THE

HISTORY AND PROGRESS

OF THE

ELECTRIC TELEGRAPH.

WITH

DESCRIPTIONS OF SOME OF THE APPARATUS.

BY

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C.

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PREFACE.

The favourable reception with which this work has been met by the public, and the kindly expressions of encouragement and approval accorded to it by the press, not in England alone, have determined the publishers to reprint it, with some additions, in this smaller and cheaper form. The edition in one volume is divided into two parts: the first containing a history of the rise and progress of the art of telegraphy, with descriptions of most of the apparatus in use at the present day; the second being devoted exclusively to the more scientific part of the subject, dealing particularly with matter having an immediate relation to submarine work. It has now been decided to separate these parts into distinct volumes, it being thought that there are many who, whilst interested in the history and apparatus, may not care for the scientific part; whilst others, and especially those connected with telegraphic engineering, may find only the information collected in the second part useful to them. For carrying out these objects there could be no better channel than "Weale's Rudimentary Series," the high character of which has rendered it deservedly celebrated.

Following the issue of the first edition of this work, there have appeared new and improved editions of Mr. Culley's excellent handbook for operators; of Lardner's work, edited by Mr. Bright—a work of great interest to the reader for general information; and a new work, with useful tables, by Mr. Clark—a valuable contribution to the desk of the telegraph engineer. We see, therefore, that telegraph literature, which slumbered in England during so long a period, is not only awake and active, but, as the result has proved, is welcomed by the reading public; and ere long we hope to see each of our friends follow us in the endeavour to make this interesting branch of civil engineering still more widely familiar, in putting their books within the reach of all by reducing them, as far as possible, to cheaper editions.

But ample room is still left for a more comprehensive, elaborate, and able treatise on telegraphy than this, and any of these, are or can be. And it is much to be desired that the history, the practice, and the science of the subject may be treated of separately and exhaustively. As far as the history goes, the author has done his best, with the scanty materials and limited space at his command, to give a short and truthful sketch of the origin, rise, and progress of an art grown to an importance sufficient in itself to immortalise its century. Where individual claims to a part of this immortality prominently occurred, they have been dealt with according to the author's lights. But the arrogance of any individual claim to the title of "*the inventor of the electric telegraph*" has not been recognised, for the reasons stated; and if a further reason be required, it may be given by the fact that those men who deserve the most credit happen to be those who advance the least claim to it.

Some means of rapid communication is, and probably always has been, not only a necessity, but an accomplished fact, in some form or other. It is difficult to understand that the mere knowledge of the attractive and repulsive forces of magnets was not in itself sufficient to suggest to an imaginative mind its application to the communication of intelligible signals. It is also no less difficult to conclude that an employment of frictional electricity to this purpose did not occur to Grey, Watson, Franklin, and others, but, from its apparently chimerical nature, it may, perhaps, have been dismissed, from time to time, from their minds as impracticable.

It is not in the first conception of this idea that so much credit lies, as in its gradual development into the proportions of a reality. How long a way to attain this may not have been struggling for birth in the thinking minds of past centuries it is now impossible even to imagine.

Mr. Bellamy has kindly called the author's attention to the fact that Galileo was fully alive to the importance which would attach to the employment of magnets for transmitting intelligence to a distance, but failed to see his way to the attainment of that object. In one of his dialogues on the two great rival astronomical systems, written in 1632, he makes

Sagredus say:*—"Tu facis ut meminerim alicujus, qui mihi venditabat occultam artam, qua per acûs magneticæ sympathiam quandam, ex intervallo duorum triumve millium milliariorum, invicem Colloqui liceret. Cumque dicorum, libenter empturem esse me, dummodo prius experimentum artis caperem, eamque ad rem sufficere, si ego in uno, ipse in alio cubiculi angalo consistamus, respondit mihi, operationem in tam exigua distantia cerni vox posse, quare dimisi hominem, ac dixi, mihi commodam non esse hoc tempore in Ægyptum aut Muscoviam illius experimenti capiendi causâ tendere: si tamen ipse ès ire velit, me Venetiis manentem partes alteras obiturum."

Galileo here, speaking in the name of his myth, "*Sagredus*," exposes himself to one of two suppositions: the first is, that he was himself the author of the idea which he very ingeniously transfers to an imaginary fellow who tried to swindle him; the second is, that, if not so (probably an accidental admission on his part), he, in the event of success, would have become the willing purchaser of (the credit or profit of?) another man's invention.

* "Galilei Systema Cosmicum." Dial. I. (near the end). Latin Translation published at Leyden in 1700.

Translation.—"You remind me of one who offered to sell me a secret art, by which, through the attraction of a certain magnet needle, it would be possible to converse across a space of two or three thousand miles. And I said to him that I would willingly become the purchaser, provided only that I might first make a trial of the art, and that it would be sufficient for the purpose if I were to place myself in one corner of the sofa and he in the other. He replied that, in so short a distance, the action would be scarcely discernible; so I dismissed the fellow, and said that it was not convenient for me just then to travel into Egypt or Muscovy for the purpose of trying the experiment, but that if he chose to go there himself I would remain in Venice and attend to the rest."

Things are little changed in this regard since Galileo's days: inventors are still to be found ready to sell fantastical schemes, and capitalists, when they think they see their way clear, to buy them.

As far as the descriptions of methods and apparatus go, which have been admitted into this book, the author has endeavoured to follow the example of *Sagredus*, by dismissing those which, from their professions, claimed a passing attention, but which, on nearer inquiry, turned out to belong, in his opinion, to the category of the fantastical.

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THE ELECTRIC TELEGRAPH.

SKETCH OF THE HISTORY AND PROGRESS OF THE ELECTRIC TELEGRAPH, WITH DESCRIPTIONS OF SOME OF THE APPARATUS.

I. Early Observations of Electrical Phenomena.

1. The history of the electric telegraph includes three distinct periods. The first of these embraces the earliest observations of electrical phenomena, their classification, and the inquiry into their physical causes. The second begins with the first suggestion of the application of electricity to the transmission of intelligence, and includes the experiments with frictional electricity. The third period dates from the discovery of galvanic electricity to the present time.

2. The phenomenon of electrical attraction produced by friction of bodies was, in some instances, known to the ancients. It was first noticed about six hundred years before the Christian era by Thales of Miletus, the founder of Ionic philosophy. He observed that when amber was subjected to friction it acquired the power of attracting light substances, such as bits of feathers; and on this account was led to attribute to it a species of vitality. The next mention we find is that of Theophrastus, who, three hundred

years later, observed that a hard stone (supposed to be tourmaline), when rubbed, attracted straws and little pieces of sticks in its vicinity. Pliny (70 A.D.), as well as other naturalists, both Greek and Roman, remarked, at different dates, the same phenomenon, which they regarded, in the spirit of the times, with superstitious reverence.

The ancient philosophers appear to have been but little inclined to institute researches into the laws governing the natural phenomena they observed, partly because their studies were confined to observations made at long intervals and unassisted by experimental investigations, partly perhaps because the conservative spirit of the times discouraged such inquiries, by preferring fantastical theories combined always with superstition.

3. No systematic inquiry into the subject was undertaken until Dr. Gilbert, towards the close of the sixteenth century, at the expense of much pains, arranged and published in his celebrated work, "De Magnete," a list of all those bodies in which he had observed the same property.

Towards the middle of the seventeenth century Dr. Wall discovered the electric spark on rubbing a cylinder of amber with a piece of flannel. On approaching the cylinder with his finger he obtained, for the first time, the spark, and noticed the noise which always accompanies it.

Boyle—who observed that warmth increased the electrical effects—and Otto Guericke, the inventor of the electrical machine, added to the little stock of electrical knowledge then in hand.

4. The first discovery which we have on record of the power of transmitting the electric fluid to a distance through an insulated wire is that of Stephen Grey, pensioner of the Charter House. Grey, having succeeded in electrifying a glass tube open at both ends, was desirous of finding out whether he could obtain the same result if he stopped up the ends with corks. This shows how at random the experiments were conducted at that date, and how little system

had been introduced into these inquiries. But Grey's experiment succeeded, and he was surprised to find the corks also highly electrified. On presenting the corked ends of the tube to a feather, he found that the feather was first attracted and then repelled. This led him to infer that the electricity which the tube had acquired by friction passed spontaneously to the corks. From the communication of electricity from tubes to corks Grey was led to transmit it through strings and wires; and in 1727 we find him employing a wire 700 feet long, suspended in the air by silk threads, to one end of which he brought his excited glass tube, whilst another person at the other end observed the electrification.

To Grey and Wheeler we owe the discovery that different materials possess different conducting powers. These physicists at first imagined that all materials would be equally capable of transmitting the electric impulse. In one of their experiments they employed a line formed of a hempen cord supported in the air by means of very fine silk fibro, believing that the loss of electricity at the points of support would be in proportion to the smallness of the diameter of the fibre, and that the greater part of the fluid would pass to the further end of the line. One end of the line supported an electrometer formed of a small ivory ball and piece of feather; the other end was brought into contact with an excited glass tube. When Grey rubbed the tube Wheeler observed the bit of feather attracted towards the ivory ball. Experimenting in this way on one occasion, one of the supports of the line became injured, and, not having any more silk at hand, a piece of metallic wire was employed to replace it, from which moment no more electricity could be made to reach the further end; and Grey discovered that the conduction of electricity was not only dependent upon the thickness, but also upon the material of the body interposed.

5. After Grey the subject was taken up by Desaguilliers,

who instituted inquiries into the different conductibilities of bodies. The discoveries of Grey had caused the bodies operated on to be assorted into two classes, which Desaguilliers proposed to distinguish by the names of "electrics," or non-conductors, and "non-electrics," or conductors.

6. On making experiments on the attraction of any light substance by an electrified body, it had been observed by Grey that the former was repelled from the moment that it was itself electrified by contact. It was further remarked that when the electrified body was a rod of glass, the light body would be strongly attracted by a stick of resin also electrified by friction. It is not a settled question whether it was Symner* or Dufay, who, in 1733, first concluded, from the combination of these facts, the existence of two electricities. It was supposed that all bodies in their natural state contained an equal amount of each of these electricities in equilibrium, but that from the moment this equilibrium was upset, and until it was re-established, the elements would divide themselves between the rubber and the rubbed body—those identical with the electricity of a glass rod showing themselves in some bodies, and, in others, those of the same nature as the electricity of a piece of resin. This occasioned the former to be called *vitreous electricity*, and the latter *resinous electricity*.

7. Benjamin Franklin believed, however, in the existence of only a single fluid, and explained the phenomena by supposing that on exciting any substance till the equilibrium of the electricity was destroyed, an excess of it would be deposited on one side, and a deficiency, necessarily to the same amount, would occur on the other. Hence he gave the name of *positive electricity* to that which Dufay had called vitreous, and *negative* to that called resinous.

Dufay, without the remotest idea of the transmission of signals for practical purposes, and with the pure curiosity of

* Phil. Trans., vol. lxi., part i., p. 340.

a physical experiment, made some capital attempts to ascertain the distance to which the electric attraction could be observed in an insulated wire.

Winckler, in Leipsic, and Lemonnier, of Paris, in 1746, and Dr. Watson, Bishop of Landaff, in 1747, took up the same inquiry.

8. The discovery of the Leyden jar by Muschenbrœck, of Leyden, in 1746, came very opportunely for the experimenters in the transmission of electric power.

Muschenbrœck, struck by the escape of electricity into the air, which he attributed to the vapours and effluvia suspended in it, had determined on an experiment by which he sought to preserve some of the mysterious fluid, to keep it out of contact with the air. For this purpose he selected water as its recipient, and a glass bottle as the best means of imprisoning it. On one occasion, happening to hold the bottle in his right hand, whilst he was charging the water contained in it by a wire leading to the prime conductor of a very powerful electrical machine, Muschenbrœck removed the wire with his left hand, and received a shock which his imagination probably led him to regard as much more terrible than it really was; for, in a conversation with Réaumur, he is reported to have said that he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two days before he recovered from the effects of the blow and the terror. "For the whole kingdom of France," added Muschenbrœck, "I would not take a second shock."

9. The Leyden jar—such was the name given to it thenceforth—was soon endowed with a more convenient form, and became one of the chief instruments in the hands of the students of electricity.

The form given to it by Watson resembled that shown in Fig. 1, in which *a a* is a coating of tinfoil upon the outer surface of a glass jar, *b b* an inner coating of the same material, and *c* a knob attached to a wire in connection with the inner coating. On charging the knob and inner coating of the jar with, for example, positive electricity, the charge acts upon the natural electricity of the outer coating, which, during the operation, should be connected by a conductor with the earth, decomposes it, and repels the positive element, attracting and retaining the negative element on the outer coating. If the communication between the knob and

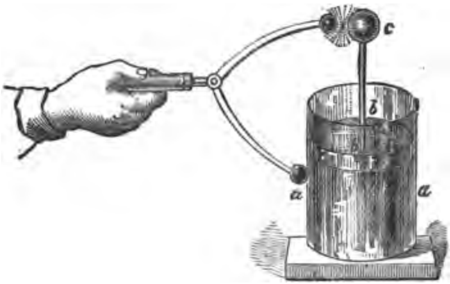


Fig. 1.

the source of electricity be broken, the charge will remain accumulated on the inner coating of the jar; and if a connection be then made between the knob and the outer coating by means of a wire or of a discharger, as shown in the figure, the opposite electricity accumulated on the coatings of the jar will rush towards each other through the conductor, producing, on its approach to complete communication, a spark of brilliant light.

Suppose that, instead of the short discharger, a wire of several yards' length were employed, the effect would be the same. And it was virtually to ascertain the maximum length of this wire that formed the purpose of those researches of Grey, Desaguilliers, Watson, and others, to which we are indebted for the first suggestion of a telegraph.

10. Watson, in 1747, stretched a wire across the Thames, over old Westminster Bridge. One end was fixed to the exterior coating of a Leyden jar, the interior coating being

connected to earth through the body of the experimenter, and the other end held by a person who grasped an iron rod. The moment the latter dipped the rod into the river, both felt a shock.

Subsequently, in the same year, Watson transmitted an electric discharge through 2,800 feet of wire, and the same distance of earth, at Stoke Newington; and on the 14th of August, in the same year, repeated his experiments on a considerably larger scale, transmitting the electric impulse through 10,600 feet of wire suspended from insulators of baked wood screwed upon a line of wooden poles erected on Shooter's Hill.

Franklin made similar experiments in 1748 across the Schuylkill, at Philadelphia, and Du Luc, about the same date, across the Lake of Geneva.

But up to this time the experiments had been conducted without a suspicion of the glorious results to which they were leading. And even in the hands of the ingenious and original Franklin, we do not find that the idea suggested itself to him to apply the power he found capable of being felt at the end of a wire of considerable length, to the communication of intelligence.

II. Telegraphs by Frictional Electricity.

11. In the *Scot's Magazine* for 1753 * is a letter to the editor, from a correspondent signing himself "C. M.," to whom we must give the credit of being the first who published the idea of applying electricity to the telegraph.

This interesting communication is as follows:—

"To the Editor of the 'Scot's Magazine.'

Renfrew, Feb. 1st, 1753.

"Sir,—It is well known to all who are conversant in electrical experiments that the electric power may be propagated along a small

* *Scot's Magazine*, vol. xv., p. 73. The page is headed, "An expeditious method of conveying intelligence."

wire, from one place to another, without being sensibly abated by the length of its progress. Let, then, a set of wires, equal in number to the letters of the alphabet, be extended horizontally between two given places, parallel to one another, and each of them about an inch distant from that next to it. At every twenty yards' end let them be fixed in glass, or jeweller's cement, to some firm body, both to prevent them from touching the earth or any other non-electric, and from breaking by their own gravity. Let the electric gun-barrel be placed at right angles with the extremities of the wires, and about one inch below them. Also let the wires be fixed in a solid piece of glass, at six inches from the end; and let that part of them which reaches from the glass to the machine have sufficient spring and stiffness to recover its situation after having been brought in contact with the barrel. Close by the supporting glass let a ball be suspended from every wire; and about a sixth or an eighth of an inch below the balls place the letters of the alphabet, marked on bits of paper, or any other substance that may be light enough to rise to the electrified ball; and at the same time let it be so continued that each of them may re-assume its proper place when dropped. All things constructed as above, and the minute previously fixed, I begin the conversation with my distant friend in this manner:—Having set the electrical machine agoing as in ordinary experiments, suppose I am to pronounce the word *Sir:* with a piece of glass, or any other *electric per se,* I strike the wire *S*, so as to bring it in contact with the barrel, then *i*, then *r*, all in the same way; and my correspondent, almost in the same instant, observes these several characters rise in order to the electrified balls at his end of the wires. Thus I spell away as long as I think fit; and my correspondent, for the sake of memory, writes the characters as they rise, and may join and read them afterwards as often as he inclines. Upon a signal given, or from choice, I stop the machine; and taking up the pen in my turn, I write down whatever my friend at the other end strikes out.

"If anybody should think this way tiresome, let him, instead of the balls, suspend a range of bells from the roof, equal in number to the letters of the alphabet, gradually decreasing in size from the bell *A* to *Z;* and from the horizontal wires let there be another set reaching to the several bells; one, viz. from the horizontal wire *A* to the bell *A*, another from the horizontal wire *B* to the bell *B*, &c. Then let him who begins the discourse bring the wires in contact with the barrel, as before; and the electric spark, breaking on bells of different size, will inform his correspondent by the sound what wires have been touched: and thus, by some practice, they may come to understand the language of the chimes in whole words, without being put to the trouble of noting down every letter.

"The same thing may be otherwise effected. Let the balls be suspended over the characters as before, but instead of bringing the ends of the horizontal wires in contact with the barrel, let a second set reach from the electrified cable, so as to be in contact with the horizontal ones; and let it be so contrived at the same time, that any of them may be removed from its corresponding horizontal by the slightest touch, and may bring itself again into contact when set at liberty. This may be done by the help of a small spring and slider, or twenty other methods, which the least ingenuity will discover. In this way the characters will always adhere to the balls, excepting when any one of the secondaries is removed from contact with its horizontal; and then the letter at the other end of the horizontal will immediately drop from its ball. But I mention this only by way of variety.

"Some may perhaps think that, although the electric fire has not been observed to diminish sensibly in its progress through any length of wire that has been tried hitherto, yet, as that has never exceeded some thirty or forty yards, it may be reasonably supposed that in a far greater length it would be remarkably diminished, and probably would be entirely drained off in a few miles by the surrounding air. To prevent the objection, and save longer argument, lay over the wires from one end to the other with a thin coat of jeweller's cement. This may be done for a trifle of additional expense; and as it is an *electric per se*, will effectually secure any part of the fire from mixing with the atmosphere.

"I am, &c.,

"C. M."

This is one of the most interesting documents to be found in the whole history of telegraphy. The writer was, evidently, not acquainted with Watson's experiments, or he would not probably have suggested insulation by "jeweller's cement;" but the suggestion was an ingenious one. The idea which we find of keeping his lines charged with electricity, and giving the signals by discharging them, as well as that of reading signals by sound of bells, both of which, long years afterwards, were brought, with certain modifications, into practice, deserve to be remembered to his credit.

12. To Lesage,* however, belongs the honour of having established, in practice, the first telegraph wire for the transmission of intelligible signals. His system was almost the realisation of the idea of the Scotchman, "C.M." He erected

* Moigno's "Télégraphie Electrique," p. 59.

at Geneva, in 1774, a telegraph line of twenty-four metallic wires, insulated from each other. Each wire was connected at the further end to a separate pith-ball electroscope, and corresponded with one of the letters of the alphabet. In this way any letter could be indicated by bringing to the end of the wire a source of static electricity produced by friction, which would immediately cause the divergence of the pith balls of its particular electroscope.

13. The electroscope used in these experiments consisted of two small pith balls suspended from a common metallic support, by cotton threads or fine wires. It will, without further explanation, be evident from what has gone before, that in charging the system, shown in equilibrium at *a*, Fig. 2, the two pith balls, having the same kind of electricity, would repel each other, and assume a position similar to that shown at *b* in the same figure. This would continue as long as the charge lasted. The balls would in course of time, however, approach each other again by their own gravity, the escape of their electricity into the surrounding air diminishing the repelling force. This could, and perhaps was, effected by Lesage suddenly, by discharging his line as soon as he had given a signal; in other words, by letting the line and pith balls reassume a state of electrical equilibrium.

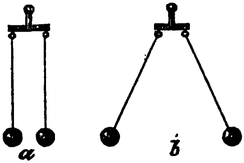


Fig. 2.

14. Lomond, in 1787, by the employment of a delicate electroscope, and combinations of signals, given by the divergence of pith balls, succeeded in transmitting intelligence with the aid of a single line-wire.

A short account of this invention is given by Arthur Young,* in the following words:—

"M. Lomond has made a remarkable discovery in electricity. You write two or three words on a paper; he takes it into a room, and turns a machine enclosed in a cylindrical

* "Travels in France," vol. i. p. 979, 4th edition. 1787.

case, at the top of which is an electrometer, a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife, by remarking the corresponding motions of the ball, writes down the words they indicate, from which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance, within or without a besieged town, for instance, or for objects much more worthy of attention, and a thousand times more harmless."

15. In 1794 Reusser proposed, in the *Magasin de Voigt*,* the construction of a telegraph by means of electrical discharges passing over the parts of a broken conductor enclosed in a glass tube, or by letters formed by spaces cut out of parallel strips of tinfoi pasted on square plates of glass. Such letters are shown in Fig. 3. An electric discharge from the interior coating of a Leyden jar being sent, for instance, through the double strips of tinfoil, from the end marked + to the end marked — connected with the outer coating of the jar, a spark would pass over each of the intervening spaces at the same time, and the letter would appear beautifully illuminated in the dark. This experiment of Reusser forms to this day a very common illustration of tension electricity in lecture-rooms.

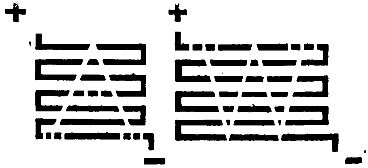


Fig. 3.

Reusser further suggested to call the attention of the observer, at the distant station, by firing an electric pistol by means of the spark.

16. In Spain, about the same time, Don Silva read a paper before the Academy of Sciences of Madrid, on a system of telegraphing with a single wire, by means of continuations of sparks, said, by the *Magasin de Voigt*, to have been carried out, two years later, with no small success, by the Infanto

* *Magasin de Voigt*, vol. ix. p. 183.

Antonio; and Betancourt stretched a single line in the air, over a space of twenty-seven miles, beween Madrid and Aranjuez. He employed a battery of Leyden jars, and received signals by observing the divergence of suspended pith balls.

17. Cavallo was the next who strove to attain the perfection of a telegraph by means of frictional electricity. In 1795 he published his "Traité d'Électricité," in which he gave descriptions of his systems of electric signalling and communication. He proposed to transmit letters and numerals by combinations of sparks and pauses. His electric alarm was based upon the explosion of a mixture of hydrogen and oxygen gases or of gunpowder by the electric discharge.

18. It is necessary here to depart a little from historical order, to mention the last and most ingenious invention of a telegraph worked by frictional electricity; this was the invention of Mr. Ronalds, of Hammersmith. For the purposes of experiment he erected a line, eight miles long, insulated by silk and dry wood, in his garden, and also buried a considerable length of wire, insulated in glass tubes, encased in pitch and wood, in the earth. This was in 1823. For the following description of the invention we are indebted to Mr. E. Highton's * book:—

Ronalds employed an ordinary electric machine and the pith-ball electrometer in the following manner. He placed two clocks at two stations; these two clocks had upon the second-hand arbour a dial with twenty letters on it; a screen was placed in front of each of these dials, and an orifice was cut in each screen, so that one letter only at a time could be seen on the revolving dial. The clocks were made to go isochronously; and as the dials moved round, the same letter always appeared through the orifices of each of these screens. The pith-ball electrometers were hung in front of the dials.

* "The Electric Telegraph," by E. Highton, p. 50. 1852.

It is evident, therefore, that if these pith balls could be made to move at the same instant of time, a person at the transmitting station, by causing such motion in both those electrometers, would be able to inform the attendant at the

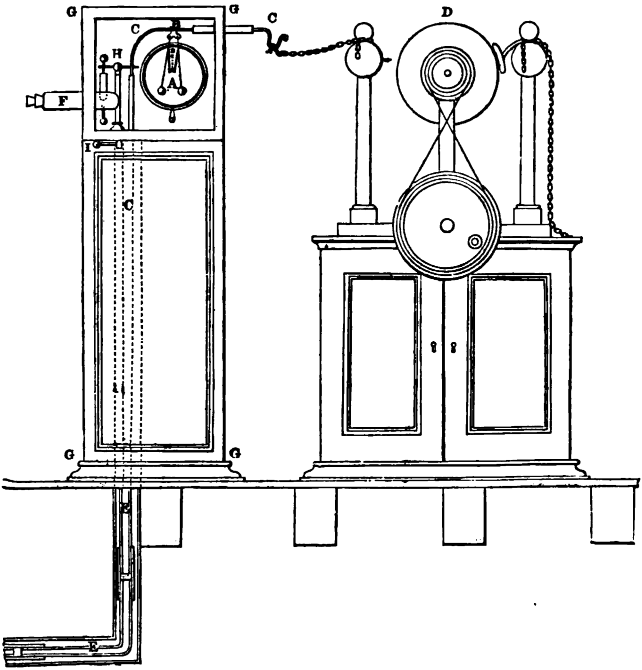


Fig. 4.

distant or receiving station what letters to note down as they appeared before him in succession on the dial of the clock.

This was accomplished in the following manner. The transmitter caused a current of electricity to be constantly operating upon the electrometers, except only when it was required to denote a letter, and then he discharged the electricity from the wire, and instantly both balls collapsed. The distant observer was thereby informed to note down the letter then visible. In this way letter after letter could be denoted, words spelt, and intelligence of any kind transmitted. All that was absolutely required for this form of telegraph was, that the clocks should go isochronously *during the time* that intelligence was being transmitted; for it was easy enough by a preconcerted arrangement between the parties, and upon a given signal, for each party to start their clocks at the same letter, and thus, if the clocks went together during the transmission of the intelligence, the proper letters would appear simultaneously, until the communication was finished. The attention of the distant observer was called by the explosion of gas by means of electricity from a Leyden jar.

Fig. 4 shows an elevation of the apparatus, in which D is an electrical machine, B a pith-ball electrometer, A the screen hiding the letters on the dial-plate except the one seen through the orifice, F the gas alarm, and E the tube conveying the wires from the station.

Fig. 5.

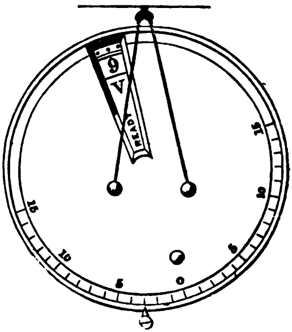


Fig. 6.

Fig. 5 shows the dial; and Fig. 6 the same with the screen before it, and the pith-ball electroscope.

Too much credit cannot be given to all these men for their energy in struggling, with the imperfect means and small experience at their command, to realise an end which the nature of the electricity they employed rendered impossible.

And if we can award to none of them the title of the inventor of a practical telegraph, we must, at least, give them credit for having fully appreciated its importance, and for having dedicated their energies to the accomplishment of the task they set themselves, and persevered in the face of many sad difficulties and disappointments.

III. TELEGRAPHS BY VOLTAIC ELECTRICITY.

19. A new discovery—that of voltaic electricity—had for some years occupied the attention of the scientific world, and at the beginning of the present century the thoughts of students of electricity were directed to its application for the purposes of telegraphy, instead of the unmanageable frictional electricity with which they had hitherto had to content themselves.

The first mention we find of this species of electricity is in the recital which Sulzer published, in 1767, of the following experiment in his "Théorie du Plaisir." On taking two pieces of different metals—silver and zinc—and placing one of them above and the other underneath his tongue, he found that, so long as the metals did not make contact with each other, he felt nothing; but that when the edges were brought together over the tip of his tongue, the moment contact took place, and during the time it lasted, he experienced an itching sensation, and a taste resembling that of sulphate of iron. If he changed the relative positions of the metals, he experienced a different sensation, which he found difficult to describe.

Sulzer supposed that the contact of the two metals occasioned a vibration of their particles, which, acting on the nerves of the tongue, produced the taste in question.

The next to whom chance afforded an opportunity of making the discovery of galvanism, but who let it pass with as little profit as Sulzer had done, was a student of medicine in Bologna. Cotugno, professor of anatomy in Naples, in an article in the "Journal Encyclopédique de Bologne" for 1786, tells us that his pupil was once occupied in dissecting a mouse which he held in his hand, when, having touched one of the nerves with his scalpel, he felt a shock resembling that produced by electricity.*

In 1790 Madame Galvani, wife of the professor of anatomy at Bologna, being attacked with a slight cold, her physician prescribed her *frog broth.* Frogs were provided for the purpose, skinned, washed, and laid upon a table in the laboratory of the professor to await the moment when they were to undergo the culinary operation. Whether this operation was to be performed in the laboratory, is not said; it is certain, however, that Madame Galvani was there with one of the professor's assistants, who was at the moment engaged in some experiments with a large electrical machine which stood upon the same table. Whenever the assistant, in the course of his experiments, took sparks from the conductor of the machine, Madame Galvani was astonished to observe a twitching resembling life in the limbs of the dead frogs.

This circumstance excited the lady's curiosity in the highest degree, and she related her observation to her husband, who immediately repeated the experiment, and found the convulsions return whenever he took sparks from the machine.†

The professor, who was luckily not more learned in electrical science than in some of the other branches of physics, was unable to give the explanation of the phenomenon, with

* "Essai sur l'Histoire Générale des Sciences pendant la Révolution Française," par J. B. Biot, p. 9.

This phenomenon, as related by Cotugno, made much sensation at the time in Italy, and gave rise to a considerable series of experiments by Vassalli, who conjectured that nature had provided means of retaining electricity accumulated in some part of the animal body. These experiments, which were published in 1789, were probably known to Galvani, who, the following year, took up the same inquiry.

† "Aloysii Galvani de Viribus Electricit. in motu musculari Commentar," p. 2.

which he would probably have contented himself, and have let the matter drop, had he been an experienced electrician. But he was struck by the novelty of the new fact, and he determined to follow it up.

Galvani thenceforth prosecuted his studies and experiments on the electricity of animals, with perseverance, and accident rewarded him for his industry by again coming to his aid. In his experiments on the electricity of frogs, he had occasion to separate the lower parts of the bodies from the upper. Having prepared a frog in the ordinary manner, on one occasion he remarked that, on hanging it up to an iron balustrade of his house, by a hook of copper wire passed through part of the dorsal column remaining above the junction of the thighs, it all at once underwent a series of lively convulsions.

The professor was more than ever astonished, for there was this time no electrical machine to account for the appearance, and he was compelled to take refuge in the hypothesis of what he called "animal electricity," supposing opposite kinds of electricity to exist in the muscles and nerves of the animal. In this hypothesis he regarded the muscles and nerves as the charged coatings of a Leyden jar. It is worthy of remark and regret that Galvani should have so thoroughly mistaken the important part played in the affair by the two metals, iron and copper. He regarded these, however, only in the light of a compound conductor, through which the opposite electricities assumed to exist in the nerves and muscles, discharged themselves.

It is not a rare thing in the annals of science that accidents, the result apparently of mere chance, have suggested experiments which have led to some great discovery. But we seldom meet with accidents so favourable to advancement as those which directed the attention of Galvani to the study of animal electricity by a phenomenon of electroscopic sensibility in the nerves of a frog; his fortunate ignorance. which, combined with his ardent imagination, caused him to form hypotheses only excellent because, in being stubbornly supported by himself, he added to the stock of facts, through his many and varied experiments, and occasioned a discussion in which his views were successfully refuted by the masterly intellect of Alexander Volta. "In der Beobachtung einer anfangs isolirt stehenden Erscheinung liegt oft der Keim einer grossen Entdeckung," says Humboldt; * and Galvani found it so, and, drawing the attention of the *savans* of Europe to a phenomenon which, although he had not been the first to observe it, was the first to busy himself about, deservedly earned his title of a pioneer in science.

20. Immediately after the publication of Galvani's hypothesis, Alexander Volta, professor of physics at Pavia, occupied himself with an inquiry into the causes of the frog phenomenon, and was not long in perceiving a want of basis in Galvani's theory. With much penetration Volta recognised the intrinsic elements in the complicated appearance which Galvani had discovered, and sought, with success, to produce the same by substituting other materials for the frogs and other animal bodies. He contended that the two metals, copper and iron, in the experiment of Galvani, were the real electromotors, and that the muscles of the dead frogs only played the part of a moist conductor in completing the circuit. Volta was of opinion that the simple contact of two dissimilar metals was sufficient to develop electricity, and that the strength of the electricity excited depended upon the nature of the metals. This was vigorously opposed by the partisans of Galvani, who held tenaciously to the doctrines of their master, and a scientific war of opinions ensued between the schools of Pavia and Bologna, out of which Volta came victorious even before he had completely verified his sagacious conjectures by experimental proof.

If the tongue be applied to the conductor of an electric machine which is being turned, an acid or alkaline taste

* "Cosmos," Einleitende Betrachtungen.

will be perceived according as the conductor is being charged with positive or negative electricity. The similarity of these results with those obtained by Sulzer was an analogy advanced by Volta in support of his contact theory.

Another theory, and that now very generally accepted, was first suggested by Fabroni, and is known, in contradistinction, as the chemical theory. This theory regards chemical decomposition as necessary to the development of the voltaic current.

A discussion of the arguments advanced in support of these two theories would be out of place here; but we shall discuss them in the second volume of this work. The German physicists for the most part hold out for the contact theory, whilst the French and English generally accept the chemical as the most rational, and as that affording the most satisfactory explanations of known phenomena.

21. Volta, in 1800, wrote a letter from Como to Sir Joseph Banks, President of the Royal Society in London, stating that he had found a means of augmenting, at pleasure, the development of galvanic electricity. This he had accomplished by placing upon a plate of glass first a disc of copper, then on this a disc of zinc, and over these a similar sized disc of damp cloth; and by continuing to pile up discs of these materials, in the same order, copper, zinc, cloth, until he had a sufficient number. He then connected wires to the lower and upper plates.

22. This apparatus is known as the voltaic pile.* Its properties are concisely stated as follows:—

1st. It communicates a charge of positive electricity to a condenser in connection with the wire attached to the last zinc disc, when the last copper disc is connected with the earth.

2nd. It communicates a charge of negative electricity to the condenser when the poles are reversed, that is to say,

* The more recent forms given to the pile, as at present employed in telegraphy, are explained in the second volume.

when the zinc of the upper part is put into contact with the earth, and the condenser with the copper disc at the bottom. These experiments may be repeated *ad infinitum* even after the pile has been mounted some hours, provided the cloth retains some moisture.

3rd. It produces chemical effects with an energy proportional to the number of elements accumulated.

The zinc disc which forms one of the extremities of the pile, being that which, in communication with the condenser, gives a positive charge, has been called the *positive pole*, and the copper plate at the bottom of the pile the *negative pole*.

23. Immediately after the receipt of Volta's letter, by the President of the Royal Society, a pile was constructed on this principle by Mr. Nicholson (the conductor of *Nicholson's Journal*) and Sir Anthony Carlisle. A drop of water being, on one occasion, used by them to make a good contact between the conducting wire and a plate of metal with which they were experimenting, Carlisle observed a disengagement of gas from it. Further experiments discovered very shortly the decomposition of water by the electric current. Thus was a fortunate accident once more on the stage in promoting electrical discovery, and this time the magnificent investigations of Humphrey Davy were the result.

24. In the year 1808, Herr S. T. Sömmering, a surgeon, communicated to the Munich Academy of Sciences his invention of a system of telegraphing based upon the discovery of the British chemists, Nicholson and Carlisle,* that water is decomposed into its constituents of oxygen and hydrogen by the voltaic current.

At the station which was to receive signals were arranged, in a narrow vessel of water, thirty-five glass tubes, each containing a gold point, twenty-five marked with letters of the alphabet, nine with numerals, and one with a zero. From each point an insulated wire was led to a metal terminal at the transmitting station.

* "Galvanism," by Sir W. S. Harris, p. 35.

To send a signal it was only necessary to bring the two poles of a voltaic pile to two of the terminals in question. The current passing from one terminal traversed its line wire to the voltameter at the receiving station, where it passed between the gold points corresponding to the terminals touched by the poles, and returned through the other line wire to the terminal of the other pole of the pile.

In doing this, bubbles of hydrogen appeared at the gold

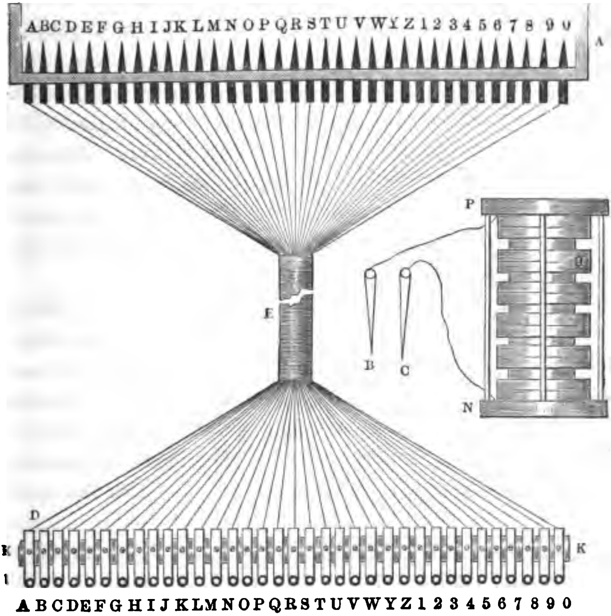


Fig. 7.

point in communication with the positive pole, and bubbles of oxygen at the other one. Thus two signals were given simultaneously, to which that of the hydrogen took precedence. When it was desired to indicate only one letter, the positive pole of the battery was brought in connection with zero, and the negative with the letter to be transmitted.

The connection wires were well insulated, and, at a little distance from the transmitting terminals at one end, and from the voltameters at the other, were bound up in the form of a cable. Sömmering proposed to call the attention of the receiving station by liberating an alarm by means of accumulated gas.

Fig. 7, a copy of that given by Sömmering in his description of this telegraph will illustrate the foregoing. A A is a sectional view of the glass reservoir. A B C . . . . 8 9 0 are the thirty-five gold points of the voltameter arrangement, passing through the bottom of the glass reservoir. The lower ends of the thirty-five gold points were soldered to copper wires insulated with silk, passing through the tube E of glass or porcelain to the transmitting station. Here the wires, marked with the respective letters and numerals, were insulated on a wooden support, K K. The ends of the terminals were furnished with holes, I, to receive the poles B and C of the voltaic pile P N.

The construction of this telegraph—the first in which voltaic electricity was employed—involved an outlay which, in conjunction with the slowness of working, would have prevented its commercial utility even if the science had not advanced by any of those astonishing strides which marked its progress a few years afterwards. The idea of a practical telegraph was, however, too new not to meet with the opposition which good inventions almost invariably enjoy in starting into life. That his telegraph did not come to be of public use cannot lessen, nevertheless, Sömmering's credit of having been the first who showed how important the discovery of voltaic electricity might become in the service of the telegraph.

25. An improvement on the system of Sömmering was published by Professor Schweigger, of Erlangen, in an appendix to his memoir of Sömmering. He suggested that, for the alarm, it would be possible to employ a pistol by the connection of a battery to the pile. In addition to this, he

proposed to diminish the number of wires used in Sömmering's telegraph to two, by using two galvanic piles of unequal power, so that the amount of gas given off in a certain time by the one battery would be much more than by the other, and, by varying the time of development of the gas and of the intervals, he proposed to form a code of signals.

26. About the same time that Sömmering invented his telegraph, the same system was suggested by Professor Coxe, of Pennsylvania, and described by him in a paper published in Thomson's "Annals of Electricity," 1810. Coxe had the idea also of telegraphing by means of the decomposition of metallic salts. His systems were, as he described them, considered, however, impracticable.

IV. Telegraphs by Electro-Magnetism and Magneto-Electricity.

27. The power of lightning to weaken the magnetism of the compass needle, and even sometimes to reverse its polarity for a long time, suggested the suspicion of a near relation between electricity and magnetism. The discovery of the power of a galvanic current to deflect a magnet needle, as well as to polarize an unmagnetized one, were known to, and described as early as 1804, by Professor Izarn, in his "Manuel du Galvanisme." The paragraph which especially refers to this subject is headed "Appareil pour reconnaître l'action du galvanisme, sur la polarité d'une aiguille aimantée." * After explaining the way to prepare the apparatus, which consists simply in putting a freely suspended magnet needle parallel and close to a straight metallic conductor through which a galvanic current is circulating, he describes the effects in the following words: "D'après les observations de Romagnési, physicien de Trente, l'aiguille déjà aimantée, et que l'on soumet ainsi au courant galvanique,

* "Manuel du Galvanisme," etc., par Joseph Izarn. Paris, 1804 The copy was kindly lent us by Mr. Latimer Clark, from his valuable library of electrical works.

éprouve une déclinaison; et, d'après celles de J. Mojon, savant chimiste de Gènes, les aiguilles non-aimantées acquièrent, par ce moyen, une sorte de polarité magnétique."

To Romagnési, physicist of Trent, therefore, and not, as is generally believed, to Oerstedt, physicist of Copenhagen (who first observed, in 1820, the phenomenon of the deflection of a magnet needle by a voltaic current), is due the credit of having made this important discovery. Little was known about it, however, until Oerstedt repeated the experiment, and no use was made of it until Ampère, in Paris, found the law by which this influence was governed, and which he briefly expressed as follows :—

"Imagine a human figure in the direction of a conductor through which a positive current is flowing upwards, the figure will have the north pole on the left hand if its face be turned towards the needle."

Thus, if a positive current pass along the upper wire in the annexed figure (Fig. 8) from *a* towards *b*, the magnetic

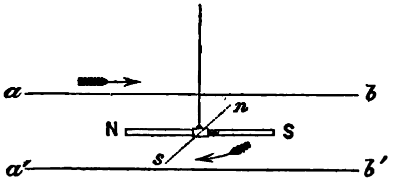


Fig. 8.

needle N S, suspended in its neighbourhood, will be deflected, and take up a position indicated by the dotted line *n s*, at nearly right angles to the wire. When the current is reversed the poles will be deflected in the other direction, the pole *n* being where *s* is, in the figure. It will become evident on regarding the figure also that, if a similar current pass in the lower wire from *b'* to *a'*, it must produce the same magnetic direction upon the needle as a current in the upper wire would from *a* to *b*. In the case of the upper wire the observer's head is supposed to be near *b*, and his feet near *a*, the current passing upwards in the direction of the arrow, and the north pole is found on his left hand when he faces the needle. In the case of the lower wire, however, the direction of the current is reversed, and the position of the observer must be supposed to be reversed also—head at *a′*, feet at *b′*. While he faces the needle the north pole is still found on his left hand. When currents pass, therefore, in both wires at the same time in opposite directions, they act in the same sense on the magnetic needle N S, and, other things being equal, their combined force is double that of a single wire. The same would be reached by joining *b* and *b′* by a wire, and letting a current of equal strength pass from *a* to *b*, *b′*, and *a′*.

28. Professor Schweigger, of Halle, the same who suggested improvements of Sömmering's telegraph, soon after the publication of the law of electro-magnetism by Ampère,

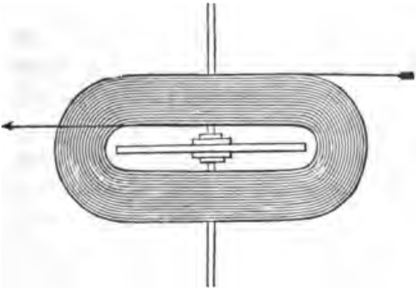


Fig. 9.

invented an apparatus made by coiling a wire several times round a magnetic needle, and found that the deflecting force increased with the number of turns. Such an apparatus, called an electro-magnetic multiplier, is shown in Fig. 9. It has since become one of the most essential instruments for the measurement and indication of galvanic electricity.

29. The brilliant discovery of electro-magnetism was speedily followed by attempts to employ it for the telegraph, which made, from this time, gigantic progress towards its present state of perfection.

The idea of substituting magnetic needles suspended in multipliers of wire in place of the voltametres of Sömmering seems first to have occurred to La Place, and to have been warmly seconded by Ampère, who explained it in a paper read before the Academy of Sciences at Paris, in October, 1820.*

He says that by means of the same number of magnetic needles and line wires as there are letters of the alphabet, and with the help of a voltaic battery whose poles could be brought in connection, one after the other, with the ends of the wires, a telegraph might be produced by which all possible communications might be made to a person at a distance off, who was charged to observe the needles. If a keyboard whose keys were each marked with a letter of the alphabet were adapted to the battery, so that on pressing down the key of any letter the circuit corresponding to that letter would be closed, correspondence could be carried on with ease, and would require only the time necessary to press down the keys at the one station, and to read off the letters from the deflected needles at the other.

This telegraph, as imagined by Ampère, was, however, doomed to the same fate as that of Sömmering, of never coming into practice, and for the same reasons, principally the number of line wires. Had Ampère combined his system, or rather that of La Place, with that which Schweigger proposed of reducing Sömmering's telegraph to two wires, or with any other using a code of signals, the problem of the electric telegraph would have been solved from the year 1820.

Two years later, Fechner, of Leipsig, proposed the simplification of this telegraph to two wires and a single magnet needle, the deflections of which, to the right or left hand, were to supply the elementary signals for the construction of an alphabet. But two serious inconveniences—the irregularity of the batteries, and, above all, the rapid decrease

* "Annales de Physique et de Chemie," vol. xv. p. 72.

of their intensity—only permitted the application of this great idea on a small scale.

30. Ritchie, however, carried out a really excellent modification of Ampère's invention by encircling thirty magnetic needles with coils of wire; each needle being furnished with a small screen, so that when it was unaffected by a current, the screen covered over a letter of the alphabet, which was exposed as soon as the needle was deflected. This telegraph was first exhibited in public, some years later than the date of its invention, by Mr. Alexander, of Edinburgh. He divided his thirty wires into twenty-six letters of the alphabet, three signs of punctuation, and an asterisk for indicating the end of a word. The return circuit was formed by a single wire.

31. In 1825, Mr. Sturgeon, of London, discovered that when a soft iron bar is surrounded by a helix of wire, through which a galvanic current is passing, it acquires magnetism, which lasts only as long as the current continues in the coil. In this way he constructed some powerful magnets. A form which he made, and which acquired an immense lifting power, is shown in Fig. 10. For this purpose, pieces of soft iron were bent in the form of a horse-shoe, round the horns of which he wound spirally a length of well insulated copper wire. One end of the magnet so arranged became a north pole and the other a south pole if the spiral wire were wound in the same direction throughout, supposing the horse-shoe to be bent straight.

Fig. 10.

The positions of the poles depend, of course, upon the direction in which the spirals are wound, and upon the direction in which the current traverses them, according to the same law as that by which Ampère expressed the positions of the poles of deflected magnets.

In the coil, Fig. 11, for example, the positive current descending between the observer and the soft iron bar, the spiral being right-handed, the north pole would be on the right hand of the observer.

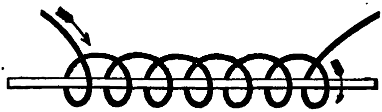


Fig. 11.

In order to increase the power of electro-magnets, the wire has to be wound several times round each of the horns. This is generally done by means of bobbins which can be removed at pleasure. Such magnets have been made with iron cores 3 inches and more in diameter, and over a foot in length, which have carried nearly a ton weight. It is strange that this discovery, which has since proved so important in practical telegraphy, was not made use of in any system until some years later.

32. The next important step towards the perfection of present telegraphy was that made in 1832 by Baron Schilling von Cannstedt. In some of the accounts of his system we read that it consisted of a certain number of insulated platinum wires united by a silk cord, which set in motion, by means of a sort of piano, five magnetic needles placed in a vertical position within coils of wire. According to other accounts, he employed only one magnetic needle and multiplier, with two leading wires, as proposed by Fechner, and was enabled by means of a combination of the deflections of this needle to the right and left, by changing the poles of the battery at the ends of the wires, to give all the signals necessary for a complete correspondence. His call signal was given by means of an alarm consisting of a bell in connection with a clockwork, which was released by the deflection of a magnet. Schilling executed models of his apparatus, which were exhibited before the Emperor Alexander, and still later before Nicholas. He, however, unhappily died before carrying out his invention in practice. The probability is that he suggested both the systems of five and single needle instruments, the latter as an improvement on the former; but his constructions appear to have been of

a complicated nature, and therefore unsuitable for practical use.

33. We owe to the enterprising genius of Michael Faraday the two discoveries not less important in physics than useful in relation to the telegraph—volta-electric induction, and magneto-electricity.

These were no chance discoveries; and in this they differ from those made by Galvani, who stumbled over his phenomena; they were results of profound consideration; Faraday anticipated his discoveries, advancing systematically towards them step by step. He says, in his "Experimental Researches,"* "Certain effects of the induction of electrical currents have already been recognised and described; as those of magnetism; Ampère's experiments of bringing a copper disc near to a flat spiral; his repetition, with electro-magnets, of Arago's extraordinary experiments, and perhaps a few others. Still it appeared unlikely that these could be all the effects which induction by currents could produce. . . . . These considerations, with their consequence, the hope of obtaining electricity from ordinary magnetism, have stimulated me at various times to investigate experimentally the inductive effects of electric currents. I lately arrived at positive results, and not only had my hopes fulfilled, but obtained a theory which appeared to me to open out a full explanation of Arago's magnetic phenomena, and also to discover a new state which may probably have great influence in some of the most important effects of electric currents."

The first successful experiment of Faraday was made with 203 feet of copper wire, coiled in one length on a wooden bobbin, and a similar length interposed on the same bobbin between the turns of the first coil. The wires were insulated from each other by twine. The ends of one of the coils were connected to the two ends of a multiplier with a finely suspended magnetic needle—a galvanometer; and the ends of

* "Experimental Researches in Electricity," 1st series, vol. i. p. 1.

the other coil with a battery of one hundred pairs of four-inch square plates with double coppers. When contact was made with the battery, there was, says Faraday, a sudden and very slight effect at the galvanometer, and there was also a similar slight effect when the contact with the battery was broken. But during the continuance of the voltaic current through the one helix, no galvanometer appearances, nor any effect like induction upon the other helix, could be perceived.

Faraday began these experiments in 1831, and continued them during following years. He found that not only were currents induced in helices by induction of others in their neighbourhood, in which currents were passing, but that on inserting the end of a permanent magnet into the middle of a helix of wire, a current of electricity was generated whose direction depended upon the pole inserted and the end of the spiral with regard to the direction of its windings. He says, "If such a hollow helix as that described be laid east and west, or in any other constant position, and a magnet be retained east and west, its marked pole always being one way, then, whichever end of the helix the magnet goes in at, and, consequently, whichever pole of the magnet enters first, still the needle is deflected the same way: on the other hand, whichever direction is followed in withdrawing the magnet, the deflection is constant, but contrary to that due to its entrance."

In the month of October, 1832, Mr. Samuel F. B. Morse, an American artist of celebrity, whilst on his homeward voyage on board the S.S. *Sully*, from France to the United States, developed the idea of constructing an electric telegraph. Much dispute has arisen in America as to the authorship of the idea, whether it originated with Mr. Morse or with a Dr. Jackson, who was a fellow-passenger on board. The legal as well as the popular verdict has, however, been given in favour of Mr. Morse, who for a long period has enjoyed his patent rights in the invention of an apparatus which has become the most practical, simple, and most universal of any used in telegraphy. Our limited space will not allow us to enter into the details of the celebrated case, "Jackson *v.* Morse," but we may, nevertheless, state concisely the impression left upon our minds after the perusal of the evidence *pro* and *con.*, which was kindly placed in our hands by Professor Morse.

A conversation appears to have been started amongst the passengers on board the S.S. *Sully*, upon the subject of electricity and Franklin's experiment of transmission of it along a suspended wire. This led to the inquiry if it would not be possible to apply it to the communication of intelligible signals; to which Dr. Jackson says he answered in the affirmative, suggesting, at the same time, the possibility of effecting this—1st, by the observation of the spark due to extra current on breaking the galvanic circuit at any point; 2nd, by the perforation of paper, if interposed between the disconnected wires (!); and 3rd, by the decomposition of saline compounds, to produce colours upon the paper. So far we see neither reason nor evidence why Dr. Jackson should not have the credit of these suggestions, the last of which gives him a fair title to the priority in the invention of chemical telegraphy. Dr. Jackson had with him on board an electro-magnet and two galvanic elements, which were, however, stowed away with his luggage between decks, and this prevented him getting at them during the voyage. Dr. Jackson says, however, that he described them to Mr. Morse, and gave him rough sketches of them. There is nothing improbable in this, and, indeed, it is just that which would most naturally occur—the allusion to the absolute possession of instruments so intimately connected with the subject of general consideration on the one side, and the desire to have sketches which aided the comprehension, on the other.

The description of this electro-magnet and of its properties undoubtedly suggested to Morse, either then or afterwards, the idea of employing it for a telegraph; but we can find no shadow of evidence, beyond the mere assertion of Jackson, that he it was who proposed it to Morse. Dr. Jackson —who possesses an unenviable reputation in America for setting up claims to other people's inventions—in his statements made in 1837* and in 1850,† is guilty of considerable self-contradiction, and only in the latter does he even allude to the employment of an electro-magnet. Apart from this gentleman's equivocal character and conduct, we do not see anything remarkable in the fact that he should have considered himself entitled to some participation in the credit arising from the invention of a telegraph in America. Two men came together. A seed-word, sown, perhaps, by some purposeless remark, took root in fertile soil. The one, profiting by that which he had seen and read of, made suggestions, and gave explanations of phenomena and constructions only imperfectly understood by himself, and entirely new to the other. The theme interested both, and became a subject of daily conversation. When they parted, the one forgot or was indifferent to the matter, whilst the other, more in earnest, followed it up with diligence, toiling and scheming ways and means to realise what had only been a dream common to both. His labours brought him to the adoption of a method not discussed between them, and Morse became the acknowledged inventor of a great system. Fame and fortune smiling upon the inventor, it was natural enough that Jackson, awakening from his unfortunate indolence, should remember his share in their earlier interchange of ideas, that had, perhaps, first directed Morse's attention to the subject of telegraphy. And, although we are compelled to pronounce dishonest those attempts which Jackson made to claim the later and proper invention of Morse—that of the *electro-magnetic recorder*—and strong as is our confidence in the spotless integrity of our friend, we cannot entirely ignore Jackson—little as he has done—nor deny

* Letter of Dr. Jackson to Prof. Morse, 7th November, 1837.

† Jackson's evidence in the case of "Smith *v.* Downing," in 1850.

him an inferior place amongst those men whose names are associated with the history and progress of the electric telegraph in America.

34. In 1833, Schilling's proposition of the manner of giving signals with a single needle was carried out in a more complete form by the Göttingen physicists, Gauss and Weber. Their telegraph consisted of a single magnetic needle surrounded by a multiplier of wire, the needle being moved, however, by magneto-electricity instead of galvanism. This was the first employment of Faraday's discovery in the service of telegraphy.

