No. 783,514. PATENTED FEB. 28, 1905.

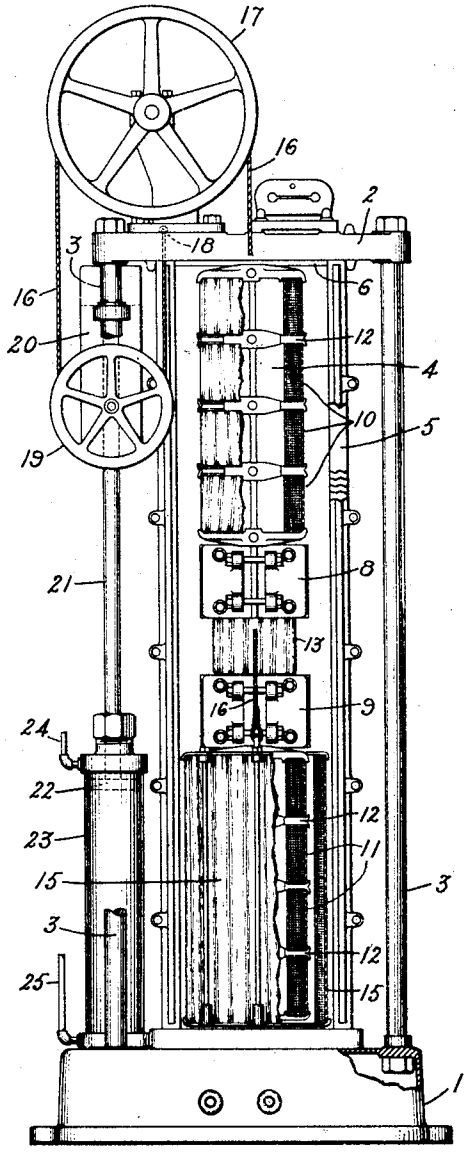
R. FLEMING.

REGULATOR.

APPLICATION FILED APR. 25, 1904.

2 SHEETS—SHEET 1.

Fig. 1.



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2 SHEETS—SHEET 2.

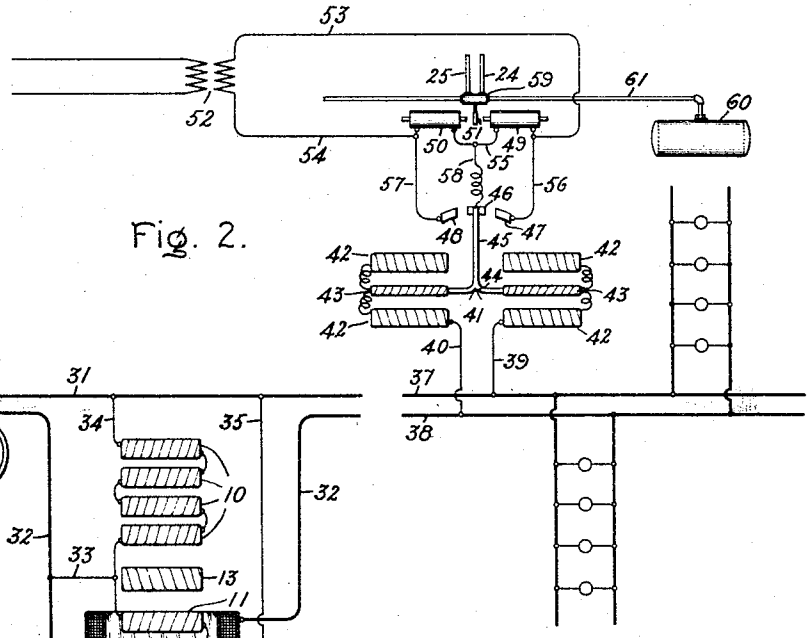


Fig. 2.

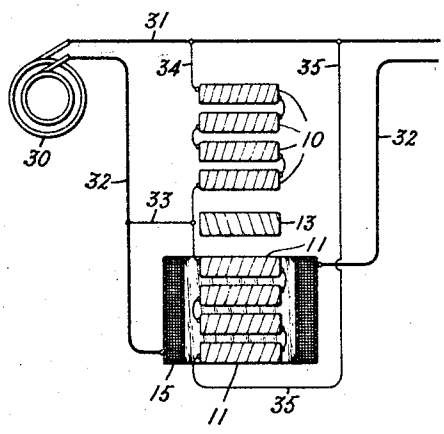


Fig. 3.

