau ...	24 0
Myslowitz ...	24 0	Rendsburg ...	24 6	Trubau ...	22 0
NAMUR ...	12 0	Rheineck ...	22 0	Turin ...	22 0
Neufchâtel ...	22 0	Richterschwyl ...	22 0	UDINE ...	20 0
Neuhausel ...	24 0	Riesa ...	20 0	Ulm ...	16 0
Niederurnen ...	22 0	Rotterdam ...	14 0	Utrecht ...	16 0
Nieuw Diep ...	17 8	Rorschach ...	22 0	Uznach ...	22 0
Novare ...	24 0	Rosenheim ...	18 0	VENICE ...	20 0
Novi ...	24 0	Roveredo ...	20 0	Verceil ...	24 0
Nuremburg ...	18 0	Rovigno ...	32 0	Verona ...	24 0
Nyburg ...	24 6	Rzeszow ...	26 0	Verviers ...	14 0
Nyon ...	22 0	SAINT GALL ...	22 0	Vevey ...	22 0
ODERBERG ...	24 0	Sainte Croix ...	22 0	Vicenza ...	20 0
Offenbach ...	16 0	Saint Ghislain ...	12 0	Vienna ...	22 0

TO	s. d.	TO	s. d.	TO	s. d.
Wadenschwhl ...	22 0	Winterthur ...	22 0	YVERDUN ...	22 0
Wattwyl ...	22 0	Wittenburg ...	22 0	ZOFFINGUE ...	20 0
Weimar ...	20 0	Worms ...	16 0	Zug	22 0
Werdau ...	20 0	Wurzburg ...	18 0	Zurich	22 0
Wesel ...	20 0	Wyl	22 0	Zwickau ...	20 0

⁂ *The above rates are exclusive of the usual charge for Porterage for Delivery of the Messages to any part of France. No charge to other places. N.B.—The Minimum length of a Message viâ Belgium is Twenty-five Words, any other route Twenty Words.*

The Public are informed that, in order to provide against mistakes in the transmission of MESSAGES by the SUBMARINE and EUROPEAN TELEGRAPH COMPANIES, every Message of consequence ought to be REPEATED, by being sent back from the Station at which it is to be received, to the Station from which it is originally sent.—Double the usual price for transmission will be charged for repeating the Message to or from any part of France, and Half the usual charge to or from any other part of Europe.—The Company will not be responsible for Mistakes in the transmission of unrepeated messages, from whatever cause they may arise.—Nor will they be responsible for Mistakes in the transmission of a repeated Message, nor for delay in the transmission or delivery, nor for non-transmission or non-delivery of any Message, whether repeated or unrepeated.—No Message that is unintelligible can be transmitted to the Continent in consequence of the regulations of the Foreign Governments.—These Companies reserve to themselves the right of refusing all those Despatches which in their opinion are unintelligible.—All persons sending more than one Message as a Single Despatch will be held liable to pay such further sum, in addition to the amount paid on transmission, as would have been charged by these Companies if each message had been sent separately.

TELEGRAPHIC LINES IN THE UNITED STATES.

285. Owing to the rapid progress and unrestricted freedom of enterprise in the United States, a great number of independent companies have been formed, by which the vast territory, from the Atlantic Ocean to the Mississippi, and from the Gulf of Mexico to the frontiers of Canada, is overspread with a network of wires, upon which intelligence of every description, and personal and commercial correspondence are flowing night and day incessantly from year's end to year's end in a torrent of which the old continents offer no similar example. It is almost impossible to ascertain, even with a tolerable degree of approximation, the actual extent of wires which at any given time are in operation. When we commence an investigation of the statistics, with a view to the collection of facts necessary to form the basis of a report, we are overwhelmed with statements of lines commenced, lines half completed and nearly completed, and many which undoubtedly must be completed before our report can come under the eyes of our readers. All that can be done in such a case is to give the nearest practicable estimate of the extent of these enterprises at a given epoch, indicating in a general manner such as are in progress and likely sooner or later to be completed and brought into practical operation.

The American lines are generally classified according to the telegraph instruments with which they work. These are those of Morse, House, and Bain, all of which transmit despatches by means of a single conducting wire, and all of which write or print the despatches they transmit, those of Morse and Bain, in a telegraphic cipher, and that of House in the common Roman capitals.

Of these three systems, that of Morse is in the most general use—a circumstance which is partly explained by the fact, that it was the earliest adopted, and had established its ground long before either of the competing systems. It must be admitted, that so far as public opinion and favour can be accepted as a test of practical excellence, the system of Morse has received not only a large majority of the suffrages in the United States, but also in the northern and eastern states of Europe.

According to a report published in 1853, the total length of telegraphic wire, at the end of 1852, then in operation in the United States, was 24375 miles, which was distributed between the three systems of telegraphs in the following proportion:—

	Miles
Morse	19963
House	2400
Bain	2012
	24375

It appears by a more recent estimate, published in a report presented by Mr. T. P. Shaffner to the Telegraphic Convention, that in March, 1854, the total extent of telegraphic wire then in operation was above 40000 miles, which were thus distributed:—

	Miles.
Morse	36972
House	3850
Bain	570
	41392

The decrease of the extent of the Bain lines was owing to the coalition of some of the most extensive ot them with the Morse companies.

It would thus appear that in little more than twelve months the increase of telegraphic wire amounted to 17000 miles. It is probable, however, that the estimate which we have quoted of the extent in operation at the end of 1852 may have been below the actual length.

The following estimate of the capital absorbed by these enterprises is given in Mr. Shaffner's report:—

	Dollars.
Morse lines . . .	5,545800
House	955000
Bain	171000
	6,671800

Being equivalent to 1,400000*l*.

Except in cases where a great commerce or intercourse prevails, each company maintains only a single conducting wire between station and station. As examples of the exceptions to this may be mentioned, Washington and Philadelphia, connected by seven Morse wires; New York and Buffalo, and New York and Boston, by three; Cleveland and Cincinnati, and Boston and Portland, by two.

In some cases, important terminal stations, such as New York and Boston, are connected by the wires of several competing companies, which follow, however, different routes, serving different intermediate stations.

The State of Ohio, a tract of country lying between the upper part of the river of that name, and the southern shore of Lake Erie, the chief part of which, within the lives of the present generation, was an uncultivated and uninhabited waste, is now overspread with between 3000 and 4000 miles of electric telegraph.

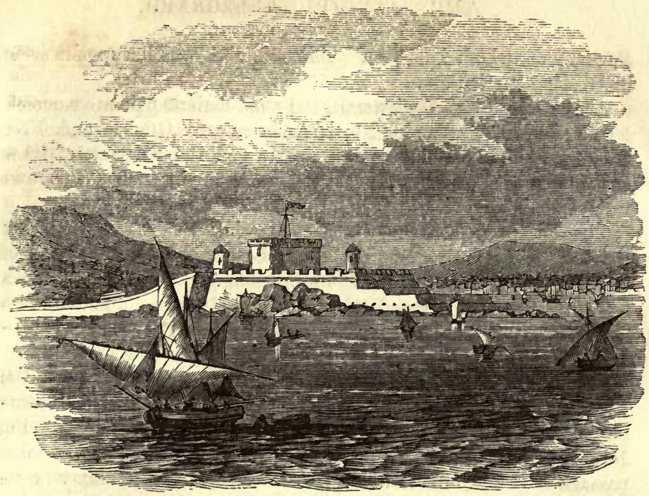
286. Stupendous as have been the projects actually realised in this application of science to the social uses of the United States, they sink into comparative insignificance when others, which are contemplated, and likely to be executed, are stated. Thus we find a report presented to Congress, in the session of 1851, by the Post-office Committee, in which a project of a line of electric telegraph to California is recommended for ultimate adoption. This report says that—

"The route selected by the committee is, according to the survey of Captain W. W. Chapman, U.S. Army, one of the best that could be adopted, possessing as it does great local advantages. It will commence at the city of Natchez, in the State of Mississippi, running through a well settled portion of Northern Texas, to the town of El Paso, on the Rio Grande, in latitude 32°; thence to the junction of the Gila and Colorado rivers, crossing at the head of the Gulf of California to San Diego, on the Pacific; thence along the coast to Monterey and San Francisco. By this route, the whole line between the Mississippi River and Pacific Ocean will be south of latitude 33°; consequently, almost entirely free from the great difficulties to be encountered, owing to the snow and ice on the northern route, by the way of the South Pass, crossing the Sierra Nevada Mountains in latitude 39°. The whole distance from the Mississippi to San Francisco will be about 2400 miles.

"In a commercial point of view, the line in question assumes a gigantic importance, and presents itself not only in the attitude of a means of communication between the opposite extremes of a single country, however great, but as a channel for imparting knowledge between distant parts of the earth. With the existing facilities, it requires months to convey information from the sunny climes of the East to the less favoured, in point of climate, but not less important regions of the West, teeming as they do with the products of art and enterprise. Let this line of wires be established, and the Pacific and Atlantic Oceans become as one, and intelligence will be conveyed from London to India in a shorter time than was required ten years since to transmit a letter from New York to Liverpool.

"Nor does the importance of the undertaking claim less interest, when regarded in a social point of view. California is being peopled daily and hourly by our friends, our kindred, and our political brethren. The little bands that a few centuries since landed on the western shores of the Atlantic, have now become a mighty nation. The tide of population has been rolling onward, increasing as it approached the setting sun, until at length our people look abroad upon the Pacific, and have their homes almost within sight of the spice groves of Japan. Although separated from us by thousands of miles of distance, they will be again restored to us in feeling, and still present to our affections, through the help of this noiseless tenant of the wilderness."

A company is stated to be organised for carrying out this vast project, with a capital of 5,000000 dollars.



SPEZZIA,
THE ITALIAN TERMINUS OF THE MEDITERRANEAN SUBMARINE TELEGRAPH LINE.

THE ELECTRIC TELEGRAPH.

CHAPTER XV.

287. Telegraphic lines in British America.—288. Belgian lines.—289. Their extent and cost.—290. Correspondence transmitted on them.—291. Large proportion of foreign despatches.—292. Classification and proportion of despatches.—293. Tariff.—294. Paris telegraphic congress and convention.—295. Telegraphic instruments used in Belgium.—296. Language of despatches.—297. French telegraphic lines.—298. Instruments used on them.—299. Their connection with those of other states. —300. Repetition necessary at intermediate stations.—301. Case of despatches between France and England.—302. Advantages of increased number of wires.—303. Of instruments requiring only one wire.—304. Organisation of the French telegraphic administration.—305. Austro-Germanic Union.—306. Stations and tariff.—307. Netherlands telegraphic lines.—308. Swiss telegraphic lines.—309. Italian telegraphic lines.

TELEGRAPH LINES IN BRITISH AMERICA.

287. The length of lines of electric telegraph in operation in British America in 1853, was about 1000 miles.

Mr. Joseph Whitworth, as one of the British Commission sent to the New York Exhibition of 1854, presented a report to

Parliament, which has been published, and which supplies some interesting particulars.

According to Mr. Whitworth, the most distant points connected by electric telegraph in North America are Quebec and New Orleans, which are 3000 miles apart, and the network of lines extends to the west as far as Missouri, about 500 towns and villages being provided with stations.

There are two separate lines connecting New York with New Orleans, one running along the sea-board, the other by way of the Mississippi, each about 2000 miles long. Messages have been transmitted from New York to New Orleans, and answers received, in the space of three hours, though they had necessarily to be written several times in the course of transmission.

When the contemplated lines connecting California with the Atlantic, and Newfoundland with the main continent, are completed, San Francisco will be in communication with St. John's, Newfoundland, which is distant from Galway but five days' passage. It is, therefore, estimated that intelligence may be conveyed from the Pacific to Europe, and *vice versâ*, in about six days.

The cost of erecting telegraph lines varies according to localities, but the expenses upon the whole are estimated to average about $180 (36*l.*) per mile throughout the States; the moderate amount of this estimate is, in a great measure, to be attributed to the facilities afforded by the general telegraph laws for the formation of companies and the construction of lines.

The electric telegraph is used by all classes of society as an ordinary method of transmitting intelligence.

Government despatches, and messages involving the life or death of any persons, are entitled to precedence, next come important press communications, but the latter, if not of extraordinary interest, await their regular turn.

The leading newspapers of New York contribute jointly towards the expenses of daily telegraphic communications. The annual sum paid by the "Associated Press" averages $30,000 per annum.

The following is the tariff for the press despatches:—

	Under 200 miles,	1	cent	per word.
Between	200 and 500	,, 2	,,	,,
,,	500 ,, 700	,, 3	,,	,,
,,	700 ,, 1000	,, 4	,,	,,
,,	1000 ,, 1500	,, 5	,,	,,
,,	1500 ,, over	,, 6	,,	,,

Assuming three cents as the average, the total amount of matter received by telegraph for the "New York Associated Press" amounts to a million words per annum, or about 600 columns of a London newspaper of the largest size, averaging almost two columns per day.

Supposing six papers to be associated together, the share of each would annually amount to about $5000, or 1000*l*., for two columns of telegraphic intelligence daily.

Commercial men use the electric telegraph in their transactions to a very great extent. In 1852 there were transmitted by one of the three telegraph lines that connect New York and Boston, between 500 and 600 messages daily. The sums paid on this line by some of the principal commercial houses who used it averaged in 1852 for each from $60 (12*l*.) to $80 (16*l*.) per month.

On other lines the leading commercial houses were estimated to pay from $500 to $1000 (100*l*. to 200*l*.) per annum for telegraphic despatches.

Interruptions occur most frequently from the interference of atmospheric electricity; in summer they are estimated to take place on an average twice a week, but many contrivances have been adopted for obviating this inconvenience, such as lightning arrestors, &c., which are generally known; the number of interruptions have been thereby reduced about 30 per cent.

Other accidental causes of interruption occur irregularly from the falling of the poles, the breaking of the wires by falling trees, and, particularly in winter, from the accumulated weight of snow or ice.

The electric current is made to act through long distances, by using local and branch circuits, and relay magnets, in those systems where it would be otherwise too weak to operate effectually.

In Mr. Bain's system, a weak current is found sufficient for very long distances; between New York and Boston, a distance of 270 miles, no branch or local circuit is required. In some cases, where both Morse's and Bain's telegraphs are used by an amalgamated company in the same office, it is found convenient, in certain conditions of the atmosphere, to remove the wires from Morse's instruments, and connect them with Bain's, on which it is practicable to operate when communication by Morse's system is interrupted.

It is generally believed that by laying insulated wires underground the interruptions will be reduced so as to be altogether inconsiderable. The expense of the process, however, is regarded as a great impediment in the United States, where cheapness of construction is an object of the highest consideration.

The application of the electric telegraph is not confined to the transmission of messages from one part of the States to another: in the form of a local or municipal telegraph, it is employed as an important instrument of regulation and intelligence in the internal administration of towns.

No adaptation of the system can be more interesting and useful than that which is made for the purpose of conveying signals of alarm and intelligence in the case of fire.

This system has been very completely developed in Boston.

The city is divided into seven districts, each provided with a powerful alarm bell. Every district contains several stations, varying in number according to its size and population. There are altogether in the seven districts forty-two stations. All these stations are connected with a chief central office, to which intelligence of fire is conveyed, and from which the alarm is given; two telegraph wires are employed, a return wire being used to complete the circuit, and provide as completely as possible against accidental interruption or confusion.

At each of the forty-two stations, which are placed at intervals of 100 rods throughout the city, there is erected in some conspicuous position a cast-iron box containing the apparatus for conveying intelligence to the central office. The box is kept locked, but the key is always to be found in the custody of some person in the neighbourhood, whose address is painted on the box door.

On opening this door, access is gained to a handle which is directed, by a notice painted above it, to be turned slowly several times. The handle turns a wheel that carries a certain number of teeth, arranged in two groups, the number of teeth in one representing the district, in the other, the station; those teeth act upon a signal key, closing and breaking the circuit connected with the central office, as many times as there are teeth in the wheel. Signals are thus conveyed to the central office, and, by striking the signal bell a certain number of times, the district and station from which the signal is made is indicated.

An attendant is always on the watch at the central office, and on his attention being called to the signals by the striking of a large call bell, he immediately sets in motion his alarm apparatus, and by depressing his telegraph-key, causes all the alarm bells of the seven districts to toll as many times in quick succession as will indicate the district where the fire has occurred, the alarm being repeated at short intervals for as long a time as may be necessary.

The signal-boxes erected at the stations contain, in addition to the signal-handle, a small electro-magnet, an armature, and a signal-key, so that full and particular communications can be made between each box and the central station, the clicks of the armature forming audible signals. They have also an apparatus called a "Discharger of Atmospheric Electricity," for preventing the occurrence of injuries during thunderstorms.

By this system certain information is given to the central office at the earliest possible moment of the exact locality in which a fire may have broken out, and the alarm is immediately spread over the entire city.

Every one who is aroused by the alarm is enabled to tell at once whether interest or duty calls him to the scene of action, and the exact point to which assistance is summoned. Should the alarm be given in the night, those whose attention is awakened may ascertain from the tolling of the bell the precise quarter in which danger threatens, and should they have been needlessly disturbed, may rest in peace, and find in the knowledge that they and theirs at least are in safety, a consolation for broken slumbers.

Telegraph wires in towns are almost universally carried along the tops of houses, or on poles erected in the streets, instead of being conveyed in pipes underground. So little difficulty is met with on the part of proprietors of houses, that telegraph lines are in some cases erected by private individuals for their own particular use. As an instance, may be mentioned the case of a large manufacturer in New York, who has an office in one part of the city, while his works lie in a contrary direction. In order to keep up a direct communication between both, he has erected a telegraphic wire at his own expense, and carried it over the tops of the houses intervening between his office and his works, having obtained without any trouble the permission of their various owners.

BELGIAN TELEGRAPH LINES.

288. Although in the extent of its territory Belgium is one of the least considerable of the Continental States, it derives from its position in relation to this country, much importance, so far as regards telegraphic communications. By the submarine cable between Dover and Ostend, or failing that, by the cable between Dover and Calais, Belgium constitutes the most direct stage in the telegraphic route to the Northern States.

The Belgian telegraph lines, as well as the railways, are constructed, maintained, and administered by the state. Separate systems of conducting wires are appropriated to the service of the railways, which is performed exclusively with the alphabetical apparatus of M. Lippens, already described (202). There are a few exceptional cases on branch lines of railway, upon which the state has not yet constructed telegraphs for the public service, where private despatches are sent by the railway telegraphs, but generally an extensive system of independent wires, with their accessories, are adapted to this purpose, for which a large corps of telegraphists has been formed.

289. The state telegraph lines, appropriated to the public service, have at present (1854) a total length of about 550 miles, upon which about 16000 miles of wire have been erected. With the exception of some short distances through Brussels, these wires are everywhere supported on posts.

The total capital absorbed in this establishment is estimated at 23000*l.*, and the gross annual receipts in 1854, were computed at 10000*l.*,* of which the net profit was 3600*l.*, being nearly 16 per cent. of the capital.

Immediately on the completion of the submarine cable between Dover and Ostend, an active daily intercourse between London and Brussels commenced, and has since been sustained. The connections were completed on the 20th June, 1853, and on the 27th of the same month, 111 despatches were interchanged between the two capitals.

It is proposed to construct wires and apparatus sufficient to maintain the communications on this important line, so that even with the greatest pressure of business, the public shall not have reasonable ground of complaint on account of delay. "A telegraphic line," observes the Minister of Public Works, "should not be organised with the mere powers which suffice for the ordinary or average business, but should be such as to meet the exigencies of occasional pressure, without subjecting the public to delay, or interrupting other regular business. Besides which, it ought never to be forgotten, that in telegraphic business great pressure must always come at particular hours, when prompt expedition is indispensable. This will be easily understood in the business of the Belgian lines, which constitute the route upon which the quotations of the money markets of all the great centres of affairs—London, Paris, Amsterdam, Berlin, Antwerp, &c.—are transmitted at certain hours."

290. The business transacted by the Belgian telegraphs consists of three classes of despatches.

Home despatches, being those transmitted between two Belgian stations.

International despatches, being those between a Belgian and Foreign station.

Foreign despatches, being those transmitted through Belgium in passing between two foreign stations.

Of these three classes of telegraphic business, the second has proved to be the greatest in number, and the third the most productive, as appears by the following statement of the results of the year ending 31st December, 1853.

* Report of Minister of Public Works to the Chamber, Feb. 14, 1854.

Despatches.	Number of despatches.	Receipts.	Number per cent. of total.	Receipts per cent. of total.
Home	14160	£1813	27·2	16·7
International	20664	3831	39·7	35·2
Foreign	17232	5227	33·1	48·1
Total	52056	£10871	100·0	100·0

291. It appears from this statement that about 40 per cent. of the despatches transmitted and received in Belgium, are interchanged with foreign countries, and that one-third of all that passes on Belgian wires is matter passing *en route* between foreign places. Nearly half the gross amount received for telegraphic despatches is produced by despatches transmitted between foreign stations, and only passing *en route* through Belgium. This is explained by the fact that such despatches passing always from frontier to frontier, and in the majority of cases from Ostend to the Prussian frontier, the entire length of the kingdom, pay for the longest class of telegraphic distance. This is one of the advantages which the Belgian telegraph derives from the geographical position of the country.

292. To show the proportion in which the telegraphic service is shared by different subjects of correspondence, we shall take the classified subjects of dispatches of August, 1853, the month in which the correspondence was most active. In this month there were 5799 despatches transmitted on the Belgian wires, which are thus classified:—

	Number.	Per cent. of Total.
Commerce	3247	56
Money market	1566	27
Private	754	13
Press	116	2
Government	116	2
Total	5799	100

In relation to length the proportion was as follows:—

	Number.	Per cent. of Total.
From 1 to 20 words	4741	81·8
From 21 to 50 words	921	15·9
From 51 to 100 words	122	2·1
Above 100 words	15	0·2
Total	5799	100·0

TELEGRAPHIC MAP.—In the annexed Map is presented a General View of the Telegraphic Network

BY WHICH EUROPE WAS OVERSPREAD AT THE CLOSE OF THE YEAR 1854.

Thus it appears that commerce and the Stock Exchange supply 83 per cent. of the whole telegraphic business, 13 per cent. being personal and domestic, and the press and government each employing the insignificant proportion of one despatch in every fifty.

It is also apparent, that a very small proportion of the despatches exceed the length of 20 words, and almost none that of 50 words.

293. According to the Belgian tariff, messages not exceeding 20 words are charged 2*s.* for distances not exceeding 60 miles; 4*s.*, from 60 to 140 miles; and 6*s.* above 140. No distances within the limits of Belgium exceed 200 miles.

For messages of 21 to 50 words the charges are doubled, and for 51 to 100 words are tripled.

It will be seen that these charges are more than double the corresponding charges on the English lines.

294. The large proportion of international and foreign despatches transmitted upon the Belgian wires, and the necessity of prepayment for despatches, in all cases, to their ultimate destinations, rendered it necessary for the Belgian administration of telegraphs to make some general arrangement with the principal contiguous states, for such an interchange of correspondence. A telegraphic congress was accordingly convened at Paris, in September, 1853, which was attended by delegates from France, Belgium, Prussia, Austria, and the minor German States. A telegraphic convention was concluded and signed on the 4th of October, 1852, fixing definitely a general tariff for all despatches transmitted to or from the several States.

According to this convention, each telegraphic region was divided into a series of zones, measured from the Belgian frontier, according to a series of direct distances (as the bird flies), the charges to places in each successive zone, for single despatches (1 to 20 words), being fixed at 2*s.*, 4*s.*, 6*s.*, 8*s.*, and so on, an increasement of 2*s.* being made for each increase of distance.

France is, by this convention, resolved into six telegraphic zones, the tariff for single messages being 2*s.*, 4*s.*, 6*s.*, 8*s.*, 10*s.*, and 12*s.* The first zone includes the chief northern towns, Arras, Douai, Lille, and Valenciennes; the second, Amiens, Boulogne, Dunkerque, &c.; the third, the chief places in the nearer central parts, including Paris, Orléans, Havre, &c.; the fourth, the more distant central parts, such as Châlons, Lyons, Strasbourg, &c.; the fifth, the nearer southern parts, Avignon, Grenoble, Bordeaux, &c.; and the sixth, the most remote southern parts, Marseilles, Bayonne, &c.

The German States, including Lombardy, are resolved into eight zones, of which the tariff is 2*s.*, 4*s.*, 6*s.*, 8*s.*, 10*s.*, 12*s.*, 14*s.*, and 16*s.* These zones include the whole extent of Northern and

Eastern Europe beyond the Rhine, as well as the north-eastern part of Italy.

The tariff for single messages crossing the channel, by the Ostend submarine cable, is 8*s*. For these charges, however, they are transmitted, if required, to London.

295. At the chief stations on the Belgian lines, the double needle instruments, as used in England, the French State instruments, and the Morse telegraph, as used in the German States, are provided. By the first the telegraphic correspondence with England, by the second with France, and by the third with the German States, is carried on.

296. It is intended generally to receive and transmit despatches written at the option of the sender, either in French, German, or English, at all the Belgian stations; but for the present this is only done at Brussels, Antwerp, and Ostend.

Despatches transmitted between Holland and Belgium can be transmitted and received in Dutch, and all despatches between Belgian stations may be sent in Flemish. At all stations despatches are transmitted and received in French.

If the place to which a despatch is addressed be not a telegraphic station, the despatch will be forwarded to its destination either by post or by a special messenger, at the option of the sender. If the former, the postage is 10*d.*, if the place be within the State where the telegraphic station at which the despatch arrives is situate, and 20*d.*, if in another State. If the latter, a charge of 10*d.* is made for a distance of a kilomètre (five furlongs), and 5*d.* for every additional kilomètre.

FRENCH TELEGRAPHIC LINES.

297. Although late in the adoption of this improved agency of intercommunication, France, having once commenced, has prosecuted the work with great vigour, and the country is now overspread with a net-work, the extent of which, in actual operation at the close of the present year, 1854, will not be less than 6000 miles. This system is everywhere erected upon posts chemically injected to insure their durability, and there are nowhere less than two conducting wires; but a greater number between all stations where an active correspondence is maintained.

