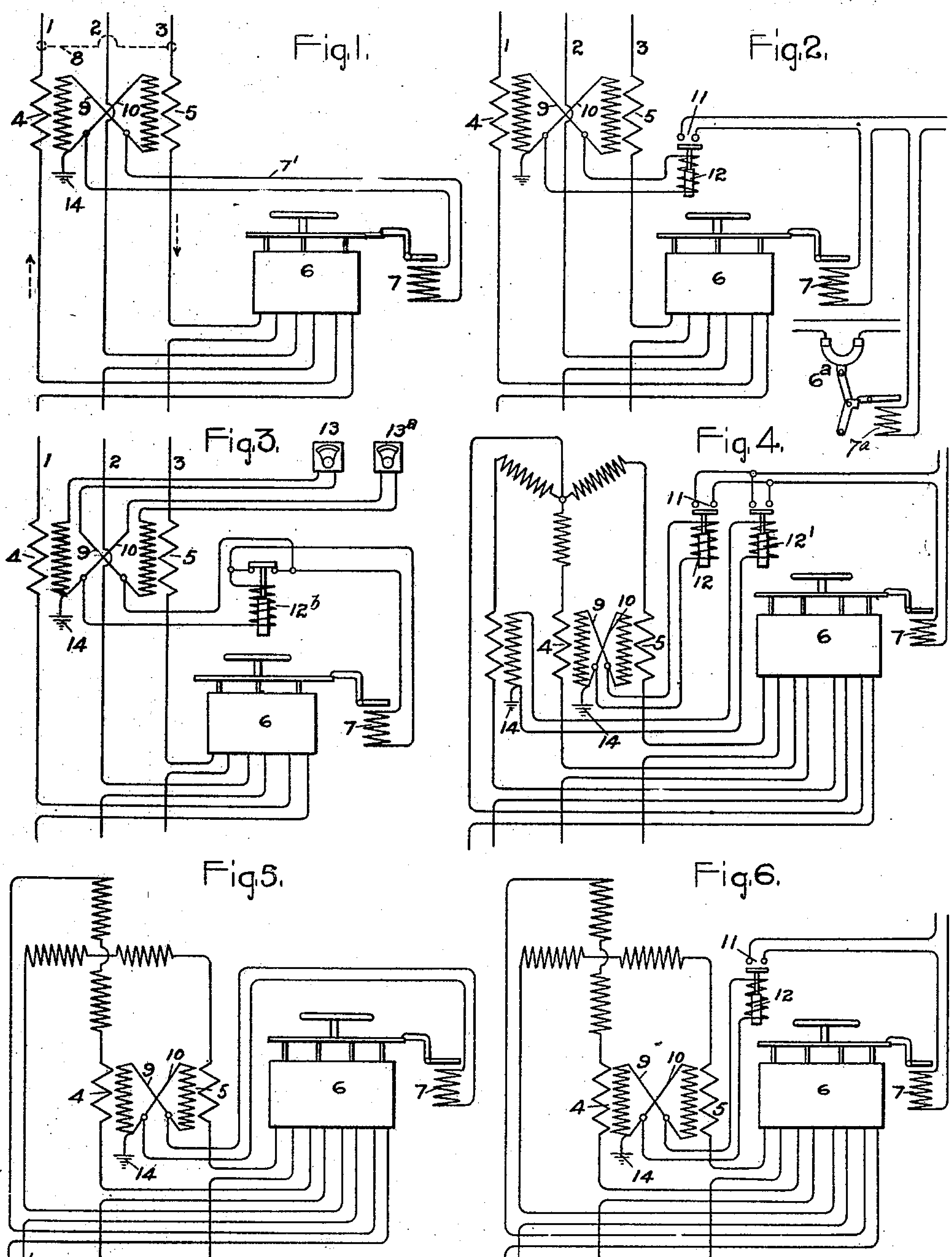
No. 827,353. PATENTED JULY 31, 1906.

C. E. EVELETH.

CONTROLLING ELECTRIC SWITCHES.

APPLICATION FILED OCT. 3, 1903.

3 SHEETS—SHEET 1.

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3 SHEETS—SHEET 2.

Fig. 7.