We read, in relation to this telegraph, in a report of the magnetic observations of these physicists,* the following:—

"There is, in connection with these arrangements, a great and until now, in its way, novel project, for which we are indebted to Professor Weber. This gentleman erected, during the past year, a double-wire line over the houses of the town (Göttingen), from the Physical Cabinet to the Observatory, and lately a continuation from the latter building to the Magnetic Observatory. Thus an immense galvanic chain (line) is formed, in which the galvanic current, the two multipliers at the ends being included, has to travel a distance of wire of nearly 9,000 (Prussian) feet. The line wire is mostly of copper, of that known in commerce as 'No. 3,' of which one mètre weighs eight grammes. The wire of the multipliers in the Magnetic Observatory are of copper, 'No. 14,' silvered, and of which one gramme measures 2·6 mètres. This arrangement promises to offer opportunities for a number of interesting experiments. We regard, not without admiration, how a single pair of plates, brought into contact at the further end, instantaneously communicates a movement to the magnet-bar, which is deflected, at once, for over a thousand divisions of the scale."

And further on, in the same report:—

"The ease and certainty with which the manipulator has

* "Pogg. Ann.," 32, p. 568; and "Dingler's Journal," 55, p. 394.

the direction of the current, and therefore the movement of the magnetic needle in his command, by means of the communicator, had, a year ago, suggested experiments of an application to telegraphic signalling, which, with whole words and even short sentences, completely succeeded. There is no doubt that it would be possible to arrange an uninterrupted telegraph communication in the same way between two places at a considerable number of miles' distance from each other."

The purpose of setting up this aërial line was not for the study of telegraphy, nor for the perfection of telegraph apparatus; but to enable these physicists to institute inquiries into the laws of the intensity of galvanic currents, under different circumstances, on a large scale. At the same time the lines were used for regulating the clocks at the Cabinet de Physique and observatories; and in this capacity the lines were used uninterruptedly between 1833 and 1844, when a stroke of lightning destroyed them.

The telegraph apparatus consisted of three parts:—

1. The apparatus for production of the currents;
2. The receiving instrument; and
3. The commutator, or instrument for reversing the currents.

The arrangements used by Gauss and Weber for the production of magneto-electric currents at the transmitting station consisted of two or three large bar magnets, *n s*, Fig. 12, each weighing 25 lbs., fixed together vertically, with their similar poles in the same direction, on a stool P P. A wooden bobbin, *a a*, supplied with handles, *b b*, and wound with more than one thousand turns of insulated copper wire,* rested on the stool and around the upper ends of the magnet, so that, on lifting up the bobbin by the handles, a current would be induced in the coil in one direction; and on lowering it again, a current would traverse the coil in the

* In the apparatus constructed at a later date by Gauss and Weber they increased the number of turns to seven thousand.

opposite direction. The ends + and — were connected to

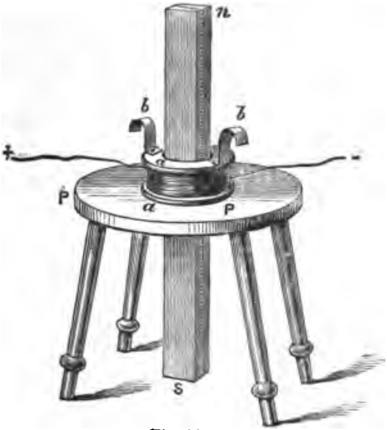


Fig. 12.

the commutator, and thence to the line wires. The coil, *a a*, was called the inductor.

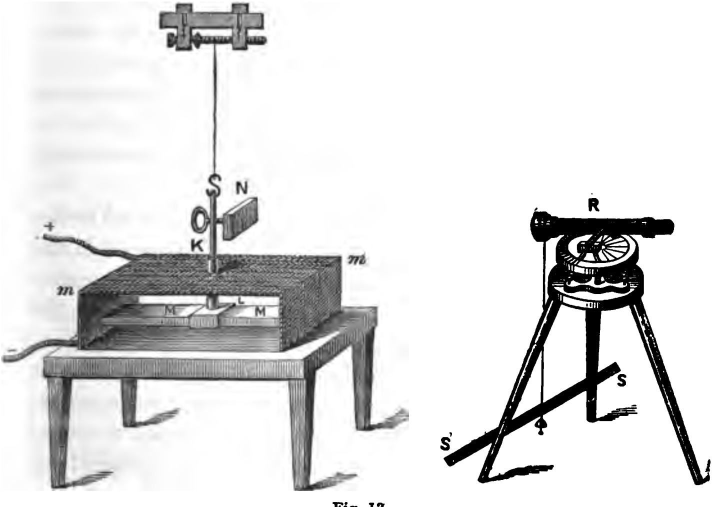


Fig. 13.

The receiving instrument placed at the distant station is represented in Fig. 13. It consists of a large coil or multiplier, *m m*, of insulated copper wire, on a copper frame, the ends + and — being in connection with the line wires.

A permanent steel magnet, M M, 18 inches long and $3''' \times 5'''$ transverse section, was suspended in the middle of the multiplier by a number of parallel silk fibres from the ceiling of the room.

To enable the observer to read off with care the small deflections of the magnet, a mirror, N, was affixed to the shaft, K, carrying the magnet, in which was seen, through a telescope, R, at a distance of 10 or 12 feet, the reflex of a horizontal scale, S S.

The commutator, introduced for directing the currents in one direction or the other through the line, consisted of an arrangement for bringing two points alternately in communication with two others. Let *a* and *c*, Fig. 14, be two points in connection with the two poles of a battery, or other electromotive system, and *b* and *d* the ends of any other circuit; if the metal bars, *e* and *f*, be pressed upon the ends, *a b* and *c d* respectively, the current will pass in the direction B + *a e b* R *d f c* — B. But if the bars, *e* and *f*, be removed from these positions and placed at right angles, that is to say, *e* between *b* and *c*, and *f* between *a* and *d*, as shown by the dotted lines, the current will go through B + *a d* R (in the opposite direction) *b c* — B.

On lifting up the coil *a a*, Fig. 12, from the stool to the top of the vertical magnet-bars, a current was induced in the wire encircling them. This current passed by the commutator, placed, as in Fig. 14, from *a* to *b*, through one of the line wires and the multiplier R of the receiving station, deflecting the magnet for an instant in one direction, and returned by the other wire over *c* and *d* of the commutator. When it was wished to deflect the needle of the receiving instrument in the opposite direction, this was attained by simply lowering the coil *a a* again to its original place, and the observer at the receiving station read off one deflection to the right, for instance, and one to the left. But, in constructing a code of signals, it was necessary that two or more deflections to the right or left should frequently follow each other. This was done by means of the commutator. Thus, on lifting the coil *a a*, if we suppose a deflection of the magnet was produced to the right, by reversing the commutator and then lowering the coil again, another deflection in the same direction would be observed. To produce a third deflection in the same direction it would be necessary, evidently, to reverse the commutator again before raising up the inductor. After this fashion Gauss and Weber were enabled, by an ingenious combination of deflections to the right and left, to form the following alphabet and numerals with a maximum of four elementary signals in a letter:—

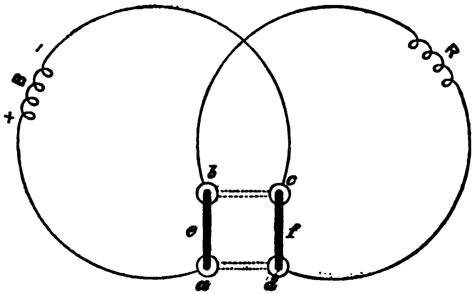


Fig. 1

r = *a*	*rrr* = *c*, *k*	*lrl* = *m*	*lrrr* = *w*	*llrr* = 4
l = *e*	*rrl* = *d*	*rll* = *n*	*rrll* = *z*	*lllr* = 5
rr = *i*	*rlr* = *f*, *v*	*rrrr* = *p*	*rlrl* = 0	*llrl* = 6
rl = *o*	*lrr* = *g*	*rrrl* = *r*	*rllr* = 1	*lrll* = 7
lr = *u*	*lll* = *h*	*rrlr* = *s*	*lrrl* = 2	*rlll* = 8
ll = *b*	*llr* = *l*	*rlrr* = *t*	*lrlr* = 3	*llll* = 9

r represents the swing of the north pole of the magnet towards the right, and *l* the swing of the same pole towards the left, of the magnetic meridian.

Various lengths of the pauses between the signals indicated the conclusion of words and sentences.

The copper frame around the needle was necessary in order to prevent the great number of oscillations which the magnet would have made across the meridian had no such check been introduced. The checking action of a mass of metal in the vicinity of an oscillating magnet was discovered by Arago, and has been described by Sir William Snow Harris,* in whose experiments the oscillations of a freely-suspended magnetic needle were reduced from 420 without a damper, to 14 with a damper of copper surrounding the needle.

In the case of the magnet used by Gauss and Weber, its mass and the minuteness of the angle which was necessary for the deflection to be read off with the aid of the telescope and mirror must have assisted materially in bringing it back to the meridian line.

35. Gauss and Weber's line, as has been said, was erected between the Physical Cabinet and the observatories of Göttingen for other than telegraph purposes. It was for this reason that Gauss, unable to afford the time necessary to perfecting the system, which he believed capable, with modifications, of leading to brilliant results, requested Professor Steinheil, of Munich, to simplify the apparatus and endow it with a practical application. The perfection to which this ingenious inventor brought Gauss and Weber's telegraph has rendered it as much or more his than theirs. He studied thoroughly the subject of magneto-electricity, and made experiments, discoveries, and suggestions which have earned for him the name of the founder of electro-magnetic telegraphy.

A description of this telegraph by its inventor is to be found in *Dingler's Journal*, 70, p. 292.

It consists principally of three parts—the inductor, the receiving apparatus, and the line.

* "Magnetism," p. 58; "Phil. Trans.," 1831, part i.

The compound permanent magnet employed by Steinheil in his apparatus consisted of seventeen horse-shoe magnets, weighing together 60 lbs., capable of lifting about five times its own weight. Two induction coils, of together 15,000 convolutions of insulated copper wire, turned on an arbor, and presented in rotation the axes of the coils to the poles of the magnet, so that when one coil was under the north end of the magnet, the other would be under the south end. The commutator in connection with these coils was so constructed that, in turning them from right to left, the alternate currents, or all those going in one direction only, passed through the line, and, on turning them backwards or from left to right, only those currents in the opposite direction were let into the circuit, the others being cut off.

Steinheil was careful to admit his currents for the shortest possible space of time, and for this purpose allowed the contact springs of his commutator to make contact with the lines only at the moment when the induced current was at its maximum. Fig. 15 represents the contact plate to which the leading wires from the receiving station were connected. The contact springs to which the ends of the wire coils were attached travelled in the white annular spaces, and made contact only at *a* and *b*, whilst in every other position the circuit was interrupted.

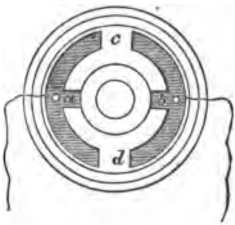


Fig. 15.

The receiving apparatus consisted of an oblong coil of wire or multiplier of 600 turns, in the centre of which were supported, on vertical axes, two magnetic needles, their neighbouring ends having opposite magnetic polarity. Fig. 16 gives a vertical, and Fig. 17 a horizontal section of this instrument. *a b* is the coil of wire; N S and N S, the magnet needles, turning on the axes *m* and *m′*, and carrying on their neighbouring ends brass continuations with small ink reservoirs, *c c′*. These reservoirs were furnished with capillary tubes and filled with printers' ink, so that on coming in contact with the strip of paper travelling before them they each printed a dot. Two plates, *h h'*, prevented the needles from being deflected in the direction opposite to that in

Fig. 16.

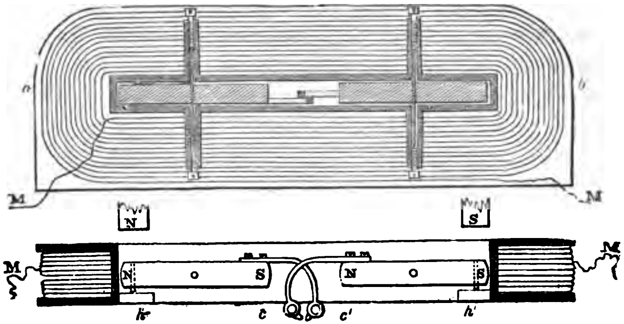


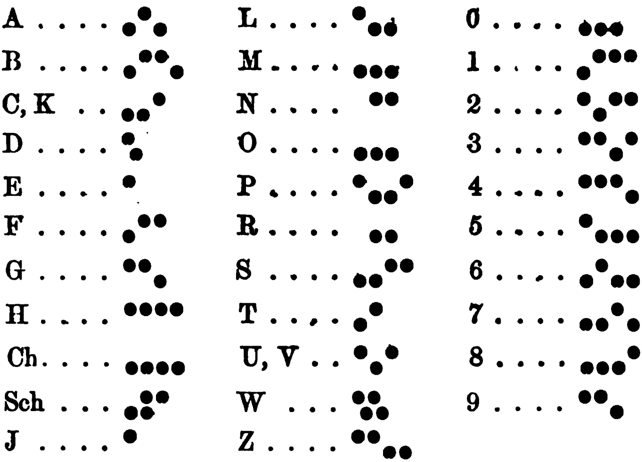
Fig. 17.

which they were to print, as the deflection by the current would otherwise have caused them to swing, and perhaps mark the paper, not only when responding to signals, but also when oscillating.

By means of the plates, therefore, a current sent through the coil deflected only one of the needles at a time, the other being held back; and on the current being changed, the reverse took place—the other needle only being deflected. Thus the signals on the paper were recorded in two lines—those to the right marking the deflections in that direction, and those on the left indicating the left-hand deflections. A paper strip was kept in uniform motion by means of clockwork, which, whenever a mark was made, moved the paper onwards, leaving a blank space before the next signal. These signals were necessarily only dots, because induction currents are only of momentary duration.

Much nicety was required in obtaining magnets of exactly the right size. They could not, for example, be large, because their inertia would have been too great; nor too small, because their mechanical force would not have been great enough to have effected the printing. Two small permanent magnets in the rear of the printing needles retarded their inclination to be deflected when not under the influence of currents.

The letters of the alphabet were constructed from combinations of, at most, four of the dots given in succession by the pointers of the two printing needles. They were arranged by Steinheil as follows:—



Messages were sent with this apparatus at the rate of ninety-two words in a quarter of an hour,* or over six words per minute.

The line wires completed in 1837 were in three parts. The first included a length of 30,500 feet, erected in the air a few inches over the roofs of the houses between the Royal Academy of Munich and the Observatory at Bogenhausen. The weight of this section was about 200 lbs. The greatest span between two poles was 400 yards. The second section of the line connected the residence of Professor Steinheil with the Observatory in the Lerchenstrasse,—there and back

* "Dingler's Journal," 67, p. 370.

a length of 2,000 yards; and the third section, a length of about 400 yards, connected the Academy with the workshop of the Physical Cabinet.

86. When experimenting on the Nurenburg and Fuerther Railway, to ascertain if the rails could not be made use of as lines for the service of a telegraph, Steinheil made the important discovery that the earth might be used as part of the circuit of an electric current. This discovery, which ranks with those of Volta and Oersted, was one of the greatest contributions ever made to the progress of the telegraph. Had the identity of the electricities been known earlier, return circuits other than the earth for voltaic currents would never have been used; for, in all the earlier experiments and attempts with frictional electricity, the earth was used as the return circuit.

Steinheil took advantage of his discovery, and removed the halves of his lines, leading, in their stead, the corresponding connections of his apparatus to plates of metal buried in the earth.

A communicator of peculiar construction enabled the operator to transmit to, and receive from, either Bogenhausen or Lerchenstrasse at pleasure. It was arranged that when the indicator was in circuit with one station, the wire of the other should be connected to the multiplier of the receiving instrument.

The receiving instrument was not used exclusively to record the messages on the paper strips; sometimes small hammers were substituted for the ink reservoirs, striking against bells of glass or metal of different notes. Thus Steinheil's apparatus formed also, upon occasion, an acoustic telegraph.

The history of the subject, so far, shows us that no single individual can claim the distinction of having been the "inventor of the electric telegraph;" but if there is one worker, up to this date, who deserves more credit than another for his energy, intelligence, and success in the service of his adopted science, that man is certainly Professor Steinheil.

37. The ingenious experiments with which Professor Wheatstone occupied himself, in 1834, in his researches on the velocity of the electric wave in solid conductors, seem to have first directed his attention to the subject of telegraphy; and, in 1835, he exhibited one of Baron Schilling's single-needle telegraphs by means of two galvanometers at his lectures in King's College. In 1836, Mr. W. F. Cooke, when in Heidelberg, was shown by Dr. Mönke a similar instrument which he had prepared the previous year to illustrate his lectures in the university. Before Mr. Cooke returned to England, he constructed a system of telegraphing with three needles on this principle, and made the designs for a mechanical alarm. He appears to have made some progress in negotiating with the Liverpool and Manchester Railway Company for the use of his telegraphs before he became acquainted with Professor Wheatstone, whom he joined the year following in a regular partnership. In the meantime Professor Wheatstone, starting also from the same original, had advanced towards a more perfect construction. Thus, these gentlemen appear to have come together with different, but doubtless both very excellent, constructions of the same thing.

Their "hatchment" dial telegraph was constructed as follows:—Five multipliers of fine insulated copper wire, with light magnet-needles, were arranged in a line across the back of a diamond-shaped dial-plate. The upper side of the plate, which served at the same time as a cover for the case containing the multipliers, was marked with twenty letters of the alphabet, C, J, Q, U, and Z being omitted, as capable of being replaced by others, at the expense, perhaps, of a little orthography, but at the saving of another line wire with its magnet-needle and multiplier. The margin contained the nine numerals and 0. Fig. 18 shows the upper side of the dial-plate, with pointers attached to the axes of the magnet-needles, broken away in the middle, to show the multipliers.

Each pointer was deflected from its position of rest always under the same angle on each side, so that by observing the deflections of any two needles, and following with the eye the direction pointed out by their nearer ends, at the point of intersection of these imaginary lines would be found the letter intended to be transmitted. Thus, in telegraphing a letter of the alphabet, the deflections of two needles in contrary directions were always necessary. In Fig. 18, for

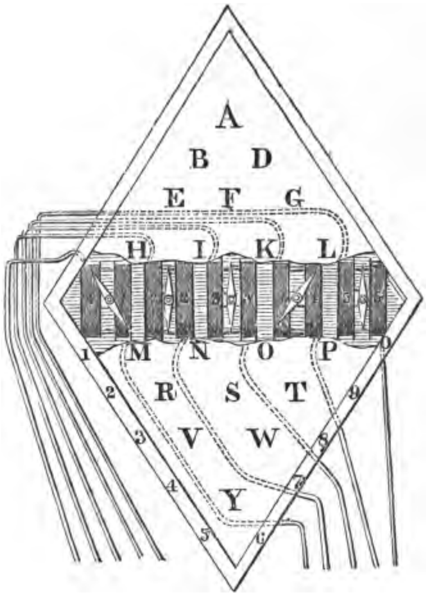


Fig. 18.

example, the needles 1 and 4 are deflected, pointing to the letter V. The numerals and 0 were telegraphed by the deflections, to the right or left, of single needles.

One end of each of the multipliers was brought out on the lower half of the right-hand side, and continued to one of the five line wires; the other ends were joined together and attached to the line used for a return circuit.

The manipulator or key, Fig. 19, consisted of six metallic springs—6, 1, 2, 3, 4, 5—each of which was provided with two buttons with contacts working downwards upon two parallel metal strips, P and N, to which the poles of a voltaic battery were connected. With this arrangement, the operator, by pressing down, at the same time, the buttons of two springs, one over each of the strips P and N, could

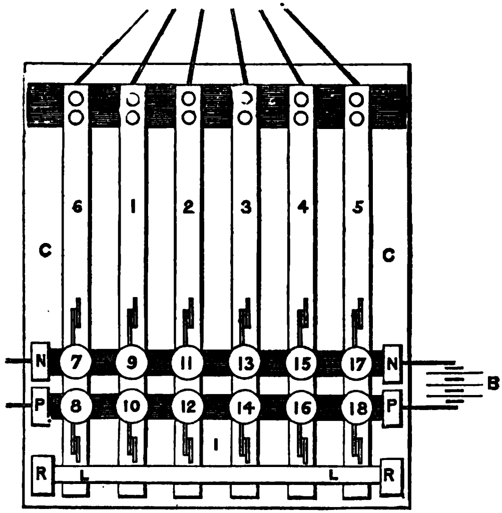


Fig. 19.

transmit a current through one line and back through another, deflecting thereby the two needles at the receiving station for signalling a letter.

As the numerals were indicated by the deflections of single needles, a sixth wire was provided for the return circuit.

This telegraph, although extremely beautiful in detail, was inferior, in point of simplicity, to Fechner's modification of La Place's telegraph, made as early as 1822, and in which a single magnet-needle and two line wires were employed. Cooke and Wheatstone's telegraph with five needles and five line wires was put up on the London and Birmingham and Great Western Railway lines, and tried fairly, but found, on account of the number of line wires, to be too expensive, and was accordingly given up.

38. The necessity of supplying the receiving station with some signalling apparatus for calling the attention of the observer to the commencement of a correspondence had been fully understood by every inventor since Reusser, who proposed to attain this by firing an electric pistol, and Sömmering, who proposed to do the same by the liberation of mechanism by accumulated gas. It was left, however, to the energy and persevering genius of Cooke and Wheatstone to completely solve the problem.

The first alarm employed by them was an apparatus in which the attraction of a soft iron armature to the cores of an electro-magnet, whose coils were in connection with the line, released a wound-up mechanism.

This alarm arrangement is given in Fig. 20. The tooth-wheel *n* was arrested by the end of the lever *p*. On the

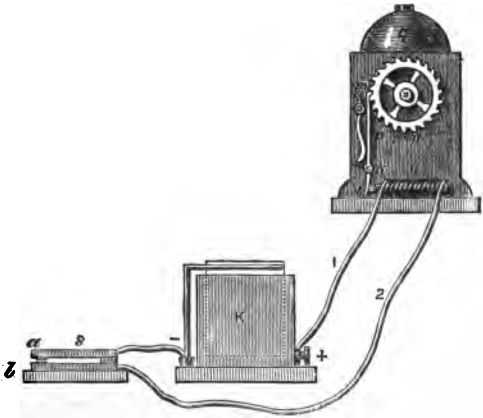


Fig. 20.

other end of *p* was a soft iron armature, *v*, which, when a current passed through the coil, U, of the electro-magnet, was attracted, and released the wheel. The case contained a clockwork, and was surmounted by a bell, which was struck by a hammer, moved backwards and forwards by means of an eccentric.

At the sending station were a small battery, K, and a key, *s*, consisting of two metallic springs, *a b*, of which the lower one, *b*, was fixed on a block of wood, and insulated from the other by a strip of ivory. The spring, *a*, could be pressed against *b*; but, when untouched, remained separated from it by its own elasticity.

From the positive pole of the battery, a wire, 1, went to the electro-magnet, U, of the alarm, and was turned several times round the horns of soft iron; a second wire, 2, returned to the transmitting station, where the line was connected with *b*, whilst the spring, *a*, was connected by a wire with the negative pole of the element.

39. On long lines of telegraph, Wheatstone found that the current became much weakened by the resistance of the wire, the coils of the apparatus, and by indifferent insulation, so that he was obliged to employ a considerably augmented battery power in order to effect the attraction of an armature; whereas, when he employed a magnetic needle, the latter was always easily deflected. This suggested to him a way to overcome the difficulty, which he succeeded in doing by closing the circuit of a local battery, by the deflection of a magnetic needle at the receiving station, by means of which the electro-magnet of the alarm described above, or an electro-magnet whose armature formed a hammer, and struck directly on a bell, was put in action. The battery at the receiving station was called the *local battery*, in contradistinction to the *line battery*, which was placed at the transmitting end. The local battery consisted of fewer elements, as its circuit was short, and the resistance of the coils of the electro-magnet not great.

40. It was once a popular fallacy in England that Messrs. Cooke and Wheatstone were the original inventors of the

electric telegraph. The electric telegraph had, properly speaking, no inventor; it grew up, as we have seen, little by little, each inventor adding his little to advance it towards perfection. Messrs. Cooke and Wheatstone were, however, the first who established a telegraph for practical purposes, comparatively on a large scale, and in which the public were more nearly concerned than in those experiments in which the ends of the wires were brought into laboratories and observatories. Therefore it was that the names of these enterprising and talented men came to the public ear, whilst those of Ampère, of Schilling, the inventor of the system adopted by them, and of Steinheil remained comparatively unknown.

41. We have already alluded at some length to the invention of the electro-magnetic recorder by Professor Morse, of New York. We did so because his invention dates from 1832, although the successful application of it was not attained until 1836. His apparatus consists of a transmitting key or lever, the oscillations of which by the hand of the operator alternately close and break the circuit of a galvanic battery at the sending station, and of an electro-magnet whose wire coils are in the line circuit at the receiving station. Over the poles of this electro-magnet a soft iron armature is held on one end of a lever, on whose other end a pencil or style is carried, which either marks a zigzag line or presses into a strip of paper pulled with a uniform velocity over it.

42. Morse's telegraph underwent in a few years many modifications, especially in the form of the electro-magnet. In the first apparatus constructed the magnet was very light, weighing scarcely 2 lbs. Finding his instrument not sufficiently delicate for great distances, by reason of the line-resistance and loss of current by bad insulation, Morse had recourse to an expedient of relays or repeating circuits. The arrangements designed by him for this purpose in 1836 were of a somewhat primitive form, but in principle they are the same as that known as translation, and used on all submarine

lines at the present day. When the telegraph was practically applied on a line these relays were employed, whose magnets weighed 158 lbs., requiring two men to carry them. The reason for taking such huge bobbins arose from the knowledge that the introduction of a fine-wire helix into the circuit weakens the current, and the belief that by constructing the helices of the same wire as that used for the line this enfeeblement of the current would be lessened. These large magnets were used for a few weeks, and performed their duty accurately and rapidly.

The transmitting key used by Morse in his later apparatus is shown in Fig. 21. It consisted of a lever turning on the axis, supported by uprights which were screwed into a small

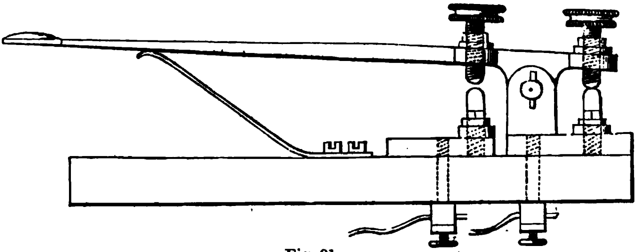


Fig. 21.

block of dry wood. The screw on the longer arm of the lever was pressed upon the front contact, whilst the similar screw in the shorter arm was used only to regulate the play of the key.

One pole of the battery was connected to the front contact, called the *anvil*, and the other pole to earth. The line was connected through the supports with the lever, which was kept on the back, or what has since been termed the *reposing contact*, when not in use, by means of a steel spring underneath the longer arm. The surfaces of the hammer and anvil of the contact were faced with platinum, in order to prevent oxidation by dampness from the atmosphere, or by being burnt by the action of the current.

43. In 1838 Edward Davy obtained a patent for an electro-magnetic chemical telegraph, in which he had ingeniously applied Wheatstone's idea of combining an electro-magnet with a clockwork in the construction of a receiving instrument.

Davy's telegraph required at least four line wires, which, independently of its complication, would be reason enough to account for the fact that it never came into practice. It has, however, the merit of having been the first system in which the movements of a clockwork were governed by an escapement worked by an electro-magnet, and probably, in its turn, suggested many of the subsequent inventions.

With three batteries at the sending station, Davy was enabled, by reversing the currents, to deflect at pleasure the tongues or needles of six relays at the receiving station. This was done by putting in each line two relays, similar in construction to those used by Wheatstone in conjunction with his alarm, one being acted upon by positive currents and the other by negative only. Beyond the second relay coils, the three lines were connected together with the fourth line wire, which was used as a common return circuit.

The receiving apparatus consisted of a sheet of cloth or other chemically-prepared material, drawn between a metallic cylinder and a series of six platinum rings, placed equidistant on the outside of a wooden drum. Each of these rings was connected with the contact points of one of the relays, and a common local battery was inserted between all the tongues or needles of the relays and the metallic cylinder, so that when the needle of either of the relays was deflected, the current of the local battery passed through the chemically-prepared cloth to the metallic cylinder, producing a dot.

On the arrival of a current the metallic cylinder was moved forward a certain distance by means of the clockwork.

The operation of successively opening and closing the circuit at the sending station imparted to the cylinder a the receiving station a rotatory motion resembling that of the long hand of a clock governed by the pendulum and escapement.

The cloth used for receiving the marks was impregnated with iodide of potassium and muriate of lime. Six longitudinal lines, intersected by transverse ones at similar distances, divided the whole surface of the cloth into regular squares, which facilitated reading off messages.

44. The system which we have next to notice is another invention of our ingenious countryman, Professor Wheatstone: this is his first dial instrument, patented in 1840. The apparatus in question seems to have undergone several modifications in the course of a year or so. The principle remained, however, unaltered in all of them: it was that of sending, from the transmitting station, a series of alternate currents through the line, which, passing round the soft iron of an electro-magnet, moved an armature, and regulated the motion of an escapement similar to that of a clock.

It consisted of two parts:—

1. The transmitter, and
2. The receiving instrument.

The transmitting portion of the original apparatus consisted of a commutator, to direct the current of a battery alternately through two electro-magnets at the receiving station. The direction of the current was effected by means of a tooth-wheel, supported by a metal upright. The teeth of this wheel, to the number of fifteen, were so arranged that the teeth and the spaces in rotation represented thirty letters of the alphabet, numerals, &c. On each side of the wheel was a spring contact, only one of which made contact with the wheel at the same time; when the one pressed against a tooth, the other was always opposite to a space. These springs were connected to two line wires, and a battery was inserted between the tooth-wheel and earth. From the circumference of the wheel protruded thirty spokes, and on the base of the upright was a bar, used as a stop for the hand of the operator when turning the spoke-wheel, and it was wished to signal the letter opposite the spoke taken hold of.

The receiving instrument or indicator was formed by a dial having thirty divisions corresponding to the letters, numerals, &c., of the transmitter. The index which moved over the dial was driven by a clockwork, the escapement of which was fixed in the axis of a beam supporting two armatures of soft iron, over the poles of two electro-magnets, in the circuits of the two line wires. As the tooth-wheel of the transmitter was turned round, currents were alternately sent through the side contacts, through the lines, and round the cores of the escapement magnet. Whenever, therefore, the tooth-wheel of the transmitter rested at any place, a current circulated in one or other of the escapement magnets, the armature was held down on one side, and the index prevented from moving further round the dial.

45. An improvement in the apparatus was made by dispensing with one of the line wires, as well as one of the contact springs, of the sending commutator, and one of the electro-magnets of the indicator. This was a material step in the right direction, and fulfilled the first condition of a successful telegraph—that of requiring only a single line wire.

In the improved indicator the duties of the one electro-magnet were fulfilled by a spiral spring with an adjusting screw for tightening or loosening it. This spring acted in the contrary direction to the single electro-magnet, but, of course, with inferior force. It had tension enough, however, to separate the armature from the poles, and to bring over the beam bearing the escapement, whenever the current in the electro-magnet was interrupted.

46. But the most important improvement introduced into the construction of this apparatus was in the substitu-

tion of magneto-electric currents for those of a voltaic battery.

The sending apparatus, so modified, is shown in Fig. 22. It consisted of a permanent horse-shoe magnet, or combination of magnets, fixed to the base board B, between the poles of which was placed a vertical shaft, supporting, on opposite sides, the coils *c c'* of an electro-magnet. They were so arranged that, on turning the shaft, the cores of *c c'* at the same moment approached, and left the poles of the permanent magnet. The ends of the coils of wire round the

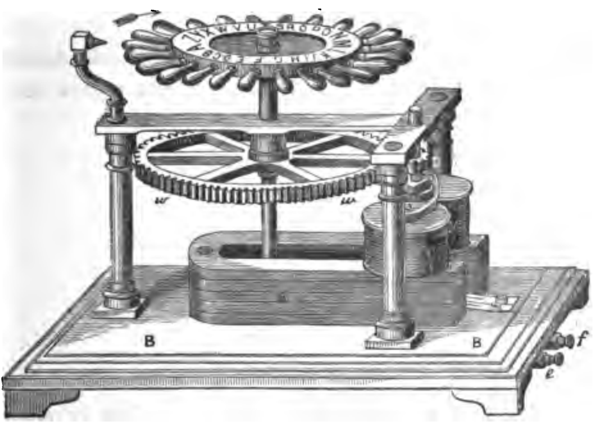


Fig. 22.

electro-magnet were connected, by means of a sliding contact underneath, with the terminal screws *e* and *f*. On the top of the shaft was a pinion D, locking into the tooth-wheel *w*. The number of teeth of the wheel *w* were in relation to those of the pinion D, so that one complete revolution of *w* would cause D to revolve half as many times as there were letters, numerals, &c., engraved on the corresponding dials of the sending and receiving instruments. It will be evident, without further explanation, that a half-revolution of the pinion and the coils of the electro-magnet would produce a current in the line in one direction, and that the continued motion in the same direction another half-revolution would produce a current in the contrary direction.

This arrangement required a slight modification also of the receiving apparatus; but in principle it remained the same.

M. Froment, of Paris, has constructed some step-by-step instruments, on the system of Professor Wheatstone, in which he has succeeded in simplifying the mechanism.

V. Telegraphs now in use.

47. We shall describe the telegraphs now in use, classified according to the following order, and without regard to the dates of their construction:—

(*a*) *Needle and acoustic telegraphs.*
(*b*) *Morse telegraphs.*
(*c*) *Automatic telegraphs.*
(*d*) *Dial telegraphs.*
(*e*) *Type-printing telegraphs.*
(*d*) *Copying telegraphs.*

(*a*) *Needle and Acoustic Telegraphs.*

48. Needle instruments, which were the first introduced into practical telegraphy in England by Messrs. Cooke and Wheatstone, are gradually dying out, having, to a great extent, been superseded by acoustic and Morse telegraphs. The former, whilst possessing all the advantages of simplicity and cheapness which caused the needle telegraphs to be once so extensively employed, have a practical superiority in the facility with which they may be worked by continuous currents. The needle telegraphs are now almost entirely confined to the railways.

49. *Single-needle Telegraph of Wheatstone and Cooke.*—The single-needle telegraph of Messrs. Wheatstone and Cooke is

a modification of the five-needle system by the same inventors, described above. The principle of the system depends upon the construction of an alphabetical code whose

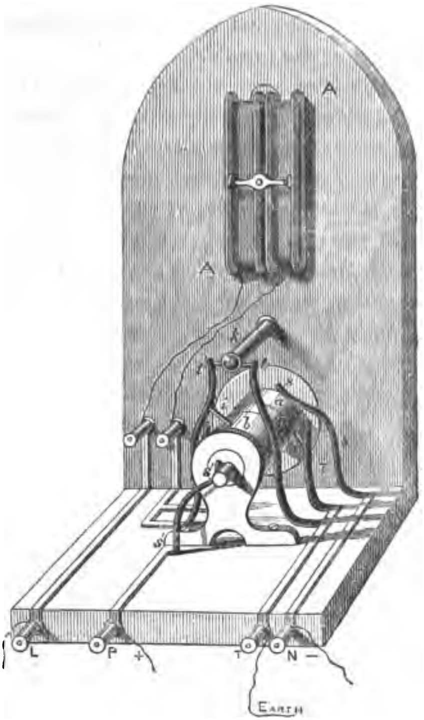


Fig. 23.

basis consists in two elementary signals—the deflections of a vertical pointer to the right and to the left—as in Gauss and Weber's telegraph.

Fig. 23 represents the interior view of the single-needle apparatus. A A is a long vertical coil of fine silk-covered wire, in the middle of which a small magnetic needle plays, having at the end of its axis the pointer seen on the outside face of the instrument. One end of the coil is connected permanently with the terminal screw L, to which the line wire is attached at the back of the instrument, and the other end with the commutator, by which a battery is put between it and the earth, and its direction reversed according to the position of the handle.

The commutator is of simple construction. The arbor of the handle is divided electrically into two halves, *a* and *b*, insulated from each other by an intervening thickness of dry wood, *p*. The half *a* is connected permanently, through a spring, *s*, with the copper plate of the battery, and *b* with the zinc pole of the same, through the spring *s'*.

On the lower side of *a*, and on the upper side of *b*, are attached projecting pieces of metal, *i* and *i*, which play between the springs *t t'* and *τ τ'*, respectively. When the handle is vertical, the metal arms *i* and *i'* are also vertical, and the springs *t* and *t'* repose against the opposite sides of the rest *k*. On turning the handle to the right, however, the spring *t'* is lifted by the projection *i* from the rest *k*, and the projection *i'* makes contact with *τ*, whilst *t* and *τ'* remain unmoved. The spring *τ'* is not seen in the figure. The circuit is thereupon completed from the — pole of the battery, through N, spring *s*, half *a* of the arbor, the arm *i'*, spring *τ*, terminal T, earth, and from the + pole of the battery, terminal P, spring *s'*, part *b* of arbor, arm *i*, spring *t'*, multiplier, terminal L, line, opposite station apparatus, and earth.

The opposite springs are lifted and the current reversed on turning the handle the other way. The apparatus serves both as transmitter and receiver. When receiving signals, the handle remains vertical. The currents arriving by the line pass through L, coils of the indicator, spring *t'*, metal stop *k*, spring *t*, terminal T, to earth; and the needle is deflected to the right or left, according as the arriving current is positive or negative.

If signals are to be given by the apparatus, the manipulator has only to turn the handle to the right or left to effect corresponding deflections of the needle of his own instrument and of that at the station to which he is sending.

50. *Double-needle Telegraph of Wheatstone and Cooke.*—Another form, used also to some extent on the English railway lines, is the double-needle telegraph, consisting of two single-needle instruments combined in the same case. They are, however, totally independent of each other in so far as their electrical connections are concerned, each being worked with a separate line wire. The handles in front of the case are connected with two arbors inside, similar to the one shown in Fig. 28, each of which commutates the current of a battery through the galvanoscope coils surrounding the needle attached to one of the pointers.

The discs over which the pointers move are provided with ivory pegs to limit the deflections on each side of the vertical line. These discs are sometimes made circular, and may then be turned round in the dial-plate, enabling the operator to shift the pegs, in order to keep the pointers midway between them when the magnet-needles are deflected by constant atmospheric currents.

The employment of two needles in receiving the signs renders this telegraph very expeditious, the rate at which it is worked being about double that of the common Morse telegraph. The necessity of two lines, however, prevents it taking any prominent place amongst the existing systems of useful telegraphs.

51. Professor Glœssener, of Liège, has modified the needle telegraphs by the addition of two electro-magnets in the same circuit as the multiplier. The poles of these electro-magnets are placed so that they act upon the poles of the needle within the multiplier, and considerably increase the deflective force without materially increasing the total resistance of the circuit.

52. Professor Sir William Thomson's reflecting galvanometer, as used to receive signals through the Atlantic cables,

forms the most recent and novel construction of single-needle instruments. It consists of a multiplier and wire, in the centre of which a small glass mirror is suspended, having a little steel magnet cemented to it. Before the mirror is a white paper scale, upon which a beam of light reflected by the mirror is thrown. The mirror and magnet being very light, are deflected by weak currents, and their distance from the scale being sufficiently great, very small deflections can be read off with distinctness.

53. On the American lines the system most commonly employed is that of an acoustic telegraph known as the "Sounder." A continued practice with Morse apparatus leads the *employés* involuntarily to recognise the signals by ear, and, when they have once attained proficiency in this way of reading, they seldom or never return to the more fatiguing one of reading by sight. This system is frequently combined with that of continuous currents, the line containing several instruments being traversed by the current of a single battery at one of the stations, and signals given by interrupting the circuit at any point. On railway lines this method is found to be very useful in cases of accidents occurring to trains. The guard, who is supplied with a small pocket apparatus, has only to cut the line wire, insert his "Sounder" in the circuit, and communicate with the neighbouring stations. The constructions of "Sounder" are various. Those in America are very simple and practical, consisting generally of only the electro-magnet, armature, key, and terminals. The English and German "Sounders" are supplied mostly with local batteries and relays, which add to their complication without always increasing their usefulness. The French telegraph administration has adopted a "Sounder" constructed by M. Bréguet, which is formed by a small vertical electro-magnet, over whose poles a soft iron armature is held upon a flat spring, which dispenses with the axis, bearings, beam, and adjusting screws. The armature strikes upon upper and lower

anvils, one of which is supported upon a piece of wood hollowed out underneath to form a sounding-board.

The great drawback of this system is the want of a record, which is so necessary for the justification of the *employés* and the administrations. On this account the Morse, or some other recording system, will continue to be employed upon all lines on which telegrams of importance are transmitted.

(*b*) *Morse Telegraph.*

54. *Simple Morse Circuit.*—In its simplest form the Morse telegraph consists of a transmitting key and a recording instrument, with intervening line wire, battery, and earth connection. The purpose of the key is to close the circuit of the battery conveniently for the formation of arbitrary

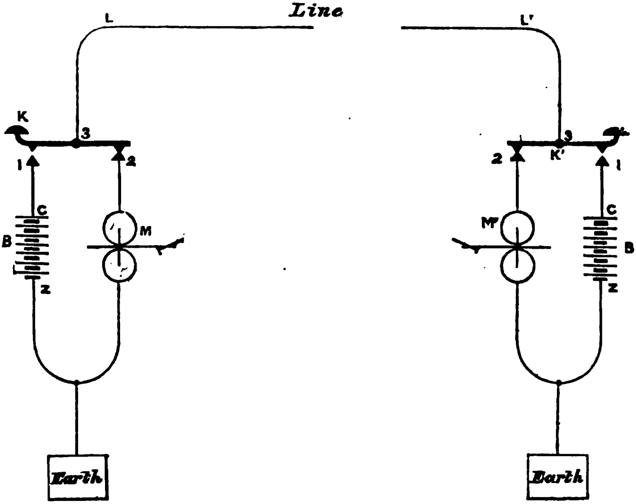


Fig. 24.

signals. The signals representing the letters, &c., consist of combinations of two elementary marks, a dot and a dash. The former is given by the momentary closing of the circuit and the latter by closing it for a longer time, by means of the key. The signs are received at the distant station by the corresponding attractions of the armature of an electro-magnet, which marks them on a strip of paper in its vicinity. The plan by which these arrangements are made at two stations is represented in Fig. 24. At each of the stations, B is a battery of voltaic pairs, connected between the point 1, underneath the metallic lever K, and the earth. When the lever K is not being manipulated, it is held by a spring upon the metal point 2, between which and the earth are inserted the coils of the electro-magnet M, whose armature is employed to mark the paper and record the signals given from the distant station. On pressing down the key K, for

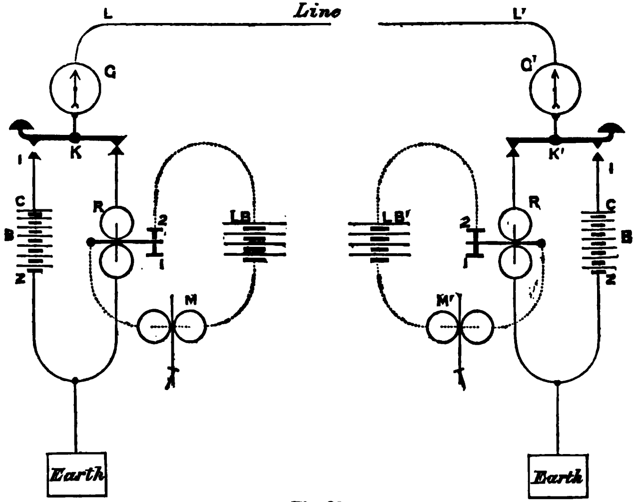


Fig. 25.

example, the contact between the lever and the point 2 is interrupted, and that at 1 established, the current of the battery B goes from C through the contact point 1, and front part of the lever to 3, where it enters the line L. Arriving by L', the current passes over K', from the middle 3, to the back contact point 2, and from this, the key being at rest, it traverses the coils of the electro-magnet M′, and then goes through the earth back again to the battery B.

55. *Simple Morse Embosser for two Stations with Relay.*—When the line connecting two stations is long it is impossible sometimes, even with very great battery power, to move the armature of the electro-magnet with force enough to impress the paper legibly. It was on this account that Morse employed a relay to work his recording apparatus. Fig. 25 represents a plan of connection of a Morse embosser with relays and local batteries for two stations. G is the line galvanoscope connected, on the one side, with the line, on the other, with the lever of the key K. Its purpose is to show the presence of current in the line, and to give a rough idea of its strength. The front or working contact 1 of the key is connected with the pole, C, of the line battery B, and the other pole, Z, with the earth-plate. The back, or reposing contact, of the key is connected with one end of the electro-magnet coils of the relay R, the other end being in communication with the earth-plate. Lastly, between the contact-point 2 of the relay and its tongue or armature are inserted the coils of the Morse M and the local battery L B.

When in repose the levers of both keys are on the contacts 2, and the line, therefore, at both ends to earth through the coils of the relays. On pressing down either of the keys the current passes direct from the Z-pole of the battery to the earth-plate and earth, and from the C-pole through the line galvanoscope, line, key of opposite station, and relay to earth. The deflection of the relay-tongue from contact 1 to contact 2 closes the local circuit, and the armature of the receiving instrument works in conformity with the motions of the key at the sending station.

56. Another method of connecting up the same instrument for two stations is shown in Fig. 26. In this method the lever of the key is in permanent contact with earth. The C-pole of the battery is connected with the front contact of

the key, and the z-pole with the point of junction between the galvanoscope and relay, the latter being inserted between the galvanoscope and back contact of K. The local circuit is arranged as before.

A current arriving by the line while the key is at rest passes through the galvanoscope, coils of relay, back contact and lever of key, to earth. When the key is pressed down on the contact 1, the c-pole of the battery is put to earth through the lever of the key, and the circuit being thus completed, the current from the z-pole passes through the galvanoscope into the line.

In the former method (Fig. 25) the operation of the key

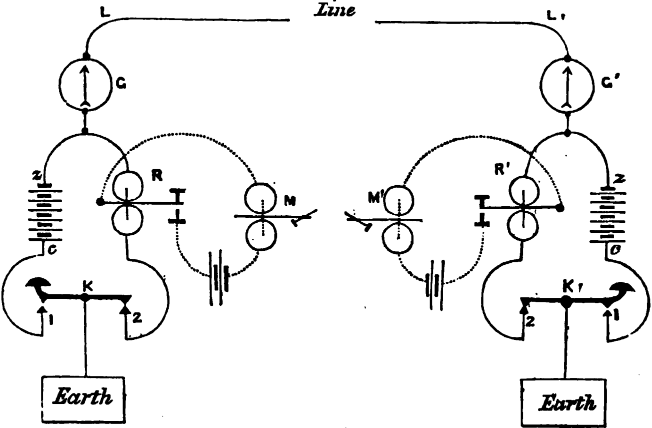


Fig. 26.

consists in shifting the line from relay to battery. In the other method, the battery and relay have the same fixed contacts 1 and 2 of the key; but the earth and line change places, the line taking the place of the earth in the former, and the earth being shifted by the key from relay to battery.

This is by no means so good as the former method, because it necessitates a good insulation of the battery, without which a current, depending on the magnitude of the fault, will not only pass always through the line, but also through the coils of the home-relay; and any accidental contact of the battery with earth will give a signal at the relays of both stations; whilst, with the former method, a similar accident would be entirely without effect further than weakening the currents sent on to the line, notice of which is amply given by the galvanoscope.

57. *The Morse Code.*—The elementary signs of the Morse telegraph are two, a dot and a dash, produced by the recording instrument according to the time which the key at the transmitting station is held down.

The general adoption of this system on the Continent some years back occasioned the establishment of certain rules for the settlement of the letters, numerals, &c., which have been subsequently almost universally adopted.

The formation of so many letters, &c., out of two elementary signs required the greatest number of variations with the given number of elements.

The number of variations, with repetitions of two elements, are :—

With single signs	2	$= 2$
With two signs	2^2	$= 4$
With three signs	2^3	$= 8$
With four signs	2^4	$= 16$

Therefore, by using variations of from one to four of the two elementary signs, we have at our command

$$2 + 4 + 8 + 16 = 30$$

variations for the formation of an alphabet.

These variations, with some others, have been disposed as follows :—

I. Alphabet.

Letter.	Sign.	Letter.	Sign.
A	· —	O	— — —
Ä	· — · —	Ö	— — — ·
B	— · · ·	P	· — — ·
C	— · — ·	Q	— — · —
D	— · ·	R	· — ·
E	·	S	· · ·
É	· · — · ·	T	—
F	· · — ·	U	· · —
G	— — ·	Ü	· · — —
H	· · · ·	V	· · · —
I	· ·	W	· — —
J	· — — —	X	— · · —
K	— · —	Y	— · — —
L	· — · ·	Z	— — · ·
M . .	— —	Ch. . .	— — — —
N	— ·		

II. Numerals.

Numeral.	Sign.	Numeral.	Sign.
1 . .	· — — — —	6 . .	— · · · ·
2 . .	· · — — —	7 . .	— — · · ·
3 . .	· · · — —	8 . .	— — — · ·
4 . .	· · · · —	9 . .	— — — — ·
5 . .	· · · · ·	0 . .	— — — — —

III. Punctuation, etc.

	Sign.
Full stop	· · · · ·
Colon	— — — · · ·
Semicolon	— · — · — ·
Comma	· — · — · —
Interrogation	· · — — · ·
Exclamation	— — · · — —

	Sign.
Hyphen	— · · · · —
Apostrophe	· — — — — ·
Fraction line*	— — — — — —
†Inverted commas	· — · · — ·
†Parenthesis	— · — — · —
†Italics or underlined	· · — — · —
New line	· — · —— ·

IV. Official Signals.

Public message	· · ·
Official (Telegraph) message . . .	· —
Private message	· — — ·
Call	— · — · — · —
Correction or rub out	· · · — ·
Interruption	· · · · · · · · ·
Conclusion	· — · — · — ·
Wait	· — · · ·
Receipt	· — · · — · · — ·

The length of a dot being taken as a unit, the length of a dash = 3 dots.

The space between the signs composing a letter = 1 dot.
" " two letters of a word = 3 dots.
" " two following words = 6 dots.

The formation of the numerals is ingenious; they are each represented by five of the two elements, so that, disregarding the dashes which stand on the right hand, and giving a value of unit to a dot and two to the dashes on the left, the value of the numeral represented is expressed.

The signs of punctuation, official signals, &c., are either

* To be placed between the numerator and denominator of a vulgar fraction.

† To be placed before and after the words to which they refer.

higher variations or arbitrarily-chosen letters of the alphabet, whose single appearance is a sufficient indication that they are not to be construed as forming parts of words.

The alphabet differs very slightly from that which Professor Morse himself originally proposed. His arrangement of the signs was based upon information given him by his brother—the editor of a newspaper in America—as to the numerical relation in which the letters of the alphabet stand to each other in their occurrence in English composition. It was for this reason that the letters *e* and *t*, which enter most largely into our language, were selected, each to be represented by single signs, whilst *a*, *i*, *m*, and *n*, which are less employed, were compounded of each two elements.

58. *Transmitting Keys.*—The simple Morse key consists of a lever or beam turning in bearings at about its middle, and striking upon two fixed contact-anvils, one on each side. It is usually held down upon one of these, when at rest, by the force of a spring, and the contact upon which it rests is called the reposing contact. The other end of the beam is provided with a button or knob, which the operator takes in his hand and presses when he wishes to give a signal, by depressing the fore part of the beam upon the front or working contact.

In France, M. Villette has lately made a key for employment with the Morse telegraph, which he believes to have some advantages. Instead of the common lever turning upon an axis in the middle and striking upon anvil-contacts, front and back, M. Villette proposes to use a simple steel spring fixed upon a block of brass at one end, and terminating in a knob, for convenience of manipulating, at the other. When at rest the spring, which is in connection with the line, presses upwards against a contact-point leading to instrument and earth; but, when pressed down, this contact is interrupted and another established between the spring and an anvil in connection with the battery. This key is cheaper than the ordinary form, and is probably more durable, as the axis and bearings are dispensed with. A similar key was tried in America a quarter of a century ago, but gave place to the newer constructions.

59. *Submarine Keys.*—It has already been explained that the outside of a Leyden jar becomes charged by induction when the interior coating is charged by contact with some source of static electricity; and the similarity in the behaviour of galvanic and frictional electricities has also been spoken of.

When Siemens and Halske were engaged in the construction of their subterranean line between Berlin and Frankfort-on-the-Maine, and Kramer his between the Prussian capital and Cologne, in 1848, they were both astonished to observe a phenomenon resulting from the two facts alluded to above.

Whilst Kramer was able to speak with the greatest ease on an overland line from Berlin to Magdeburg, he found it absolutely impossible to do the same on a subterranean line. With the greatest trouble and slowness, according to his own account, it was scarcely possible for him to accomplish a satisfactory correspondence between Potsdam and Magdeburg. Siemens and Halske found the same difficulty with their instruments, particularly on the line between Erfurt and Halle, which set all their efforts at defiance. An exchange of the apparatus was also without result. Bad insulation was, at first, supposed to be the cause of the disturbances; but it soon appeared that the better the insulation the greater became the difficulty. Kramer says that he has often left his bureau and destroyed the insulation of his line at a thousand paces distance, in order to be able to forward a despatch with greater ease.

Dr. Werner Siemens, writing about the same date, in a paper * presented to the Academy of Sciences in Paris, says that when the extremity, B, of a covered wire was insulated, and the other end, A, made to communicate with a battery, of

* "Mémoire sur la Télégraphie Electrique," 1850.

which the opposite pole was to earth, the instant of contact being established, a current of short duration was observed in those parts of the wire not too remote from the battery, in the same direction in which the current traversed the line, when the end B was brought into contact with the earth. When the wire was perfectly well insulated, he did not observe, after the first instant, the least trace of current. On replacing, suddenly, the battery (by means of a key) by a short circuit to earth, however, he observed a momentary current, the intensity of which was equal to the current first observed, but in the reverse direction. And, lastly, when the connection at A with battery and earth was interrupted, and the end B suddenly put to earth, a current was observed at B, of almost the same intensity as the two preceding currents, and in the same direction as the current due to the battery.

Both Kramer and Siemens came to the conclusion that these phenomena were attributable to static electricity. They compared the subterranean cable to a Leyden jar of very great surface, the interior coating being formed by the metal conductor, the dielectric by the gutta-percha or other insulator, and the outer coating by the metallic covering, or by the dampness occasioned by contact with the earth; and this view was subsequently confirmed by the experiments of Faraday and Wheatstone.

Several arrangements have been proposed for rendering the return currents harmless in the practice of subterranean and submarine telegraphy. They consist, for the most part, of constructions by which the line is put to earth for an instant before bringing the relay in circuit, and by which the signals and pauses are given by reversed currents instead of by the occasional contacts of the same pole of a battery as in overland lines.