298. The instruments used for the transmission of all home despatches, that is, all despatches transmitted between any two French stations, are the French State telegraphs, explained in (183). For international dispatches, the double needle and Morse's instruments are used. These instruments are provided at the central station, in the Ministry of the Interior at Paris. The double needle instruments are provided also at Calais, and

Morse's instruments at Strasbourg. As the system is developed and extended, the double needle instruments will be provided in addition to the French telegraphs, at all stations which may be in direct communication with England, and Morse's instruments at all stations which may be in direct communication with the German States.

299. The French telegraphic lines communicate with those of England at Calais by the submarine cable; with those of Belgium at Lille and Douai; with those of Prussia and Northern Germany, at Metz; with the Rhenish States, Wirtemburg, Bavaria, and Austria, at Strasbourg; with those of Switzerland, at Mulhouse and Mâcon, the former communicating with Bâle, and the latter with Geneva; and, in fine, with those of Savoy and Piedmont, at Grenoble.

Other links of electric connection will speedily be formed. Thus the present lines are continued to the Spanish frontier at St. Sebastian, and lines of wire are now being laid between that place and Madrid, so that the capital of Spain will be in electric connection with that of France, and therefore also with London, and the other capitals of Europe, most probably, before these pages are in the hands of the reader.

300. In practice the transmission of despatches is not always so direct or immediate as it would appear to be upon the inspection of a telegraphic map. Thus, by the submarine cable between Dover and Calais, Paris is in permanent direct communication with London. But when it is desired to transmit a despatch from Paris to any of the provincial towns of England, the despatch is at present received and written down at the central station in London, and then repeated and transmitted to the place of its destination in the provinces. This repetition could of course be avoided, by uniting, in the London station, the wire from Paris with the wire leading to the provincial station to which the despatch is addressed, and if the despatch were one of extraordinary length this course would be the most expeditious; but to adopt it with the ordinary class of short messages, would involve much inconvenience and more delay in general than is incurred by its repetition and retransmission. Thus, to send each message direct to its destination in the provinces, it would be necessary that, previously to the transmission from Paris, notice should be transmitted to London to connect the Paris wires with those between London and the place of destination, and as this change would have to be made separately for every provincial message, and as the wires between London and the various provincial stations must necessarily be occupied, more or less, at all times, in the transmission of home correspondence, the business of trans-

mission in this direct manner would not only be far more dilatory than the process of repetition, but would, in fact, at busy times of the day be totally impracticable.

301. What has been here stated respecting the Paris and London line will be applicable, *mutatis mutandis*, not only to all international messages, but in many cases to messages transmitted between home stations, which it is often more convenient and expeditious to repeat and retransmit at certain intermediate stations than to send direct by the connection of the wires at those stations.

302. It will be understood, nevertheless, that the necessity for this circuitous transmission, and intermediate repetition of despatches, arises in all cases from the insufficiency of the number of conducting wires in relation to the quantity of correspondence to be transmitted. In the transmission of each despatch by the English and French instruments, two wires are employed. Now, if the direct correspondence between London and Paris, during the most busy hours of the day, be sufficient to employ one pair of conducting wires, another pair would be necessary to communicate with intermediate places, and if the correspondence with these were very unequal, some engrossing a large share of it, a third pair might be required, and so on.

303. It must be, therefore, very apparent that great convenience would in such cases be gained by substituting, for the English and French telegraph, that of Morse or Bain, or any other which transmits by a single conducting wire. In that case, the four wires contained in the submarine cable, between Dover and Calais, would do much more than double their present duty. Instead of carrying two streams of messages simultaneously, as they do at present, they would carry four. If one were put in permanent connection with London and Paris, the three others could be reserved, one for direct connection with chief provincial towns, such as Birmingham, Manchester, Liverpool, Glasgow, Dublin, &c., and the two others for messages to less important stations, subject to occasional repetition. These latter would be to the telegraphic line what the second and third class trains are to the railway. It might be found even advantageous to fix a higher price of transmission for messages thus sent without intermediate repetition, just as a higher fare is paid for express than for ordinary trains.

304. The French government has recently re-organised the administration of the telegraphs throughout its entire territory, and besides modifying and reducing the tariff, it has placed the whole upon a more efficient footing. It now constitutes an important department of the state, placed under the superintendence of a director-general, four inspectors-general, twelve chief directors, and an hundred inspectors. The director-general

established in Paris holds his office under the Minister of the Interior, and has authority over all the inferior functionaries. The four inspectors-general control and direct under him the entire telegraphic service throughout the empire. These inspectors, aided by scientific men nominated from time to time by the Minister, form a superior council, charged to consider and decide upon all improvements proposed to be made in the processes, or in the telegraphic apparatus.

The telegraphic lines will be distributed into twelve distinct systems or sections, over which the twelve chief directors will preside, so as to inspect, direct, and by communication with the inspectors-general and director-general, to centralise the service.

The hundred inspectors will each be charged with the direction of one or more stations, and will have under their authority deputy station-masters, telegraphists, surveyors, artisans, and labourers, charged with the maintenance of the apparatus, the conducting wires, posts, and all the accessories of the line.

In all chief places, the bureaux will be open night and day. The number of stations open on 1st November, 1853, was 78; in June, 1854, the number was 105. At the close of 1854 all the Prefectures of France will be in electric connection with the capital.

The posts, a large proportion of which had not sufficient magnitude and strength to bear the necessary number of wires, have been everywhere replaced by others of suitable dimensions, and the telegraphists are augmented in number, and measures taken to ensure their efficiency.

It is decided also to give ample trial to the telegraphic instruments of Morse and Bain, already adopted to a great extent in Germany and in the United States; and if the result of experience on a large scale is favourable to them, they will be adopted either in conjunction with the present telegraphs, or to the exclusion of them according to circumstances. In all, there are manifest signs of activity and of exemption from prejudice, national or personal, which argue favourably for the progress of this great social improvement.

AUSTRO-GERMANIC TELEGRAPHIC UNION.

305. The electric telegraph had not been long in operation in the German States before it became apparent that great inconvenience and much obstruction to the progress of correspondence arose from different states adopting different telegraphic instruments and signals. The difficulties arising from this cause became at length so great as to demand prompt and effectual remedy. A telegraphic congress was accordingly convened at Vienna in October, 1851, at which deputies from all the German States

attended; and after a full discussion of the subject, it was resolved to form an Austro-Germanic Telegraphic Union. This union includes all the states of Europe east of the Rhine, and also the Austrian provinces in Northern Italy. It was agreed that a common system of telegraphic instruments and symbols should be adopted throughout all the associated states, and that for the present, Morse's telegraph, with its receiving magnets, registers, and uniform alphabet, should be everywhere used, so that telegraphic communications may at all times be made between any two stations of the Union without the delay and inconvenience of translating despatches at intermediate stations from one system of telegraphic symbols into another.

306. Despatches are transmitted and received at all the stations of the Union, either in German or French. They are also transmitted and received in English at such of the chief stations as are found by experience to have frequent communication with this country.

Since the convention was concluded, the Germanic lines have received considerable extensions, so that many important stations have been recently established within the telegraphic connection. Thus a line of telegraphic wires has been laid extending from Bremen to Gluckstadt, and from Hanover to Lauenburg. Also from Hamburgh through Denmark, by Rendsburg, Kiel, Schleswig, to Kiel, across the Little Belt, by Odense, across the Great Belt to Copenhagen and Helsingor.

Lines are also in operation from Dantzic to Königsberg, from Troppau to Lemberg, from Vienna, by Pesth, with various branches to Klausenberg, Orsova, Semlin, Peterwardin, and Eszeg.

THE NETHERLANDS TELEGRAPHIC LINES.

307. Notwithstanding the dense population and active commerce of the kingdom of the Netherlands, its limited territory has rendered a very small telegraphic net-work sufficient for its purposes. Only eight of its chief towns are connected by telegraphic wires. These are:

Amsterdam (*e*), Rotterdam (*e*), the Hague (*e*), Utrecht, Haarlem, Breda, Dordrecht (*e*), and Arnheim.

They are connected at the Hague by seven submarine wires with the English lines, at Antwerp with those of Belgium, and at Arnheim with those of the German Union.

Despatches are received in German and French at all the stations, and in English at those marked (*e*).

THE SWISS TELEGRAPHS.

308. The natural difficulties opposed to the construction of railways in Switzerland did not offer such serious impediments

to the construction of telegraphic lines, an extensive net-work of which has been constructed and brought into operation. Thus Berne is connected with the French lines by wires to Besançon, and with the German lines at Bâle. Lausanne is connected with Besançon by an independent line, and also with Berne on one side and Geneva on the other. Geneva is also connected with the French system at Mâcon, and with that of Savoy at Aix, from whence a line of wires is carried across Mont Cenis to Turin.

From Lausanne the wires are carried by Vevay and Sion through the Valais to the foot of the St. Gothard, across which they are continued by Bellinzona to Milan.

Another line passes from Bâle by Lucerne, Glaris, and Coire, to the Splügen, which it crosses, and is carried to meet the former line at Bellinzona, and thence to Milan.

Another line from Bâle passes by Zurich and St. Gal to Innspruck, from whence it passes by Batzen and Trente to Verona, and by Salzburg and Linz to Vienna.

Lines have, however, been since constructed, including some other stations.

ITALIAN TELEGRAPHIC LINES.

309. Italy is put in electric connection with the more northern countries of Europe at six points, Nice, Mont Cenis, the St. Gothard, the Splügen, the Tyrolese Alps, through Innspruck, and by Trieste.

The French lines are already extended to Nice, and a line between Nice and Turin will probably be completed before these pages come into the hands of the reader. The French and Swiss lines are connected with Turin by the wires over Mont Cenis already mentioned; the Swiss and Rhenish lines, with Milan by the wires over the St. Gothard, and the Splügen and the Austrian and Bavarian lines by the wires over the Tyrolese Alps, and those from Trieste round the shores of the Gulf to Venice.

From Venice to Milan a line is carried by Verona and Brescia, which is continued to Turin. From this line there are two branches going southwards, one from Verona by Mantua, Parma, Modena, Lucca, Leghorn, Florence, Sienna to Viterbo in the Papal States. This line will speedily be continued to Rome. The other branch goes from Alexandria to Genoa.

Such is the extent of Italian telegraphs completed in 1854.

L.T.Y. JUIEE. SC.

LISBON, AFTER THE EARTHQUAKE OF 1755, REDUCED FROM AN ENGRAVING, DATED 1756, IN THE IMPERIAL LIBRARY AT PARIS.

EARTHQUAKES AND VOLCANOES.

CHAPTER I.

1. Science tends to the discovery of general laws—admits no accidental phenomena.—2. Atmospheric phenomena neither uncertain nor accidental.—3. Physical subterranean agencies.—4. Convulsions incidental to the solid shell of the earth.—5. Increase of temperature at increasing depths.—6. Central parts in a state of fusion.—7. Depth at which this liquid state commences.—8. Proportional thickness of the solid shell.—9. Surface of the earth subject to frequent convulsions from the reaction of the internal fluid matter on the solid shell. —10. Geological evidences of this.—11. Physical causes of earthquakes and volcanoes.—12. Undulations of surface produced by the internal fluid.—13. Their effects on buildings and other objects.—14. Vertical and oscillatory motions.—15. Undulations propagated

in parallel lines—sometimes in circles.—16. Effects of the vertical shock in the earthquake of Riobamba.—17. Examples of circular propagation.—18. Examples of horizontal and gyratory derangement. —19. Strong shocks sometimes felt without overturning buildings.—20. Gyratory earthquakes most destructive.—21. Singular displacement at Riobamba.—22. Earthquakes are not generally attended by any peculiar atmospheric prognostics.—23. Earthquakes most frequent at the equinoxes.—24. Well described by Pliny and Seneca.—25. Attended by subterranean thunder.—26. Character of these sounds. —27. Are heard at great distances from the place of the earthquake. —28. Examples of this.—29. Subterranean roaring of Guanaxuato. —30. Their effects on the inhabitants.—31. Great extent over which earthquakes spread.—32. They affect the bottom of the ocean.—33. Curious examples of these effects.

1. It is the tendency of undisciplined minds to refer all unusual and occasional phenomena to local and accidental causes, and, mistaking trivial and unimportant differences for essential distinctions, to ascribe to very different physical agencies what are only various effects proceeding from the operation of a single principle. The tendency of science is the reverse. It ignores accident in nature. It admits no contingencies. The Architect of the universe operates by fixed and general laws, the results of which are uniform and regular. The apparent uncertainty of some natural phenomena arises merely from our imperfect knowledge of the laws which govern them. Before the science of astronomy had reached a certain degree of advancement, solar and lunar eclipses were regarded as preternatural manifestations, during which the common laws of nature were suspended, and as the forerunners of terrible calamities to the human race. Now that the laws which govern the motions of the heavenly bodies are known, these phenomena have lost their terrors. They are no longer regarded as either preternatural, uncertain, or accidental. They are, on the contrary, as regular, periodical, and certain as the seasons, or the returns of light and darkness; and the times of their occurrence, and all the circumstances attending them, are predicted with the greatest conceivable certainty and the last degree of precision.

2. Nothing is more usual than to apply the term "uncertain" to the weather, yet nothing can be more absurd. The causes which govern its phenomena being physical agencies independent of the will or interference of any being, save of Him "who rules the storm," are as fixed and as certain in their operation, and as regular in the production of their effects, as those which maintain and regulate the motions of the solar system. The moment of the rising or setting of the sun on any given day of the ensuing year, is, therefore, *in the nature of things,* not more certain than

the atmospheric phenomena which will take place on that day. The doubt and uncertainty which attend these events belong altogether to our anticipations of them, and not to the things themselves. If our knowledge of meteorology were as advanced as our knowledge of astronomy, we should be in a condition to declare the time, duration, and intensity of every shower, which shall fall during the ensuing year, with as much certainty and precision as we are able to fortel the rising, setting, and southing of the sun and moon, or the rise and fall of the tides of the ocean.

3. If our knowledge of the laws which govern the movements of the aërial ocean which floats above the crust of the earth be obscure and imperfect, it is infinitely more so of those which rule the matter which lies below that crust. Yet what various and apparently different and unconnected phenomena are governed by these undiscovered laws, which, through ignorance of them, have been regarded as arising from local, accidental, and totally independent and different agencies. Earthquakes, volcanic eruptions, the production and submersion of islands, the issue of gases such as sulphurous and carbonic acid from fissures in the earth, hot springs, eruptions of warm mud, the increase of temperature at increasing depths, the origin of mountain chains, such as the Andes, the Pyrenees, the Alps, and the Himalaya, the alternate elevation and submersion of vast continents, the variations of the configuration of the land, and the distribution of the waters on the surface of the globe, all these so apparently different phenomena, it has been the triumph of science to trace to a common origin, the reaction of the matter confined within the earth against its external shell.

4. It is our present purpose briefly to explain the physical conditions out of which these stupendous phenomena arise, and to describe the characters and circumstances which attend them. With this view, it will be necessary first to state what is known, either by observation or inference, respecting the condition of that part of the earth included within the solid shell, the external surface of which is the habitation of the human race, and other organised tribes, and to explain generally what have been at past epochs and at the present time the chief effects produced by the reaction of the matter thus confined upon the crust which encloses it.

When it is considered that the actual distance of the surface from the centre, or the length of the terrestrial radius, is more than twenty millions of feet, and that the utmost depth to which we have been able to descend in boring or mining operations has not much exceeded two thousand feet, that is the ten-thousandth part of the entire radius, it will be apparent that the data supplied by so scanty a range of observation must be very limited. Less direct sources of observation, though not less certain and precise, have, however, been opened by the researches of geologists, who have shown that the crust of the earth fractured by eruptions produced by forces acting from the interior outwards has been exposed to view, so that the condition of the external shell, to a depth of about forty thousand feet, or the five-hundredth part of the entire distance from the surface to the centre, can be ascertained.

5. From what has been explained in former numbers of this series, in which the subject of terrestrial heat has been considered, it will be seen that extended and general thermometric observations made in mines and other deep excavations, and on the temperature of water rising in Artesian wells, prove that in descending to greater and greater depths into the crust of the earth, there is a constant and regular increase of temperature at the rate of about one thermometric degree for every fifty feet of depth, or what is nearly the same, an increase at the rate of 100° per mile.

6. Now supposing this law of increase to continue without interruption downwards, it would follow that at the depth of forty miles, or the hundredth part of the distance from the surface to the centre, a temperature of 4000° prevails. It is certain that no part of the matter composing the crust of the earth could remain solid at such a temperature, being higher than those at which the most refractory bodies are fused.

7. No great degree of precision in the numerical data on which this calculation is based is necessary to establish the conclusion to which it leads. Whatever be the exact rate at which the temperature is augmented in descending, it is beyond all doubt that at a depth of thirty or forty miles it must be such as to reduce to the state of an incandescent liquid the most refractory bodies which enter into the composition of the earth.

This liquid fire must extend to the very centre of the globe, and from the well understood properties of fluidity, it may be considered certain that an uniform temperature is maintained throughout the liquid mass thus enclosed within the solid spheroidal shell.

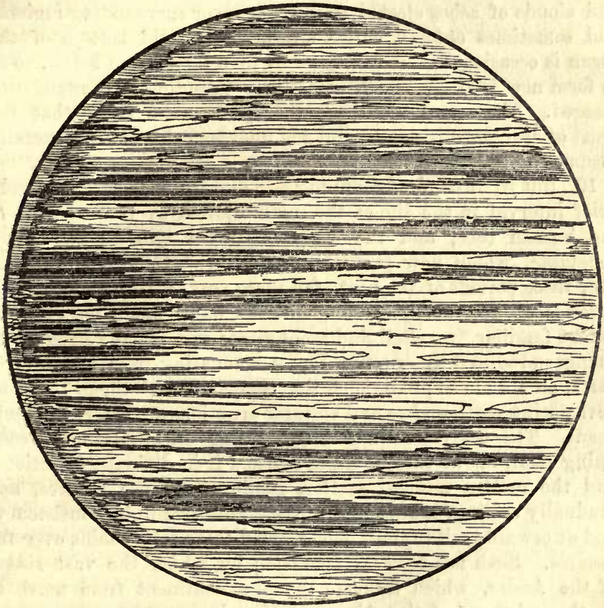
Now let us pause for a moment to consider the consequences to which this leads, and to contemplate the spectacle which it offers of the condition of our terrestrial dwelling.

8. Let us take the extreme estimate of forty miles as the depth below which the matter composing the earth is completely liquified. This depth is the one-hundredth part of the terrestrial radius.

We are then to regard the earth as a spherical shell of solid matter filled with liquid fire. The thickness of this shell being in the proportion to its diameter just stated, it will be represented by the black circle surrounding fig. 1.

If the egg of a fowl or an ostrich be imagined to represent the earth, its shell would be much too thick to represent its solid crust!

Fig. 1.



It is no rhetorical exaggeration, then, to affirm that the globe we live on is a stupendous but very thin bombshell charged with liquid fire! If such be the case, it may naturally be asked how it happens that so thin a crust, supported on so mobile a fluid, can maintain that general state of stability and equilibrium which characterises the surface of the earth, so that it is referred to in times ancient and modern as the type of all that is most solid and durable?

9. To this it may be answered that many phenomena with which mankind in certain localities is only too familiar, and which are known to all by authentic contemporary reports and historical records, prove that this imputed stability cannot be admitted without most serious qualifications and exceptions. Not a year passes that earthquakes are not reported in various parts of the

earth. Not a century passes that these terrible phenomena are not occasionally developed with such an energy and extent that vast tracts of country are laid waste, cities and towns destroyed, and thousands of human beings buried beneath their ruins. Volcanic eruptions are permanent indications of subterranean agencies, modifying more or less the surface. Torrents of lava and clouds of ashes ejected from them cover surrounding regions, and sometimes entomb entire cities. The solid bottom of the ocean is occasionally heaved upwards by a force from below, so as to form new islands, which sometimes subsiding are again submerged. These and countless other phenomena show that the crust of the globe is not so solid and unchangeable as it is generally assumed to be.

10. But if, instead of confining our view to that comparatively brief interval in the life of the earth limited by the existence of the human race, and the other organised tribes animal and vegetable, which now prevail upon it, we extend our enquiries over those periods of the past, far more vast, with which the discoveries of astronomers and geologists have made us to some extent familiar, we shall find monuments and records of physical changes produced by eruptive forces emanating from the central parts, on a scale so prodigious, that compared with them, the most devastating earthquakes and volcanic eruptions are utterly insignificant. The central fluid matter pressing unequally on its confining shell, has at various times cracked it in different directions, and the molten mineral matter, issuing from the fissures, and gradually cooling, taking first a pasty and semifluid consistency, and afterwards solidifying, has formed mountain chains over the fissures. Such has been the operation by which the vast ridges of the Andes, which traverse the new continent from north to south, and those of the Alps and Himalaya, which traverse the old continents from east to west, have been formed.

11. Postponing, however, for the present all notice of those physical revolutions of which the date is prior to the creation of the present inhabitants of the earth, we shall limit our observations to the circumstances which produce and attend the principal convulsions of nature which have manifested themselves in historical times, and which must be traced to the reaction of the interior fiery fluid upon the thin solid shell of the earth.

That fluid, like the waters of the ocean, is subject to undulation. If its undulations be so limited in their play that the materials of which the terrestrial shell is formed have sufficient elasticity to yield to their pressure without being fractured, they will produce on the exterior surface of that shell corresponding undulations by which all bodies placed upon its surface must be affected, as a floating body is by the waves of the ocean. If the height of the waves of the subterranean fluid be greater than the elasticity of the solid shell which confines them can bear, that shell must be fractured to a greater or less extent, and through the openings thus produced in it, the internal matter, in a state of igneous fusion, may issue, producing volcanic phenomena. Or in fine, the fracture may be only external, in which case the consequences will be limited to local derangement and disturbance of the surface.

Let us first consider the case in which an undulation is propagated to the surface without fracture.

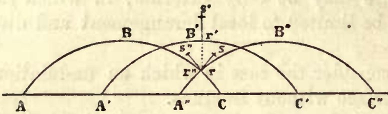
12. The part of the surface of the earth thus affected, and all bodies placed upon it, suffer in this case the same sort of disturbance and dislocation as does a ship floating on water upon which a system of waves is formed. The waves have a progressive motion in some certain direction, passing successively under the ship, which is alternately raised to the crest and lowered to the hollow of each successive wave as it passes. Neither the water nor the ship partakes of this progressive motion. If they did no alternate rise and fall would take place; the ship once placed on the crest of a wave would be carried forward by the water on which it floats, and would still remain on the crest of the same wave, a circumstance which never takes place. In the same manner exactly the undulations imparted to the surface of the earth by the fluid confined within it, have a certain progressive motion which causes every part of the surface over which they pass, alternately to rise and fall, through a height equal to the difference of the levels of the crest and hollow of the wave.

13. But besides this, another effect of much importance is produced upon solid structures, which are placed, as buildings are, in a position perpendicular to the level surface of the ground. That surface when it is affected by the wave, ceases to be level. As the wave passes it, it is first inclined in one direction, and after being raised to the summit of the wave it is inclined in the opposite direction. Any solid structure, having a vertical position, would, therefore, while the wave passes, be inclined from the vertical, first to the right; and then to the left, according as it is successively at one side or other of the wave.

Such superficial undulation of the ground, would therefore produce a twofold displacement of all such objects; first an alternate motion upwards and downwards in the vertical direction, and secondly, a sort of rocking or oscillating motion like that of a pendulum, leaning alternately right and left of its true vertical position.

This will be better understood by reference to fig. 2, in which three successive positions of the wave are represented by A B C, A′ B′ C′, and A″ B″ C″. A building or other object in a position perpendicular to the ground is represented at *r s* on the slope of the wave where it leans from the vertical to the right. When the wave has advanced to the position A′ B′ C′, the foot of the building

Fig. 2.



is raised to the crest of the wave at *r′*, and the building, *r′ s′*, is then vertical, having in the interval been gradually raised from its inclined direction. When the wave has progressed to A″ B″ C″, the foot of the building has been again lowered to its first position, but being now on the slope, A″ B″, it will be inclined to the left of the vertical, as represented at *r″ s″*.

14. Thus by the undulations passing successively under it, such a building will be alternately raised and lowered through a certain vertical height, and at the same time *rocked* right and left through a certain angle of vibration.

The undulations which produce earthquakes are sometimes rectilinear and propagated in parallel lines and in a single direction. In other cases they form concentric circles, and are propagated from a certain central point, like the waves produced on the surface of still water round the point at which a pebble is dropped into it.

The angle through which objects will be deflected from the perpendicular in the rocking motion imparted to them, will depend on the angle of the slope of the wave, and the latter will depend on the proportion which the height of the undulation bears to its amplitude. The less the height, and the greater the amplitude, the less will be the deflection from the perpendicular. In the cases of many earthquakes, this deflection is so small, that the cohesion of the materials of building is generally sufficient to prevent them from falling notwithstanding their deflection.

That a building may stand, though inclined considerably from the perpendicular, is proved by examples which occur in almost every city. The leaning towers of Pisa and Bologna have stood for seven hundred years.

The effect of the alternate motion, upwards and downwards in the vertical direction, must depend more upon the rapidity of the alternation than upon the range of the elevation and depression. It is easily conceivable that the ground may be *slowly* raised and depressed through a very considerable height or depth, without producing any superficial derangement, but if such elevation and depression take place with much rapidity, great disturbance must ensue.

15. Humboldt, who has been personal witness of a considerable number of these phenomena, and has elaborately investigated the recorded effects of the most remarkable of them, says that the undulations are propagated chiefly in parallel lines, and with a progressive velocity of from twenty to thirty miles per minute. He observes that the cases in which the waves issue from a centre of undulation, and are propagated in circles around it, are more rare, and that when it takes place, the height of the waves diminish as their distance from the common centre increases.

In general, the undulations are inconsiderable in their vertical height and velocity of oscillation, so that in places affected by them, the strength of buildings is sufficient to resist their effects, and we constantly hear of slight shocks of earthquakes being sensible, which are attended with no injurious consequences. Bells are sometimes thus rung, and furniture and other loose objects more or less displaced without other more serious consequences.

16. The vertical shock however, in places more subject to these visitations, is sometimes attended with far more grave effects. In the case of the earthquake, by which the town of Riobamba, at the foot of Chimborazo, was destroyed in 1797, the bodies of many of the inhabitants were hurled to a height of several hundred feet, and thrown upon the hill of La Cullca, beyond the small river Lican.