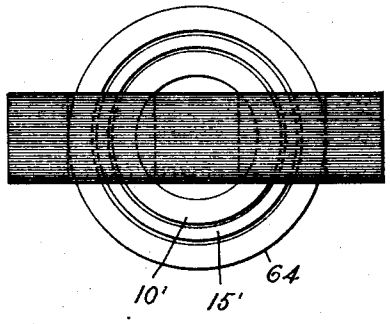
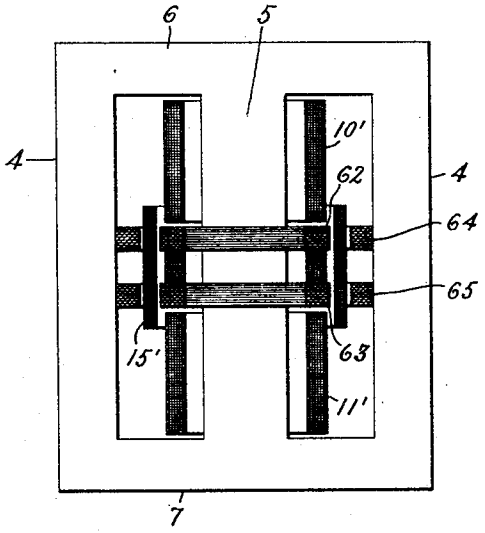


Fig. 4.



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No. 783,514. Patented February 28, 1905.

UNITED STATES PATENT OFFICE.

RICHARD FLEMING, OF LYNN, MASSACHUSETTS, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

REGULATOR.

SPECIFICATION forming part of Letters Patent No. 783,514, dated February 28, 1905.

Application filed April 25, 1904. Serial No. 204,713.

To all whom it may concern:

Be it known that I, RICHARD FLEMING, a citizen of the United States, residing at Lynn, county of Essex, State of Massachusetts, have invented certain new and useful Improvements in Regulators, of which the following is a specification.

My present invention relates to means for regulating the electrical condition of electric circuits.

More particularly, my invention relates to means for regulating the voltage of an alternating-current-supply circuit, though all of the features of the invention are not limited to use in such a relation.

In carrying out my invention I have devised a construction in which means are employed for varying the inductive relations between a movable winding and a fixed winding or windings. One of these windings, which I call the "secondary" winding, is arranged to combine the electromotive force induced in it with that of the main source of electromotive force in a circuit, and I regulate the voltage of said circuit by varying the voltage induced in the secondary winding. The primary and secondary windings are so arranged that without changing the electrical connection for either of said windings I may not only vary the amount of electromotive force induced in the secondary winding, but I may vary its direction.

My invention comprises many novel features of construction and arrangement, all of which are pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, however, reference may be had to the accompanying description and drawings, in which I have described and illustrated one embodiment of it.

In the drawings, Figure 1 is an elevation with parts broken away and in section, showing the voltage-changing mechanism proper. Fig. 2 is a diagram showing the electrical circuits of the regulator as a whole; and Fig. 3 is a plan and Fig. 4 an elevation showing a modified form of magnetic circuit, parts being broken away and in section in both views.

Referring particularly to Fig. 1 of the drawings, 1 represents a base which may be formed of cast-iron or the like, and 2 represents a cap-piece or platform connected to the base by a number of bolts or posts 3. Between the base 1 and the platform 2 is secured a core 4 in the form of a laminated vertical mass or leg of magnetic material. Two similar vertical legs or masses 5 are placed one at each side of the core 4. The three legs are connected at their upper and lower ends by suitable cross-pieces or yokes 6 and 7, respectively. Enlarged pole-pieces 8 and 9 are carried by the core 4 a short distance respectively above and below its center. A number of coil-sections 10 are located on the core 4 above the pole-pieces 8, and similar coil-sections 11 surround the core 4 between the pole-pieces 9 and the base 1. The coil-sections 10 and 11, which together form the primary windings, are secured in place by brackets 12, carried by the leg 4. The outer surfaces of the coils 10 and 11 are substantially flush with the outer surface of the pole-pieces 8 and 9. A heavy short-circuited conductor 13 is wound about the leg 4 between the pole-pieces 8 and 9, for a purpose to be hereinafter explained. A movable coil 15 also surrounds the leg 4. This coil is so proportioned that it may be moved freely up and down without engaging the side legs 5 or the outer surfaces of the coils 10 and 11 or polar projections 8 and 9. The coil 15 is supported at its ends by flexible cords or cables 16, which pass over large pulleys 17, carried by and above the platform 2. The ends of the cords or cables 16 are secured to the platform 2, as indicated at 18. The cords 16 between the pulleys 17 and the points at which they are secured to the platform 2 pass around grooved wheels 19. The wheels 19 are carried at the ends of a weight 20, which slides up and down on the rods 3. The weight 20 acts as a counterbalance for the weight of the coil 15. A piston-rod 21 is connected at its upper end to the weight 20. The lower end of the piston-rod 21 is