60. *Siemens and Halske's Submarine Key.*—With the ordinary key, when the current of the battery is sent through the submarine line L by pressing down the lever

K on the front contact 1 (Fig. 25), and the key then let go till it makes contact with the rest at the back, the return current or discharge passes from the line, over the key, and through the relay, R, to earth.

In order to avoid the derangement incidental to the discharge currents passing through the relay, the plan Fig. 27 is sometimes adopted.

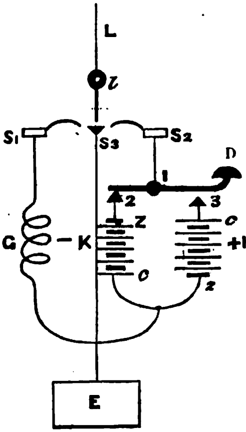


Fig. 27.

When the line L is brought, by means of the switch l, into contact with the point s_1, the relay G is in circuit for receiving despatches. When l is in contact with the point s_2, the key D is put into circuit for forwarding despatches, and the relay cut off from the line and prevented receiving the discharge currents.

If, in this position, the key D is pressed down on the front contact 3, a positive current is sent from the main battery + K; but whilst the key rests upon contact 2, a negative current is sent from the counteracting battery, — K, into the line. The discharge currents are thus made use of in signalling. Lastly, in order to prevent the final discharge passing through the relay when communication is re-established with s_1, a contact is made by l with s_3 and earth in passing by, so as to discharge the line.

The mechanical construction of this key is shown in the plan, Fig. 28. The bearings *b*, *b*, in which the lever *c* works, are cast on a base, b_1, movable horizontally on a vertical axis in the board *a*, in permanent contact with the terminal 1 and the line wire, and also with the spring *i*. When the key is at rest, a spiral spring underneath the board keeps it in contact with the point s_1. This point is in metallic communication with the terminal 4, which leads to relay and earth. The conditions under these circumstances are, therefore, precisely the same as when the line is brought into communication with s_1, by means of the switch *l*, in Fig. 27.

While in this position it is impossible to press down the knob *d*, the lever *c* resting upon a small elevated bed on the bar *g*.

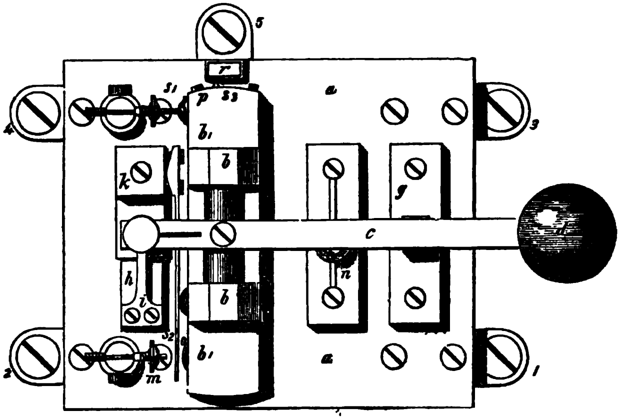


Fig. 28.

To forward signals the lever must be turned to the left, by which the contact at s_1 is broken; that is to say, the relay is cut out of circuit, and the little insulating buttons, *o o*, press the spring s_2, which is fixed at the side of the slab *k*, against the contact-point *m*, permanently connected to terminal 2, which is in connection with the counteracting battery — K. If the key is pressed down now, the back contact is broken and the front one *n* established, by which the circuit of the counteracting battery, — K, is interrupted, and the main battery, + K, brought into play. Consequently the same takes place as in Fig. 27 when the line L is connected, by means of the arm *l*, with the contact-point s_2, and the key D pressed down.

In order completely to discharge the line after finishing the transmission of a despatch, a metal point, *p*, projecting from one end of the base b_1 of the bearings of the lever, rubs against a contact-point, s_3, connected with the terminal 5

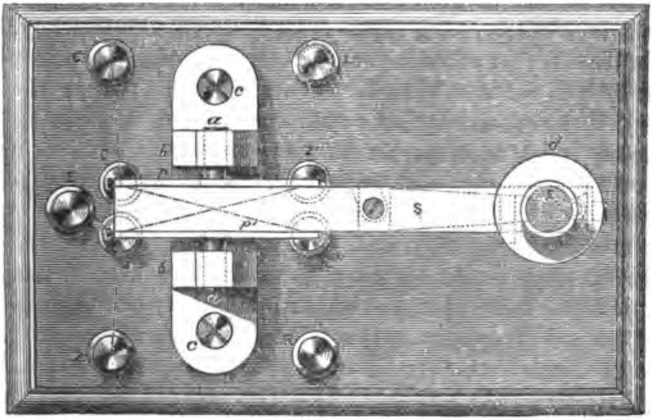


Fig. 29.

and earth, when the former returns to its position of rest at s_1.

61. *De Sauty's Submarine Key.*—A submarine key has been invented by M. C. V. de Sauty, with which the operator in manipulating presses down a button in the middle of the knob, and thus removes the line connection from the relay to the battery-commutator.

Fig. 29 represents a plan of this key. The lever is of vulcanite, supported on a pin, *a a*, in the bearings *b b*, on the base *c c*. On each side of the lever at its fulcrum is a plate of brass, *p* and *p'*, insulated from the pin *a*, and from the bearings. At each end of the plate *p*, underneath, is a platinum contact-point which presses upon one of the contact-anvils, c' and z''; the underside of the plate p' carries a spring at whose ends are similar contacts, which ress alternately upon the anvils z' and c''. The board is furnished with five terminals for the reception of the outside wires. L is the line terminal, R that to which the one side of the relay is brought, the other side being to earth; E the earth terminal, and between C and Z is inserted the line battery, only one battery being required for reversals with this key. In the fore part of the key, underneath the lever, is a spring, or strip of brass, S, in permanent contact with L; when the key is at rest this spring makes contact with a platinum point, which is in permanent contact with the terminal R (relay); a second point, underneath the spring, is in permanent connection with the plate p of the commutator arrangement just described. When working the key, the operator presses the button, E, down into the knob d, and establishes contact between S and p. Half-way between the upper and lower contacts of S, the spring meets with a small strip of metal in connection with the earth, by which means, after working the key, the line is discharged. The strip S is fastened to a block, from which a pin presses upon a spring underneath, reaching from the line terminal L, keeping at the same time the metallic strip S in connection with the line, and holding the lever back upon the reposing contacts c', z'.

The anvils c' and c'' are in permanent connection with the terminal C of the battery, and z' and z'' with the terminal Z. The spring S being down whilst the lever rests on c' and z', therefore the current from Z goes through z', spring, plate p', spiral of wire, to E, and thence to earth; the current from the C-pole goes from C, through c', plate p, the connection wire, from this to the contact with the spring S, terminal L, line, opposite station apparatus, to earth, &c. The finger being still kept upon the button, when the lever is pressed down, the contacts c' and z' are broken, and c'' and z'' made with the plates p and p'. The current from Z now goes through *s'*, *s''*, plate *p*, connecting wire, to E, spring S, L, line, &c.; whilst the current from C goes through *c'*, *c''*, plate *p'*, spiral, E, earth, &c. Thus, by keeping the button pressed down and manipulating the key, reversed currents are sent into the line.

62. *Varley's Switch for Submarine Work.*—This arrangement, used on the Electric and International Company's submarine line between England and Amsterdam, is for sending a reverse current into the line when a usual signal has been given by the key, and at the same time for keeping the relay out of circuit so long as to insure it against the injurious effects of the return currents.

This is done by means of an extra relay, or electro-magnetic switch.

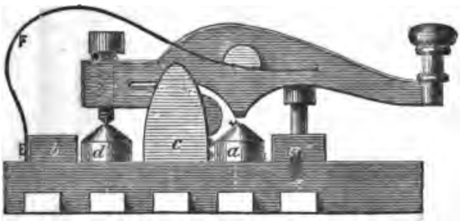


Fig. 30.

When the key is depressed at the transmitting station, a positive current passes directly into the line, and a second circuit is closed, which includes the electro-magnetic switch, the attraction of whose armature breaks the relay circuit, but completes the circuit by which a reverse current is sent into the line as soon as the key is let go again.

The key used in this arrangement is shown in Fig. 30. The customary working and reposing contacts are represented by *a* and *d*; *c* is the bearing of, and in contact with, the lever. A third contact is brought on in front at *a′*, which is touched by the spring F, attached to the terminal *b*, when the lever is pressed down. F is, of course, pressed down by an insulated arm so as not to be in metallic contact with the key. The circuit of the switch is made between *a′* and *b*.

The switch is shown in Fig. 31. It consists of a bent metal beam, *e e*, supported by the uprights *e′*, and makes contact at one end with the screw *u*, at the other by means of a spring, *f*, with the screw *w*. The beam is held in its position of rest by the spiral spring S, and is deflected by the attraction of a soft iron armature, *a*, to the poles of the

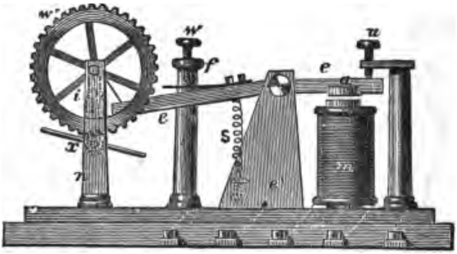


Fig. 31.

electro-magnet *m*. On the upright *n* is a tooth-wheel, *w′*, engaging with a pinion. On the axis of the latter is a fly, and round that of the former passes a cord with a weight at one end, the other end being attached to the extremity of the beam. By this means the extremity of the beam may be raised very quickly, allowing the weight to drop and the cord to run over the axis; but it cannot be lowered without first turning the wheel, pinion, and fly, and raising the weight, an operation occupying about half a second.

The purpose of this is that the armature may be attracted suddenly to the poles of the electro-magnet when a signal is given, but that on being released the beam shall take some time to return to its position of rest, and that during the greater part of this time the spring, *f*, shall remain in contact with the screw, *w*, in connection with the reverse battery.

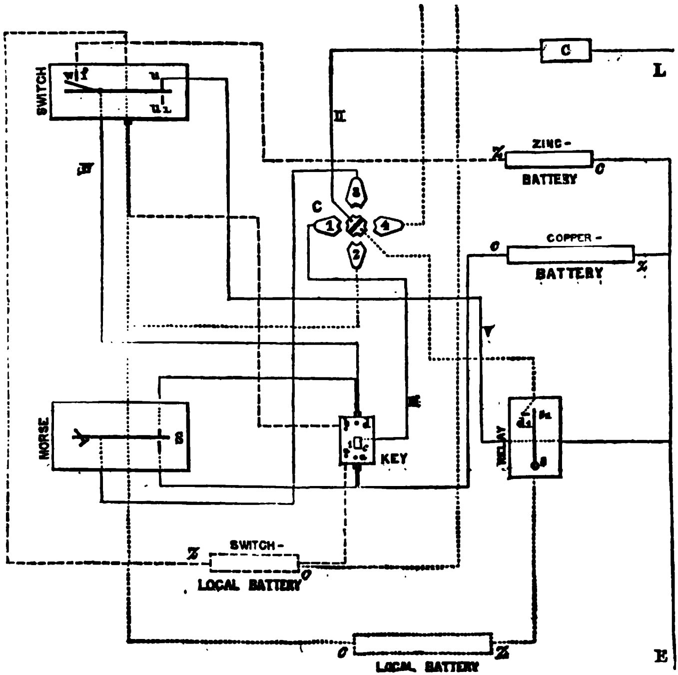


Fig. 32.

A plan of the station arrangements at London on the line working to Amsterdam is shown in Fig. 32.

When transmitting or receiving, contact-pegs are put into the holes 1 and 2 of the commutator C. On giving a signal by pressing down the key, contacts between *a* and *c* by the beam, and between *a'* and *b* by the spring moved by the lever before mentioned, are established. By means of the former, the circuit of the *copper battery* is closed (*c*, *a*, *e*, III, commutator 1, II, G, line), and by means of the latter that of the switch (*b*, coils of switch, Z, switch battery, C, *a*, spring of key). The beam of the switch is in permanent connection with the reposing contact, *d*, of the key, and by oscillating puts on one side the relay, and on the other the zinc-pole of the battery, into circuit.

When the switch is at rest the relay is in circuit with the reposing contact of the key (line, G, II, comm. 1, III, key, *e*, *d*, IV, switch-beam, *u*, V, coils of relay, earth); but as the return currents would take this way when the key is lifted up, the contact *u* is interrupted by the attraction of the armature. At the same time the contact *w* with *f* is made, and this advances Z of the zinc-battery (Z, switch, *w*, *f*, IV, *d*) to the back contact of the key, so that the moment the key is let go the circuit of the *zinc-battery* may be completed (key, *d*, *c*, III, comm. 1, II, G) with the line.

If this takes place in London the positive currents will arrive at Amsterdam by cable, commutator, key, switch, coils of relay, earth. The tongue of the relay at the Amsterdam station will be deflected against the contact-point and close

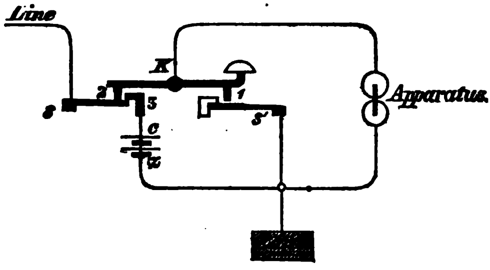


Fig. 33.

the local circuit, working the recording instrument. The negative current will take the same road as the positive, and throw back the tongue of the relay against its insulated contact, thereby breaking the local circuit.

63. A very useful key which may be used with submarine lines is that constructed by M. Lacoine, consisting of a lever (*K*, Fig. 33), with spring contacts front and back. The lever is connected with the coils of the apparatus, the front contact (*s'*) with earth, the back contact (*s*) with line, and a contact (3) which the line meets when the lever (*K*) is pressed down, but which is interrupted when the key is at rest, with the copper pole of the battery. The springs are so arranged that when oscillating the lever remains an instant in contact with both line and earth at the same time. The advantage which M. Lacoine proposes to gain by the employment of this key is, the discharge of the line between each signal and the replacing of the relay in the circuit, in order that the receiving station may interrupt the transmission in the event of a misunderstanding, and have the doubtful letters or words repeated, without waiting for the end of the despatch, as is necessary in those systems in which the relay is entirely cut off during transmission.

64. *Morse's Transmitting Plate.*—Soon after Morse's invention of the transmitting key his attention was directed to the fact that some people find great difficulty in manipulating the arbitrary combinations with uniformity in the length of the marks and spaces. He therefore constructed an arrangement for facilitating the transmission. On a metal plate, B B, Fig. 34, are soldered series of raised rectangular pieces of metal, whose lengths and distances apart correspond with the arrangement of the Morse alphabet. Between these pieces strips of ivory of equal thickness are inlaid, making the whole surface, A A, level. These metal pieces are shown black in the figure, and the ivory white. From a binding screw, C, attached to the plate B B, and therefore in electrical connection with each of the metallic rectangles, a wire, *m*, is led to the receiving instrument and a battery, the further pole of the latter being to earth. The line wire *w* ends in a spiral of insulated wire fastened to a style, G, with blunt platinum point and insulated handle.

This apparatus is intended to replace the key. In order to transmit a message with it the operator takes the insulated

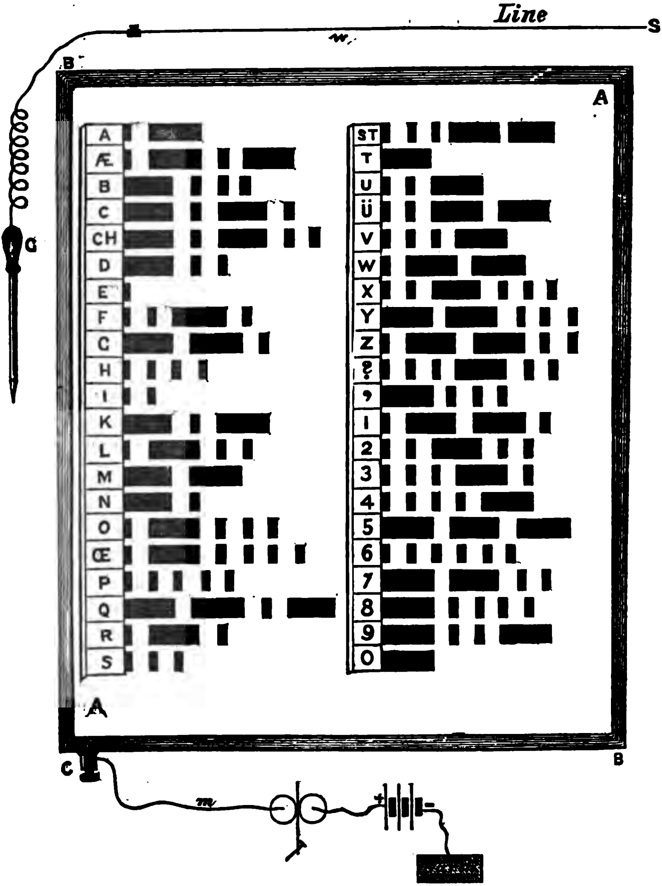


Fig. 34.

style in his hand, and scores the point with a uniform speed over the signs of the letters, one after the other, which he wishes to telegraph. In doing so the circuit is closed as soon as the point of the style touches any of the metal pieces, and is broken again when it moves over the ivory.

The arrangement has never enjoyed an entensive employment, and is now, perhaps, entirely out of use. The reason of this is probably to be found in the fact that the imperfect appreciation of time which prevents some acquiring uniformity in manipulating the key renders them as unable to move the style with an equal velocity over the plate, time being a factor of velocity.

65. *Relays.*—The principle of the relay has already been explained. The form of relay used with the original Morse instrument differed from that invented by Wheatstone, and, as they were invented as nearly as possible at the same time, on different sides of the Atlantic, and for different purposes, there can be no doubt that they were invented independently of each other. Instead of the magnetic needle and mercury cups employed by Wheatstone, the local circuit is closed by the contact of the armature of an electro-magnet with a metal anvil, both being inserted in the local circuit. The relays as at present employed may be divided into two classes: 1st, those in which the contact-point is pressed upon the anvil by the force of attraction between the cores of an electro-magnet and a soft-iron armature held over them; and 2nd, those in which this is done by the deflection of a magnetised needle suspended within a multiplier of wire or of a soft-iron tongue between the poles of an electro-magnet, both being polarised by contact with one or more permanent magnets.

66. To the first class belongs the common form, known as the American relay, from its general employment on the American lines, shown in Fig. 47. The electro-magnet M M is fixed horizontally on a board, having before its poles the soft-iron armature *a*, supported by a tongue turning on the axis *b*. The armature is held back by a spiral spring, *f*, stretched between the tongue and an adjusting screw, *g*. The coils M M of the electro-magnet terminate in the binding-screws

L′ L″, to which are brought respectively the line and earth wires. The local battery and Morse apparatus are inserted between the terminals L′ L″. The former of these is in permanent connection with the axis *b* by a wire, *x*, and the

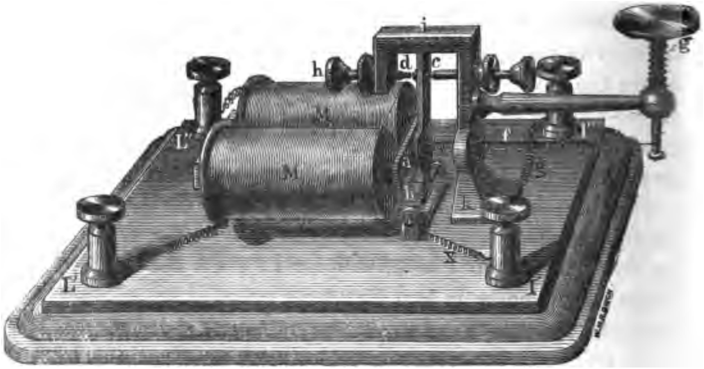


Fig. 35.

latter with the body of the bracket *k i*, which carries two screws, *h d*, with a platinum point, and *c*, whose point is insulated with agate.

When at rest the tongue leans against the agate point, and the local circuit is open; but when a current circulates in the line and coils of the electro-magnet, the armature is attracted towards the poles, and the tongue strikes against the point of the contact-screw *h d*, and closes the local circuit, the current of which passes from *l′* (*x*, *b*, *d*, *i*, *k*, *g*) to *l″*.

M. Leopolder, of Vienna, has introduced a novelty in the construction of this apparatus, L′ and L″, the line and earth terminals, being formed of slabs, and each being divided into three parts, with two holes for screw-plugs. The two ends of the electro-magnet coils are connected on each side with the first and last pieces, and the line and earth with the middle ones. By altering the places of the plugs, therefore, the coils of the relay may be from time to time inverted to prevent any lasting effects from residuary magnetism in the soft iron. One of the two terminals of the local battery is also divided and supplied with a hole for a contact-plug, by removing which the operator can break the circuit of his local battery at pleasure.

67. Polarised or magnetic relays—those belonging to the other class—are preferable to the simple electro-magnetic, as the adjusting spring is dispensed with, its functions being performed by gravitation in the so-called galvanometer relays, and by magnetism in the polarised relays.

The galvanometer relays are very little used, because the contact which they give is uncertain, and they are not so sensitive as either of the others. The polarised relays are undoubtedly the best, and of these we give the preference to that constructed by Messrs. Siemens.

In this relay the armature and the soft-iron cores of the electro-magnet are oppositely polarised by contact with a permanent magnet. Fig. 36 is a sectional view in the direction of the armature, and Fig. 37 a top view. The perpendicular electro-magnet, E, is composed of two cores of soft iron united below, in the ordinary manner, by a cross-bar, A, also of soft iron. The coils of wire terminate at the screws 1 and 2. The north end, N, of an angular-bent permanent magnet, N S, is screwed on to the cross-bar A, to which it communicates north polarity beyond the point of contact, and also to both the cores and poles of the electro-magnet, E. The soft-iron tongue, C, is supported on an axis in a slit in the south end, S, of the permanent magnet, and thus receives south polarity. This tongue is so placed that it may oscillate between the poles, N and N′, of the electro-magnet. Its play is limited by the contacts D and D′. D is used as a contact for closing the local circuit, in which are included the printing instrument and the local battery, when the tongue, C, strikes against it. D′ is furnished with an agate point, and while the tongue rests against it, the local cir-

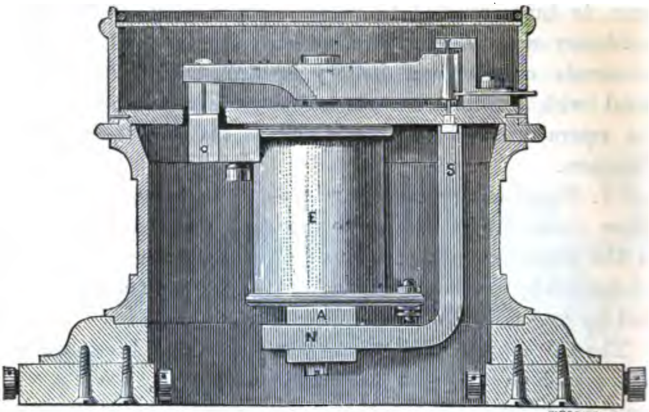


Fig. 36.

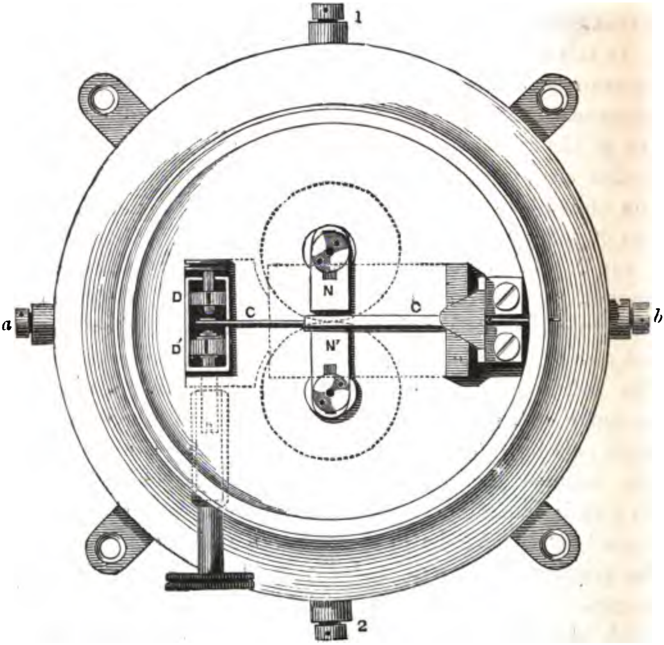


Fig. 37.

cuit is open. A and B are the terminal screws of this circuit.

Whilst it is situated equidistant from both the north polarised ends, N and N′, of the electro-magnet, the south polarised tongue, C, is attracted towards each of them with equal force. When, at the sending station, the key is pressed down, the current passes through the line and relay, which has the effect of magnetising the pole, N, of the electro-magnet north and the pole, N′, south; but as both poles were previously north by the influence of the permanent magnet, N S, the effect of the current is to strengthen the north magnetism of N, and at the same time to weaken only that of N′. The tongue, C, is, therefore, attracted to the pole, N, with double force, and remains on that side after the cessation of the current, attracted by the pole N, whose distance from C is then less than that of N′. The platinum contact of C remains against D, and closes the local circuit until the key at the transmitting station is let go back upon the reposing contact, by which a current in the opposite direction is transmitted through the relay, having the reverse effect of the last current, strengthening the north magnetism of N′, and correspondingly weakening that of N. The pole N′ thereupon attracts C against the insulated point D′, where it rests until another positive current passes and throws it off again.

When only a single battery is used in transmitting, the contact-slab which carries D and D′ is shifted, by means of the adjusting screw, so as to bring the tongue, C, when in contact with D, nearer to N′ than to N. By this arrangement, when no current passes, the contact of C is always at rest against the agate point, D′, because of the superior attraction of N, and only leaves it when a current arrives, which strengthens the magnetism of N, and weakens or reverses that of N′. Thus the counteracting spring used in the common form of relay is dispensed with, being replaced by the unequal attraction of the poles.

Sometimes this relay is combined with a galvanoscope, the same currents working both. On the top of the glass cover of the relay, under a small glass dome, is a single-magnet needle supported upon a point. When a current passes through the coils of the relay the polarisation of the electro-magnet cores is altered, and the needle deflected. The telegraphist who is receiving can therefore see when currents are arriving through the relay without employing a separate galvanoscope, as has hitherto been done.

68. *Morse Recorders.*—The Morse recording instrument consists essentially of an electro-magnet whose wire coils are in the line circuit, an armature suspended over its poles on the end of a beam or lever whose other end carries a style or instrument for marking a strip of paper, and a clockwork for drawing this strip of paper with a uniform velocity over the marking-point.

The original apparatus was all constructed simply and strongly. The paper was marked by the point of a style carried on the end of the beam, being pressed into the paper strip so as to emboss it. Subsequently various improvements and modifications have been introduced, some of which are of value, but all at the expense of its original simplicity.

69. *Embossing Instrument with Movable Magnet.*—This is a construction of the Morse by Messrs. Siemens and Halske, of Berlin, once extensively used on the Russian, Danish, and some of the German lines, but at present replaced, to a great extent, by newer constructions. The movement of the writing lever is effected by the attraction of the opposite poles of two electro-magnets rendered active by the same currents.

Fig. 38 gives a perspective view of the instrument. *m m′* are two straight electro-magnets. The core of *m′* is furnished with a facing of soft iron, *r*, on each of its poles; that of *m* is supported between two screw-points, and is furnished at each end with a continuation, *p*, ending in a facing opposite to and of the same size as *r*. Between the two continuations, *p p*, is a frame carrying the printing-lever. *a b* and *a′ b′* are the ends of the coils of the electro-magnets connected with the terminals A and B.

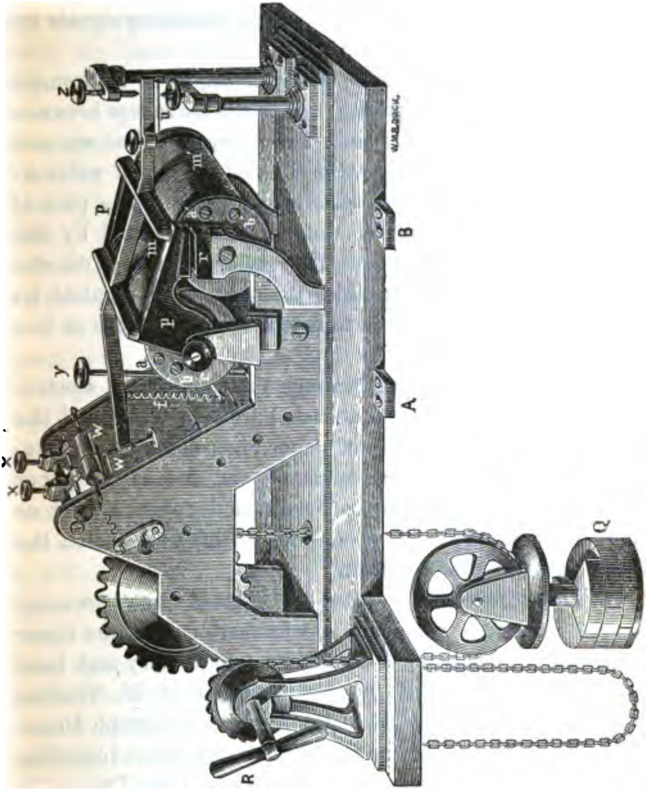


Fig. 33.

When a current traverses the coils it polarises their cores in reverse directions; that is to say, when the end and continuation *p* of the core in front are south-polar, the corresponding end of the other core, with its continuation *r*, will be rendered north-polar—the reverse polarities being, of course, at the further end—and the faces of *p* and *r* on each side, having opposite magnetism, will attract each other.

The attraction of these four poles in the same sense renders the instrument extremely delicate, and the force with which the poles tend to approach each other being very great, the instrument is well adapted for recording signals by scoring the style into the paper strip.

When the current ceases, the printing-lever is brought back by means of the spring *f*. w w′ are the rollers between which a paper strip is drawn. The style, carried at one end of the beam, enters a groove in the middle of the roller w, when the other end of the beam is depressed. The play of the beam which turns on the axis, c, is limited by the adjusting screws *u* and *s*. The style is carried on the end of a screw, which enables the operator to regulate its position in the groove so as to indent the paper more or less legibly.

When the current passes through the coils of the electro-magnets, the armatures are attracted to each other, and the style forced into the strip of paper underneath the groove, where it is held while the current lasts, and as the paper during this time continues to be drawn through, a long or short score is produced, according to the time which the transmitting key is held down.

70. *Direct-working Recorders.*—The great force necessary to press the style with sufficient firmness against the paper strip, and the consequent employment of a relay and local battery, were obviated by the invention of M. Thomas John, a Hungarian *employé* of the Austrian Telegraph Direction. This was one of the first methods of direct recording made known in Europe;* it was patented in France in 1856.

In his apparatus the marks were made upon the paper

* Mr. Morse informs us that a similar construction was suggested by him, and is contained in his patent of 1837.

strip by means of a small circular disc of metal kept revolving in a dish of coloured fluid, and pressed gently against the paper, when the armature of the electro-magnet was attracted. Beyond this, all the rest of the Morse arrangements of clockwork, &c., remained unaltered. The object of the invention was solely to diminish the force necessary for marking the paper, so that the electro-magnets might be able to work the beam when inserted directly in the line. The apparatus, as constructed by the inventor, was by no means a piece of elaborate workmanship, nor were his arrangements of levers and paper guides quite so commodious as was desirable; but the happy fate of the Morse system is, probably, in no slight degree indebted to this idea.

In Fig. 39 the clockwork is left out. E is the electro-magnet, whose armature, D, is affixed to one end of the beam, A C, and plays between adjusting screws. The beam is supported at Z, and has on its shorter arm, A, a connecting rod, B, hinging at *h* on the horizontal arm of the bent lever, *h l* M, which turns on an axis at *x*. At M the lever carries the printing-disc, the lower segment of which is immersed in a dish of Indian ink, R. On the axis of this printing-disc is a small pulley, P, with a cord passing over, and receiving motion from the pulley P′ below. P′ is attached to a drum, Q, which revolves with it. The paper strip, shown in the figure by dotted lines, is led to the apparatus from V underneath a guide-drum, H, at the back of the drum, Q, which it rubs against and turns round (thereby imparting a rotary motion to P, P′, and to the printing-disc), behind the drum, I, over a knife-edge, S, and across the stage, L O, where the message is read off. The purpose of the knife-edge, S, is to present a sharp corner of the paper to the printing-disc in order that it may receive well-defined marks.

When the electro-magnet is in action, the armature, D, is attracted, the connecting-rod lifted up, and the inking-disc, which needs not be at a greater distance than half a millimètre, pressed gently against the paper on the part which is travelling at the moment over the edge s. During this time the motion of the paper keeps the printing-disc revolving in

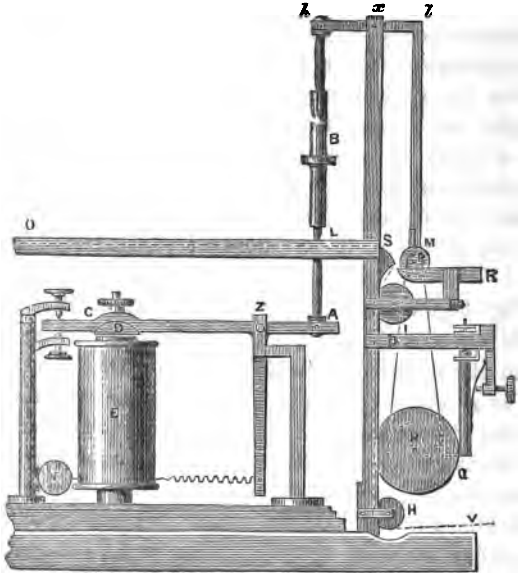


Fig. 39.

the dish, which causes a freshly-inked surface to be always presented.

71. *The Direct-working Ink-Recorder of Beaudoin and Digney.**—The difficulties in the way of the arrangement proposed by M. John were well considered by Digney, who modified it accordingly, with the view of rendering it simpler in its construction and surer in its effects. Instead of making the printing-disc approach the paper strip, Digney lifts the paper up to the disc, which he keeps

* "Revue des Applications de l'Electricité en 1857-8," par Du Moncel, p. 169.

rotating on a fixed axis, moved by the same mechanism which draws the paper through. Over the top of the disc he places a roller of felt or cloth, moistened with oil-colour, which turns by the friction of the printing-disc, and keeps the periphery of the latter always freshly inked. The paper strip passes underneath the disc, over a knife-edge, forming the continuation of a beam, carrying, at its other end, the armature of the electro-magnet. When the latter is attracted, therefore, the knife-edge presses the paper against the revolving disc. John's idea is thus reversed, but the principle remains the same.

Fig. 40 represents an elevation of the apparatus, the clockwork being in the interior. The parts turned directly by the clockwork are the roller, R, and the printing-disc, D. The paper strip is drawn from the drum, P, through the slit, G, under the guide-pulley, U, between the printing-disc, D, and knife-edge, K, between the rollers, R and R_1, and across the horizontal stage, S. The jockey-roller, R_1, turning freely within the frame, F, and pressed down by the spring, Y, holds the paper strip tight upon the roller, R, so that, as the latter turns round, a progressive motion is imparted to it. The jockey, R_1, can be lifted up from the paper by turning the lever, H, to the left. The force with which it presses upon the paper on the roller, R, is regulated by means of the adjusting screw, s, against which the end of the spring, Y, abuts. T is the feeding roller of felt, kept moist with fresh oil-colour, and turning freely on its axis in a frame supported on a regulating-screw on the axis, B. The purpose of the screw is to move the roller in or out a little to prevent its surface always riding over the disc in the same line.

The axis, B, consists of a pin fixed in the side of the apparatus, from which the frame containing T can be easily removed. T rests, when at work, a little obliquely, by its own weight only, on the top of the printing-disc, with which it revolves.

M is the electro-magnet, A its armature, supported by the beam, L L, turning on its axis, I, and is held in its position of rest by the spring, *f*, stretched between a right-angled arm, *l*, of the beam and the adjusting screw, S_1.

When the armature is attracted to the poles of the electro-

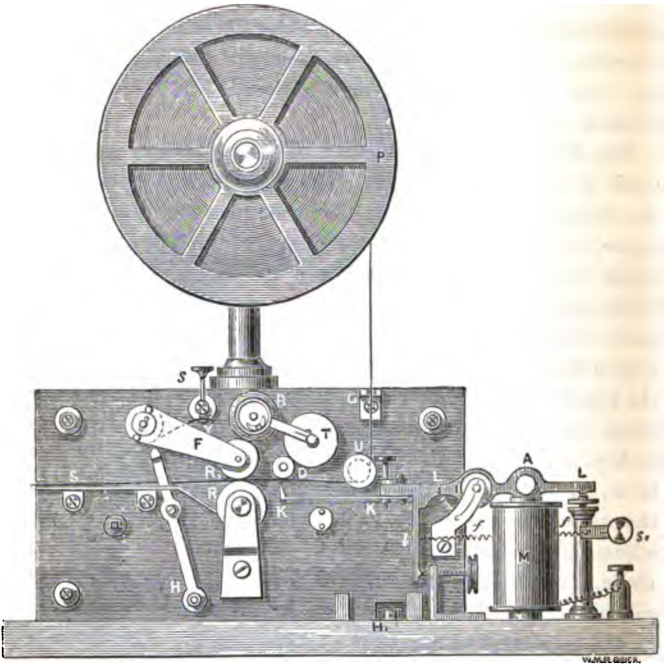


Fig. 40.

magnet, the knife-edge, forming the end of the continuation, K K, of the beam, is raised, and lifts the paper against the disc D, which revolves in the reverse direction to that of R and to the passage of the paper, against which it rubs so long as the armature is kept down. On the cessation of the current the spring pulls back the beam, and the paper strip falls off the disc.

This instrument is worked without relay and local battery, and has become a great favourite with *employés* who are unable to read by the ear; the deciphering of inked letters being infinitely less fatiguing than that of embossed. The renewal of ink, when the apparatus is in full work, is not required more than once a day.

Thus the principal difficulties in the way of the Morse apparatus are removed. The Digney instrument has been found by the French Administration of Telegraphs to work so well, that they have adopted it for use on the Government lines in France and the colonies. This success is in a great measure due to the nice discrimination between the sizes of the movable and fixed portions of the apparatus having reduced the *vis inertia* of levers, armatures, &c., to a minimum, whilst amply sufficient strength is insured to effect the complete marking of the paper.

M. Guillemin, in 1862, made a series of interesting experiments with this apparatus to determine the maximum number of elementary signals, and, consequently, how many words it was capable of recording in a given time. The transmitting apparatus he employed consisted of four wheels of twenty-five centimètres diameter on a common axis: one of them made dots, the second dashes, whilst the two others served to discharge the line after every elementary signal. The words *France* and *Paris*, which in the Morse alphabet represent a mean of the French words, were repeated on a line of 750 kilomètres, in fine weather, thirty times per minute, and in wet weather he easily attained the rate of forty words. On a line of 450 kilomètres, passing by Le Havre, the reception was augmented to seventy-five words per minute—six times that which the *employés* are able to attain with the hand.

72. *Direct-working Ink-Writers of Siemens and Halske.*—

An important modification of Digney's instrument is made by Siemens and Halske, who substitute a small inverted bottle containing ink, and secured by a felt stopper, for the inking-roller of felt, described in the preceding paragraphs.

This arrangement is represented in Fig. 41. B B is a small inverted glass bottle containing the printing fluid; its neck is cemented into a brass ring, *c*, fitting into a collar, D. At the back of the collar is a horizontal hollow axis, E, supported by a pin fixed in the side of the apparatus, on which the whole thing turns, and from which it may be removed in the same way as Digney's felt roller. A stopper of thick felt, *f f*,

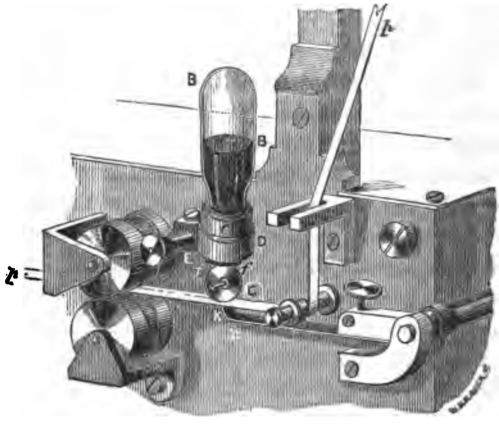


Fig. 41.

is put into the mouth of the bottle to allow the colouring fluid to come through very gradually. The bottle presses, by its own weight, upon the printing-disc, which is in connection with the clockwork, and performs the same functions as the corresponding member of Digney's instrument—printing on the upper side of the paper strip, *p p*, which is lifted by the knife-edge, K.

Both this method and that of Digney are not entirely without objection, however, on account of the printing-disc and paper being underneath the reservoir of ink, from which, when the apparatus stands inactive for some time, the colouring fluid runs down and makes a blot on the paper; besides this, they are both liable to the objection that the surface of the felt quickly dries up in warm weather.

To remedy these defects, Siemens and Halske have made a second and still more valuable improvement in the inking process. It consists in again reversing the order of things, in making the printing-disc revolve with its lower half immersed in a dish of coloured fluid, and in lifting the disc up against the paper, which runs above it, instead of pressing the paper against the disc. This is the perfection of the mechanical arrangements which M. John was able, only in an incomplete way, to carry out.

This modification is shown in Fig. 42. A is a glass phial cemented into a brass neck, *a*, supported between screw-

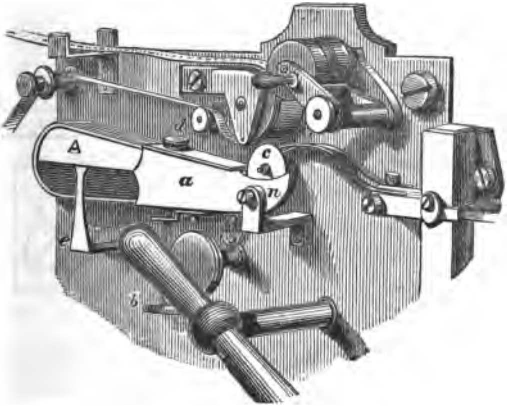


Fig. 42.

points at *n*, and by the point of the levelling screw, *b*. The fore part of the brass neck, *a*, is cut out in a curve, and forms a gutter, in which the lower half of the printing-disc, *c*, dips. At *d* a round hole in the upper part of the neck, usually covered by a metal cap, facilitates the filling of the phial. The index, *e*, is intended to guide the operator in adjusting the *niveau* of the printing fluid in the phial, so as to cover the requisite segment of the disc, *c*.

73. M. P. Vinay, of Paris, has constructed a Morse ink-recorder, in which the inking arrangement differs from the constructions of both Digney and Siemens. The apparatus is provided with a disc, *d d* (Fig. 43), rotating in a scraper the lower part rubbing against a piece of inked felt contained in a shallow dish, H. On the upper left-hand side of the disc rides a little jockey-disc, *c*, which turns upon an axis in the frame, E. This frame turns upon an axis in the bearings, K. An arm, E′ E′, attached to the frame, is provided with a pin held by a fork at the end of the writing-beam. The paper strip is drawn between the rollers, R and R′, over the pulley *b*,

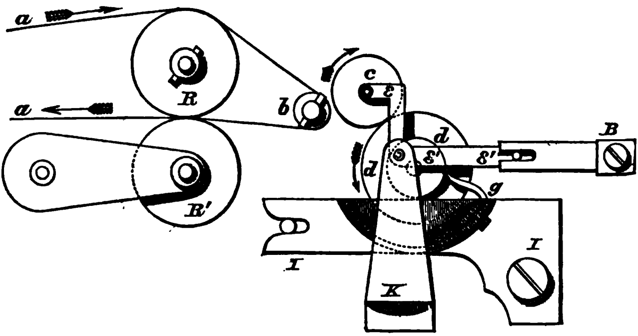


Fig 43.

where it is struck by the disc *c*, whenever the armature of the electro-magnet is attracted and the writing-beam lifted, turning the frame, E, on its axis. By this arrangement the disc which marks the paper is never overloaded with ink.

74. A very convenient form of ink-writer has been constructed by M. Bréguet, in which he has placed the electro-

magnet horizontally upon the base-board of the instrument, and the paper roller above them, as is shown in Fig. 44. The clockwork does not differ materially from that in the ordinary Morse recorder. The paper strip is drawn from the roller by the passing over the rotating cylinder, N, upon which it is pressed by the jockey-cylinder, N′. It passes over a guide, G, underneath a hollow drum, R, whose surface is roughened, and then over the thin steel roller, *i*. The writing-disc, *m*, upon which the felt ink-roller, *t*, rides, is carried upon the upper end of a vertical lever, *l l*, whose lower end carries the soft-iron armature of the electro-magnet, E. A rotatory motion is imparted to the writing-disc by a pinion attached to it, engaging with the teeth of a wheel attached to the drum, R, which is turned by the paper strip in passing. This form of Morse apparatus allows the signals to be read off as they are given, thereby enabling the clerk at the receiving station to stop his correspondent and get a doubtful word repeated, without having to wait for the signals to pass first through the drawing-rollers, as in the ordinary form of Morse apparatus.

75. *Sortais's Self-starting and Stopping Morse.*—Amongst the various modifications interesting and useful, we must mention also one upon which M. Sortais, of Lisieux, has expended much time and money—that of rendering the starting and stopping of the paper strip automatic.

With the usual Morse receiver, when the telegraphist hears the signal for commencing a correspondence, he releases the clockwork and lets the paper run. In case of absence or inattention, the message cannot be received. To remedy this evil, various inventors, and amongst them M. Sortais, have proposed arrangements for making the Morse clockwork self-releasing, so that the paper of the receiving station is started by the telegraphist who transmits. His releaser is made as follows:—The last horizontal axis of the clockwork carries a wheel, M (Fig. 45), which gears into an endless screw, *p*, upon a vertical axis. A thin spiral steel

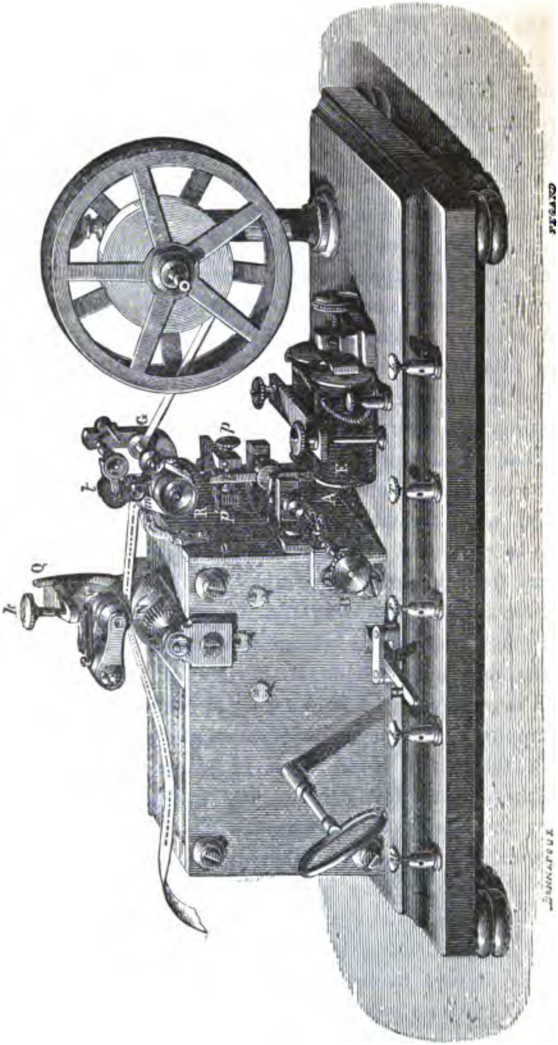


Fig. 44.

spring, P, is fixed, at its upper end, to this shaft, and, at its lower, to a horizontal arm, *n*, which turns upon the shaft. A single projecting tooth, *m*, on the axis of the wheel M, turns a ratchet-wheel, G, upon an axis fixed in the side of the apparatus. This wheel carries, on one side, a bent wire, *h i*, and, on the other, a counterpoise, *i'*, of ten grammes, at the extremity of an arm, *h'*, tending always to turn the ratchet and lift the bent wire away from the arm, *n*, against which it rests. This is, however, prevented by a

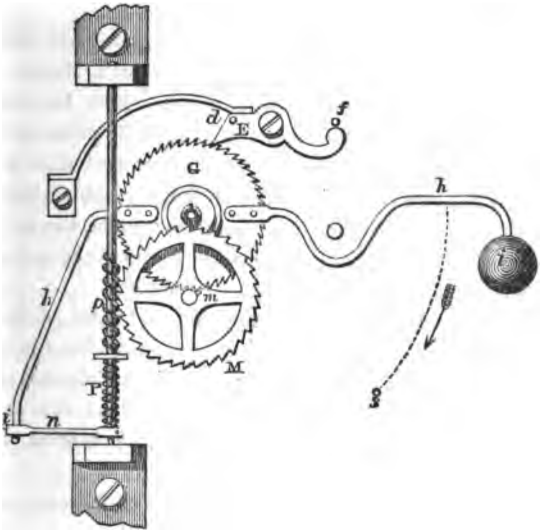


Fig. 45.

click, E, held down upon the wheel by a weak spring. On the click, E, is a pin, *d*, which goes through a hole in the side of the apparatus, and is so placed that the writing lever, when deflected half-way between its highest and lowest points, will strike against it. In repose, the arm, *n*, rests against the end, *i*, and the force with which the wheelwork tends to turn the endless-screw shaft is balanced by the tension of the spiral spring, P. When a current is received the writing-lever is deflected, strikes the pin, *d*, raises the click, and lets the ratchet-wheel turn round with its counterpoise, releasing the catch, *n*, from the wire, *i*. As long as currents are being sent, the click is continually being struck out of gear. When the reception ceases, the click keeps every tooth of the ratchet which is pushed forward by the tooth, *m*, until the wire again blocks the way, and prevents the rotation of the catch. The use of the spring, P, is to allow the tooth, *m*, to get clear of the ratchet-wheel, so as not to prevent its release.

76. The principle of self-starting and stopping has also been applied by Messrs. Siemens and Halske in a Morse apparatus of very beautiful construction, in which the electro-magnet and armature are polarised as in their polarised relay already described. A strong angular permanent steel magnet polarises the two cores of an electro-magnet, which both partake of north polarity; while between their ends the printing-beam of soft iron, moving on an axis in the other end of the permanent magnet, has the opposite polarity.

The clockwork does not, in any material point, differ from that of the ordinary instruments. A hollow drum is turned by means of a mainspring in its interior, which also puts in motion the entire train of wheels, as well as the printing and driving rollers. A fly regulates the motion of the whole.

The self-starting apparatus is arranged as follows:—Close to the electro-magnet of the printing lever is a smaller electro-magnet, A B, Fig. 46, called the releasing magnet, the coils of which are in the same circuit as those of the larger one. When a current passes, therefore, through, both their armatures are attracted at the same instant. The armature, C, of the releasing magnet is carried by the releasing beam, turning on the axis H. At the other end of the releasing beam is a friction-spring, O E, which, when the armature is in its position of rest, presses upon the ivory break-wheel, F, by means of a weight. The last wheel of the system is carried upon the axis on which the break, F, and a fly are fixed. The clockwork is therefore stopped when the armature is at rest, or when no current passes. When, however, the armature is attracted, the friction-spring, E, is raised from F, and the clockwork starts; a boot, I, hanging from the beam and resting on the rim of the revolving drum, M, is lifted up, and continues to dance upon the rim by the friction of the drum in revolving. After the current ceases the armature is released, and the boot, descending on the drum, is carried off by the rotation, not allowing the spring E to stop the clockwork until after the last current has ceased for some seconds. The starting of the clockwork may be effected at pleasure by the operator, by raising the friction-spring E, and it may be stopped by pressing it against the ivory break-wheel.

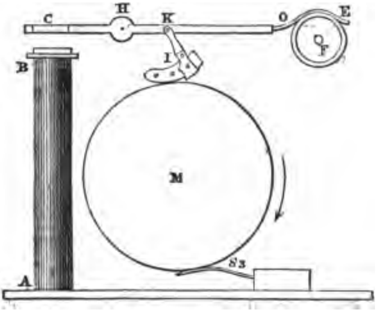


Fig. 46.

77. *Translation or Re-transmission of Morse Signals.*—On long telegraph circuits, where the wires are insulated by the ordinary means of suspension, a considerable decrease in the intensity of the currents which leave the transmitting station occurs before they reach their destination; and this waste it is impossible to prevent. If no other causes were present, the resistance of the wire, combined with the fact that no absolute insulation, even under the most favourable

conditions, exists, would alone put a limit to the length of line on which it would be possible to work direct. But this limit is, in practice, very considerably contracted, as the methods of insulation employed are always liable to temporary derangements by dampness of the atmosphere, dirt, and other causes, which account for the innumerable little shunts that a current finds all along the line, and by which it tries its utmost to get back, without going to the end of the line.

Imagine a long line between two distant stations, A and E, with three intermediate stations, B, C, and D, also far apart. If A wanted to send a message to E, the line being too long and the leakage of the current too great, it would have to send the message first to B; B would receive it and forward it to C; C, in like manner, to D; and, lastly, D to E. This method was adopted once, and not only took much valuable time, but was found to be a prolific source of mistakes, which crept into the unfortunate despatches so transmitted.

The arrangement introduced by Morse, described before, to remedy these inconveniences, remained for some years in abeyance. At length a modification of his plan was adopted. It consists in making the printing lever of the instrument at station B perform the functions of a transmitting key for the line between B and C, and, by the motions imparted to it by the currents arriving from A, of sending the currents of another battery on to C. At C the instrument does the same, and so on, until the despatch finally reaches E, in the same signals, and practically at the same instant as the despatch leaves the hand of the operator at A. The manipulation at the intermediate stations is therefore performed by the apparatus without the least interference on the part of the *employés*.

Fig. 47 is a plan showing the manner in which the printing-beam of the Morse apparatus is arranged to perform this duty. L_1, L_2 are the up and down lines. A current arriving by L_1 passes through the coils, *m m'*, of the electro-magnet to earth, and back to the transmitting station. The beam, *b*, of the recording apparatus is deflected from its position of rest on the contact screw 1, and makes contact with the screw 2. A circuit is thus closed:—Earth, c (battery), *z*, 2, *b*, L_2, line to the next station on the side of L_2, recording apparatus, and earth. Through this circuit the current of the battery, c z, passes as long as the current from L_1 attracts the armature, and keeps the beam *b* against the contact 2.

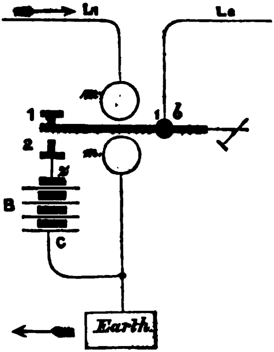


Fig. 47.