17. Humboldt cites examples of the circular propagation of terrestrial undulations at the Holy Sea, or Lake Baikal, in Siberia (between lat. 51° and 55°, and long. 103° and 110° E.), and in the Celestial Mountains, or Thian-schan, in Chinese Turkestan, (between lat. 42° and 43°, and long. 80° and 90° E.) The intermediate region is subject to the double influence of the circular undulations propagated from these two centres, and Humboldt ingeniously explains the freedom from earthquakes of a certain intermediate tract between two such centres of undulation, by the principle of interference which plays so important a part in optics and acoustics. He supposes that along such a tract the crests of the waves of one system coincide with the hollows of those of the other, so that the ground being just as much elevated by the one as it is depressed by the other, remains undisturbed, while the country at either side is agitated, and perhaps devastated, by the shocks.

18. In certain cases, the motion imparted to the surface is not merely that of undulation properly so called, which, as already

explained, can only produce vertical and oscillating motions, it has been found, in some cases, that the ground has been affected by an horizontal as well as vertical displacement. In some cases also a gyratory movement of the ground has been observed, so that after the shock, the direction of the walls of buildings, and the relative bearings of fixed objects, such as buildings, trees, and the directions of hills and valleys have been changed.

19. Humboldt states, that although the undulations of the surface of the ground, which take place in earthquakes, have been ascertained with some degree of precision, their periods of alternation have not been so well observed. In the city of Quito, which stands at the foot of the volcano of Rucu-Pichincha, at an elevation of nearly 10000 feet above the level of the sea, he often felt strong shocks of an earthquake at night. Yet the buildings of the city, including many lofty churches, fine cupolas, and houses consisting of many stories, were very rarely injured by them, although much slighter shocks damaged lower buildings on the Peruvian plains.

The natives of the country, who are accustomed to the phenomena, many hundred earthquakes occurring during a single generation, explain this difference by the greater or less rapidity of the horizontal oscillation, which, according to their experience, is far more destructive than the vertical or rocking motion produced by regular undulation.

20. The earthquakes which produce a gyratory motion of the ground are the most destructive, and happily also the most rare. After the earthquake which destroyed Riobamba in 1797, and that which took place in Calabria in 1783, walls were changed in their direction without being thrown down, rows of trees, which were previously strait and parallel, were, after the shock, in different directions, and even in curved rows. Fields were changed in their relative positions, those in which two different crops were growing having interchanged places.

21. Humboldt was shown among the ruins of Riobamba a place where the entire furniture and contents of a certain house were found buried under the remains of another. Numerous cases occurred in which heavy articles of furniture were transported several hundred yards from their original position, so that questions of ownership were raised and brought before the courts of justice.

In this case the ground, rent in various places, was affected at once by vertical and horizontal oscillations, so that while one part was heaved upwards another adjacent to it was sunk downwards and transferred horizontally under the former. Such tossing and agitation of the surface presents a striking resemblance to the irregular and tumultuous agitation of the surface of the sea after a storm, and must arise from such a condition prevailing for the moment in the igneous ocean upon which the solid crust of the earth rests.

22. A popular impression prevails that earthquakes are preceded by peculiar atmospheric phenomena, such as a profound stillness of the air, a suffocating and oppressive heat, and a misty horizon. Exact and extensive observations made in various countries, and for long periods of time, have proved that this is without any foundation in fact. Humboldt states not only as the result of his own experience, but as that of those who have lived for many years in regions where earthquakes are frequent, that they take place indifferently in all weathers and in all states of the atmosphere. He experienced them himself in clear and fair as well as in rainy weather, and as often in a fresh east wind, or in a storm, as in a calm. He observed no disturbance or exceptional condition in the magnetic needle, the barometer or thermometer, either on their approach or during their continuance. His own observations within the tropics, and those of Adolphe Erman during the earthquake of the 8th of March, 1829, at Irkutsk, near Lake Baikal, lat. 53°, were in this respect in complete accordance.

Nevertheless, the subterranean convulsion appears to have been in some cases attended with atmospheric effects, which would indicate some connection between the phenomena and the electric state of the surface and of the atmosphere. Thus, for example, during the long-continued trembling of the ground in the Piedmontese valleys of Pelis and Clusson, considerable variations of the electric tension of the atmosphere were observed, which could not have arisen from any storm, the sky being at the time quite serene and unclouded.

23. From some statistical results, it would seem that there are grounds for supposing a connection between the prevalence of earthquakes and the season of the year. Numerical data, collected with much care, by MM. de Hoff, Merian, and Hoffmann, indicate the greatest frequency of these phenomena at the epochs of the equinoxes.

24. It is a fact not unworthy of remark, that notwithstanding the backward state of physical science generally among the ancients, and their total ignorance of the modern science of geology, the true physical cause of earthquakes was indicated in unequivocal terms by Pliny,* who denominated them "Subterranean storms;" and Seneca† gave the germ of all that was known about their causes until a very recent date.

* Pliny, ii., 79. † Nat. Quæst, vi., 4—31.

25. Earthquakes are often attended, though not at all, as is commonly supposed, preceded by awful subterranean sounds. These noises, however, appear to have no relation whatever to the violence of the shock. Some of the most tremendous of these convulsions have, on the contrary, been unaccompanied by any noise whatever. This was the case with the great earthquake of Riobamba already mentioned, one of the most terrible catastrophes of its class which has been recorded in the physical history of the globe.

The noises which are heard most commonly occur after the shock, and seldom at the place where the earthquake has the greatest violence. In the case of the earthquake of which Tacunga and Hambato were the centre and points of greatest action, no noise was heard at these places, but violent subterraneous detonations were heard at Quito, which is fifty-five miles, and at Ibarra, about one hundred miles distant from those points, at twenty minutes after the shock.

The subterranean thunder, if it may be so called, is sometimes heard at places situate beyond the limits of the shocks. Thus in the case of the violent earthquake which occurred at Lima and Callao, on 28th October, 1746, a noise resembling a clap of subterranean thunder was heard at Truxillo, where no shock whatever was felt, nor even the least trembling of the ground.

Sometimes the subterranean thunder is heard after the shocks have ceased. The great earthquake which occurred on 16th November, 1827, in New Grenada, and was described by Boussingault is an example of this. Some time after the cessation of the shocks, subterranean detonations were heard at regular intervals of half a minute along the whole Cauca valley.

26. The character of the noise attending earthquakes has differed greatly in different cases. Sometimes it has been a rolling sound like that of thunder, or the discharges of cannon in rapid succession. Sometimes it is described as resembling the clanking of chains. At Quito it is often sudden, like a near thunder-clap, and sometimes it is clear and ringing like the clashing of glass, as if enormous masses of vitrified matter were shattered in subterranean caverns.

27. Owing to the fact that solid bodies are good conductors of sound, the sonorous undulations being propagated through them with a velocity ten or twelve times greater than through the atmosphere, the subterranean noise developed in these convulsions may be heard at great distances from the seat of the agency which produces it. During a violent eruption of the volcano of St. Vincent, one of the smaller West India Islands, and while a prodigious torrent of lava issued from it, a loud noise resembling

thunder unaccompanied by any trembling of the ground, was heard at the distance of 632 miles to the south-west of the crater on the plains of Calaboso, and on the banks of the river Apure, one of the tributaries of the Orinoco. This noise was audible over an area of nearly 50000 square miles. So far as distance is concerned, this was as if a noise attending an irruption of Vesuvius were heard at London.

28. During the great eruption of Cotopaxi, one of the most lofty peaks of the Andes, subterranean sounds like discharges of artillery were heard at Honda, on the Magdalena river. This is the more remarkable, inasmuch as the crater of Cotopaxi is not only 18000 feet above the level of Honda, and the distance measured in a direct line between the two points is 463 miles, but vast mountain masses such as Quito, Pasto, and Popayan, as well as innumerable valleys and ravines are interposed between them. The sound was therefore evidently in this case propagated through the solid crust of the earth from a great depth, and not through the air.

Another striking example of the propagation of sound from the depths of the earth to great distances through its crust was presented in the case of the violent earthquake which occurred in New Grenada, in 1835. On that occasion, subterranean thunder was heard at Popayan, Bogota, Santa Martha, and Caraccas, and also in Hayti, in Jamaica, and on the shores of Lake Nicaragua. At Caraccas the thunder continued without any sensible trembling of the ground for seven hours.

It would appear that in some cases the solid telluric shell is strong enough to resist the undulations of the subterranean igneous fluid while it transmits the sonorous vibrations. It is difficult to convey an adequate idea of the impression which these terrible sounds, issuing from the depths of the earth, produce, when they are not attended by any dynamical or other phenomena. It is as if a preternatural voice coming from below addressed the entire population. The listener waits after each roll of the sound in an agony of suspense for what may follow.

29. One of the most remarkable examples of these subterraneous sounds unaccompanied by any disturbance of the surface of the ground, was that which occurred in the great mining regions of Mexico, in 1784, and which is known in that country as the *Bramidos subterraneos* (subterraneous roaring) of Guanaxuato.*

* Humboldt, Essai Polit. sur la Nouv. Esp., vol. i., p. 303. Cosmos, Trans. vol. i., p. 196, and note 187.

Guanaxuato is the capital town of the mining district of that name, situate in the Sierra de Santa Rosa, at 160 miles north-west of Mexico, and at an elevation of 6000 feet above the level of the sea. It is irregularly built on mountain declivities, and is surrounded by deep shafts, through which the produce of the rich gold and silver mines is brought to the surface. More than an hundred of these shafts are sunk within a radius of fifteen miles round the town. There is no active volcano in the neighbourhood.

The subterranean sounds were first heard at midnight on the 9th January, 1784, and they continued without intermission for more than a month. A circumstantial description of the progress of the phenomenon was obtained by Humboldt on the spot, from the reports of numerous witnesses, and from the documents of the municipality, which he was allowed to copy.

From the 13th to the 16th it seemed as if a rolling thunder alternately with loud and sharp thunder-claps issued from storm clouds beneath the foundation of the town. These sounds, which increased from the beginning by slow degrees, until they attained their greatest loudness and violence, ceased by the same slow degrees. It was remarked, however, that the range of the phenomena was not considerable, the sounds being heard only in the mountainous part of the Sierra, from the Cuesta de los Aquilares to the north of Santa Rosa. No sounds were heard in a basaltic district at a few miles distance, nor in the detached portions of the Sierra, twenty-four to twenty-eight miles north-west of Guanaxuato. Not only was the surface of the ground free from the least trembling or other movement, but none was felt in the workings of the mines, which passed in all directions at great depths below the surface.

30. When this extraordinary phenomenon commenced, the inhabitants of the place were seized with uncontrollable terror, and with a spontaneous movement began to take flight. This was at first resisted by measures of extraordinary severity on the part of the authorities. Flight from the city was punished with a fine of 1000 piastres, or two months imprisonment, and the militia were ordered to arrest and bring back the fugitives. One of the most curious circumstances attending the commencement of the disturbance was a proclamation issued by the magistracy, declaring "that in their wisdom they would be well aware of the approach of real danger, and that whenever it might arise they would give notice to the inhabitants to fly, but that as yet it would be sufficient to continue the processions," meaning no doubt some religious ceremonies.

The inhabitants of the surrounding table lands being prevented by their fright from bringing supplies into the markets of the town, a famine commenced, and the power of the authorities being at length overborne, a general flight ensued. Nearly the whole population deserted the town, in which large masses of the precious metals, the produce of the surrounding mines, had been stored. Bands of plunderers lingered to seize this treasure. After a while the inhabitants being familiarised with the continuance of the subterraneous thunder, unaccompanied by any other symptoms of earthquake, the more courageous returned to the town and fought with the robbers in defence of their property.

In no part of the mountainous regions of Mexico was anything of this kind ever before known or heard of, nor has it ever recurred since. Thus it would appear, that as chasms in the inferior parts of the crust of the earth are opened or closed, the sound produced by the agitation of the igneous ocean, which roars beneath it, is propagated or intercepted in different directions and at different times.

31. It would be a great mistake to assume that earthquakes are always merely local phenomena of very limited range. On the contrary, they have in some cases been manifested over a large portion of the surface of the globe. The great earthquake by which Lisbon was destroyed on the 1st November, 1755, was felt over the whole extent of Europe, from the Alps to the coast of Sweden, over Northern Germany and the shores of the Baltic, across the Atlantic to the West Indies, where the shocks were sensible in the islands of Barbadoes, Martinique, and Antigua, and across the continent of North America to the great northern lakes.

Distant fountains were interrupted in their flow. Thus the hot springs of Töplitz were first dried up but soon reappeared, sending up unusual quantities of water of an ochreous colour.*

32. That the solid surface of the bottom of the ocean shared in the general undulation manifested over so great an extent of the continents on this occasion could not be doubted, if no other evidence of it existed save the transmission of the undulation across the Atlantic. But we have more direct evidence of this in the sudden changes of elevation of the water of the ocean itself. At Cadiz the sea rose above sixty feet, and in the islands of Barbadoes, Martinique, and Antigua, where the normal rise of the tide does not much exceed two feet, the water suddenly rose

* The fact that earthquakes had the effect of interrupting the flow of springs was known to the ancients, and is noticed by Demetrius of Calatia.

twenty feet, and was moreover discoloured, having the blackness of ink.

33. During the earthquake the water retired from the harbour at Lisbon, leaving the bar uncovered and dry, but it soon returned, rushing in enormous volumes, so as to rise in some places to the height of sixty feet. The shores were everywhere inundated, and the seaport of St. Eubal's, about twenty miles south of Lisbon, was submerged and totally disappeared.

The records of these convulsions of the earth supply many examples showing that the bottom of the sea has shared the perturbations of the land. In the case of the great earthquake which desolated Peru, in 1746, the Pacific rushed upon the coast with irresistible fury, destroyed several seaports, carrying the vessels which floated in them to great distances up the country, and submerging a large tract of land near Callao, so as to convert it into a permanent bay.

VIEW OF NAPLES AND VESUVIUS.

EARTHQUAKES AND VOLCANOES.

CHAPTER II.

rises.—51. Also certain gases—Artesian fire-wells.—52. Carbonic acid—its effects in former states of the globe—origin of coal beds.—53. And marbles.—54. Mud volcanoes.—55. Those of remote origin.—56. Progressive development.—57. Formation of dome-shaped mountains.—58. Crater of elevation.—59. Active volcanoes.—60. Successive stages of their formation.—61. Not uniformly or permanently active.—62. Intervals of activity and repose.—63. Dependent on the height.—64. Stromboli.—65. Guacamayo.—66. Volcanoes of the Andes.—67. Exceptions explained.—68. Eruptions often lateral.—69. Groups of small cones.—70. Remarkable spectacle of Cotopaxi.—71. View of an active crater.—72. Remarkable permanence of the form of craters.—73. Effects of snow-capped cones.—74. Cause of the fiery appearance of ejected matter.—75. Islands of volcanic origin.—76. Volcanic theories.

34. A REMARKABLE submarine earthquake occurred in the Gulf of Mexico in 1780, during which a mass of water was carried against the western coast of the island of Jamaica, which in an instant submerged the entire town of Savannah la Mar. Not a building nor living thing escaped this prodigious irruption of water.

The same island underwent still more extensive devastation from an earthquake which occurred there in 1692. Three-fourths of Port Royal, the capital of the island at that time, suddenly sunk down, and with all its inhabitants was submerged by the sea. Large warehouses which stood upon the quays were submerged to such a depth, that their roofs were from 20 to 40 feet below the surface of the water. The subsidence was so evenly vertical and so free from any lateral displacement or rocking motion, that many of the houses sunk without falling; so that after the catastrophe the chimney-tops of some of them were seen, as well as the topmasts of ships wrecked in the harbour, projecting from the surface of the water. A vessel of war which had been under repair in one of the docks was transported over several of the submerged buildings, and finally rested upon one of the sunken houses, breaking through the roof.

In the first shock of this earthquake a tract of the adjacent country of the extent of above a thousand acres was instantaneously submerged.

35. It has been calculated that in the great earthquake of Lisbon, a portion of the earth's surface more than four times the area of Europe was affected by the undulation, without taking into account any part of the submarine disturbances which attended it.

36. As examples of shocks and tremblings of the ground which have continued from hour to hour for several successive months, Humboldt produces the following examples, all of which took place at great distances from any active volcano. On the eastern slope

of Mount Cenis, at Fenestrelles and Pignerol, the phenomena commenced in April, 1808. The liquid contained in full glasses exhibited a constant agitation and trembling. In the United States, at New Madrid, and Little Prairie, north of Cincinnati, the trembling commenced in December, 1811, and continued through the winter of 1812. In the Pachalik of Aleppo the shocks continued during the months of August and September, 1822.

37. Since the perturbation of the crust of the earth is produced by the agitation of the subjacent igneous ocean, it is no otherwise dependent on the nature of the matter which forms that crust than so far as such matter may be more or less susceptible of receiving and transmitting the undulations. Accordingly we find earthquakes occurring in every sort of soil, and strata from the loose alluvial soil of Holland to superficial strata of granite.

38. It is, however, certain that the mechanical structure of certain strata are such as to arrest the undulation. Thus, when an earthquake shock, or wave as we shall call it, is propagated along a line of coast, or along the foot of a mountain chain, certain points of interruption have been observed, over which the wave passes without producing any disturbance, resuming its character beyond their limits. Such tracts are well known, and have preserved their immunity from the shocks which affect the country at either side of them for centuries. It appears that the undulation of the subterranean fluid passes under these without affecting them. The Peruvians, who are of all people the most familiar with earthquakes, call these tracts *bridges*.

39. It does not at all follow, however, that because the superficial strata are not affected by the undulation, the inferior strata are exempt from it. At the beginning of the present century earthquake shocks were felt with such violence in the workings of the deep silver mines of Marienberg, in Saxony, that the miners took flight in alarm, and ascended by the shafts to the surface, where, nevertheless, they found that no shocks or trembling had been felt.

40. On the other hand, the superficial strata are sometimes affected by undulations, from which inferior strata are exempt, as is proved by what took place at Fahlun and Persberg, a mining district of Sweden, in November, 1823, during a violent shock of an earthquake, which spread terror among the inhabitants, while the miners employed in the deep workings experienced no disturbance whatever.

41. The undulations of earthquakes proceed so often in directions parallel to mountain chains, that it might be conjectured that they are directed by some influence exerted by the walls of

the fissures of the strata, between which the matter forming the chain was originally forced up. Many exceptions, however, to this are presented by earthquakes which have been propagated in directions transverse to those of the mountain chains. Thus, in South America they have crossed the littoral chain of Venezuela and the Sierra Parime. In Asia they have been propagated in January, 1832, from Lahore and the foot of the Himalaya, across the chain of the Hindoo Coosh as far as Badakschan on the Upper Oxus, and even to Bokhara.

42. We shall conclude this brief notice of these terrible terrestrial perturbations by the general reflections upon them made by Humboldt, who himself witnessed so many, and who has more than any other observer of nature studied and investigated them.

"In conclusion," says he, "I would advert to the cause of the deep and peculiar impression produced on the mind by the first earthquake we experience, even if it is unaccompanied by subterranean noise. I do not think that this impression is produced by the recollection at the moment of the dreadful images of destruction which historic relations of past catastrophes have presented to our imaginations: it is rather occasioned by the circumstance that our innate confidence in the immobility of the ground beneath us is at once shaken. From our earliest childhood we are accustomed to contrast the mobility of water with the immobility of the earth: all the evidences of our senses have confirmed this belief; and when suddenly the ground itself shakes beneath us, a natural force of which we have had no previous experience presents itself as a strange and mysterious agency. A single instant annihilates the illusion of our whole previous life; we feel the imagined repose of nature vanish, and that we are ourselves transported into the realm of unknown destructive forces. Every sound affects us—our attention is strained to catch even the faintest movement of the air—we no longer trust the ground beneath our feet. Even in animals similar inquietude and distress are produced; dogs and swine are particularly affected, and the crocodiles of the Orinoco, which at all other times are as dumb as our little lizards, leave the agitated bed of the river, and run with loud cries into the forest.

"To man the earthquake conveys a sense of danger of which he knows not the extent or the limit. The eruption of the volcano, the flowing stream of lava threatening his habitation can be fled from; but in the earthquake, turn where he will, danger and destruction are around him and beneath his feet. Though such emotions are deeply seated, they are not of long duration. The inhabitants of countries where long series of weak shocks succeed each other, lose almost every trace of fear. On the coasts of Peru, where rain scarcely ever falls, and where hail, lightning, and thunder are unknown, these atmospheric explosions are replaced by the subterranean thunder which accompanies the trembling of the earth. From long habit and a prevalent opinion that dangerous shocks are only to be apprehended two or three times in a century, slight oscillations of the ground scarcely excite so much attention in Lima as a hail-storm does in the temperate zone."

43. Although we are in the habit of congratulating ourselves, in this country, for our exemption from the terrible visitations of convulsions of the ground, it is certain that beneath the floor upon which our dwellings are established, there exists a seat of disturbance of a certain force and constancy. This is abundantly proved by the fact, that not less than 256 or 257 slight earthquake-shocks have been recorded, of which 139 took place in Scotland. Yorkshire, Derbyshire, Wales, and the south coast of England, have been the principal theatres of the remainder.

44. In the cases of convulsions which have been noticed in the preceding chapter, the effects of the phenomena have been generally limited to derangement more or less violent of the surface. When the internal forces acting outwards are exercised with greater energy, or when the external strata of the earth's crust exercise less resistance, disruptions take place, and through the openings thus produced the internal matter is ejected. The physical character of the matter thus thrown out, and the state in which it is found at the moment of its ejection, depend in a great degree upon the depth of the strata from which it has proceeded.

Of all the substances thus thrown out through the external crust from the interior of the earth, the most frequent is water. That liquid appears to be deposited in terrestrial strata, having depths more or less considerable, and it necessarily acquires the temperature of the strata in which it is thus confined. In ordinary springs rising from inconsiderable depths within the limits of the superficial strata, the temperature in warm seasons is generally lower considerably than that of the air at the surface, and hence arises the coolness of common spring-water. But when water rises from depths much more considerable, lying below the stratum of invariable temperature,* it is found to have a higher temperature than the air.

45. It was first observed by Arago, that water rising in Artesian wells had a temperature greater and greater as the depth of the well augmented. This observation involved a physical principle of high importance, supplying, as it did, a thermal index to the depth of hot springs.

* See Tract on Terrestrial Heat.

46. It has been shown in our tract on Terrestrial Heat, that in descending below the stratum of invariable temperature, the temperature of the strata increases at the rate of about 1° for every 50 feet. The stratum of invariable temperature, at the mean latitudes, being at a depth of less than 100 feet, and its temperature being nearly the same as the mean temperature at the surface; we may state in round numbers, that if the temperature at the surface be taken to be 50°, the temperature at the depth of one mile will be 150°, at the depth of two miles will be 250°, and at the depth of three miles will be 350°. Now, water at the temperature of 250° produces steam bearing a pressure of 30 lbs. per square inch, being about half that of the steam generated in a common locomotive, while water at 350° produces steam having a pressure of 130 lbs. per square inch, being more than twice the pressure in a locomotive.

47. The natural hot springs which exist in various parts of the globe must issue from strata whose depth corresponds to their temperature, rising through fissures or perforations in the superior strata, produced by disruptions effected by the pressure from within prevailing over the tenacity of the materials composing such strata. If the temperature of the water issuing from such springs could be taken to be that which it had in the reservoir from which it has risen, such temperature would supply at least an approximate index of the depth of such reservoir. But it must be considered, that in rising to the surface it passes through a succession of strata of constantly decreasing temperature, composed of materials of various conducting powers and capacities for heat, and that in its ascent it must part with more or less of its heat, and therefore that its temperature on issuing from the spring at the surface must be less than that of the subterranean reservoir from which it has risen. How much must, in each case, be allowed for this loss of temperature is a problem of considerable difficulty, and one which at best, with our present data, admits of no more than a rough approximative solution.

48. Observations made very extensively upon thermal springs, prove them to be completely independent of the strata from and under which they rise. Neither do they prevail exclusively in volcanic regions. Indeed, Humboldt affirms that the hottest permanent springs hitherto discovered are some found by himself, at a great distance from any volcano, as for example, the "Aguas Calientes de las Trincheras," between Puerto Cabello and New Valencia, in Venezuela, South America, the temperature of which was 194½°, and which issued through a stratum of granite; and the "Aguas Comangillas," near Guanaxuato, in Mexico, of which the temperature was 205½°, being only 6½° below the boiling point.

According to what has been explained of the law of temperature in relation to depth, the reservoirs from which these springs rise must be at a depth of nearly two miles.

It is remarked that springs of such moderate temperatures as from 120° to 160° are very constant, not only in their thermal state, but also in their chemical composition, while the hotter springs are subject to considerable variation. Thus, the thermal springs within these limits which have been known and observed in Europe, have never undergone the slightest change, either in their temperature or in their chemical analysis, since exact physical observations have been made upon them, which comprises at present an interval of about sixty years. While the hotter springs contain in solution the smallest proportions of mineral matter, they are found to be subject to a variation of temperature not inconsiderable. Thus, the springs of Las Trincheras above-mentioned, which, when observed by Humboldt in 1800, had a temperature of 194½°, were found by Boussingault, in 1823, to have a temperature of 206½°, having thus increased in temperature 12° in 23 years.

49. Nothing is more remarkable and curious respecting springs, whatever be their temperature, than the secular permanency which attends so many of them. The fountains of Greece still flow in the same places as they did when described by the historians, and sung by the poets, of the classic age. The river Erasinos, which rose in lake Stymphalus, after flowing a certain distance disappeared in the earth, but sprung up again out of the declivity of the mountain Chaon, two hours' journey south of Argos. This spring, which is mentioned by Herodotus, still issues from the same point in the slope of the mountain. In the centre of the temple of Apollo, at Delphi, was a small opening in the ground from which, from time to time, an intoxicating vapour was said to proceed, and which was supposed to proceed from the adjacent well of Cassotis. Over this chasm the priestess Pythia took her seat whenever the oracle was to be consulted, and the words she uttered after inhaling the mephitic vapour were believed to be the revelations of the god.

