No. 725,692. PATENTED APR. 21, 1903.

J. B. FOOTE.

REGULATOR.

APPLICATION FILED JULY 23, 1901.

NO MODEL. 2 SHEETS—SHEET 1.

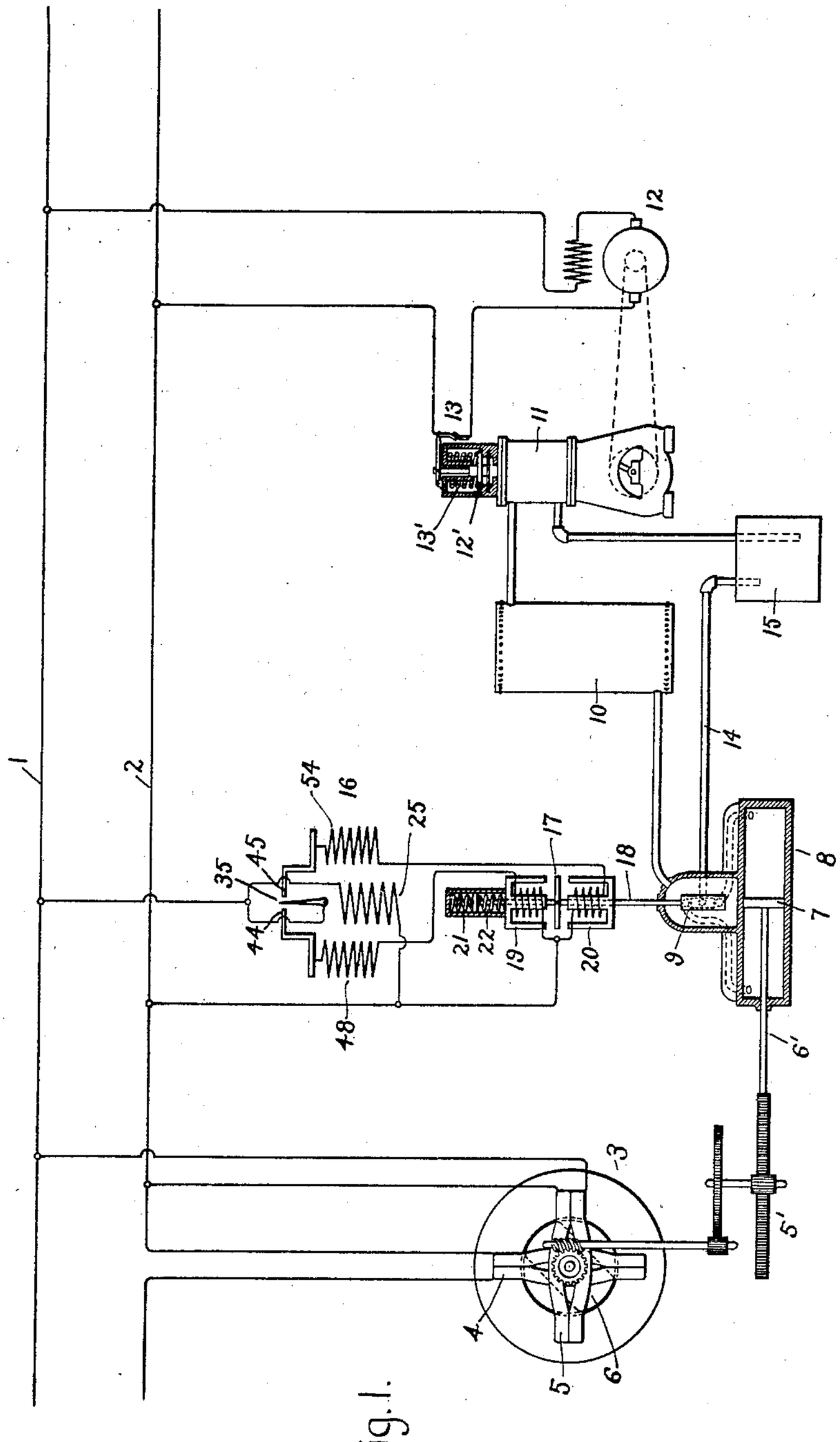


Fig. 1.

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NO MODEL. 2 SHEETS—SHEET 2.

Fig. 2.