It is evident, therefore, that the currents arriving by L_1, and transmitted along L_2, exactly correspond with each other, and that, with regard to the battery c z, and the line L_2, the

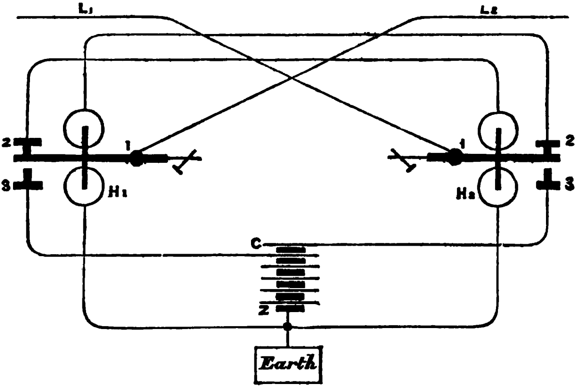


Fig. 48.

beam, *b*, of the apparatus in the figure replaces a common transmitting key.

Each station corresponding with two lines, however, is almost invariably provided with two instruments, so that correspondence in both directions may be carried on at the same time.

When this is the case, the two instruments are connected up, as is shown in the plan Fig. 48, in which the necessary commutators for altering the position of the apparatus for other uses are left out. The currents arriving by L_1 on the left go across to the beam 1 of the Morse apparatus, H_2, on the right, which remains passive, through contact, 2, to coils

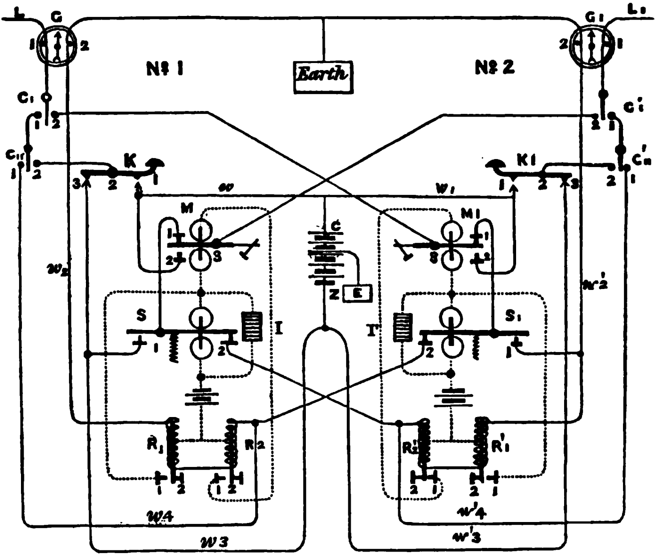


Fig. 49.

of Morse H_1 on the left, earth, &c. Each movement of the beam of the latter closes the circuit of the line-battery, C Z, with the line L_2, through C, 3 (beam of Morse H_1), 1, L_2, opposite station apparatus, earth, back to Z of battery.

78. *Varley's Translating Apparatus.*—A highly ingenious arrangement has been invented by Mr. C. F. Varley, formerly

engineer to the Electric and International Telegraph Company, and is used on that company's lines.

A theoretical plan of the system, arranged for a translating station, with two Morse apparatus, is shown in Fig. 49, in which the letters and other indications of the various pieces on the board correspond, those on the right being distinguished by dashes. G is a galvanoscope, provided with two separate coils of wire of different lengths, the purpose of which is, that the outgoing currents, having their full strength, may pass through the shorter coil, and the arriving currents, which are comparatively weak, through the longer. A single galvanoscope is thus used for showing the strengths of both the currents. The shorter coil, or that intended for showing the transmitted currents, may be short-circuited by means of a contact-peg inserted in a hole between two terminals.

K is a transmitting key of ordinary construction.

M is an embossing apparatus precisely similar to those ordinarily used on Morse circuits.

R_1 and R_2 are two polarised relays of the construction invented by Mr. Varley, each consisting of a soft-iron bar turning horizontally on points within the two coils of a cylindrical electro-magnet. Each end of the bar plays between the poles of a permanent horse-shoe magnet. The contacts 1 and 2 limit its motion; 1 being a platinum point forming, with the soft-iron bar, part of the local circuit; and 2 an insulated rest.

One of the relays, R_2, is used for closing the circuit of the Morse instrument, and that of a key or spacing apparatus; and the other, R_1, for closing the circuit of the spacing apparatus alone.

The spacing apparatus, S, performs the functions of a key; it consists of a metal beam, with an armature of soft iron at one end, held in close proximity to the poles of an electro-magnet. The beam is supplied with two contact points, one at each end, which strike upon two upright anvils, and is held by a spiral spring upon the reposing contact 2 until the armature is attracted by the electro-magnet, when it is deflected and makes contact with the other anvil, 1.

An important adjunct to this apparatus is a series of induction plates, I, connected across the terminals of the coils of S. It is composed of several similar plates of lead or carbon, made up in the form of a battery, and charged with dilute sulphuric acid. By itself a system of this kind gives no current, but it becomes polarised by the current of a battery being sent through it; and on removing the battery and replacing it by a conductor, a current passes through the latter in the reverse direction to the battery current, decreasing in strength until the polarisation is neutralised. Its purpose, in this instance, is to prevent, for a moment, the armature of the spacing apparatus being released from the poles of its electro-magnet when the circuit of the local battery is interrupted by the relay on the cessation of the positive current in the line. The polarisation current magnetises the cores before the armature is released, and retains the beam on the contact 1 until the opposite current in the line deflects the bar of the relay, R, which closes the local circuit including the electro-magnet of the spacing apparatus.

C_I and C_{II} are two switches for altering the position of the apparatus to suit the requirements of the service. The former—the line switch—is for directing the line, on one side for translation, and on the other for ordinary reception from, and transmission of, signals to the station on the side of the switch; the latter, or key switch, is for arranging the board for sending or receiving.

When the apparatus is connected up for translation, which is done by simply turning over the arms of the switches C_I and C_{II} to their contacts, 2, a positive current arriving by the line L, on the left-hand side, has to pass through the longer coil, 1, of the galvanoscope, G, of apparatus No. 1, by G_1 to the point 2, and from this direct by the leading wire, across to apparatus No. 2, where it passes passively over the printing-beam, 3, of the Morse instrument, M_1, by the contact screw 1, to the beam of the spacing apparatus, over which it also passes passively to the reposing contact 2; from this back again to apparatus No. 1, where it traverses in succession the coils of the two relays, and finally, by wire w_2, passes through the shorter coil, 2, of the galvanoscope, and goes to earth at the plate marked "Earth."

The coils of the relays, R_1 and R_2, being connected up so that the current circulates in reverse directions in them, the positive current, which we are considering, can only deflect the armature of R_2, which closes that side of the local circuit containing both Morse and spacing apparatus, the beams of both which will be depressed.

The beam of the Morse, M, being connected by means of the line switch G'_1, through G', with the down line L_1; and the contact point 2, on which the beam of the Morse strikes, being connected by wire, w, with the copper pole of the battery, C E, a positive current passes from C E (w, 2 M, 3, G'_1, 2, G'_1) to L_1,

During this time, the armature of the spacing apparatus, although drawn down, has sent no current into the line, because its circuit is interrupted by the depression of the printing-beam of M from the contact screw 1. When the line current in L stops, the tongue of the relay, R_2, falls back on the insulated rest 1, the local circuit is interrupted, and the beam 3 of M returns to the reposing contact 1. The beam of the spacing apparatus, S, is, however, not released at the same moment, because the current of the polarisation battery, I, has quickly reversed the magnetism of the coils of S, before the armature had time to get away. And a negative current immediately following the positive one by the line L, deflects now the bar of the other relay, R_1, which closes that part of the local circuit containing the spacing apparatus only. The beam of S is therefore retained during the continuance of this current, and a negative current passes into the down line from E Z (w_3, contact 1 and beam of S, contact 1 and beam 3 of M, to c'_I, 2 G_I, 1) to L_1.

On the interruption of this negative line current in L, the polarisation battery performs its functions again.

When the translation is from the down to the up line, the connections remain precisely the same; the Morse spacing apparatus and relays, however, are in action on the other side, whilst those on the left become passive.

Signals are given to the line L by turning the switch, C_I, on 1, and C_{II} on 2. The positive current given by pressing down the key then goes in the circuit E, C, w, 1, and 2 (of key) C_{II} 2, C_I 1, G 1, L; the negative, when the key rests on the reposing contact 3, passes in the direction E Z w_3, 3 and 2 (of key), C_{II} 2, C_I 1, G 1, L, &c.

To receive from the same side, C_I is put on contact 1, and C_{II} on 1. The arriving current from L goes through G 1, C_I 1, C_{II} 1, w_4, coils of both relays, w_2, G 2, and earth. When the arriving current is positive, it deflects the bar of relay R_2, and closes the local circuit of the Morse and spacing-apparatus; when negative, it deflects the bar of R_1, and closes the local circuit of the spacing apparatus only.

79. *The Polarised Ink Recorder used as a Submarine Key—Translation.*—The manner in which the ordinary Morse apparatus is connected up for translation has already been explained. It is performed with the polarised apparatus as follows:—

When the tongue of the relay e_I, Fig. 50, of the receiving apparatus is deflected against the local contact, the local battery is put into circuit, and the printing instrument draws the beam H_1 from the screw 2 to the screw 3, the former being connected with the counteracting battery, — K, and the latter with the line battery, + K. When the printing-beam is connected by S_2 and l with the line L_2, supposing the printing lever, H_2, to be resting against the contact 2, a negative current enters the line L_2 in the following way: K, earth, opposite station apparatus, L_2, l, S_2, H_1, 2, — K. But when the printing lever, H_1, is attached to the contact 3, a positive current enters the line L_2 as follows: + K, 3, H_1, S_2, l, L_2, opposite station apparatus, earth, + K.

It is therefore evident that the printing instrument will translate any signals it may receive to the next station. As there is no communication between the line and the point S_1, the discharge current does not pass through the relay.

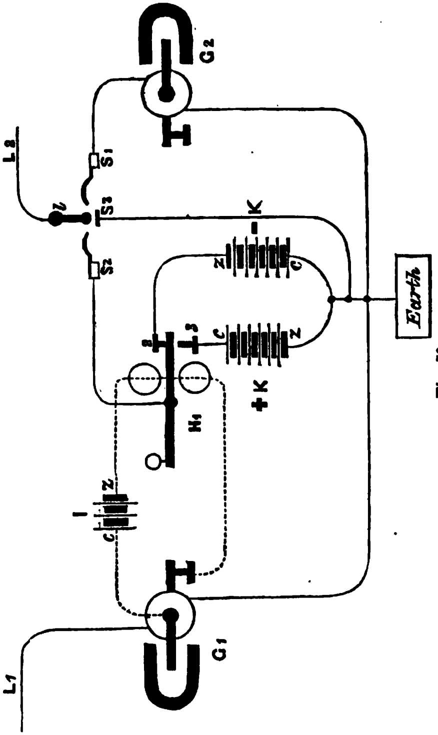


Fig. 50.

Suppose now the relay, G_2, placed in circuit for reception of signals, by transferring the switch from S_2 to S_1, the arm l, in going over, rubs against the earth contact, s_3, and consequently the line will be discharged before being connected with the relay.

At the back of the apparatus, the axis supporting the releasing lever carries also a commutating beam, which, when at rest, makes contact with s_1, in connection with the

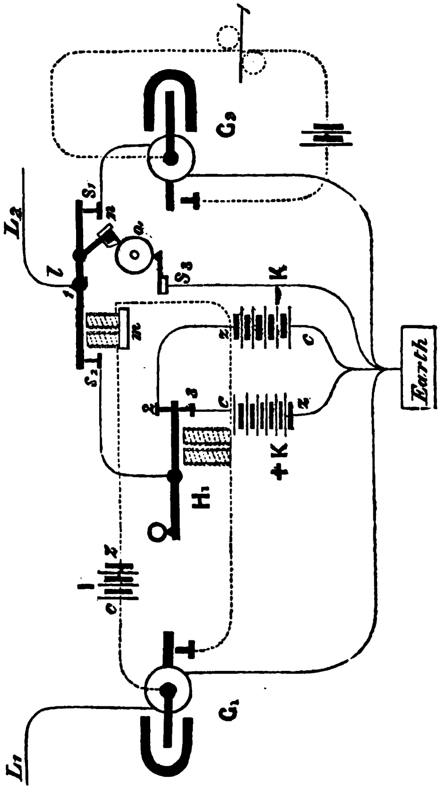


Fig. 51.

relay; but when the armature of the small electro-magnet is attracted, the commutating lever makes contact at the point s_2, in communication with the printing lever. The discharge of the line is effected by means of the boot I, Fig. 46. This boot is insulated at the toe and heel, but not in the middle of the sole, so that, either in a state of repose or when dancing, no electrical connection exists between the boot, that is to say, the lever O H O, and the drum M. As soon, however, as the current ceases, and the boot is pushed sideways, the conductor, let into the middle of the sole, comes into contact with an insulated platinum ring on the edge of the drum, and communicates through the spring, S_3, with earth. The course of the current is shown in Fig. 51. In repose it would be as follows: L_2, l, S_1, G_2, earth, opposite station instrument, L_2.

In this position the relay is in circuit. If, however, the printing lever, H_1, be attracted (through the agency of an inward current through L_1), the releasing magnet, m, will at the same instant attract the lever l to the contact S_2, and thus break the relay circuit at S_1. The course of the current will then be as follows: + K, 3, printing lever, S_2, l, L_2, opposite station instrument, earth, + K; and as soon as the printing lever makes contact at 2, as follows: — K, earth, opposite station instrument, L_2, l, S_2, printing-beam, H_1, 2, — K.

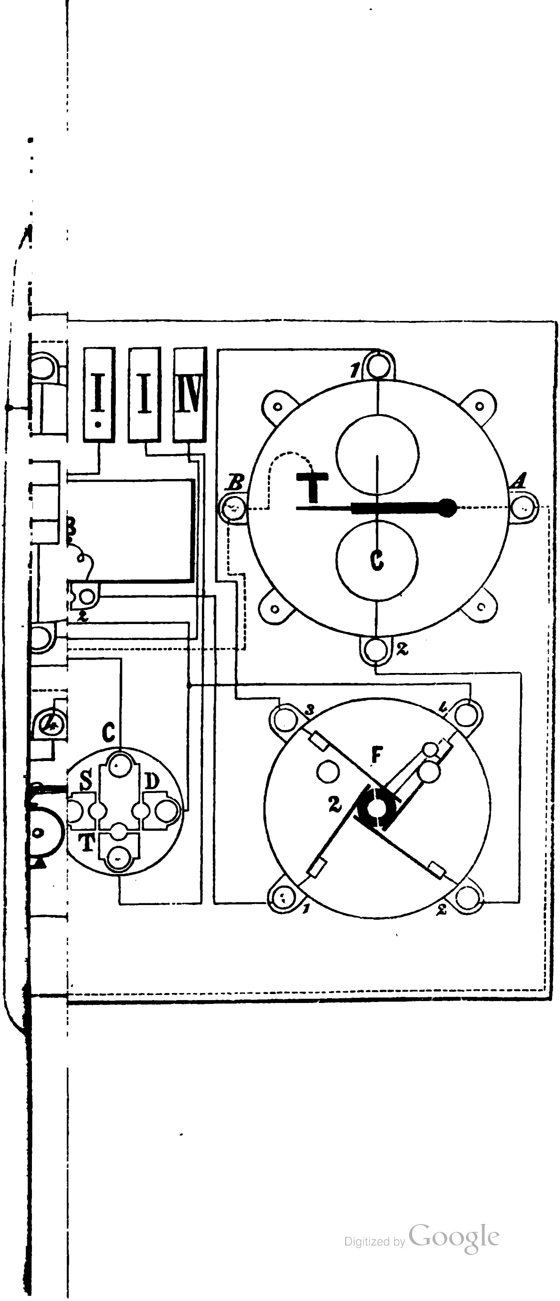
Lastly, if the conducting sole of the boot be in contact with the platinum ring, o_1, of the drum, the following will be the manner of discharging the line: L_2, l, n, o_1, S_3, earth.

80. *The Translation Spring.*—In translating, the introduction of the main and counteracting batteries into the line is effected by means of the printing-beam, in order that when intermediate stations connect up for translation, the signals may be passed through the whole with no interference on the part of the *employés.* When the printing-beam is drawn from the upper contact, 2, to the lower one, 3, by the galvanic current, a certain interval is necessary, and this interval would be subtracted from the time the armature is actually held down, and consequently from the lengths of

signals on the paper. The printing-beam would, therefore, actually be attracted for a shorter space of time than the key is held down at the sending station. The diminution would be repeated at each following station, so that, in fine, if there were several stations translating, the primary signals would have to be transmitted very slowly, in order that they might be legibly received at the terminal instrument. This is remedied in an ingenious way by the translating spring, which is situated under the printing beam, and immediately above the contact point 3. As soon as the beam commences its downward motion, following the attraction of the armature, the spring touches the contact point; and when the beam leaves the point, the spring still presses upon it for a time, and only separates from it at the last moment, so that the manipulator need not give any especial attention to the length of his signals in working the key, as they will be transmitted exactly as he sends them, provided the line be properly discharged.

81. *Complete Submarine Board.*—Siemens and Halske have arranged their polarised relay, polarised recording instrument, and submarine key upon a board ready for use in making the battery, earth, and line connections.

Fig. 52 gives a theoretical plan of the connections of two such boards at a translation station, and Fig. 53 the arrangement of the different parts of one of these boards. B B (Fig. 53) are the galvanoscopes, C the translation commutator, D the submarine key, F the current commutator, G the relay, H the printing instrument, and M the circuit-breaker. Behind the galvanoscopes, B B, are fourteen terminal screws, to which the wires leading from the apparatus are brought, their arrangement being as follows: L is the line wire, E the earth wire, C copper pole, and Z zinc pole of battery. The local circuit, indicated by dotted lines, shows the terminals between which the local battery is connected. The remaining terminals, I, I, II, II, &c., are for the connections between the two slabs.


I
I
IV
1
B
A
T
C
2
3
4
F
2
1
2
C
S
D
T

The following are the different positions of the commutators, &c., for different uses of the apparatus:—

1. The Apparatus as Terminal Station.

Position I.

Both translation commutators are stoppered at *S*. Both current commutators are at 1. Contact cones in both the circuit-breakers.

A) *Apparatus I.* (*left*) *receives Signals.*

The current coming from L_1 passes through the screw, L_1, the galvanoscope (1, B_1, 2), the translating commutator C_1, contact cone in *S*, key (1, D_1, 4), galvanoscope B_1, current commutator (1, F_1, 3), relay (1, G_1, 2), current commutator (2, F_1, 4), screw *Z*, circuit-breaker, M_1, screw *E*, and earth, and through the earth back to the battery of the sending station.

The tongue of the relay, G_1, is attracted against the metal contact point, and the local circuit closed as follows:—

> Local Battery (*Z*, I, *C*), the screw *A* of the printing instrument, *a*, through the releasing magnet *b*, at the same time through both coils of printing magnet, *B*, to the relay, *A*, tongue, and metal contact *B*, and back to the *Z* of the local battery.

Thereupon both the magnets of the instrument are made to attract; the releasing magnet sets the clockwork in motion, and the printing lever of the other magnet is held down until an opposite current coming from L_1 repels the tongue of the relay from the metal contact.

B) *The Apparatus I. is made to transmit Signals.*

The key, D_1, is drawn sideways, so that the spring, s_2, is pressed against the contact 2. The counteracting battery, — K, is then in circuit as follows:—

(Z, — K, C), Z, M_1, E, earth, opposite station apparatus, L_1, lightning-guard A, Apparatus I. (1, B_1, 2), (C_1, S), (1, D_1, s_2, 2), back to the battery, — K.

A negative current, therefore, passes through the line and the relay of the opposite station, the tongue of which is consequently pressed firmly against the stone.

When the key is depressed to give a signal, the positive battery, + K, is put into circuit thus:—

(z, + K, c), 3, D_1, 1 (c_1, s), (2, B_1, 1), L_1, line, opposite station apparatus, earth, E, M_1, back to battery.

2. Apparatus I. and II. Translate.

Position II.

Both translation commutators in T.

Both current commutators at 1, and both circuit breakers stoppered. The self-releasing clockwork is in action in both instruments. In this case a positive current from the opposite station would take the following direction:—

L_1 (1, B_1, 2), (C_1, T), I, I (1, 2, s_1, 4), II, II, 4, B_1 (1, F_1, 3), (1, G_1, 2), (2, F_1, 4), Z, M_1, E, and through the earth to the opposite station battery.

The relay, G_1, completes the local circuit, and therefore both magnets of the printing instrument, H_1, become active; the releasing magnet allowing the clockwork to run, and the printing magnet working the beam. When, in so doing, the printing lever touches the contact 3, the battery, + K, is put in circuit with the line L_2; and when it touches the contact 2, the counteracting battery, — K, will be similarly put in circuit with the same line.

3. Apparatus I. intermediate between both Lines.

Position III.

a) For receiving legible signals from L_1 the commutators of Apparatus *I.* must be respectively in *S* and 1.

In Apparatus *II.* the translating commutator is in *D*, and communication with the earth cut off at M_1 and M_2.

b) For receiving signals from L_2 on Apparatus *I.*, the commutators are in *S* and 2; in Apparatus *II.*, translating commutator in *D*, communication with the earth being cut off at M_1 and M_2.

When the commutator of the Apparatus *II.* is stoppered in *D*, the latter instrument is entirely out of circuit, by the connection (c_2, *D*) *Z*; while a current coming from *L* will pass through L_1, B_1 (c^1), *s*, 1, s_2, 4 of *D*, F_1, G_1, F_1, Z, *Z*, *D* of C_2, and so on to L_2.

In translating, both relays are in motion, but only one Morse apparatus—that on the side from which the message comes.

82. *Morse Apparatus worked by Closed Circuit.*—The method adopted by Kramer, and also by Morse in an early telegraph of his, of working by interruptions of a current instead of by occasional currents, has been taken up by Frischen, and used by him on the Hanoverian railway lines for working the Morse instruments.

A great advantage of this arrangement is that, on lines with several intermediate stations, only the terminal station requires to be provided with a line battery, whilst a local battery is necessary at each intermediate station. By this the cost of batteries is considerably reduced; besides which, the relays, by reason of the uniform current, do not require often to be adjusted, and the *employé* is enabled to place confidence in the call signal without continually having the apparatus under his eye. The last point is of particular importance when the *employé* intrusted with the care of the apparatus has other business to attend to, which is often the case on railway lines.

In arranging a Morse line for closed circuit between two stations, the line current must traverse the galvanometer, relays, and keys in such a way as to hold the tongues of the relays on their reposing or insulated contacts, and the galvanometer needles permanently deflected. When a signal is given by interrupting the circuit, the force of the adjusting

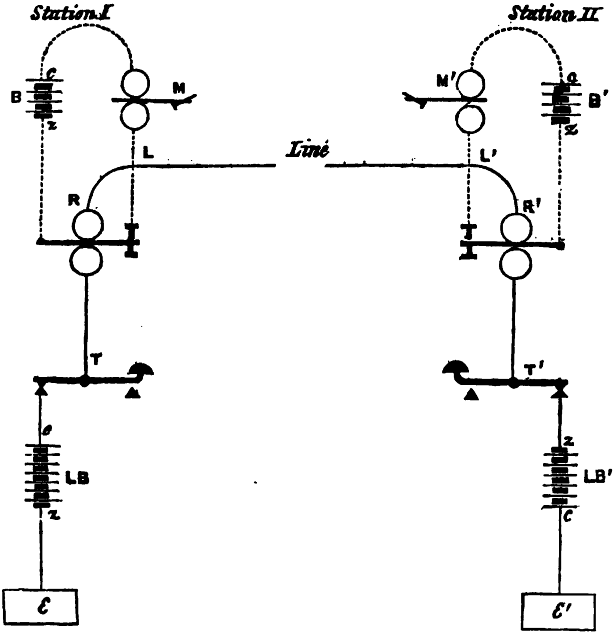


Fig. 54.

spring of the ordinary relay, or the superior attraction of the nearer pole of the polarised relay, must be sufficient to overcome any residuary magnetism which may be in the cores of the electro-magnet, and by pulling it against the working contact, close the local battery and work the Morse.

Fig. 54 shows the connections of the apparatus for two stations with the Morse recorder. R and R′ are the polarised relays, the coils of which are connected with line and with the levers of the keys, T and T′, respectively. To the back contacts of the keys are brought the opposite poles of the two line batteries; L B having the zinc and L B′ the copper pole to earth. The front contacts of the keys are used only as stops or anvils without electrical connections. Between the working contacts of the relays and their armatures, the local batteries, B and B′, and the Morse apparatus, M M′, are inserted. Whilst the keys repose on the back contacts, as shown in the figure, the currents of the two line batteries circulate in the same direction through the line and coils of the relays: that of L B goes from Z to *E* (earth), *E′* of Station II., *c*, battery L B′ (whose current adds itself to that of L B), Z, back contact of T′, lever, coils of R′, line, coils of R, over the lever T, and back to *c* of L B.

Frischen, who has more than any one else given his attention to the application of closed-circuit methods for railway and other lines, has constructed plans of connections for station apparatus, for translation between two lines worked by closed circuit, and also for translation between a line with closed circuit and another worked with intermittent currents, and *vice versâ*, which is often found useful in shunting despatches between lines already arranged with different systems.

88. *Method of Translation between a Line with closed and one with open Circuit.*—Fig. 55 gives a plan of connections for this operation, in which the single parts of the apparatus on the right-hand side differ from those on the left-hand side in being supplied with additional contacts of the switch and Morse. The line battery, L B, is divided in halves.

It is supposed that Line I. on the left, L, is worked by continuous, and Line II. on the right by intermittent currents.

For station work, the continuous current circulating in

Line I. (R, relay, 2, switch, S, K 1, back contact, L B, &c.) and earth is interrupted. The armature of R then goes from the insulated to the working contact, and closes the local

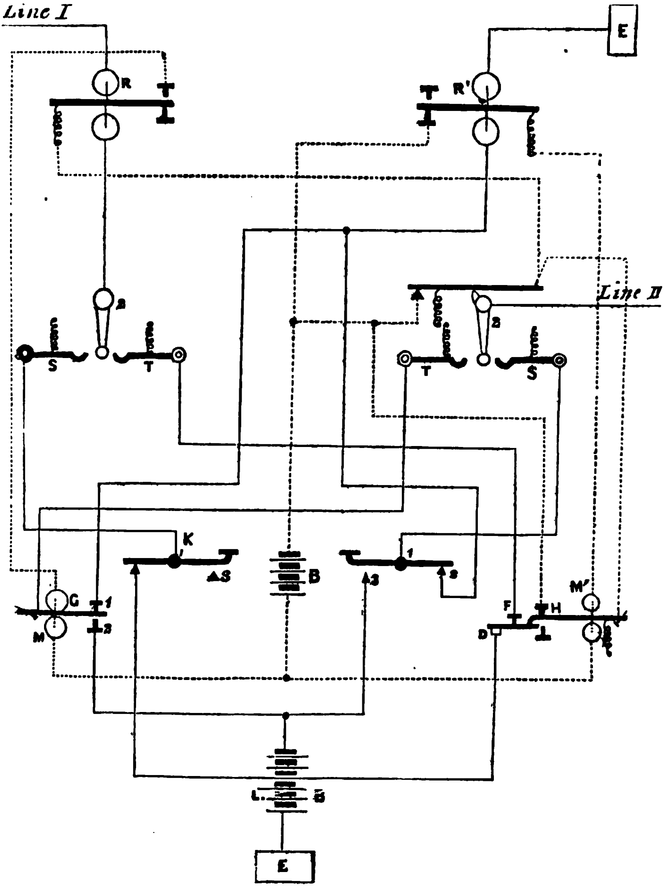


Fig. 55.

circuit by which the Morse, M, is moved. On the other side, the currents arriving, go from Line II. (switch 2, S, K, 1, 2, R′ E) to earth, and close the other local circuit, setting M′ in motion. To transmit a message from either side, the arm 2 of each of the switches rests on S, and the keys, K and K′, are simply manipulated.

In translation, the arms of the switches rest on the terminals T. The continuous current circulates in Line I., R, 2, T of switch, over to the right hand, F, D, L B, earth, &c.

An interruption in this circuit causes the relay to work, and therefore the Morse M, which directs a current, corresponding to each interruption of Line I., in the circuit E, L B, M, 2, G, to T of switch on the right-hand side, 2, into Line II.

A current from Line II. passes through 2 and T of switch to Morse M, G, 1, coils of relay, R′, to earth. The Morse M′, thereby put in motion, interrupts the current of Line I. between the screw, F, and spring D; and, by the separation of the beam of M′ from the upper contact H, divides the local circuit of M, which, therefore, in spite of the movement of its relay, remains passive.

The armatures of R and R′ are therefore continually attracted to the insulated contacts, and the local circuits are open. When one of the keys is pressed down upon its front contact and the circuit interrupted, the armatures of both the relays are simultaneously released, falling upon their working contacts, closing the local circuits, and putting the Morse machines, M and M′, in motion.

84. *Method of Translation between two Lines with closed Circuit.*—Fig. 56 represents a plan of connections for translation with closed circuits. R_1 and R_2 are the relays of the two apparatus at the intermediate station; K S T two switches, which, when the arms are in the middle between T and S, establish contact between 1 and K; when the arm of a switch rests on T, contact is made between it and T, and that between K and 1 interrupted by means of a cam of ivory on the arm, which lifts it up; and, lastly, when the arm rests on S, contact is established between them, whilst that between K and

1 is also made. M and M′ are the two Morses of the usual construction, but with an additional contact at the end of the lever which makes and breaks contact between T of the switch and the line battery. K and K′ are the manipulating

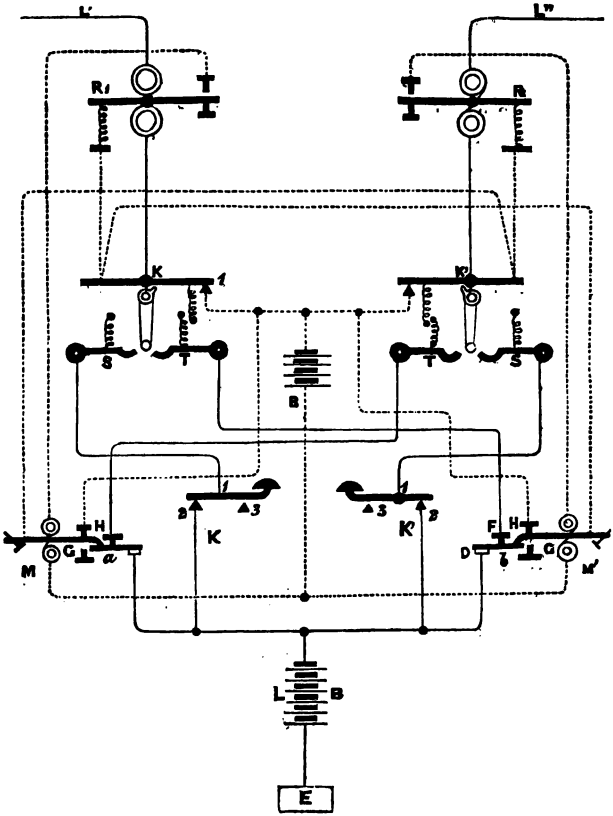


Fig. 66.

keys, B the local battery common to both local circuits, and L B the line battery of the station.

For station work, the handles of the switches on both sides are placed on s; and the circuits of these and the corresponding terminal stations are established through the line, coils of the relay, arms and contact, s (of switches), 1 and 2 of keys, L B, earth, &c. The tongues of the relays are therefore held on the insulated contacts. On breaking the line circuit at any point, the local circuits are closed, and the current of B goes through the coils of the printing instruments, which are set in action.

For translation, the arms of the switches are shifted to the spring terminals, T; the circulating current then takes its way through L′, R′, K and T (of switch), over to the other side, beam of Morse M′, D, line battery L B, earth, &c. The current of L B goes also to the Morse on the other side, switch T, K′, relay R_2, and L″.

85. *Methods of Telegraphing in opposite Directions at the same Time in a Single Wire.*—This feat was for a long time considered to be an impossible one. Judging from the plans employed for ordinary circuits, it was urged that, on sending currents of equal intensity in opposite directions from the ends of a single wire, they would eliminate each other, and no indications could be observed at the relay or other receiving apparatus.

86. The problem was first solved in the year 1853 by Dr. Gintl,* an Austrian telegraph director, a plan of whose arrangement is shown in Fig. 57. The conditions which it was necessary to observe were, that the relay or other receiving instrument at each of the stations should remain always in circuit with the line, and that the currents transmitted from either station should nevertheless not affect the relay of that station.

These two conditions are fulfilled in Gintl's plan by the employment of a relay with coils wound with two separate wires, in one of which the current of his line battery circulates, and in the other that of an equating battery. These

* Schellen, p. 310.

coils, wound in opposite directions on the cores, have equal and opposite magnetic effects on the relay when connected up in their proper circuits; so that on pressing down the key, although the whole of the current of the line battery passes through the relay, the latter remains perfectly unaffected. For convenience of closing the circuits of these two batteries at the same moment, Gintl employs a double key, *a b c* and *a′ b′ c′*, consisting of two separate levers insulated from each other, being connected together by an insulating cross-piece, and having in front a common knob.

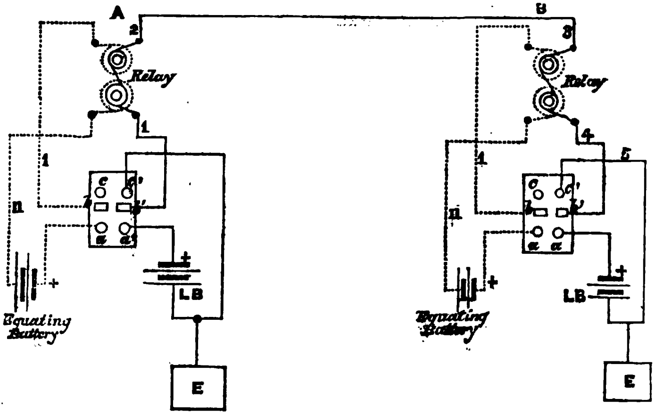


Fig. 57.

In the circuit of one series of the coils of the relay (usually the outer and thicker) are inserted, by means of the leading wires I and II, the equating battery, and the front and middle contacts, *a* and *b*, of the right side of the key. The front contact of the other side of the key is connected to the positive pole by the line battery, the negative pole being to earth; the middle contact, or lever, is connected with remaining coils of the relay, and thence, on the other side, to the line wire; and the back contact of the key to earth.

On pressing down the knob of the key, the current of the line battery, L B, goes from the + pole over the lever *a′ b′*, leading wire, terminal 1 of relay, the interior coils, terminal 2, through the line to B, where it passes from 3 through the interior coils of the relay, 4, key *b′ c′*, 5, E, earth, and, at station A, E to the — pole of the battery.

The current of the equating battery, at station A, goes, at the same time, through its circuit: +, key, *a*, *b*, I, the outer coils of the relay, II, &c., neutralising the effect of the line battery upon the relay.

Suppose now that, while the key of station A is depressed, that of station B is also pressed down, the line current from station B will pass from + of the battery through *a′*, *b′* of the key, 4, coils of relay, 3, B to station A, where it will enter the coils of the relay at 2, and go from 1 over the key, *b′*, *a′*, through L B to earth, &c. Thus the equilibrium, previously established by the equating battery, is destroyed; and the relay of A will give a signal corresponding to the length of time which B keeps down his key. During also the whole time that A keeps down his key, the relay of B will be affected, whether the key at station B be pressed down or not, because, as we have seen, the effect of his own current on his relay is neutralised by his equating battery. If, therefore, both stations work their apparatus at the same instant, signals will be given properly by the respective relays.

There is only one position in which a perfect reception of the signals transmitted from one station is not attained by the other. It is when, during the manipulation at either of the stations, the lever of the key is removed from the back contacts, *c c′*, until it touches the front contacts, *a a′*, or *vice versâ*. In these cases the line circuit is interrupted for an instant at *b*, and the signal which should be given by the relay of the same station is disturbed.

This is, however, a small evil compared with the great difficulty in retaining the compensation of the line and equating batteries for any length of time. The plan adopted by Gintl of using a thicker and shorter coil on his relay for the equating circuit occasioned the equating battery to expend itself quicker than the line battery, which encounters considerably more resistance; and this continued diminution of the intensity of the compensating current, whilst the line battery kept nearly constant, caused a corresponding effect on the home relay, which often gave the operator some of his own signals back again, if he did not continually see to the strength of the currents.

87. This system was first used on the line from Prague to Vienna, but difficulties soon induced Gintl to forego the attempt to work Morse instruments by this method, and to adopt instead a chemical telegraph, by which he obtained much better results.*

The plan of this modification is shown in Fig. 58, in which *a b* is the line wire from one station to the other, connected

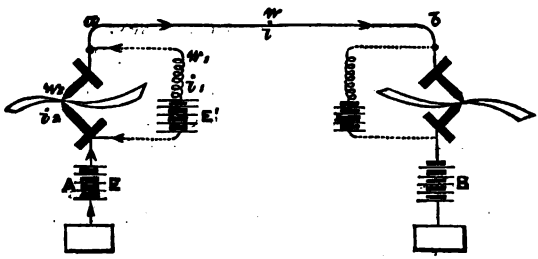


Fig. 58.

at each end with a metal style, which rests on a strip of chemically-prepared paper, supported on the under side by a metal contact. The two contacts are connected to the + poles of batteries E, the — poles being to earth. Between the metal styles and contacts are inserted resistances, and secondary or compensating batteries, whose currents traverse the paper strips in the reverse direction to those of the line batteries, and prevent the decomposition of the salts contained in the paper.

* Dub's "Anwendung," &c., p. 461.

Let the negative current of the line battery at station *a* go from E to earth, and the positive current from E through the metal supporting the paper strip, through the paper and the style to the line *a b*, in the direction of the arrows; at station *b* it will go through the style, paper, contact rest, and line battery, to earth. In traversing the paper at station *a*, a decomposition of the salts would take place were it not for the counteracting battery E′, whose current, of equal strength, passes from E′ through *w*, style, paper, &c., preventing the chemical action, until a current, arriving from *b*, or some such disturbance of the balance, causes an appreciable difference of the currents, enough to affect the paper.

The value of the resistance *w′*, which is inserted in the circuit of the counteracting battery to balance the currents, may be calculated by the aid of Ohm's law.

Gintl subsequently employed a single key with five contacts instead of the double key just described.

88. *Plan of Frischen and Siemens-Halske.*—About the same date (1854) these celebrated engineers invented, independently of each other, an improved system in telegraphing in opposite directions in a single wire at the same time; their plan, by which the counteracting batteries and double keys—both sources of difficulty—are entirely dispensed with, possesses important advantages over the methods of Gintl, and brings the problem of telegraphing in opposite directions as near to perfection as is possible with the conditions of so delicate an arrangement.

Fig. 59 represents the plan of connections of two stations, *A* and *B*. The negative pole of the battery, E, is connected to earth, and the positive pole to the working contact of the ordinary transmitting key, K; the back contact being, as usual in the Morse plan, connected to earth. Instead of the common arrangement of putting the relay in the earth circuit from the back of the key, it is inserted above the lever of the key. The relay consists of two coils, *r* and *p*, of equal and opposite magnetic effects. The coil r is connected between the lever of the key and line; and the other coil, p, between the lever and a resistance, R, to earth.

When the resistances, r and p, are equal to each other, and R is equal to the sum of the resistances in the circuit of the line, L L_1, and of one side, r^1, of the relay at station *B*, &c., to earth, then, on pressing down the key, the current of E will be equally divided between the coils r and p, which, having equal and opposite magnetic effects on the needle or tongue of the relay, will produce no effect at *A*, but will

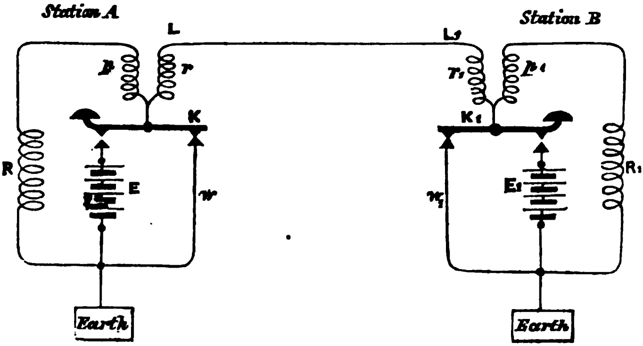


Fig. 59

deflect the tongue of *B*'s relay by passing through the coil r_1. The same arrangements being made at station *B*, when the key K_1 is pressed down also, it is evident that the deflection of the armature of relay, B, will not be disturbed, because the magnetic effect of the home circuit is neutralised, as in the case of *A*.

But the current from *A* can now no longer pass so directly to earth, in consequence of the interruption at the back contact of the key, K_1. It has, however, two paths open to it: the one through E_1, and the other through p_1 and R_1 to earth. During the manipulation of the key in Gintl's apparatus, the circuit is interrupted during the instant which elapses between the breaking of one contact and the making of the other by the key. With the method before us this cannot be the case; the current passes from the line L_1, through both the coils r_1 and p_1 of the relay, and R_1, to earth. The current encounters, therefore, twice as much resistance—that is to say, that of the line, &c., and that of R_1 also, which are equal—and has, in consequence, only half the intensity it formerly had. The effect on the relay remains, however, the same, because the current has to pass through both the coils, r_1 and p_1, which, being wound in opposite spirals, work now in the same sense and with double force upon the armature. At *A* the relay is also deflected, since the balance between the currents in *r* and *p* has been destroyed by the opposing current from *B*, which passes, as in the case of the current arriving at station *B*, through both the coils, *r* and *p*, of the relay and the resistance, R. When at this moment the key, K, is let go back on to its reposing contact, the arriving current is shunted from *p* and R to the back contact of the key and short circuit, *w*. Only half the resistance now opposes the current, whose intensity is, therefore, doubled; but to balance this, as before, only half the relay is traversed by the current.

One of the greatest benefits to be derived from this method of telegraphing in opposite directions is a system of repetition and control very necessary on some lines, by an arrangement of translation, by which a message transmitted by the employé from station *A*, for example, is not only received on the relay and Morse at station *B*, but also retransmitted by the Morse apparatus at *B* to station *A*, where it can be examined at once to be sure of its correctness.

89. *Methods of transmitting Two Messages along a Single Line in the same Direction at the same Time.*—The first success attained in this direction was by Stark of Vienna, in 1855. His method consists of sending from the transmitting station, by two keys, two currents of different intensities, which, on arriving at the receiving station, each set a relay in motion.

The relays are arranged in such a way that, when the weaker currents traverse the line, only one of the relays is put in motion; when the stronger current traverses the line, the other relay is affected; and lastly, when both currents go together, both the relays respond to them.

At the sending station Stark arranged two keys as in the plan Fig. 60; K being a simple Morse key, and K′ a similar lever, supplied at the back with an insulated earth contact, which it moves against the two anvils, 5 and 6. The usual front and back contacts of the keys are marked in the figure, 1 and 3 respectively, and the levers 2. The battery, which

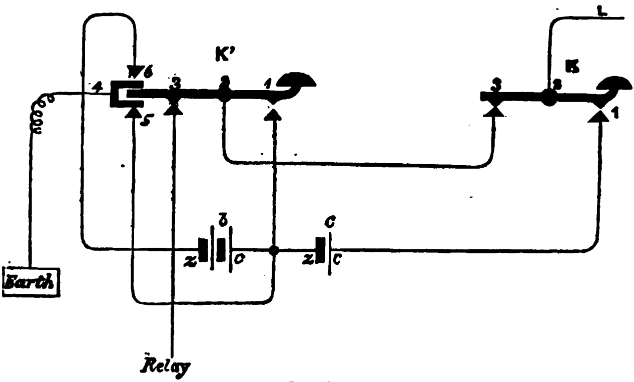


Fig. 60.

is connected up in series, or one element after the other, is used in two unequal parts, *b* and *c*, the number of elements represented by *b* being double that of *c*. The battery, *c*, is put into circuit with the line by pressing down the key, K; *b*, by the key K′; and both together by depressing both the keys at the same time.

The copper pole of *c* is, therefore, connected to the contact 1 of K, the zinc pole of same to 5 of K′. Copper pole of *b* is connected with 1, and zinc pole with 6 of K′. Lever of K′ is in connection with the back contact, 3 of K; line is brought to the lever 2 of K, and the back contact of K′ goes to relay, &c.

When K alone is depressed, the currents of *c* pass from *z* (5 and 4 of K′) to earth, and from *c* (1 and 2 of K) to line.

When K′ is depressed alone, the currents of *b* pass from *z* (6 and 4 of K′) to earth, and from *c* (1 and 2 of K′) to line.

When both K and K′ are depressed, the united currents of *b* and *c* pass from zinc of *b* (6 and 4 of K′) to earth, and from copper of *c* (1 and 2 of K) to line.

By the depression of one or other or both the keys at the sending station, three currents are therefore produced, whose intensities are in the relation of 1, 2, 3. These currents we will call S, S_1, and S_2.

At the receiving station all currents pass through two relays, I and II, Fig. 61. A common local battery, E_1, serves both these instruments; its zinc pole being connected with the tongue of each of them, and its copper pole with their metal contacts. The relay II is furnished with outer coils, which are put into circuit with another local battery, E_2, and a resistance, R, by means of the tongue of relay I.

The tongue of relay I is held on its insulated contact by a spiral spring, whose force is adjusted so that the currents S, or those of the portion, *c*, of the battery, are unable to move it, but so that it is easily moved by S_1 and S_2—the currents of section, *b*, and the whole. Relay II, on the contrary, is adjusted delicately, so as to be deflected by the weaker currents.

When, therefore, the key, K, at the sending station is pressed down, the current of *c* is sent through the line, and passes through the coils of relays I and II to earth. Relay I is unaffected, but relay II is put in action, and the Morse, M_1, in the local circuit (E_1, *z*, relay II, 3, 2, M_1, *c*, &c.), prints whatever signals are given by K.

When K′ is depressed at the sending station, current S_1 is transmitted, and the tongue of relay I deflected against the local contact. Thus two local circuits are closed; the first is that including the battery E_2, R, and the extra coils of relay II, by which the action of the line current in this relay is counteracted, and the tongue held still against the insulated contact; therefore M_1 does not respond to these stronger currents. The second local circuit is that of the Morse, M, and battery E_1.

The intensity of the counteracting battery E_2, whose mag-

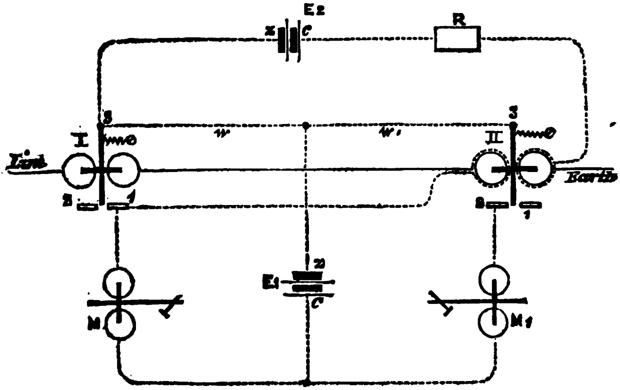


Fig. 61.

netic effect upon the armature of relay II we will call s_3, is regulated by the interposed resistance, R, until it balances the magnetising power of the line current sent by K.

The third case is that in which, during the manipulation of the two keys, both happen to be pressed down together. When this occurs, the current, s_2, of the whole battery goes through both the relays, I and II. Relay I is put in action as before, and closes its printing circuit, and that of the counteracting battery E_2. But as the opposite magnetic effect, s_3, of the extra coils of relay II is only equal to that of s_1, and since s_2 is equal to the sum of s and s_1, it is evident that the relay II will be acted upon by the difference of the magnetic effects due to the line and the counteracting currents, or by s, which is precisely the same as that produced when K alone is depressed. The Morse M_1 will therefore also be set in motion. Combinations have been made, also, by which in a single line, at the same moment, two messages could be sent in one direction, whilst two were being received from the opposite direction; and thus four independent communications could be kept up. Other arrangements have also been made for telegraphing in the same direction at the same time to different stations along the line, both directly and by translation.

Preece, Maron, Edlund, and others have invented also many similar and equally beautiful methods, all of which have been tried, but none of which have found their way to any extent to practical application; and the reason is very simply to be found in the varying resistance of telegraph lines, and in the varying electro-motive forces of the batteries, which occasion the inconvenience of having to adjust the systems by means of resistances to compensate these disturbances. Both these systems of telegraphing in opposite directions, and of telegraphing in the same direction more than one message at a time, must be looked upon as little more than "feats of intellectual gymnastics"—very beautiful in their way, but quite useless in a practical point of view.

90. *Stoehrer's Double-Style Apparatus.*—Stoehrer sought to remedy the inconveniences arising from the multiplicity of signals required in forming letters when only two elementary signals—the dot and dash, as in Morse's system—are employed, by the employment of two electro-magnets, with separate printing-beams acting upon the same strip of paper.

This method puts four elementary signals, instead of two, at his disposal for the construction of an alphabet; and thus places his method, in point of speed of working, on a level with the needle apparatus of Wheatstone.

The two beams of the Morse are not moved by the currents of two batteries, but by that of a single local battery directed to the one or other electro-magnet by a delicate relay which differs in its construction from those generally used; the armatures being formed by two light permanent magnets whose opposite poles are alternately attracted or repelled according to the direction of the current in the coils. It is of necessity very delicate in its action in changing the local current from one to the other electro-magnet of the recording instrument.

The recording apparatus consists of a Morse with two electro-magnets and two printing-beams. The styles at the ends of the beams press upon the paper strip in the same transverse line, about a quarter of an inch apart, underneath a common roller, in which two grooves are cut to receive the points.

A double transmitting key is used; each lever being of the ordinary construction.

A plan of the arrangement is shown in Fig. 62: K, K_1 are the two levers of the key. The lever K is to earth; and K

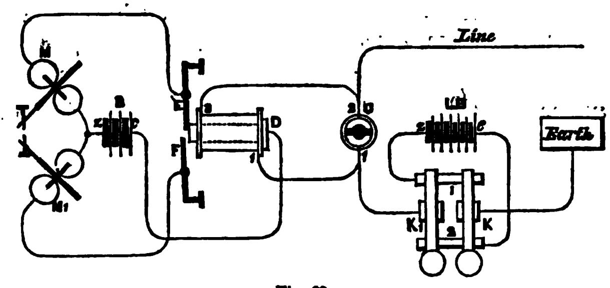


Fig. 62.

connected with a circuit-breaker, U, thence to end 1 of the relay coils; the other end, 2, of the coils is connected to the opposite side of U, and thence to line. The front and back contacts of K and K_1 are made with metal bars, 1 and 2, common to both levers, and between 1 and 2 is inserted the line battery L B. The pole, c, of the local battery, B, goes to D, and is therefore in permanent connection with the poles of the electro-magnet; the other pole, z, goes to both the printing magnets, M and M_1, and from the further ends of their coils to the armatures, E and F, of the relay magnets.

When the apparatus is to be used as transmitter and to correspond with another station on the line, the contact peg is put into the hole of the circuit-breaker, U. The levers, K and K_1, of the key are then pressed down one at a time, according to arrangement of alphabet and words to be transmitted. When the knob of the lever, K, is pressed down, the current of L B goes from *c* (copper, over 2 and lever of K) to earth, and from *z* (zinc, over bar 1, K_1, U) to zinc, and through the apparatus at the other station to earth. K being let go, and K_1 pressed down, the current of L B goes from *c* (bar 2, K_1, 1, U, contact peg, 2) to line, &c.; and from *z* (through 1, K) to earth.

In case it is wished that the Morse apparatus print the message, for the sake of control the contact peg of U is not put into the hole. On pressing down the lever K, the current of L B passes from *c* (2, K) to earth, and from *z* (1, K_1, 1 of U, coils of D, 1, 2, U 2) to line, &c. The other lever, K_1, being pressed down, whilst K is at rest on the back contact, the positive current goes from *c* (2, K_1, 1 of U, coils of D, 1 and 2, U 2) to line; and the negative current from *z* (1, K) to earth.

In this way the station apparatus M M_1 prints the message as well as that of the receiving station.

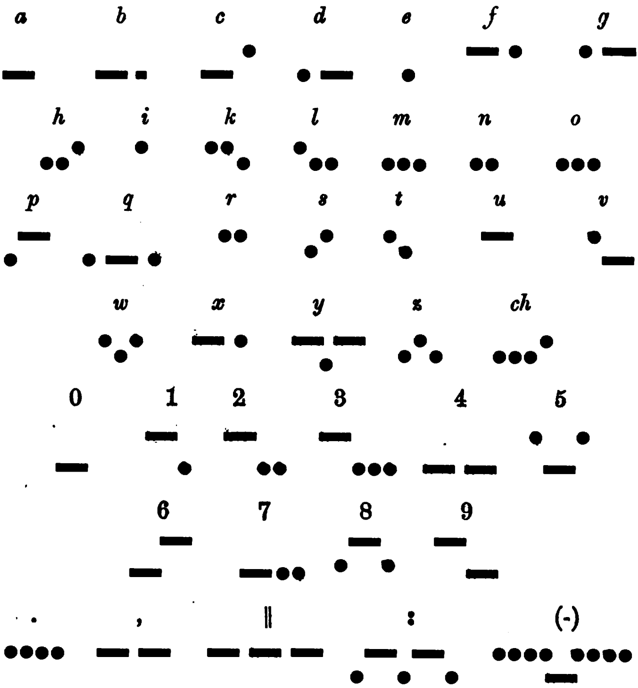
The apparatus is ready for the reception of messages when the contact stopper is out of U.

The currents arising from the line have to pass U 2, coils D, 2, 1, U 1, K_1, bar 1, K, to earth, and back to the sending station. The poles of the electro-magnet D become magnetic, and according to the direction of the current in the line attract one or other of the keepers, E F.

When a positive current arrives, F is attracted and E repelled. The result is that the local circuit of M_1 is closed; the current of the local battery B moves in the circuit C, cores of D, F, coils of M_1 Z. The beam of M_1 is attracted, and the style impresses the paper with marks on the lower side. When the sending station reverses the direction of the current by pressing down the other lever of his key, the keeper, E, of the relay is attracted, and F repelled. By this the current of M_1 is interrupted, and that of M established; the local current of B now circulates in C, soft-iron cores of D, E, coils of M, Z, by which the beam of M is acted upon, and the style marks the paper on the upper side.

The elementary signs, dot and dash, in each of the rows marked by the styles, give four elements for the composition of an alphabetical code. The consequence is that fewer signals are required for the formation of letters, &c., than in Morse's code.

91. The alphabet, numerals, signs of punctuation, &c., arranged by Stoehrer are as follows:—



“ ”	;	!	§
▬ ▬ ●●●	▬ ▬ ●●●●	●●● ●	● ● ● ●

=	?	*New Line.*
●● ●●	●● ▬	● ▬ ▬ ▬ ●

92. *Morse Telegraph worked by Induction Currents.*—In numerous instances has magneto-electricity been pressed into the service of the telegraph, but always in conjunction with the step-by-step or needle systems. For the Morse it was formerly considered useless, as the currents developed, being only of momentary duration, are only capable of themselves of giving successions of dots, whereas the Morse alphabet requires also a longer elementary signal. This difficulty was removed by the ingenious invention of Siemens and Halske, in the construction of a polarised relay, the tongue or armature of which would remain of itself on either contact, when once deflected, until a current different from the one last sent through removed it to the other side. If, therefore, when the tongue was in a state of rest on the insulated contact, a momentary current of magneto-electricity were sent in the right direction through the coils of the relay, the armature would move to the local contact, and would remain there, closing the local circuit, notwithstanding the current which deflected it had long since vanished, until a current in the opposite direction brought it back to the reposing contact. In this way either lines or dots could be produced at pleasure by regulating the interval between the succeeding currents.

