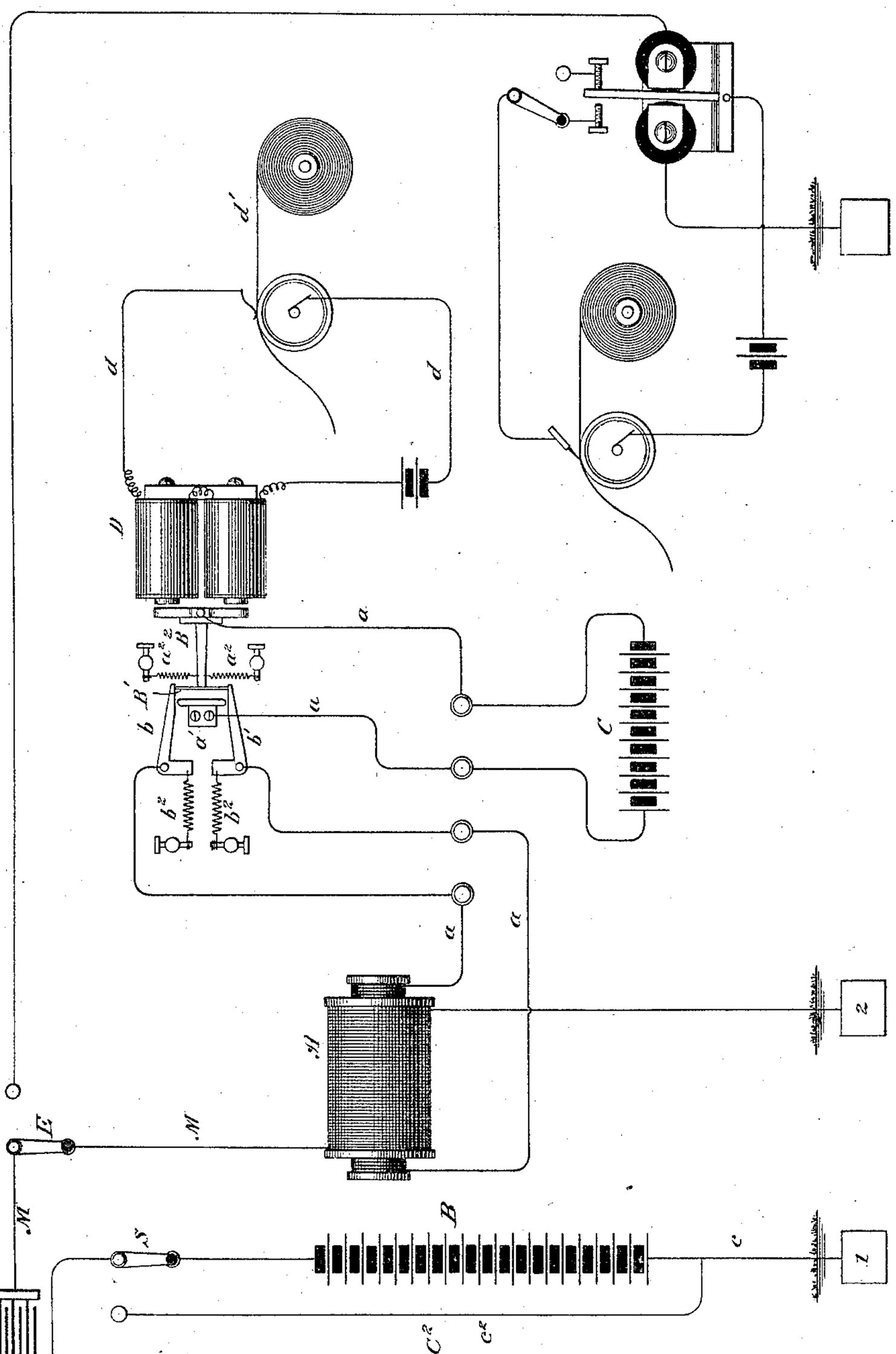
(No Model.) 4 Sheets—Sheet 1.