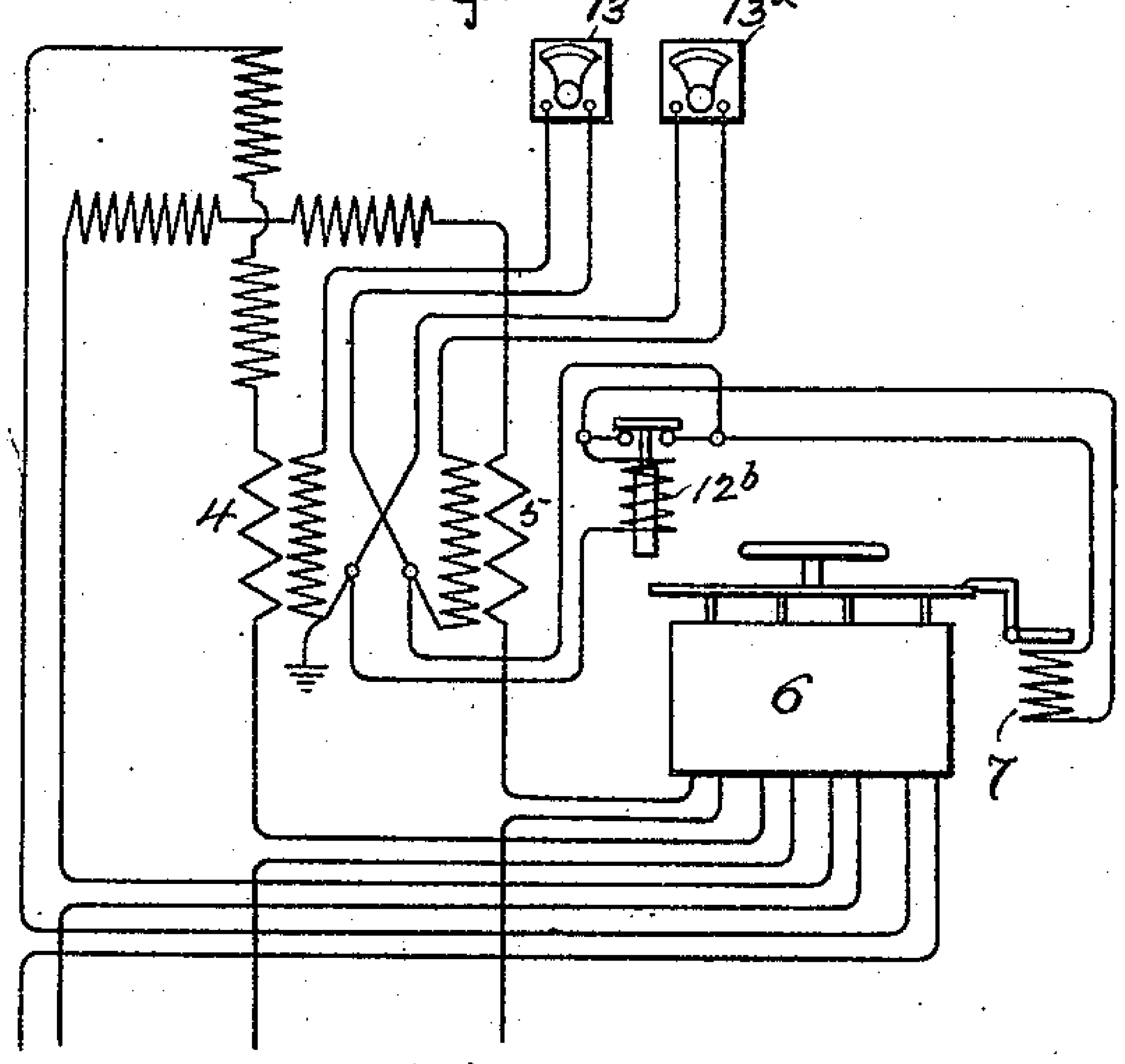



Fig. 8.

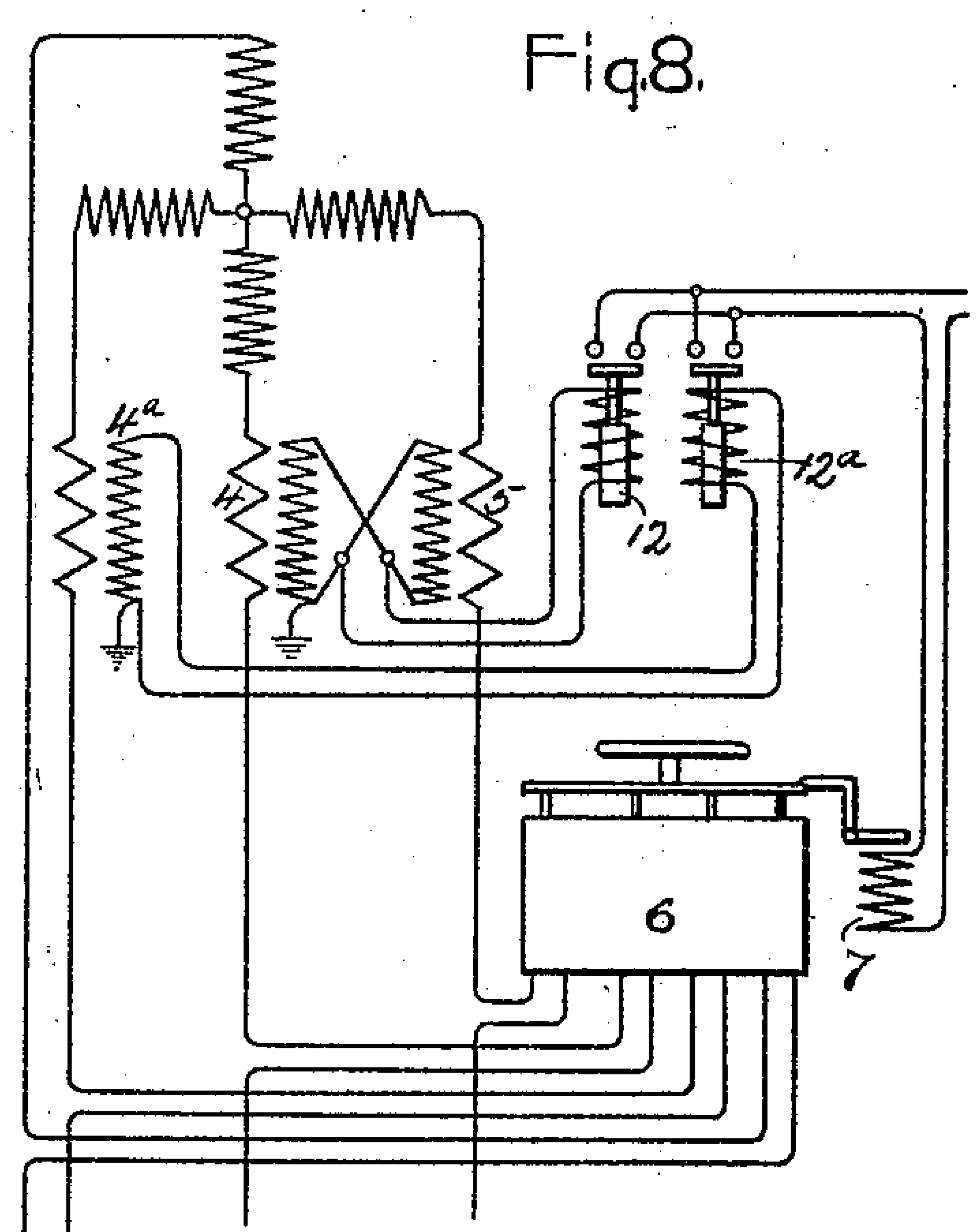



Fig. 9.