Of this chasm no trace remains, but the well of Cassotis still exists, and is known as that of St. Nicholas. Its waters still pass under the site of the temple of Apollo.

Of the other classic fountains which still flow may be mentioned that of Castalia at the foot of Mount Parnassus, Piréné at Corinth, the thermal springs of Ædepsus on the coast of Eubœa near Chalcis. It is remarkable that in a tract of country so peculiarly subject to frequent and violent earthquakes, the strata in the main continue to preserve their relative position, so that even those narrow holes and fissures, through which those subterranean waters force themselves up, have remained unchanged during the long interval of 2000 years.

As further examples of this permanency, Humboldt adduces the example of a natural jet d'eau at Lillers, near Calais, which was bored in 1126, and now, after a lapse of seven centuries, still supplies the same quantity of water, which issues with the same force.

50. If the reservoir from which water rises be at such a depth that its temperature greatly exceeds the boiling point, the water will be converted into vapour the moment it escapes from the place of its confinement, just as was the case with the water shut up in the generators of the steam apparatus projected by Perkins. In that case, the steam will issue from the crevice of the earth exactly as it would from the safety-valve of a high-pressure steam-engine.

51. The vapour of water is not however by any means the only elastic fluid which forces its way to the surface from the interior of the globe. Various gases are also ejected in enormous quantities. The gas called carburetted hydrogen, which, evolved by artificial processes, is now so universally used for the purposes of illumination, issues in vast quantities from the interior of the earth through fissures of greater or less magnitude, and thus presented by Nature herself, has actually been used for illumination in China for more than ten centuries back. The artesian FIRE-WELLS of China, at Ho-tsing are well-known. The gas has from very ancient times been collected in tubes of bamboo, and being thus rendered portable, has been used for illumination in the city of Khiung-tscheu.*

52. But of all the gaseous ejections from the interior, the most frequent and abundant is carbonic acid. It is certain that at earlier epochs in the history of our globe, thousands of centuries before the appearance of man and of the other tribes of animals that now inhabit it, when the fissures and crevices supplying free communication between the surface and the interior were far more numerous and capacious than they are at present, and when the temperature of the solid crust was much higher, this gas, mixed with hot steam, issued from the interior in quantities infinitely greater than at present, so as to give totally different qualities to the atmosphere. These qualities, owing to the large proportion of carbonic acid, and the great quantity of aqueous vapour always suspended in the air, were eminently favourable to the production of a vegetation exuberant to a degree of which there is now no existing parallel. Hence arose those vast forests and other large collections of vegetable matter, which, being fossilised in succeeding

* Humboldt, "Central Asia," tom ii. 519—530.

revolutions of the globe, have supplied those inexhaustible stores of mineral fuel which have, through the application of science, become mechanical agents of infinite power, as well as sources of artificial light and heat.

53. These prodigious volumes of carbonic acid also supplied other purposes in the terrestrial economy at that early period. Entering into combination with lime, which also prevailed in abundance, lime-stone rocks of every kind, including those beautiful marbles which have become so important a material in the industrial and ornamental arts, were produced; for these rocks, as is well known, are nothing but carbonates of lime, the carbonic acid constituting nearly half of their entire mass.

54. The transition from the ejection of gases and liquids to that of molten rocks exhibited in the effects of volcanoes, is marked by the intermediate phenomena of the ejection of hot mud. According to Humboldt, although SALSES or mud volcanoes in their normal state present little to arrest attention, their origin is characterised by the imposing phenomena of earthquakes, subterranean thunder, the upswelling of vast tracts of country, and the ejection of lofty jets of flame. A recent and well-observed example of such a phenomenon is presented in the case of the mud volcano of Jokmali, on the peninsula of Apscheron, east of Baku on the shores of the Caspian sea. This peninsula has always been the theatre of singular subterranean phenomena, and flames have so frequently, in past times, issued from the ground upon it, that it has been regarded with veneration by the oriental fire-worshippers. On this peninsula on the 27th November, 1827, flames blazed up from the ground to so great a height that they were seen at the distance of 24 miles, in which state they continued for three hours, after which they decreased to the height of three feet. They issued from a crater which was formed by their ejection, and continued to burn in that way for 20 hours. This ended in the ejection of enormous fragments of rock, and quantities of hot mud.

55. Of mud volcanoes of more remote origin we have examples in the case of the Monte Zibio, near Sassuolo in the Duchy of Modena, and the salse near Girgenti, in Sicily. Fragments of rocks like those ejected by Jokmali may be seen around the former. The salse has continued in the secondary state of activity for fifteen hundred years, descriptions of it at that early epoch having come down to us. It consists of several cone-shaped mounds, varying in height from eight to thirty feet, and subject to constant change, not only in height but in shape. Small craters are formed at the summit of the cones, which contained more or less water, and from which gas from time to time is disengaged.

The mud which is ejected from these volcanoes is cold. In a similar mud volcano mentioned by Humboldt, at Damak, in the province of Samarang, in the island of Java, the mud ejected has a high temperature.

The gaseous eruptions from these salses are usually attended by noise, and consist of different sorts of gas, sometimes hydrogen, sometimes carbonic acid, and occasionally nitrogen. The hydrogen is often mixed with naphtha.

56. After the first imposing phenomena such as those above described in the case of Jokmali have ceased, the mud volcanoes in general seem to be the result of a feeble activity of the interior forces of the globe obstructed in their effects by some impediments in the fissures or openings by which communication with the surface is obtained. The coldness of the mud seems to prove that the seat of the force is not at any great depth.

57. From the examples of subterranean activity presented by superficial convulsions, earthquakes, thermal springs, and jets of gas and steam, we pass to the formation of volcanoes properly so called. The internal forces, acting with unequal effect on different parts of the solid crust of the earth, surmount its resistance at points where it has least tenacity, and upheaving the incumbent strata, raise them into dome-shaped masses, like those of the Puy de Dome and Chimborazo, without, however, producing actual fracture. Sometimes the mass thus upheaved gives way at the summit of the dome, which separates so as to leave a circular cavity of a certain depth surrounded by a nearly perpendicular wall, having on the exterior a gradual slope, which formed the declivity of the dome before the disruption.

58. The roundish cavity thus formed is called a "crater of elevation."

59. If the energy of the subterranean forces be sufficiently intense, the floor of this crater will be disrupted, holes and fissures will be formed in it, communicating with the liquid fire which fills the solid shell of the earth, steam and acid gases will be ejected in vast quantities, followed by ignited scoriæ, and red hot stones, and fragments of rock, after which will follow torrents of that incandescent earthy matter in a state of pasty fusion, which has been called LAVA; in a word, an active VOLCANO will be formed.

60. Now there are here several distinct stages, at any one of which the phenomena may be brought to a close, according to the relation between the energy of the upheaving force and the local tenacity of the earth's solid crust. If the upheaving force do not much exceed that tenacity it may spend its entire energy in producing swelling of the surface of the ground more or less pro-

nounced. If the excess be greater still, a dome-shaped hill or mountain will be produced. A greater excess again will cause the disruption of this dome, and its conversion into a crater of elevation. Finally, if the internal force be sufficient to break a way through the entire mass of solid strata which forms the shell of the earth, the fiery fluid central matter, rising through the opening thus made for it, will issue from the holes, crevices, and fissures in the floor of the crater, and overflowing or breaking a way through the surrounding wall, rush in a torrent of fire down the slopes of the dome-shaped hill thus formed.

61. The volcano thus formed is never uniformly active. The eruptions are only occasional. When an internal wave or tide of the fiery central ocean passes the base of the opening, a pressure is produced by which the molten matter is forced up and ejected in the form of lava. In its ordinary state, however, when no eruption takes place, volumes of smoke more or less dense usually rise from the fissures, and upon looking down into them, the luminous incandescence of their walls and of the matter they include is visible. The light of this illuminating the smoke and ashes, which rise over the crater, often give to them a lurid light which appears like, and is sometimes mistaken for flame.

62. The intervals of activity and repose of volcanoes are often of very long duration. Thus in the case of Vesuvius, the eruptions were renewed with unabated force after an interruption of several centuries. In the time of Nero, Etna was considered as approaching to entire extinction, and according to Ælian, the summit of the mountain at a later period was gradually sinking, so that it could no longer be seen as a landmark by vessels at sea from the same distances.

63. Humboldt affirms that it may be considered as a pretty well established law of volcanoes that those which have least elevation are characterised by the most unceasing activity. He proves this law by many examples, and explains it by the supposition that a less internal force is sufficient to raise the molten masses to low than to high summits. He gives the following series of elevations of the craters of remarkable volcanoes:—

	Feet.
Stromboli	2318
Guacamayo	2500
Vesuvius	3876
Etna	10,870
Peak of Teneriffe	12,175
Cotopaxi	19,070

64. Now of these, Stromboli has been in a state of activity from the Homeric age to the present, so unceasing that it has served

and still serves all the purposes of a stupendous light-house to ships navigating that part of the Mediterranean. The entire island situate off the north coast of Sicily is of volcanic formation.

65. The activity of Guacamayo, situate in the province of Quiros, at about 88 miles from Chillo, near Quito, is so continuous that detonations are heard daily from it, even at the distance of Chillo. On the other hand, the eruptions of Vesuvius are comparatively rare, and those of Etna still more so, while those of the lofty volcanic peaks of the Andes are separated by intervals of little less than a century.

66. As a further evidence of the prevalence of this volcanic law may be mentioned the cases in which volcanoes do not rise, like Etna and Vesuvius, from the midst of extensive plains, but have their bases established on table-lands of great elevation, in which cases it is observed, that even in the most terrible eruptions no lava properly so called is ejected, the matter thrown up being merely ignited scoriæ. Yet the violence of the subterranean commotion is rendered manifest by the terrible detonations which are heard at distances of four hundred miles. Examples of this are presented in the volcano of Popayan, South America, the base of which is 6000 feet above the level of the sea, that of Pasto upon the table-land of the Andes at an elevation of 8500 feet, and those of the Andes near Quito.

67. Wherever exceptions to this volcanic law have been presented, Humboldt considers them as only apparent, and that they may be explained by the casual obstruction of the fissures of communication between the seat of the volcanic force and the surface.

68. The volcanic eruptions do not necessarily proceed from the crater. Indeed, in some volcanoes, eruptions from the crater are much less frequent than those which proceed from other parts of the mountain; as, for example, from the sides where the solid walls of the internal fissure often present less resistance. Lateral fissures and openings are in such cases produced, over which "cones of eruption," as they are called, are formed. In this case, a series, or row of cones, are formed at certain distances along the line of fissure, from each of which the eruption takes place, all the intermediate part of the fissure being immediately closed up.

69. The internal forces also often break out at numerous points, distributed over a large space, forming a number of smaller cones which are described as having the form of bells or beehives. The cones produced by the eruption of Vesuvius in October, 1822, offer an example of these, as do also the Hornitos de Jorullo, observed by Humboldt, and delineated by him in his

"Vues des Cordillères," pl. XLIII., p. 239. Other examples are presented by the small cones of the volcano of Awatscha, and of the field of lava in Kamtschatka, described by Erman.

70. Around each mouth from which the fiery matter is projected, a cone of cinders and ashes is formed by the return of the matter which has been projected upwards. These cones vary greatly in height and magnitude, and appear to have no relation to the general elevation of the mountain, the smaller class of volcanoes often producing the highest cones. One of the most remarkable of these cones is that of the Volcano of Cotopaxi, in the eastern Cordillera of the Andes, about 34 miles S.S.E. of Quito. The general form of this remarkable mountain is that of an immense cone, shaped with an accuracy almost geometrical. The summit is about 19000 feet above the level of the sea, and nearly 10000 above the adjacent table-land. The snow line is at 4400 feet below the summit. The cone, therefore, above this line is coated with perpetual snow, except at the times of eruptions, in which the solid sides of the cone becoming incandescent, the snow suddenly melts, and descending in torrents down the flanks of the mountain, leaves the conical summit uncovered. "Of all the volcanoes which I have seen," says Humboldt, "in either hemisphere, the cone-formed Cotopaxi is at once the most regular and the most picturesque. Before each great eruption, the sudden fusion of the snow, which habitually invests its vast cone, announces the coming catastrophe. Even before the appearance of smoke issuing from its lofty crater, the sides of the cone acquire a glowing temperature, and the mass of the mountain assumes an aspect of most awful and portentous blackness."

71. It is difficult to imagine any spectacle more awfully grand than the view of a crater in activity presented to an observer stationed at the summit of the surrounding wall. The space beneath him appears like the surface of agitated half-molten matter contained in a colossal cauldron. The surface swells and intumesces; from the cracks and fissures vapours issue; small chasms here and there alternately open and close, showing within them red hot molten matter; burning fragments are from time to time thrown up, and fall back upon the sides of the mounds surrounding the mouths from which they have been vomited; each small eruption of this kind is regularly preceded and announced by small earthquake shocks, which sensibly shake the ground beneath the feet of the observer; occasionally lava issues in a fiery torrent from these fissures and mouths, but not in sufficient quantity to break through the walls of the crater, but sometimes the flow of this red hot pasty matter is so abundant

that it breaks the wall, and rushes down the side of the mountain.

72. It might be inferred from the occurrence of such tremendous phenomena, that the form and condition of volcanic craters would be subject to constant and considerable change. Their variation is, nevertheless, much less than might naturally be expected. Thus, for example, the ramparts of the crater of Vesuvius were accurately measured by Saussure in 1773, and again by Humboldt and Lord Minto in 1822-3. In that interval of 50 years no considerable variation took place.

73. The case of Cotopaxi producing torrents of water mixed with scoriæ and enormous blocks of ice precipitated down the slopes of the mountain by the sudden fusion of the snow which crowns its summit, is not singular. The same phenomena attend all the volcanoes whose cones rise above the line of perpetual snow, of which the chain of the Andes presents many examples. Independently of these occasional inundations of the external surface, these volcanoes exert a constant action even during their apparent repose, by the slower fusion of the snow in immediate contact with them, and the infiltration of the water through the crevices and fissures of the rocks of which they are formed. Subterranean reservoirs of water are thus formed at and below their bases, with which the streams and rivulets of the surface communicate. It has been ascertained that in these dark reservoirs fish multiply more largely than in the open waters, and that when the caverns containing such waters are suddenly opened, as they sometimes are, by the earthquakes which always precede violent eruptions, water, fish, and tufaceous mud are thrown out in one confused mass. Humboldt says, that when on the night of the 19th June, 1698, the summit of the Carguairazo, at the height of nearly 20000 feet above the level of the sea, suddenly fell in, leaving two stupendous peaks of rock as the sole vestiges of the rampart of the crater, masses of tufa, in a liquid state, and of clayey mud, containing immense numbers of dead fish, were spread over a tract of about fifty square miles in extent, rendering the whole space barren.

In some cases, the quantities of this dead fish which have been ejected have produced putrid fevers, fatal to a large part of the population.

74. The fiery appearance which is so often observed over the volcanic craters in great eruptions is not flame, as it is commonly supposed to be. It is due principally, if not altogether, to the reflection of the lurid light which issues from the crater, by which the clouds, vapour, ashes, and other ejected matter, forming the column over it, are illuminated, but in part, also, from scoriæ and

dust ejected in a state of incandescence. There is, strictly speaking, no combustion in or over the crater, and therefore the term burning mountain is physically incorrect.

75. The production of volcanoes, or of volcanic craters, which remain passive, as above explained, is by no means confined to those parts of the solid crust of the earth which lie above the waters of the ocean. The bottoms of seas, and even of lakes, are subject to such convulsions still more frequently than the land. When the bottom of the sea is thus up-heaved, islands are produced, the form, character, and magnitude of which depend on that of the up-heaved mass. The form of Palma, one of the Canaries, and the peaks which it throws up to the height of 7000 feet, and that of Nisyrus in the Ægean, present examples of this. The volcanic origin of the latter was known to the ancients, which gave rise to the fable that Neptune, when pursuing Polybotes, one of the giants that fought against the gods, followed him across the sea as far as this land of Cos, where having torn off a part of the island, he hurled it upon him, and buried him under it. This fragment of Cos was called Nisyrus.

When the dome up-heaved from the bottom of the sea breaks at the summit, so as to form a crater of elevation, a part of the annular rampart is sometimes destroyed, so that the sea enters, and an enclosed bay is formed, where innumerable tribes of coral animals build their cellular dwellings.

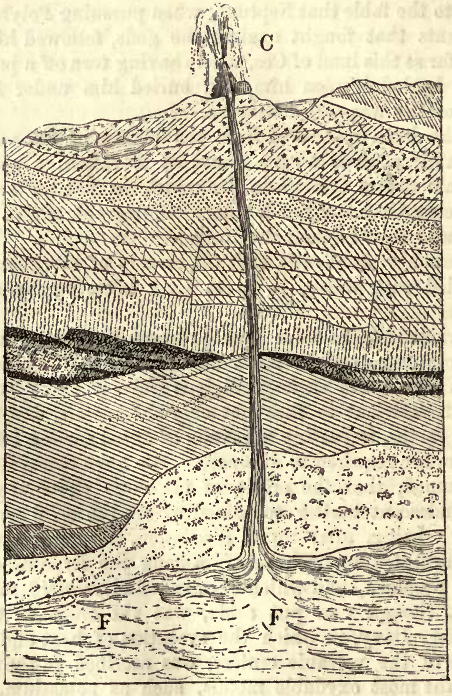
It happens also frequently that the craters of elevation on land become filled with water, so as to form lakes surrounded by a rampart.

76. Various theories have been proposed to explain the phenomena of volcanoes, and to solve the questions, What is it that burns? What excites such prodigious degrees and quantities of heat? heat sufficient to fuse not only the metals, but the most refractory earths, imparting to masses of fused earth a heat which many years are required to dissipate. We have throughout these pages assumed, that the origin of all these phenomena is the fluid incandescent matter contained within the solid crust of the earth, such being, after much discussion, the explanation now generally accepted by geologists. Among the hypotheses which have been proposed, and which received and merited much consideration, though now put aside, was the chemical theory of Sir Humphry Davy, in which the evolution of heat and light in the depths of the volcanic craters, was ascribed to the chemical action of the most oxydable metals, such as potassium, sodium, calcium, &c. It is a fact, familiar to all that have studied the elements of chemistry, that a piece of potassium immersed in water will instantly become decomposed, combining with its

oxygen and liberating the hydrogen. If the existence of the metals in their simple state in the lower strata of the earth be admitted, any accession of water to them would immediately produce this sort of combustion.

Our limits, and the object of this tract, preclude us from entering upon this question here beyond this mere indication of the ingenious hypothesis of the illustrious chemist; and as the theory proposed has been generally abandoned, such a discussion is the less necessary.

To illustrate the generally received theory, we have here subjoined an hypothetical section of the crust of the earth, showing the progress upwards of the igneous fluid from the internal liquid fire, FF, to the mouth of the crater at C.



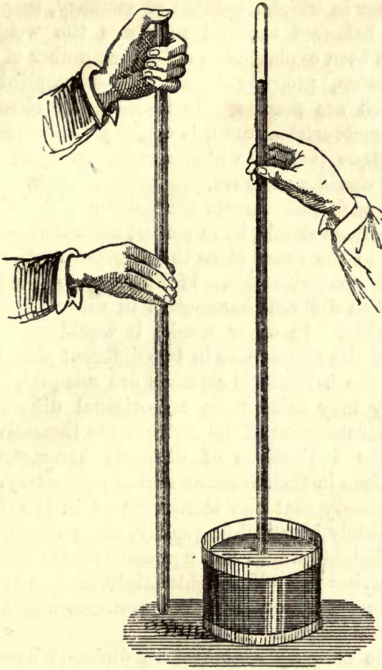


Fig. 1.—PROCESS OF MAKING A BAROMETER.

THE BAROMETER.

1. Origin of the name.—2. Conditions necessary to render the instrument useful.—3. To purify the mercury.—4. To cleanse the tube.—5. To fill the tube.—6. To invert it in the cistern.—7. Construction of a barometer.—8. Effect of temperature on the barometric column.—9. To ascertain if the vacuum above the column be perfect.—10. Expedients to render minute variations of altitude visible.—11. Diagonal barometer.—12. Wheel barometer.—13. Common siphon barometer.—14. Use of the barometer to measure heights.—15. Density of strata affected by their temperature.—16. Fall of barometer in the balloon ascent of Gay Lussac.—17. Extreme variations of the barometric column in a given place.—18. Its diurnal variation.—19. How it may prognosticate the weather.—20. Fallacy of popular rules.—21. Barometric prognostics.

1. The manner in which a column of mercury, suspended in a glass tube, is balanced by, and measures the weight of, the atmosphere, has been explained in a former number of this series. Such an apparatus, properly mounted and supplied with the accessories which are necessary to indicate the changes of the altitude of the mercurial column, is called a barometer, from two Greek words, βαρος (*baros*), which signifies weight, and μετρον (*metron*),which signifies measure.

2. To render such instruments generally useful, it is necessary that their indications should be in perfect accordance, that is, that being brought to the same place they should at the same time always have the same altitudes. If this were not the case, observations made with different barometers in different places would not be comparable. In other words, it would not follow that the pressures of the atmosphere in two different places are really different when the barometric columns are unequal, inasmuch as such inequality may arise from an original difference in the materials and construction of the instruments themselves.

To render the indications of different barometers identical several precautions in their construction are necessary.

3. It is necessary that the mercury used in the instruments should be absolutely identical in quality, since otherwise columns having equal heights would not necessarily have equal weights, and columns having unequal heights might happen to have equal weights. In fine, the weights of two columns would not be proportional to their heights.

To render the mercury contained in different barometers perfectly identical, the first requisite is that it be perfectly pure and free from admixture with any other substance. To attain this object is not quite so easy as may at first appear. It frequently happens that small particles of solid impurities, such as dust and dirt, are mixed with mercury; so much so, that they may be seen upon its surface, often forming a sort of scum. To separate these from it, the mercury is enclosed in a bag of chamois leather, and squeezed there until it passes through the pores of the leather. By this process the chief part of the solid impurities are extricated, since they will not pass through the pores of the leather, and are therefore *strained* from the mercury.

Aqueous, and other liquid matter, is also sometimes mixed with the mercury. These are disengaged by boiling it. All such liquid matter is evaporated at a temperature much lower than that at which mercury boils, and they are consequently expelled in the form of vapour long before the mercury reaches its boiling temperature.

4. When the mercury has been thus purified, it is next

necessary to render the tube perfectly clean on its inner surface. It generally happens that tubes exposed to the air, always more or less damp, have a film of moisture upon them. It is necessary therefore to expel this. After cleaning the tube by internal friction, it is warmed over the flame of a spirit lamp from end to end, so as to evaporate any moisture which may remain upon it and render it perfectly dry.

5. Mercury is then poured into it by means of a funnel with a very small aperture, until a column of about ten inches has entered. However pure this mercury may be, and however clean the tube, it will be more or less mixed with air, which will enter with it as it passes from the funnel. To dismiss this air the tube with the mercury in it is heated over a spirit lamp, until it is raised to a temperature higher than that of boiling water. By this process the air combined with the mercury, or adhering to the inner surface of the tube, being expanded by the heat, escapes from the tube, as well as any moisture that may have entered with the mercury.

Mercury is again introduced in the same manner, and again heated, and the process is repeated until the tube has been completely filled.

In this process it is usual to heat the mercury to nearly the same temperature as that of the tube before pouring it in, since otherwise there would be some danger of cracking the tube, by the expansion or contraction of the glass consequent on the sudden change of temperature.

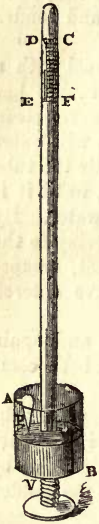
6. When the tube is in this manner completely filled, the open end is finally stopped with the finger, and being inverted it is plunged in a small cistern of mercury (fig. 1, p. 177). When the finger under the mercury in the cistern is withdrawn, the column in the tube will subside until it falls to the altitude which will be balanced by the atmospheric pressure.

If several tubes be prepared in this manner, it will be found that the columns of mercury sustained in them at the same time will be exactly equal.

7. In adapting such an apparatus to indicate minute changes in the pressure of the atmosphere, there are several provisions to be made.

The height to be measured being that of the surface of the column in the tube above the surface of the mercury in the cistern, it is not enough to ascertain the position of the surface in the tube, unless the surface in the cistern have a fixed level. Now it is evident, that whenever the surface in the tube rises, the surface in the cistern must fall, and *vice versâ*, inasmuch as whatever mercury enters the tube must leave the cistern, and whatever flows from the tube must return to the cistern. If the magnitude of the surface in the cistern be very considerable compared with the bore of the tube, and if extreme accuracy be not necessary, the effects arising from this cause will be too minute to need any correction; but if that extreme accuracy is desired, which is necessary in barometers used for philosophical experiments, then means must be provided for keeping the mercury in the cistern at a fixed level, or for measuring the change of level.

Fig. 2.



In fig. 2, the cistern A B is represented as having an index at P, showing the point at which the level of the mercury in the cistern should stand. A screw is represented at V, by turning which the bottom can be elevated or depressed, so that when the level in the cistern falls it may be raised, or when it rises it may be lowered, and thus the level may always be adjusted so as to correspond with the point of the index. The scale represented at D E is divided with reference to the level determined by the point of the index P.

8. In most of the uses to which the barometer is applied the variations in the altitude of the mercurial column are very minute, so minute indeed that the most refined and delicate expedients are necessary in the observation and measurement of them. It is a fact familiar to every one, that all bodies, and more especially fluids, expand and contract by changes of temperature. Mercury, like others, expands when its temperature is raised, and contracts when it is lowered. Now when it expands it becomes bulk for bulk lighter, and when it contracts it becomes bulk for bulk heavier. It follows, therefore, that the barometric column, even when its altitude is the same at different times, will have different weights, the weight being less when the temperature is higher, and greater when the temperature is lower.

The dilatation and contraction of mercury has been ascertained to amount to the 9990th part of its entire volume for each degree of temperature by which it is raised or lowered, and a column of 30 inches would therefore suffer a change of the 333rd part of an inch for each degree of temperature.

The extreme variations of temperature in this climate between summer and winter being about 50°, the barometric columns which indicate equal pressures at the two extreme temperatures, would differ in height by about the sixth or seventh part of an inch.