M. G. FARMER.

REPEATER FOR SUBMARINE CABLES.

No. 312,831. Patented Feb. 24, 1885.



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REPEATER FOR SUBMARINE CABLES.

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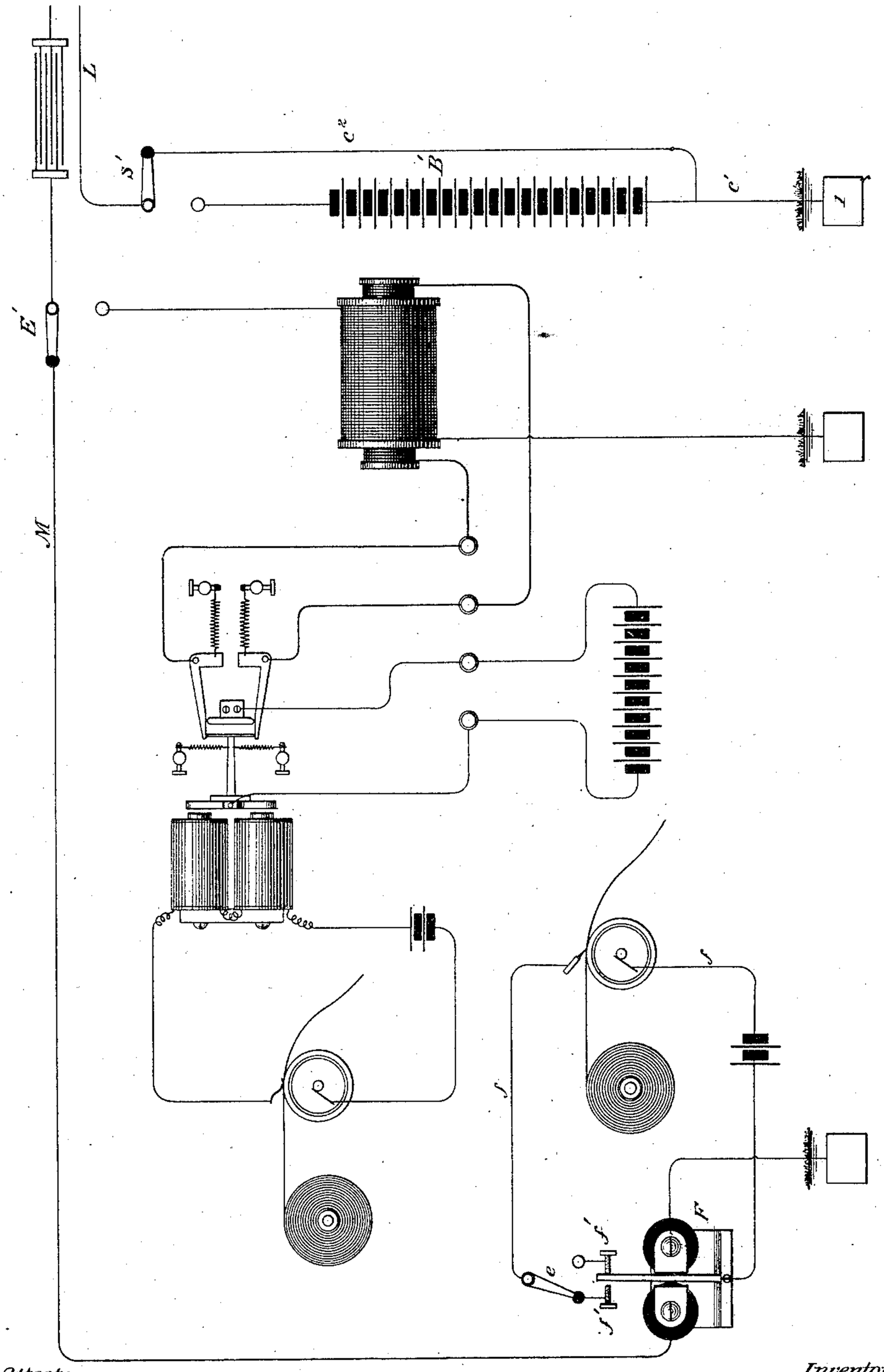

Fig. 2.