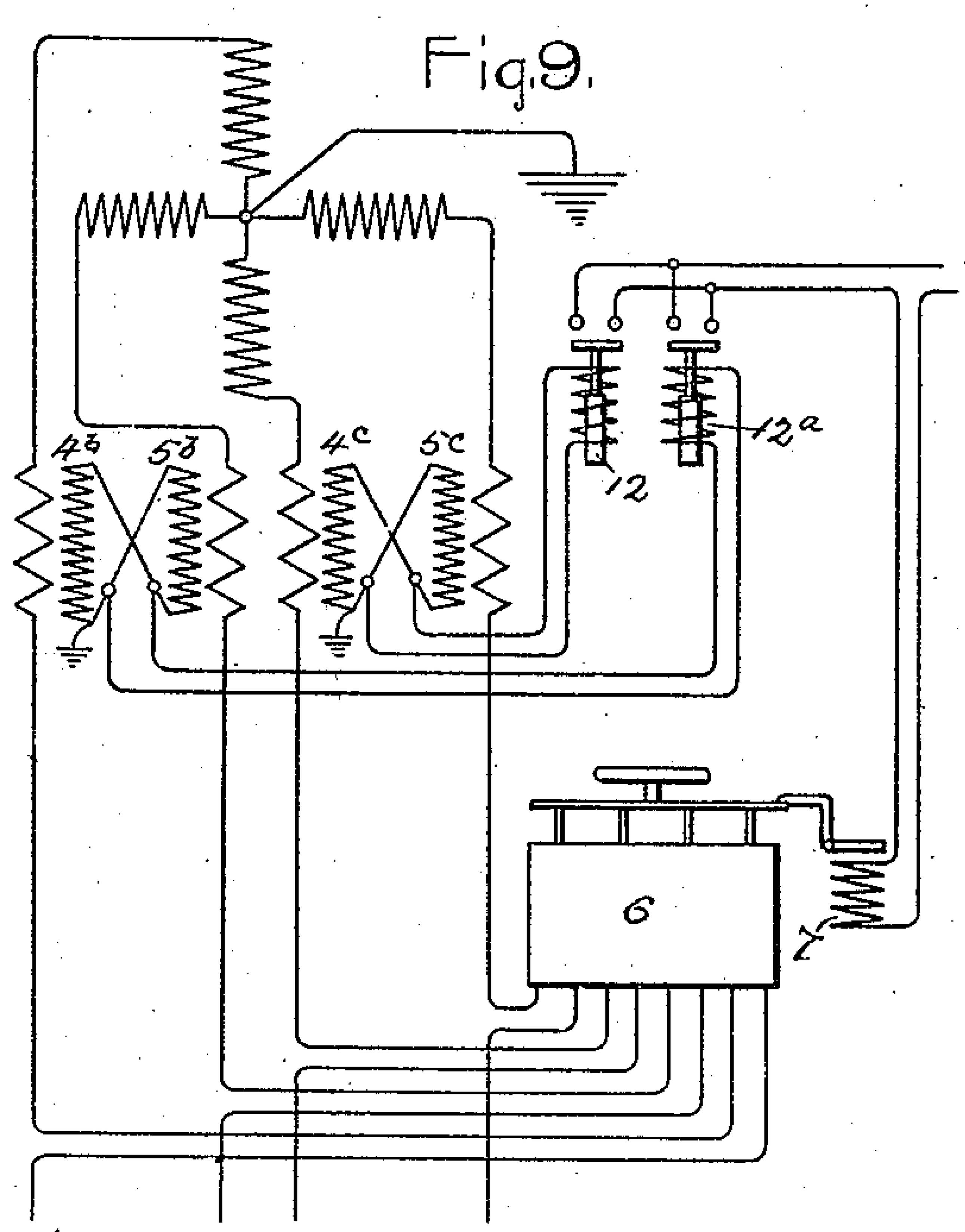
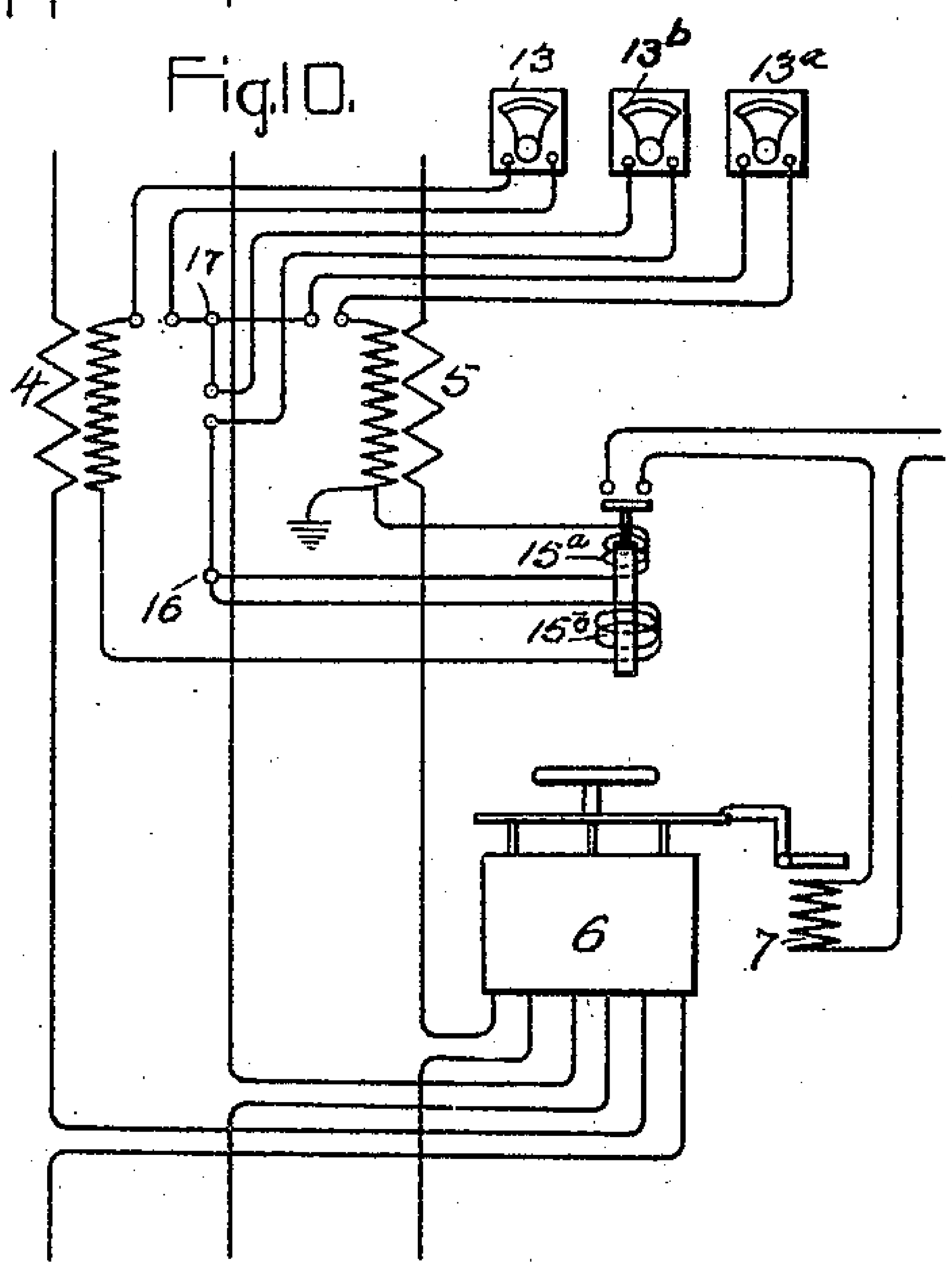