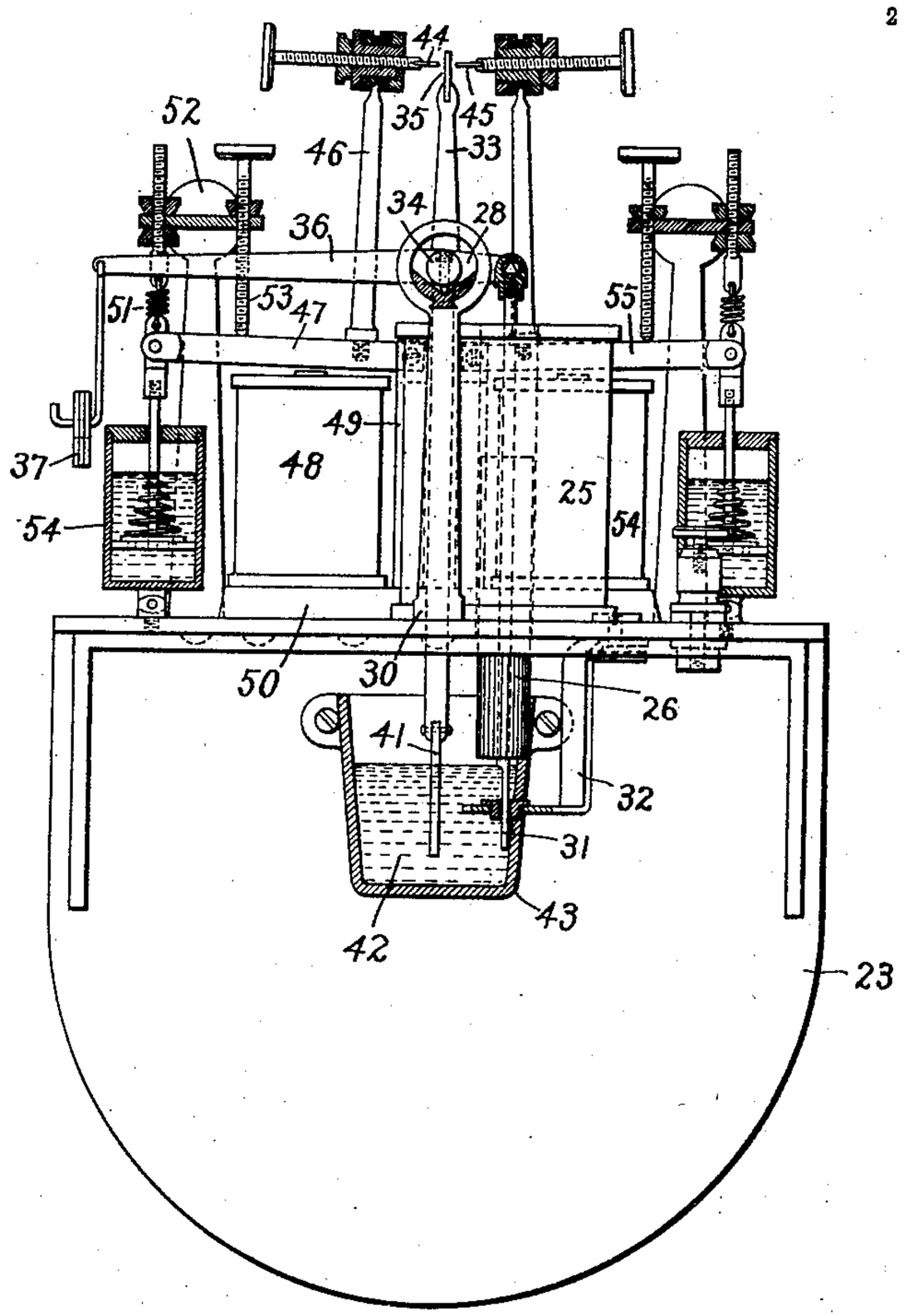
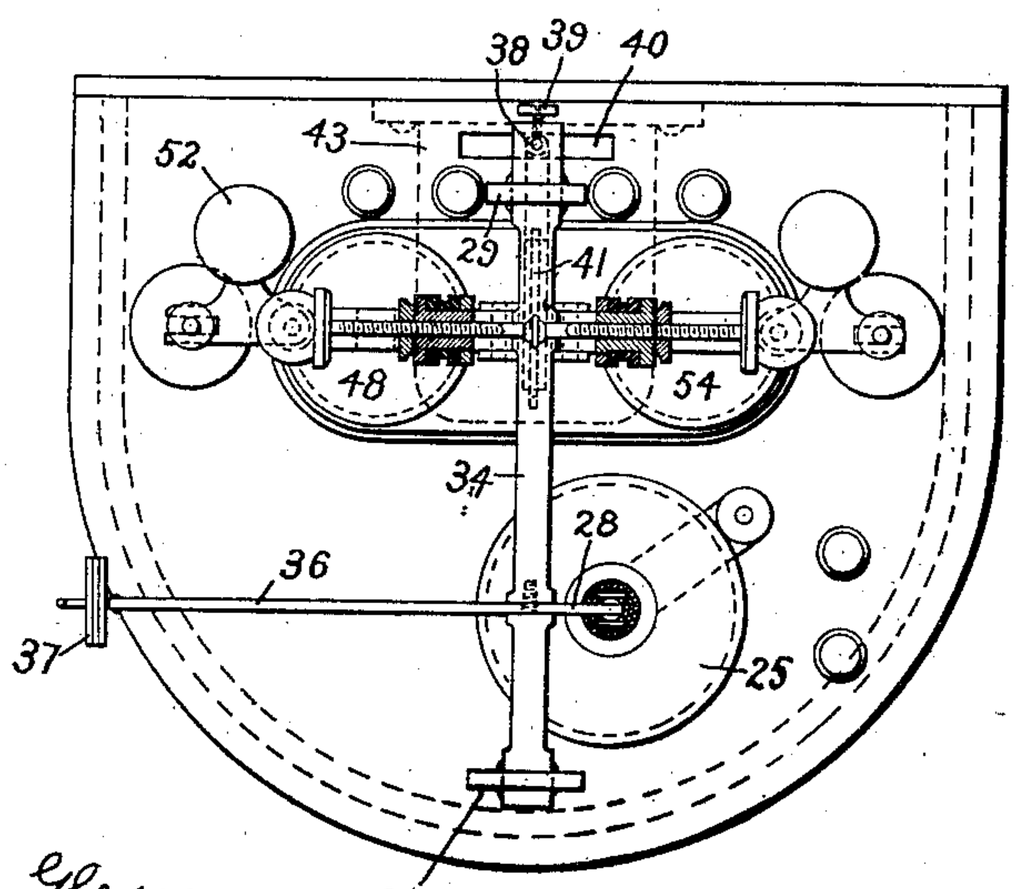