connected to piston 22, which reciprocates in a cylinder 23. Suitable pipes 24 and 25 are employed for admitting some fluid, such as compressed air, into the cylinder 23 above or below the piston 22, as may be desirable. When air is admitted to the cylinder above the piston 22, the piston will be moved downward. This will raise the coil 15. When air is admitted into the cylinder 23 below the piston, the latter will be raised and the coil 15 lowered. The range of the piston should be great enough to move the coil 15 from its extreme lower position (shown in Fig. 1) to a position in which its upper end is just beneath the under side of the platform 2. With the construction shown the movement of the piston will of course need to be only half that of the coil.

Referring to Fig. 2 of the drawings, 30 represents a generator of alternating current, to the brushes of which conductors 31 and 32 are connected. The coil 15 is connected in series in the line 32. The coil-sections 10 are connected in series with each other, as are the coil-sections 11. A conductor 33 connects one terminal of the lower coil-section 10 and one terminal of the upper coil-section 11 to the line 32. A line 34 connects one terminal of the upper coil-section 10 to the line 31, and a line 35 connects one terminal of the lower coil-section 11 to the line 31. Lines 37 and 38 represent the conductors of working circuits which are connected to the conductors 31 and 32 at points which may be remote from the place where the regulator is located. It will of course be understood that the working conductors may be connected to the lines 31 and 32 directly or through suitable translating devices. Lines 39 and 40 connect the terminals of a potential balance 41 to the lines 37 and 38, respectively. The potential balance, which may be of any well-known form, is shown in diagram as similar to the well-known Kelvin balance comprising fixed coils 42 and movable coils 43, all of said coils being in series with one another. The movable coils 43 are rigidly connected together and are pivoted at 44. An arm 45, projecting upward from the frame connecting the movable coil 43, carries at its upper end a contact device 46. Fixed contact devices 47 and 48 are located to the right and left, respectively, of the contact device 45. The parts are so constructed that at the normal voltage of the circuit the arm 45 will be held in the position shown in Fig. 2. When the voltage rises above the normal amount, the arm will be moved, say, to the right, and if the voltage rises great enough the contact 46 will be moved into engagement with the contact 47. Similarly, when the voltage falls below the normal sufficient amount the contact 45 will be moved into engagement with the contact 48. A pair of electromagnets 49 and 50 are arranged with their axes in line with one another, with an armature 51 between them. The armature 51 is normally held in the position shown midway between the electromagnets 49 and 50 by springs. (Not shown in the drawings.) One terminal of the magnet 49 is connected to a suitable source of energized current, such as a transformer 52, by a line 53. A line 54 connects the other terminal of the transformer to one terminal of the magnet 50. A conductor 55 connects the other terminal of the magnets 49 and 50 together. A conductor 56 connects the line 53 to the contact 47, and a conductor 57 connects the line 54 and the contact 48. A flexible conductor 58 connects the line 55 to the contact 46. The magnets 49 and 50 and the armature 51 are so constructed that when the contact 46 is in the position shown in Fig. 2 the armature will be held in the position shown midway between the coils 49 and 50. When, however, the contact 46 is moved into engagement with one of the side contacts—say 47—a low-resistance shunt, comprising the contacts 58 46 and conductors 48 50, is thrown about the electromagnet 49, whereupon the armature 51 will be moved toward the coil 50. Similarly, on engagement between the contacts 46 and 48 the armature 51 will be moved toward the coil 49.

The armature 51 operates or controls a valve mechanism 59, which controls the admission of a working fluid, such as compressed air, into the cylinder 23 from a suitable source, such as a reservoir or tank 60.

61 represents an exhaust-pipe connected to the valve mechanism.