When barometric observations made in different places are to be compared one with another, it is therefore necessary to allow for the difference of temperature, and this is usually done by calculating at both places what the height of the column would be if the temperature were that of melting ice, or 32°.

9. It is of extreme importance in the use of barometers to be always sure that no portion however small, of air or other elastic fluid, is contained in that part of the tube which is above the summit of the mercurial column, for if any such fluid be there, it will react upon the mercurial column and will depress it, so that its altitude, instead of expressing the pressure of the atmosphere, will express that pressure diminished by the pressure of the air or other elastic fluid which is above the column in the tube.

Now it happens that nothing is more easy than to ascertain whether any such fluid is there. It is only necessary suddenly to incline the tube from the vertical position, so as to cause the mercury to be forced up to the top by the atmospheric pressure, in consequence of the *vertical* height of the column being rendered less than that which balances the weight of the atmosphere. If in such case the mercury striking the top of the tube renders the blow audible by a distinct, sharp, and well-defined sound, it may be concluded that the top of the tube is free from air, for if air be present, even in the smallest quantity, it will react like a cushion or *buffer*, so as to soften the blow of the mercury, and deprive the sound of that sharp and distinct quality.

10. The changes of altitude incidental to the barometric column are so minute that various expedients have been resorted to, to render them more easily and accurately observable.

More sensible indications would be obtained by adopting a barometer of a lighter fluid than mercury. Thus, water is $13\frac{1}{2}$ times lighter than mercury, and, consequently, a water barometer would exhibit a column $13\frac{1}{2}$ times greater than that of mercury.

Such a column would, therefore, measure about 34 feet, and a change which would produce a variation of about the tenth of an inch in the column of mercury, would produce a variation of an inch and a third in the column of water.

But to the use of water, or any other liquid save mercury, for barometric purposes, there are numerous and insuperable practical objections. Independently of the unwieldy height of the column, which would render it impossible to transport the barometer from place to place, all the lighter liquids would produce vapour in the upper part of the tube, which would vitiate the vacuum, would react against the barometric column, and disturb its indications. The consequence of this has been, that mercury has been invariably retained as the only practicable fluid for barometers.

Several expedients, however, have been adopted in barometers used for common domestic purposes to render their indications more sensible. Although these are inapplicable in barometers used for scientific purposes, yet, as they are frequently adopted in domestic barometers, it may be useful here to notice them.

11. A form of barometer, called the diagonal barometer, is represented in fig. 3. In this the upper end of the tube is bent, so that the scale, instead of being limited to the length C D, is extended over the greater length C B.

Fig. 3.

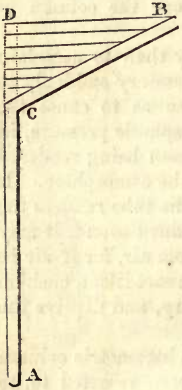
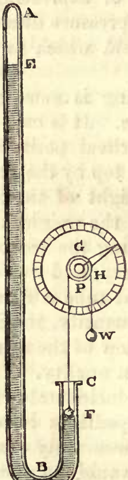


Fig. 4.

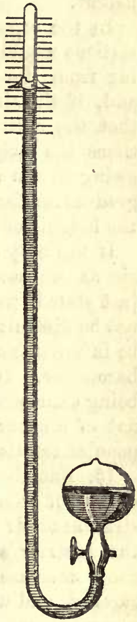


12. A form of barometer, called the wheel barometer, is represented in fig. 4. In this, the tube, instead of having a cistern, is continued of the same diameter, having its lower end bent upwards at B C. A float is placed upon the mercury at F, which rises and falls with it. The change of altitude of the level F corresponds with that of E, and the difference between the two levels E and F is the height of the barometric column. The changes of this height are always double the change of level of the surface E F. The float F is connected by a string with a wheel, H, which carries an index that plays upon a graduated dial plate, G. In this manner the magnitude of the graduated scale may be made to bear any proportion, however great, to the change of level of the mercury at E, so that the smallest change of the barometric column will produce a considerable motion of the index.

13. One of the most common forms of this instrument is represented in fig. 5. The lower part of the tube being bent into the form of a siphon, like the wheel barometer, is inserted in the lower part of an iron stop-cock, the upper part of which is inserted in a small globular cistern containing the mercury. When the stop-cock is open the column in the tube is subject

to the pressure of the atmosphere acting on the mercury in the cistern. If the tube be inclined so that the mercury will fill the top of it, and the stop-cock be then closed, the instrument may be transported from place to place without risk of air entering the tube, or other derangement. The diameter of the globular cistern bears so great a proportion to that of the tube, that a rise or fall of the mercury in the tube, within the usual limits of barometric variation, produces a very inconsiderable variation in the level of the mercury in the cistern, or if greater accuracy be desired, the scale attached to the tube may be so divided as to measure, not the actual variation of the level of the column in the tube, but its variations relatively to that of the mercury in the cistern. Thus, if the diameter of the cistern be four times the diameter of the tube, the area of its section will be sixteen times that of the tube, and when the level of the mercury in the tube falls through an inch, the level of the mercury in the cistern rises through the sixteenth of an inch, so that the real decrease of the mercurial column is only fifteen sixteenths of an inch. It is evident that, if it be desired, the scale may be so divided that an actual fall of an inch may be marked as one-sixteenth less than an inch, and so of other variations.

Fig. 5.



In barometers for domestic use this extreme precision is not necessary, and is so much the less so, as the most important indications of the barometer are those which depend on the *variation* of the height of the column, and not on its absolute height.

14. It has been shown, that when a barometer is carried upwards in the atmosphere, the column of mercury in the tube falls, because the force which sustains it is diminished by an amount equal to the weight of the column which it leaves below it. By comparing, therefore, the height of the column in the barometer at any two stations, one of which is above the other, we can ascertain directly the weight of a column of atmosphere extending from the lower to the higher station. Thus, for example, if the column of mercury in the barometer at the lower station be 30 inches, and at the higher station 20 inches, it follows that a column of air whose base is at the lower station, and whose summit is at the higher station, will have a weight equal to that of a column of mercury 10 inches high, and there-

fore that the quantity of air composing such a column will be one-third of the quantity composing a column extending from the lower station to the summit of the atmosphere.

If the atmosphere were uniformly dense, the barometer would supply a most easy and simple means of determining its actual height.

In the example just given, the column of air between the two stations would weigh one-third of the weight of a column extending from the lower station to the summit of the atmosphere; and, if the air were uniformly dense, it would follow, therefore, that the entire height of the atmosphere would be just three times the height of the upper above the lower station. But, owing to the circumstances already explained, which produce a gradual rarefaction of the air as the height increases, it follows that the heights of columns of air are not proportional to their weights.

If the only cause which produces a gradual rarefaction of the air as we ascend in the atmosphere were that which has been just stated, namely, the weight of the incumbent air, it would not be difficult to find a rule by which a change of altitude might be inferred from observing the change of pressure indicated by a barometer. Such a rule has been determined, and is capable of being expressed in the language of mathematics, although it be not of a nature to be rendered intelligible in an elementary and popular treatise.

15. But there are other causes affecting the relation of the change of pressure to the change of altitude. The density of any stratum of air is not alone affected by the incumbent pressure of the superior strata, but also by its own temperature. If any cause increase this temperature, the stratum will become more rarefied, and with a less density will support the same incumbent pressure; and if, on the contrary, any cause produce a fall of temperature, it will require a greater density with the same pressure. In the one case, therefore, a change of elevation which would be necessary to produce a given change in the height of the barometer would be greater than that computed on theoretical principles; and in the other case it would be less. The temperature therefore forms an essential condition in the calculation of heights by the barometer.

Formulæ have been contrived, partly by theoretical principles, and partly from observation, by which the difference of height of two stations may be deduced from the observations simultaneously made at them on the barometer and the thermometer. To apply such a rule it is necessary to know, first, the latitude of the place of observation; secondly, the heights of the barometer and thermometer at each of the two stations, besides some other physical data, to comprehend which it would be necessary to have reference to some principles drawn from the physics of heat and from physical astronomy, which cannot be introduced here. Such a formula, therefore, cannot be usefully given here.

16. The barometer in the balloon in which the celebrated De Luc made his scientific voyage, fell at the greatest altitude to 12 inches. Supposing the barometer at the surface to have stood at that time at 30 inches, it follows from this, that he must have left below him in quantity exactly three-fifths of the entire atmosphere, since 12 inches would be only two-fifths of the complete column sustained in the barometric tube. His elevation at this moment was estimated to have been 20000 feet; but it is certain that he had not attained a point amounting to more than a small fraction of the entire altitude of the atmosphere.

Since the density of air is proportional to its pressure, other things being the same, it would follow that the density of the air in which the balloon floated on this occasion was only four-tenths of the density at the surface.

Now when the barometer is at 30 inches, air is 10400 times lighter than mercury; and, consequently, the air surrounding De Luc's balloon must have been 26000 times lighter, bulk for bulk, than mercury. The height, therefore, of air above the balloon, supposing its density to be undiminished in rising, would have been 26000 feet, and in this case the entire height of the atmosphere would be nearly 50000 feet. But here it is to be considered, as in the former case, that in rising above the level of the balloon, the air would constantly diminish in density; and, consequently, a column supporting 12 inches of mercury would have a much greater elevation than 26000 feet.

17. The physical effect of which the barometric column is the measure, is the weight of the atmosphere at the place where this barometric column is situated; and consequently, the variations, whatever they may be, which are incidental to the column, indicate corresponding variations in the weight of the atmosphere. Now it has been found that the barometric column is subject to two species of variation: one of an extremely minute amount, and which takes place at regular periods; the other of much greater amount, and which may be considered as comparatively contingent and accidental. The extreme limit of this latter variation is, however, not great. The greatest height, for example, which the barometer kept at the Paris Observatory has been known to attain is 30·7 inches, and the lowest 28·2 inches, the difference being 2·5 inches, or $\frac{1}{12}$th of the average height of the column.

The mean height of the barometer at Paris, obtained from observations continued for several years, has been found to be 29·77 inches.

18. The periodical variations of the barometric column are extremely complicated, though very minute. In winter, it is found that the column attains a maximum height at nine in the morning; it falls from this hour until three in the afternoon; it then begins to rise, and attains another maximum at nine in the evening. In summer, the hour of the first maximum is eight in the morning, and that of the minimum four in the afternoon; that of the second maximum being eleven at night. In spring and autumn, this maximum and minimum take place at intermediate hours.

19. The accidental variations of the barometer, or, to speak more properly, those which are not periodic, and which are much greater in magnitude, have been generally supposed to be prognostics of change in the weather, and hence the barometer is sometimes called a weather-glass. Rules have been attempted to be established by which from the absolute height of the mercurial column the coming state of the weather may be predicted; and we accordingly find the words, Rain, Fair, Changeable, &c., engraved upon the scale attached to common domestic barometers, as if, when the mercury stands at the heights marked respectively by these words, the weather is always subject to the vicissitudes expressed by them.

It requires but little reflection on what has been stated to show the fallacy of such indications. The absolute height of the mercurial column varies with the position of the instrument. A barometer in Fleet Street will be higher at the same moment than one on the top of St. Paul's, and consequently two such barometers would indicate different coming changes of the weather, though absolutely situate in the same place. Two barometers, one of which is placed at the level of the Thames, and the other at the top of Hampstead Hill, will differ by half an inch, and, consequently, would indicate, according to the usual scales, different coming changes.

20. It is evident, therefore, that the absolute height of the barometer cannot in itself be an indication of anything but the weight of the atmosphere in the place where the instrument stands, and the words engraved on barometric plates, which have been just referred to, are altogether unworthy of serious attention.

Nevertheless, at a given place the column varies between certain limits, usually from $2\frac{1}{4}$ to $2\frac{1}{2}$ inches, and when the mercury is at its highest limit, the prevailing character of the weather is fair, when at its lowest it is rainy and stormy, while at the intermediate altitude it is variable.

21. Different meteorological observers have attempted to embody and generalise the results of their observations in a collection of rules, by which the weather may be prognosticated. The following brief general maxims have been proposed :—

1. Generally the rising of the mercury indicates the approach of fair weather, the falling of it shows the approach of foul weather.

2. In sultry weather, the fall of the mercury indicates coming thunder. In winter the rise of the mercury indicates frost. In frost, its fall indicates thaw, and its rise indicates snow.

3. Whatever change of weather suddenly follows a change in the barometer, may be expected to last but a short time. Thus, if fair weather follow immediately the rise of the mercury, there will be very little of it; and, in the same way, if foul weather follow the fall of the mercury, it will last but a short time.

4. If fair weather continue for several days, during which the mercury continually falls, a long succession of foul weather will probably ensue; and again, if foul weather continue for several days while the mercury continually rises, a long succession of fair weather will probably succeed.

5. A fluctuating and unsettled state in the mercurial column indicates changeable weather.

Here is another set of weather barometric prognostics :—

1. If the barometer begin to fall slowly and steadily after a long continuance of dry weather, rain will certainly follow; but if the fair weather have been of very long duration, no perceptible change may take place for some days, and the longer the time which elapses between the fall of the barometer and the commencement of the rain, the longer will be the subsequent continuance of the foul weather.

2. The preceding rule may be inverted. If the barometer begin to rise slowly and steadily, after a long continuance of rainy weather, fair weather will certainly follow; and if several days elapse between the rise of the barometer and its commencement, it will have so much the longer continuance.

3. If, in either of these cases, the changes follow promptly upon the motion of the mercury, the new state of the weather will not be of long continuance.

4. If, during two or three days successively, the barometer rise slowly and steadily, rain nevertheless falling constantly, fair weather will certainly follow, and *vice versâ*. But if the barometer rise during rain, and then fall at the commencement of fair weather, the fair weather will be very transient; and *vice versâ*.

5. A sudden fall of the mercury in spring or autumn is followed by high winds; in summer, and especially during sultry weather, it is followed by a thunder-storm. In winter, a sudden fall after

long-continued frost, is followed by a change of wind, and a thaw and rain; but after a continued frost, a rise of the mercury is usually followed by snow.

6. No rapid fluctuations of the mercury are to be taken as indications of any change of long continuance. It is only the slow, steady, and continuous rise or fall, that is to be attended to as such a prognostic.

7. A rise of the mercury late in the autumn, after a long continuance of wet and windy weather, generally indicates a change of wind towards the north, and approaching frost.

THE SAFETY LAMP.

1. Introductory observations.—2. Fire-damp—Sir Humphry Davy invents the Safety Lamp.—3. Nature and laws of flame investigated and discovered by him, and rendered subservient to his invention.

1. Art often presses into its service the discoveries of science, but it sometimes provokes them. Art surveys the fruit of the toil of the philosopher, and selects such as suit her purposes; but sometimes, not finding what meets her wants, she makes an appeal to science, whose votaries direct their researches accordingly towards the desired object, and rarely fail to attain it.

One of the most signal examples of the successful issue of such an appeal presents itself in the *safety-lamp*.

2. The same gas which is used for the purposes of illumination of our cities and towns (and which, as has been stated, is obtained from coals by the process of baking in close retorts), is often spontaneously developed in the seams of coal which form the mines, and collects in large quantities in the galleries and workings where the coal-miners are employed. When this gas is mingled with common air, in a certain definite proportion, the mixture becomes highly explosive, and frequently catastrophes, attended with frightful loss of life, occur in consequence in the mines. The prevalence of this evil became so great, that government called the attention of scientific men to the subject; and the late Sir Humphry Davy engaged in a series of experimental researches with a view to the discovery of some efficient protection for the miner, the result of which was the now celebrated safety-lamp.

3. Davy first directed his inquiries to the nature and properties of flame. What is flame? was a question which seems until then never to have been answered or even asked.

All known bodies, when heated to a certain intensity, become luminous. Thus iron, when its temperature is elevated, first gives a dull red light, which becomes more and more white as the temperature is increased, until at length it becomes as white as the sun. Davy showed that gaseous substances are not exempt from this law, and that flame is nothing more than *gas* rendered *white hot.*

He further showed that if the gas thus rendered white hot be cooled, it will cease to be luminous in the same manner, and from the same cause, as would be the case with a red hot poker plunged in water.

He showed that the gas which forms flame may be cooled by putting it in contact with any substance, such as metal, which is a good conductor.

Thus, if a piece of wire net-work, with meshes sufficiently close, be held over the flame of a lamp or candle, it will be found that the flame will not pass through the meshes. The wire will become red hot, but no flame will appear above it.

It is not, in this case, that the gas which forms the flame does not pass through the meshes of the wire, but in doing so, it gives up so much of its heat to the metal, that when it escapes from the meshes above the wire, it is no longer hot enough to be luminous.

Sir Humphry Davy, in the researches which he was called to make discovered this important fact, which enabled him to explain the nature and properties of flame; and having so discovered it, he did not fail promptly to apply it to the solution of the practical problem with which he had to grapple.

This problem was, to enable the miner to walk, lamp in hand, through an atmosphere of highly explosive gas, without the possibility of producing explosion. It was as though he were required to thrust a blazing torch through a mass of gunpowder, without either extinguishing the flambeau or igniting the powder; with this difference, however, that the gaseous atmosphere to which the miner was often exposed was infinitely more explosive than gunpowder.

The instrument by which he accomplished this was as remarkable for its simplicity as for its perfect efficiency. A common lantern, containing a lamp or candle, instead of being as usual enclosed by glass or horn, was enclosed by wire gauze of that degree of fineness in its meshes which experiment had proved to be impervious to flame. When such a lantern was carried into an atmosphere of explosive gas, the external atmosphere would enter freely through the wire gauze, and would burn quietly within the lantern; but the meshes which thus permitted the cold gas to enter, forbade the white-hot gas within to escape without parting with so much of its heat in the transit as to deprive it of the character and properties of flame; so that, although it passed into the external explosive atmosphere, it was no longer in a condition to inflame it.

The lamp thus serves a double purpose: it is at once a *protection* and a *warning*. It protects, because the flame within cannot ignite the gas outside the lantern. It warns, because the miner, seeing the gas burning within the lantern, is informed that he is enveloped by an explosive atmosphere, and takes measures accordingly to ventilate the gallery, and meanwhile to prevent unguarded lights from entering it.

Nothing can be imagined more triumphantly successful than this investigation of Sir Humphry Davy. Some philosophers have the good fortune to arrive at great scientific discoveries in the prosecution of those inquiries to which the course of their labours leads them. Some are so happy as to make inventions of high importance in the arts, when such applications are suggested by the laws which govern the phenomena that have arisen in their experimental researches. But we cannot remember any other instance in which an object of research being proposed to an experimental philosopher, foreign to his habitual inquiries, having no associations with those trains of thought in which his mind has been previously involved, he has prosecuted the inquiry so as to arrive not only at the development of a natural law of the highest order, the fruitful parent of innumerable consequences of great general importance in physics, but at the same time, to realise an invention of such immense utility as to form an epoch in the history of art, and to become the means of saving countless numbers of human lives.

WHITWORTH'S MICROMETRIC APPARATUS.

AMONG the many admirable machines produced by Mr. Joseph Whitworth at the Great Exhibition, was a micometric apparatus for establishing uniform standards of magnitude for taps, axles, and other important component parts of machines. By this instrument, magnitudes, so minute as even to elude the microscope, are submitted to mechanical measurement.

Two perfectly plane and smooth metallic surfaces are first formed, partly by friction against each other, and partly by abrasion with a peculiar tool.

So plane are the surfaces of metal thus formed, that when one is laid upon the other no one part comes into closer contact than another, and there is included between them a stratum of particles of air which act like infinitely smooth rollers, and the surfaces move in contact one with another with a degree of freedom, owing to the lubricity of the air, which must be felt to be conceived. If, however, the surfaces be so severely pressed against each other as to exclude the air, the contact becomes so complete that it is with great difficulty they can be separated.

These surfaces, thus accurately formed, are used as standards to test other plane surfaces, and with these are tested the ends of a standard measure of metal, which is placed in an accurately formed horizontal metallic bed. One end bears against a metallic pin; another metallic pin, urged by a screw, presses against the other end; and if this metallic bar, by change of temperature or any other cause, suffer a change in its length amounting to the millionth part of an inch, that change is rendered perceptible by the following arrangement;—

The pin which bears against its extremity is moved by a screw, which has ten threads to the inch. On the head of this screw is a wheel, consisting of 400 teeth, which works in a worm driven by another wheel, the rim of which is divided into 250 visible parts. Now, since each thread of the original screw corresponds to the 1-10th part of an inch, each tooth of the wheel upon its head will correspond to the 4000th part of an inch, and each division of the wheel attached to the worm will correspond to the millionth part of an inch.

It is found, in the application of this apparatus, that a change in the position of the wheel attached to the worm, through one of the 250 divisions, is rendered sensible at the point of the screw which bears against the standard bar; but since the motion of the former wheel through one division can produce a motion amounting only to the millionth part of an inch in the point of the screw, this magnitude is thus rendered sensible.

To prove the accuracy of this micrometric apparatus, a standard yard measure made of a bar of steel, about three quarters of an inch square, having both the ends rendered perfectly true, was placed in it. One end of the bar was then placed in contact with the face of the machine, and at the other end, between it and the other face of the machine, was interposed a small flat piece of steel, termed by the experimenter "the contact piece," whose sides were also rendered perfectly true and parallel. Each division on the micrometer represented the one-millionth part of an inch, and each time the micrometer was moved only one division forward, the experimenter raised the contact piece, allowing it to descend across the end of the bar by its own gravity only. This was repeated until the closer approximation of the surfaces prevented the contact piece from descending, when the measure was completed, and the number on the micrometer represented the dead length of the standard bar to the one-millionth part of an inch.

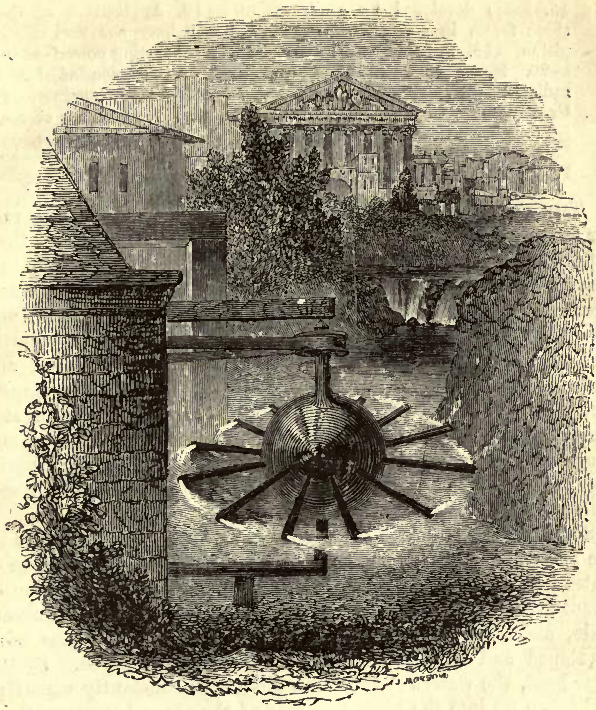
Eight repetitions of the experiment in a quarter of an hour produced identical results, there not being in any case a variation of one-millionth of an inch.

This method of operating was termed "the system of proof by the contact of perfectly true surfaces and gravity;" and in connexion with it was shown another interesting experiment.

When the micrometer was screwed up within one division of the number where contact would be presumed to occur, the warmth of the finger applied to the centre of the steel bar sufficed to expand and lengthen it instantaneously, so as to prevent the descent of the "contact piece."

The other method of proof was by having a small simple battery composed of a piece of zinc soldered on to a piece of copper and plunged into rain water, without the admixture of any acid; this was connected with the two ends of the measuring machine, and also with a delicate galvanometer. On pursuing the same process of advancing the micrometer one division at a time, no effect was produced until the last millionth of an inch of distance was traversed, and absolute contact occurred with the end of the bar, when the deflection of the needle of the galvanometer instantly betrayed the movement. Repeated experiments showed this to be unerring in the result, and on placing the finger on the middle of the bar, under the same circumstances as in the other course of experiments, the expansion was instantly detected by the deflection of the galvanometric bar.

By the application of this instrument, standard gauges for axles, taps, and other parts of machinery which it is desirable to maintain uniform, are constructed, and have been adopted by the Admiralty.



HERO OF ALEXANDRIA.

STEAM.

1. Power of steam manifested by natural evaporation. — 2. Early attempts at its mechanical application—Inventions of Watt.—3. Influence of steam power on mankind.—4. Its agency in commerce and the arts.—5. Analysis of its operation.—6. Combustion of coals.—7. Force developed by the evaporation of water.—8. Steam an invisible aeriform fluid.—9. Measure of the mechanical force developed.—10. Heat absorbed in evaporation.—11. Latent heat of steam.—12. Effect of varying pressure. — 13. Mechanical force independent of the pressure.—14. Force developed by expansion.—

15. Force developed by condensation. — 16. Application of these three forces in steam engines.—17. Steam may act variously on piston.—18. Furnaces and boilers.—19. Evaporating power of fuel —20. Means of economising heat. — 21. Prevention of loss by radiation.—22. Inspection and reports of Cornish engines.—23. Greatly improved efficiency.—24. Actual mechanical virtue of coals. —25. Illustrations—Pyramids of Egypt.—26. Menai Bridge.—27. Railway engines.—28. Exhaustion of coal mines improbable.—29. Prospects of scientific discovery.

1. The surface of the globe has been inhabited by the human race for at least fifty or sixty centuries. During that long period their intelligence has been as acute, their interests as exigent, and their craving for material good, as insatiable as at present; yet a natural agent of vast power which existed around them, below them, and above them, whose play was incessant in the air, upon the earth, and in the waters under the earth, remained unobserved and undiscovered until the last century; its powers were imperfectly developed until late in the present century, and its still undeveloped consequences and effects, affecting the well-being and progress, physical, moral, and intellectual, of the whole human race, are such as the most acute and far-sighted cannot foresee. This giant power is Steam.