Fig. 3.

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# UNITED STATES PATENT OFFICE.

JAMES B. FOOTE, OF JACKSON, MICHIGAN, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## REGULATOR.

SPECIFICATION forming part of Letters Patent No. 725,692, dated April 21, 1903.

Application filed July 23, 1901. Serial No. 69,394. (No model.)

*To all whom it may concern:*

Be it known that I, JAMES B. FOOTE, a citizen of the United States, residing at Jackson, county of Jackson, State of Michigan, have invented certain new and useful Improvements in Regulators, of which the following is a specification.

My invention relates more particularly to electric regulators, and comprises various novel features set forth with particularity in the claims appended hereto.

The more especial aim of my invention is to secure a regulating action which shall be checked as soon as the proper regulating effect has been secured and not be permitted to pass through a series of oscillations of decreasing amplitude about the desired point.

In carrying my invention into practice I may make use of a mechanically-actuated regulating mechanism, the mechanical actuator being governed in its motions by a controlling device of novel construction.

The invention may perhaps be best understood by first describing in general terms a system embodying my invention and then referring in detail to the construction of the controlling device for said system.

Figure 1 is a diagrammatic representation of one embodiment of my regulating system taken as a whole, while Figs. 2 and 3 are detail views of the electric controlling device forming a part of the system.

In Fig. 1 the lines 1 2 represent conductors forming part of an electric distribution or transmission system the voltage of which it is desired to control. It is obvious that the immediate means for controlling the voltage may be of widely-different character. Thus, for example, the field strength of the generator (in this case not shown) may be varied or the speed of the generator may be changed or various other means employed without departing from my invention. In the present instance, however, I have assumed that the system is to be regulated by a potential-regulator of well-known construction and such, for example, as is set forth more in detail in the patent to Steinmetz, No. 548,400, dated October 22, 1895. A winding 4 on this regulator is in series with one of the mains—as, for example, the main 2—while a second winding 5, located in this instance at right angles to the winding 4, is connected in shunt to the mains 1 2. A flattened body 6 of magnetic material is located within these coils or windings and is mounted on bearings, so that it may be rotated. By changing the angular position of this body the mutual induction between the series and the potential coils may be varied, thereby causing the potential coil to exert a correspondingly varied boosting effect upon the series coil, this boosting effect acting to regulate the voltage of the lines 1 and 2 as desired.

For the purpose of mechanically actuating the regulator 3 I may connect the rotating member thereof through gearing 5′ of any suitable construction to the piston-rod 6′, extending from a piston 7, to which motion is communicated by fluid-pressure derived from any suitable source.