As the construction of the valve mechanism and potential-balance forms no part of my present invention and as valves and balances of this character are well known in the art, I have not thought it necessary to illustrate their exact construction in the present case. It will be readily understood, however, that the valve mechanism may be so constructed that when the voltage of the system to be regulated rises and the armature 51 is moved to the left compressed air will enter the cylinder 23 through the pipe 25, thus raising the piston 22 and lowering the coil 15, while upon a decrease of voltage in the circuit to be regulated air will be admitted to the cylinder 23 through the pipe 24, whereby the coil 15 will be raised.

The coil-sections 10 and 11 are all wound in the same direction. Consequently as they are connected to the lines 31 and 32 in opposite ways the magnetizations produced by the two sets of coils are in opposite directions. If the electromotive force induced in the secondary coil 15 decreases the voltage between the lines 31 and 32 when the coil 15 is in the position shown in Figs. 1 and 2, when the coil 15 is in its extreme upper position and surrounds the sections 10 the voltage between the lines 31 and 32 will be increased by the amount induced into coil 15. It will thus be seen that

the maximum change in voltage produced by the coil 15 by moving it from its extreme lower or bucking position to its extreme upper or boosting position will be double the voltage induced in the coil. When the coil 15 is in an intermediate position, the voltage change produced by it will be less than when in its extreme end positions, and the direction of change produced will depend upon whether the center of the coil is above or below the center of the core E. When the coil 15 is midway between its two end positions, the voltage induced in the coil 15 by the coil-sections 10 will be exactly counterbalanced by that induced by the coil-sections 11, and the coil 15 will neither buck nor boost the voltage between the lines 31 and 32. The short-circuited coil 13 will materially reduce the self-induction of the coil 15 when in the intermediate position.

The construction described furnishes a comparatively simple and very reliable and efficient means for regulating the voltage of an alternating-current system. The voltage change produced is progressive, and the disagreeable features sometimes experienced in connection with a step-by-step regulating device are not encountered.

While I have illustrated and described my invention as employed in connection with a single-phase supply system, it will be readily understood that one of my regulating devices might be employed in connection with each leg or branch of a polyphase system.

Though I have hereinbefore illustrated and described the best form of my invention now known to me, it is evident that many changes may be made in the form of my invention without departing from its spirit. For instance, in Figs. 3 and 4 of the drawings I have shown somewhat diagrammatically a modification of the magnetic circuit of my regulator, which I may use under some circumstances. In this form of my invention the pole-pieces 8 and 9 (shown in Fig. 1 of the drawings) are replaced by annular pole-pieces 62 and 63. These pole-pieces engage the middle leg 4 of the core and are laminated transversely to said leg. The pole-pieces 62 and 63 are surrounded by annular pole-pieces 64 and 65, carried by the outer legs 4 of the core. The pole-pieces 64 and 65 are laminated similarly to the pole-pieces 62 and 63, from which they are separated by a space through which the coil 15 may move. Windings 10′ and 11′, in general similar to the coil-sections 10 and 11, are placed on the leg 5 in this construction. A circular coil 15′, shaped to pass between the pole-pieces 62 63 and 64 65, but otherwise like the coil 15 of the other construction, is also employed.

Certain features of the construction described and illustrated, but not claimed in the present application, are claimed in my copending application for patent on improvements in regulators, Serial No. 174,695, filed September 26, 1903.

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

1. In combination, a pair of windings movable with respect to each other one of said windings having portions producing magnetizing forces acting in opposite directions, a circuit with which the other winding is operatively connected, and means for automatically bringing into proximity said other winding and one or the other of said portions in response to changes in the electrical condition of said circuit.

2. In combination, a pair of windings movable with respect to each other one of said windings having portions producing magnetizing forces acting in opposite directions, a circuit into which the other winding is connected, and means for bringing into proximity said other winding and one or the other of said portions to control the electrical condition of said circuit.

3. In combination, a base, a platform, a core extending between said base and said platform, windings producing magnetizing forces acting in different directions surrounding different portions of said core, and a movable coil surrounding said core which may be moved to embrace either of said windings.

4. In combination, a secondary winding, a pair of primary windings, circuit connections therefor by which said primary windings produce magnetizing forces acting in opposite directions upon said secondary winding, and means by which said secondary winding can be subjected more or less exclusively to the influence of either of said primary windings.

5. In combination, a circuit to be regulated, a secondary winding in series with the circuit to be regulated, a pair of primary windings connected in shunt to said circuit so as to produce magnetizing forces acting in opposite directions upon said secondary winding, and means for automatically varying the inductive relations between each of said primary windings and said secondary winding in response to changes in the condition of a circuit operatively connected to the circuit to be regulated.