Since the day on which the land was divided from the waters by the Word of the Most High, evaporation,—that is the conversion of water into steam,—and condensation,—that is the reconversion of steam into water,—have been incessantly in operation upon a vast scale, and a corresponding amount of mechanical force has been developed and manifested on every part of the globe. By the solar heat, the waters of the ocean have been constantly vaporised and taken up into the higher regions of the air. Assuming there the form of clouds, they have been attracted by the mountains, and the more elevated parts of the land. There condensation has taken place, and the vapour has been re-converted into water, or even reduced by still greater cold to the solid state, and has been precipitated in the form of rain, hail, or snow, more or less, on all parts of the land, but chiefly, and most abundantly, on the summits of mountain chains, and on the more elevated regions. Descending from thence along the surface, they form the streams of rivers, and the torrents of cataracts, manifesting everywhere vast mechanical force, of which man has eagerly availed himself, without reflecting on its origin, or being conscious that he was using the indirect power of steam. By the force exhibited in the flow of rivers, transport from the interior of continents to their coasts has been effected since the earliest times, and among people the least advanced in the arts of life. By the force of cataracts, mills have been worked even in ancient times and among rude nations. In a word, what is called WATER-POWER is, in reality, in all cases, the indirect power of steam, being due to the descent of that mass of liquid which had been previously elevated on so vast a scale by natural evaporation.

2. Nevertheless, these phenomena failed to suggest the artificial application of the same power. It was not until the commencement of the last century that any serious progress had been made towards the solution of that problem. About that time, engines were constructed, in which the elastic force of steam, as well as the force resulting from its re-conversion into water, was applied, as a mechanical power. The engines first constructed were defective, their performance unsatisfactory, and the cost of their maintenance greater than that of the power, which they aspired to supersede. At length, however, towards the middle of the last century, the genius of Watt was fortunately turned to this problem, and those great inventions were made, and improvements effected, the final result of which has been the creation of a power which has exercised a greater influence upon the condition of the human race, material, social, and intellectual, than was ever before recorded in the history of its progress.

3. To enumerate the benefits which the application of steam has conferred upon mankind, would be to count every comfort and every luxury we enjoy, whether physical or intellectual, many of which it has created, and all of which it has augmented in an immense proportion. It has penetrated the crust of the earth, and drawn from beneath it boundless treasures of mineral wealth, which, without its aid, would have remained inaccessible; it has drawn up, in measureless quantity the fuel on which its own life and activity depend; it has relieved men from many of their most slavish toils, and reduced their labour in a great degree to light and easy superintendence. It has increased the sum of human happiness, not only by calling new pleasures into existence, but by so cheapening former enjoyments as to render them attainable by those who before could never have hoped to share them: the surface of the land and the face of the waters are traversed with equal facility by its power; and by thus stimulating and facilitating the intercourse of nation with nation, and the commerce of people with people, it has knit together remote countries by bonds of amity not likely to be broken. Streams of knowledge and information are kept flowing between distant centres of population; those more advanced diffusing civilisation and improvement among those that are more backward. The press itself, to which mankind owes in so large a degree the rapidity of their improvement in

modern times, has had its power and influence increased in a manifold ratio by its union with the steam engine. It is thus that literature is cheapened, and, by being cheapened, diffused; it is thus that Reason has taken the place of Force, and the pen has superseded the sword; it is thus that war has almost ceased upon the earth, and that the differences which inevitably arise between civilised nations are for the most part adjusted by peaceful negotiation.

If this last result of a high state of civilisation and intelligence fails to be manifested, the case can only arise where a barbarous power intervenes, which is deaf to reason, and only controllable by brute force.

4. The steam-engine is a piece of mechanism by which fuel is rendered capable of executing any kind of labour. By it coals are made to spin, weave, dye, print, and dress silks, cottons, woollens, and other cloths; to make paper, and print books on it when made; to convert corn into flour; to press oil from the olive, and wine from the grape; to draw up metal from the bowels of the earth; to pound and smelt it, to melt and mould it; to forge it; to roll it, and to fashion it into every form that the most wayward caprice can desire. Do we traverse the deep?—they lend wings to the ship, and bid defiance to the natural opponents, the winds and the tides. Does the wind-bound ship desire to get out of port?—they throw their arms around her, and place her on the open sea. Do we traverse the land?—they are harnessed to our chariot, and we outstrip the flight of the swiftest bird, and equal in speed the fury of the tempest.

The substance by which these powers are rendered active is one which Nature has provided in boundless quantity in all parts of the earth, and though it has no price, its value is inestimable. This substance is WATER.

5. Those who desire to comprehend clearly and fully this vast agency, to which so much of the advancement and civilisation of mankind is due, must learn successively, 1st. The principles on which heat is evolved from fuel; 2nd. The expedients by which that heat is imparted to water; 3rd. The quantity of it which is absorbed in the conversion of water into steam; 4th. The mechanical power developed in this physical change; and 5th. The mechanism by which that power is applied to industrial uses.

It is obvious that the last of these points would include the exposition of the structure and operation of the varieties of steam-engines which have been applied to the purposes of commerce and manufactures, to railways and navigation. Upon this large subject it is not our present purpose to enter. We shall, however, explain the preceding, so as to enable our readers, with moderate attention, to comprehend clearly the origin of the power of steam, and the physical conditions which determine its maintenance and its limits.

6. The general principles upon which heat is developed in the combustion of fuel have been already explained in our Tract on FIRE. It appears from what is there stated, that the varieties of coal are chiefly combinations of carbon and hydrogenous gases, the proportion varying in different sorts, but the carbon entering into its composition in very large proportions in all cases. In different sorts of mineral combustibles, the proportion of carbon varies from 75 to 90 per cent.

When carbon is heated to a temperature of about 700° in an atmosphere of pure oxygen, it will combine chemically with that gas, and the product will be the gas called *carbonic acid.* In this combination heat is evolved in very large quantities. This effect arises from the heat previously latent in the carbon and oxygen being rendered sensible in the process of combustion. The carbonic acid proceeding from the combustion is by such means raised to a very high temperature, and the carbon during the process acquires a heat so intense as to become luminous; no flame, however, is produced.

Hydrogen, heated to a temperature of about 1000°, in contact with oxygen, will combine with the latter, and a great evolution of heat will attend the process; the gases will be rendered luminous, and flame will be produced.*

If coals, therefore, or other fuel exposed to atmospheric air be raised to a sufficiently high temperature, their combustible constituents will combine with the oxygen of the atmospheric air, and all the phenomena of combustion will ensue. In order, however, that the combustion should be continued, and should be carried on with quickness and activity, it is necessary that the carbonic acid and other products should be removed from the combustible as they are produced, and fresh portions of atmospheric air brought into contact with it; otherwise the combustible would soon be surrounded by an atmosphere composed chiefly of carbonic acid to the exclusion of atmospheric air, and therefore of uncombined oxygen, and consequently the combustion would cease, and the fuel be extinguished. To maintain the combustion, therefore, a current of atmospheric air must be constantly carried through the fuel: the quantity and force of this current must depend on the quantity and quality of the fuel to be consumed. It must be such that it shall supply sufficient oxygen to the fuel to maintain the combustion, and not more than sufficient, since

* For the full explanation of this process, see Tract on Fire.

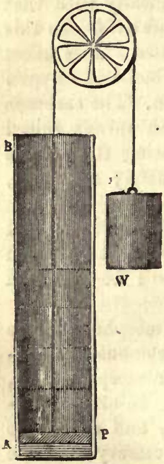
any excess would be attended with the effect of absorbing the heat of combustion, without contributing to the maintenance of that effect.*

The mechanical force of steam is developed in three ways—I. By evaporation; II. By expansion; and III. By condensation. We shall accordingly explain these severally.

7. I.—FORCE DEVELOPED BY EVAPORATION.

To render intelligible the manner in which a mechanical power is developed in the conversion of water into steam, and the circumstances which attend that remarkable physical change, we will suppose a quantity of pure water deposited in the bottom, A, of a tube, B A, fig. 1. To render the explanation more simple, we will suppose that the area of the section of the tube is equal to a square inch, and that the quantity of water deposited in it is a cubic inch. We will further imagine the tube to be glass, so that the phenomena developed in it may be visible. Let a piston, P, be imagined to be fitted in the tube, air tight and steam tight, and to be placed in immediate contact with the surface of the water, so as to exclude all communication between the water and the air above the piston. In this case the piston would be pressed upon the water by the pressure of the atmosphere upon a square inch of surface added to the weight of the piston itself. But the former pressure is equal to 15 lb.,† and therefore the pressure on the surface of the water will exceed the weight of the piston by 15 lb. Now to simplify our explanation by excluding all reference to the atmospheric pressure, and the particular weight of the piston, P, we shall suppose both of these exactly counterpoised by the weight, W, so that the piston shall be placed in contact with the surface of the water, without, however, exerting any pressure upon it.

Fig 1.



These conditions being understood, let a weight, say of 15 lb., be placed upon the piston P, and let a fire, a lamp or any other regular source of heat, be applied to the bottom of the tube. If a thermometer were immersed in the water under the piston, the following effects would then be observed:—

* See Tract on Fire. † See Tract on Air.

The thermometer would rise, the piston maintaining its position, and this would continue until the thermometer would rise to the temperature of 212°. Upon rising to that temperature the thermometer would remain stationary, and at the same time the piston, P, would begin to rise, leaving a space apparently empty between it and the surface of the water. The lamp, or fire, still continuing to impart the same heat to the water, the thermometer nevertheless will remain stationary at 212°, but the piston will continue to rise higher and higher in the tube, and if the depth of the water in the bottom of the tube be measured, it will be found that it is constantly diminished. If a sufficiently exact measurement of the decrease of the depth of water, and the height to which the piston is raised could be made, it would be found that the one would bear a fixed and invariable proportion to the other, the height of the piston being always 1669 times the decrease of the depth of water.

In fine, if this process were continued for a sufficient time, and if the tube had sufficient length, the water would altogether disappear from the bottom of the tube, and the piston would be raised 1669 inches, or 139 feet very nearly. For the convenience of round numbers, in a case where the most extreme arithmetical accuracy is not needed, we shall then assume that the piston loaded with 15lb. has been raised 140 feet.

8. After this has taken place the tube below the piston will appear to be quite empty, the water having disappeared, and no visible matter having taken its place. If, however, the tube and its contents were weighed, they would be found to have the same weight precisely as they had when the water was deposited under the piston.

The phenomenon is easily explained. The heat applied to the tube has converted the visible liquid water into invisible steam. It is a great but very common error to suppose that the whitish cloudy vapour which is seen to issue from the safety valve of an engine, or the funnel of a locomotive, or the spout of a boiling kettle, is steam. The semi-transparent matter which floats in the air, and continues to be visible for some time after it escapes from the boiler, is in fact not steam, but water existing in very minute particles, produced by the condensation of the steam by the contact of the colder air. When those particles coalesce and form small drops of water, they either fall to the ground or are evaporated at a lower temperature, and in either case disappear. If the vapour issuing from the safety valve of an engine, or the spout of a boiling kettle, be closely examined, it will not be found to have that cloudy semi-transparent appearance until it has passed to some distance from the point from which it issues.

Pure steam is, in fact, a transparent and invisible elastic fluid like air, and this explains how it is, that in the tube, A B, the space below the piston, after the evaporation of the water, *appears* to be empty. It is, however, no more empty than if it were filled with air. It is filled with the invisible elastic vapour into which the water has been converted by the heat which has been applied to it.

9. It remains now to show what is the quantity of mechanical force evolved in this conversion of water into steam, and what quantity of heat has been absorbed in producing it.

From what has been stated above, it appears that the water in passing into vapour has swelled into 1669 times its original bulk, being subject to a compressing force of 15lb. upon the square inch. In thus expanding, the weight of 15lb. has been raised 140 feet, an effect which is mechanically equivalent to 140 times 15lb., that is 2100lb. raised one foot.

10. To estimate the quantity of heat absorbed in producing this effect, let us suppose that in the commencement of this process, the water under the piston has the temperature of 32°, and that the lamp, or other source of heat, which is applied to it acts with such uniformity as to impart exactly the same quantity of heat per minute.

Let the time which elapses between the first application of the lamp and the moment at which the water attains the temperature of 212° and begins to be evaporated, be observed, and also the interval between the commencement of evaporation and the total disappearance of the water. It will be found that the latter interval is $5\frac{1}{2}$ times the former. It follows consequently that to convert water at 212° into steam requires $5\frac{1}{2}$ times as much heat as is necessary to raise the same water from 32° to 212°, or what is the same, the quantity of heat which would convert water at 212° into steam would increase the temperature of the same water by $5\frac{1}{2}$ times 180°, that is by 990°, if it had remained in the liquid state.

It follows also, that to convert water at 32° into steam will take $6\frac{1}{2}$ times as much fuel as would be sufficient to boil the same water.

11. It may be asked, what becomes of the enormous quantity of heat thus imparted to the water during the process of its evaporation, seeing that the water itself receives no increase of temperature, being maintained steadily at 212°, and that the steam into which it is converted has the same temperature? This is answered by showing that the entire quantity of heat which thus disappears to the thermometer is absorbed by the steam, and must in fact be regarded as the immediate cause of its maintaining the elastic or vaporous form. That it is actually contained in the steam, though

its presence is not indicated by the thermometer, is incontestably established by the result of the following process :—

Let the steam, at 212°, which has been evolved from a cubic inch of water at 32°, be mixed with $5\frac{1}{2}$ cubic inches of water at the temperature of 32°. The steam will be at once reconverted into water, and the mixture will be $6\frac{1}{2}$ cubic inches of water, the temperature of which will be 212°. Thus it appears that the steam at 212°, when reconverted into a cubic inch of water at 212°, parts with as much heat as suffices to raise $5\frac{1}{2}$ cubic inches of water from 32° to 212°, which is exactly the quantity of heat which disappeared while the water was converted into steam.

The heat which is thus contained in steam, without affecting the thermometer, is said to be LATENT, and the latent heat of steam is therefore stated to be about 1000°, the meaning of which is, that to convert boiling water into steam as much heat must be imparted to it as would raise it 1000° higher in temperature if it did not undergo that change of state.

12. In the preceding explanation we have supposed the piston P to carry a weight of 15 lb. Let us now consider in what manner the phenomena would be modified if it were loaded with a greater or less weight.

If it were loaded with 30lb., the conversion of the water under it into steam would not commence until the temperature is raised to $251\frac{1}{2}$°, and when the whole of the water is evaporated, the piston would be raised to the height of only 883 inches, being a very little more than half the height to which it was raised when the evaporation took place under half the pressure. For all practical purposes, then, we shall be sufficiently accurate in stating, that when the weight on the piston P is doubled, it will be raised by the evaporation of a given quantity of water to half the height.

In general, in whatever proportion the weight on the piston is increased, the height to which it is raised by the evaporation of a given quantity of water will be decreased, and in whatever proportion the weight is diminished, the height will be increased.

13. It follows, therefore, that in all cases, whatever be the pressure under which the evaporation takes place, the same mechanical force is developed by the evaporation of the same quantity of water. Strictly speaking, there is a little more force with greater pressures, but the difference is so small, and so nearly balanced by certain practical disadvantages attending high pressures, that it may be wholly disregarded.

Since the amount of force developed by each cubic inch of water evaporated is equivalent to 2100 lb. raised one foot, we shall be sufficiently near the truth in stating in round numbers that such a force is equivalent to a ton weight raised a foot high.

It appears also, that under a pressure of 15 lb. per square inch, water swells into 1669 times its bulk when it is converted into steam. Since a cubic foot is 1728 cubic inches, and since the mean atmospheric pressure is a little under 15 lb., it may be stated with sufficient precision for all practical purposes, that a cubic inch of water, evaporated under the mean atmospheric pressure, will produce a cubic foot of steam.

14. II.—FORCE DEVELOPED BY EXPANSION.

Steam, in common with all vapours and gases, exerts a certain mechanical force by its property of expansibility.

To render this source of mechanical power intelligible, let us suppose the piston P loaded at first with 60 lb. for example, and under this pressure let the water be evaporated, and the piston raised to the height of 35 feet. The power thus developed will be that due to evaporation alone. But after the evaporation has ceased, and when the piston, with its load of 60 lb., is suspended at the height of 35 feet, let 15 lb. be taken from it, so as to leave a load of only 45 lb. The pressure below the piston being then greater than its load, it will be elevated, and as it is elevated, the steam below it increasing in volume, will be diminished in pressure in the same proportion, until the piston is raised to a height equal to one-third part of 140 feet, when the pressure below it will be equal to the load upon it, and it will remain suspended. During this expansive action of the steam, therefore, 45 lb. have been raised through a height equal to a difference between $\frac{1}{3}$ and $\frac{1}{4}$, that is, through $\frac{1}{12}$ of 140 feet.

At this point let 15 lb. more be supposed to be removed from the piston, so that its load shall be reduced to 30 lb. The pressure below it being, as before, greater than its load, the piston will be raised, and will continue to rise, until it rise to a height equal to half of 140 feet, when the pressure, reduced by expansion, will become equal to the load, and the piston will again become suspended.

In this interval 30 lb. have therefore been raised by the expansive action of the steam, through the difference between $\frac{1}{2}$ and $\frac{1}{3}$, that is, through $\frac{1}{6}$ of 140 feet.

Finally, suppose 15 lb. more to be removed, and the piston will rise with the remaining 15 lb. to the height of 140 feet, so that, in this last expansive action, 15 lb. are raised through a height equal to the half of 140 feet.

It is evident that the result of the expansive action may be indefinitely varied by varying the extent of its play.

Meanwhile, whatever may be its amount, it is clearly quite independent of the process of evaporation, and, indeed, of every property by which vapours are distinguished from air or gases, inasmuch as these latter, being similarly compressed, would similarly expand, and would develope in their expansion precisely the same force.

15. III.—FORCE DEVELOPED BY CONDENSATION.

It has been already explained * that as heat converts water into steam, so, on the other hand, will cold convert steam into water; and as water, in passing from the liquid to the vaporous state, is swelled into a vastly increased volume, so, on the other hand, in passing from the vaporous to the liquid state, it suffers a proportionate diminution of volume. Thus if the evaporation take place under a pressure of 15 lb., a cubic inch of water is dilated into a cubic foot of steam. Now, if by the application of cold this steam is converted into water, it will resume its original dimensions, and will become a cubic inch of water. This change of vapour into water has therefore been called CONDENSATION, inasmuch as the matter of which it consists, contracting into a much smaller volume, is rendered proportionally more dense.

This property has supplied another means of rendering steam a mechanical agent. Let us suppose that after the piston P, fig. 1, has been raised 140 feet high by the evaporation of a cubic inch of water, the counterpoise, W, having descended through the same height, an additional weight of 15 lb. is placed upon W, and, at the same time, the lamp withdrawn from the tube and cold applied to its external surface. The steam by which the piston was raised will then be converted into water, or condensed, and will, as at first, fill the bottom of the tube to the height of an inch. The space within the tube above the surface of the water extending to the height of 140 feet, will then be a vacuum, and the atmospheric pressure acting above the piston, not being resisted by any corresponding pressure below it, will force the piston down with a force of 15 lb., and will raise the weight W, loaded with the additional 15 lb. through the same height.

Thus, it appears that when steam is condensed, or reconverted into water, by producing a vacuum, it developes a mechanical force equal to that which was developed in the conversion of water into vapour.

The mechanical power developed by the evaporation of water has been sometimes called the *direct* power, and that produced by the conversion of vapour into water the *indirect* power of

* See Tract on Water.

steam, because the immediate agent in the former case is the elastic force of the steam itself, while the agent in the latter case is the atmospheric pressure, to which effect is given by the vacuum produced by the condensation of steam.

16. The three sources of mechanical power which have been explained, have been used sometimes separately and sometimes together in different forms of steam engine.

In the class of engines commonly called high-pressure engines, the direct power alone is used. In a class of engines, now out of use, called atmospheric engines, the indirect power alone was used. In the engines most generally used in the arts and manufactures, known as low pressure or condensing engines, both powers are used.

To obtain the mechanical effect of the vacuum produced by the condensation of steam, it is not necessary that the atmospheric pressure should be used. If we suppose that while the vacuum is produced below the piston P, steam having a pressure equal to that of the atmosphere be admitted to the upper side of it, the piston will be urged downwards into the vacuum with the same force exactly as if the atmosphere acted upon it.

And, in effect, this is the method by which the indirect force of steam is rendered effective in all engines as at present constructed, the piston being in no case exposed to the atmosphere.

17. In the preceding illustration of the power of steam, we have supposed the piston P to have the area of a square inch, and to be raised continuously to the height of 140 feet. But it is evident that such conditions are neither necessary nor practicable. If the piston had an area of ten square inches the same amount of evaporation would raise it to the tenth part of the height; but the force with which it would be raised, being at the same time increased in a tenfold proportion, the mechanical effect would be the same, for it is evident that whether 15 lb. be raised 140 feet, or 10 times 15 lb. be raised the 10th part of 140 feet, the same mechanical effect would be produced.

The piston acted upon by the steam, instead of being continuously driven in one direction, may be alternately elevated and depressed, and still the same amount of power will be developed. Thus the evaporation may be continued until the piston has been raised 10 feet. The steam which raised it may then be condensed, and the piston having descended to the bottom of the tube, it may again be raised 10 feet by evaporation as before, and this may be continued indefinitely. In this way, by means of a short tube or cylinder, the mechanical effect attending the evaporation of any quantity of water may be obtained, and this, in fact, is what is accomplished in steam engines as they are practically worked.

The direct and indirect powers of steam may also be easily combined as well in the ascent as in the descent of the piston. If we suppose the upper part of the tube, instead of being open to the atmosphere, to communicate with a reservoir of water, to which, like the bottom of the tube, a lamp or other source of heat is applied, steam may be admitted above the piston P as well as below it. Now, if such be the case, it is easy to imagine how the piston can be at the same time affected by the direct and indirect power of the steam. Thus, if we suppose that a vacuum has been formed above it, by the condensation of steam, admitted from the upper reservoir, while steam produced from the lower reservoir acts below it, the piston will be forced upwards by the combined effect of the direct action of the steam below and the indirect action of the condensed steam above, and when the piston has been thus raised, we can imagine that while steam is admitted above it from the upper reservoir, that which is below it may be condensed, in which case it will be forced down by the combined effect of the direct action of the steam above it and the indirect action of the condensed steam below it, and it is evident that such alternate action may be indefinitely continued.

Such is the effect of the broad principle upon which all engines of the class called condensing, or low-pressure engines, are constructed. In their details there are numerous points of great practical importance and of much interest in a mechanical point of view. These arrangements, however, not affecting the principle of steam, regarded in its most general sense, need not here be further noticed. On a future occasion we shall explain such of them as have the greatest popular interest.

18. The apparatus by which the combustion of the fuel is effected, and by which the heat evolved is transmitted to the water to be evaporated, are furnaces and boilers of very various forms and construction, according to the circumstances in which they are applied, the one being adapted to the other, so that as much of the heat shall arrive at the water as the circumstances of their application permit.

19. The quantity of water which would be evaporated, if all the heat evolved in the combustion of a given weight of fuel could be transmitted to the water, is the THEORETICAL EVAPORATING POWER of the fuel, and the quantity of water actually evaporated by it is the PRACTICAL EVAPORATING POWER.

The theoretical evaporating power varies with the quality of the fuel. A given weight of certain species of coal will evolve in combustion a greater or less quantity of heat than other species.

In general, it may be stated that the strongest coals, meaning by that term those which have the greatest evaporating power, are those which are richest in carbon.

The practical evaporating power of a given species of coal varies with the form, construction, and magnitude of the furnace and boiler. That portion of the heat which does not reach the water is dissipated in various ways. A part of it is lost by radiation from the grate; a part by radiation from the boiler; a part is carried by the heated gases of combustion into the chimney. The first two sources of waste of heat are reduced to a very small amount by a variety of ingenious contrivances. But the last is indispensable to the maintenance of the combustion, and ought to be considered as the power by which the furnace is worked, rather than a waste of heat.

20. The grate upon which the fuel is placed is surrounded on every side by parts of the boiler within which water is contained.

In some boilers, even the ash-pit is a part of the surface of the boiler under which there is water. In this case, all the heat radiated from the grate, and the fuel upon it, is transmitted to the boiler; and in all cases the furnace is surrounded on every side, except the bottom of the grate or ash-pit, with surfaces having water within them.

21. The waste of heat by radiation from the surfaces of the boiler, steam-pipes, cylinder, and other parts of the machinery in which steam is contained, or through which it passes, is diminished by various expedients, which in general consist in surrounding such surfaces with packing, casing, or coating, composed of materials which are non-conductors, or at least very imperfect conductors of heat.

In some cases the boiler is built round in brick work. In Cornwall, where economy is carried perhaps to a greater extent than elsewhere, the boiler and steam-pipes are surrounded with a packing of sawdust, which being almost a non-conductor of heat, is impervious to the heat proceeding from the surfaces with which it is in contact, and consequently confines all the heat within the boiler. In marine boilers it has been the practice recently to clothe the boiler and steam-pipes with a coating of felt, which is attended with a similar effect. When these remedies are properly applied, the loss of heat proceeding from the radiation of the boiler is reduced to an extremely small amount. The engine houses of some of the Cornish engines, where the boiler generates steam at a very high temperature, are frequently maintained at a lower temperature than the external air, and on entering them they have in a great degree the effect of a cave.

The cylinders are often cased in wood. The boilers of locomotive engines are always covered with a coating of boards.

By these and many other expedients for the economy of heat, and more especially by the extensive application of the expansive force of steam, the mechanical power evolved from the combustion of coals has been increased to an almost incredible extent.

22. A system of public inspection, of the performance of the engines worked in the mining districts of Cornwall, was established about forty years ago, which has been continued to the present time with the greatest advantage to the mining interests in particular, and to the engineering and commercial world in general. An exact account is kept, and periodical reports published of the quantity of fuel consumed by each engine, and the quantity of work done, the latter being expressed always by an equivalent weight, raised one foot high. The ratio of the fuel consumed to the weight thus raised is called the DUTY of the engine.

23. The improved efficiency of steam machinery is illustrated in a striking manner by these reports. It appears by them, that, in 1813, the average mechanical effect of a bushel of coals, applied in the best of the Cornish engines, was 11785 tons raised one foot. In 1837, this duty was 38935 tons raised one foot. The duty was therefore augmented in the ratio of 1 to $3\frac{1}{3}$.

The increase of the mechanical efficiency of fuel has still gone on from year to year, and it may now be considered that a bushel of coals, of average quality, applied under good conditions of economy to the most efficient engines, is capable of producing a mechanical effect equivalent to 50000 tons raised one foot.

24. It follows, therefore, that a pound of coal has a mechanical virtue expressed by six hundred tons weight raised one foot high.