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REPEATER FOR SUBMARINE CABLES.

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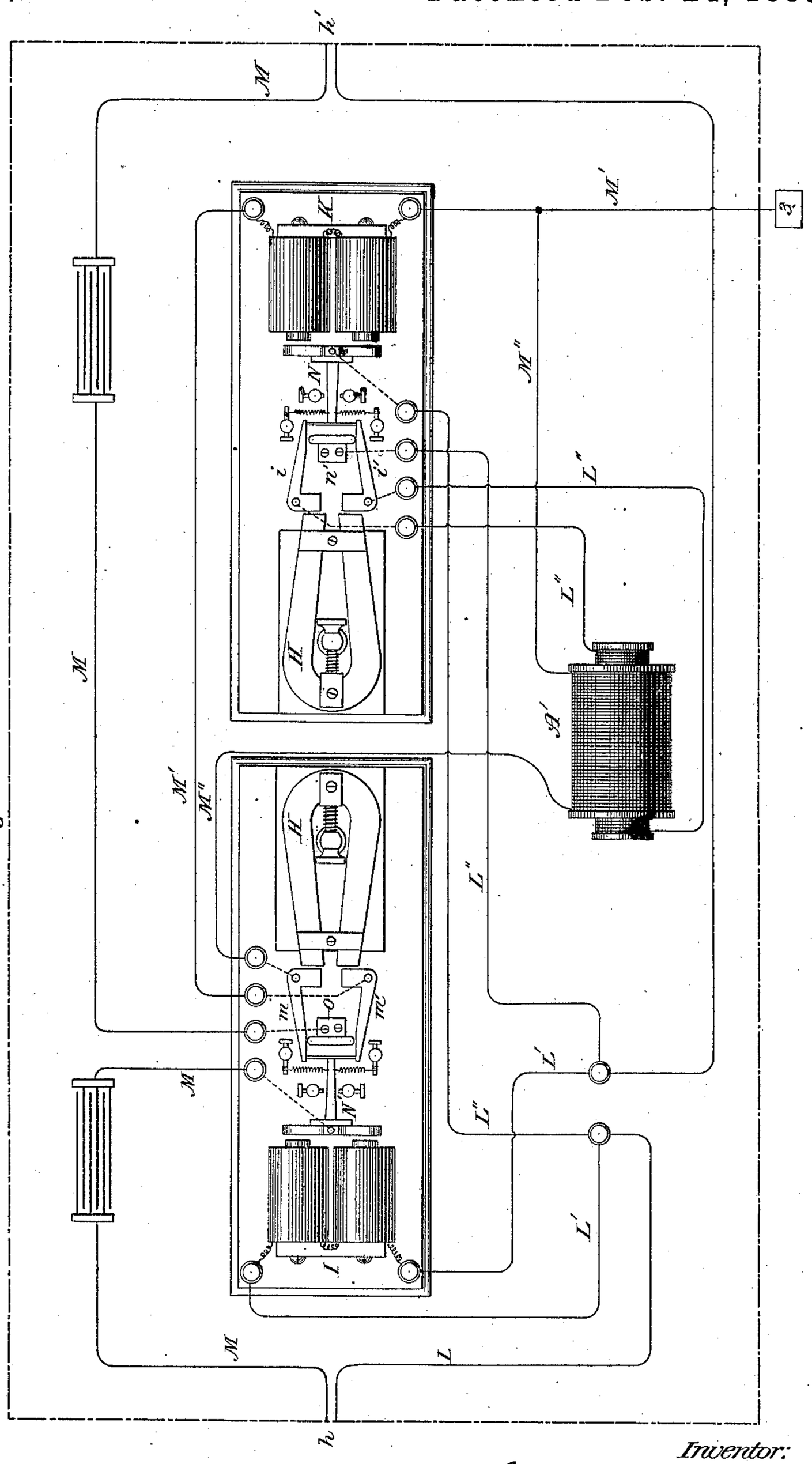

Fig. 3.