6. In combination, a pair of primary windings, a secondary winding movable from a position in which it surrounds one of said windings to a position in which it surrounds the other of said primary windings, a piston and a cylinder for moving said movable coil, and a potential responsive device for controlling the admission of a working fluid into said cylinder.

7. In combination, a three-legged mass of magnetic material, a pair of windings on the middle leg of said mass, said windings being arranged to produce magnetizing forces acting in opposite directions, a movable coil surrounding said middle leg and said windings, and means for moving said coil along said leg.

8. In combination, a three-legged mass of magnetic material, a pair of windings on the middle leg of said mass, circuit connections by means of which the magnetizing forces produced by said windings are in opposite directions, a movable coil embracing said middle leg and said windings, a potential-measuring device, and automatic means controlled by it for moving said movable coil along said core in response to variations in the potential measured by said device.

9. In combination, a magnetic core in the form of three substantially parallel legs and connecting end pieces, a polar projection carried by the middle leg at each side of its center, a winding carried by each end of said middle leg, said windings being connected to produce magnetizing forces acting in opposite directions, a movable coil surrounding said leg and said windings of a length substantially equal to the distance between each end of the leg and its adjacent polar projection, and another winding surrounding said leg between said polar projection to reduce the self-induction of the movable coil when the latter surrounds it.

10. In combination, a mass of magnetic material, a polar projection or projections carried by said mass between its ends, windings on said mass at each side of said polar projection or projections, a movable coil surrounding said mass and said windings, and means for moving it from one side to the other of said polar projection or projections.

11. In combination, a base, a platform, a mass of magnetic material extending between the base and the platform, a primary winding carried by said magnetic material, a movable coil surrounding said magnetic material and said winding, a pulley carried by said platform, and a flexible cord or cable passing over said pulley or pulleys, said movable coil being connected to one end of said cord or cable.

12. In combination with a circuit to be regulated, a primary winding formed in two parts, and a secondary winding movable from a position in which it surrounds one of said parts to a position in which it surrounds the other of said parts, one of said windings being connected in said circuit.

13. In combination with a circuit to be regulated, a primary winding formed in two parts, and a secondary winding movable from a position of good inductive relation with respect to one part of said primary winding to a position of good inductive relation with respect to the other part of said primary winding, one of said windings being connected in said circuit.

14. In combination, a pair of windings connected in shunt to the circuit to be regulated, and a movable winding which can be moved from a position in which it will surround one of the shunt-windings to a position in which it will surround the other of said shunt-windings, said movable coil being connected in series in the circuit to be regulated, and the shunt-coils being so connected that the magnetizing forces produced by them act in opposite directions upon the movable coil.

15. In combination, an electrical circuit, a secondary winding in series with said circuit, a pair of primary windings connected in shunt to said circuit so as to produce magnetizing forces acting in opposite directions upon said secondary winding, a device responsive to the electrical condition of a circuit, and means controlled thereby for varying the inductive relations between each of said primary windings and said secondary winding.

16. In combination, a circuit to be regulated, a core of magnetic material, means for producing magnetizing forces acting in different directions in different portions of said core, and a winding surrounding and movable with respect to said core, said winding being connected in said circuit.

17. In combination, a core, a pair of windings on said core arranged to produce magnetizing forces acting in different directions in said core, a movable coil surrounding said core, a potential responsive device, and means controlled thereby for moving said coil along said core.

18. In combination, a supply-circuit, a core, a pair of windings on said core connected in shunt to said circuit in such manner as to produce magnetizing forces acting in different directions in said core, a movable coil surrounding said core connected in series in said circuit, a device responsive to the potential in said circuit or a circuit derived therefrom, and means controlled thereby for moving said coil along said core.

19. In a potential-regulator, a core, a polar projection carried thereby at each side of its center, a magnetizing-winding on each end of said core, and a short-circuited winding between said polar projections.

20. In a potential-regulator, a core laminated in the direction of its length, and a polar projection in the form of an annular mass of magnetic material surrounding said core and laminated transversely to the length of said core.

21. In a potential-regulator, a magnetic circuit formed by three parallel legs of magnetic material connected at their ends, the middle leg being surrounded by a polar projection located at each side of the center, and annular polar portions carried by the outer of said legs and surrounding each of the polar portions carried by the middle leg.

In witness whereof I have hereunto set my hand this 22d day of April, 1904.

RICHARD FLEMING.

Witnesses:

DUGALD McK. McKILLOP,

HENRY O. WESTENDARP.