Fig. 10.

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3 SHEETS—SHEET 3.

Fig. 11.

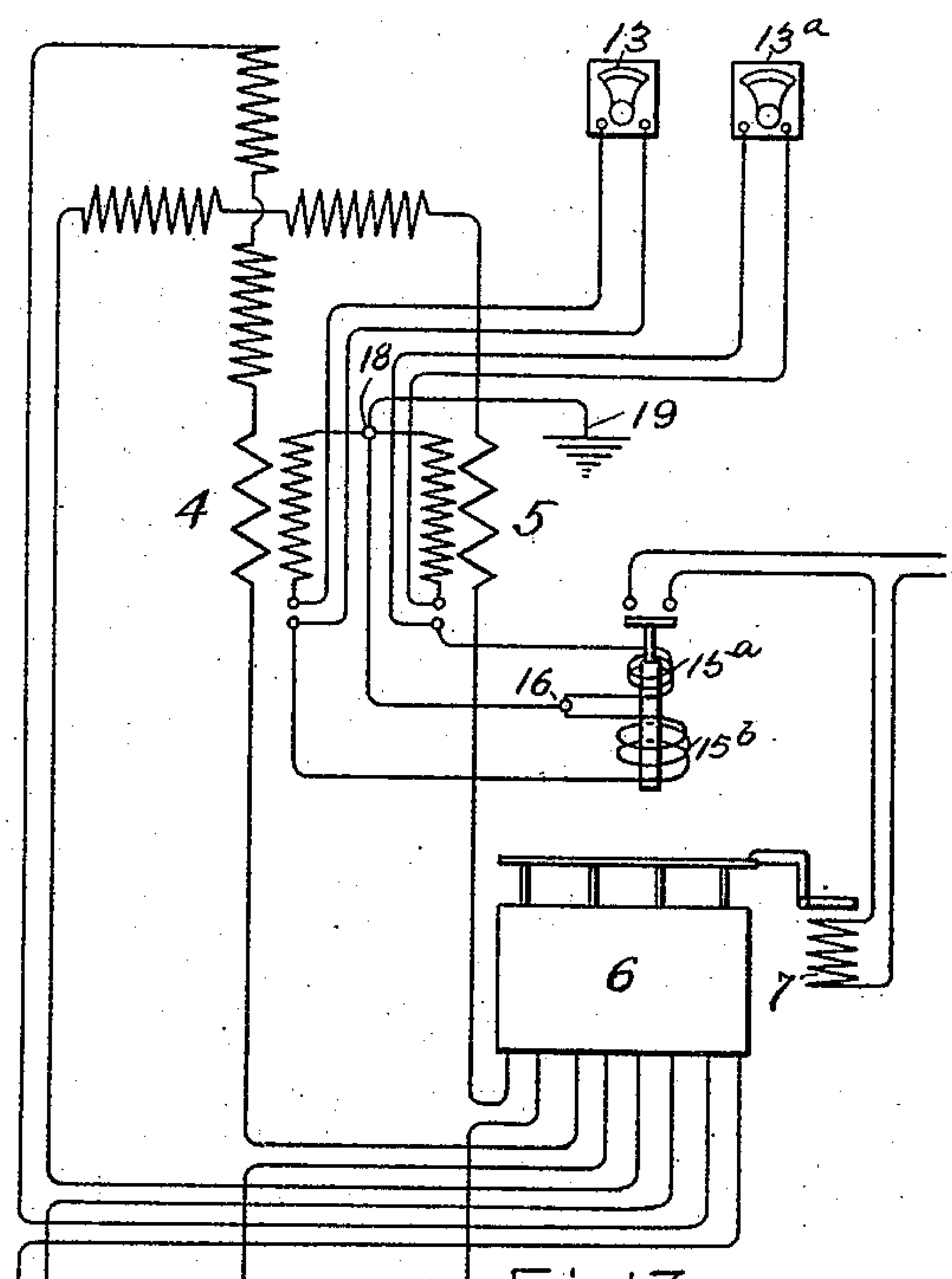



Fig. 12.