This principle is the same as that used at a later date in the indicator of the magneto-electric telegraph of the same inventors, which will be described further on.

The solution of this problem has placed at the command of the telegraphist a source of electricity of much greater intensity for working the Morse instruments through great distances than the voltaic current, and which he is able to produce at considerably less expense.

The complete apparatus consists of—

A transmitting key,

An induction apparatus,

A polarised relay, and

A Morse recording instrument worked by a local battery.

The induction apparatus sometimes used consists of an iron core—a bundle of soft-iron wires—surrounded by convolutions of thick copper wire, forming the primary, and by a long fine wire outside this, forming the secondary coil. The primary coil is put in circuit with the key and with a battery of large surface and little internal resistance. The secondary coil is connected at one end with the earth, at the other with the line. It is sometimes divided into two parts, which may be connected parallel or in series, according to the resistance of the line.

A plan of this system is shown in Fig. 63, arranged for two stations. C and C′ are the induction coils, of which e e′ are the soft-iron cores; the limits of the primary and secondary coils are shown by concentric rings. K is a transmitting key, which closes two working contacts in front; R the polarised relay; B the local battery; and I the receiving instrument.

At each of the stations the middle contact of the key is connected to line, and also to one end of the primary wire of the induction apparatus. The battery is included in two circuits: first, between the remaining end of the primary coil and the second contact, *b*, of the key; and, secondly, in the ordinary local circuit of the relay and recording instrument. One end of the secondary wire of the induction coil is to earth, the other connected with the first contact, *a*, of the key, the back or reposing contact, *c*, leading through relay to earth.

The key differs slightly from that used in the ordinary Morse circuits, having, as we have seen, two working contacts. The lever is furnished with a spring, which presses upon the contact *a*, by which, when the key is lifted up, the contact with *a* is interrupted an appreciable time after that with *b*.

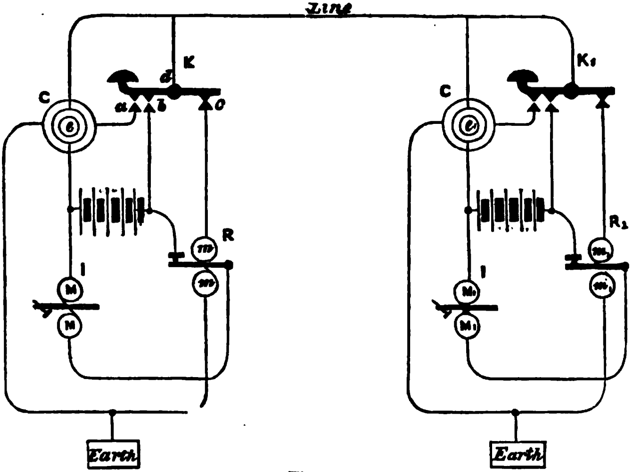


Fig. 63.

This is necessary, because if they were both interrupted at the same instant it is evident that no induction current could arise in the secondary coil, its circuit being broken. By the contact *a* continuing an instant longer than *b*, however, the induction current which follows the interruption at *b* has time to pass over *a* and through the line.

The Morse telegraph has been worked by this system of induction currents to a considerable extent on the lines in Russia, Bavaria, and Hanover. Schellen says that messages have been sent direct, without translation, by this method, on a line of two hundred German miles, equal to nearly one thousand English.

Compared with the methods of working the Morse telegraph by voltaic electricity, that of induction currents offers many advantages; the line batteries are opened, and spaces between the signals are given by reversed circuits, which always work cleaner than those given by making and breaking the same current.

The polarised relay above described is also profitably employed on lines worked only with galvanic currents, with

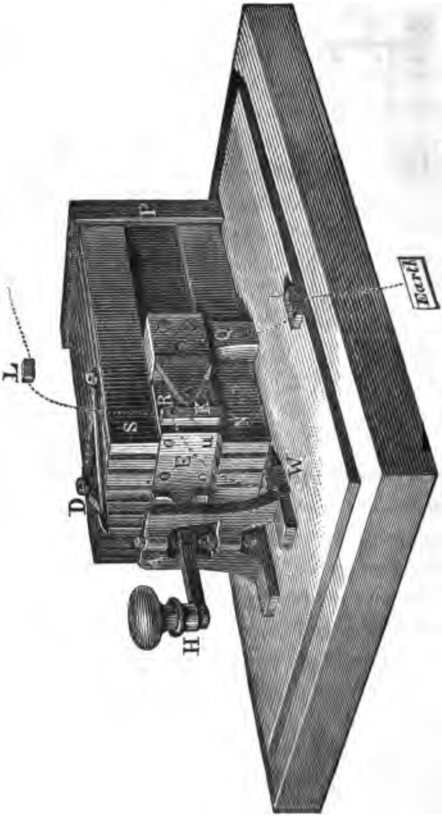


Fig. 64.

which it is found to be far more delicate than the relays with springs. It is, however, necessary to give the armature c (Fig. 37) a bias on the side D′, which is done by advancing the soft-iron continuation of the pole, N′, of the electro-magnet a little nearer to the armature than N, by which, when no current passes, the tongue is held against the insulated contact, and the distances may be so finely adjusted that a very weak current suffices to move it.

93. *The Magneto-Induction Key.*—Instead of the Morse key, induction coil, and local battery, Siemens and Halske use also an instrument arranged in the form of a key, by which a coil of wire, wound on a soft-iron armature, is oscillated between the poles of a permanent magnet, and develops alternate currents for working the polarised relay.

The magneto-induction key is shown in Fig. 64, in perspective. S and N are two rows of permanent bar-magnets; the upper ones with their north ends, and the lower ones with their south ends, in contact with a stout plate, P, of soft iron,

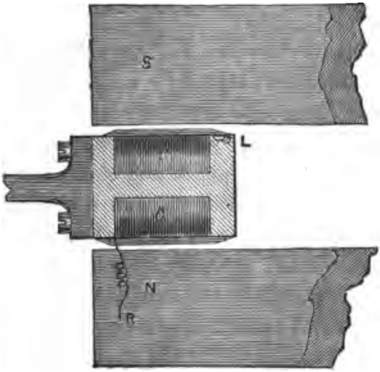


Fig. 65.

which acts as a neutral block for all the magnets forming the battery. Between the poles of this system, and oscillated in an angle of a few degrees by means of a handle, H, in the frame between two screw points, is the soft-iron armature, as long as the magnet system is wide, cut in deep longitudinal grooves on opposite sides, as is shown by the sectional sketch, Fig. 65. In these grooves the coil, C, of fine insulated wire is wound. The play of the handle is limited by two adjusting screws in the frame, A. When at rest, the handle is held against the upper screw by a spiral spring, S, stretched between the handle and front of the triangular piece, D, on the top.

One end of the coil of wire on the armature is attached to the screw, *k*, on the terminal, K, from which one connection goes to line and another to the screw *w*, at the foot of the frame, A. The other end of the coil is connected with the metal frame supporting the armature, and through the axis *f*, to the upright support Q, from which a leading wire goes to terminal, *t*, and earth.

When a current arrives while the instrument is in circuit with the line, it goes from L over K, W, upper adjusting screw in A, through handle H, axis *f*, Q, *t*, earth, without traversing the coil. This is the purpose of the connection between K and W.

When the handle is pressed down, the polarity of the armature is reversed, and a positive magneto-electric current induced in the coil, which circulates also in the line wire, deflects the tongue of the polarised relay at the receiving station from the insulated point, and closes the local circuit so long as the key is held down, and no negative current induced by letting it go back to its position of rest.

94. *Intermediate-Station Commutators.*—Where intermediate stations occur, which are supplied each with only one Morse instrument, it becomes necessary to employ a commutator or current director to put the apparatus at pleasure in the circuit of the up or down line, in order to meet the requirements of the service. At such a station the apparatus must be so arranged as to be able to assume either of these three positions :—

(1.) When the intermediate station is entirely cut out of circuit, and the end or distant stations on opposite sides correspond directly through the line.

(2.) When two end or distant stations on opposite sides correspond with each other, and the intermediate station receives the despatch, at the same time.

(3.) When the intermediate station wishes to communicate with a station up or down the line whilst it has notice of currents arriving from the other side.

To avoid the inconvenience of altering continually the connections to suit these various positions of the apparatus, commutators are employed. Various forms of these instruments are given by Nottebohm, Borggreve, Siemens, and others.

95. One of the completest is that of Nottebohm. It consists of six bars of metal screwed on to a wooden base, cut out in seven holes to receive contact pegs between them, so as to bring them in metallic contact with each other.

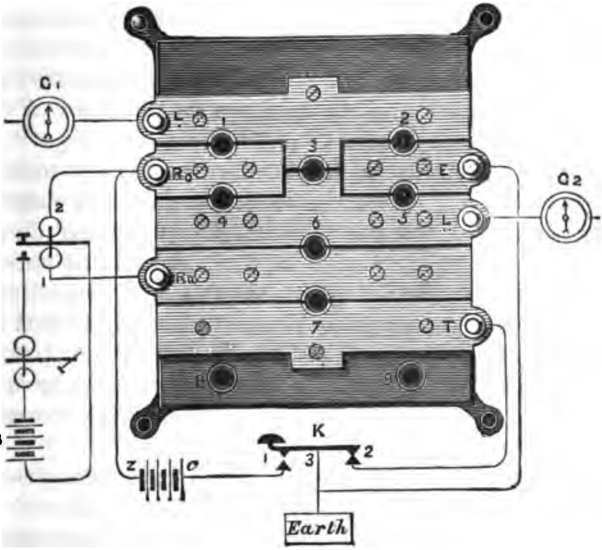


Fig. 66.

Fig. 66 gives the commutator in half size, and Fig. 67 the contact peg in full size. L and L are the terminal screws to receive the line wires coming from the galvanoscopes, R_o and R_u the ends of the electro-magnet coils of the relay. T is connected with the back contact, 2, of the key, and E with earth. Between the front contact of the key and the bar R_o the line battery is inserted. The beam of the key is also to earth, according to the second plan mentioned above (Fig. 26) for arranging the Morse system.

Fig. 67.

In the first position, when the intermediate station is to be cut out of circuit to let two other stations correspond direct, the contact peg is put into the hole 3. The current coming from the left-hand side passes over G_1, L, 3, L, G_2, and so on, to the other line. The employé can see, by the deflections of the needles, his two galvanoscopes, G_1 and G_2, when the stations are corresponding; and when both have done, at a given signal, he re-arranges his commutator for regular work.

This signal is given by both stations simultaneously, and consists in pressing down their keys for the space of one minute, by which the needles of the galvanoscopes are deflected steadily in one direction for that length of time.

In the second position, by which the intermediate station participates in the messages transmitted by the distant stations, and which are, for the most part, official instructions, time, or information for the employés, contact pegs are put into holes 1 and 6. A current then arriving from the same side will traverse G_1, L, 1, R_o, 2 (coils of relay), 1, R_u, 6, L, G_2, to the other line. The relay then performs its functions of closing the local circuit and setting the recording instrument in motion.

Position No. 3 is attained by two different arrangements of the contact pegs, according as the one or the other of the lines is to be used. When the apparatus at the intermediate station is to correspond with a station on the right, whilst the line on the left remains in circuit with the board, holes 2, 4, and 7 are provided with pegs. If the intermediate station now works the key, currents circulate from the c-pole of the battery through 1, lever of key, 3, earth; and from the z-pole to R_0, through the peg in hole 4, L̤, G_2, to the line on the right. In receiving signals from the same side the key remains at rest, the currents arriving pass over G_2, L̤, peg 4, R_0, 2, coils of relay, 1, R_u, peg 7, T, back contact of key, 2, 3, earth, &c.

During both transmission to and reception from the station on the right-hand side, if a current arrive from the opposite direction, it must pass through the coils of the galvanoscope G_1 (deflecting the pointer), over peg 2, to earth. The deflection of the galvanoscope pointer is observed by the employé, who takes his measures accordingly.

When the reverse is to take place, that is to say, the intermediate station is to correspond with a station lying to the left, whilst that on the right remains in circuit with the galvanoscope, the pegs are inserted in holes 1, 7, and 5. The signals given by the key take the following road: z of battery, R_0, peg 1, Ḷ, G_1, to line on the left, apparatus at the opposite station, and earth, and from the c-pole of the battery to 1, lever of key, 3, earth. Arriving currents from the same direction come over G_1, Ḷ, peg 1, R_0, 2, coils of relay, 1, R_u, peg 7, T, key, 2, 3, earth.

Those arriving from the other side deflect the pointer of G_2, and to pass to earth by G_2, L̤, peg 5, earth.

In both cases the employés have to pay attention to the galvanoscope, as in cases of emergency it is sometimes necessary to postpone the transmission or reception of a message on one line until the more pressing one from the other side has been disposed of.

96. *Siemens and Halske's Intermediate-Station Commutator.*—The commutator represented in perspective in Fig. 68 is much simpler in construction than that of Nottebohm, and answers all the requirements of an intermediate station where a single apparatus only is used. The apparatus is put in circuit between the screws 1 and 2, to which the lines L_1

and L_2 are respectively connected, while the earth-plate is brought to one of the screws, 3 or 4.

When the contact-cone is out, the current passes through the apparatus in the circuit

$$L_2, 2, A, 1, L_1,$$

that is to say, the intermediate station receives the signals in common with a distant station.

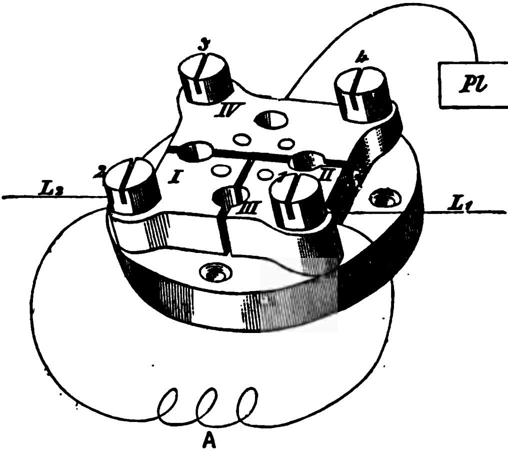


Fig. 68.

When the contact-cone is in hole III the apparatus is short-circuited, and the current passes through

$$L_2, 2, \text{contact-cone in III}, 1, L_1.$$

When the contact-cone is in hole I the apparatus is used as terminal of the line L_1, and the currents from L_1 take their way through L_1, 1, A, 2, I, earth, &c.; those from L_2 through I to earth. If the contact-cone is put in II, the instrument receives from and transmits to the line L_2 on the other side in the same way. In both positions the currents arriving by the line which is not being corresponded with pass through the galvanoscope inserted in the line circuit, and give notice to the operator.

97. *Borggreve's Commutator for Intermediate Stations.*—The many inconveniences arising from delay in the reception and transmission of messages, combined with the possibility of mistakes in stoppering the holes of Nottebohm's commutator for the different positions of the apparatus, have shown the necessity of furnishing intermediate stations with two apparatus. This enables them to correspond with the stations on both sides at the same time.

M. Borggreve, Inspector of Telegraphs in the Prussian service, has arranged a commutator for the use of intermediate stations with two apparatus, in which, as in that of Siemens and Halske, only one stopper is required. It is composed of five brass slabs screwed on an insulating base of vulcanite.

The way in which the commutator is connected with the two Morse apparatus, as well as its form and appointments, is shown in the plan, Fig. 69. The line wires, L^1 and L^2, are connected to the upper screws, while the lower screws on the same bars are connected with the levers of the transmitting keys, K^1 K^2. To the binding-screw of the middle bar is attached the earth-wire, and to the screws of two intermediate bars the cross-commutators, C^1 and C^2, whose opposite points go to the back contacts of the keys. R^1 and R^2 are the relays of the two Morse apparatus, M^1 and M^2. The two local circuits are supplied with a common local battery, B, and the two line circuits with a common line battery, L B. When the contact plug is inserted in hole 1 of the commutator U, both the apparatus are short-circuited, and currents pass through L^1, G^1, stopper 1 of commutator, G^2, L^2, &c. The employe sees by the deflections or otherwise of his galvanoscope needle when the direct correspondence of the end or distant stations is concluded, usually by an agreed signal.

If the stopper is in hole 2, apparatus 1 can correspond with the line L^1, and apparatus 2 with the line L^2, independently of each other. The currents arriving by L^1 go through G^1, U, K^1, C^1, and coils of R^1, C^1, U, 2, earth, &c. The cross-commutators are put between the back contacts of the keys and bars of the commutator U, in order to enable the operator to invert the coils of the relays, in case the residuary

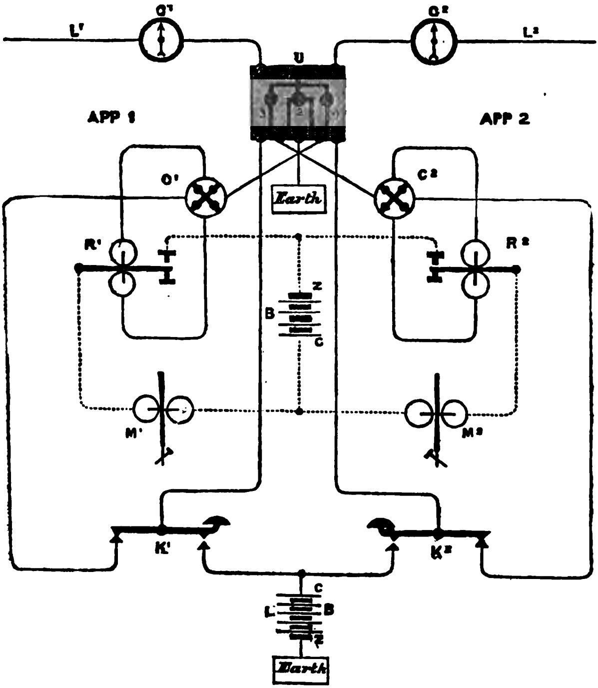


Fig. 69.

magnetism in the soft-iron cores, from continued currents in one direction, should interfere with their delicacy.

The currents transmitted from the station towards L^1, by pressing down the key K^1, take the direction from L B, copper pole C, front contact and lever of key, first bar of commutator

U, G^1, and L^1. The operations with apparatus 2 and L^2 are similar.

When the contact peg is put in one of the holes 3 or 4, the apparatus on the opposite side to that in which the peg is put in is ready for participating in any messages that may be passing through the line in either direction. Suppose the peg to be inserted in the hole 3. The currents coming from the direction L^1 go then from L^1, through G^1, peg 3 of the commutator C^2, coils of relay on the right, back contact of K^2, lever K^2, commutator U, G^2, L^2, &c. The relay R^2 will be set in action and work the Morse M^2, which will print all the signals passing from the line L^1 into the line L^2.

98. *Commutator for Stations with three or four Lines from different directions.*—Where more than two lines from different directions meet at a station, it is required to employ a commutator by which, whilst one or two lines are being corresponded with, the remainder can be connected up, two and two, for circular correspondence.

When three lines meet at a station, a commutator, arranged by Borggreve, is usually employed, by which any two of the lines may be connected together in circuit with a galvanoscope, or complete recording apparatus, while the third line is open for telegraphic communication from the same station as terminal.

When four lines meet, it is necessary to arrange the commutator so that, upon occasion, they may be connected up two and two with intervening receiving apparatus, by which the corresponding stations are in direct communication, and the intermediate stations able, at the same time, to participate in the information transmitted.

Fig. 70, *a*, gives a plan of connections of Borggreve's commutator for three lines, by which the following combinations are possible :—

1. L_I	circular	with	L_{II},	L_{III}	with apparatus.
2. L_I	,,	,,	L_{III},	L_{II}	,, ,,
3. L_{II}	,,	,,	L_{III},	L_I	,, ,,

In using this commutator three of the holes are always stoppered at the same time. Fig. 70, *b*, gives the position of the stoppers in the holes answering to the positions 1, 2, and 3, above.

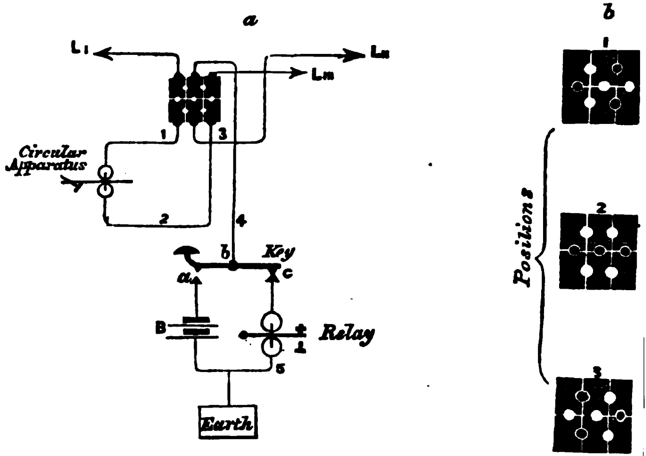


Fig. 70.

In the first position the circular current traverses L_I, 1, circular apparatus, 2, commutator, 3, L_{II}, &c., and the currents received or transmitted by the intermediate station, L_{III}, commutator, 4, back contact of key, relay, 5, earth, &c. In the second position, the circular current goes through L_I, 1, circular apparatus, 2, commutator, L_{III}, &c., and the station currents through L_{II}, 3, commutator, 4, back contact of key, relay, 5, earth, &c. In the third position, circular currents go over L_{II}, 3, commutator, 1, circular apparatus, 2, commutator, L_{III}, &c., and station-currents over L_I, commutator, 4, back contact of key, relay, 5, earth, &c.

The plan of connections for a station with four lines combines both Borggreve's commutators; and the combinations in which the operator can arrange the lines are as follows :—

1. L_I with L_{II}, and L_{III} with L_{IV}
2. L_I „ L_{III} „ L_{II} „ L_{IV}
3. L_{II} „ L_{III} „ L_I „ L_{IV}

In each combination the positions of the lines with regard to the apparatus may be :—

(1.) Direct, the station not receiving the message.

(2.) Circular, the station participating in the despatches.

(3.) Corresponding, the station transmitting and receiving by the lines.

99. *Battery Commutators.*—When the insulation of the line varies, or by any other reason—as, for instance, when an end station has to transmit to a near station with little line resistance in the circuit—it becomes necessary to alter the strength of the current, a battery commutator is inserted, by which one-third, two-thirds, or the whole of the elements may be brought into service by simply changing the place of a contact peg. Such an apparatus consists of four slabs, as in Fig. 71. The copper pole of the battery is connected to the screw of the bar, B, and connections from elements one-third and two-thirds of their number from the copper pole are brought to the screws of the bars C and D respectively, the zinc pole being connected in the usual way with earth. The place of the stopper in *b*, *c*, or *d* determines the battery power used.

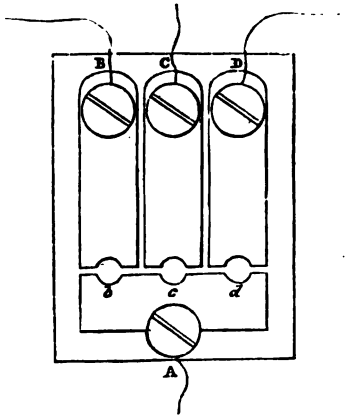


Fig. 71.

When more than one line is worked with a single battery, a bar-commutator (Fig. 72) is used. Three brass bars, 1, 2, and 3, are screwed on a slab of dry wood or vulcanite, and above them, at right angles, three others, I, II, III. The bars are insulated from each other when the holes are open, but when a contact cone is inserted in one of them, the corresponding cross-bars are electrically connected. If the front contacts of the keys are connected to the three bars I, II, III, and three parts of the battery, as above, to the bars 1, 2, 3, the operator is able to work the lines with either of the battery powers which may be necessary.

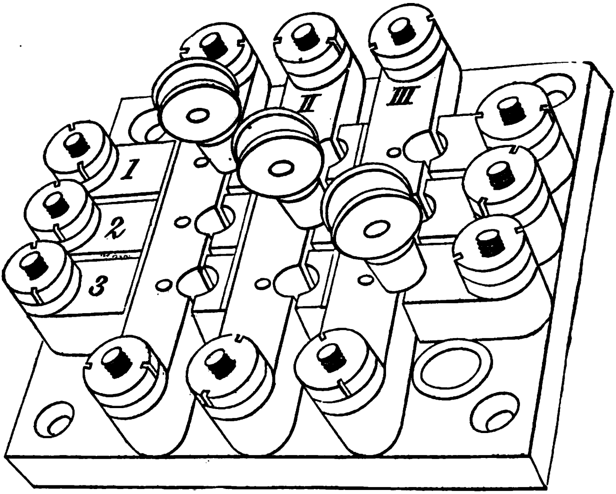


Fig. 72.

(c) *Automatic Telegraphs.*

100. With the ordinary Morse transmitting key, an operating clerk can send in regular work at an average rate of twenty to twenty-five words per minute. The receiving apparatus are, however, capable of recording at a much higher rate, something like seventy-five words or more. It was, therefore, desirable to devise some means of more speedy transmission, and as no increase in rate was to be expected from the clerks, recourse was had to automatic systems. The two principal systems were proposed by

Bain and by Morse. Bain's system consisted in punching holes out of a strip of paper, which was drawn with a uniform velocity between a spring contact and an anvil. Where a hole occurred the contact fell through and closed the circuit with the anvil, but was insulated from it when the paper intervened. Morse's system consisted in the employment of a "port-rule" in which metal types were set up, and which was drawn over pulleys and underneath a contact lever which, being caught and lifted up by the elevations of the types, closed the circuit of a galvanic battery with the line. Thus, instead of direct transmission, the messages were first set up in type and moved through the machine which transmitted the corresponding signals automatically. An improvement on these systems was patented by Henley, who proposed the employment of magneto-electric currents together with an automatic transmission.

101. *Wheatstone's Automatic Telegraph.*—This is a modification of Bain's system: it consists principally in the mechanical transmission of signals by means of contacts given by series of perforations in bands of paper previously prepared and drawn through the manipulator, the signals being printed by the recording instrument.

Three separate apparatus are required; the perforator, by which groups of holes are punched out of the paper; the transmitting or contact key, which is worked by the perforated paper strip; and the recording instrument of peculiar construction.

The perforator as in use at the station of the Electric and International Telegraph Company consists of a framework, in front of which is a keyboard having three keys, like those of a piano, side by side. These keys, which are retained in equilibrium by the pressure of light springs, when depressed, have only to perform the duty of opening valves. Above the keys are three little vertical cylinders supplied with pistons, whose rods protrude underneath and work the punches. These cylinders are connected through the valves worked by the keys with a chamber of compressed air used for the pneumatic transmission of despatches between Telegraph Street and the Exchange. The perforator has a guiding groove, through which a paper strip passes. At the bottom of the groove is an opening to admit of the to-and-fro motions of the upper end of a frame containing the three punches, the extremities of which are in a line transverse to the direction of the paper. The two external punches form the groups of perforations which make up the message, and the middle one, which is smaller, marks the spaces between the letters and words. On pressing down one of the external keys, its punch is struck down and perforates the paper; at the same time, the middle punch is carried down by means of a collar, and makes a perforation in the middle of the strip. On letting go the key the air valve is shut off, the piston rises again, and the punch is restored to its normal position. The paper is drawn forward each time a key is elevated.

The inventor has adopted the Morse alphabet by making the upper line of perforations represent the dots, and the lower the dashes.

The apparatus used for automatically transmitting the currents consists of a clockwork arranged so as to draw the slip of perforated paper, step by step, over the contacts which give the signalling currents to the line. In the front of this apparatus is a rocking piece with a groove to receive the paper strip, a spring-clip, which holds the paper firmly during the recession of the rocking piece, and three wires or pins, placed transversely to the paper, which, by entering the external apertures of the strip, or by being prevented entering the paper by the absence of apertures, regulate the succession and frequency of the currents sent into the line. The two alternate pins are elevated alternately, one of them being allowed to rock with the middle pin, and the other having only a vertical motion. The method of accomplishing this motion is by means of an arrangement of eccentric gear. The paper strip is moved forwards by the rocking motion of the central pin. During the recession of the rocking piece the paper strip stands still; and whilst the rocking piece advances, the exterior rocking piece enters an aperture in the paper if one presents itself. The vertically-moving pin, on the contrary, acts only during the recession of the rocking piece, therefore, whilst the paper is stationary. The rapidity and precision with which these two external pins give the currents corresponding to the holes they meet with in being elevated, and the central pin pushes the perforated strip, hole after hole, along, is truly marvellous. The recording instrument used with this system differs materially from the ordinary forms of Morse receivers which we have described. A train of wheels is used to draw the blank-paper strip through the printing apparatus with a uniform velocity. The printing apparatus consists of a trough of fluid ink, in which a vertical disc, grooved at its circumference, rotates, and takes up ink, holding it in the groove by capillary attraction. A smaller disc, called the "tracer," or marker, is carried upon a horizontal axle protruding from the side of the case, rotating partly within the groove of the former disc, and taking some of the ink which is contained there. The marking or tracing disc is so mounted that its axle, whilst rotated by the clockwork, is capable of being moved by the action of the contact sufficiently to bring it into contact with the paper strip. The armature between the poles of the electro-magnet consists of a pair of curved permanent magnets similar to those used in the receptor of the beautiful recording apparatus by the same inventor.

Sir Charles Wheatstone, in his description, shows how the apparatus may be arranged for translation, and also how it may be used with a magneto-electric machine instead of a voltaic battery, as the source of electric power.

This excellent method is said to combine the advantages of a fivefold speed in transmission with a considerably greater security for correctness and legibility. The great difficulty which many people find in acquiring dexterity in manipulating by the present system of Morse would vanish were such a system of automatic transmission in general use, in which the demand for skill from the employés is reduced to a minimum.

102. *Siemens and Halske's Type Telegraphs.*—Towards the end of the year 1861 Messrs. Siemens and Halske succeeded in the construction of a transmitting apparatus combining Morse's automatic transmitter with the principle of Henley's system with magneto-electric currents.

The transmitter consists of a long insulated wire wound upon a soft-iron armature, revolving between the poles of a number of permanent magnets. Of the alternate currents thus generated, those which are required to form the signals go through the line to the receiving station; the others are cut off by an interruption. This is effected by the motions of a contact-lever, raised by the teeth of a series of metal types drawn under the lever by the same mechanism which is used to turn the coil.

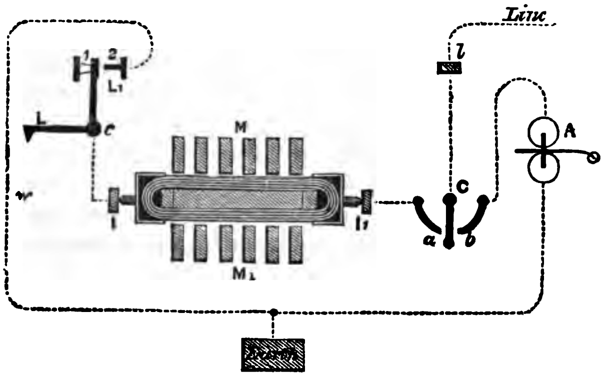


Fig. 78.

Fig. 78 represents a plan of the complete apparatus. L, L1 is the angular contact-lever turning on the axis *c*. When its point, L, is lifted up, the platinum face on the right side of the upper end, L_1, comes in contact with the metal screw 2; and when it falls, the back of L_1 rests against the agate point 1, and breaks the circuit. I, I_1 is the inductor or revolving coil of wire in close proximity to the poles of the permanent magnets M, M_1. C is a switch, the terminals *a*, *b*, and C of which are respectively connected with the transmitter, receiving instrument, and line. One end of the coil, I, I_1, is in permanent connection with the centre, *c*, of the contact-lever L, and the other end with the terminal, *a*, of the switch. The contact-point 2, against which the lever L, L_1 plays, is to earth; and, lastly, the side *b* of the switch is connected by a wire to the coils of the polarised Morse, and thence to earth.

If the inductor I be turned round between the poles of the permanent magnets M, M_1, whilst L_1 rests against the insulated point 1, and the arm of the switch C is on *a*, the currents induced in the wire will meet with an infinite resistance between L_1 and 1, and no impulse will be transmitted through the line; but if L be lifted up, and the contact between L_1 and 2 established, the currents will pass from the coils I, I_1 (*c*, L_1, 2) to earth, and on the other side from I, I_1 (*a*, C, *l*) to line, and at the distant station, through the Morse instrument, to earth. When the arm C is put on *b*, the transmitter is cut out of circuit, and the currents arriving pass from line (*l*, C, *b*, A) to Morse and earth.

The types, which are set up in a port-rule in order, like printing types, are made of thin pieces of metal cut in teeth, in forms resembling those shown in Fig. 75, representing the letters A and B. The bottom of the port-rule is provided with a row of teeth, locking into the worm of an endless screw on the shaft which turns the inductor-coil. Thus, while the inductor-coil is turned, and alternate currents generated, the types are moved forward with a corresponding velocity, and make and break contact by lifting and letting fall respectively the point of the contact-lever.

Fig. 74 gives an elevation of the contacts, with the lever and part of the port-rule containing the three letters A, B, and C. c', c'' is the port-rule, moving along in the direction indicated by the arrow, by the rotation of the screw T, and is held in its place by the roller *r*. The lever L, L^1 is held back against the contact 1, when not raised by the types, by means of the spring *s*. The figure, however, shows the point L lifted up by the broad tooth of the letter

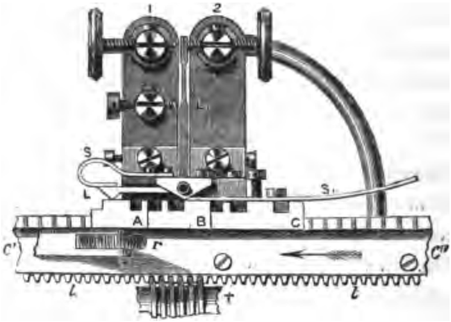


Fig. 74.

A, and the arm L^1, therefore, pressed against the contact screw 2. The types are straightened in the event of getting shifted upwards, by passing under the spring s^1.

When the arm L^1 is against the contact 2, or the hook L lifted up, as in the figure, whilst T is revolving with the coil, currents, alternately positive and negative, traverse the line, and the polarised Morse at the receiving station gives a series of dots. But when the contact L^1 with 2 is interrupted, the armature of the printing magnet remains on one of the contacts, upper or lower, until a reverse current removes it.

Suppose *a*, *b*, Fig. 75, to represent a series of alternate positive and negative waves, produced by the revolutions of the coil between the poles of the permanent magnets, whilst L^1, connected with earth, completes the circuit. During each complete revolution a positive and a negative current within the space *c* are developed, each succeeding half-revolution sending a different current into the line. At the receiving station, whilst this continues, the armature of the polarised Morse will vibrate up and down, and print a series of short lines corresponding to the intervals between the transmission of the positive currents and the negative which follow them.

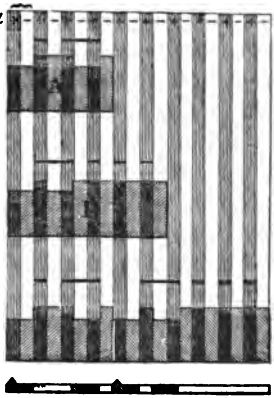


Fig. 75.

If the port-rule be not so far advanced along the stage as in Fig. 74, so that the types A, B, C are all on the right of the lever L, the arm L^1 will rest on the insulating contact 1, and the beam of the polarised Morse, at the receiving station, on the upper screw, by which no mark is made upon the paper. As soon as the hook L, however, touches the first tooth of the type A, it will be pushed up, and L^1 thrown on 2. A positive current will instantly afterwards traverse the line, and make a dot at the receiving instrument. A negative current succeeds, which makes a space; and then another positive current, which re-attracts the armature. Before the next following negative current is produced, the tooth has passed by, and L dropped into the space which corresponds to a whole revolution. The Morse-beam therefore prints a dash which continues till the next tooth pushes L up in time to complete the circuit for the negative current, which draws up the armature again, and produces a space which lasts until the first tooth of the letter B pushes up L, and allows a positive current to go to the Morse. This tooth is narrow, to break the circuit before the succeeding negative current is developed, so that the Morse prints a dash until the broad tooth of B pushes up L in time for the circulation of a negative current, which begins a space. The tooth in question is just so broad as to include three positive currents, and ends at a negative current.

The principal advantages of this system are the opportunities which it offers of controlling the correctness of each message when set up, by simply reading off the plain Roman letters engraved in the fronts of the types, which give it an important advantage over other systems.

The mechanical part of the transmission of a message consists in nothing else than in laying the port-rules, set up with the consecutive parts of the message, one after the other, on the stage appointed for their reception, removing those which have gone under the lever L, and in treading the lathe during the time.

An arrangement has subsequently been made with this apparatus by which the magneto-electric inductor is replaced by a galvanic battery, and the contact (Fig. 74) by a rocking commutator, which transmits alternate currents into the line. The system is at work on some of the German lines, and is said to give much satisfaction.

(*d*). Dial Telegraphs.

103. For railway and private lines dial telegraphs are more convenient than the Morse, on account of the ease with which they are manipulated.

104. *Magneto-electric Pointer Telegraph of Siemens and Halske.*—This system is almost exclusively employed on the lines of the *Grande Société des Chemins de Fer Russes*, by the London, the Danzig, and the Kœnigsberg fire brigades, and on various other lines in England and elsewhere.

The apparatus consists of a battery of permanent magnets, between the poles of which a coil of insulated wire on a revolving armature of soft iron develops, on being turned on its axis, alternately positive and negative currents. These currents traverse the line one after the other, and passing through the coils of an electro-magnet at the receiving station, cause its armature to vibrate and turn an escapement-wheel and pointer.

Fig. 76 represents an external view of the complete apparatus. A A is a cylindrical case, containing the transmitter; C, a handle which, in operating with the apparatus, is turned round from letter to letter, marked on the horizontal dial-

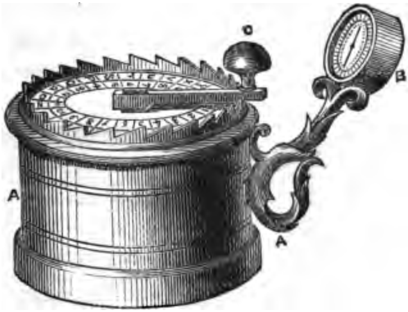


Fig. 76.

plate, stopping always against the tooth opposite the letter to be indicated; and B, the receiving instrument, supported by a bracket at the back. The latter has in front a small dial, corresponding in its arrangement with that of the transmitter, and a pointer whose motions follow faithfully those of the handle of the instrument which is working.

Fig. 77 shows the internal mechanism of the transmitter. The metal disc J, with inclined teeth on its rim, is supported by the back *x*, and by two square pillars *y*. On the back, which consists of a stout plate of soft iron, are screwed a series of several pairs of permanent magnets, G G; those on one side with their north, and those on the other with their south poles projecting.

Between the poles of this system is a cylinder of soft iron, E, which serves as keeper of all the magnets. It is cut out longitudinally in two deep, broad grooves, on opposite sides, in which a spiral of fine well-insulated copper wire is coiled.

The whole armature is supported by the brass caps F F′, in pivots above and below. Above the spiral, the pinion T locks into the tooth-wheel L, turning on an arbor, A A, by means of the handle H above the disc J. The proportion between the teeth of the wheel and those of the pinion is such that one revolution of the wheel causes the pinion to revolve thirteen times, changing the magnetism along the whole length on each side of the armature, and thereby

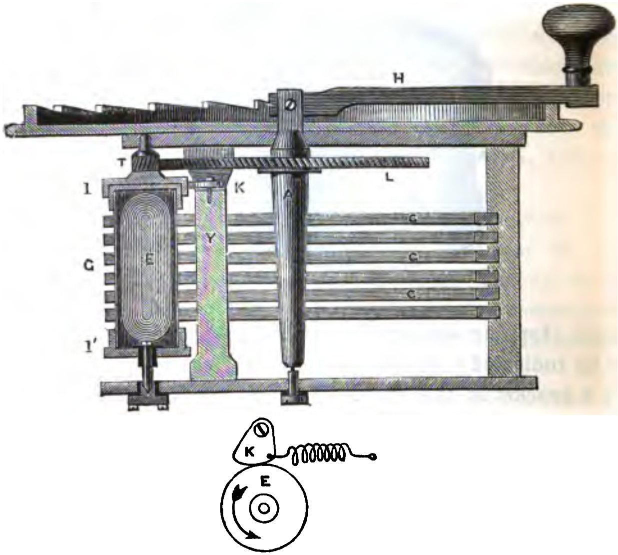


Fig 77.

inducing in the coil, if the circuit is closed, thirteen positive and thirteen negative currents of equal magnetic effect.

When the coil is turned half round on its vertical axis, the polarity of the armature is also changed, and a magneto-electric current induced in the coil W in one direction, and on turning it half a revolution farther round, so that it takes up its former position, a current in the opposite direction is induced.

The ends of the coil of wire, which are attached to the brass caps, are connected, one to an earth plate, the other to the coils of the electro-magnet of the indicator, and thence to the line.

In employing a series of separate magnets, arranged at a distance from each other, a greater inductive effect is produced than if only a single permanent magnet were used, or if the separate magnets were combined in the form of a battery; because the poles, acting at the same time upon the armature, produce along its whole length on each side a uniform magnetism, so that the wire coil receives, in every point, the same magneto-electric impulse.

The interior of the indicator is shown in Fig. 78. The top, s s, of a permanent magnet of hard steel, bent in a

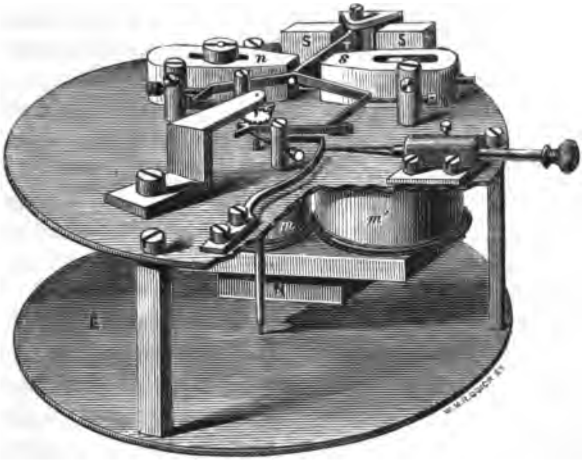


Fig. 78.

rectangular form, and having a space cut out of its upper end, protrudes through the side of a circular brass plate, A A, one-eighth of an inch thick. In the slit in the upper end, s s, of the magnet is the axis of a movable tongue of soft iron, having at its extremity the same polarity as the end s, and vibrating between the poles *n* and *s* of a polarised electro-magnet, *m m'*. By polarised is meant that the soft-iron cores around which the wire is wound receive polarity from a permanent magnet.

In this case the cores of the electro-magnet are attached to a stout piece of soft iron, resting on the north pole of the angular magnet which distributes to the whole system above the point of contact north polarity. The tongue or armature of soft iron is, therefore, attracted by both the poles of the electro-magnet with equal force, and if not exactly balanced in the middle between them, will rest on one side or on the other by the superior attraction of the nearer pole.

When a current is sent through the coils of the electro-magnet in the direction which increases the magnetism of the more distant pole, whilst it reverses the magnetism of the nearer, the latter forthwith repels the armature with nearly the same force with which the former pole attracts it, and the armature in consequence goes over to the former pole, and rests there, not only as long as the current lasts, but afterwards, when no current is circulating in the line. It is this which renders this indicator so sensitive for induction currents which are only of momentary duration.

At the end of the armature is a German-silver fork, carrying two horizontal arms—thin steel springs with hooks, which catch into the teeth of a ratchet-wheel. The ratchet-wheel has thirteen teeth, so that when the armature oscillates from right to left, or from left to right, the wheel advances half a tooth; and in order that the pointer may march over the whole dial, the armature must oscillate thirteen times in each direction. This is provided for by exactly that number of reverse currents being transmitted from the sending station, when the handle of the transmitter is turned once round the dial.

Behind the hooks are two screw stops which limit their motion and prevent the skipping of the wheel.

105. The alarm is generally a separate piece of mechanism; it was, however, sometimes in the earlier forms of this appa-

Fig. 79.

ratus combined with the indicator by attaching a hammer to a continuation of the armature of the electro-magnet, and letting it strike on two bells placed just within its reach; but this plan has been almost entirely abandoned in favour of the alarm shown in Fig. 79. The principle is the same as that on which the indicator is constructed: a polarised electro-magnet, *m m′*, is supported by the upper pole of the angular bent permanent magnet, M, on a wooden base, *b*. From the lower pole of M springs a movable armature or tongue of soft iron which takes polarity from it, and plays between the projecting cores of the electro-magnet, which are also polarised. A continuation of the armature forms a hammer, *h*, and strikes upon the bells *b b′*.

A commutator is sometimes employed for directing the arriving currents, at pleasure, through the indicator or through the alarm; but, more usually, the alarm is inserted in the same circuit, and when it is not required to give notice of the arrival of a current, its coils are short-circuited by a contact-peg inserted in a hole between the terminals, *s s′*, of the electro-magnet coils.

The plan according to which two such instruments are connected up for two stations is shown in Fig. 80, where the line L is connected at each station to an alarm, A, which

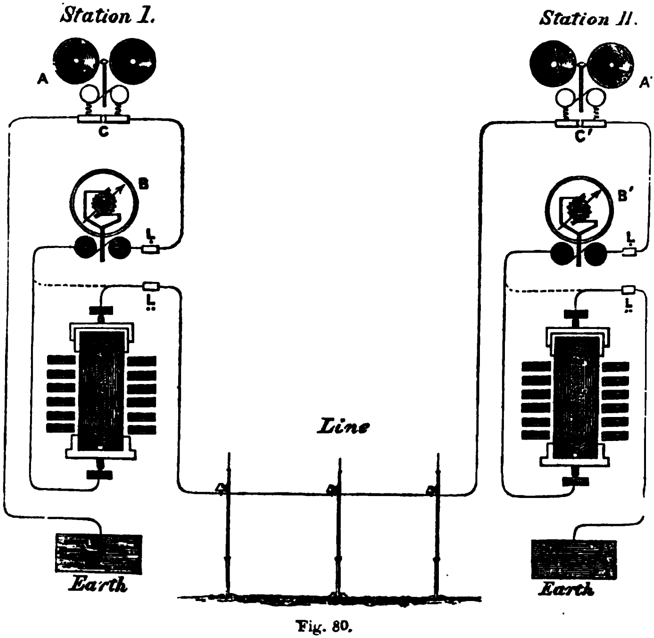


Fig. 80.

can be short-circuited at C, if required; the other side of the alarm is connected with one side of the coils of the indicator, B, by a wire; thence a connection leads to the coil of the transmitter or inductor T, and to earth.

On turning the handle of the transmitter, the currents pass through the indicator of the home apparatus, the pointer of which turns correspondingly with the handle, and thence to the line.

106. *Bréguet's Electro-Magnetic Dial Instrument.*—The principle of Bréguet's apparatus, which is used almost exclusively upon the French railway lines, and in rare instances on private lines in England, is that of alternately making and breaking at the transmitting station the circuit of a voltaic battery. At the receiving station is an electro-magnet, whose armature is correspondingly attracted and let go. The armature acts on a pallet, which interposes itself between the teeth of two scape-wheels turned by clock-work.

The apparatus consists of three parts:—

The transmitter,

The receiving instrument, and

The alarum.

The transmitter is shown in Fig. 81. It consists of a metal dial, supported by three pillars on a wooden base. The whole dial is divided into twenty-six equal sections, separated by two circles. In the inner circle are engraved twenty-five letters of the alphabet and a +, and in the outer circle the numbers from 1 to 25, and a +. Opposite each letter, on the periphery of the dial-plate, is an indentation for dropping the handle into. Underneath the dial-plate is a disc, G, with a serpentine groove on its under side, turning on the axis of the handle H, which moves above the dial. A small peg with a friction-wheel runs in the groove, and imparts a vibrating motion to the contact-lever. The further end of this lever is faced with platinum on each side, and makes contact alternately with the screws *p p'*,—with *p* when the handle is over the even numbers, and with *p'* when it covers the uneven.

The terminal C is connected with the positive pole of the battery. It is also connected by a wire, *v′*, to the contact-screw *p′*. The terminal R, on the left, is in permanent connection by a wire, *v*, with the contact *p*, and is intended for the wire leading to the receiving instrument. The terminal L of the left line-wire communicates with the contact-lever N. The point of N touches, at pleasure, either the contact S, to which the alarm is connected, or *r*, which is in

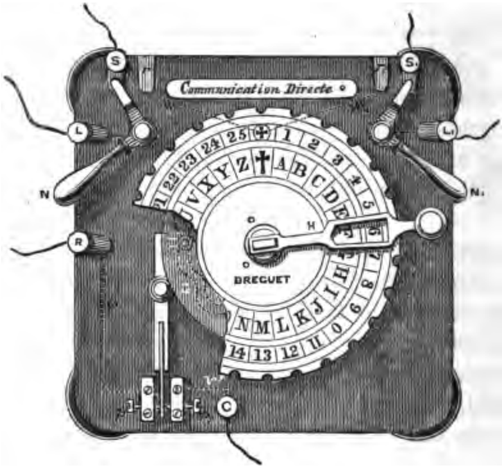


Fig. 81.

communication with the revolving disc, and through this and the friction-wheel and *l l′* with battery and earth, or lastly, it may touch the end of a metallic strip marked *communication directe.* On the other side of the dial is a similar lever, N′, connected with the terminal L′ of the line on the right. N′ may be placed on S′, the alarm, or on *r′*, which, like *r*, is connected with *l l′*, or lastly, it may be placed on the other end of the metal strip *communication directe.*"

Fig. 82 represents the interior of the receiving instrument seen from the back. M M is a horizontal electro-magnet, whose armature, suspended between screw points, carries on its upper side a metallic rod, *q*, which is limited in its play by adjusting screws in the frame *f*. At right angles to *q*, near the top, is a peg, *q'*, working in a fork, F, fixed to one end of the horizontal shaft *a*. At the other end a pallet, *g*, engages alternately with two parallel scape-wheels, impelled by a clockwork in the case above, and placed so that the thirteen teeth of the front and back wheels alternate when

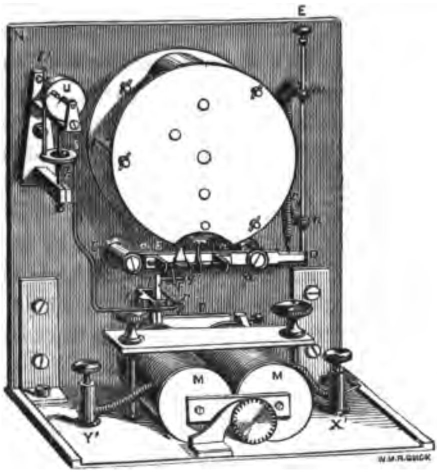


Fig. 82.

looked at from the front. When the apparatus is at rest and the armature held back by the spring, the pallet locks into the teeth of the back wheel; but on the attraction of the armature to the poles of the magnet, the pallet springs into the teeth of the front wheel, which, being half a tooth in arrear, allows the wheels and pointer to turn $\frac{1}{26}$th of the whole circle. As soon as the armature is released the pallet leaves the teeth of the front wheel, and re-enters between those of the other. The latter being half a tooth behind, the clockwork turns the wheels and pointer another $\frac{1}{26}$th. Thus every time the circuit is made or broken, the pointer advances one of the twenty-six divisions of the dial.

The spring for drawing the armature from the poles is adjusted by means of a bent lever, *t*, on the end of which it is hooked. The lever itself is fixed to the under side of a disc, *s*, turning on the vertical axis *h*. On the opposite side of the disc *s* is a long vertical pin, *t′*, which is gradually turned with the disc in a small angle by an inclined plane on the rim of the drum U.

The shaft *a*, with its pallet and fork, is supported by a frame or lever, C D, turning on the centre C on the left, and on the right held up by a spiral spring, which forces it against a pin passing through the guides M and N. On pressing upon the button, E, of the pin, the frame is moved downwards, and releases the escapement-wheels from the control of the pallet, but carries down with it a check which prevents their unlimited run. As soon as they are free to rotate, the wheels turn round with the pointer until their further progress is arrested by the check, which catches hold of a pin at the back of one of the scape-wheels, corresponding in position with the zero or + of the dial.

The alarm generally used with this instrument contains no new principle whatever. The attraction of an armature liberates a clockwork, which turns a disc with an eccentric crank. The latter in revolving moves the hammer of a bell to and fro. It is similar in construction to Wheatstone's first alarm.

Another alarm which Bréguet has supplied with some of his telegraphs is constructed on the principle of the self-acting make-and-break already described.

The connections of the apparatus for a station will be seen by reference to Fig. 83, which shows tho various pieces of the apparatus.

When neither of the stations is using the line the switches N and N′ of both the apparatus are placed on *s* and *s′*, so that a signal arriving from either side, L or L′, will be given notice of by the alarms A and A′. In this way the current from the left goes from L, past a lightning guard, *e*, through the galvanoscope, G, L, N, *s*, alarm A, earth, and back again.

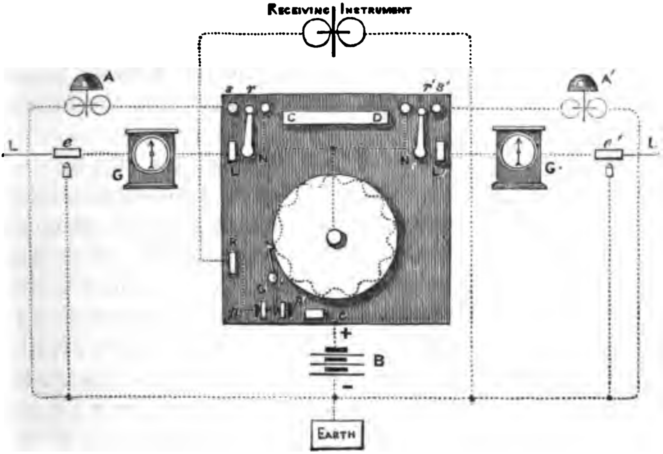


Fig. 83.

Arriving by L, a current passes the lightning guard *e*′, G′, L′, N′, *s*′, alarm A′, earth, and so on.

When a signal is given from L, the employé turns his switch N on *r*. The current passes then from L through the galvanoscope G, the needle of which it deflects, L, N, *r*, disc, contact-lever, *p*, R, receiving instrument, earth, &c.

Bréguet has also made use of an idea previously adopted in the construction of telegraphs in Germany. Instead of the movable armature and stationary electro-magnets, he sometimes employs a cylindrical electro-magnet made to turn on its longer axis on screw-points. The poles of the soft-iron core are furnished with soft-iron continuations, which hang down between the opposite poles of two permanent horseshoe magnets. When the current magnetises the soft-iron core and its continuations, the coil, with core and continuations, is deflected to one side or to the other, attracted by one of the permanent magnets, and repelled by the other

When the current is reversed, the polarity, and therefore the deflection, is also changed.