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M. G. FARMER.

REPEATER FOR SUBMARINE CABLES.

No. 312,831. Patented Feb. 24, 1885.

Fig. 4.

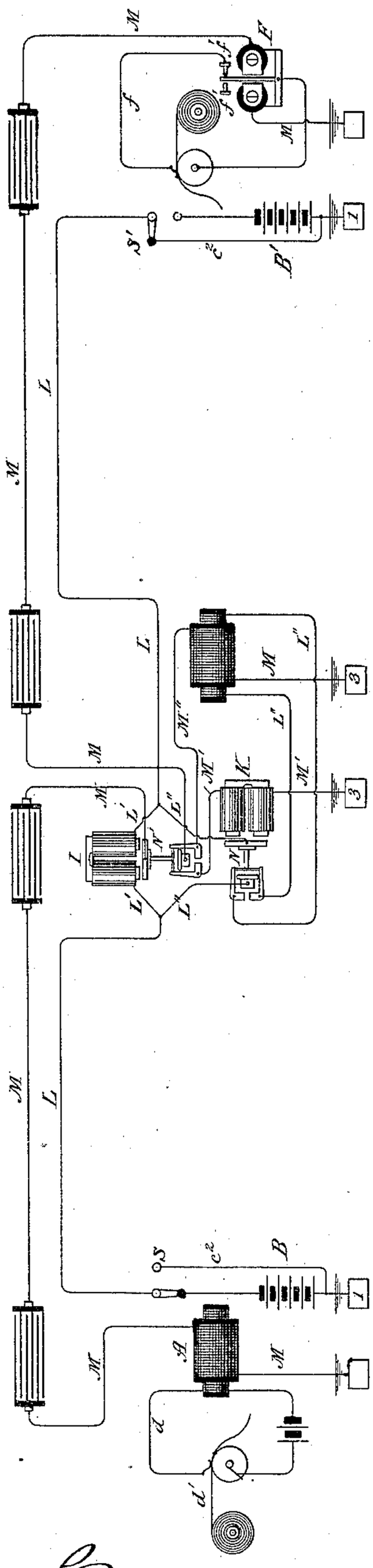
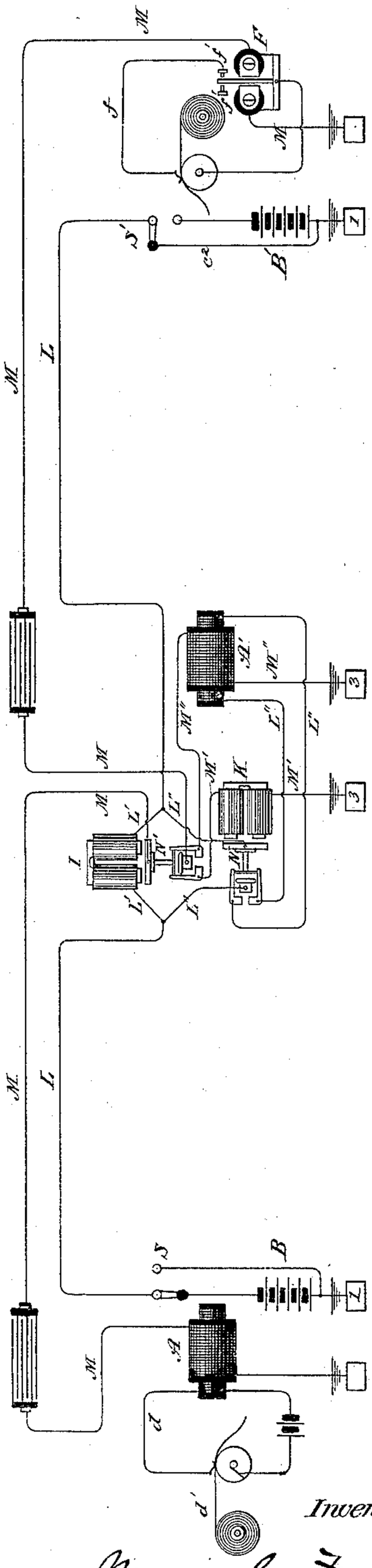


Fig. 5.