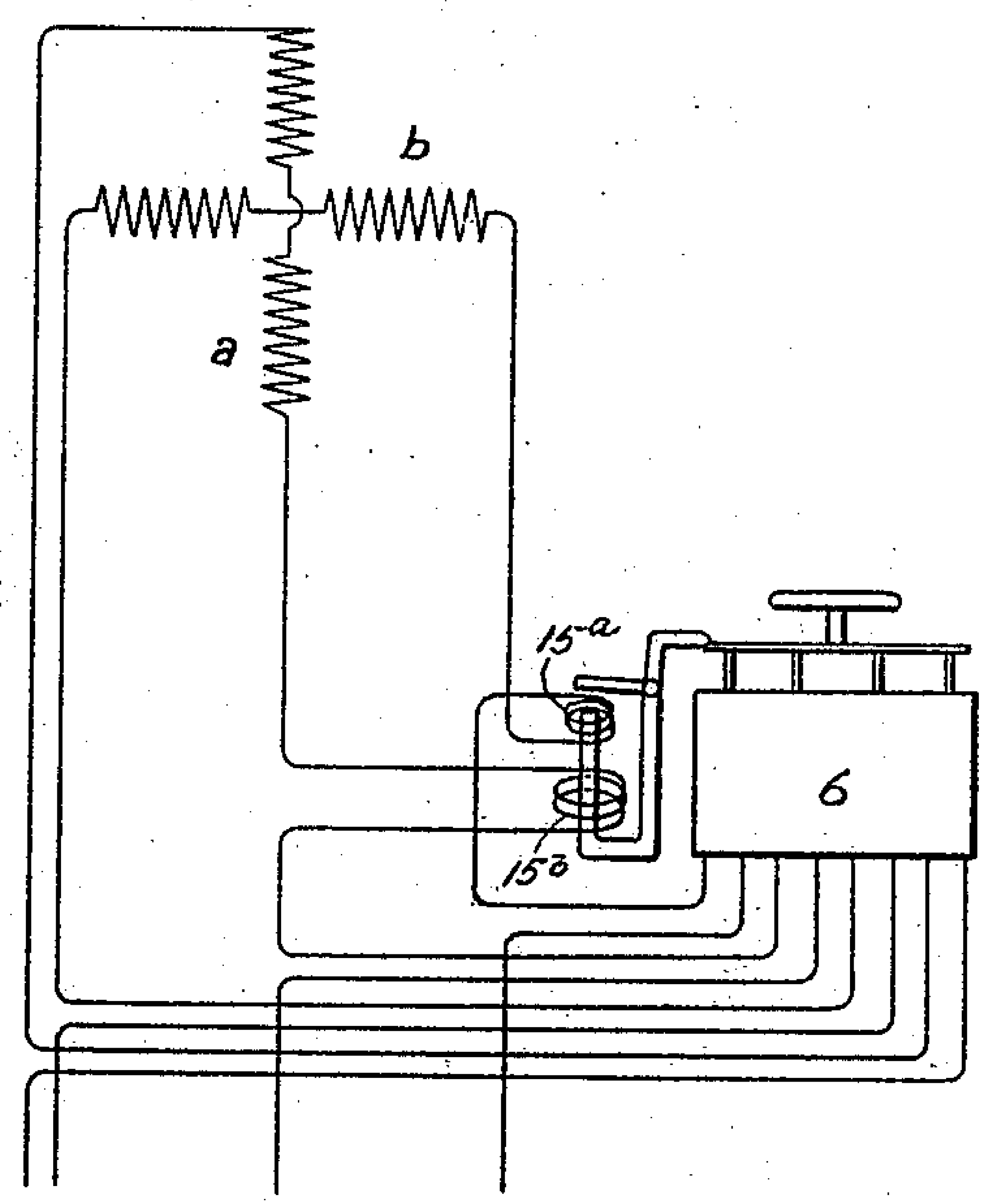
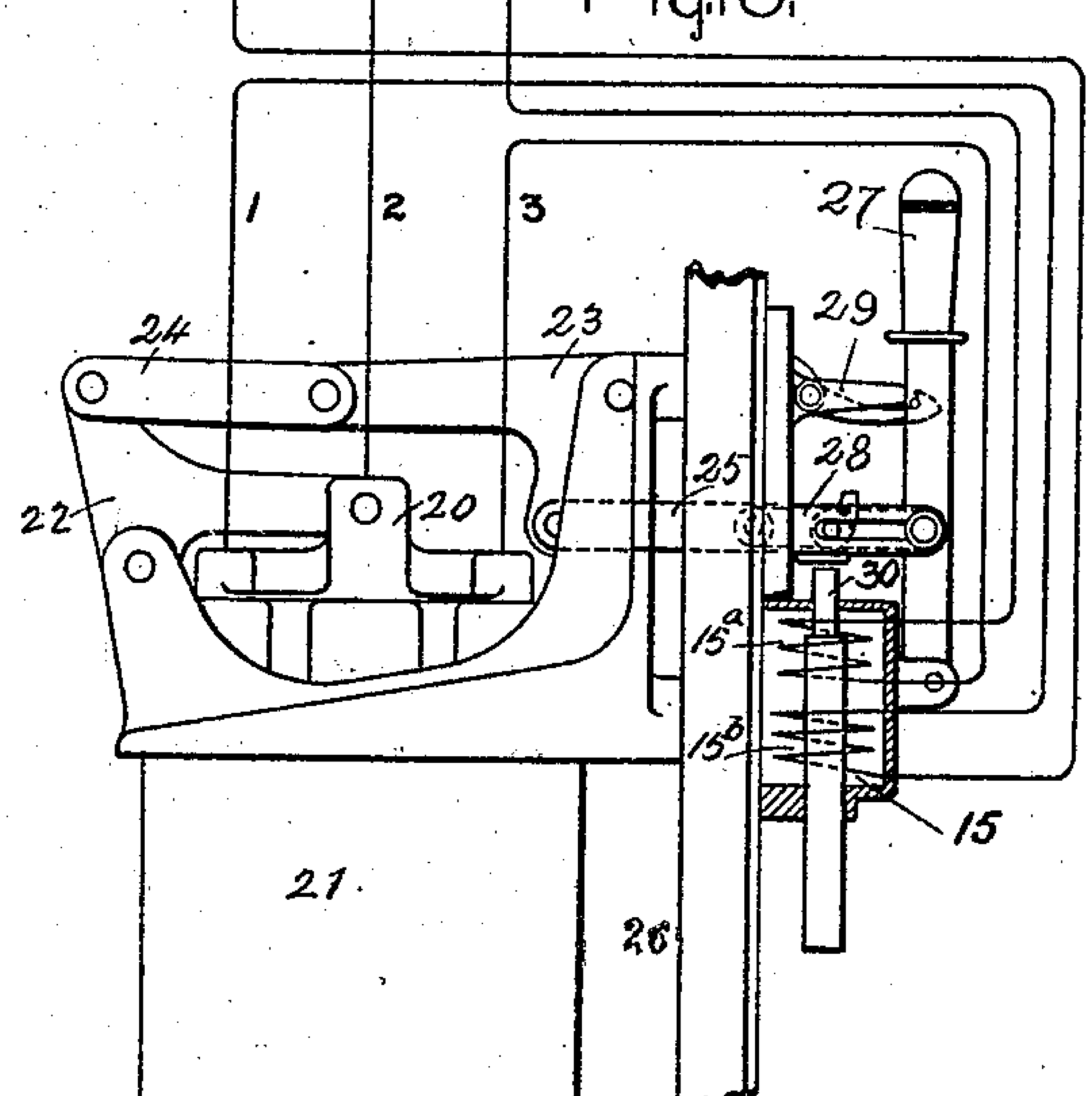