25. It is only by comparison with other physical agents that we can duly appreciate this prodigious mechanical power of coals.

It is calculated that the materials composing the great pyramid of Egypt might have been elevated from the level of its base to their actual places by the combustion of 700 tons of coal.

26. Those of the Menai Bridge might have been raised from the level of the water by 400 lb. of coal.

27. A train of coaches weighing 80 tons, and conveying 240 passengers, is drawn from Liverpool to Birmingham, and back from Birmingham to Liverpool by the combustion of 4 tons of coke, the cost of which is *5l.* To carry the same number of passengers daily on a common road would require an establishment of 20 stage coaches and 3800 horses.

The circumference of the earth measures twenty-five thousand miles; if it were begirt with an iron railway, such a train as above-described, carrying two hundred and forty passengers, would be drawn round it by the combustion of about three hundred tons of coke, and the circuit would be accomplished in five weeks.

28. The enormous consumption of coals produced by the application of the steam-engine in the arts and manufactures, as well as to railways and navigation, has of late years excited the fears of many as to the possibility of the exhaustion of our coal-mines. Such apprehensions are, however, altogether groundless. If the present consumption of coal be estimated at sixteen millions of tons annually, it is demonstrable that the coal-fields of this country would not be exhausted for many centuries.

But in speculations like these, the probable, if not certain progress of improvement and discovery ought not to be overlooked; and we may safely pronounce that, long before such a period of time shall have rolled away, other and more powerful mechanical agents will supersede the use of coal. Philosophy already directs her finger at sources of inexhaustible power in the phenomena of electricity and magnetism. The alternate decomposition and recomposition of water, by electric action, has too close an analogy to the alternate processes of vaporisation and condensation, not to occur at once to every mind: the development of the gases from solid matter by the operation of the chemical affinities, and their subsequent condensation into the liquid form, has already been essayed as a source of power. In a word, the general state of physical science at the present moment, the vigour, activity, and sagacity with which researches in it are prosecuted in every civilised country, the increasing consideration in which scientific men are held, and the personal honours and rewards which begin to be conferred upon them, all justify the expectation that we are on the eve of mechanical discoveries still greater than any which have yet appeared; that the steam-engine itself, with its gigantic powers, will dwindle into insignificance in comparison with the energies of nature which are still to be revealed; and that the day will come when that machine, which is now extending the blessings of civilisation to the most remote skirts of the globe, will cease to have existence except in the page cf history.

JURISPRUDENCE.

ELEMENTS of Jurisprudence. By CHARLES JAMES FOSTER, M.A., LL.D., Professor of Jurisprudence in University College, London. Crown 8vo, 5*s.* cloth.

"Mr. Foster treats his subject in a masterly manner, and his volume may be read with profit both by students and men of the world."—*Athenæum.*

RHETORIC.

ELEMENTS of Rhetoric; A Manual of the Laws of Taste, including the Theory and Practice of Composition. By SAMUEL NEIL, Author of "The Art of Reasoning." Large 12mo, 4*s.* 6*d.* cloth.

LOGIC.

THE Art of Reasoning; A Popular Exposition of the Principles of Logic, Inductive and Deductive, with an Introductory Outline of the History of Logic, and an Appendix on Recent Logical Developments. By SAMUEL NEIL. Crown 8vo, 4*s.* 6*d.*

"This work is of undoubted merit. It displays a great thoughtfulness and research, and contains a vast amount of useful information on the subject of which it treats. The author seems to have thoroughly mastered his subject, and to the illustration of it has skilfully applied his extensive and varied knowledge."—*Glasgow Constitutional.*

An Investigation of the Laws of Thought, on which are founded the Mathematical Theories of Logic and Probabilities. By GEORGE BOOLE, Professor of Mathematics in Queen's College, Cork. One Vol. 8vo, 14*s.* cloth.

Formal Logic; or, the Calculus of Inference necessary and PROBABLE. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Cheap Issue, 8vo, 6*s.* 6*d.*

HISTORY, ANTIQUITIES, &c.

DICTIONARY of Greek and Roman Biography. Edited by WILLIAM SMITH, LL.D., Editor of the Dictionaries of "Greek and Roman Antiquities," and of "Biography and Mythology." With very numerous Illustrations on Wood. Volume I. (1100 pages), 1*l.* 16*s.* cloth lettered.

The Work will be continued in Quarterly Parts, each 4*s.*, and will be completed in Two Volumes.

Dictionary of Greek and Roman Biography and Mythology. Edited by WILLIAM SMITH, LL.D., Classical Examiner in the University of London. Medium 8vo. Illustrated by numerous Engravings on Wood. Complete in Three Vols., 5*l.* 15*s.* 6*d.*

Dictionary of Greek and Roman Antiquities. By various Writers. Edited by Dr. WILLIAM SMITH. Second Edition. Revised throughout, with very numerous Additions and Alterations. One thick Volume, medium 8vo, with several hundred Engravings on Wood, 2*l.* 2*s.*

A New Classical Dictionary of Ancient Biography, Mythology, AND GEOGRAPHY. Edited by Dr. WILLIAM SMITH. New Edition. One Volume, 8vo, 15*s.* cloth.

This work comprises the same subjects as are contained in the well-known Dictionary of Lemprière, avoiding its errors, supplying its deficiencies, and exhibiting in a concise form the *results* of the labours of modern scholars. It will thus supply a want that has been long felt by most persons engaged in tuition.

A Smaller Dictionary of Antiquities; Selected and Abridged from the "Dictionary of Greek and Roman Antiquities." By WILLIAM SMITH, LL.D. New and Cheaper Edition. One small Volume, Two Hundred Woodcuts, 7*s.* 6*d.* cloth.

A Smaller Classical Dictionary. Abridged from the larger work. By Dr. WILLIAM SMITH. Cheaper Edition. Two Hundred Woodcuts, Crown 8vo, 7*s.* 6*d.* cloth.

The Odes of Horace, translated into Unrhymed Metres. With Introductions and Notes. By F. W. NEWMAN, Professor of Latin, University College, London. Crown 8vo. 5*s.* cloth.

Niebuhr's History of Rome, from the Earliest Times to the FALL OF THE WESTERN EMPIRE. Translated by BISHOP THIRLWALL, ARCHDEACON HARE, Dr. WILLIAM SMITH, and Dr. SCHMITZ. Fourth and Cheaper Edition. Three Vols., 8vo, 36*s.*

Niebuhr's Lectures on Roman History. Translated and Edited by LEONHARD SCHMITZ, Ph. D., Rector of the High School of Edinburgh. New and Cheaper Edition, in Three Vols. 8vo, 24*s.*

Niebuhr's Lectures on Ancient History, comprising the Asiatic Nations, the Egyptians, Greeks, Carthaginians, and Macedonians. Translated by Dr. L. SCHMITZ. Three Vols. 8vo, 1*l.* 11*s.* 6*d.*

In reference to Babylonia, Assyria, and Egypt, it is particularly interesting to notice how clearly the historian foresaw and anticipated all the great discoveries which have since been made in those countries. A thousand points in the history of ancient nations, which have hitherto been either overlooked or accepted without inquiry, are here treated with sound criticism and placed in their true light.

Niebuhr's Lectures on Ancient Ethnography and Geography. Comprising Greece and her Colonies, Italy, the Islands of the Mediterranean, Spain, Gaul, Britain, Northern Africa, and Phœnicia. Translated from the German by DR. LEONHARD SCHMITZ, F.R.S.E., Rector of the High School of Edinburgh, with additions and corrections from his own Notes. Two Vols., 8vo, 1*l.* 1*s.* cloth.

A History of Rome; from the Earliest Times to the Death of COMMODUS, A.D. 192. By Dr. L. SCHMITZ, Rector of the High School of Edinburgh, Editor of "Niebuhr's Lectures." New Edition. With 100 Illustrations on Wood. One thick Vol., 12mo, 7*s.* 6*d.* cloth.

Questions on Schmitz's History of Rome. By JOHN ROBSON, B.A. 12mo, 2*s.* cloth.

A History of Greece. With Supplementary Chapters on the Literature, Art, and Domestic Manners of the Greeks. By William Smith, LL.D., Editor of the Dictionaries of "Greek and Roman Antiquities," "Biography," &c. Woodcuts and Maps. Post 8vo, 7*s.* 6*d.* cloth.

"A good plan capitally executed, is the characteristic of Dr. Smith's introductory History of Greece."—*Spectator.*

The Book of Almanacs. With Index, by which the Almanac belonging to any year preceding A.D. 2000 can be found; with means of finding New and Full Moons from B.C. 2000 to A.D. 2000. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Demy 8vo, oblong, 5*s.* cloth.

"This is quite a novelty in chronological literature. It is an *universal almanac*—universal, that is, as respects time, past, present, and future. The main object of it is, as the compiler states, to supply the place of an old almanac, which is never at hand when wanted; of the older almanac, which never was at hand; and of the universal almanac in every shape! A more useful chronological handbook could scarcely be conceived. It will save an immensity of calculation, and is in many other respects invaluable as a chronological guide and instructor."—*Oxford Herald.*

Four Lectures on the Contrasts of Ancient and Modern HISTORY. By F. W. NEWMAN, Professor of Latin in University College, London. Foolscap 8vo, 3*s*. cloth.

A Numismatic Manual; or, Guide to the Collection and Study of Greek, Roman, and English Coins. Illustrated by Engravings of many hundred types, by means of which even imperfect and obliterated pieces may be easily deciphered. By J. Y. AKERMAN, F.S.A. 8vo, 21*s*. cloth.

POETRY.

DISCOVERY. A POEM. By EDWARD ALDAM LEATHAM, M.A. Foolscap 8vo, 2*s*. 6*d*. cloth.

"His execution is finished and of a good school."—*Spectator.*

"Mr. Leatham's style is vigorous, his lines are musical, and his versification is correct. * * His peroration is truly eloquent."—*Britannia.*

Love in the Moon; A POEM. With Remarks on that Luminary. By PATRICK SCOTT, Author of "Lelio." Foolscap 4to, 5*s*. 6*d*. cloth gilt.

Poetical Works of John Keats. Royal 8vo, sewed, 2*s*.

A Collection of Poetry for the Practice of Elocution. Made for the use of the Ladies' College, Bedford Square. By Professor F. W. NEWMAN. Foolscap 8vo, 2*s*. 6*d*.

The Georgics of Virgil. Translated into Verse by the Rev. W. H. BATHURST, M.A., Rector of Barwick-in-Elmet. Foolscap 8vo, 4*s*. 6*d*. cloth.

MISCELLANEOUS.

BUSINESS as it is and as it might be. By JOSEPH LYNDALL. Crown 8vo, 1*s*. sewed, 1*s*. 6*d*. cloth.

*** This Work obtained the Prize of Fifty Guineas offered by the Young Men's Christian Association for the best Essay on "The Evils of the Present System of Business, and the Difficulties they Present to the Attainment and Development of Personal Piety, with Suggestions for their Removal."

Christian Philosophy; or, an Attempt to Display the Evidence and Excellence of Revealed Religion by its Internal Testimony. By VICESIMUS KNOX, D.D., late Fellow of St. John's College, Oxford; and Master of Tunbridge School.

Suggestions on Female Education. Two Introductory Lectures on English Literature and Moral Philosophy, delivered in the Ladies' College, Bedford Square, London. By A. J. SCOTT, A.M., Principal of Owen's College, Manchester, late Professor of the English Language and Literature in University College, London. Foolscap 8vo, 1*s*. 6*d*.

Guesses at Truth. By TWO BROTHERS. New Edition. Foolscap 8vo. First Series, 6*s*.; Second Series, 7*s*.

Mr. Frere's Works on Prophecy.

BRIEF INTERPRETATION OF THE APOCALYPSE. 8vo, 3*s*. 6*d*. cloth.

GENERAL STRUCTURE OF THE APOCALYPSE, chiefly relating to the Individual Antichrist of the Last Days. 8vo, 2*s*.

THREE LETTERS ON THE PROPHECIES. 8vo, 2*s*.

EIGHT LETTERS ON THE PROPHECIES; viz. on the Seventh Vial; the Civil and Ecclesiastical Periods; and on the Type of Jericho. 8vo, 2*s*. 6*d*.

GREAT CONTINENTAL REVOLUTION, marking the expiration of the "Times of the Gentiles." 8vo, 2*s*. 6*d*.

STEAM NAVIGATION AND RAILWAYS.

THE Steam Engine, Steam Navigation, Roads, and Railways, EXPLAINED AND ILLUSTRATED. A New and Cheaper Edition, revised and completed to the present time. By DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. One Vol., 12mo, Illustrated with Wood Engravings, 8*s.* 6*d.* cloth.

Railway Economy; or, the New Art of Transport. Its Management, Prospects, and Relations, Commercial, Financial, and Social; with an Exposition of the Practical Results of the Railways in operation in the United Kingdom, on the Continent, and in America. By DIONYSIUS LARDNER, D.C.L. One Vol., large 12mo.

Sketch of the Origin and Progress of Steam Navigation. By BENNET WOODCROFT, late Professor of Machinery in University College, London. With 17 Lithographic Plates, Fcap. 4to, 12*s.* cloth.

The Pneumatics of Hero of Alexandria; from the Original Greek. Translated for and Edited by BENNET WOODCROFT, late Professor of Machinery in University College, London. Fcap. 4to, 12*s.* 6*d.* cloth.

NATURAL PHILOSOPHY AND ASTRONOMY.

FAMILIAR Letters on the Physics of the Earth. By H. BUFF, Professor of Physics in the University of Giessen. Edited by Dr. A. W. HOFMANN, Professor in the Royal College of Chemistry, London. Fcap. 8vo, 5*s.*

Introduction.—Gravity and its Effects.—Tides.—Heat within the Earth.—Warm Springs.—Hot Springs and Jets of Steam.—Jets of Gas and Mud Volcanoes.—Volcanoes and Earthquakes.—Temperature of the Outermost Crust of the Earth.—Temperature of the Lowest Layer of the Atmosphere.—Lines of equal Heat.—Temperature of the Upper Layers of the Atmosphere.—The Snow Limits.—Glaciers.—Temperature of the Waters, and their Influence on Climate.—Currents of the Sea.—Winds.—Moisture of the Air and Atmospheric Precipitation.—Electricity of the Air, Lightning, and Thunder.

An Elementary Treatise on Mechanics, for the Use of Junior University Students. By RICHARD POTTER, A.M., Professor of Natural Philosophy in University College, London. Second Edition, 8vo, with numerous Diagrams, 8*s.* 6*d.* cloth.

An Elementary Treatise on Optics, PART I. By RICHARD POTTER, A.M. Second Edition, 8vo, corrected, with numerous Diagrams, 9*s.* 6*d.* cloth.

An Elementary Treatise on Optics, PART II., Containing the Higher Propositions. By RICHARD POTTER, A.M. 8vo, with numerous Diagrams, 12*s.* 6*d.*

This volume contains the discussions of direct and oblique pencils to the higher approximations according to previously known methods. Also new discussions of the *aberrations of oblique pencils* and the forms of the images produced; together with the application to the theory of Optical Instruments. Many other new investigations will be found in the volume.

Twelve Planispheres, forming a Guide to the Stars for every Night in the Year, with an Introduction. 8vo, 6*s.* 6*d.* cloth.

Ecliptical Charts, Hours, 1, 2, 3, 4, 5, 7, 9, 10, 11, and 13, taken at the Observatory, Regent's Park, under the direction of GEORGE BISHOP, Esq., F.R.S., &c. 2*s.* 6*d.* each.

Astronomical Observations, taken at the Observatory, Regent's Park, during the Years 1839—1851, under the direction of GEORGE BISHOP, Esq., F.R.S., &c. 4to, 12*s.* 6*d.*

DR. LARDNER'S
MUSEUM OF SCIENCE AND ART.

A Miscellany of

INSTRUCTIVE AND AMUSING TRACTS ON THE PHYSICAL SCIENCES, AND ON THEIR APPLICATION TO THE USES OF LIFE.

ILLUSTRATED BY ENGRAVINGS ON WOOD.

"'Dr. Lardner's Museum,' one of the few works of the kind which can be recommended as at once popular and accurate."—*Sir David Brewster.*

"This series, besides affording popular but sound instruction on scientific subjects, with which the humblest man in the country ought to be acquainted, also undertakes that teaching of 'Common Things' which Lord Ashburton and every well-wisher of his kind are anxious to promote. Many thousand copies of this serviceable publication have been printed, in the belief and hope that the desire for instruction and improvement widely prevails; and we have no fear that such enlightened faith will meet with disappointment."—*The Times, Feb.* 9, 1854.

"This serial, which will form quarterly eighteenpenny volumes, is, we are disposed to think, the best literary investment of a penny a week now extant."—*Examiner.*

"A cheap and interesting publication, alike informing and attractive. The papers combine subjects of importance with great scientific knowledge, considerable inductive powers, and a popular style of treatment."—*Spectator.*

CONTENTS OF

VOL. I., *price* 1*s.* 6*d.*, *in handsome boards.*

PART I., price 5*d.*

1. The Planets; Are they Inhabited Globes?
2. Weather Prognostics.
3. The Planets. Chap. II.
4. Popular Fallacies in Questions of Physical Science.

PART II., price 5*d.*

5. Latitudes and Longitudes.
6. The Planets. Chap. III.
7. Lunar Influences.
8. Meteoric Stones and Shooting Stars. Chap. I.

PART III., price 6*d.*

9. Railway Accidents. Chap. I.
10. The Planets. Chap. IV.
11. Meteoric Stones and Shooting Stars. Chap. II.
12. Railway Accidents. Chap. II.
13. Light.

VOL. II., *price* 1*s.* 6*d.*, *in handsome boards.*

PART IV., price 5*d.*

14. Common Things.—Air.
15. Locomotion in the United States Chap. I.
16. Cometary Influences. Chap. I.
17. Locomotion in the United States Chap. II.

PART V., price 5*d.*

18. Common Things.—Water.
19. The Potter's Art. Chap. I.
20. Locomotion in the United States Chap. III.
21. The Potter's Art. Chap. II.

PART VI., price 6*d.*

22. Common Things.—Fire.
23. The Potter's Art. Chap. III.
24. Cometary Influences. Chap. II.
25. The Potter's Art. Chap. IV.
26. The Potter's Art. Chap. V.

VOL. III., *price* 1*s.* 6*d.*, *in handsome boards.*

PART VII., price 5*d.*

27. Locomotion and Transport, their Influence and Progress. Chap. I.
28. The Moon.
29. Common Things.—The Earth.
30. Locomotion and Transport, their Influence and Progress. Chap. II.

PART VIII., price 5*d.*

31. The Electric Telegraph. Chap. I.
32. Terrestrial Heat. Chap. I.
33. The Electric Telegraph. Chap. II.
34. The Sun.

PART IX., price 6*d.*

35. The Electric Telegraph. Chap. III.
36. Terrestrial Heat. Chap. II.
37. The Electric Telegraph. Chap. IV.
38. The Electric Telegraph. Chap. V.
39. The Electric Telegraph. Chap. VI.

DR. LARDNER'S MUSEUM (*Continued*) :—

VOL. IV., *price* 1*s.* 6*d.*, *in handsome boards.*

PART X., price 5*d.*

40. Earthquakes and Volcanoes. Chap. I.
41. The Electric Telegraph. Chap. VII.
42. The Electric Telegraph. Chap. VIII.
43. The Electric Telegraph. Chap. IX.

PART XI., price 5*d.*

44 Barometer, Safety Lamp, and Whitworth's Micrometric Apparatus.
45. The Electric Telegraph. Chap. X.
46. Earthquakes and Volcanoes. Chap. II.
47. The Electric Telegraph. Chap. XI.

PART XII., price 6*d.*

48. Steam.
49. The Electric Telegraph. Chap. XII.
50. The Electric Telegraph. Chap. XIII.
51. The Electric Telegraph. Chap. XIV.
52. The Electric Telegraph. Chap. XV.

*** *This work is continued in Weekly Numbers at* 1*d.*, *in Monthly Parts at* 5*d.*, *and Quarterly Volumes at* 1*s.* 6*d.*, *in Ornamental Boards.*

First Book of Natural Philosophy; or, an Introduction to the Study of Statics, Dynamics, Hydrostatics, and Optics, with numerous examples. By SAMUEL NEWTH, M.A., Fellow of University College, London. 12mo, 3*s.* 6*d.*

Elements of Mechanics and Hydrostatics. By SAMUEL NEWTH, M.A. Second Edition, small 8vo. 7*s.* 6*d.*, cloth.

Handbook of Natural Philosophy and Astronomy. By DIONYSIUS LARDNER, formerly Professor of Natural Philosophy and Astronomy in University College, London. Three Vols., large 12mo, with very numerous Illustrations on Wood.

FIRST COURSE, One Vol., 12*s.* 6*d.* cloth, contains :—Mechanics; Hydrostatics; Hydraulics; Pneumatics; Sound; Optics.

"We have much pleasure in recommending Dr. Lardner's 'Handbook of Natural Philosophy;' it is one of the best popular scientific works that has yet appeared."—*English Journal of Education.*

"Our examination of the work leads us to speak most favourably of it as a handbook for students; it will be a useful addition to the library of every medical student, as well as a serviceable guide to all who are about to commence the study of physics."—*Medical Gazette.*

SECOND COURSE, One Vol., 8*s.* 6*d.*, contains :—Heat; Common Electricity; Magnetism; Voltaic Electricity.

THIRD COURSE, One Vol., 16*s.* 6*d.*, contains :—Astronomy and Meteorology. With 37 Plates and 200 Woodcuts.

*** *Any volume may be purchased separately.*

CURRENCY.

A CATECHISM of the Currency. By JOHN TAYLOR. Third Edition, 12mo, 2*s.*

A Catechism of the Foreign Exchanges. By JOHN TAYLOR, Second Edition, 12mo, 2*s.*

A View of the Money System of England. By JAMES TAYLOR. 8vo, 3*s.* sewed.

MATHEMATICS, &c.

ELEMENTS of Arithmetic. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Fifth Edition, with Eleven Appendixes, Royal 12mo, 5*s.* cloth.

De Morgan's Elements of Algebra. Preliminary to the Differential Calculus. Second Edition. Royal 12mo, 9*s.* cloth.

De Morgan's Trigonometry and Double Algebra. Royal 12mo, 7s. 6d. cloth.

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, AND RECIPROCALS, up to 10,000. Stereotype Edition, examined and corrected. Under the superintendence of the Society for the Diffusion of Useful Knowledge. Royal 12mo, cloth, 8s.

Arithmetical Books and Authors. From the Invention of Printing to the present time; being Brief Notices of a large Number of Works drawn up from actual inspection. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Cheap issue. Royal 12mo, 2s. 6d. cloth.

"A great number of persons are employed in teaching Arithmetic in the United Kingdom. In publishing this work, I have the hope of placing before many of them more materials for the prevention of inaccurate knowledge of the literature of their science than they have hitherto been able to command, without both expense and research."—*Preface.*

A Course of Arithmetic as Taught in the Pestalozzian School, WORKSOP. By J. L. ELLENBERGER. 12mo. 5s. cloth.

The First Book of Euclid Explained to Beginners. By C. P. MASON, B.A., Fellow of University College, and Principal of Denmark Hill Grammar School. Fcap. 8vo. 1s. 9d. cloth.

Reiner's Lessons on Form; or, an Introduction to Geometry, as given in a Pestalozzian School, Cheam, Surrey. 12mo, with numerous Diagrams, 3s. 6d. cloth.

A First Book on Plane Trigonometry. Geometrical Trigonometry, and its applications to Surveying, with numerous Examples. For the use of Schools. By G. W. HEMMING, M.A., Fellow of St. John's College, Cambridge, and Author of a Treatise on the "Differential and Integral Calculus." With Diagrams, 12mo, cloth limp, 1s. 6d.

Ritchie's Principles of Geometry, familiarly Illustrated, and applied to a variety of useful purposes. Designed for the Instruction of Young Persons. Second Edition, revised and enlarged, 12mo, with 150 Woodcuts, cloth limp, 1s. 6d.

Tables of Logarithms, Common and Trigonometrical, to Five PLACES. Under the Superintendence of the Society for the Diffusion of Useful Knowledge. Fcap. 8vo, cloth limp, 1s. 6d.

Lessons on Number, as given at the Pestalozzian School, Cheam, Surrey. By CHARLES REINER. The Master's Manual. New Edition. 12mo, cloth, 5s. The Scholar's Praxis. 12mo, 2s. bound.

GREEK.

THE Anabasis of Xenophon. Expressly for Schools. With Notes, a Geographical and Biographical Index, and a Map. By J. T. V. HARDY, B.A., Principal of Huddersfield College; and ERNEST ADAMS, Classical Master in University College School. 12mo, 4s. 6d. cloth.

Lexicon to Aeschylus. Containing a Critical Explanation of the more Difficult Passages in the Seven Tragedies. By the Rev. W. LINWOOD, A.M., M.R.A.S. Second Edition. Revised. 8vo, 12s. cloth.

New Greek Delectus; Being Sentences for Translation from Greek into English, and English into Greek; arranged in a Systematic Progression. By Dr. RAPHAEL KUHNER. Translated and Edited from the German, by Dr. ALEXANDER ALLEN. Third Edition, revised. 12mo, 4s. cloth.

Four Gospels in Greek. For the use of Schools. Fcap. 8vo. cloth limp, 1*s.* 6*d.* This part of the Greek Testament is printed separately for the use of Students beginning to learn Greek, the Evangelists being more generally read than the rest of the Testament.

London Greek Grammar. Designed to exhibit, in small compass, the Elements of the Greek Language. Edited by a GRADUATE of the University of Oxford. Fifth Edition. 12mo, cloth limp, 1*s.* 6*d.*

Greek Testament. GRIESBACH'S TEXT, with the various readings of MILL and SCHOLZ. Second Edition, revised. Fcap. 8vo, cloth, 6*s.* 6*d.*; morocco, 12*s.* 6*d.*

Plato. The Apology of SOCRATES, CRITO, and part of the PHAEDO, with English Notes, a Life of Socrates, &c. Edited by Dr. W. SMITH. Second Edition. 12mo, cloth, 5*s.*

Robson's Constructive Greek Exercises. 12mo, cloth, 7*s.* 6*d.*

*** This Work, which was originally intended to be a new edition of "Allen's Constructive Greek Exercises," will take the place of that book. The general principles of both are identical.