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UNITED STATES PATENT OFFICE.

MOSES G. FARMER, OF NEWPORT, RHODE ISLAND.

REPEATER FOR SUBMARINE CABLES.

SPECIFICATION forming part of Letters Patent No. 312,831, dated February 24, 1885.

Application filed July 29, 1884. (No model.)

To all whom it may concern:

Be it known that I, MOSES G. FARMER, a citizen of the United States, and a resident of Newport, in the county of Newport and State of Rhode Island, have invented certain new and useful Improvements in Repeaters for Submarine Cables, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that the capacity of long submarine cables is very limited in comparison with aerial lines of equal length. For instance, in a cable, say, two thousand miles or more in length, it is impracticable to transmit messages at a greater rate of speed than twenty-five or thirty words per minute, and this with the most approved forms of the mirror instrument. With instruments of a less sensitive character the rate is very much less. For instance, with the Morse apparatus the speed of practicable transmission is limited to two or three words per minute. In contrast to this necessarily slow rate is that over aerial lines, which may reach two hundred and fifty words per minute over a line at least two thousand miles long. It has been found that the speed of transmission through submarine or similar cables varies inversely as the square of the length of the line, so that if two words per minute could be transmitted through a cable two thousand miles in length, eight words could be sent in the same time over a cable half as long, thirty-two words over a cable one-fourth as long, and two hundred words over a cable one-tenth as long, or two hundred miles, the speed of transmission under such circumstances being limited to the efficiency of the operators or signaling apparatus rather than by the retardation encountered in the line. The capacity of a cable, therefore, could be increased by dividing it into two or more sections and repeating the signals from one section to the other by apparatus used between the sections at the repeating-stations.

The object of my invention is to provide practicable and efficient means for accomplishing this result.

Heretofore it has not been found practicable to employ more than one repeating-station or repeating apparatus in submarine cables, if any, partly on account of defective construction of the apparatus proposed for this purpose, but mainly on account of the impracticability, if not impossibility, of providing for a local current to be used at the repeating-station. This difficulty, however, I have overcome by the employment of two wires or lines, as I shall more fully hereinafter describe. The other main difficulties hitherto met in all ordinary forms of repeater are the necessity for constant adjustment and the rapid deterioration of the instruments due to oxidation of the points of contact and like causes; but these also I have obviated by the novel construction and mode of operation of the instruments which I have devised.

I will describe first the general nature of the apparatus which forms the subject of my invention, and then indicate more in detail the particular features of novelty which distinguish the same. I use a cable with two wires or lines insulated throughout, and it may be here stated that as the invention applies more particularly to what are commonly known as "submarine cables," the construction of which is well understood and largely a matter of choice, no further description of the precise construction of cable is given. One of the wires is not divided into sections, but forms an unbroken circuit throughout its whole length. The other wire or line, which, to distinguish it from the first or continuous line, is herein designated the "main line," operates the signaling apparatus. These consist, in the main, of a transmitter and receiver at each end, a relay at each repeating-station, that makes and breaks or preferably reverses the current in one of the branches of the local circuit, in which is contained the primary of an induction-coil, and secondary coils, in which impulses of current are induced by the primaries in the continuous circuit. I also use certain accessories for controlling the direction of signaling and for neutralizing the effects of the earth's electricity and the like, which will be hereinafter referred to. The first section of the main line enters the first repeating-station, which is a water-tight box containing the necessary apparatus and connected directly to the cable, and there connects to a switch controlled by the polarized

armature of an electro-magnet in a branch of the continuous line. One portion of this switch carries the main line to a magnet controlling by means of a polarized armature a circuit-reverser in the other branch of the continuous line, from which magnet the line goes to earth. In the branch of the continuous line with the circuit-reverser is also the primary of an induction-coil. The secondary coil has one end grounded and the other connected to the second section of the main line through the polarized switch when the latter is in the position just described. The other repeating-stations are like the first, and it is obvious that an electrical impulse in the first section of the main operates the circuit-reverser in the local branch of the continuous line, and induces thereby a corresponding impulse in the second section of the main, and so on.