Fig. 13.

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# UNITED STATES PATENT OFFICE.

CHARLES E. EVELETH, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## CONTROLLING ELECTRIC SWITCHES.

No. 827,353. Specification of Letters Patent. Patented July 31, 1906.

Application filed October 3, 1903. Serial No. 175,579.

*To all whom it may concern:*

Be it known that I, CHARLES E. EVELETH, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Controlling Electric Switches, of which the following is a specification.

In distributing polyphase alternating electric currents it is now the practice to employ series transformers in the several lines to operate a trip-coil and open a main switch when a dangerous overload occurs, and in order to reduce cost only a sufficient number of such transformers is employed to assure an opening switch movement in case any line is overloaded. Thus in triphase systems two such transformers only need be employed, since if any of the three lines is overloaded one of the transformers will respond. It has been found, however, that while such an arrangement operates reliably under most conditions of overload it will not do so when a short circuit occurs between the two lines in which the transformers are interposed unless each transformer is provided with a separate trip-circuit.

It is the object of my invention to provide a system in which a minimum number of transformers and a single trip-circuit may be used.

My invention consists in so coördinating the phases, either in the transformers themselves or in the circuit, that any change of phase relation under a short circuit cannot operate to prevent a heavy current flowing in the trip-circuit. Suppose, for example, a short circuit to occur between two lines of a triphase system in which are placed two series transformers. Evidently the energy of these two lines instead of passing to the distributing-station will pass directly through the transformers. The short circuit destroys the phase difference on the lines and the electromotive forces are no longer displaced one hundred and twenty degrees, but are one hundred and eighty degrees apart. In other words, when the short circuit occurs the two lines in which the transformers are connected form a single-phase circuit, the current at an assumed instant passing out through one transformer and in through the other. Hence the two transformers will be pitted against each other or "buck" one another, and the voltage in the trip-circuit will be reduced to zero or to a low value, depending on the severity of the short circuit. The switch will therefore fail to trip and the safety apparatus be endangered. Now I have found by repeated tests that this possibility can be avoided by reversing the connections of the transformers with relation to the trip-magnet, and this may be effected by relatively reversing the primary windings or the secondary windings or different sections of the trip-coil The result of this system of connections is that when the phase relations are destroyed by a short circuit the two electromotive forces no longer oppose one another at an angle of one hundred and eighty degrees, but act together in phase or with such difference as may result from the nature of the short circuit. Thus in a triphase system the currents in two lines have a phase difference in normal operation of one hundred and twenty degrees; but by reason of my reverse system of connections the trip-circuit carries a resultant not of two currents one hundred and twenty degrees apart, but of two currents sixty degrees apart, since the transformers are cross-connected, thus shifting one phase one hundred and eighty degrees and bringing the two phases nearer together. This system of connections operates with just as great a degree of certainty for moderate overloads as those using independent trip-circuits; but in the case of short circuits it acts also with reliability, and thereby affords equal security at less expense of equipment.

My invention may be applied to polyphase systems of any order, as quarter-phase, triphase, &c., and three, four, or more lines, as will be hereinafter fully set forth.

My invention therefore comprises a trip system for an electric switch in a polyphase circuit in which several current phases are combined to maintain an effective trip-current in case of short circuit between the lines.