Introduction to the Art of Composing Greek Iambics, in Imitation of the Greek Tragedians. Designed for the use of Schools. By the Rev. CHARLES TAYLER. 12mo, 2*s.* 6*d.*

What is the Power of the Greek Article; and how may it be expressed in the English Version of the New Testament? By JOHN TAYLOR. 8vo, 2*s.* 6*d.*

LATIN.

NEW Latin Delectus; being Sentences for Translation from Latin into English, and English into Latin; arranged in a Systematic Progression, on the plan of the Greek Delectus. By Dr. ALEXANDER ALLEN. Third Edition, 12mo, 4*s.* cloth.

Constructive Latin Exercises, for teaching the Elements of the Language on a System of Analysis and Synthesis; with Latin Reading Lessons, and copious Vocabularies. By JOHN ROBSON, B.A., late Assistant Master in University College School. Third Edition, thoroughly revised. 12mo, 4*s.* 6*d.* cloth.

London Latin Grammar; including the Eton Syntax and Prosody in English, accompanied with Notes. Edited by a GRADUATE of the University of Oxford. Fifteenth Edition. 12mo, 1*s.* 6*d.* cloth limp.

First Latin Reading Lessons; with complete Vocabularies. Intended as an Introduction to Cæsar. By JOHN ROBSON, B.A., Assistant Master in University College School. 12mo, 2*s.* 6*d.* cloth.

The Principal Roots of the Latin Language, simplified by a display of their Incorporation into the English Tongue; with copious Notes. By HENRY HALL. Fifth Edition. 12mo, 1*s.* 6*d.* cloth limp.

The Germania of Tacitus. With Ethnological Dissertations and Notes. By Dr. R. G. LATHAM. Author of the "English Language," &c. With a Map. Demy 8vo, 12*s.* 6*d.*

Tacitus, Germania, Agricola, and First Book of the Annals. With Notes Translated into English from RUPERTI, PASSOW, and WALCH, and BOTTIGER'S Remarks on the style of TACITUS. Second Edition. Edited by Dr. W. SMITH. 12mo, 5*s.* cloth.

Caesar for Beginners. Latin and English; with the Original Text at the end. 12mo, 3*s.* 6*d.* cloth.

Mythology for Versification; or, a Brief Sketch of the Fables of the Ancients, prepared to be rendered into Latin verse. By the late Rev. F. HODGSON, M.A. (Provost of Eton). New Edition. 12mo, 3*s*. bound. KEY to Ditto. 8vo, 7*s*.

Select Portions of Sacred History, conveyed in sense for Latin Verses. By the late Rev. F. HODGSON, M.A. (Provost of Eton). Third Edition. 12mo, 3*s*. 6*d*. cloth. KEY to Ditto. Royal 8vo, 10*s*. 6*d*. cloth.

Sacred Lyrics; or, Extracts from the Prophetical and other Scriptures of the Old Testament; adapted to Latin Versification in the principal Metres of HORACE. By the late Rev. F. HODGSON, M.A. (Provost of Eton). 12mo, 6*s*. 6*d*. cloth. KEY to Ditto. 8vo, 12*s*. cloth.

Latin Authors. Selected for the use of Schools; containing portions of Phædrus, Ovid's Metamorphoses, Virgil's Æneid, Cæsar and Tacitus. 12mo, 1*s*. 6*d*. cloth.

HEBREW.

GRAMMAR of the Hebrew Language. By HYMAN HURWITZ, late Professor of Hebrew in University College, London. Fourth Edition, revised and enlarged. 8vo, 13*s*. cloth. Or in Two Parts, sold separately:—ELEMENTS, 4*s*. 6*d*. cloth; ETYMOLOGY and SYNTAX, 9*s*. cloth.

Book of Genesis in English Hebrew; accompanied by an Interlinear Translation, substantially the same as the authorised English version; Philological Notes, and a Grammatical Introduction. By W. GREENFIELD, M.R.A.S. Fourth Edition. Cheap Issue. 8vo, 4*s*. 6*d*. cloth. With the original Text in Hebrew characters at the end. 8vo, 6*s*. 6*d*. cloth.

MAPS.

TEACHING Maps:—I. RIVERS AND MOUNTAINS, of England, Wales, and Part of Scotland. 6*d*. II.—TOWNS of Ditto. 6*d*.

Projections. Three Maps. MERCATOR. EUROPE. BRITISH ISLES. Stitched in a Cover, 1*s*. Single Maps, 4*d*. each.

Projections; with Outline of Country. Three Maps stitched in a Cover, 1*s*. Single Maps, 4*d*. each.

ENGLISH.

THE English Language. By Dr. R. G. LATHAM, F.R.S., late Fellow of King's College, Cambridge. Fourth Edition, greatly enlarged. 8vo. *In the Press.*

An English Grammar for the Use of Schools. By Dr. R. G. LATHAM, F.R.S., late Fellow of King's College, Cambridge. Sixth Edition. 12mo, 4*s*. 6*d*. cloth.

Elements of English Grammar, for the Use of Ladies' Schools. By Dr. R. G. LATHAM, F.R.S. Fcap. 8vo, 1*s*. 6*d*. cloth.

Elements of English Grammar, for Commercial Schools. By Dr. R. G. LATHAM, F.R.S. Fcap. 8vo, 1*s*. 6*d*. cloth.

A Handbook of the English Language. By Dr. R. G. Latham, F.R.S. 12mo, 8s. 6d. cloth.

The object of the "Handbook" is to present to students for examination, in a more condensed form, the chief facts and reasonings of "The English Language." Less elaborate than that work, it is less elementary than the "English Grammar." Like all the other works by the same author, it gives great prominence to the ethnological relations of our tongue; and insists upon historical investigation, and the application of the general principles of comparative philology, as the true means of exhibiting its real growth and structure, in opposition to the more usual method of treating it as a mass of irregularities. It has the further object of supplying a knowledge of those laws of speech and principles of grammar which apply to language generally.

History and Etymology of English Grammar, for the Use of CLASSICAL SCHOOLS. By Dr. R. G. Latham, F.R.S. Fcap. 8vo, 1s. 6d. cloth.

First Outlines of Logic, applied to Grammar and Etymology. By Dr. R. G. Latham. 12mo, 1s. 6d. cloth.

New English Spelling Book. By the Rev. Gorham D. Abbott. Second Edition, with Reading Lessons. 12mo, sewed, 6d.

First English Reader. By the Rev. G. D. Abbott. 12mo, with Illustrations. 1s. cloth limp.

Second English Reader. By the Rev. G. D. Abbott. 12mo, 1s. 6d. cloth limp.

FRENCH.

MERLET'S French Grammar. By P. F. Merlet, Professor of French in University College, London. New Edition, 12mo, 5s. 6d. bound. Or, sold in two Parts: Pronunciation and Accidence, 3s. 6d.; Syntax, 3s. 6d. (Key, New Edition, 3s. 6d.)

Merlet's Traducteur; Or, Historical, Dramatic, and Miscellaneous Selections from the best French Writers; accompanied by Explanatory Notes; a selection of Idioms, &c. New Edition. 12mo, 5s. 6d. bound.

Merlet's Dictionary of the Difficulties of the French Language; containing Explanations of every Grammatical Difficulty; Synonymes explained in a concise manner; Versification; Etymological Vocabulary; Free Exercises, with Notes; Mercantile Expressions, Phrases, and Letters; Elements of French Composition. A new and enlarged Edition. 12mo, 6s. 6d. bound.

Merlet's French Synonymes; explained in Alphabetical Order, with Copious Examples. (From the "Dictionary of Difficulties.") 12mo, 2s. 6d. cloth.

Stories from French Writers. Interlinear (from Merlet's "Traducteur"). 12mo, 2s.

GERMAN.

The Adventures of Ulysses: a German Reading Book; with a short Grammar and a Vocabulary. By Paul Hirsch. Twenty-four Woodcuts. 12mo, 6s. cloth,

Separately,

A Short Grammar of the German Language. 12mo, cloth, 2s.

ITALIAN.

First Italian Course; Being a Practical and Easy Method of Learning the Elements of the Italian Language. By W. Browning Smith, M.A., Second Classical Master of the City of London School. Royal 18mo, cloth, 3s. 6d.

Panizzi's Italian Grammar. 12mo, cloth limp, 1s. 6d.

INTERLINEAR TRANSLATIONS.

Cheap Issue, at 1s. 6d. per volume.

LOCKE'S System of Classical Instruction, restoring the Method of Teaching formerly practised in all Public Schools. The Series consists of the following Interlinear Translations with the Original Text, in which the quantity of the doubtful Vowels is denoted; critical and explanatory Notes, &c.

*** By means of these Works, that excellent system of Tuition is effectually restored which was established by Dean Colet, Erasmus, and Lily, at the foundation of St. Paul's School, and was then enjoined by authority of the State, to be adopted in all other Public Seminaries of learning throughout the kingdom. Each Volume, 1*s*. 6*d*.

LATIN.

1. Phædrus's Fables of Æsop.
2. Ovid's Metamorphoses. Book I.
3. Virgil's Æneid. Book I.
4. Parsing Lessons to Virgil.
5. Cæsar's Invasion of Britain.

GREEK.

1. Lucian's Dialogues. Selections.
2. The Odes of Anacreon.
3. Homer's Iliad. Book I.
4. Parsing Lessons to Homer.
5. Xenophon's Memorabilia. Part I.
6. Herodotus's Histories. Selections.

FRENCH.—Sismondi; the Battles of Cressy and Poictiers.

GERMAN.—Stories from German Writers.

*** A Second Edition of the Essay, explanatory of the System, with an Outline of the Method of Study, is published. 12mo, sewed, price 6*d*.

ANIMAL MAGNETISM.

BARON Von Reichenbach's Researches on Magnetism, Elec- TRICITY, HEAT, LIGHT, CRYSTALLISATION, AND CHEMICAL ATTRACTION, IN THEIR RELATION TO THE VITAL FORCE. Translated and Edited (at the express desire of the Author) by Dr. Gregory, of the University of Edinburgh. Cheap Issue. One Volume, 8vo, 6*s*. 6*d*., cloth.

"The merits of this remarkable volume are great. The painstaking, conscientious, cautious, ingenious,—we had almost said the religious, and certainly the self-possessed enthusiasm with which the experimental clue is followed from turn to turn of the labyrinth, is surpassed by nothing of the same sort in the whole range of contemporary science."—*North British Review*.

ANATOMY, MEDICINE, &c.

DR. Quain's Anatomy. Edited by Dr. Sharpey and Mr. Quain, Professors of Anatomy and Physiology in University College, London. Fifth Edition. Complete in Two Volumes, 8vo. Illustrated by four hundred Engravings on Wood. Price 2*l*.

Demonstrations of Anatomy. A Guide to the Dissection of the Human Body. By George Viner Ellis, Professor of Anatomy in University College, London. Third Edition. Small 8vo. 12*s*. 6*d*. cloth.

Lectures on the Principles and Practice of Midwifery. By Edward Wm. Murphy, A.M., M.D., Professor of Midwifery in University College, London. One Volume, 8vo, many Illustrations, 16*s*.

"The work will take rank among the best treatises on the obstetric art. By this work, Dr. Murphy has placed his reputation and his fame on a solid and durable foundation."—*Dublin Medical Press*.

A Handbook of Physiology. By WILLIAM SENHOUSE KIRKES, M.D., Demonstrator of Morbid Anatomy at St. Bartholomew's Hospital. Assisted by JAMES PAGET, Lecturer on General Anatomy and Physiology at St. Bartholomew's Hospital. Second Edition. One Volume 12mo, with Illustrations. 12*s.* 6*d.*

On Pain After Food; its Causes and Treatment. By EDWARD BALLARD, M.D., Lond., Lecturer on the Practice of Medicine at the School of Medicine adjoining St. George's Hospital. One vol. 4*s.* 6*d.* cloth.

Physical Diagnosis of the Diseases of the Abdomen. By EDWARD BALLARD, M.D., Late Medical Tutor in University College, London. Large 12mo, 7*s.* 6*d.* cloth.

"The profession is much indebted to Dr. Ballard for this unpretending little volume, which, we feel certain, if carefully studied, will accomplish its object of removing many of the difficulties at present surrounding the diagnosis of abdominal diseases."—*Lancet.*

A Practical Treatise on Diseases of the Heart and Lungs, their Symptoms and Treatment, and the Principles of Physical Diagnosis. By W. H. WALSHE, M.D., Professor of the Principles and Practice of Medicine and Clinical Medicine in University College, London; Physician to University College Hospital, and Consulting Physician to the Hospital for Consumption and Diseases of the Chest. A new and considerably enlarged edition. One Volume, 12*s.* 6*d.* cloth.

"This work is what its name indicates it to be—eminently practical. That it will add largely to the already great reputation of its author, no question can be entertained. It is far in advance of any other Treatise on Diseases of the Chest, either in this or any other country. Every page—we were about to say every line—contains a fact, often new, and *always resting on the Author's own observations.* Cases are quoted to prove every new statement, and to support every argument adduced in opposition to others. To the practitioner, the clinical teacher, and to the student, this work will prove alike invaluable."—*Medical Times.*

The Nature and Treatment of Cancer. By W. H. WALSHE, M.D., Professor of Medicine in University College, Physician to University College Hospital, and Consulting Physician to the Hospital for Consumption and Diseases of the Chest. One Volume, 8vo, with Illustrations. Cheap Issue, 6*s.* 6*d.*

The Diseases of the Rectum. By RICHARD QUAIN, F.R.S., Professor of Clinical Surgery in University College, and Surgeon to University College Hospital. With Lithographic Plates. Post 8vo. 7*s.* 6*d.* cloth.

"This Treatise is eminently of a practical character, and contains much original and valuable matter. It is not indeed a literary compilation, but rather an exposition of the author's opinions and practice in those diseases."—*Association Journal.*

The Science and Art of Surgery. Being a Treatise on Surgical Injuries, Diseases, and Operations. By JOHN ERICHSEN, Professor of Surgery in University College, and Surgeon to University College Hospital. 250 Wood Engravings. 8vo. 1*l.* 5*s.*

"The aim of Mr. Erichsen appears to be, to improve upon the plan of Samuel Cooper; and by connecting in one volume the science and art of Surgery, to supply the student with a text-book and the practitioner with a work of reference, in which scientific principles and practical details are alike included.

"It must raise the character of the author, and reflect great credit upon the College in which he is Professor, and we can cordially recommend it as a work of reference, both to students and practitioners."—*Medical Times.*

The Microscopic Anatomy of the Human Body in Health AND DISEASE. Illustrated with numerous Drawings in Colour. By ARTHUR HILL HASSALL, M.B., Fellow of the Linnæan Society, Member of the Royal College of Surgeons, &c. &c. Two Vols., 8vo, 2*l.* 5*s.*

Hassall's History of the British Freshwater Algæ, including Descriptions of the Desmideæ and Diatomaceæ. With upwards of 100 Plates, illustrating the various species. Two Vols. 8vo, 2*l.* 5*s.*

Morton's Surgical Anatomy of the Principal Regions. Completed by Mr. CADGE, late Assistant Surgeon, University College Hospital. Twenty-five Lithographic Illustrations Coloured, and Twenty-five Woodcuts. Royal 8vo, 21*s.* cloth lettered. It may also be had as under—Perinæum, 5*s.*; Groin, Femoral, and Popliteal Regions, 7*s.* 6*d.*; Inguinal Hernia, Testis and its Coverings, 7*s.* 6*d.*; Head and Neck, the Axilla, and the Bend of the Elbow, 7*s.* 6*d.*

"The work thus completed constitutes a useful guide to the student, and remembrancer to the practitioner. We can speak very favourably of the general execution of the work. The coloured lithographs are, for the most part, well drawn, and faithfully represent the broad features of the several parts. The woodcuts are well engraved, and very clearly exhibit the points which they are intended to illustrate. We think that Mr. Cadge's contributions in no degree fall short of the original work; and we trust that the volume in its complete form will find a cordial reception from the profession.—*Medical Gazette.*

A Series of Anatomical Plates in Lithography. Edited by JONES QUAIN, M.D., and ERASMUS WILSON, F.R.S.

		Plain.			Coloured.		
		£	*s.*	*d.*	£	*s.*	*d.*
Muscles.	51 Plates, bound	1	18	0	3	12	0
Vessels.	50 Plates ,,	1	18	0	3	3	0
Nerves.	38 Plates ,,	1	10	0	2	16	0
Viscera.	32 Plates ,,	1	5	0	2	8	0
Bones and Ligaments,	30 Plates	1	5	0	1	11	6

The work complete in 2 vols. royal folio, half-bound, morocco, gilt tops, price 8*l.* 8*s.* plain; 14*l.* coloured.

*** Proposals for publishing a remarkably cheap edition of this work have been issued, and may be had of the Publishers.

On Gravel, Calculus, and Gout; chiefly an Application of Professor Liebig's Physiology to the Prevention and Cure of those Diseases. By H. BENCE JONES, M.D., F.R.S., Physician to St. George's Hospital. 8vo, cloth, price 6*s.*

CHEMISTRY, &c.

FAMILIAR Letters on Chemistry. In its relations to Physiology, Dietetics, Agriculture, Commerce, and Political Economy. By JUSTUS VON LIEBIG. A New and Cheap Edition, revised throughout, with many additional Letters. Complete in one Volume, Foolscap 8vo, price 6*s.* cloth.

Annual Report of the Progress of Chemistry, and the Allied Sciences, Physics, Mineralogy, and Geology; including the Applications of Chemistry to Pharmacy, the Arts, and Manufactures. By PROFESSORS LIEBIG and KOPP, with the co-operation of Professors Buff, Dieffenbach, Ettling, Knapp, Will, and Zamminer. Edited by DR. HOFMANN and DR. BENCE JONES. Vols. 1, 2, and 3, for 1847, 1848, and 1849, 2*l.* Vol. 4 (1850), 1*l.* 1*s.*

Practical Pharmacy. The Arrangements, Apparatus, and Manipulations of the Pharmaceutical Shop and Laboratory. By FRANCIS MOHR, Ph. D., of Coblentz; and THEOPHILUS REDWOOD, Professor of Chemistry and Pharmacy to the Pharmaceutical Society of Great Britain. 400 Engravings on Wood. 8vo, 6*s.* 6*d.*, cloth.

Gregory's Handbook of Inorganic Chemistry. For the use of Students. By WILLIAM GREGORY, M.D., Professor of Chemistry in the University of Edinburgh. Third Edition, revised and enlarged. 12mo, 5*s.* 6*d.*

"A young man who has mastered these few and by no means closely printed pages, may venture to face any board of examiners on Chemistry, without fear of being posed by any fair question."—*Association Journal.*

Gregory's Handbook of Organic Chemistry; being a New and greatly Enlarged Edition of the "Outlines of Organic Chemistry, for the Use of Students." One volume, large 12mo, 9*s.* 6*d.* cloth.

Handbook of Organic Analysis. By JUSTUS LIEBIG. Edited by DR. HOFMANN, Professor in the Royal College of Chemistry, London. Large 12mo. Illustrated by 85 Wood Engravings. 5*s.* cloth.

"The work now before us is a most valuable contribution to our knowledge on this most important subject. The style is lucid, and the processes are not only explained to the mind, but are made manifest to the eye by a profusion of beautiful illustrations."—*Medical Times.*

Handbook of Inorganic Analysis. By FRIEDRICH WÖHLER, M.D., Professor of Chemistry in the University of Gottingen. Translated and Edited by DR. HOFMANN, Professor in the Royal College of Chemistry, London. Large 12mo, 6*s.* 6*d.* cloth.

"Next to Rose of Berlin in the ranks of living analytic chemists, particularly in the inorganic department of the art, stands Friedrich Wöhler, who has in this book given us a compendium of inorganic analysis, illustrated by examples of the methods to be pursued in the examination of minerals, both of a simple and complex constitution, which, if followed out by the student with ordinary care and patience, and with some little practical instruction, will not fail to render him a thorough master of this division of chemical knowledge."—*Association Journal.*

Elements of Chemical Analysis, Qualitative, and Quantitative. By EDWARD ANDREW PARNELL, author of "Applied Chemistry; in Arts, Manufactures, and Domestic Economy." Second Edition, revised throughout, and enlarged by the addition of 200 pages. 8vo, Cheap Issue, 9*s.* cloth.

Animal Chemistry; or, Chemistry in its Applications to Phy-SIOLOGY AND PATHOLOGY. By JUSTUS LIEBIG, M.D. Edited from the Author's Manuscript, by WILLIAM GREGORY, M.D. Third Edition, almost wholly re-written. 8vo, Part I. (the first half of the work) 6*s.* 6*d.* cloth.

Chemistry in its Application to Agriculture and Physiology. By JUSTUS LIEBIG, M.D. Edited from the Manuscript of the Author, by LYON PLAYFAIR, Ph. D., and WM. GREGORY, M.D. Fourth Edition, revised. Cheap Issue. 8vo, 6*s.* 6*d.*

Dyeing and Calico Printing. By EDWARD ANDREW PARNELL, Author of "Elements of Chemical Analysis." (Reprinted from Parnell's "Applied Chemistry in Manufactures, Arts, and Domestic Economy, 1844.") With Illustrations. 8vo, 7*s.* cloth.

Outlines of the Course of Qualitative Analysis followed in the GIESSEN LABORATORY. By HENRY WILL, Ph. D., Professor Extraordinary of Chemistry in the University of Giessen. With a Preface by BARON LIEBIG. 8vo, 6*s.*, or with the Tables mounted on linen, 7*s.*

Turner's Elements of Chemistry. Edited by Professors LIEBIG and GREGORY. Eighth Edition. 1 Vol. 8vo, 1*l.* 10*s.*

COMMON-PLACE BOOKS AND LITERARY DIARIES.

THE Private Diary. Arranged, Printed, and Ruled for receiving an account of every day's employment for the space of one year. With an Index and Appendix. Cheaper Edition. Post 8vo, strongly half-bound, 3*s.* 6*d.*

The Student's Journal. Formed on the plan of the "Private Diary." Cheaper Edition. Post 8vo, strongly half-bound, 3*s.* 6*d.*

The Literary Diary; or Complete Common-Place Book, with an Explanation and an Alphabet of Two Letters on a Leaf. Cheaper Edition. Post 4to, ruled throughout, and strongly half-bound, 8*s.* 6*d.*

A Pocket Common-place Book. With LOCKE'S Index. Cheaper Edition. Post 8vo, strongly half-bound, 6*s.* 6*d.*

DRAWING, &c.

LINEAL Drawing Copies for the Earliest Instruction. Comprising 200 subjects on 24 sheets, mounted on 12 pieces of thick pasteboard. By the Author of "Drawing for Young Children." In a portfolio. *5s. 6d.*

Easy Drawing Copies for Elementary Intruction. By the Author of "Drawing for Young Children." Set I. Twenty-six Subjects mounted on pasteboard. Price *3s. 6d.*, in a Portfolio. Set II. Forty-one Subjects mounted on pasteboard. Price *3s. 6d.*, in a Portfolio.

*** The Work may also be had (two sets together) in one Portfolio, price *6s. 6d.*

Drawing Models. Consisting of Forms for Constructing various Buildings, Gateways, Castles, Bridges, &c. The Buildings will be found sufficiently large to be drawn from by a numerous Class at the same time. In a Box, with a small Treatise on Drawing and Perspective. Price *2l. 10s.* Length of the Box, 18½ inches; breadth 13 inches; height 8½ inches.

Drawing Materials. A Quarto Copybook of 24 leaves, common paper, 6d. A Quarto Copybook of 24 leaves, paper of superior quality, *1s. 3d.* A Quarto Copybook of 60 leaves, *1s. 6d.* Pencils, with very thick lead, B.B.B. *2s.* per half dozen. Pencils, with thick lead, F. at *1s. 6d.* ditto. Drawing Chalk, *6d.* per dozen sticks, in a Box. Port-crayons for holding the Chalk, *4d.* each.

Perspective. Its Principles and Practice. By G. B. Moore. In two parts, Text and Plates. 8vo, cloth, *8s. 6d.*

The Principles of Colour applied to Decorative Art. By G. B. Moore, Teacher of Drawing in University College, London. Fcap., *2s. 6d.*

SINGING.

THE Singing Master. People's Edition. (One-Half the Original Price.) Sixth Edition. 8vo. *6s.*, cloth lettered.

"What chiefly delights us in the *Singing Master* is the intermixture of many little moral songs with the ordinary glees. These are chiefly composed by Mr. Hickson himself; and we could scarcely imagine anything of the kind better executed. They relate to exactly the class of subjects which all who wish well to the industrious orders would wish to see imprinted on their inmost nature—contentment with their lowly but honourable lot, the blessings that flow from industry, the fostering of the domestic affections, and aspirations for the improvement of society."—*Chambers' Journal.*

*** *Sold also in Five Parts, any of which may be had separately as follows:—*

FIRST LESSONS IN SINGING AND THE NOTATION OF MUSIC. Containing Nineteen Lessons in the Notation and Art of Reading Music. 8vo, *1s.* sewed.

RUDIMENTS OF THE SCIENCE OF HARMONY OR THOROUGH BASS. 8vo, *1s.* sewed.

THE FIRST CLASS TUNE BOOK. A selection of thirty single and pleasing airs, arranged with suitable words for young children. 8vo, *1s.* sewed.

THE SECOND CLASS TUNE BOOK. A selection of Vocal Music adapted for youth of different ages, and arranged (with suitable words) as two and three-part harmonies. 8vo, *1s. 6d.*

THE HYMN TUNE BOOK. A selection of Seventy popular Hymn and Psalm Tunes, arranged with a view of facilitating the progress of children learning to sing in parts. 8vo, *1s. 6d.*

The words without the Music may be had in three small books as follows:—
MORAL SONGS, from the First Class Tune Book. *1d.*
MORAL SONGS, from the Second Class Tune Book, *1d.*
HYMNS from the Hymn Tune Book, *1½d.*

*** The Vocal Exercises, Moral Songs, and Hymns, with the Music, may also be had, printed on Cards, price Twopence each Card, or Twenty-five for Three Shillings.

BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

L.H.

THE MUSEUM OF SCIENCE & ART.