The purpose of the polarized switch is to control the direction of transmission, for by reversing the direction of current in the continuous line the switch is shifted to its second position, by which the first section of the main is taken to earth through the secondary of the induction-coil, while the second is carried to earth through the magnet that operates the circuit-reverser—in other words, the section of main wire that previously transmitted the impulses to the next now receives them, and so for all the other sections, however many there may be. It is desirable to use condensers in the main line between the secondary coil and the earth, or between the other end of the secondary and the cable, or both. Such use of the condensers frees the line from the influence of earth-currents partially or wholly, but is not essential to the operation of the system.

Referring now to the drawings, by means of which the invention will be understood in detail, Figure 1 is a diagram of the terminal apparatus of the line in the condition in which it remains while signals are being transmitted therefrom. Fig. 2 is a diagram of the terminal apparatus at the time of receiving. Fig. 3 is a plan view of the repeating box or station. Fig. 4 is a diagram of the circuit with the inactive portions omitted, showing the mode of using the condenser. Fig. 5 is a similar diagram with fewer condensers.

Similar letters and characters indicate corresponding parts in all the figures.

In Fig. 1, which represents for the time being the transmitting-station, B designates the large battery for charging the local line L. By wire *c* it is grounded at 1. A switch, S, connects the continuous line L with its opposite pole or with a shunt, c^2, around the battery to wire *c*.

M designates the main line over which signals are sent. It is grounded at 2 through a switch, E, and the secondary of an induction-coil, A. The primary of this instrument is in a circuit, *a*, containing a circuit-reverser. The latter device consists of a metal block, *a'*, between two pivoted levers, *b* and *b'*; by springs b^2 these levers are drawn toward each other, with a tendency to come into contact with the block *a'*. B^2 is a pivoted lever carrying a polarized armature. To the end of this lever is fixed an arm or plate, B', between the two levers *b* and *b'*, and of slightly greater width than the plate or block *a'*. Lever B^2 is held in a position at right angles to plate *a'* by means of opposing springs a^2, and when in this position it touches both levers, while they are also in contact with the plate *a'*. The wires from the battery C connect to lever B^2 and plate A', respectively, and the ends of the wire, including the primary of coil A, are connected to the levers *b b'*, as shown. The polarized armature is actuated by an electro-magnet, D, in a circuit, *d*, containing a signaling-instrument operated by drawing a perforated strip or tape, *d'*, between two contact-points, or by any other device for producing makes and breaks or reversals of the circuit. These impulses of current actuate the armature B^2, and send corresponding impulses through the circuit *a*, for either one or the other of the levers *b b'* is brought by the movement of the armature into contact with the plate *a'*, while the parts may be so adjusted that a direct current impulse will produce a reversal in circuit *a* by the momentum of the lever B^2 on its backward movement. A more positive movement of this lever would be produced by a reversal of current in the magnet D. These impulses or reversals induce corresponding impulses in the secondary coil of the induction-coil A, which go to line M, and are received at the other end after being repeated at the repeating-stations, as hereinafter described.

Fig. 2 represents the receiving-station for the time being. The instruments are in every respect similar to those at the transmitting-station; but the battery B' of the continuous line is cut out by turning the switch S' onto the shunt-wire c^2, and the transmitting apparatus is disconnected from the main line by switch E', while by the same switch the main line is grounded through the relay of the receiving apparatus. This apparatus consists of a polarized relay, F, the armature of which is in a local circuit, *f*, and vibrates between stops *f' f'*. A switch, *e*, is used to connect either stop *f'* with the local, so that dots or dashes may be read from the chemical receiver G, instead of spaces. Any ordinary form of chemical receiver may be used in the local *f*.

Fig. 3 illustrates one of the repeating-stations. As above stated, I inclose the apparatus in a strong water-tight box, which is represented by the dotted line G'. The cable is severed at the point where it is desired to insert a repeater and its ends joined to the box by proper splicing. In each of the boxes or stations are two instruments, which may be designated as the "director" and the "repeater."