It comprises also connection in such a system for normally shifting the phases one hundred and eighty degrees relatively to one another on the trip-magnet, either by direct or remote means, so that in case of reversal of current under short circuit an effective working phase difference will be always maintained.

The several features of novelty will be more particularly pointed out hereinafter.

In the accompanying drawings, Figure 1 shows a simple embodiment of my invention in an ordinary triphase circuit. Fig. 2 shows a similar embodiment with a local source of trip-current. Fig. 3 shows an embodiment where the trip-current is furnished by the alternating lines; but the trip-coil is normally short-circuited to promote a better action of the measuring instruments. Fig. 4 shows an application of my invention to a four-wire triphase system. Fig. 5 shows an application to a quarter-phase system where the two currents have independent circuits. Fig. 6 shows a system similar to Fig. 5, having an independent source of trip-current. Fig. 7 shows a quarter-phase system in which the trip-coil is normally short-circuited, as in Fig. 3. Fig. 8 shows an equipment suitable for an interconnected quarter-phase system. Fig. 9 shows an equipment suitable for an interconnected quarter-phase system having a grounded neutral. Fig. 10 shows an application to a triphase system in which the phases are magnetically interlinked on the core of the trip-magnet. Fig. 11 shows the same arrangement as Fig. 10 in a quarter-phase system. Fig. 12 shows an embodiment of the invention without the use of current-transformers, and Fig. 13 shows an application of the invention to a standard type of oil-switch.

Referring first to Fig. 1 of the drawings, 1, 2, and 3 represent a triphase circuit, and 4 and 5 series transformers. 6 is an oil-switch adapted, when set, to be opened by the trip-coil 7. With two series transformers obviously under ordinary overload in any of the three mains the transformers would transfer to one or the other secondary a heavy current and the switch would be tripped; but if a short circuit occurred between the lines 1 and 3 at a point 8 between the generating and distributing stations energy would flow out on one line and directly back to the generator through the short circuit. Thus the normal phase difference between the coils 4 and 5 would be destroyed partially or wholly and, as indicated by the dotted arrows, current would be reversed relatively in the two transformers. Thus if the secondaries were similarly related to a common trip-circuit the two opposing electromotive forces would neutralize each other. I counteract this by cross-connecting the wires 9 and 10. With this arrangement a common trip-circuit 7′ may safely be used. The phases being normally one hundred and twenty degrees apart in the main circuit are now combined in the trip-circuit sixty degrees apart, giving a resultant current in the trip-coil of approximately 1.73 times that of either secondary. It is not absolutely necessary that this reverse relation should be made in the secondaries. It might be made in the primary or on the trip-coil, as will be hereinafter shown. In any case the phases must be relatively reversed and brought to a phasal relation in which under a short circuit a greater than normal current will flow on the trip-coil. This system of connections has other advantages besides rendering a single trip-circuit for all lines available. As indicated above, the phases are normally acting at sixty degrees instead of one hundred and twenty degrees, and thus less energy is required of the transformers, permitting smaller transformers to be used, or if standard current-transformers are used the readings of the measuring instruments used in the system have less error, due to less load on the transformers.

In Fig. 2 the tripping energy is furnished by an auxiliary circuit normally open at a point 11, and the transformers act on a relay 12 when overloaded to close the circuit. In addition to the oil-switch 6, with its trip-coil 7, an ordinary toggle-operated circuit-breaker $6^a$ is here shown, having a trip-coil $7^a$, also operated by said relay 12. Obviously it is immaterial what may be the type of apparatus in the circuit governed by the current-transformers so long as it acts only when excessive loads are carried by the transmission-lines. The breaker $6^a$ may control any desired circuit which in the operation of the system it is desired to open when the oil-switch is open—as, for example, the direct-current circuit of a rotary transformer fed from the alternating system in which the oil-switch is included.

It is customary to include in the trip-circuit measuring instruments such as ammeters and wattmeters. Where a number of meters are used, it is often found that the trip-coil requires so much energy that an error is involved in the meter indications. To avoid this, a relay of small energy capacity with its contacts normally short-circuiting the trip-coil may be used. This arrangement is shown in Fig. 3, where 13 $13^a$ are ammeters measuring the current of the transformers and $12^b$ the relay. Obviously the trip-coil takes energy only when overload occurs, and thus the accuracy of the measuring instruments is normally not disturbed.

In Fig. 4, representing a four-wire three-phase transmission system, a current-transformer for each phase is employed. Two of the transformers in this case have their connections crossed and govern a common relay or trip device, while the third governs an independent trip device 12′. In all cases I prefer to ground the secondaries of the transformers, as indicated at 14, for reasons of safety, as is the usual practice.

In Figs. 5 and 6 are represented a quarter-phase or two-phase transmission system having disconnected phases, Fig. 5 showing the cross-connected transformers 4 and 5 controlling the trip-coil 7 directly and Fig. 6 through a relay 12. Fig. 7 represents such a quarter-phase system with ammeters 13 $13^a$ connected up with each secondary of the transformers 4 and 5, the trip-relay $12^b$ normally short-circuiting the trip-coil 7, as in Fig. 3, to conduce to more accurate indications.

Fig. 8 shows an arrangement suitable for a quarter-phase interconnected transmission-line. Three of the lines here include transformers 4, $4^a$, and 5, the transformer $4^a$ controlling a separate relay $12^a$, the other two having their connections crossed and controlling the relay 12.

In Fig. 9 is represented a grounded quarter-phase system. Here it becomes necessary for reliable operation to insert a transformer for each line, (designated $4^b$ $5^b$ $4^c$ $5^c$,) the two pairs $4^b$ $5^b$ and $4^c$ $5^c$ being cross-connected and each pair controlling a trip device 7 through the relay 12 $12^a$. A similar arrangement would answer for a five-wire quarter-phase interconnected system.