107. *Wheatstone's Universal Telegraph.*—This is another form of step-by-step telegraph. During the last few years it has obtained considerable employment on private lines, being found at nearly all the ends of the network which Professor Wheatstone has helped to spin over the metropolis.

This is the lightest and neatest of all the step-by-step telegraphs. The transmitter consists of two bobbins coiled upon an armature, and rotated continually over the two poles of a battery of permanent horse-shoe magnets. With the bobbins turns correspondingly a wheel with inclined teeth. When a letter is to be telegraphed a certain number of currents is sent into the line, which moves the indicator exactly as far as is required. This is done as follows:—The tooth-wheel is fixed upon a hollow axis, and above it, on a central axis, an arm with a spring, which falls into the teeth of the wheel, a contact-disc, and the pointer, which denotes upon the dial the last letters telegraphed. The letters are telegraphed by pressing down buttons on the circumference the transmitter. Each of these buttons depresses a lever inside, against which the rotating arm catches and is arrested, the spring being lifted out of the teeth of the rotating wheel. During the time, however, that the contact-disc is rotating, it makes and breaks contact continually in such a way that, at those points where the arm could meet a lever, the line circuit is interrupted. Therefore when the arm does meet a lever, which prevents the contact-disc rotating any further, the line remains interrupted. When another letter has to be telegraphed its corresponding button and lever are depressed. By this the lever of the first button is pushed back, and the spring on the arm allowed to fall into the teeth of the rotating wheel, by which the arm and contact-disc are carried round until the former comes into contact with the last lever. In this way just so many currents of equal strength are sent into the line as there are letters between the two buttons. The levers are all arranged in a circle vertically, and press a pitch-chain into a series of indentations on the periphery of a metal disc. The chain has slack enough to allow one lever to press it in; but, as soon as a second is depressed, not having slack enough for both, the first lever is pushed out again, and the arm released.

The receiver of this apparatus has two electro-magnetic bobbins, between which two little bent magnets oscillate and move a small ratchet-wheel between two fixed clicks, by which the wheel acquires a rotary motion. A pointer is fixed upon the same axis, and indicates upon a dial-card.

In the front of the indicator a contact-lever is moved between stops marked A and T. When the lever is placed on A the arriving currents ring the alarm, the telegraph being thrown out of circuit; when it is placed on T, the alarm is out of circuit and the indicator works.

The working of this instrument, as well as the neatness with which the whole is constructed, cannot be too highly spoken of. The great advantage which it possesses over the other step-by-step telegraphs, in which the coils or armatures are stopped and started at every letter, is that its currents are uniform, whereas in the other systems, at starting and stopping, the operator cannot avoid moving his handle slower than when driving it midway between two letters, which very frequently gives rise to "skipping" of the pointer.

108. *Kramer's Pointer Telegraph.**—The different telegraphs which have hitherto been mentioned are worked by sending currents of electricity from the transmitting station, either from a galvanic battery or from an induction apparatus. As soon as the signal is given, or the work done, the current is cut off, and the line becomes inactive. The reverse of this mode of operation was introduced by Kramer in his dial telegraph, and subsequently by Frischen, for working the

* "Der Elektro-magnetische Telegraph." Schellen, p. 19.

Morse instruments on the lines under his charge. In both these systems the current of a galvanic battery circulates continually in the line, and attracts, when at rest, the armature of an electro-magnet at the receiving station. On breaking the line at any point the armature falls off, and remains off until the battery circuit is closed again.

With the system of currents transmitted for each signal, it is obvious that a separate battery is required for each station. This is not the case when the system of closed circuit is used, because an interruption in any point must be followed by the same effect on the armatures of all the electro-magnets in the circuit.

Kramer's apparatus consists of a round dial, with thirty keys on the circumference, numbered from 0 to 29, inclusive. An inner circle is marked, in corresponding sections, with the letters of the alphabet irregularly placed; and a third circle, concentric with the others, contains a double row of numerals from 1 to 9, and some other figures and blanks.

The principle of this apparatus is shown in the diagram, Fig. 84. Two circular plates of metal are connected together by means of three pillars near their periphery; through their centres passes the axis, c, of the pointer, z z, seen on the dial. This axis carries a scape-wheel, *r*, and a tooth-wheel, R; it is turned by the tooth-wheel, H, engaging with its pinion 3. On the axis of the wheel, H, is a pinion locking into a tooth-wheel attached to the barrel, on which is wound a cord passing over a pulley and carrying the weight G.

The escapement *r* is formed by a horizontal wheel, on the rim of which are sixty vertical steel pins—thirty projecting downwards, and the same number upwards—arranged alternately at equal distances from each other. The prongs of a steel fork lock into the pins, and are just so far apart that when one prong touches the rim on one side, the next pin can pass under the other prong. The fork is supported by a bell-crank lever, *h*, turning on the axis W, between upright bearings. An armature, A, of soft-iron is supported by the lower arm of the lever, opposite the poles of an electro-

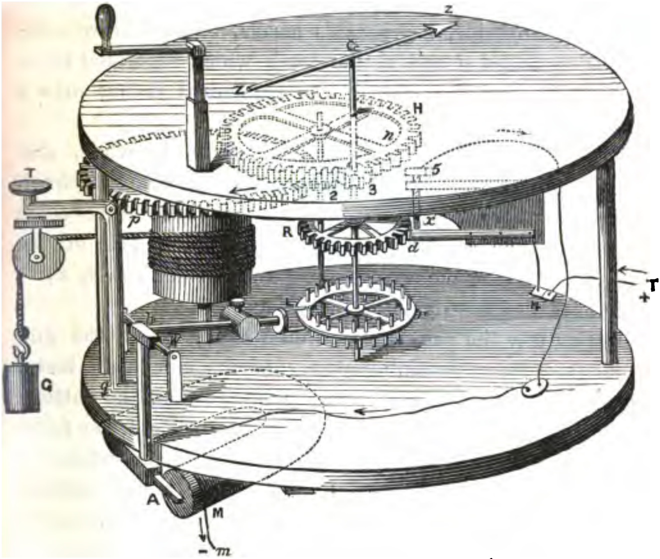


Fig. 84.

magnet, M, which regulates the movements of the fork and scape-wheel. The poles of the magnet are covered with thin pieces of German silver soldered to them, to prevent the armature making close contact with them. The figure shows the armature attracted to the poles, which is the position of rest of the apparatus.

The wheel commutator R, the tongue *d*, and contact-anvil *x*, are provided to regulate the interruptions of the currents. The wheel has on its circumference thirty teeth, which, in the course of one revolution, lift the hammer, therefore, thirty times from its contact with the anvil.

When the armature of the electro-magnet is attracted to the poles, a tooth of the wheel R lifts up the hammer from the anvil, and interrupts the circuit; the electro-magnet immediately becomes demagnetised, and the armature falling off again, depresses the fork of the escapement, and allows the scape-wheel to advance six degrees, together with the wheel commutator, R. By this means, contact is re-established between *d* and *x*, the tooth which separated them passing by, and the end of the hammer *d* falling into a space.

The electrical circuit is shown in the figure by wires, and in following the motions of the scape-wheel, contact-wheel, R, &c., it is necessary to imagine a battery inserted between T′ and *m*. The current then goes from the + pole of the battery, following the arrows along the circuit T′, *n*, *d*, *x*, 5, coils of M, to the — pole of the battery.

In this way the pointer keeps on running round the dial as long as the maintaining power of the clockwork lasts. The motion may be arrested either by breaking the battery circuit, in which case the armature falls off, and the fork-escapement rests on the upper surface of the scape-wheel, or by arresting the pointer itself. The latter is the method employed in telegraphing: the key over the dial, corresponding to any letter, on being pressed down, interposes a peg which bars the further progress of the pointer, and, in this respect, resembles the arrangement of Siemens and Halske's pointer telegraph.

When it is wished to advance or to put back the pointer on the dial at any station without the assistance of the current, this is done by pressing on the button of the lever T, *p*, *q*, which presses the armature against the electro-magnet, and lifts the fork.

109. An alarm used with this telegraph is rung by the release of a soft-iron armature from the poles of an electro-magnet. At an intermediate station, during the correspondence between two end or distant stations, when the continued interruptions of the circuit would cause the alarm to sound whilst the correspondence lasts, which would become

annoying to the employés, an arrangement is made for so weakening the currents in the coils of the electro-magnets by means of a shunt, that the alarm does not sound. This shunt is shown in Fig. 85, by a wire, *w w′*, and resistance

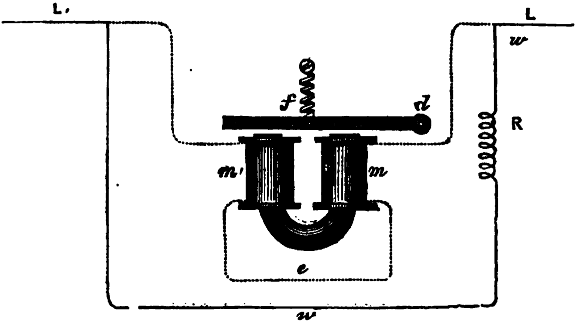


Fig. 85.

coil, R, which has about five times the resistance of the coil of the electro-magnet, allowing therefore only about five-sixths of the current to pass through the legitimate route.

This shunt circuit has another object. At the moment a current is sent through the coils of the electro-magnet *m m′*, the induced current tends to weaken the effect of the battery current. This would not be perceptible if the induced current were obliged to traverse the whole line. But in going round the shunt L, R, L′, with little resistance, it exercises its full opposing force on the magnet, and prevents the armature being attracted.

The plan, Fig. 86, shows an ingenious arrangement for providing against the errors frequently arising, in systems based on the principle of closed circuits, from bad insulation of the line. Should there be, as is sometimes the case, a battery at each of the end stations, and the line, in some points intermediate, in imperfect contact with the earth, it is evident that when either of the intermediate stations interrupts the circuit, the current at the stations near the ends will not be interrupted, but only weakened. Kramer, unable to realise a perfectly-insulated line, and having to provide against emergencies, makes his alarm work as well by a weakening as by a complete interruption of the current.

For this purpose he short-circuits one of the coils of his electro-magnets in the following manner. In front of the

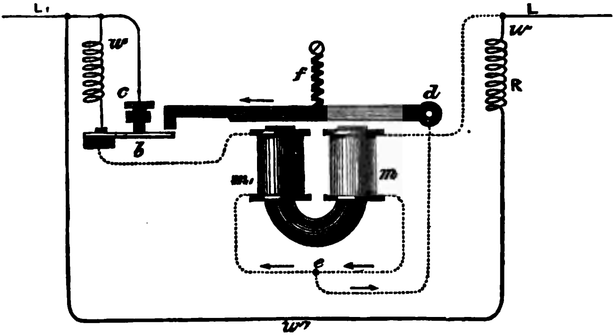


Fig. 86.

armature a contact-screw, c, is pressed upon by a metal spring, *b*, so that when the armature is attracted towards the poles of the electro-magnet at half-way, it comes in contact with *b*, and separates it from *c*. The axis on which the armature turns is connected by a wire with the middle, *e*, of the electro-magnet coils; the contact-screw *c* is in connection directly, by a wire, with the line L′; and between the back of the spring *b*, and the same line-wire L′, a resistance, *w*, equal to that of the half, *m′*, of the electro-magnet coils, is inserted.

A current, arriving by the line L (disregarding the shunt R), passes from L by *m*, *e*, *m′*, *b*, *c*, to L′. Very little goes through *w*, because its resistance is very great in proportion to the resistance of *c*. The armature is thereupon attracted, and as it descends, carries down the spring *b* with it, and interrupts the short circuit *c* L′, but makes, at the same time, contact between itself and the spring *b*, and in so doing shunts the current from the half, *m′*, of the electro-magnet coils, by the circuit *e, d, b, m′*. The short circuit to line *c* L′ being broken, the current must pass from *b* through *w*, whose resistance is equal to the resistance *m′*; thus the total resistance of the circuit remains unaltered. The armature is now held by only the one pole *m*, and the spring *f* is so adjusted that on the slightest decrease in the magnetism of *m*, it exerts force enough to pull back the armature.

The idea of attracting the armature a certain distance by two poles, and this done, of holding it there by one, is as novel as it is ingenious, and answers its purpose very well in this instance. The plan is, however, complicated, and the apparatus, of course, requires very nice adjustment.

110. *Principle of Self-acting Make-and-break.*—A considerable step in advance of then existing systems was made by Dr. Werner Siemens, of Berlin, by the invention of his first beautiful step-by-step motion telegraph.

The principle of this apparatus was that of the automatic transmission of currents, or what has been called the self-acting make-and-break.

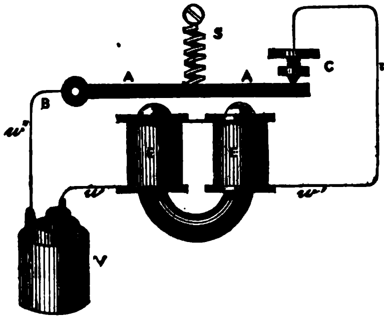


Fig. 87.

Suppose the soft-iron armature A A, Fig. 87, of the electro-magnet E, is supported on an axis, B, at one end, and by the spiral spring, S, in the middle, by which it is pressed gently upwards against the contact-screw, C, at the other end, and that an electric circuit is established, as is represented in the figure, in which the positive pole of the battery, V, is connected by a wire, *w*, with one end of the wire-coil of the electro-magnet E, the other end of the wire-coil being connected with the contact-screw C, by a wire, *w′*, whilst a third connection wire, *w″*, joins the axis of the armature A, with the negative pole of the battery. It is obvious that the current circulates in the coils of the electro-magnet, magnetises them, and causes the armature to be attracted to the poles, leaving the contact-screw C, and thereby interrupting the battery circuit. The instant this occurs, and the battery current ceases to circulate in the coils, the soft-iron cores of the electro-magnet lose their magnetism, and have no longer the power to retain the armature, which is consequently lifted up again by the spring S. On reaching its position of rest, it makes contact again with C, and re-establishes the battery circuit. This is followed by an immediate interruption; and the same play must necessarily be repeated, the armature being always re-attracted to the poles of the electro-magnet, breaking thereby the circuit, and being again let go, and making the circuit again, and so on *ad infinitum*.

The system of the self-acting make-and-break was invented by Herr Neef, of Frankfort-on-the-Maine.

The manner in which Dr. Siemens applied this method of interruption to the service of his telegraph system will be easily seen from the accompanying plan, Fig. 88.

If we were to take the apparatus just described and attach to the end of the armature, in any way, a continuation with an escapement, so that when the armature is moved up and down, the escapement, moved by it, works round a little scape-wheel, *e*, carrying a light pointer, *p*, around the circumference of a dial, D, it is evident that when the apparatus is connected by the wires as shown in the figure, the armature will always be moving up and down, and the pointer, therefore, always running round the dial.

If we now insert into the same circuit another electro-magnet, E′, with a similar armature, escapement, tooth-wheel, and dial, the electro-magnets being both magnetised by the same currents and demagnetised at the same time, the movements of the armatures will be synchronous; and if the pointers have been started from the same places on each dial, they will stop at the same points on the dials

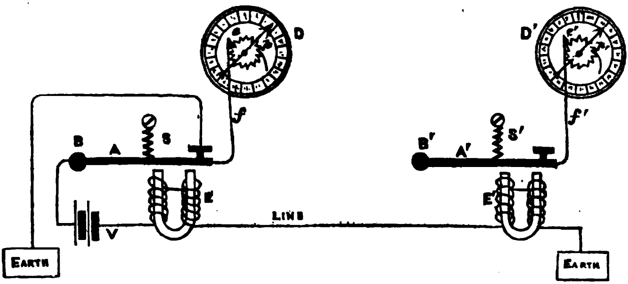


Fig. 88.

whenever the armature E is arrested in its upward or downward motion.

This apparatus is employed on some of the Prussian railway lines. It has, however, not found any extensive employment in England. Apart from its somewhat complicated mechanism and costliness, it is a most ingeniously-constructed telegraph system.

All these telegraphs are based upon the step-by-step pointer system, invented by Professor Wheatstone in 1840, which has been modified and improved in various ways to suit the various services in which it has been applied. These modifications and improvements have taken gradually a national character. Thus in France, in the hands of Bréguet, Froment, and Digney, the step-by-step apparatus has been endowed with a form highly perfect, but totally different in type from those of Stöhrer, Siemens, and Kramer in Germany. And these, again, have taken a form totally distinct from that which Wheatstone has given his later apparatus.

In France the railway instruments are, almost without exception, worked with galvanic currents. In Germany and England, on the contrary, magneto-electric currents are almost invariably employed with the step-by-step apparatus.

Both these systems have individual advantages and disadvantages which render it impossible to acknowledge one in the end superior to the other. The system with galvanic currents is convenient, as it enables the operator, by augmenting or diminishing his battery power, to accommodate his apparatus to the length and conditions of his line; it is inconvenient, as it necessitates a continued attention to the battery. The systems with magneto-electric currents are convenient, as, being without batteries, they are ready at a moment's notice for work, and require no attention. They have the disadvantage, however, that their force cannot be augmented to suit an increased length or decreased insulation of the line, and that the magnets gradually lose their power, and therefore require renewing.

(*e*) *Type-Printing Telegraphs.*

111. Printing telegraphs are probably of American origin. One of the first apparatus which Morse brought to perfection was of this nature. After him came Vail and Wheatstone. In this, as in some other branches of telegraphy, however, Morse seems to have given only the first idea, and to have left it to the energy of others to convert it into a reality. The inventions which have followed since of type-printing telegraphs are more numerous than those of any other kind. The reason is that this is one of the prettiest problems in telegraphy, and at the same time not the most difficult. Of these inventions the greater number have long since fallen into disuse: the remainder are either those which possess merit sufficient to recommend them as practical instruments, or those which are new and have not yet had time to become failures.

There are two classes of type-printing telegraphs:—

1. Those whose wheels are worked by means of clockwork;
2. Those without clockwork.

The majority of type-printing telegraphs belong to the first class; those whose receivers are constructed with mechanical driving-power. The apparatus at each end is similar, and the movements of the clockworks, with type-wheels and contacts, are regulated either by means of synchronously-oscillating pendulums or by means of the currents themselves, which control the movements of escapements. Mr. Hughes's type-printing telegraph is of the class in which the clockwork is regulated by a pendulum. This apparatus, the best of all the type-printing telegraphs, differs from others in the printing being done whilst the type-wheel is in motion, by which means an immense saving of time is effected, and a correspondingly increased amount of work got through. The bold idea of constructing a telegraph apparatus sufficiently strong, and at the same time sufficiently sensible to respond to single currents, to print letters whilst in full rotation, and not lose its synchronism in doing so, occurred to Mr. David Hughes, an American, eighteen years ago. Since then he has but slightly modified his original construction: the principle has remained the same, and only the mechanical details, in the hands of Froment and Digney, have taken more comely forms.

112. *Hughes's Roman-type printing Telegraph.*—The essential principles of this highly ingenious system are the synchronous movements of type-wheels at two or more stations, and the power to press a strip of paper at each of the stations simultaneously against the types on the corresponding parts of the wheels, by the action of a single electric wave or impulse.

A clockwork at each station turns, with a continuous and uniform motion, an axle, at the extremity of which the type-wheel is supported. The synchronism is attained by the aid of a vibrating spring and anchor escapement. The rotation of the type-wheel is transmitted to a vertical arbor, furnished at its lower extremity with a horizontal arm travelling over a circular disc, in which is arranged a series of contact-pins, in number corresponding with the types. Each pin therefore represents a letter, and is raised when it is wished to telegraph this letter along the line. The horizontal arm, which travels round the disc with a motion uniform with that of the type-wheel, comes in contact with the pin just at the moment when the corresponding type is at the lowest point and closes an electric circuit, by which the paper is lifted up against the type-wheel, and the letter printed.

The key-board used to elevate the contact-pins is shown

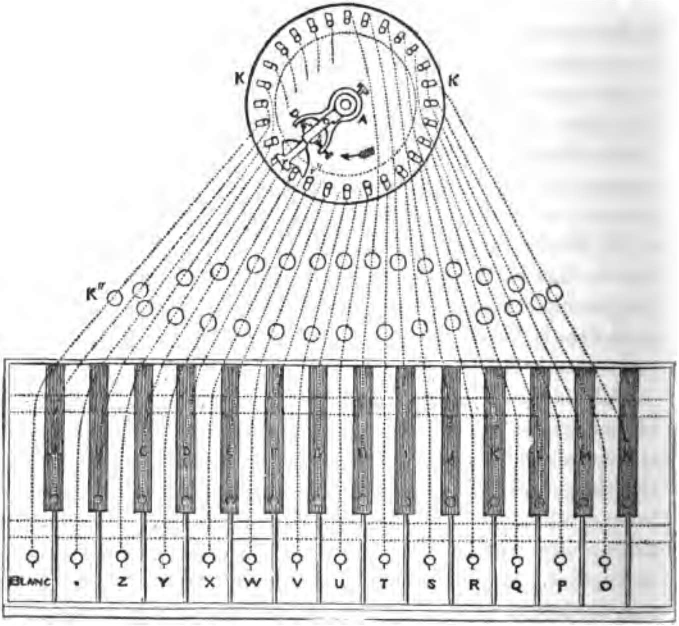


Fig. 89.

in Fig. 89. It consists of twenty-eight keys, alternately white and black, marked with the twenty-six letters of the alphabet, a full stop, and a blank, corresponding to an empty space in the type-wheel. Below each of the keys is a movable lever, whose fulcrum is at K″, and which terminates at the bottom of one of the contact-pins, K K, arranged in a circle in the metal box A, in the top and bottom of which are holes for the ends to protrude—the upper holes being long, to allow of a radial motion. Each pin is held down by the pressure of a small spring, but may be elevated by pressing down the corresponding key of the piano-board.

Fig. 90 gives a vertical section of the printing instrument and key-board. The section shows a white key, hinged at K″, connected to its lever K′, a contact-pin, *k*, on the right, and also to a black key, whose lever reaches to a contact-pin on the left of the box A. The contact-pins are provided with shoulders to limit their movements in each direction.

The horizontal arm, which travels over the circle of contact-points, is attached to the bottom of the vertical arbor Q, to which motion is imparted by the bevelled wheel G_2, on the shaft G. It is made up of three principal parts—the arm *r*, jointed at *a*; the resting piece, or earth contact, *r′*; and the shovel *r″*. The vertical shaft Q is of brass, and is divided electrically into two parts by an insulating ring of ivory, *q*. The lower part is supported by the central pedestal, which is insulated from the box, A, by a non-conducting ring.

The continuation of the jointed arm *r*, which is held by the portion of the shaft above the insulating ring *q*, is pressed down by a spring, which keeps a small screw in the middle of the continuation in metallic contact with the second piece *r′*, supported by the portion of the shaft below the ring. The shovel, *r″*, is of steel.

When a key is depressed, the corresponding contact-pin is elevated, and if the arbor Q is in motion, the extremity of the arm *r* mounts upon the elevated pin, by which contact between *r* and *r′* is interrupted, and that of *r* with *k* established. The arm *r* having made contact, the shovel *r″*, which immediately follows it, pushes the pin *k* in its slot outside the circumference swept over by *r*; so that if the

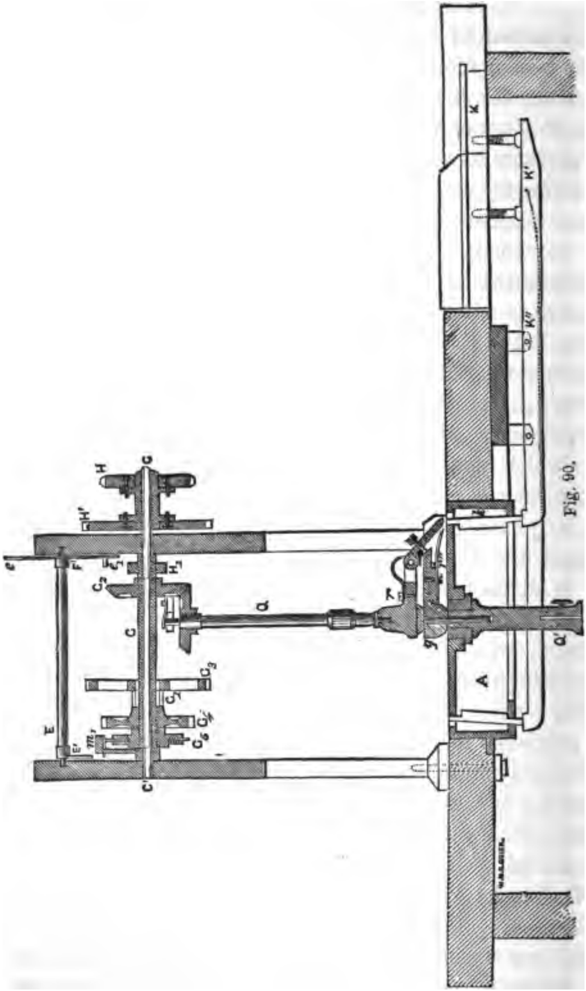


Fig. 90.

latter make another revolution whilst the finger is kept down upon the key, no second contact is made, and the same letter is not repeated. The operator feels a vibration of the key as the shovel passes by the pin, and is thus made aware that the letter has been printed.

The type-wheel H contains on its circumference, in twenty-eight equal spaces, twenty-six letters of the alphabet, a dot, and a blank space; it is fixed to the extremity of the axis C C′, which is put in motion by means of the hollow axis, G, enveloping it in the greater part of its length. The connection between C C′ and G is made by the mediation of a fine ratchet-wheel, G_5, attached to the axis G, the click, m_1, being on the axis C C′. On the latter are supported, besides the type-wheel and click, a corrector, H′, or wheel with long narrow teeth, equal in number to the types, serving to establish precision between the movements of the horizontal arm, *r*, and the type-wheel. On the same axis is a wheel, H_1, having a notch at one part of its circumference for stopping the type-wheel when the blank space is opposite the printing-press in case it should spring forward.

The hollow axis G is turned by a clockwork moved by a weight, a wheel of which engages with the pinion G_1, and supports, besides the ratchet, G_5, and bevilled wheel, G_2, already mentioned, the escape-wheel, G_4, and a tooth wheel, G_3, which locks into the pinion, I_1, of the printing shaft I, which is shown in section in Fig. 91, and in the plan, Fig. 92.

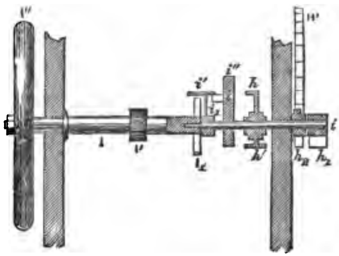


Fig. 91.

The printing shaft turns seven times as fast as the type-wheel, and carries a fly-wheel, I″, at one extremity, in order to overcome the inertia of a small shaft, whose duty is to lift the paper up to the type-wheel at the other extremity. The printing shaft I, and its continuation *i*, are locked together by means of a ratchet-wheel, I_1, and click, *i*′. At the end of the continuation shaft, *i*, is a cam, h_1, for lifting the press and the paper against the type-wheel.

The printing-press is shown in Fig. 93. Underneath the type-wheel is a small cylinder, *a*, over which the paper is

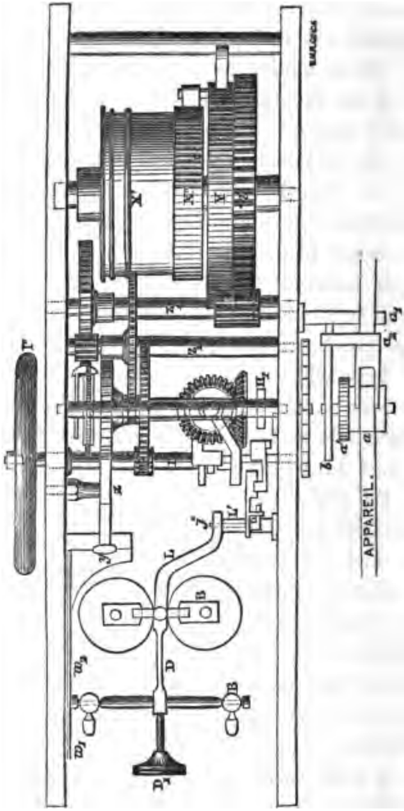


Fig. 92.

led, its axis being in the middle of a bent lever, *b*, turning at a_1; attached to it is a ratchet-wheel, in the teeth of which catches a click affixed to a movable piece, b_1, terminating in the rectangular arm b_2, which is forced upwards by a spring attached to the frame of the apparatus, but is stopped against the axis *i*. When *i* makes one revolution, the cam lifts the arm, *b*, of the lever, together with the cylinder, *a*, and paper strip, up to the lowest tooth of the type-wheel, by which the paper strip is impressed with the print of the type, kept inked by an inking roller, M. The cam being very sharp, the movements of ascent and descent are proportionally rapid, and the paper touches the type during only an infinitely short space of time. The axis continuing to turn, the cam meets the arm *b*, and depresses it, causing the click to draw round the cylinder and advance the paper a certain distance.

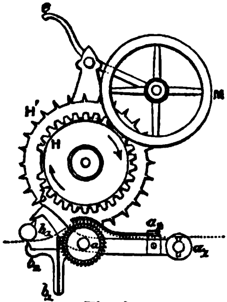


Fig. 93.

By the side of the ratchet-wheel I′ the printing shaft carries an escapement, *h h′*, arrested by a continuation of the lever L L′, moving with the armature of the electro-magnet. The armature is of soft-iron, supported at the extremity of a lever, D, over the poles of the electro-magnet (Fig. 94). The lever turns between supports on the axis, and tends to rise by the force of a spring regulated by the adjusting screw D_1.

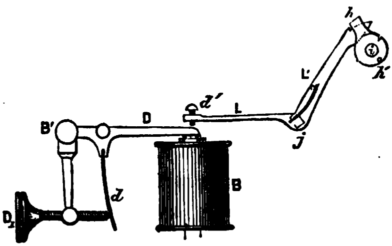


Fig. 94.

The screw *d′* on the end of the lever L L′, turning on the axis *j*, sits over the armature; the other end of the lever engages with one of the pallets of the escapement *h h′*, and governs the motion of the axis *i*. When a current traverses the coils of the electro-magnet, the armature and lever are depressed, the click is put in gear, and the pallet *h* of the escapement, released, turns with the axis *i*. At the moment when the pallet *h′* passes under the lever, it relifts it, and depresses the screw *d′*, returning thereby the armature to the poles of the electro-magnet, and, at the same time, throwing the click out of gear.

The magnet, B, is of novel construction. It consists of a permanent horse-shoe magnet, with soft-iron cylindrical continuations on the poles. These continuations are each encircled by a coil of wire. When no current passes through the coils, the armature is attracted to the poles by the magnetism distributed in the iron. This force is opposed by the adjusting spring, which is so regulated that, the armature being in contact, a very weak current is able to neutralise the attraction.

The printing shaft has also the duty of correcting the movements of the type-wheel, and of insuring always that, at the moment of printing a letter, the type is in its proper position. This is effected by means of a curved cam, h_2, on the axis *i* (Figs. 91 and 93). The instant the cam, *h′*, lifts the arm, *b*, of the frame carrying the printing roller, the projection h_2 locks into the teeth of the wheel H′, and adjusts, if it be necessary, its position. If, on entering the teeth of H′, the cam has to push the wheel forwards, or to accelerate the motion of the axis C C′, the click *m* is pushed onwards, passing over one or more of the teeth of the ratchet-wheel G_5 (Fig. 90). If, on the contrary, the cam has to retard the motion, the click pulls the ratchet-wheel backwards, for which purpose the latter is not made rigid on the axis, but is formed of a disc held between leather washers supported by two plates of metal, fixed on the hollow shaft G.

The electric circuits of the apparatus are very simple. The bottom of the vertical shaft, Q, is connected to earth, and the upper part to one end of the coils of the electro-magnet, the other end being to line. One pole of a battery is connected to the levers, *k*, of the contact-pins, the other pole to earth. At two corresponding stations the plates of the batteries must always be looking the same way, because the home apparatus is intended always to work as well as that of the distant stations, and the armature of its magnet is only liberated by currents in one direction.

When a current arrives, therefore, from the line, it passes first through the coils, B, of the magnet, then through the vertical shaft Q, which it descends, and goes over from the screw in the jointed arm, *v*, to the resting piece *r′*, and from this to earth. When a current is to be transmitted, the operation consists principally in interrupting the earth circuit, and in inserting the battery into the break. This is done by the contact-pins and jointed arm of *r*. A key being depressed, the arm *r* in its journey rides over the pin, and its screw is lifted up from contact with *r′*, which breaks the direct earth circuit. At the same time the contact of *r′* with the pin *k*, which is in communication with a pole of the battery through the lever K, sends a current from the battery (K *k*, *r* Q), through the coils of the magnet into the line, &c.

Suppose two such apparatus properly adjusted at the extremities of a line of telegraph, the clockwork wound up, the electrical connections properly established, and the type-wheels locked. The employé who desires to transmit presses down the blank key of his instrument; this pushes up the corresponding contact-peg in the circle, and when the chariot arrives over the pin, the extremity of the piece *r* rides over it, separating the earth contact, and introducing the battery into the line circuit. The current passes through the vertical shaft, the coils of the magnet, and line-wire to the other station, where it circulates in the coils of the magnet, the vertical shaft, &c., and goes to earth.

In traversing the coils of the magnets of both instruments, the current weakens the attractions of the armatures to the poles of the electro-magnets; the former are forced off by the spring, the screws, *d′*, are raised, and the levers, L, at the same time depressed. The pallets, *h*, of the escapements, *h h*, are thereupon released, the axes, *i*, put into gear with I, and the type-wheels released. During the revolution made by the axes *i*, the cylinders, *a*, are raised by the cams, and lift the paper up to the printing-wheels at the moment when the latter are unlocked. No letter is printed, because the blank space in the type-wheel occurs just there. The paper strips and cylinders descend again, the former advancing a step. The clicks are then disengaged from the ratchets, and the pallets, *h*, recaught by the levers L′, which were lifted up, causing the armatures to be pushed down again to the poles of the magnets.

If a key answering to any letter be now pressed down, the current is repeated the moment the chariot passes over the raised contact-pin; the printing axis is put in motion, the letter printed, and the paper pushed on as before, and so on, until the message is completed.

It sometimes happens that the apparatus do not agree when one of the stations sends its message. In this case, the employé at the receiving station advises his correspondent of it by giving him a signal; both then arrest their type-wheels, and the transmission is recommenced, beginning always with the blank.

To avoid the inconvenience of irregular working which might arise from changes in the battery power, Mr. Hughes has adopted a method of short-circuiting the coils of the electro-magnet the instant after the armature is released, so that the current, whatever may be its intensity, comes into play only long enough to effect the required weakening of the magnetic attraction. This is done by connecting one end of the electro-magnet coils with D, and the other end with L, in addition to the other connections, and by adjusting the screw, *d′*, so that when at rest the armature, reposing on the poles, does not touch it; but as soon as the neutralisation occurs, it is lifted up by the force of the spring, and the coils short-circuited by contact of D with *d'*.

The speed of transmission attained with this apparatus is very great. The chariot and type-wheel revolve about 120 times in a minute, and an expert manipulator can transmit on the average two letters during a single revolution of the shaft.

The word "telegraph," for example, is completed in six turns, as follows:—

1st turn	blank and *t*.
2nd ,, ...	*e* and *l*.
3rd ,, ...	*e*.
4th ,, ...	*g* and *r*.
5th ,, ...	*a* and *p*.
6th ,, ...	*h*.

The French word *bonté* is done in four turns:—

1st turn	blank.
2nd ,, ...	*b* and *o*.
3rd ,, ...	*n* and *t*.
4th ,, ...	*é*.

Another example is the word "dintz," more fortunate than either, being transmitted during a single revolution.

This invention was brought by Professor Hughes from America, before the submersion of the old Atlantic cable, on which he made his first experiments on the speed attainable in working his apparatus on submarine lines. Since then important improvements have been made in the construction and mechanical execution of the apparatus in the *atelier* of M. Froment, of Paris. The principles have, however, undergone no change.

The system has been adopted by the United Kingdom Telegraph Company, under an arrangement giving the company the exclusive right to use the apparatus themselves, and grant its use to others in this country. On the company's line between Birmingham and London, on which messages and press matter are constantly passing to and fro with the aid of this apparatus, the average speed, as stated by the company, is forty messages per hour, and is believed to be capable of considerable augmentation when the employés have had more practice. The company intend introducing this system on all their lines, and have reasonable hopes of its ultimate success. In France the system is gaining daily a wider employment; in Russia, Italy, and Germany the Administrations of Telegraphs have likewise adopted it.

The following is a fac-simile of the printing:—

BY HUGHES' TELEGRAPH INSTRUMENT.

118. *House's Printing Telegraph.*—This telegraph, the work of Mr. House, of New York, was the subject of an application for patent in 1845. It belongs to the class of step-by-step motion telegraphs, and consists of two separate parts—the transmitter or commutator, and the receiver or printing instrument.

The transmitter is composed of a contact-wheel in every way resembling that used by Wheatstone in one of the modifications of his dial instrument, which, in turning, sends a series of currents from a battery at the transmitting station. As each make-and-break of the circuit indicates a letter, whenever a letter is to be transmitted the contact-wheel is arrested at a certain point, by which either the current is allowed to flow, or is interrupted during the continuance of the indication, according as a contact-spring happens to rest upon a tooth of the wheel or opposite a space at the moment of stopping.

For the purpose of stopping the contact-wheel at its proper place for each of the letters, House employs a key-board like a piano, with twenty-eight keys, representing twenty-six letters of the alphabet, a dash, and a dot.

The contact-wheel is of brass, four or five inches in diameter; its circumference is divided into twenty-eight equal spaces, alternately indented to the depth of a quarter of an inch, so as to expose on the surface fourteen shallow teeth. A spring of metal, insulated from the contact-wheel and shaft, is placed before the former of these, so that, when it revolves, the top of the spring comes in contact with each of the teeth in succession, but has not the power to penetrate into the spaces and make contact there.

The plan adopted by Wheatstone to hold his current on, or to interrupt it, during the reading of a signal, was to stop his commutator opposite an index or pointer at the letter to be indicated. House does this otherwise, with the aid of his piano keys: he puts two rows, each of fourteen pegs, on the outside of a cylinder, each peg turning with the cylinder underneath one of the keys of the piano. The latter are held up by springs, and furnished with hooks or cams which, when depressed, catch hold of the pegs of the revolving cylinder and arrest its motion.

The pegs of successive letters follow each other round the circle in a spiral at distances of $\frac{1}{28}$th of the circumference, and therefore, when the cylinder is turned from one letter to another, just so many contacts and interruptions are given as will bring the pointer or wheel of the receiving apparatus round the same distance.

The receiving apparatus is rather complicated; it is started by an electro-magnet of very novel construction.

Above the movable armature, on a common shaft, is a hollow cylindrical slide-valve, in connection with a chamber of compressed air, filled by means of a pump, and supplied with a safety-valve to permit the escape of superfluous air when the pressure becomes greater than is required for working the apparatus.

The piston, moved by the compressed air let into the cylinder by the slide-valve, moves horizontally, and is in connection with the lever of an anchor escapement engaging with the teeth of the scape-wheel of the printing machine.

The scape-wheel has fourteen teeth, and requires, therefore, twenty-eight movements of the lever to complete a revolution. A steel type-wheel revolves with the same shaft as the scape-wheel, its circumference being furnished with twenty-eight equidistant projections, on which are engraved the letters of the alphabet, a dot, and a dash. The shaft also carries a little drum with letters painted on it in the same order as those on the type-wheel, by which the operator may read off the message when the type-wheel is not printing.

On the upper surface of the type-wheel, at the extreme edge, are twenty-eight teeth, against which plays a small steel arm, attached to a metal cap, turned by friction on a shaft revolving in the reverse direction. When the type-wheel is in motion, this arm plays over the teeth; but as soon as the wheel is stopped, falls in between them, which it has not time to do during the revolution. By falling in the teeth of the type-wheel, the arm allows the cap to revolve with its shaft, and, by means of two pins, to release a detent, which, in its turn, permits an eccentric to revolve. A connecting-rod from the eccentric pulls the paper strip to the type-wheel, and prints the letter.

An ingenious arrangement is also made for the progression of the paper, by means of a ratchet-wheel and clicks attached to a notched drum over which the paper passes.

The line from Philadelphia to New York was the first on which this instrument was used. It found adoption on some of the American lines after the year 1849, and is still to be found at work. It is said to be much less liable to get out of order than would be judged, at first sight, from the complication of the receiving apparatus.

114. *The Type-printing Telegraph of M. Desgoffe* approaches in principle nearest of any to the ideal of a type-printing

instrument in which the type-wheel is arrested during the printing, because the clockwork is not stopped, and only two currents are required for each letter. This is the only apparatus in which the type-wheel is automatically adjusted between each letter. It consists of synchronously-rotating type-wheels, the printing-press being set in motion by a current sent from the transmitting station at the instant when any type which it is desired to print is underneath. The synchronism is obtained by an ingenious arrangement for sending a periodical current. On the axis of the type-wheel is an arm rotating with it, and making contact against a stop, which is released when the current passes through the coils of an electro-magnet, but prevents the further rotation when no current passes. The rotating arms, stops, and electro-magnets of both apparatus are in the same circuit, so that the two type-wheels can only be released and commence a rotation at the moment when both arms are in contact with the stops. Should one arrive sooner than the other, it is held fast until the arm at the other station makes contact. Then both are released by the same current, and start together. The contacts for printing various letters are elevated on a disc of metal which revolves with the type-wheel. They are arranged correspondingly with the rotation of the types, but at different distances from the centre, and in different sections of the circle. The transmitting contact is made with a spring moved in a line across the centre of the disc by a handle pointing to an engraved alphabet, half of which is on each side of the vertical line, passing through the centre of the contact-disc. As the disc rotates, one of its elevated contacts meets the spring point and closes the circuit of the battery, sending the current through the relays, which are not moved by the synchronous currents, and with the aid of local batteries lifting the printing-press. The type-wheel is stopped during the printing; but the clockwork, contact-arm, and disc continue to rotate. This is done by attaching the type-wheel to the axis—not rigidly, but by means of a spiral spring under tension. During the short interval required for printing a letter, this spring is simply wound up a little way, and, when the current (printing) ceases, the type-wheel flies round to its stop upon the axis, ready to commence another synchronous revolution. This movement is new, and has the advantage that no time is lost during the printing.

115. *A. Joly, Paris*, exhibited in the Paris Exhibition a Roman-type printing telegraph, worked by interruptions of a galvanic current on the principle of that which Jacob Brett used in 1850 on the Dover-Calais cable. The mechanical details are ingenious; but, in point of speed, it is far inferior to the Hughes. The transmitter consists of a Bréguet's dial-plate, with a simple commutator for reversing the poles of the battery any moment it is required to do so. The receiver is supplied with two clockworks for turning the type-wheel and for working the printing-press. The type-wheel is turned by an escapement released by means of an electro-magnet, whose coils are in the same circuit, whenever the armature is attracted to or let go from the poles. The same axis carries, also, a wheel with spike teeth, which strike against the end of a thin steel spring, and make and break a contact in the circuit of a local battery, and the electro-magnet whose armature releases the printing-press; the length of the steel spring is made such that its velocity of vibration is less than the velocity with which the spokes of the wheel strike against it. It is thus prevented returning to its position of rest during the time the type-wheel is being turned round. When the latter, however, stops, the spring resumes its normal position, and closes the circuit of the local battery. On the type-wheel are two rows of type—one with letters of the alphabet, the other with numerals, signs of punctuation, &c. The paper strip underneath the type-wheel passes in a guide-fork over a cushion of india-rubber, which causes it to be slightly elevated in the middle just where it strikes the type. The position of this cushion, underneath one or other of the

rows of types, is determined by the keeper of an electro-magnet whose coils are in a second circuit of the local battery, and of a contact-tongue formed by a permanent magnet suspended between the poles of the electro-magnet used to release the escapement of the type-wheel. The position of this tongue depends, therefore, upon the nature of the currents sent from the transmitting station. If positive currents, it lies upon that side which leaves the second local circuit open, and the cushion underneath the row of letters. When the telegraphist wishes to print numerals, &c., he simply reverses his battery during the time this is to last. In doing so, he throws the permanent magnet-tongue at the receiving station over to the other side, closing the second local circuit, and drawing the cushion under the second row of types. This will be better understood by reference to Fig. 95.

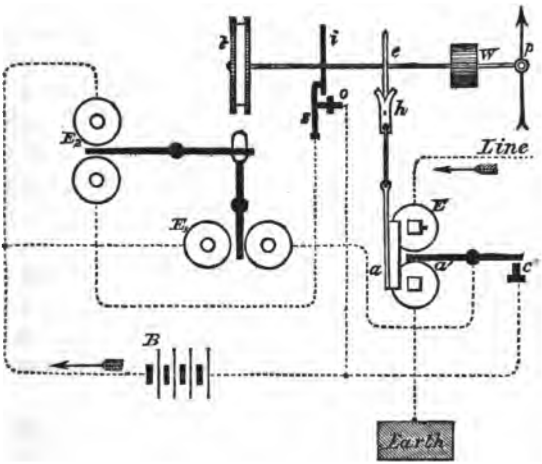


Fig. 95.

The axis of the type-wheel carries—1, the disc, *t*, with double row of types; 2, the wheel of radial spikes for striking the contact-spring, *s*, from the contact-point, *o*; 3, the scape-wheel, *e*, caught by the pallet, *h*; 4, the pinion, *w*, gearing into the next wheel of the train; 5, the pointer, *p*, indicating upon a dial-plate the position of the type-wheel. A series of positive currents arriving from the line passes through the coils of the electro-magnets, E, causing the armature, *a*, to oscillate and allow the escapement to turn round step by step. In turning the spokes of *i* strike against the spring, *s*, which moves too slowly to return to the contact, *o*, until the revolution of the wheel ceases. As soon as this is the case, the first local circuit is closed, and the current of the battery, B, passes through E_2, *s*, and *o*, releasing the printing-press. If a series of negative currents arrive, the armature, *a*, is moved as before; but the first current also causes the permanent magnet-tongue, *a′*, to go to the other side and close the contact, *c*, by which the second local circuit, B, E_1, *c*, is completed, and the armature of E_1 attracted, draws the cushion of the printing-press underneath the second row of types.

The method adopted by M. Joly for drawing the paper strip along after each letter is that of a Geneva stop without the convex tooth. The printing-press is lifted by a lever attached to a connecting-rod whose upper end is coupled to a crank, making a revolution each time a letter is to be printed. A stop-finger on the axis of this crank turns the stop-wheel on the axis of the roller, which pulls the paper forward.

The principal disadvantage of this system is the great expenditure of current, too much work being thrown upon the battery. Could this be remedied, this telegraph would be well adapted for use on private lines where a record is required to be kept.

116. The Spanish Telegraph Direction, Madrid, has employed a type-printing telegraph on the system of M. Ramon Morènes, of Madrid, Sub-inspector of Telegraphs. The transmitter used with this instrument is identical with that of Bréguet's French railway telegraph, having a metal disc underneath the dial-plate, provided with a sinuous groove, in which a small roller carried by a lever runs and communicates an

oscillating motion to a spring, thus making and breaking the circuit of a single battery. The receiver resembles that of M. Joly, just described. It is provided with two separate clockworks, one for turning the type-wheel, the other for lifting the printing-press. The mechanism for turning the type-wheel contains nothing novel. The latter is carried outside the case of the clockwork on an axis having a tooth-wheel, which gears into a pinion of one-fourth its diameter upon the axis of the scape-wheel. A double pallet, oscillating between the teeth of the latter, is fixed upon an axis at right angles to that of the type-wheel, and is regulated in its movements by the armature of an electro-magnet in the line circuit. The printing-press is set in motion by a local battery in a circuit including a releasing electro-magnet and a vibrating contact. The latter, which is ingenious, is shown in Fig. 96.

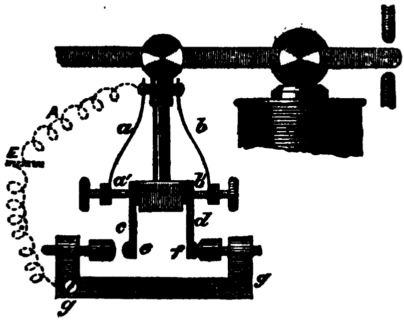


Fig. 96.

On an ivory arm at right angles to the beam are two thin springs, *a* and *b*, whose heads, *a'* and *b'*, press lightly against the tops of the two arms, *c* and *d*, one of the extremities, *e f*, of the latter pressing always against screw-points in a common metal piece, *g g*. The local circuit is made by way of *b*, *c'*, and *d'*, or by *a*, *c*, and *d*, according as the armature is attracted to the poles or not. Whilst currents are arriving the armature vibrates continually, and the *vis viva* of the screw-heads, a' b', is sufficient to carry either of them off the upper contacts at the same moment that *c* or *d* meets the lower contact. In this way, until the armature rests on either side sufficiently long to enable the screws to fall back upon the contacts, the local circuit is interrupted and the printing-press cannot act. An arrangement is provided for lifting the pallets out of gear of the scape-wheel in order to bring the type-wheel back to zero in case it should skip.

117. Guyot d'Arlincourt, Paris, has introduced a step-by-step printing telegraph, based upon a principle slightly differing from the foregoing. The type-wheel is turned round by a clockwork regulated by an escapement in connection with the armature of an electro-magnet, whose coils are in the line circuit. The armature of the electro-magnet operates also as a relay in the circuit of a local battery and of an electro-magnet which releases the printing-press. When a quick succession of currents arrives, the armature of the printing electro-magnet, which is sluggish, is not attracted, but as soon as the current becomes continuous, the printing-press is released, and is lifted by an eccentric of triangular form. The paper strip is drawn forward between two rollers by means of a ratchet-wheel on the axis of one of them, which is caught by a click moved by the armature of the printing-magnet.

118. The second class of type-printing telegraphs, the type and original of which is the self-interrupting instrument of Messrs. Siemens and Halske, in which the receiving portion is set in motion without the employment of clockwork, is represented by that of Messrs. Levin and Co., of Berlin. In this telegraph reverse currents of a galvanic battery are used. The currents put in motion the armature of a polarised electro-magnet, which oscillates a small ratchet on the axis of the type-wheel and pointer between two spring pallets, the same as in Professor Wheatstone's receiver. The type-wheel differs from those of other type-printers in being formed, not of a rigid disc, but of thin steel springs radiating from the centre,

each of which carries a type. When the armature of the printing electro-magnet is moved, it depresses only one of the springs upon the paper strip, and as they are very light, the work to be done is little. A second line-wire is necessary for working the printing-press. The transmitting handle, which turns over the dial-plate, is provided with a button, to be pressed down when it is wished to print a letter. The workmanship of this apparatus is excellent, but the whole arrangement displays a want of electrical experience.

(*f*) *Electro-Chemical and Copying Telegraphs.*

119. *Bain's Chemical Telegraph.*—Mr. Alexander Bain has been, since the year 1845, the author of several improvements and inventions in telegraphy. The most important of these is his electro-chemical telegraph, patented in England in 1846.

The sending apparatus is a simple Morse contact-key. The receiving apparatus consists of a circular disc of chemically-prepared paper stretched upon a similar disc of metal kept in rotation by clockwork. On the upper surface of the paper rests the point of a style, which, while the disc revolves, is drawn towards the periphery so as to travel over the paper in a spiral curve. When the circuit is closed, the salt with which the paper is prepared becomes decomposed under the style.

On a base board are erected the clockwork, or driving portion of the instrument, and the recording disc which it turns round. The clockwork is regulated by the fly, and is connected with the recording disc by the shaft, to which it imparts motion by the friction of a small roller pressing upon its under surface.

When no current is moving in the line, the style rubs on the surface of the paper without producing any mark; but as soon as a current in the right direction is established, the salt solution with which the paper is saturated becomes decomposed, and leaves a blue mark upon the surface.

When the circuit of the current is made and broken repeatedly, a series of dots or dashes is imprinted upon the receiving disc, the lengths and succession of which depend upon the manipulation of the key or contact-maker.

To render these dots and dashes intelligible, Bain has adopted an alphabetic code like that of Morse.

The paper is rendered sensitive by being saturated in a mixture of prussiate of potash dissolved in water, to which are added two parts of nitric acid and two of ammonia.

An interesting rather than practical modification of this apparatus consists in substituting a revolving disc with style travelling in a spiral curve, exactly similar in form to that just described at the sending station, for the key; only, instead of being covered with prepared paper, it is left naked, and letters or words written upon its surface, within the limits of the journey of the style, in some insulating material; so that, when the style passes over the insulating writing, the current is interrupted.

When both the discs are made to revolve synchronously, which is very difficult, it is evident that the paper at the receiving station will be marked with a dark spiral curve broken in just those places where the letter, written down on the transmitting dial, interrupts the passage of the current, and a fac-simile of the writing will be obtained.

The same idea has been carried out, in a more convenient form, by the employment of short cylinders instead of the discs, on the sides of each of which are printers or styles running to and fro upon long screws as the cylinders are turned round.

But the apparatus by which Bain has earned most credit is that with which Leverrier and Lardner experimented before the committees of the Institute and Legislative Assembly at Paris. A band of paper, punched with groups of holes forming letters, conventional like those of the Morse alphabet, is passed between a metal roller and contact-point in such a way that the point falls through the holes and comes in contact with the top of the cylinder, thereby closing the line.

The messages are received upon a strip of chemically-prepared paper passed between a style and metal cylinder.

Lardner thus describes his results: *—

"Two wires, extending from the room in which we operated to Lille, were united at the latter place so as to form one continuous wire, extending to Lille and back, making a total distance of 336 miles. This, however, not being deemed sufficient for the purpose, several coils of wire wrapped with silk were obtained, measuring in their total length 746 miles, and were joined to the extremity of the wire returning from Lille; thus making one continuous wire measuring 1,082 miles. A message, consisting of 282 words, was then transmitted from one end of the wire. A pen attached to the other end immediately began to write the message on a sheet of paper moved under it by a simple mechanism, and the entire message was written in full in the presence of the committee, each word being spelled completely and without abridgment, in *fifty-two seconds*, being at the average rate of *five words and four-tenths per second*. By this instrument, therefore, it is practicable to transmit intelligence to a distance of upwards of 1,000 miles at the rate of 19,500 words per hour."

The alarm used with Bain's telegraph consisted of two round plates of glass of different sizes, struck by a hammer which vibrates between them. The glass discs were supported from their centres by two horizontal arms of an upright. The hammer consisted of a vertical tongue of brass turning on a horizontal axis, and carrying, half-way up, a cross-bar of soft-iron, which served as armature for the poles of an electro-magnet.

120. Pouget-Maisonneuves, a native of France, writing in

* "Museum of Science and Art," vol. iii. p. 117.

the *Comptes Rendus* in 1856, describes a method of electro-chemical telegraph with which he proposed to supersede the Morse recorder. Instead of the style at the end of the printing-beam moved by the electro-magnet, Pouget takes a simple fixed style, and records the messages by chemical decomposition instead of by embossing, thus dispensing with the printing magnet and beam; he, however, retains the relay and other arrangements of the Morse system.

His paper is prepared by being soaked in a mixture of—

150 parts crystallised nitrate of ammonia;
5 ,, ferro-cyan. potassium; and
10 ,, water.