They are both in construction similar in every essential particular to the transmitting apparatus which I have already described, except that I prefer to use in place of the springs b^2 b^2 a permanent horseshoe-magnet, H. This magnet is clamped to a suitable base, with its poles close to the ends of the levers corresponding to b b, which are bent at right angles and made of soft iron, so that the effect of the magnetic attraction upon them will be the same as that of the springs b^2. The wires of the cable are carried into and out of the box at the two points h h'. The wire L is branched after entering the box. One branch, L', passes through the coils of the directing-magnet I, beyond which it joins the other branch, L'', the path of which is through the armature-lever N of the repeater-magnet K, the plate n', and from one of levers i i' to the other through the primary of an induction-coil, A'. The main wire M, after entering the box, is connected to the armature-lever N' of the director-magnet I. From one of the levers, as m', a wire, M', leads to and includes the magnet K, and is then carried out through the box and attached to a plate, 3, or otherwise grounded. From the other lever, m, a wire, M'', is taken. It is connected with the secondary of the induction coil A', and then grounded.

Supposing it be desired to transmit signals from the side of the repeating-station at which the cable enters at h, the mode of operation and the condition of the apparatus are as follows: One pole of the battery B—say the positive—is connected to the line L by the switch S. The battery at the other end, the positive pole of which is also adapted to be connected to line L by switch S', is disconnected, as shown in Fig. 2. The current entering the repeating-station on this line divides, part passing through the coils of magnet I, and the rest through the primary of induction-coil A'. The effect upon the polarized armature is to move the lever m' away from plate o, leaving the other lever, m, in contact with the plate. This carries the main line M through the coils of magnet K and grounds it at 3. An impulse of current coming over the line sets in motion the lever N, and reverses the current in the local branch L'' and through the primary of induction-coil A'—the impulse induced in the secondary of the coil by this means through the grounded wire M'' to the lever m, thence through plate o, and off through the second section of the main wire M to the next repeating-station, where the same operation is repeated. If, now, it be desired to transmit signals in the opposite direction, the battery B is disconnected and B' connected with the line L, so that a current will flow therein in an opposite direction. The polarized armature of magnet I in this event tilts lever N' to a position in which lever m' is in contact with plate o and lever m forced away from it. The branch M' will operate the magnet K, as before. The currents induced in the secondary of induction-coil A' will, however, flow through wire M'', lever m, and lever N' to line.

Figs. 4 and 5 show the general arrangement of the system and the relations of the several parts of the same; but for convenience the receiving apparatus at the left-hand end of the line and the transmitting apparatus at the other are omitted. For the same reason one repeating-station only is shown; but the others, when used, are connected to the cable in a precisely similar manner.

In order to prevent the interference of earth-currents, I sometimes insert a condenser in the main line at both ends of each section, as shown in Fig. 4, or at one end only, as in Fig. 5.

In order to render the system more practicable certain conditions should be observed. Wherever in a line separable contact-points occur, they should be of iridium or some metal possessing like qualities, for although an actual make and break can be avoided by the construction and mode of operation which I have set forth, there is still a liability of exposed metallic surfaces becoming oxidized, which is present to a very slight degree in the case of iridium. It is also inadvisable to rely upon single points of contact. All separable contacts, therefore, should be multiple; for instance, in lieu of using a single lever, as b or b', a number of levers with a common pivotal shaft should be employed.

With reference to specific details of construction, I would state that for a better understanding of the nature of the invention I have illustrated many parts by the ordinary conventional representations that are used therefor. In constructing the apparatus for practical use, however, the relations and adjustments must be fixed and permanent, and the apparatus differs from others of like nature in being so constructed that there will be the least possibility of any alteration taking place. The movable parts must be carefully balanced, so that their operation will be entirely unaffected by the position in which they are held. The inclosing-boxes should have great strength combined with lightness, so as to be capable of withstanding rough usage.

It is desirable to construct the sections of cable that contain the repeating-boxes with special reference to the usage to which they are likely to be subjected, and to splice them to the main sections.