Fig. 10 shows a system in which the phases are "crossed," so to speak, magnetically—that is to say, two magnetomotive forces due to the transformers have their phases relatively reversed. This may be effected by making two windings $15^a$ $15^b$ or a split winding and connecting with the secondaries of the transformers 4 and 5, so that the coils are reversely connected relative to the corresponding transformer-poles. For example, one pole of one transformer is connected to the lower end of one coil and a like pole of the other transformer is connected to the upper end of the other coil. Thus the magnetic fluxes are relatively shifted one hundred and eighty degrees, bringing the phases of magnetomotive force sixty degrees instead of one hundred and twenty degrees apart. This arrangement provides an advantage over those hereinbefore described in admitting of the use of three ammeters or wattmeters 13 $13^a$ $13^b$. With the usual connection in a three-phase circuit of two-current transformers it is customary to use three ammeters on a trunk-circuit from which various single-phase feeder-circuits are supplied. The system shown in Fig. 10 accomplishes the same thing with a single trip-circuit and two transformers. As clearly shown, the coils $15^a$ $15^b$ are connected between the common junction-point and the poles of the transformer-secondaries, as previously indicated. The ammeters 13 and $13^a$ are in turn connected between the opposite poles of the transformer-secondaries and a common junction-point 17, while the third ammeter $13^b$ is connected between the points 16 and 17. The third ammeter $13^b$ will carry a phase one hundred and twenty degrees displaced from each of the others. As will be evident upon careful inspection, the instrument $13^b$ carries a resultant of the currents flowing through the other two, being included in a wire leading from the point 17 between the other two instruments to the middle point 16 of the trip-relay coil. Thus the two currents are combined and have a value equal to that in the third main. The trip-coils are reversely connected on the core and are therefore magnetically combined at sixty degrees. Fig. 11 represents a quarter-phase system in which the same combination of magnetomotive force is effected in the trip-relay coils $15^a$ $15^b$, the middle point 16 of the trip-coil being connected to like terminals of the two transformers 4 5 and thence to the ammeters 13 $13^a$. In this case the opposite poles of the transformer-secondaries and the middle point 16 of the relay-coils are connected together at the point 18 and grounded, as indicated at 19.

In Fig. 12 the current from the lines enters the trip device directly. Two independent coils $15^a$ $15^b$ are here employed on the trip device, being reversely connected, as in the case of the transformer-secondaries—that is to say, the connections are such that if the coils are similarly wound, as illustrated, phase *a* enters at the top of its coil $15^b$ and phase *b* at the bottom of its coil $15^a$.

In Fig. 13 a standard type of oil-switch is shown provided with a trip-magnet 15, having two independent trip-coils $15^a$ $15^b$, reversely connected relatively to two phases of a triphase transmission-line. In this construction the moving contacts are carried by a yoke and vertically reciprocated into and out of engagement with fixed contacts located in the oil-can 21 by means of a connecting system comprising the bell-cranks 22 23 and the links 24 25. The outer end of the link 25, which extends through a suitable opening in the switchboard 26, is connected to the operating-lever 27 by a pin-and-slot connection. A toggle 28 (shown in dotted lines and connected between the link 25 and the lever 27 when in the position illustrated) is slightly overset, so as to maintain a rigid connection between said lever and link. The lever 27 is held in its closed position by a latch 29, and the moving solenoid-core by striking the center of the toggle 28 breaks it in case of an overload, and therefore frees the link 25 from its rigid connection with the lever 27 and allows the switch to open under the action of gravity.

Thus it will be observed that I may combine either the electromotive forces of two lines in a common circuit or two magnetomotive forces impressed by the lines on a common core, the trip energy in all cases being a resultant of relatively reversed phases, so that under a short circuit and, in fact, under all conditions of overload a greater than normal energy is exerted on the trip mechanism and the switch opened reliably.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In a polyphase alternating-current transmission system, a switch, a trip-circuit, and connections for bringing the phases closer together in the trip-circuit to develop an abnormal flux in the trip-circuit under all conditions of excessive current in the lines.

2. In a polyphase alternating-current transmission system, a switch, a trip-circuit therefor, and connections for relatively reversing a plurality of phases in the trip system and thereby assuring opening of the switch under overload.

3. In a polyphase alternating-current transmission system, a switch, a trip device therefor, and relatively reversed connections between different lines and the trip device to maintain current in the latter when the line-phases shift under short circuit.

4. A polyphase alternating-current system provided with a switch, and a trip device therefor, two of the line phases being connected in relatively reverse directions to magnetize said trip device.

5. A polyphase alternating-current system provided with a switch for opening the lines, a trip device therefor, two of the line-currents acting in common on said trip device, and connections for shifting their phases relatively one hundred and eighty degrees.

6. A polyphase alternating-current system provided with a switch for opening the lines, a trip-circuit common to several phases, and connections combining said phases on the trip device with their phase angle increased by one hundred and eighty degrees.

7. A polyphase alternating-current system provided with a switch for opening the lines, two series transformers interposed therein, a common trip-circuit supplied by said transformers, and connections for shifting the phases relatively one hundred and eighty degrees.

8. A triphase alternating-current system provided with a switch for opening the lines, two series transformers interposed in two of the lines, a common trip-circuit supplied from the transformers, means for shifting the phase relation relatively one hundred and eighty degrees in the trip-circuit, and a measuring instrument for each line connected with the trip-circuit.

9. A triphase alternating-current system provided with a switch for opening the lines, two series transformers interposed in two of the lines, a common trip system supplied from the transformers, means for shifting the phase relation relatively one hundred and eighty degrees in the trip system, and three measuring instruments, two direct-connected with the respective transformers and the third in a combined circuit carrying a current resulting from the two.

In witness whereof I have hereunto set my hand this 1st day of October, 1903.

CHARLES E. EVELETH.

Witnesses:

ALEX. F. MACDONALD,
HELEN ORFORD.