Before being used, the paper is moistened with dilute sulphuric acid sufficiently strong to make it conduct, but not to attack, the metal of the style. This paper is said to be cheap and easily prepared; the salts are readily decomposed, and the traces permanent.

121. Gintl,* a German, in his method, dispenses with the relay, and records the messages on the prepared paper by the line current direct, in the same way as Bain.

This paper is prepared with a solution of—

1 part iodide of potassium, and
20 parts starch paste, in
40 ,, water.

The results of this process are very satisfactory, and recommend the apparatus as more convenient, in some respects, for long lines than Morse's. An experiment on a line between Amsterdam and Berlin, made in 1853, with six Daniell's elements, gave very legible signals; and even with four elements the marks, although weak, were readable when no reliable signals could be read with a Morse.

The noiseless operation of the electro-chemical telegraphs may have assisted in keeping this method of recording out of more general use. It is always indispensably necessary

* Brix's "Journal," vol. i. p. 4.

to combine an alarm with the system, to call the attention of the manipulator; not so necessary with the Morse, which is in working always accompanied by the rattle of the beam and armature. Another drawback from which the chemical telegraphs suffer is in the want of an arrangement of translation which shall not, at the same time, weaken the current. Otherwise the electro-chemical telegraphs are more convenient in manipulating, and much more simple and inexpensive as far as the apparatus goes, than the Morse.

Copying telegraphs have never reached a considerable status as an employable system. The reason of this is partly because they work too slowly to be adopted with profit in the transmission of ordinary messages, partly because occasions requiring the production of fac-similes present themselves very rarely. Copying telegraphs are of two kinds: 1, the chemical; and 2, the mechanical. The majority belong to the first kind, the mechanical copying telegraphs having only of late years been brought to comparative perfection at the hands of M. Lenoir, the ingenious inventor of the gas-engine.

122. *Bakewell's Chemical Copying Telegraph.*—This is, properly speaking, only a better mechanical construction of Bain's electro-chemical telegraph.

A clockwork is supported between the plates M M′ (Fig. 97), which puts the cylinder, C, in motion simultaneously with the screw, S, of the same length as the cylinder, and carrying a nut, *q*, with style and connection, *r*.

When the cylinder is turned by the clockwork, therefore, the style travels up or down the cylinder according to the direction of rotation of the latter, thereby marking a spiral line whose convolutions are close together.

Bakewell used an electro-magnetic governor to attain synchronism in the movements of the two apparatus, without which it would certainly have been impossible to have obtained any dependable results. Subsequent inventors have introduced innumerable alterations and modifications in this system, without having, however, materially improved upon it.

123. *Caselli's Chemical Copying Telegraph.*—The Abbé Caselli has constructed a chemical copying telegraph, in

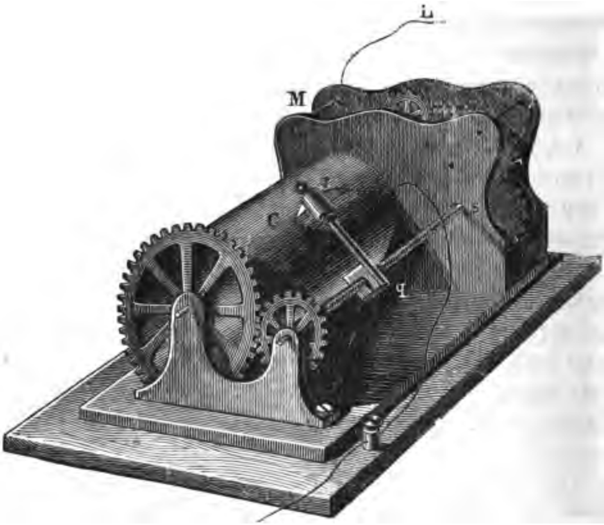


Fig. 97.

which he has attained a synchronous movement in a somewhat surer way than by the methods adopted by either Bain or Bakewell.

His apparatus consists of a long and heavy pendulum, sustained in synchronous oscillation by the electro-magnet, and rocking by means of a coupling-bar two metallic styles over the cylindrical stages.

This instrument consists of three principal parts—the motor, the copying style, and the time regulator.

The pendulum rod is suspended from the top of an iron frame; the bob of the pendulum is constructed of iron and lead, the latter being employed for giving the necessary steadiness to the oscillations, and the former as armature for two fixed electro-magnets, one on each side at the foot of the frame.

The coils of these electro-magnets are connected with a local battery, and with a contact worked by the pendulum of a clock in the station, whose duty is not only to sustain the oscillations of the telegraph pendulums, but also to retain them, if need be, an instant, in order to re-establish their synchronism.

This motor is connected with the copying style by means of a rod between the pendulum rod and the end of a lever turning upon a pin in the axis of two cylindrical segments, or stages, and carrying upon its upper end the cross-beam. The latter carries on each side a fine screw, on which a nut rides, which carries the copying style. When the pendulum oscillates, therefore, an oscillating movement is imparted to the cross-beam, screw, and style, which cross and recross the surface of the cylindrical segments, or stages, following the movement of the pendulum rod. In order to avoid the styles passing twice over the same line, the screws by which they are carried end in ratchet-wheels, which, after every oscillation, are pushed round a tooth further, and thus draw the styles a given distance along in the direction of the cylinder. The styles consist of fine iron wires carried by guides in the electrical circuit. The styles are each only allowed to fall upon the cylindrical stages during oscillation in one direction, and as each apparatus carries two styles, one of them is down during the backward, and the other during the forward stroke. It is usual to receive on one side and to transmit on the other, by which a message may be received and one transmitted at the same time. On the side upon which the transmission is effected a leaf of metallic paper is fixed, upon which the despatch or design to be sent is written in insulating ink. When, therefore, the iron style passes and repasses over the surface, the current is interrupted during the time that a line of insulating ink is between the metallic surface and style. The reception, upon the other side, is done by means of a damp sheet of paper, impregnated with a solution of ferrocyanide of potassium. Under the influence of the galvanic current, this salt is decomposed, and forms, in contact with the iron style, a blue deposit, known as "Prussian blue." Thus, when the pendulum at the receiving station corresponds in its oscillations with that at the sending station, and both styles make the down stroke together, that of the reception marks the paper with a series of blue lines corresponding with the continuations of the line current given from the transmitter.

This telegraph was invented in 1856, but was not brought into a practical form until eight years afterwards. Froment, of Paris, succeeded in overcoming the mechanical difficulties which had until then opposed its progress. In 1865 two of these instruments were set up at work between Paris and Lyons, on which line they are still employed. The despatches sent by them are, however, of limited number, and are dearer, because they occupy more time, than those sent by the other method. In its operations, the Caselli telegraph, like all the copying telegraphs, is slow. Each line through which the style runs is 111$^{\text{mm.}}$ long, and occupies one second of time; and as the lines are 0·25$^{\text{mm.}}$ apart, therefore four seconds are necessary for every millimètre breadth of despatch. On a sheet of paper 111$^{\text{mm.}}$ by 27$^{\text{mm.}}$ about twenty-five words can be written, which therefore occupy 108 sec., or 1 min. 48 sec., in transmission—a speed which is exceeded only by the common Morse apparatus. Even if the back stroke of the pendulum be, at the same time, used for a return message, the speed is still very far below that of the Hughes instrument.

124. *Cros' Chemical Copying Telegraph.*—M. Charles Cros, of Paris, has invented a chemical copying telegraph, which differs in construction from that of Bakewell in the style travelling round the cylinder, instead of the latter turning underneath the style, and in the adjustment of the synchro-

nism six times during every revolution. The apparatus consists of a clockwork driven by a heavy weight, and giving a horizontal motion to the cylinder, and a rotary motion to an axis carrying the style. By the side of the cylinder, and parallel with it, is a long screw which is turned on one of the axes of the clockwork. On this screw travels a nut fixed by a metallic arm to the end of the cylinder, the latter being supported upon a horizontal bar fixed to the side of the apparatus, that when the screw turns the cylinder is moved slowly sideways. The style is fixed to the end of an elbow-piece, and travels round the cylinder always in the same plane; but as the cylinder, when the apparatus is in motion, is moved sideways by the horizontal motion imparted by the screw to the nut, the style describes upon its surface a long line in the form of a close helix. The styles of the two apparatus do not move regularly, but are arrested and released six times in every revolution, for the purpose of regulating the synchronism. This is done by means of a circular disc attached to the style-axis, the periphery of which is indented with six equidistant notches. Above this disc is a tooth in conjunction with the armature of an electro-magnet. When the tooth falls into a notch, an electric circuit is closed. In both corresponding apparatus these contacts and electro-magnets are in a common galvanic circuit, by which the armatures of both are attracted, when both circuits are closed at the same moment, and the stop-teeth lifted out of both at the same time, allowing the styles to commence together a new sixth of a revolution. When one apparatus goes faster than the other, its style is arrested until the slower one has come up with it, and finally closed the circuit, which releases them together.

This adjustment of synchronism is the same in principle as that employed by M. Desgoffe in his type-printing instrument, and promises to become of value in apparatus requiring approximate synchronism. The relay used with the receiver of this apparatus is of the common construction in so far as regards the electro-magnet. The armature, however, is formed by a tongue of soft-iron, oscillating between, and held perpendicular by the attraction of, the poles of a permanent magnet, placed a little distance from it. It may therefore be used either with direct or with reverse currents, in the same way as a polarised relay.

125. *Bonelli's Chemical Telegraph.*—The Chevalier Bonelli has succeeded in the construction of a chemical telegraph, by which messages are transmitted automatically, and facsimiles received at the station corresponding.

Bakewell seems to have considered the employment of one style as preferable to that of many; but he, nevertheless, mentions in his patent the possibility of using several. In the notice of his patent published in the *Mechanic's Magazine* * he says:—"Instead of one style for each cylinder, any convenient number may be employed, each isolated from the others, and fitted with separate wires having their ends inlaid in an ivory disc, so as to be isolated from each other."

The apparatus of Bonelli consists of a long stage or railroad on a table, on which travels a waggon containing, on the left side of the lower half, a box of raised metal types, and on the right side of the upper half a strip of chemically-prepared paper. Over the middle of the railway is a bridge (Figs. 98 and 99), under which the waggon has to pass when transmitting or receiving a message. A A′ are two buffers for receiving the waggon at the ends of its journeys. Just in front of the buffer A′, and level with the rail, is a hook, D, which engages with an eye at the upper end of the waggon, and holds it until a current traverses the line, and releases it by means of an electro-magnet.

On the left-hand side of the bridge, over the raised types, is a type-comb consisting of five movable teeth, insulated from each other, which are connected to the ends of five

* Vol. i. p. 544.

wires going to a similar number of styles at the receiving apparatus. As the waggon, with the types looking upwards, passes underneath the type-comb, the teeth come lightly into contact with the raised portions of the types, and close the circuits whilst the contact lasts. Thus letter after letter is transmitted. The right side of the bridge, which spans the middle of the rails, is appropriated to the reception of

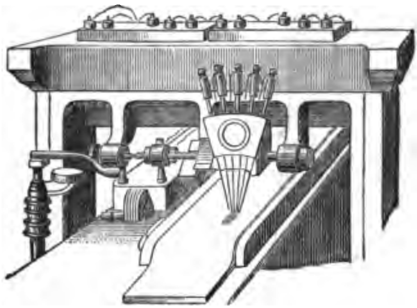


Fig. 98.

messages. It consists of a writing-comb composed of five teeth, made of platinum-iridium alloy, which is not liable to corrosion, insulated from each other, and pressing lightly upon the paper strip. This comb would produce, if each tooth were traversed at the same time by an electric current, five lines something like the lines on music-paper. As, however, they are each only traversed by a current during the time some portion of a type is underneath the corresponding tooth of the type-comb at the sending station, they can only give lines at such intervals and of such length as are determined by the form of the type.

If the teeth of the type and writing-combs be equally far apart at each of the stations, and the waggons travel over the rails at the same speed, it is evident that a dotted, or rather lined, fac-simile of the types on the transmitting waggon will be received on the paper carried by the waggon at the receiving station.

Fig. 89.

Any deviation from synchronism is, however, of very small importance, as the difference in one way or the other will only make the letters printed either a little narrower or broader than those of the fount from which the types have been taken, and in this consists the great advantage of the Bonelli arrangement over those of Bain and Bakewell.

An ordinary galvanoscope, for indicating the currents, and a mercury trough, in which to plunge five amalgamated contacts for short-circuiting the batteries when the type-box has passed through, are shown in Fig. 99. The short-circuiting is done by a catch on the waggon itself, which, passing by, turns the shaft carrying the five contacts.

The waggon when at rest is held at the top of the railway by the catch, which, being in communication with the electro-magnet, is released by the first current which passes through the line. This circuit is closed by means of the key, K. Thus the waggons of both stations are made to start together. They are impelled by similar weights, and their speed regulated by means of fans, which enable the operators to adjust the two instruments to practical synchronism.

The waggons occupy from ten to twelve seconds in passing under the bridge. In this time, therefore, the message, set up in the type-box, is transmitted, and another received on the upper half on the prepared paper.

In the instrument shown in Fig. 99, the type-box passes first under the bridge; when the waggon has got half-way, it short-circuits the batteries, and leaves the line clear for the reception of a message on the paper on the further half.

About twenty words are on the average set up in each type-box. Thus a speed of transmission and reception of twenty words in six seconds, or of 200 words per minute, is easily attained, not counting the time lost in changing the type-boxes and removing the paper.

The paper intended for receiving permanent printing by the Bonelli instrument for distribution to the public is prepared by being saturated in a solution of nitrate of manganese, which yields, under the action of the current, a light brown-coloured precipitate. That which is termed "fugitive printing," as for press work, by which the impressions are not necessarily of a permanent character, is done with paper prepared with a solution of iodide of potassium, which gives letters at first an iodine character, but which in course of time lose their intensity.

The speed said by the operators to be attainable in permanent work is 300 words per minute, and the fugitive printing is stated to be got over at the almost incredible rate of 1,200 words in the same time.

The following fac-simile of Bonelli printing is cut from a strip printed at the 1864 *conversazione* at the Institution of Civil Engineers :—

BY THE BONELLI INSTRUMENT.

126. *Lenoir's Mechanical Copying Telegraph.*—The second class of copying telegraphs is that in which the copy is attained by a mechanical instead of a chemical process. This class is represented by the so-called electrograph of M. E. Lenoir, the ingenious inventor of the gas-motor. The electrograph consists intrinsically of a rotating cylinder at each of the stations, moving synchronously. The cylinder at the sending station is covered with a sheet of metallic paper, on the surface of which is written, in insulating ink, the despatch which is to be sent. The surface of the roller at the receiving station is covered with a thin coat of printers' ink, and over this is stretched a sheet of tracing-paper. Over this cylinder is an electro-magnet, whose armature, when no current is passing, falls off, and allows a fine point, or style, to press upon the surface of the tracing-paper with sufficient force to cause the inner surface under the point to take up enough of the printers' ink to leave a legible mark, when the tracing-paper is afterwards laid upon a plane surface and submitted to pressure.

The apparatus consists of two essential parts—the clockwork, with synchronous movement, and the copying rollers.

The clockwork is driven by a weight, and turns the copying roller and also a vertical shaft, the velocity of the latter being about twelve times that of the former. In one of the apparatus this vertical shaft carries a commutator, which closes and breaks an electric circuit six times in each revolution. The vertical shaft of the other apparatus carries a soft-iron star, formed of six armatures, which turn over the two poles of an electro-magnet corresponding with the contacts given at the other station. This is the way in which the synchronism is arrived at.

Fig. 100 gives a theoretical plan of this apparatus arranged

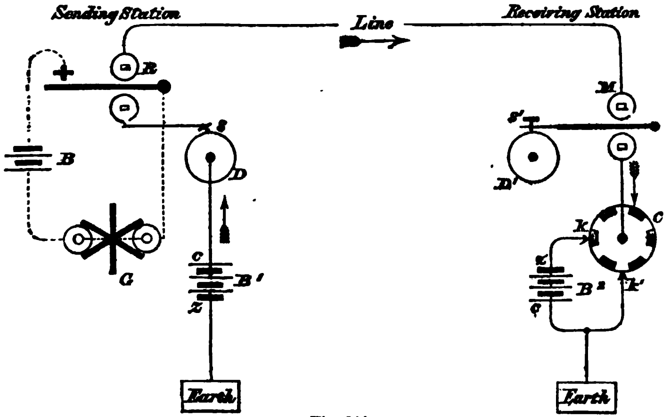


Fig. 100.

for two stations. The rollers, D, at the sending, and D′ at the receiving station, are turned by the clockworks, and connected by means of intervening wheels with the synchronous shafts, G and C, respectively. The current of the sending battery B′, when the style, S, rests upon a metallic surface of the roller D, traverses the coils of a relay, R, then the line the coils of the electro-magnet, M, whose armature holds the style, S′, up from the surface of the tracing-paper which is stretched upon the roller D′, and, lastly, the commutator C, to earth, either by the contact k, and auxiliary battery B^2, or by the contact k', and direct to earth, according to the position of the rotating commutator in regard to these two contact-points. As C rotates very quickly, it is evident that a series of auxiliary currents from B^2 will enter the line and pass through the relay R. During the rotation of C, therefore, the line current is not of constant strength, but formed of quick transitions between two given strengths. Each of these strengths is sufficient to hold the armature of M to the poles; but only the stronger waves, or those produced by the insertion of the auxiliary battery, are competent to move the armature of the relay R. The relay therefore responds faithfully to the movements of C, and closes the circuit of a local battery, B, with the coils of the electro-magnet, which acts upon the regulator armature G. In this way every time C sends an augmented current into the line, R closes its circuit and magnetises G, by which, as both C and G rotate very rapidly, the contacts and spokes can never differ apparently in their velocity.

When the style S meets a mark done in insulating ink, the line circuit is broken, the relay ceases to vibrate, and the armature of M falls off, allowing the style S′ to press the tracing-paper upon the blackened surface of the roller D′. As soon as the insulating mark is passed, the relay resumes its functions, and the synchronism is re-established.

When the style has traversed the whole length of the cylinder, and the copy is completed, the tracing-paper is recovered from the cylinder, and the inked surface pressed upon a sheet of writing-paper, by which means the copy is transferred in a fit condition to be sent to the receiver, whilst, at the same time, the original tracing is kept.

In speed of working this telegraph is superior to that of M. l'Abbé Caselli, but, like it, it is burdened with all the inconveniences of copying telegraphs. It has been tried upon the French lines with moderate success; but the demand for copying telegraphs is at present, and is likely to remain, too moderate to allow much room for their adoption.

VI. Overhead Lines.

127. The overhead line-wire, stretched between two stations, is suspended by insulating hooks from posts in the ground.

The first line of this nature which was put to any useful purpose was the double line-wire of Gauss and Weber, erected principally for researches into the laws of the galvanic current, between the Physical Cabinet and the Observatory at Göttingen, a length of 3,000 yards, suspended between the towers of the city and on cross-pieces on poles sunk in the ground. The insulation of the wire from the poles was effected by means of felt wrapped round the cross-pieces on which the wires were twisted. The insulation of this line was, of course, very imperfect. It was destroyed in 1844 by a stroke of lightning.

The English telegraph engineers were the first who succeeded in overcoming the chief difficulties which were found to obstruct the progress of overhead lines—difficulties which the continental telegraphists had partly avoided by the employment of an incomplete system of subterranean lines.

128. *The posts* generally pressed into the service of the telegraph abroad are young firs (*Pinus sylvestris*). They are selected from 25 to 30 feet long, and at the top seldom less than 5 inches diameter. The bark is stripped off, and the posts smoothed, chamfered off, and either impregnated or the lower ends charred up to about 8 feet from the bottom. Every tenth post is, or should be, a stretching-post, stronger than the others.

The wooden posts mostly in use here are of English larch; but foreign timber, although dearer, is preferable on account of its greater durability.

Impregnation with a solution of sulphate of copper is the invention of a Frenchman, Dr. Boucherie. His process seems to possess important advantages over others, accomplishing as it does, at the same time, two essential objects—that of expelling the sap, and that of filling the pores of the wood with the preservative solution.

In his experiments on the impregnation of timber, Dr. Boucherie has made the important discovery that no connection exists laterally between the tubes of a tree, and that by applying, under moderate pressure, a coloured solution to certain tubes at one end of a tree, the same tubes at the other end, and only these, are coloured. In this way, at one end of a felled tree, he applied a coloured solution to certain tubes forming the name "Faraday." The name was transmitted to the other end, and was perfect at every intermediate section.

When the tree is cut down and trimmed, a solution of sulphate of copper is forced into it from one end to the other by a moderate pressure. The sap and fermenting matter are thus expelled, and their place taken up by the solution. The small cost of the apparatus, ease of manipulating it, and the increased durability which it imparts to the wood treated by it, highly recommend the process. It is necessary, however, to take care that no ungalvanised iron comes in contact with wood so impregnated, otherwise the copper of the preservative solution will be reduced.

Chloride of zinc is also used in Germany with some success. The posts are put into wrought-iron cylinders of 4½ to 6 feet diameter, and 34 to 60 feet long, closed at one end, and covered at the other with tightly-fitting tops. The cylinders are provided with manometers, safety-valves, &c., and connected with air and pressure pumps, and a reservoir of zinc solution. The wood is prepared by being subjected to a great pressure of steam, which, penetrating into the interior, not only tends to displace the sap from the pores and prepare them for the preservative solution, but also to coagulate the albumen which is in the sap, and in this way to retard the subsequent rotting. After this the cylinders are exhausted, and immediately filled with a solution of one part of chloride of zinc and thirty parts of water, which is kept on, under a pressure of eight to ten atmospheres, for about three hours.

But it is questionable if this method is so good as that of Boucherie, as it is necessary to force the solution into the wood at right angles to its tubes, thereby injuring its strength, and letting the sap, which is the immediate cause of decay, remain; the coagulation of the albumen in the sap, to any material depth below the surface, being a matter of doubt.

Chloride of manganese, as well as a solution of oxide of zinc in wood vinegar, have been tried, and not without success. The former has the advantage of cheapness, being produced in great quantities in the manufacture of chloride of lime, and, being an incidental product, has a very small commercial value.

The method adopted by Sir Charles Bright is to have the poles well charred from the lower ends to a foot above the depth to which they are destined to be fixed into the ground, and the charred parts soaked in gas-tar for about twelve hours, the poles standing in tanks of tar in a timber framing.

The sap ingredients being the prime movers in the rotting of dead wood, the idea has occurred to put up insulators on the stems of living trees—a method which has been found to answer well in Switzerland, America, and in some parts of Germany, where trees are to be found at convenient distances. The only drawback to this system is the violence with which trees are sometimes moved in heavy storms. To obviate this difficulty, Lieut.-Col. Chauvin has constructed a swinging insulator, which will be described afterwards.

Wooden posts invariably decay first at the ground level—"the wind and water line"—where the surface is moist and in contact with the air. A method of retarding the decay by sheathing the post at this part has been tried in India with comparative success, the lower end, to a certain height above the ground, being covered by an iron casing. In

Bengal such a line was erected, the posts being of large bamboo canes, and the protection of the lower parts cast-iron sockets.

129. This brings us very near to a suggestion which has been much advocated—that of dispensing with wood, and constructing the posts entirely of iron, whose durability is so superior. The greater cost of such posts is the only objection to them.

Pillars of stone, or masons' work, would undoubtedly not only last longer, but would be less liable to accidents by violence of the weather. Such supports have repeatedly been constructed, but their cost has always been a bar to their further employment. In India, in the early days of telegraphy, many such pillars were erected; and in 1852 a line from Treviso to Tagliamento was entirely supported by obelisks 4½ mètres high, as shown in Fig. 101. In Switzerland they have begun in good earnest the use of iron posts, the line from Olten to Sissach, lately erected, being supported entirely by iron posts. In Prussia also the necessity has been fully comprehended of discarding wood and taking to some more durable material. M. Borggreve has employed, on the line between Gera and Weissenfels, a pillar constructed of a wrought-iron tube, 1½ inch diameter, fixed with lead into a socket on the top of a freestone pillar, 6 feet high and 8 inches square.

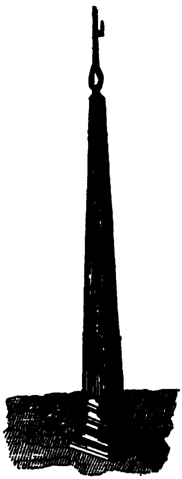


Fig. 101.

130. The iron post of M. W. Siemens is coming very generally into use abroad, and will no doubt find employment in England also, when the necessity of a durable post becomes thoroughly appreciated.

This post is formed of two tubes, one set upon the other, and the bottom of the lower one made fast to a bent plate of iron buried in the ground. One of them is shown in Fig. 102. The base consists of one of Mr. Robert Mallet's patent buckled wrought-iron plates, 1 foot 9 inches square, bent in a dish form. The buckled plate, *a a*, is secured by four bolts to the socket, *b b*—a cast-iron cylindrical tube 7 feet long and 4 inches outside diameter. Near the top, inside, the socket is furnished with a flange, upon which the bottom of the upper or main post, as it is called, rests. This upper post, *c c*, is of wrought-iron with welded joints; it stands 12 feet high out of the socket, and is somewhat conical. At its upper end an iron ring is welded in to carry an iron rod, *d*, 20 inches long, forming the lightning-guard. The stretching-posts are of the same height, but of larger diameter and stronger than the ordinary ones.

Fig. 102.

M. Siemens' post derives much of its merit from the *rôle* played by the buckled plate at the bottom. These buckled plates are things of great engineering utility. They are squares of sheet-iron, which Mr. Mallet by a simple process presses into a form very slightly different, but endows them with a strength immensely superior; so strong indeed are they, that if one of these posts were pulled up bodily out of the ground, it would bring up the superincumbent ground with it, and the buckled plate would not be deranged unless the bolts gave way; while the same piece of iron, as a simple sheet, would bend under a much less weight, offering no resistance worth speaking of against the strain.

131. The French Telegraph Administration has had some iron posts put up by way of experiment. This post is constructed by Messrs. Menans and Co., of Paris. It consists of a cast-iron socket standing 8 mètres out of the ground, in the upper part of which is wedged and cemented the end of a length of 2·5 mètres of rolled + section iron, tapering from 0·07 to 0·05 mètre in width, and is 0·01 mètre thick in the ribs. These posts, notwithstanding their very slight appearance, are found to be capable of resisting a considerable strain. The same weight of material could, however, be more profitably employed in the form of a tube.

There can be little doubt that, in course of time, only metal posts will be employed, on account of their superior durability, solidity, and freedom from damage by accidents. In some climates wooden posts require to be renewed every two or three years, and, in the most favourable, rarely last over six years; while an iron telegraph post is as durable as a lamp-post, and would certainly last ten times as long, and not cost five times as much, as a wooden one; so that in the end an immense saving would be effected by their employment, although the first cost is so much greater.

132. *Line Insulators.*—There are two different ways of supporting overhead telegraph lines. The one, as in use in Prussia, and generally in England, consists in securing the line-wire rigidly to the insulators on each of the posts, so that each insulator has the same vertical and horizontal strains to withstand. The other method—that adopted in France and Belgium—consists in attaching the wire rigidly to the insulators of two distant posts, and supporting it only by hooks at a number of intermediate points; so that the horizontal strains are borne only by what are called the stretching-posts, whilst the intermediate posts, in common with the stretchers, have to support the weight or vertical strain. Of the two methods we give the preference to the former; because, should a wire break, it can then only affect one span; whereas, with the other method, it runs back into the other

spans, which increases the chances of short circuits being made with the other lines, and of the insulators being broken.

The insulators at present employed in supporting overhead telegraph lines are of three kinds:—1, those formed of a single piece of insulating material; 2, those formed of two or more insulating cups cemented together; and, 3, those supplied with an outer armature of iron. To the first kind belong the so-called double-cup insulators of Mr. Latimer Clark, of which large numbers are in use in England, and almost exclusively in Prussia, where they are generally known as Chauvin's insulators.

133. In 1856 Mr. Clark patented an insulator in which he increased the length of surface of the porcelain over which the current escapes, without increasing its section. He attained this by a double bell formed in one piece. The insulator is supported by a stalk, D, Fig. 103, cemented into the interior of the inner cavity; the line-wire is carried through a deep groove on the top, and is tied to the bell by a binding wire.

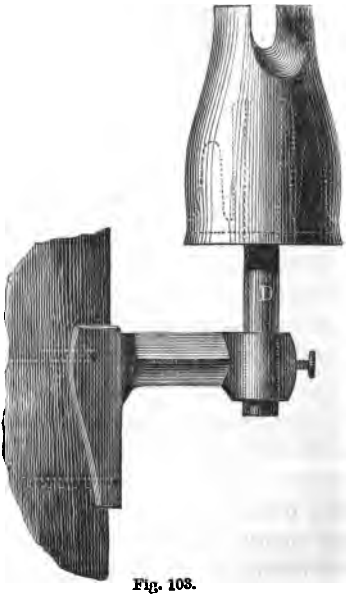


Fig. 103.

Lieut.-Col. Chauvin, Director of Prussian Telegraphs, has adopted this style of insulation for the lines under his charge. He has also made numerous experiments on the most favourable proportions between the length and section of the cups, and has given them a form differing from Mr. Clark's only in an increased depth and narrowness of the inner cavity, by which the deposit of dampness from the atmosphere is still further guarded against, as well as the sudden cooling of the insulator bell.

134. The Spanish insulator is of this class; it consists of a porcelain bell, *b*, Fig. 104, supported by a strap of hoop-iron fitting into the groove *g*, and screwed to the post. The

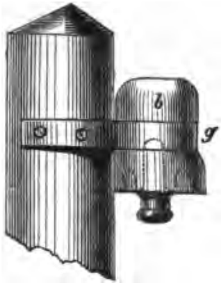


Fig. 104.

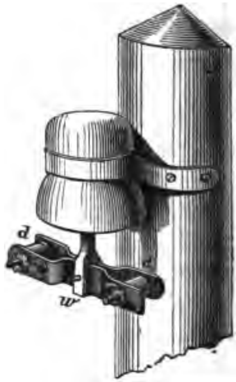


Fig. 105

line-wire is carried by a stalk cemented into the inner recess of the bell. The chief merit of this insulator is its cheapness. In climates like that of Spain it answers well enough, but would be utterly useless in England, where the atmosphere is always charged heavily with water vapour, which, condensing on the surface, would soon occasion a material loss of current.

The Spanish stretching insulator is formed with a similar bell, by means of a wrought-iron winch, *w*, attached to the stalk, as in Fig. 105. The ends of the line-wire on each side are passed through holes in the two drums, *d d′*, and wound up tightly, the drums being prevented from running back by ratchet-wheels on their axles being kept by clicks.

135. The insulator used upon the Belgian lines resembles the Spanish insulator; only the iron band which supports

it is placed higher up, and the cup underneath is deeper and better adapted for remaining clean and well-insulating.

136. The French Administration has adopted, for general use upon its lines, perhaps the worst insulators which are to be found on the Continent. This insulator, shown in Fig. 106, is provided with two ears or flanges, each of which has a hole for the screws to be passed through, which are used in fastening them to the posts. In the interior cavity is cemented a hook of galvanised iron. The under part of this insulator presents the appearance of

Fig. 106.

a cup inverted; but, until now, an insufficient surface has been given to it to insure its insulating in damp weather.

The stretching insulator used on the French lines is shown in Fig. 107. It consists of a mushroom-shaped head and inverted cup of white porcelain, cemented upon a curved bracket, which is attached to the post by means of two coach screws. The line-wire from each side is turned twice round the neck at the top, and then twisted back round itself.

Fig. 107.

137. The second class of line-supports—those formed with two separate cups—is represented by the excellent insulator of Mr. Cromwell Varley. This insulator is that most commonly employed in England. It consists of two separate red earthenware cups, *a* and *b* (Fig. 108), cemented together with sulphur. The outer cup, *a*, is provided with a groove to which the line-wire is bound; in the recess of the inner cup, *b*, a wrought-iron bolt, *c*, is cemented, by which the insulator is attached to a

bracket, *d*, on the post. A further insulation is obtained by coating the stalk with vulcanite. The rim of the outer cup, *a*, is rounded off inside. The purpose of this is to avoid the sprinkling of the interior with rain-water, when a drop, hanging upon the bottom rim, is blown off by the wind. When a strong current of air separates a drop of water from a sharp corner, the drop is never carried bodily off, but bursts in the direction of the current. With the form given to the rim by Mr. Varley, however, when a drop happens to hang on that side from which the wind comes, it is driven a little way up between the two cups, and does not burst.

Fig. 108.

138. The line-insulator of the War Department of Austria belongs, also, to this class. It consists of two bells, one glass and the other vulcanised india-rubber. The india-rubber bell has a cavity into which a pin on the top of the telegraph-post is forced. The glass bell is then drawn on, and is held firmly in its place by the elasticity of the india-rubber.

139. The third kind of line-insulator is the strongest and most expensive of all. The first insulator of this kind was that made by Messrs. Siemens, of Berlin. It consists of a cast-iron bell, *a a* (Fig. 109), with a flange, *b b*, by which it is screwed against the post. Inside the bell is cemented a porcelain cup, *c c*, ribbed inside and out to give a good hold to the cement. The cup, *c c*, in turn, carries the stalk or hook, *d d*, which supports the line-wire. The parts are put together, while hot, with a cement com-

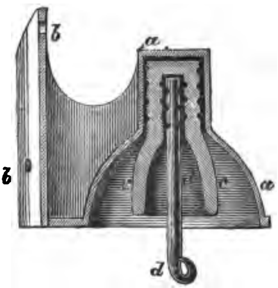


Fig 109.

posed of sulphur and oxide of iron. As a further mode of insulation, the iron stalks or hooks are covered with vulcanite before being cemented in; sometimes the porcelain cup is replaced by a cup of vulcanite. These insulators are a little heavy, but their superior solidity and insulation are ample compensation, the iron cap forming at once a perfect protection against injury and a screen against the deposit of dew on the porcelain.

Siemens and Halske's stretching insulator is made with a stronger and larger cast-iron bell than the ordinary one. The porcelain boss or cup carries a stalk with two notches (Fig. 110), through which the wire is drawn and wedged on each side, leaving a loop between them. In cold weather, when the line contracts, this loop allows the wire between the posts to be slackened, and also, in case of a rupture, gives sufficient space for making a joint.

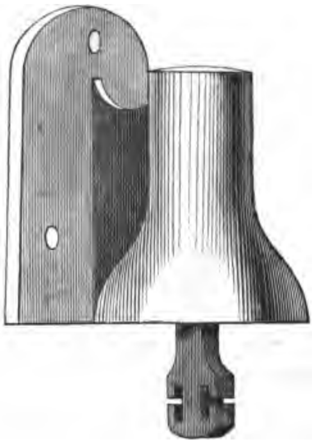


Fig. 110.

140. Lieut.-Col. Chauvin has also constructed an insulator belonging to this class, for attaching to the stems of living trees when these are used instead of posts for the support of telegraph lines. The insulator is hung upon a hook, free to swing about, and the stalk, or wire-carrier, bent in a curve away from the stem of the tree, that, when the latter is deflected by the wind, the line-wire, in swinging, may not come into contact with it. The hook, Q (Fig. 111), held in the loop, P, of the bracket, M M′, is twisted so that, in case of a sudden jerk, the line cannot be thrown upwards and the insulator disengaged from the bracket. The carrier, O, is also bent over the wire, to prevent the line jumping out.

The bracket is formed so that the insulator hangs quite free of the stem.

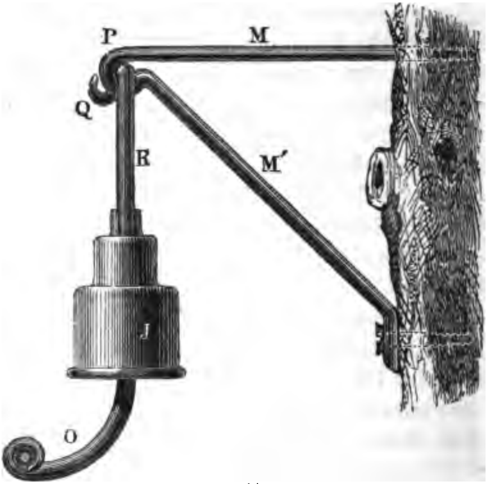


Fig. 111.

141. An insulator of this class, invented by Mr. David Brooks, of Philadelphia, has of late years been introduced in great numbers on the American lines. It consists of an outer cylindrical cast-iron armature, *a a* (Fig. 112), in which is cemented an inverted green-glass bottle, *b b*, of such a form as to allow a stalk or carrier, *c c*, of malleable cast-iron, to be cemented into its interior. The cement used in making up this insulator is sulphur, the surfaces being previously washed with shellac. The space, *d d*, therefore, offers of itself a considerable insulative resistance, which is still further increased by the use of paraffine. Mr. Brooks has found that the inner surface of a green-glass bottle which has not touched the form in blowing resists a deposit of water and dirt more

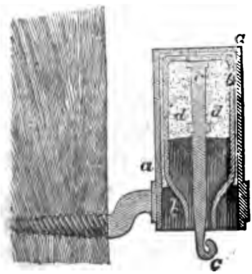


Fig. 112.

than most other insulating materials. The experiments made on these insulators by the *Commission de Perfection* of the French Telegraph Administration have established their claim to be amongst the best insulators which we possess.

142. *The Wire.*—The line-wires are of iron; very rarely of copper. The superior conducting power and durability of copper recommend it for employment, but the danger to which such a line is constantly exposed of being cut and the wire stolen is an argument against it. Were it not for this, a copper line would be much cheaper in the end than an iron one; iron having a comparatively small conducting power, and, to give the same resistance for the same length, must have a section at least seven times as great as would be required for copper. This increased section increases, of course, the weight of the line, which, as a consequence, necessitates stronger posts and stronger insulators, in order to allow each wire to be strained tightly between the supports to keep it from touching the others.

143. Various plans have been proposed for coating iron wires in order to protect them from oxidation. The plan which has met with most favour in reward of its merits is that of painting the wires with tar, or, as proposed by Romershausen, of varnishing them from time to time with a good coat of boiled linseed oil. By this method a thick crust is gradually formed, which protects the wire completely. The only objection to the process is its repetition, which renders it difficult in climates like that of England, for the painting can only be done successfully in fine weather.

The other methods consist of covering the wire with a coat of some metal which oxidises slowly. Zinc is frequently used for this purpose; it is applied by a process called "galvanising," by which the surface of the iron is covered with a thin film while the zinc is in a state of fusion. Dr. Siemens says that the "galvanising" of iron wire is only useful when the zinc is really melted together with the iron while the two metals are in contact under heat, which is the only security that the coating will not spring off or crack in bending the wire. When the wire is badly covered it rusts at those points most exposed to wear and tear, as at the points of suspension, just as soon as a naked wire. In the neighbourhood of manufacturing towns, also, the best "galvanising" is of no use, as the sulphurous acid gas in the air quickly attacks the zinc, with which it combines, and the salt, washed off by the rain, leaves the iron exposed to the weather and the further action of the acid. In addition to this, the process of galvanising is said to alter the molecular structure of the iron, and to render it brittle.

Instead of zinc, an alloy may be used, as proposed by Callan, which not only protects the wire against the attacks of acids and weather, but the coating is ductile and bends with the wire—a condition essential to its success. The alloys which Callan tried and recommends are composed of one part of tin with from one to eight parts of lead.

A proposal has also been made by Mr. Bucklin, of New York, to dip the galvanised wires into molten copper or brass, by which means a protection, that may be increased to any required thickness by repeating the operation, can be obtained. This would be a cheaper way than that suggested by Professor Brix, the editor of the German *Telegraph Journal*, to cover a bar of iron in this way with brass or copper, and then to draw it down to the required gauge.

144. Joints in land line-wire are sometimes made by bringing the ends together and wrapping them with a binding wire, sometimes by twisting them round each other.

Fig. 118.

Fig. 118 represents a joint made by the former method, called the "Britannia" joint. The wires to be joined are bent at right angles, about half an inch from the ends, as at *a a*. They are then laid together, and wrapped or bound with galvanised iron binding wire, and soldered.

By the other method the two ends are laid side by side for about 5 inches, and each turned four or five times round the other, with a space between the two helices of about three-quarters of an inch (Fig. 114). To make this joint, however,

Fig. 114.

it is necessary that the wire should be quite soft at the ends, a condition which must be seen to beforehand. The ends are cleaned with emery paper or with a file, and twisted together by means of a lever arrangement made for the purpose. This consists of two bars of steel, *a a* and *f f* (Fig. 115). In the

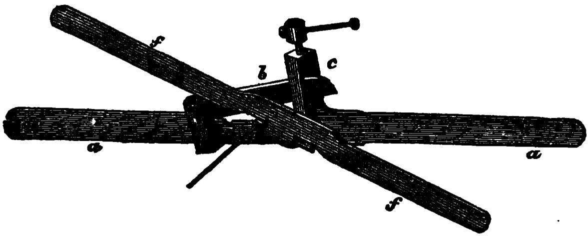


Fig. 115.

middle of *a a* is a clip, *b*, with a vice-screw, *c*, for holding it down upon the wire. In the middle of *f f* is a block, perforated with a hole in the direction of the lever. The ends of wire to be joined together are laid into the half-circular cavity in the bed of the clip from opposite sides, each end projecting about 8 inches beyond the lever. They are secured in this position by screwing the clip down upon them by the screw *c*. The projecting end of one of the wires is then bent upwards at a right angle, and put through the long hole in the block of the hand-lever. While one man holds the handles of the clip *a a*, another turns the lever *f f*, and with it the end of the bent wire, round the straight one as many times as its length will permit, keeping the hand-lever as close upon the joint as possible. When one end is completely twisted, the wires are taken out of the clip, the twisted part placed in the larger hole *d*, and screwed tight as before. The remaining end is then bent up at a right angle, and twisted round in the same way. The complete joint, after being moistened with a solution of chloride of zinc, is dipped into tin-solder, care being taken that the solder adheres firmly to the wire and fills up all the spaces between the twists of the joints.

In France the wires are joined by being twisted simultaneously round each other. This is done as shown in Fig. 116. The ends are laid one over the other for a length

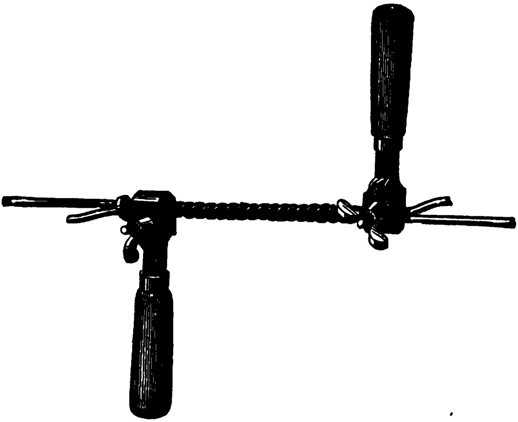


Fig. 116.

of 6 or 8 inches. The hand-vices, with long holes, are then screwed on, and turned in reverse directions until the ends are completely and tightly wound. Another method, much used in France, is by inserting the ends to be joined from opposite sides into the two holes of a little cast-iron collar, *m* (Fig. 117), after which the wire ends are flattened out by means of a hammer. These collars are, however,

Fig. 117.

inconvenient in some respects, and are dangerous for the supports when the wire is held up by hooks; because, should it break at any place, the collar, unable to run through the hook, is apt to strike it with force and break the insulator.

145. *Erection of Overland Lines.*—The erection of land lines embraces very little which affords scope for the display of anything beyond mere manual labour. The only work for the engineer is to point out where the line is to cross roadways and rivers, and when it is to make long spans and sharp angles.

When the line has been measured off and the materials distributed to different points, the posts are carried to their places for erection in the ground. It is sometimes preferable to affix the insulators to the posts before the latter are put up; but this depends upon the kind of insulator used. The posts are planted to a sufficient depth to give a firm hold—5 or 6 feet for an ordinary wooden post—and the earth well rammed down round it, with stones if they are to be had.

146. The posts which occur at angles, where a greater strain is exerted on them, are strengthened by stays or by struts.

The stays are of iron or steel wire fastened by a ring or bolt to the top, or near to the top, of the posts, and to wooden pegs in the ground, 15 or 20 feet from the post in the direction opposite to the strain which is to be counteracted.

The method of forming a strut by coupling two similar posts together is that preferred in France. The ordinary post has a notch about a foot below the top, on the side on which the strain is directed; into this notch is put the top of another similar post, planted about a foot and a half or two feet from the first one. The two are fastened together by an iron collar or by a bolt.

When Siemens' iron posts are used, they do not require to be planted so deep. The holes are dug about two feet and a half deep and two feet square, the bottom being levelled and rammed to make a firm foundation for supporting the buckled plate; and when the post is put up, the earth is rammed in, if possible with stones, above the level of the surrounding ground. In putting up these posts the lower tube, or socket, is first fixed, and afterwards the conical main, or upper tube, and the lightning guard.

This post is strengthened in points of unequal strain by means of stays. The stay consists of a length of steel wire held to the upper part of the post by a collar of wrought iron, and looped at the lower end to a hook at the end of a stay-rod, attached to a plate of iron, buried in the earth at a distance of twelve feet or so from the post. The stay is tightened by pushing the iron collar up the post.

When the posts are erected and the insulators fixed, the wire is hung up and stretched. In open country the wire is coiled upon a drum mounted upon a carriage, and is paid out from post to post; but when the line is much obstructed by trees, &c., the coils of wire are set upon drums on three-legged stools and drawn off.

Another arrangement for this purpose consists of a skeleton iron drum, one side of which is removable to admit of the coils being slipped on. The axis of the drum is hollow, for a pole to be put through it, that it may be carried by two or four men—one or two at each end of the pole. The end of the wire being made fast at starting, it is allowed to unwind as they walk along.

The wire is laid down along the line at the bottom of the posts, in which position it is examined, and suspicious places repaired. The wire is made fast at one end, then lifted into the hooks of the insulators, or tied to the bells, according to their form, and stretched by means of the winch, shown in Fig. 118, made fast to the next ordinary post beyond the

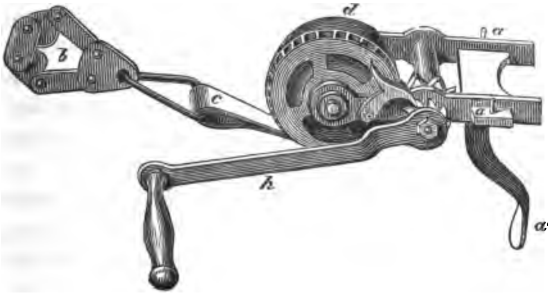


Fig. 118.

stretching-post to which the wire is to be fastened. The end links of a chain are hooked on to the two vertical pins, *a a*, at the sides of the winch, the curved frame between them and the foot, *a′*, resting upon the post. The wire is grasped by "Dutch tongs," or "devil's claw," *b*, attached to the leather strap, *c*, which is wound upon the drum, *d*, of the winch by turning the handle, *h*. A pair of pulley-blocks and line may be used for stretching, but the winch is more convenient.

When the wire is sufficiently stretched, it is made fast to the insulator on the stretching-post, and the following length to the next stretching-post served in the same way; or by the other system, from insulator to insulator.

147. *Phenomenon of Charge in Overland Wires.*—When a galvanic battery is connected to one end of an overland line, the other end being insulated, the wire becomes charged with electricity, whose tension depends upon the strength of the battery, just in the same way as a Leyden jar, or condenser, or submarine cable would under the same circumstances. The wire, stretched from post to post, forms the inner coating of a jar, the air acts as dielectric, and the

earth, the neighbouring houses, trees, &c., form the outer coating.

Dr. Siemens has determined the distances of ruptures in overland lines by measuring the discharge currents. To determine the capacity of a jar formed by a line of telegraph, he erected, in the yard of his factory at Berlin, an iron wire, 121 mètres long and 2 lines diameter, at an average height of 8 mètres above the ground. The points of suspension were carefully insulated; one end of the wire was carried directly to the instrument with which the measurements were made, and the other insulated. In comparing the charge of this wire with that of a condenser formed by a glass plate, 1 millimètre thick and 2·25 square decimètres of coated surface, it was found that a length of 1 mètre of the suspended wire had the same capacity as a plate of glass 1 millimètre thick, with 100 square millimètres, or 0·0001 square mètre, coated surface; or that an English mile of wire would have a jar-capacity equal to that of a glass-plate condenser of 1 millimètre thickness, with a coated surface of the 0·16 part of a square mètre; or of such a plate 1 mètre long and 0·16 mètre broad. Although the wire in this experiment was suspended much higher than is usual with line-wires, the result cannot be far short of the truth, as the place where the experiment was made is in the immediate neighbourhood of tall buildings and trees, which also played their *rôle* in the phenomenon.

148. *The Earth-plate.*—A proper earth connection is as essential to the working of a telegraph line as the line itself. The earth connection is customarily obtained by a plate—some 6 or 8 square feet—of sheet copper, buried in the earth at a depth that will insure its being always damp; it is connected with the apparatus by a stout insulated copper wire. In a large station it is well to employ several different earths parallel to each other. For instance, a wire soldered to the gas-pipe gives an excellent earth; a wire soldered to the water-pipe is still better. Both these give earth-plates

of large surface, being connected with the gas and water mains of the town.

The want of a good earth connection can cause serious interruptions in the service.

In temporary stations—as, for instance, those in military service—difficulty has sometimes been found in burying the plates, and in getting other means of earth. Some of the Prussian and other military stations have therefore been supplied with earth-posts which are more portable, and are said in the end to be cheaper, than buried plates of metal.

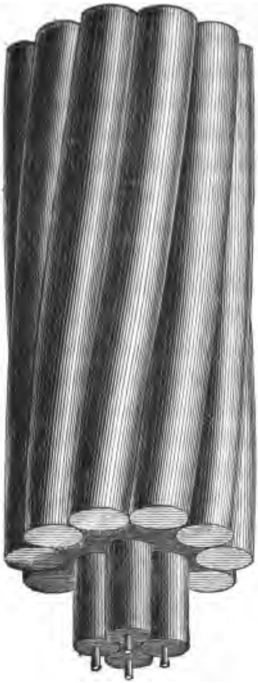
The earth-post consists of a wrought-iron tube, 12 feet long and 1 inch outside diameter. The lower portion of the iron is covered with a copper tube, soldered to it to prevent an insulating coat of oxide being formed. To the extreme end is fastened a cast-iron screw, or bore, which is screwed into the earth; the upper end is surmounted by an ornament and lightning-discharger, and is furnished with binding screws for receiving the wires leading to the apparatus.

VII. Submarine Telegraph Lines.

149. The greatest achievement of the electric telegraph is unquestionably the instantaneous transmission of intelligence across the seas. To whom the credit of the first idea of a submarine cable is due is matter of secondary importance. It has been claimed for several, with, perhaps, equal justice.

The first cable, however, which was intended to be of any real use was the gutta-percha covered copper wire paid out in 1850, between Dover and Calais, by Mr. Brett, but which, unhappily, lived only a single day—just sufficient to save the concession.

The next cable made consisted of four copper wires—No. 10, B.W.G., each twenty-seven miles long, separately insulated with gutta percha to a thickness of 0·284″ diameter, and the whole spun up in the form of a rope with tarred



hemp, with an outer protection of ten No. 1 galvanised iron wires, as shown in natural size in Fig. 119. This cable weighed, when completed, seven tons per mile. It was laid successfully in the year 1851, and is still at work. The partial success of the first wire, and the brilliant success of the second, decided the practicability of submarine telegraphy, and, after a little line of three miles had been laid down between Keyhaven and Hurst Castle, and one of eighteen miles across the Belt, both of which succeeded, and are still in working order, faith expanded, and the length of the ropes grew proportionally. In 1853 Messrs. Newall made a line, which they laid down between Dover and Ostend,

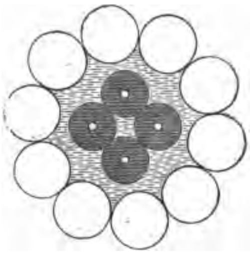


Fig. 119.

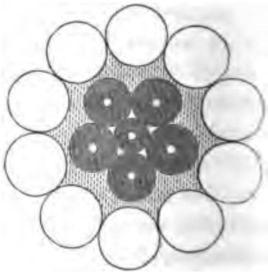


Fig. 120.

seventy miles long, weighing seven tons per mile. In this cable the number of conducting wires was increased to six;

they were of copper, No. 16, B.W.G., each covered to a thickness corresponding with No.2, B.W.G., with gutta percha. The six lines were spun up into a rope with hemp, and protected externally by ten iron wires. A section of this cable is shown in Fig. 120.

150. The success attending most of the short lines gave rise to schemes of greater dimensions, and suggested the idea of joining the Old and New Worlds by a similar connecting-link. In 1856 Mr. Brett, in conjunction with Sir (then Mr.) Charles Bright, Mr. Whitehouse, and Mr. Field, formed a company for laying a cable between St. John's, Newfoundland, and Valencia, on the south-west coast of Ireland. The form of cable selected was calculated to bear a strain of three tons, while a length of one English mile of it weighed only one ton, in air. The conductor consisted of a strand of seven copper wires, of No. 22½ gauge, weighing 93 lbs. per mile, covered with three coatings of gutta percha, weighing 227 lbs. per mile. The core was served with jute yarn, saturated with a composition of tar and other materials, and protected by a sheathing of eighteen strands of iron wire, each strand containing seven wires of No. 22 gauge, as in Fig. 121. This was for deep-sea line. For shore end, a length of thirty miles of the same core was covered with hemp, and protected by twelve thick iron wires (Fig. 122). The deep-sea cable, over two thousand miles long, was manufactured in five months—half by Messrs. Newall, of Gateshead, and the other half by Messrs. Glass, Elliott, and Co., of Greenwich. On the 5th August, 1858, the cable was successfully submerged, and congratulatory messages exchanged between the two countries. It was faulty when laid, and broke down entirely in three weeks after its submersion.

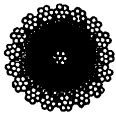


Fig. 121.

This experiment was a very costly one, but served to enlighten the electricians and caution the manufacturers.

151. The next cable of magnitude was that manufactured

for the Red Sea and Indian Telegraph Company. The core was manufactured by the Gutta Percha Company, and the sheathing done by Messrs. Newall. The core consisted of a strand of seven copper wires, weighing 180 lbs. per nautical mile, covered with wo coatings of gutta percha, alternated with two coatings of compound, weighing 212 lbs. per knot. The core was served with hemp saturated in tar. For the deep-sea portion the rope was protected with eighteen (No. 16) iron wires (Fig. 123); the shore end with nine iron wires of a larger gauge, as in Fig. 124.

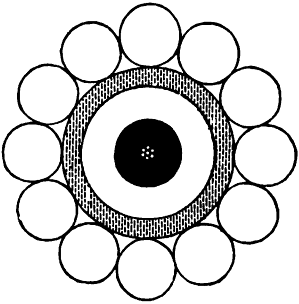


Fig. 122.

The first portion of this cable—Suez to Aden—was laid in three sections: the first between Suez and Cassire, 255 knots; the second between Cassire and Suakin, 474 knots; and the third between Suakin and Aden, a distance of 629 knots. The second portion of the cable—Aden to Kurrachee—was divided also into three sections, of which the first, that from Aden to Hallain, was 718 knots; the second, from Hallain to Muscat, 486 knots; and the third, between Muscat and Kurrachee, 481 knots.