With reference to certain features not specifically described herein, it may be stated that much pertaining to them is left to the discretion of practical users. For instance, it is largely a matter of choice in what manner the transmitting and receiving instruments at the ends of the line are constructed or used, and in what way or by what means the local line is supplied with the requisite current.

The main feature of the invention consists in repeating signals through the instrumentality of induction-coils, the primaries of

which are included in an unbroken circuit coextensive with the signaling-line or the sections thereof, and by producing such electrical changes in each primary coil as will induce impulses in the secondaries. The other parts of the invention consist in the means for accomplishing this and in the accessory devices that contribute to their proper and successful operation.

What I claim is—

1. The combination, with a cable containing a continuous line and a sectional main line or wire, of one or more devices for repeating signals from one section of the main to another, each consisting of a primary coil in the continuous line, means for reversing the direction of current through the coil connected with and operated by one section of the main and a secondary coil in the next succeeding section, all substantially as set forth.

2. The combination, with a cable containing a continuous line and a sectional main line or wire, of one or more devices for repeating signals from one section to another, each consisting of a primary coil in the continuous line, means for reversing the direction of current through the coil included in one section of the main, a secondary coil in the next succeeding section, and apparatus operated by the local for transferring the circuit-reverser and secondary coil from one section of the main to the other, all substantially as set forth.

3. A repeater for submarine electric cables, consisting of the following instrumentalities, to wit: an induction-coil, means for reversing the direction of the current through its primary, an electro-magnet for controlling the same independent of the primary coil, and an electro-magnetic switch or director in a branch of the primary circuit for connecting the said magnet and the secondary coil with either of two circuits, respectively, all as set forth.

4. The combination, with a cable containing a continuous line and a sectional main wire or line, of one or more devices for repeating signals from one section of the main to the next, consisting of a primary coil in a branch of the continuous line, means for reversing the direction of current in said branch included in one section of the main, a secondary coil in the next succeeding section, and an electro-magnetic switch or director included in a second branch of the continuous line for transferring the circuit-reverser and secondary coil from one section of the main to the other, all substantially as set forth.

5. The combination, with an electrical cable containing a continuous line and a sectional main wire or line, of one or more devices for repeating signals from one section of the main to the next, each consisting of a primary coil in a branch of the continuous line, a device for reversing the current through said branch, a magnet in one section of the main for controlling said device, a secondary coil in the next succeeding section, and an electro-magnetic switch or director for grounding the sections through the secondary and the circuit-reverser, respectively, as and for the purpose specified.

6. The combination, with an electrical cable containing a continuous line, and a sectional main wire or line, of one or more repeaters consisting of a primary coil in a branch of the continuous line, a device for reversing the current through said branch, a magnet in one section of the main for controlling said device, a secondary coil in the next, an electro-magnet with polarized armature in a second branch of the local, and a switch or director for grounding the sections through the secondary and the circuit-reverser, respectively, all as set forth.

7. The combination, with a cable containing a continuous line and a sectional main line or wire, of one or more repeaters, consisting of a primary coil in the continuous line, a circuit-reverser for changing the direction of the current in the primary, and connected with one section of the main, a secondary coil included in the next succeeding section, and condensers inserted in the sections of the main, as and for the purpose specified.

8. The combination, with a grounded section of a main line, M, a magnet, K, included therein, and a circuit-reverser operated by the said magnet, of a primary coil in a circuit coextensive with the main line, the current in which is sent through the primary in opposite directions by the circuit-reverser, and a secondary coil in the next branch of the main line M, all substantially as set forth.

9. The combination, with a cable containing a continuous line and a sectional main line, of a primary coil in the continuous line, means for reversing the direction of current through the coil, an electro-magnet for controlling said means included in one section of the main line, and a secondary coil in the next section, the sections being grounded through the magnet and secondary, respectively, as set forth.

In testimony whereof I have hereunto set my hand this 23d day of July, 1884.

MOSES G. FARMER.

Witnesses:

JOHN C. LANG,

WILLIAM B. HEATHERTON.