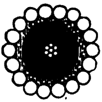


Fig. 123.

Notwithstanding the able staff of electricians and engineers present at the submersion, numerous faults were paid out. Every section of this line, one after the other, became faulty; and after repeated attempts to repair it, the cable had to be regarded as a failure. A marked progress was, however, to be observed in the manufacture and submersion of this cable; and, although the pecuniary loss was great, a corresponding amount of information was gained, which the

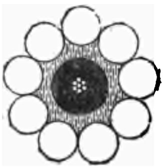


Fig. 124.

next cable, of equal magnitude, was destined to reap the benefit of.

152. Passing over the shorter cables laid in the interval, some of which struggled through the difficulties that beset them, we come to the Malta-Alexandria cable. At this date (1860) begins the scrupulous supervision of cables, both of their electrical and mechanical conditions, during the different stages of the manufacture. This progress we owe to the late lamented Mr. Lionel Gisborne, and to Messrs. Siemens, who were appointed by the Government to superintend the engineering and electrical departments. The cable was originally designed to join Falmouth with Gibraltar in telegraphic circuit.

The core consists of a strand of seven copper wires, weighing 400 lbs. per knot, covered with three coatings of gutta percha, alternating with three coatings of compound, also weighing 400 lbs. per knot. The core was served at the sheathing works at Greenwich with hemp saturated in tar, and covered with eighteen No. 11 iron wires for the deep-sea portion, of which Fig. 125 gives a perspective view and section; the shore end was made of two sizes, lengths of the same core being covered with iron wires of two thicknesses for thick shore end and intermediate shore end.

When the Gibraltar-Falmouth line was abandoned in March, 1860, it was determined to lay the cable between Rangoon and Singapoor; and in December of the same year the steam-ship *Queen Victoria* was laden with the first portion of the cable. Stress of weather compelled the ship to put into Plymouth, on her way round the channel, and while there, the electrical conditions of the cable appearing to justify a delay, and this delay preventing the possibility of the ship, which wanted some repairs after her passage, reaching the Malay coast in time to save the fine season, the expedition was decided to be put off. In January, 1861, the destination of the line was again altered, and the authorities determined that it should finally be laid in three sections between Malta, Tripoli, Bengazhi, and Alexandria. The submersion was carried out in the summer of 1861 with signal success by the engineers of Messrs. Glass, Elliott, and Co.

The length laid between Malta and Tripoli is 230 knots, that between Tripoli and Bengazhi 507 knots, and that between Bengazhi and Alexandria 597 knots.

Fig. 125.

The cable has not worked uninterruptedly since that time, and a new cable is now about to be submerged in deeper water between the same terminal points.

153. The Persian-Gulf cable, laid in 1864 by Sir Charles Bright and staff, had, during its manufacture and submersion, the advantage of all the experience accumulated in dealing with the previous cables. The conductor is a compound copper wire consisting ot five pieces, four segments forming a cylinder, and a tube in which they are contained. This conductor was made by placing the four segmental pieces in a tube, and drawing the whole down as a solid wire. The diameter of the wire so drawn is 0·111 inch; its weight 225 lbs. per knot. The conductor is insulated with four coatings of gutta percha and compound to the thickness of 0·380 inch, weighing 275 lbs. per knot. The core was served with the best Russian hemp, saturated in salt water. The outer covering consists of twelve No. 7, B.W.G., galvanised iron wires, covered with two coatings of hemp and a bituminous compound, consisting of 34 parts of mineral pitch, 56 of silica, and 10 of tar. The cable was covered with this mixture by means of an ele-

vator driven by the closing machine, so arranged that whenever the machine stopped the elevator was also stopped, and no compound was poured over the cable until the machine started again. In this way the core was guarded against exposure to heat for any length of time at one spot.

The total length of cable laid down is a little over 1,150 knots in the following four sections:—Kurrachee to Gwader, 246 knots; Gwader to Mussendom, 357·3 knots; Mussendom to Bushire, 392·7 knots; and Bushire to Fao, 154·2 knots. The cable ends approaching the Mussendom station being laid in shallow water over a rocky bottom, and frequently exposed to abrasion and faults, it has now been decided to lay a new line, insulated with Hooper's patent india-rubber, between Bushire and Jask, in deeper water.

154. Of more recent date still is the little cable laid in 1864 between Carthagena and Oran by Messrs. Siemens; in point of length comparatively insignificant, but embracing a totally novel construction, and many points which entitle it to a place here.

The core was manufactured by the Gutta Percha Company, and did them infinite credit for excellent workmanship and materials. It consisted of a strand of three copper wires, weighing 72 lbs. per knot, covered with three coats of gutta percha, alternated with as many coats of compound, weighing 144 lbs. per knot. Each separate knot was tested, at a temperature of 24° C., under a pressure of 300 atmospheres, by Reid's method, and had at that temperature and pressure an average resistance of insulation of over 600 millions per knot

The core was covered at the cable factory of Messrs. Siemens Brothers, at Charlton, with a laminous sheathing of copper. It was passed through a series of three machines in close succession. In going through the hollow spindle of the first machine, a close spiral covering of fine hemp strings was applied in such a way that the strain upon each of the strings was nearly equal. This strain was adjusted by friction springs at the sides of the bobbins containing the hemp. The second machine, similar in construction to the first, supplied a second covering of hemp, wound in the opposite direction to the first. Finally, the third machine covered the rope, spirally, with four strips of sheet copper, under a moderate pressure. By an ingeniously-constructed covering tool these strips were made to overlap each other nearly half their breadth, by which the copper covering became about twice the thickness of the sheet. Fig. 126 shows a perspective view and section of a piece of this cable.

Fig. 126.

The cable was laid completely from the *Douane* at Ain-el-Turck, on the north coast of Africa, to the harbour of Carthagena, on the south coast of Spain, but broke about ten miles from the Spanish coast soon after its submersion. During the time it lasted, the resistance of its insulation was over a thousand millions per knot, and the speed with which it could be worked quite equal to that which the telegraphists had attained. The rupture occurred over the sudden fall which runs east and west along the Mediterranean, and on which the Toulon-Algiers cable parted some years before. This experiment will probably be the last to lay down a cable over this dangerous bottom.

A cable of the same construction was subsequently submerged with success between Bona and Bizerta, and worked for a short time very satisfactorily.

155. At the date of the first Atlantic cable the mechanical department was far ahead of the electrical. The cable was successfully laid—mechanically good, but electrically bad. At the present day the electrical department has made great

progress towards perfection. A striking proof of this is that cables now rarely or never break down through electrical faults. To remedy the rapid oxidation of the iron wires in sea-water, experiments have been made, although on no very extended scale, to tar the cable as it passed out of the ship. Subsequently Messrs. Bright and Clark patented their method of covering the finished cable with a bituminous compound, which should preserve the iron by excluding entirely the sea-water. In the development of the same idea, Messrs. Siemens have made a cable based on more scientific principles. It consists in covering the iron wires with hemp, and the hemp with zinc, in such a way as to form a large iron-zinc element. Zinc is electro-positive in regard to iron, and is, therefore, dissolved; while the iron, forming the negative element, is left undisturbed. So long as the zinc lasts, the iron must remain intact; and the zinc in oxidising forms upon itself an insoluble crust, which preserves it for an indefinite time, so that a cable thus constructed must last for years.

156. The most recent and unconditionally the most important cables at present are those which have been laid over the route of the old Atlantic line. This great undertaking came at the right moment, in every respect, to realisation, when both the electrical and mechanical departments had arrived at comparative perfection.

These cables were manufactured by the Telegraph Construction and Maintenance Company—an incorporation of the firms of Messrs. Glass, Elliott, and Co., of Greenwich, and the Gutta Percha Company, of Wharf Road. The core consists of seven No. 18 gauge copper wires, twisted into a spiral, weighing 300 lbs. per knot, covered with four coats of gutta percha, between which are intervening thin layers of Chatterton's compound, weighing 400 lbs. per knot. The diameter of each wire is 0·048″; that of the strand, 0·146″; and that of the gutta percha, 0·464″. The core was manufactured in knot lengths, and tested before it left the factory, under a pressure of 600 lbs. per square inch, at a temperature of

75° Fahrenheit. At Greenwich the core was served with hemp, saturated with salt water. The outer covering of the deep-sea portion is formed by ten wires (No. 13, B.W.G.) drawn from Webster and Horsfall's homogeneous iron, each surrounded by five yarns of Manilla yarn, laid on spirally; that of the first (1865) cable being saturated with a preservative compound of tar, india-rubber, and some other ingredients, the invention of Mr. William Hooper. That of the last (1866) cable was put on with plain hemp. A section of this portion is shown in Fig. 127. Its total diameter is 1·127″. The shore-end portion, a length of 50 miles, of the deep-sea cable is served with an extra thickness of hemp, around which is an outer protection of wire strands. The weight of the deep-sea cable per knot in air is 36 cwt., and its breaking strain 8 tons.

Fig. 127.

The finished cables were subjected to careful tests of their electrical conditions under the superintendence of the electrician to the contractors. As the cables left the closing machines they were coiled into tanks of water, and, when the lengths became sufficiently great, were transported to the steam-ship *Great Eastern*, which paid them out across the Atlantic.

The electrical conditions of these cables are unexceptionable, and the complete manner in which every stage of the manufacture was carried out entitles the hope that, as they have reached the bottom in safety, these lines will last an indefinitely long time in thoroughly good condition. The employment of so large a vessel as the *Great Eastern* for cable-laying was a courageous experiment, and the result is the most brilliant engineering success of the present century.

At the present moment there are nearly 15,000 miles of insulated wire submerged in the form of submarine cables, in daily work, transmitting intelligence across different seas; and at least an equal length has been lost in the same form, partly by failure in the submersion, principally by the development of faults after the lapse of time.

157. *Submersion of Cables.*—At present all gutta-percha covered cables of any importance are sent to sea in water-tanks on board the transport ships. The tanks are circular, with as large a diameter and as high as the room of the ship will allow between the bottom of the tank and the deck; they are made of plates of iron riveted together, calked, and painted with red-lead to prevent rusting. There are usually two such tanks, the fore-hold and after-hold, on board a cable ship. In the centre of each tank a hollow cone of iron is erected (see Fig. 128), and above this a series of rings of 2″ round iron, which are lowered in the tank as the cable is paid out, are suspended

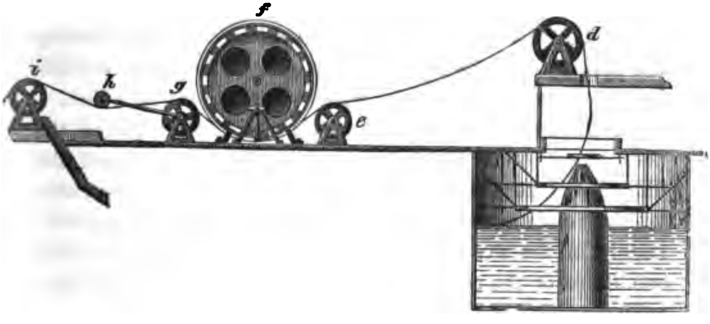


Fig. 128.

for guiding the cable as it leaves the tanks, and preventing it flying out by centrifugal force and going into kinks. On leaving the tanks the cable passes through the rings in the circular space between them and the top of the cone, which it rubs against continually. A V-wheel, *d*, is put upon deck over the middle of the tank, over which the cable is led; it then passes over the V-wheel *e*, before the brake, takes three or four turns round the drum, *f*, goes over the V-wheel *g*, under the jockey-wheel, *h*, of a dynamometer, and finally over the stern-pulley, *i*, into the sea. When the tank is at a distance from the brake, it is usual to let the cable run in a wooden trough from *d* over the tank to *e* in front of the drum. The friction which the cable exerts against the sides and bottom of the trough assists the brakes in preventing its too rapid egress from the ship.

A wheel-work with a counter is turned by the axle of the drum, *f*, for indicating the length paid out, and, by a simple mechanism, a bell is struck at the completion of each unit of length (knot or kilomètre).

In picking up a cable, the counter, or tell-tale, sometimes indicates a greater length than that really taken in, the difference being caused by the elasticity of the line, which is taken in under tension. As an instance of this, a hempen rope with a grapnel, let out over the drum of a brake, appeared by the tell-tale 3,000 mètres, but, on being recovered, the index indicated a length of 3,100 mètres, notwithstanding the shrinking of the rope in the water. Allowance for this has, therefore, always to be made when drawing in a line.

No good electrical measurements are possible during the passage out, on account of the motion of the ship and the difficulty of keeping the apparatus dry; the measurements which are made are only of value qualitatively and approximately in the event of a fault occurring. The electrical conditions of the cable are, however, always kept under surveillance.

Messrs. Siemens have constructed a galvanometer purposely for use on board ship. It consists of an astatic system of magnetic needles on a vertical bar, moving in stone pivots, and surmounted by an aluminium pointer. Each needle turns in the centre of an independent coil of wire. Above the glass cover of the dial-plate is a tall rod of brass carrying a horizontal adjusting magnet, which in different positions and at different distances from the magnet system increases or diminishes its directive force, and with this the sensibility of the instrument.

Professor Thompson has succeeded in eliminating the directive force of the earth's magnetism entirely from his marine galvanometer by surrounding it with a heavy armour of soft-iron, which gives it the advantage of retaining its constant of sensibility and zero point in whatever position the ship's head may be put; he also keeps his mirror magnet steady by attaching it to a tightly-drawn cocoon fibre.

The measuring apparatus on board does not materially differ from that used on shore, only, where it is possible, it is made simpler. On the sea everything is damp, and with a dampness caused by the particles of salt water carried by the wind; these particles of water are conductors, and provide a short circuit for the current to earth from every corner of the apparatus. Therefore, the fewer the pieces used, the fewer the chances are that the "subtle fluid" departs from the way it should go.

158. Before commencing to pay out a cable, and while the ship is quiet in harbour, careful measurements are made of its insulation, copper resistance, and temperature.

In commencing to pay out a cable, one end of the shore cable is put upon the land and carried into the station. The ship pays this out to the end, when it is joined to the middle cable, or to the deep-sea cable if no middle cable is employed. At this point the officer of the ship takes the bearings carefully in his nautical way, and the telegraph engineer takes his bearings in a less scientific and much simpler way. These consist in rough sketches of marked points on the coast. The line which a church makes with a hill, or two hills together, or an inlet with a hill behind, should be carefully noted. There are very few coasts which do not present such inequalities as to enable the engineer to find lines between distant objects. Of these lines, two at least should be noted, if possible, making an angle of 90° with each other; and the objects noticed on the land should be, one as near to the water and the other as far from it as the nature of the coast permits. In the long run, this method is the most valuable, and enables the engineer to return at any time to the exact locality of the joint in case he may want to pick it up.

From this point begins the most difficult and risky part of submarine telegraphy. The manufacture requires a constant supervision and care; it has, however, the advantages of *terra firma*, and any accident may be repaired, because the essential element—time—is to be had; but the laying demands untiring courage and caution, and that because, when once under way, there is no stopping without danger to the cable, notwithstanding the innumerable casualties which invariably attend a sea voyage.

159. In his book on telegraphy M. du Moncel says that, in order to lay a cable successfully, the speed of the ship should be precisely that of the outgoing cable. Unfortunately for the telegraph engineer, this physicist's ideas of the sea bottom do not correspond with the reality; instead of being level like a street, it is found that as great irregularities occur in the earth under the water as in the earth above it. The sea has its mountains, its valleys, its precipices, as well as the dry land, and over these mountains, and across these valleys, and up and down these precipices, the cable must be laid, and not hung from peak to peak like a tight-rope. It must everywhere rest upon the bottom; if not, it must sooner or later break by its own weight between the points of suspension, or abrade against the rocks until it is cut through.

160. The shape of the bottom is ascertained approximately by soundings made with the lead and line. Such soundings have been made in almost all seas, and diagrams of the bottom, from these data, are constructed before the operation of paying out the cable is commenced. Such, for instance, are the sections (Fig. 129) of the bottom of the sea between Iceland and Greenland, and Greenland and Labrador, constructed from soundings made for the proposed North Atlantic route. The localities where some of the

soundings were made are given by the vertical dotted lines, and the corresponding depths in fathoms by the figures at the surface. Sudden points may, and no doubt do, occur which the soundings do not discover; but when

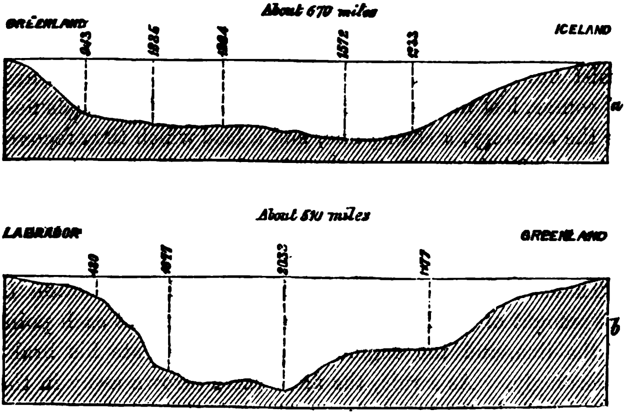


Fig. 129.

the soundings are taken at moderate distances all the great irregularities may be considered as being known. Soundings for the English Government were successfully made by Rear-Admiral Sir J. C. Ross in his expedition to the southern Antarctic Sea, in March, 1840, by a method which appears to be the only trustworthy one yet devised—that of sounding by time. A lead is sent down upon a very light line, just strong enough to withstand the friction of the water in descending, its purpose being only to give an indication when the lead reaches the bottom. The time which elapses between the moment when the lead is eased down and each successive mark passes out of the ship, as well as the moment when the lead touches the bottom, is noted and compared with data given by previous measurements or with the calculated velocities. The velocity of a body falling freely in water is found to be, after the first few seconds, uniform. When it hangs upon a line, however, the velocity of descent decreases regularly by reason of the friction of the line against the water. The results obtained in this way are more to be depended upon than those obtained by direct measurement of the line, which is liable to make curves in the water by drifting, under-currents, &c., influences which do not alter the times of descent when the resistance of the line is very small. Both line and lead are, of course, lost in this measurement. The French officials use, on the contrary, a strong line, and a lead which they recover always. Their results are therefore less reliable, unless the soundings are taken from a small boat, which is not drifted by the wind so much as the ship, and even then not where there are any considerable under-currents.

These diagrams of the bottom give a tolerable notion of the amount of slack which should be expended at each point of the line, and the engineer is able to regulate his brake accordingly. As a rule, the more cable thrown away in the form of slack, the more chance there is that the cable will succeed.

161. If the bottom were level, M. du Moncel's idea would be just, and the speed of the ship could be made uniform with the speed of the outgoing cable; in which case the cable from the stern-pulley to the bottom would form in the water a straight line. If the speed of the ship were increased, the line would bend over and form a curve concave with the bottom; and, if decreased, the cable would have a tendency to form a curve convex towards the bottom. But these curves can occur only after altering the relative speeds of ship and cable.

We have heard some engineers question the truth of the assertion that a cable descending in the water from the stern of a ship whose speed is uniform must form a straight line inclined to the bottom. The question admits of an easy solution. From what was said of the descending weight used in sounding, it will be remembered that when a heavy body is thrown into water, after the first instant it descends to the bottom through equal spaces in equal times. Suppose, therefore, from a ship sailing with uniform speed, at distances of every fathom travelled over, a pellet were dropped overboard, it is evident that by the time the second pellet touched the water the first would have descended a depth, say, *n* feet below the surface; when the third was dropped, the second would be *n* feet below the surface, and the first twice *n* feet; when the fourth was dropped, No. 1 would be thrice *n* feet, No. 2 twice *n* feet, and No. 3 only *n* feet down, and so on, forming always a straight line. The same must necessarily apply to a cable paid into the water at a uniform rate and descending uniformly; it can take no other form in the water than that of approximately a straight line.

Messrs. Brook and Longridge* have demonstrated this mathematically in a very able manner. The results of their developments are of great use in a practical sense, instructing us, as they do, on the important question of how much strain must be put upon the outgoing cable by the brake, and indicated by the dynamometer, in order to lay out the line under any desired conditions.

When a cable is being paid out, two forces act simultaneously upon it: first, gravitation, by which it falls to the bottom—this force acting perpendicularly; secondly, friction of the water, which, by reason of its position, lying upon an inclined plane, gives it a tendency to slide down in a line from the ship to the point where it touches the bottom. The angle formed by the cable in going down depends obviously only upon the relation between the speed of the ship and the velocity with which the cable falls freely in water, and is independent of the tension with which it is laid. The force, however, with which the cable tends to slide down the inclined plane is very nearly equal to the weight of a length of cable reaching from the point where it touches the bottom perpendicularly to the surface of the

* "Minutes of Proc. Inst. Civil Eng.," 1858.

water. This sliding tendency is of great use in successfully submerging a cable, as it enables the engineer to lay out his line with sufficient sliding, or slack, to cause it to fall into all the irregularities of the bottom without spanning any of them. If the bottom were quite level, a cable could without danger be laid out without any slack, in which case it is evident that the engineer would have to oppose just so much resistance or brake-power as would *balance the tendency* to slide or to take slack.

This balancing or brake power would be exactly the weight of a length of cable in water equal to the depth, if the resistance of the water against the surface of the cable did not retard the inclination to slide in a slight degree, and thus to lessen the force necessary to be applied in retaining it.

The bottom being, however, irregular, the engineer has to be supplied with soundings which instruct him at each point of the course what depth of water he is in. He knows, also, the angle which the cable makes in the water, and therefore he can tell easily under what depth of water the point of the cable is which at any moment touches the bottom, and according to this depth he has to regulate his brake-power. Were he to regulate the power according to the plumb-line from the ship to the bottom, at any moment he might fall into the error of giving too little slack just when it is most needed, that is to say, on approaching a bank.

In the late attempt to submerge the Atlantic cable, the angle at which the cable went to the bottom was 9° 30′. The average depth of the Atlantic is two knots, and, as the cable weighs in sea-water 14 cwt. per knot, it follows that in order to lay out this cable on a plane bottom, a retarding force of 28 cwt. would have been required. A very small fraction of this retarding force is found by the cable itself, in the form of friction against the water in sliding. But the strain put upon the cable by the brake on board was only 12 cwt., and consequently 15 per cent. of cable slid uniformly down the incline to accommodate accidental irregularities at the bottom, and prevent it hanging suspended between them.

VIII. Underground Telegraphs.

162. In England, as well as generally on the Continent, the system of underground telegraphs is gaining favour. The cause of this is that, besides their unsightliness, there are inconveniences attending the overhead system with which the underground is not burdened. These inconveniences arise principally from the facility with which overhead wires may be wilfully and maliciously tampered with, and from their exposure to atmospheric influences, which necessitates their continual repair, and a proportionally high cost of maintenance.

The posts on all the great telegraph highways are becoming overcrowded. To erect new wires endangers them; to erect new posts beside the old ones is offensive to the eye, without in the least diminishing the danger of their being continually wilfully or accidentally damaged. Scarcely a storm of any magnitude, indeed, passes over the country which does not play havoc with the overhead wires. Were we in possession of an efficient method of underground telegraphy, such accidents could not occur; and, therefore, we think it highly probable that the next few years will see the rapid development of systems of burying the wires; and hope to see their disappearance into the earth—in tubes, cables, sewers, or subways—anyhow that is safe, in fact, and underneath the surface.

163. The principal difficulties that underground lines have had to contend with have been the carelessness with which the wires were laid, and the decay of the insulating materials. These difficulties have been met, perhaps, more completely in France than elsewhere. The prejudice which the French have against wires crossing their streets in all sorts of dangerous spans and inelegant angles has necessitated the em-

ployment of the underground system in their towns. The result has clearly shown that, when moderate care is taken in burying the wires, and in insuring perfect cables before they are buried, their electric condition will last unimpaired for years. The underground cables in Paris are composed uniformly of seven conductors, each consisting of a strand of seven copper wires insulated with several thicknesses of gutta percha. They are placed in the sewers, in the catacombs, and in iron tubes under the streets. The cables which are carried through the sewers are enclosed in lead tubes to prevent the gases developed there destroying the gutta percha. In the catacombs, which are free from any development of gas, the seven insulated wires are simply wrapped with a tape serving prepared with sulphate of copper. Eight such cables, supported in a zinc trough 4 inches deep and 2 inches wide, are carried along the sides of the passages. The temperature of the catacombs seldom varies from 12° C.; the atmosphere is damp, the floor being generally only a few feet above the level of the wells, and water percolating always through the rock. For the lines underneath the streets, iron tubes are employed to protect them against mechanical injury, whilst they also prevent the circulation of the air and retard the deterioration of the gutta percha by oxidation, and by the escape of the essential oil, whose presence seems necessary to preserve its elastic condition. These tubes are like those used for gas; they are of cast-iron, in lengths of about 8 feet, their diameters being proportioned to the number of wires which they have to contain. They are planted in a trench a yard deep. The separate lengths are connected with lead joints, and at distances of from 50 to 150 yards a tube is inserted of larger diameter, which slides over the ends of two neighbouring ones, so that by pushing it back the lines can at any time be got at for repairs. These places are also used when drawing the cables through the tubes. This is done in lengths of 400 yards or thereabouts, the cables being first well covered with powdered talc to reduce the friction against the sides of the tubes.

In London, the Electric and International Company uses almost exclusively underground lines. They are of gutta percha, contained in 3-inch cast-iron pipes laid under the pavements, and terminating in joint boxes. Of these wires there are about 1,600 miles, contained in about twenty miles of tube underneath the pavements.

164. A very practical form of tube for underground wires has been constructed by M. Léon Delperdange, of Brussels. This tube is of iron, with a slit three-fourths of an inch broad along the uppor side for laying in the cables, and saving them from the chances of injury by being pulled through. When the cables are placed in the tube, a length of ⊥ iron, broader in the bottom flange than the slit, is put into each length, and fastened there by means of three iron wedges passing through holes in the upper rib of the ⊥ iron. The space above the flange, to the height of the top of the tube, is then filled in with some water-tight cement, which seals it up completely, but which can, at any time, be removed with a chisel, in order that the cables may be lifted out and repaired, if necessary. The joint between two lengths of tube is made by a ribbed clip which presses a collar of vulcanised india-rubber over two slightly elevated rings on the neighbouring ends of the tubes. At regular intervals, the tubes enter round testing-boxes formed by cylindrical chambers covered with flat lids packed with india-rubber rings.

165. The expense of gutta percha and india-rubber has induced repeated experiments to be made to employ asphalt and bituminous compounds for the insulation of underground lines. Until recently, these experiments have, although sometimes carried out on a large scale, not been attended with success. But it is probable that the failures have been, in the majority of cases, due more to want of sufficient care in the experiments, and familiarity with the subject, than to the unsuitableness of the materials employed. Three different

methods of insulation with bituminous compounds have recently been brought prominently forward: 1, that of manufacturing and planting lines in rigid sections; 2, that of laying down naked wires in a trench, and pouring melted gas-pitch in upon them; and 3, that of rendering the pitch plastic, by which wires covered with it may be coiled.

The first system—that of so-called rigid sections—has been strongly advocated by Mr. Nicoll. The wires are of copper, covered with hemp, which is thoroughly impregnated with an asphalt compound. This core is then placed centrally in a hollow cane saturated in some insulating and preservative compound, which protects it from mechanical injury. The cane is applied by a machine in two equal halves, being closed upon the core by a taping with some asphalt compound, and presents a very respectable appearance. This core is manufactured in lengths of about 10 feet.

At the ends of the sections the wires protrude about an inch, for the purpose of making the necessary joints. At one end of each section the wire is twisted in a hollow coil or "corkscrew;" at the other, it is straight. In planting the lines, the straight end of one section is intended to be pushed into the coil of its neighbour, and good metallic contact is then secured by the blow of a hammer or by soldering. When the wires are thus connected up, a short tube which embraces the ends of both sections is put over them, and filled up with melted insulating compound.

The great number of joints seems to be the only objection to this system; but this question depends solely upon, 1, their insulation relatively to that of the line; 2, the time occupied in making them; and, 3, the additional cost which they occasion, which the inventor finds not to turn out disadvantageously to the system.

The second system has been tried in Holland by M. Holzmann. Instead of planting previously-prepared rigid sections, M. Holzmann manufactures his line as he lays it down. He first places his cast-iron troughs in a trench; then lays the wires in them, divided by glass supports; and, lastly, pours in melted gas-pitch. The trough is afterwards covered up with a lid, which is wedged on. Half a mile of this line works very satisfactorily between Abconde and Amsterdam.

But this, like the preceding method, requires a more extended experiment of its merits in order to establish it as a practical system.

The third suggestion is that of M. Jalloureau, of Paris, who covers his wires with a flexible bituminous compound, put on with strips of brown paper wound spirally round, the whole forming a core which may be transported in any length upon a drum. The paper is thoroughly dried before being used, and is well impregnated with the compound. After the wire has been coated with the requisite number of laminous spirals and intermediate compound, it is wound round helically with two iron binding wires in opposite directions. The purpose of these wires is to invest the core with a superior longitudinal strength than it would have from the paper alone, and at the same time to keep the paper strips from injury. Core made in this way when new is very flexible, and may be coiled when cold round a drum of 6-inch radius without sustaining apparently any damage whatever. We consider, nevertheless, M. Jalloureau's system to be inferior to either of the others, although it aspires to attain more. The attempt to construct a permanently flexible core with an asphalt compound can never be successful, because the material has naturally so little tenacity, even when softened by the admixture of tar or other hydrocarbons, that a sudden jerk is almost always attended with a rupture; and it increases its degree of hardness so materially with a small decrement of temperature, that in coiling or uncoiling the core it would always be in danger of receiving faults in insulation. There is also an objection to the use of tar, that, not being procurable in large quantities in a state free from water, its specific insulation is very low, and its admixture with the asphalt would only diminish the insulating capacity of the latter. The idea of asphalt insulation is not new: it has been repeatedly tried, and has as often disappointed its advocates. Nevertheless, it has never been satisfactorily proved that the system is a bad one, but rather that some other element to success was wanting. The best invention, without energy and intellect to carry it through, will in the majority of cases fail. As probably, however, neither of these important elements is wanting now, there are reasonable hopes that, with the benefit of all the experience and failures bequeathed to them by earlier workers in the same field, the promoters of asphalt insulation may succeed in their endeavours to give us cheap underground lines, by which they will be doing a most welcome service to telegraphy.

IX. Atmospheric Electricity.

166. The study of electricity has not only placed the employment of one of the most important of the powers of nature ready for the uses and convenience of mankind, but, in cases where this power, in the hands of nature herself, occurs too violently for the safety of our tender organisms, has also provided us with a ready means of avoiding danger. In the early part of the preceding century, various physicists noticed the resemblance between electricity and lightning. It was reserved, however, for Stephen Grey, in 1735, to conjecture their identity. Fifteen years later the Abbé Nollet reproduced Grey's conjecture, and supported it by more circumstantial reasoning. But the proof was not given until Benjamin Franklin, in 1749, made his celebrated kite experiment. This experiment consisted in sending up a kite surmounted by a pointed wire, which was connected electrically with the line, the latter being made conducting. The kite was made of a cross, formed of two light strips of cedar-wood, to which the four corners of a silk pocket-handkerchief were attached. The stretched handkerchief, provided with loop, tail, and string, could be raised in the air like a

common kite, and had the advantage of being able to withstand rain and wind. At the other end of the string, near the observer, a key was fastened to intercept the electricity in its descent; and in order to prevent it from reaching the person holding the kite, a silk ribbon was tied to the ring of the key, and held in the hand, thus allowing the conducting string to fall upon the earth. Fear of ridicule compelled Franklin to make his experiments in the presence of only his son. At first his string was dry, and he got no satisfactory results; then the rain came down and wetted his string, and he received a spark from the key. Thus was Benjamin Franklin successful in one of the boldest experiments ever made by man upon the powers of nature, and from that moment he became immortal. The accomplished fact of discharging, by artificial means, the lightning from the clouds proved beyond dispute the identity of atmospheric with frictional electricity. Franklin was not a mere theorist, with no higher aim than knowledge, nor a mere adventurer, with no higher object than profit. Franklin was a true civil engineer, who sought to direct "the great sources of power in nature for the use and convenience of man." Convinced of the correctness of his views, he proposed the use of lightning-dischargers for the roofs of buildings, such as are employed to this day.

But these inquiries of Franklin did not immediately find favour. The Royal Society laughed at his speculations, and refused them a place in its "Transactions." In that great body of learned men there was not one who cared to apply his intellect to comprehend Franklin, or his courage to support him until he had established beyond question the correctness of his theory; and then the Royal Society lavished upon him its honours, as some satisfaction for the injury it had done him. Subsequent experiments have proved that the atmosphere is always more or less charged with electricity; that in some parts the charge is positive, in others negative. Accumulations of atmospheric electricity occur particularly in the clouds, which become charged in their formation, their passage, or otherwise, with high tension.

167. It is this charge of electricity which probably tends, in a great measure, to prevent the clouds falling readily in the form of rain. It is well known that bodies charged with the same kind of electricity repel each other, and it must be the same with the water-particles of which a cloud is composed: when they are charged with electricity they repel each other, and this repulsion prevents them combining and falling to the earth. But when the electricity is discharged and the repulsion over, the water-particles are free to unite and to descend to the earth in drops. This phenomenon we call a thunder-storm. It is the discharge and passage of such clouds which often prove destructive to telegraph lines and stations, and still more often disturb the regular service.

The most terrible effects are to be attributed to the electrical discharge into the line, or direct stroke of the lightning. This occurs when a charged cloud passes over and attracts, in the earth's surface immediately underneath it, the opposite electricity; and where points occur over the surface, or any object stands up high, these points and objects are charged with greater tension during the passage of the cloud. The induction between the cloud and the earth then resembles that of a Leyden jar, the dielectric being represented by the thickness of air intervening between the cloud and the nearest points above the surface of the earth. As soon as this thickness is so diminished that the tension of the electricity is able to overcome it, a neutralisation ensues in the form of lightning. The telegraph poles and line-wires are especially favourable for the discharge of atmospheric electricity, being extended over an immense surface, and offering numerous points.

As a cloud approaches, it induces an opposite charge in the earth's surface and in the line-wire, this charge becoming greater and greater as the cloud nears the line. While this goes on, electricity of the same kind as the charge of the clouds is driven along the line in the form of a current to the earth-plates of the stations at each end. When the cloud is near enough, it discharges itself into the line, and, more than neutralising the electricity of the latter, leaves the line sometimes heavily charged with the fluid, which seeks the nearest road to earth. When the charge is very intense, the lightning not unfrequently melts the line-wire in its passage along it, and splinters several of the posts. Should it succeed in entering a station and reaching the apparatus, the usual consequence is that it melts the coils of the receiving apparatus, and perhaps shatters the station.

Schellen, who has written a beautiful chapter on this subject in his book,* says that the destruction of the posts is probably caused by the water, which during rain creeps into the numerous pores and cracks of the wood, being decomposed by the lightning, the sudden expansion following its conversion into gas bursting them asunder.

At times the earth plays no part in the discharge of the clouds. This is the case when two clouds charged with opposite electricities meet in the air and neutralise each other. A line of telegraph being underneath one of them, is charged by induction, as we have already seen, in common with the surrounding earth's surface, although to a greater extent, with accumulated electricity. This charge does not change so long as the clouds remain tranquil; but the moment the discharge takes place the electricity with which the line is charged is suddenly set free and seeks the earth. It is not seldom that it takes its way over the posts and through the station, where unless sufficiently protected, it does serious damage.

There are, of course, many ways in which the positions of the clouds and their motions, with respect to the direction of the line, modify the conditions of the current. The passage of the electric discharge between two clouds over the

* "Der Elektromagnetische Telegraph," p. 341.

line is alone able to induce a powerful current, under certain circumstances, independent of the liberation of the static charge.

The remaining phenomena of atmospheric electricity confine themselves to the production of currents of more or less intensity in the line. These are also dangerous to the apparatus, but not to the same extent as the stroke of lightning.

These currents are produced in different ways. The atmosphere is everywhere electrical, either positive or negative; its electrical state depending partly upon the height above the surface of the earth, partly upon the hour of the day, and upon other causes of which our knowledge is limited. When a telegraph line runs through a region which, by reason of great difference of level or any other cause, at one end is positively electrical and at the other end negatively, the line taking the electrical tension of the atmosphere at all points, a constant current must pass through it so long as there are opposite electricities to combine in the circuit. Baumgartner, Henry, and others have made an especial study of this subject, and observed the phenomena under different conditions of height, weather, hour of the day, &c.

The passage of a single charged cloud over the line occasions sometimes also a considerable and long-continued current through the apparatus. As the cloud approaches the line it induces in it an opposite charge. To do this the natural electricity of the line must be decomposed; the electricity of the same kind as the cloud is repelled to earth through the apparatus, and a supply of the opposite kind fetched by the same road out of the earth, and held by induction. The one going to and the other coming from the earth form a single current. This continues as long as the cloud nears the line. If it stood still for any length of time the current would cease, but the line would retain its charge. As soon as it moves off on the other side, the static charge of the line becomes gradually liberated, and endeavours to establish equilibrium with the earth through the coils of the apparatus and earth-plates. Then arises a current in the opposite direction to the previous one, which lasts until the electricity of the line is neutralised.

The last-mentioned phenomena are causes of annoyance rather than danger, but have been known frequently to interrupt the operations of an overland line for many hours in succession.

Atmospheric electricity is the great enemy of overland lines; and were it not for the protection which the present system of lightning-dischargers in some measure affords, it is probable that repeated sacrifices of apparatus, stations, and even the lives of the employés would long since have compelled the rejection of the overland system, and the adoption of the subterranean and submarine only. The latter are always free from danger, and can receive no injury from atmospheric electricity, so long as they are not in electrical connection with overland lines. When this is the case, and the latter are not supplied with lightning-dischargers, or they fail to do their duty, the lightning enters the insulated wire, and, bursting through the dielectric in its struggle to reach the earth, ruins the insulation in one or more places. This is always to be guarded against, particularly in dealing with long submarine wires, which may be irreparably injured by want of sufficient foresight in enabling the high-tension electricity to go to earth soon enough.

This protection is provided by opening a way for the atmospheric electricity from the line to earth, which offers it less resistance, and which it therefore sooner strikes into than the legitimate circuit of the galvanic current.

168. *Steinheil's Lightning-discharger.*—Steinheil * seems to have been the first who supplied the receiving apparatus with an arrangement for protecting it from the effects of atmospheric electricity. The method of doing this probably was

* In 1846. Dingler's "Journal," 109, p. 302.

suggested to him from observing that sparks sprang over from convolution to convolution of the multiplier coils of the apparatus employed on the line between Munich and Nannhofen, in preference to going through the whole lengths of the coils to earth. He concluded justly from this that atmospheric electricity which charged his line resembled, in its disposition to spring over short distances, the better known frictional electricity, and differed in this respect from galvanic electricity.

The behaviour of the two electricities is in no way more contrasted than in their choice of circuits. If, for example, a galvanic battery be inserted between the points *a* and *b* (Fig. 130), the same being already joined by the long spiral wire *w*, the whole current will pass through the latter, and none will go over the space between *a* and *b*, however near they may be, if they do not make absolutely metallic contact with each other. But if, instead of the galvanic battery, a charged electric battery or Leyden jar be substituted, the inner coating, for instance, being connected to *a* and the outer to *b*, it would discharge itself immediately over the small space between *a* and *b*, and very little, if any, would pass through the coil *w*. Thus the way which for galvanic electricity offers an infinite resistance is for static electricity a short circuit.

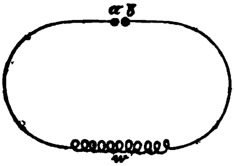


Fig. 130.

Steinheil based the construction of his lightning-guard on this physical law. Instead of bringing the two ends of the line-wire into the station, he fixed each of them to a plate of metal 6 inches square, erected over the bureau in which the apparatus was contained. These two plates were insulated from each other by an intervening layer of silk-stuff, which offered an almost infinite resistance to the passage of a voltaic current, but was at the same time so thin that a spark of static electricity of moderate tension could easily spring from one plate to the other. From the corners of each of the plates a conducting wire went to the apparatus below.

The whole was fixed on the roof by an insulated support, and, of course, protected by screens from rain and wind. In the event of the passage of atmospheric electricity of high tension along the line on one side, for instance, it would spring over from plate to plate, rather than traverse the fine wire forming the coils of the apparatus, and would go on by the other line to the next station; Steinheil's intention being to conduct the high-tension electricity along the line, and to allow the apparatus to escape.

169. *Meissner's Plate Lightning-discharger.*—Steinheil's discharger had been constructed with the sole view of affording the static electricity a short circuit across the apparatus, whilst the fluid passed in the same line circuit as the galvanic current, from end to end. Meissner introduced the method of conducting the electricity directly from the discharger to earth—a method much more in accordance with the nature of the electricity itself.

Fig. 131 gives a perspective view of Meissner's lightning-discharger. The upper plate, A, is of copper, 8 inches long, 4 inches broad, and three-eighths of an inch thick;

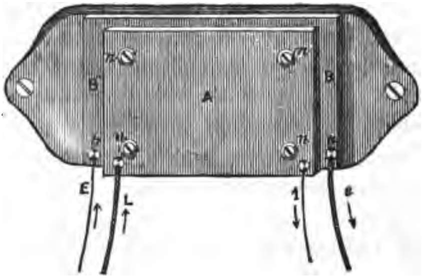


Fig. 131.

it is fastened to a second plate, B, of somewhat larger dimensions, by means of screws, *n n n n*. The two plates are, however, insulated from each other and from the coupling screws by the latter being contained in cylinders of ivory, and by the insertion of insulating rings of gutta percha one-eighth of a line thick between the plates, outside each of the ivory cylinders. The coupling screws serve also to fasten the two plates to a base board, which is nailed or screwed against the wall.

The end of the line-wire L is attached to the corner of the upper plate, A, by means of a binding screw. From the opposite corner a finer wire, *l*, goes to one end of the wire forming the coils of the receiving apparatus; the other end of the coils is connected by the wire E with the terminal *b* on the plate B, which is put in communication with earth by means of a thick wire, *e*. The two thin wires, *l* and E, are covered with silk, and are carried from the lightning-discharger to the board twisted round each other. Should the tension electricity in the line, therefore, escape by any chance a passage across the plates A B, it will certainly pass from the wire *l* through the silk covering to the wire L, before it reaches the apparatus.

The galvanic currents from the sending station, arriving by L, cross over the plate A to the wire *l*, by which they reach the apparatus; from the apparatus they come to the plate B, through the wire E, and, after crossing over B, go to earth by *e*. The intervening stratum of air between the plates offers an infinite resistance to the galvanic currents, which are therefore not weakened by the lightning-guards in the circuit; but electricity of greater tension finds this air-resistance infinitely small in comparison with that of the wire of the coil, and, therefore, on its arrival at A by the line L, it immediately springs over to B, and goes to earth through the thick wire *e*.

170. Fig. 132 gives a perspective view of a lightning-guard commonly supplied by Messrs. Siemens and Halske on Meissner's principle of two neighbouring metallic plates. Over a cast-iron plate, *a*, called an earth-plate, are placed as near as possible, but without making metallic contact, two

smaller plates, *b b*, called conductors. Each plate has two screws for attaching wires. To the screws f_1 and f_2 are attached the up and down line-wires respectively; and to the screws f^{I} and f^{II} the wires leading to the apparatus I and II; and, lastly, to the screw *g*, the earth-wire.

The upper plates, *b b*, are kept in their places by small knobs, *c c*, fixed to them, and by the buttons, *d d*, on the

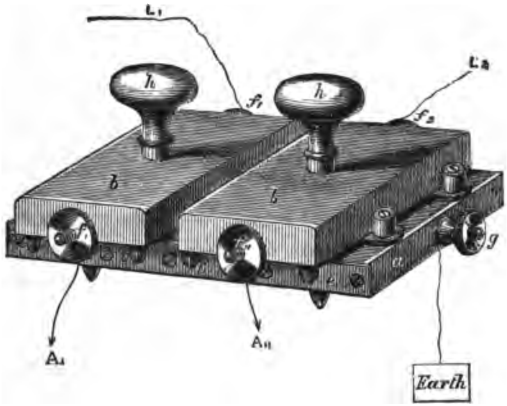


Fig. 132.

earth-plate. In order to prevent metallic contact, these buttons are covered with vulcanite, as are also the sides of the earth-plate.

The atmospheric electricity, on reaching the conductors, springs over to the earth-plate, and thus escapes the apparatus.

Another form of lightning-discharger used on the Continent, especially on railway lines, is a modification of the plate-dischargers. It consists of three brass cylinders with platinum faces, supported in an insulating frame. The line-wires are attached to the two end cylinders, between which the receiving apparatus is inserted. The middle cylinder is connected with earth.

171. *Bréguet's Wire Lightning-guard.*—An excellent idea

was carried out by Bréguet, in the construction of his first lightning-discharger, in the employment of the power of the spark to melt a fine wire, and of making the lightning itself cut the apparatus out of circuit, and save it from injury in its own endeavour to force a passage through it. He was first reminded of the necessity of protecting the instruments from the effects of atmospheric electricity by an accident which happened to the apparatus at the Vesinet station on the 5th May, 1846, when all the wires were fused and the apparatus rendered useless.

His *paratonnerre* consisted of a piece of fine wire, 15 to 20 feet long, which he carried from the apparatus to the termination of the line outside the telegraph bureau. The insertion of this fine wire in the circuit did not appreciably weaken the current by increasing the resistance of the line, and when a stroke occurred, the electricity melted the wire, on leaving the line, before it could reach the apparatus.

172. Fardley combined both the systems of discharging between plates of metal and of melting a fine wire, for better security, for protecting a line of sixty-five miles, in 1847.

He divided the line-wire at the station, and brought the ends within a distance of half a millimetre of each other at the side of a stout wooden post, which supported also a wooden roof to shield the ends from wet and dirt, instead of inserting plates of metal in the line, as Steinheil and others had done. To each of the parts of the divided line he joined some twenty feet of fine metal wire, which formed the leading wires to the apparatus. The line on either side, if struck by atmospheric electricity, would then, in all probability, discharge itself across the small space between the divided line-wire to the line on the other side; but, should this not be the case, and the fluid find its way along either of the leading wires, the wire would be fused before the electricity could reach the apparatus. The leading wires also terminated in a commutator, by which the operator, during a thunder-storm, could cut the apparatus entirely out of circuit, establishing at the same time another connection between line and earth whereby the line circuit remained entire.

173. *Nottebohm's Point Lightning-discharger.*—Nottebohm has constructed and introduced a lightning-discharger for use on the Prussian state telegraph. It consists of a double cone, supported by a stout metal bar, in connection with the earth. The points are in close proximity with the points of two metal cones, which are supported on a common base, and severally connected with the lines, and also with the two ends of the wire coils of the receiving apparatus. When the line contains free static electricity, the latter springs from the cone on the side on which the line is struck to the little double cone in the middle, and thus avoids the apparatus.

174. A lightning-guard of beautiful construction, for protecting submarine wires when connected with overland lines, is used by Messrs. Siemens and Halske, which, while sufficiently serving the same purpose as those already described, has the advantage of being fixed upon the instrument board, where no difficulty can arise in mounting it, and any disorder in which it may get will be more readily discovered. It is formed of a cube of brass connected with the earth, to three sides of which are presented sharp points of metal protruding from an arch in the circuit of the line-wire. The brass prism is faced with three metal plates, carrying agate cones on the top and on each side under the arch. The purpose of the agate cones is to prevent the points being adjusted too close to the earth-block. The points are formed by three screws, the axes of which lie in the same plane, one running vertically through the top of the arch, and the other two horizontally on opposite sides. Within each of the screws, along its axis, is a second screw of small diameter, terminating in a conical point of platinum. There is an objection, however, to the employment of this discharger, from the fusing of the points with the surfaces of the block.

175. Bréguet has constructed a point lightning-discharger,

now used on all the French lines, in which he increases the means of discharging the static electricity from the line by increasing the number of points over which it can pass, and diminishing the resistance to its passage. For this purpose he arranges two plates of copper insulated from each other upon a common board. The opposite edges are cut out in the form of sharp teeth, so that the point of each tooth on one plate is opposite the point of a tooth of the other. The plates are put as near to each other as possible without any of the teeth making contact with their neighbours opposite. The two line-wires are attached to the plates by means of binding screws. A modification of this lightning-discharger includes both the arrangements of Bréguet—the saw teeth and fine wire.

This apparatus is shown in Fig. 133. It is composed of

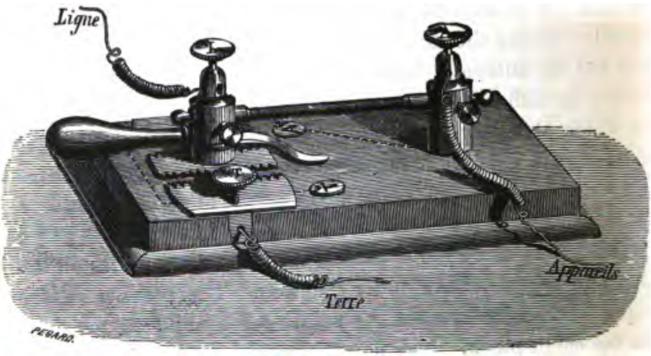


Fig. 133.

a fine iron wire (0·11 millimètre diameter) placed in the interior of a small horizontal glass or wooden tube for protection. This wire is inserted in the line circuit between the entrance to the station and the apparatus. The line-wire is connected with the terminal L, the apparatus with terminal A, and earth with terminal T. When a storm occurs, the wire is fused, and the circuit of the apparatus with the line interrupted. On each side of the line terminal, which is supported upon a base-plate of saw teeth, is an earth-plate with corresponding teeth; so that after the circuit with the apparatus is cut off, all further damage to the station is prevented. The switch contact-arm is provided for putting the line directly to apparatus or earth, as occasion may require. After a stroke of lightning has fused the

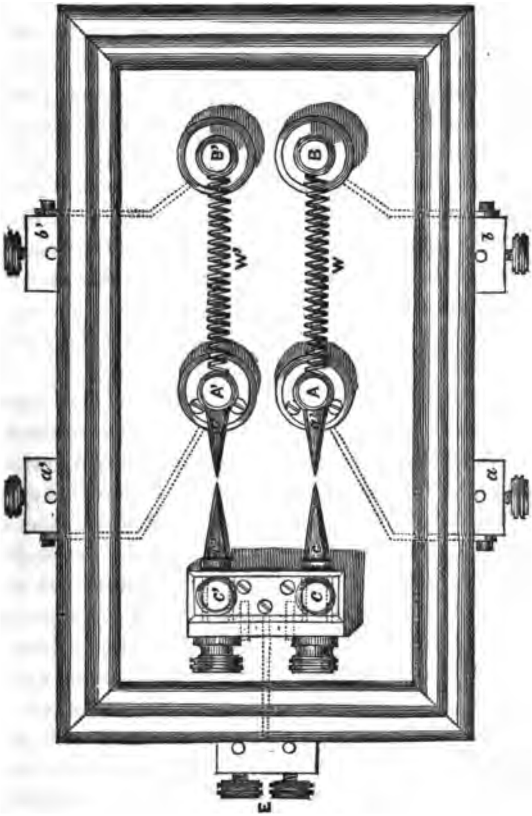


Fig. 134.

wire, the operator places the contact on T, by which the line is put to earth; when the storm has passed over, he transfers the contact to A, by which the transmission and reception can be continued whilst a new wire is being inserted in the horizontal tube between L and A.

176. The lightning-discharger used on the Prussian and Austrian telegraph lines is described in detail in Brix's "Journal." It is on the points principle, and is arranged for being placed on the instrument board. From a bar of metal, C (Fig. 134), on the left-hand side, project two points, *c* and *c′*, with adjusting screws. Opposite these points are two similar ones, projecting from the terminals A and A′, which are connected by the spirals, W and W′, with B and B′, respectively. On the margin of the board are five terminals for receiving the wires of lines, apparatus, and earth; the bar C is connected by a wire underneath the board, shown by dotted lines in the figure, with the back terminal E, destined for the earth connection; the terminal A is similarly connected with *a* on the one side, and A′ with *a′* on the other; B and B′ are also in permanent connection with *b* and *b′* on opposite sides. The two line-wires are brought to *a* and *a′*, and the apparatus is inserted between B and B′.

177. *Kerckhoff's Lightning-discharger* includes arrangements for discharging the line both between surfaces and points. A hollow brass cylinder, supported by a bracket, is in permanent connection with earth. Inside this cylinder is a second metal cylinder, insulated from it by short ivory tubes at the ends, and held in its place by screw-points. The annular space between the cylinders does not exceed one-fourth of a line, so that electricity of moderately low tension can easily spring over. The line-wire is connected with one of the two terminal screws of the inner cylinder, and the wire leading to the apparatus with the other. The outer extremities of the screws are furnished with points, by which, should the electricity fail to leap over the annular space between the cylinders, it will in all probability discharge itself to the opposite points on two screws connected to earth through their uprights and the common base-plate.

178. M. Tesse, in France, and M. Picco, in Italy, have introduced a lightning-guard, constructed upon the automatic principle; that is to say, that when the lightning fuses the wire, the line is put automatically into contact with the earth. In the guard invented by M. Tesse, electrician to the Chemin de Fer du Nord, a length of thin iron wire, held between two clamps, supports in its middle the head of a lever, the rod of which is hinged to the plate connected with the line-wire. When the wire is fused by the atmospheric electricity, the head of the lever released falls by its own weight, causing the back part of it, which is conveniently formed for the purpose, to make contact with the bottom of the earth-plate. In this way the line is put to earth, and all further danger prevented.

M. Picco, of Alessandria (Italy), employs a spring to do the same as gravitation in Tesse's lightning-guard. His special arrangement consists in leading the line-wire to a brass pillar, on the top of which is a metallic beam turning horizontally, but held in tension by a spiral spring around the pillar. When at work, one end of this beam is tied by means of about an inch of fine iron wire to the terminal leading to the instrument. When, however, the lightning fuses the wire, the spring forces the other end of the beam against the earth terminal, and thus puts the line and the earth into immediate connection.

179. *Bianchi's Vacuum Lightning-discharger.*—Du Moncel describes this apparatus, which is of a novel but somewhat inconvenient construction. It consists of a brass globe inserted in the line circuit, covered and protected by two hemispheres of glass cemented into a broad metal ring, which is provided with radial spikes pointing inwards to within a very short distance of the surface of the globe. The latter is held in its place in the centre by an axis passing air-tight through the poles of the glass hemispheres, and ending in terminal screws. A tap is also inserted in the copper ring, through which the air is pumped out. The

ring is supported by a metal plate at the back, connected to earth, and by which the lightning-discharger is fixed against the outside of the building.

The foregoing are some of the best arrangements invented as yet for protecting the apparatus from the effects of atmospheric electricity. They all, in a more or less complete degree, fulfil their purpose, but none with entire certainty, as we from time to time observe in the damaging effects of a thunder-storm to the apparatus at stations which are supplied with dischargers of the best constructions. On other occasions, however, the dischargers do their duty in saving the stations and apparatus from serious damages.

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THE END.

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