The piston 7 of the actuating device is movable within a cylinder 8, to which some suitable fluid, as oil, may be admitted through the operation of a controlling-valve—such, for example, as 9. The oil may be contained in a tank 10, in which it is maintained under pressure by means of some suitable pump. In the present instance I have by way of illustration indicated a pump 11, driven by an electric motor 12, the circuit of which is controlled automatically by a switch 13, which through the action of the fluid-pressure is caused to close when the pressure is too low and to open when the pressure is too high, the opening and closing of the switch being governed by a piston 12′, operated upon by the fluid-pressure and acting in opposition to a properly-adjusted spring 13′. The oil after it has been admitted to the cylinder 8 and has moved the piston thereof in either direction is then discharged through the exhaust-pipe 14 into a receiving-tank 15, from which it is drawn by the pump 11 and again forced into the tank 10.

The valve 9, which controls the fluid-actuating device, is is turn actuated magnetically through the operation of a controlling device, (indicated in diagram at 16.) The magnetic actuating means consists of an armature 17, carried by a rod 18 and mounted in proximity to a pair of magnets 19 and 20, the circuits

of which are opened and closed by the controlling device 16. Centering-springs 21 and 22, acting on the valve-stem 18, serve to maintain the valve 9 in its closed or intermediate position. When one of the magnets is energized, the valve 9 will be moved in one direction, thereby causing a corresponding movement of the piston 7, while when the other magnet is energized an opposite resulting motion of the piston 7 will take place.

The controlling device 16 consists of a main contact controlled by the quantity to be regulated and coöperating contacts acting in conjunction therewith to close the circuit of either of the magnets 19 and 20. These cooperating contacts are arranged so as to retreat or be withdrawn momentarily upon each engagement between the same and the main contact under control of the quantity to be regulated, which in this case is the potential upon the mains 1 and 2. A better understanding of the nature of this controlling device will be had by now referring to Figs. 2 and 3, which show the same in detail.

A frame or bracket 23 serves to support the working parts of the controller. At 25 is indicated a coil connected across the circuit to be regulated and corresponds to the coil 25 in Fig. 1. A core 26, consisting of a bundle of iron wires, is mounted loosely within the coil 25 and is supported at its upper end on a knife-edge bearing at the end of a pivoted lever 28, which lever is in turn supported on knife-edge bearings carried by standards 29 and 30, the last-named standard being shown in front view only in Fig. 2.

The lower end of the core of iron wires 26 carries a downwardly-projecting rod 31, arranged to slide loosely in an opening in an insulating-bushing in the lower end of a bracket 32. By means of this construction the core is guided and prevented thereby from engaging the walls of the solenoid 25.

A contact-carrying arm 33 is mounted upon the rod 34, which carries the lever-arm 28. The contact carried by the arm 33 is indicated at 35, and the position of this contact is determined, as will readily be understood, by the position of the parts assumed when the pull of the solenoid 25, acting upon the core 26, is counterbalanced by the movement of the core 26 and its connected parts into a position of equilibrium. To adjust this position of equilibrium, I provide an arm 36, connected with the rod 34 and, indeed, forming a continuation of the arm 28, and upon the outer end of this arm 36 I provide a hook upon which I may place a greater or less number of small weights 37 in the form of rings, the number of these weights being changed to suit the conditions required.

The balanced mechanical parts above described are from their manner of mounting and arrangement necessarily sensitive to variations in the current flowing through the solenoid 25, which in this case is intended to be connected across the mains of a distribution system and responsive to the difference of potential thereof. In order, therefore, to steady the parts carrying the contact 35 and prevent undue oscillation of the same, I provide a damping device of any suitable character, in this instance consisting of a downwardly-extending arm having its upper end 38 passed through a hole in the rod 34 and secured thereto by a set-screw 39 and its lower end through an opening 40 in the supporting-bracket and carrying at its extremity a paddle or vane 41, dipping into a body of more or less dense fluid 42, held in a containing vessel 43, the upper outline of which is indicated in dotted lines in Fig. 3 and in section in Fig. 2.

Coöperating with the main contact 35, the position of which is determined by the magnitude of the quantity to be regulated, are a pair of movable or vibratory retreating contacts 44 and 45, each of which is mounted upon a pivoted carrier and insulated therefrom. The carrier for the contact 44 consists of an upwardly-projecting rod 46, secured to a pivotally-mounted armature 47, which coöperates with a magnet 48. This armature 47 is pivoted at its right-hand end to the upper end of a projecting standard 49, of magnetic material, connected to a yoke 50 of the magnet 48 and constituting a continuation of the magnetic circuit thereof. A spring 51, adjustably attached to a standard 52 and to one end of the armature 47, serves to urge the armature 47 away from the magnet 48 and against an adjustable stop 53, also carried by the standard. A dash-pot 54 is connected, as shown, to the armature 47 and serves to prevent too violent or too rapid oscillation thereof. The other retreating contact 45 is mounted in a manner precisely similar to that already described in connection with contact 44 and seems to require no further elucidation. The magnet which actuates this retreating contact 45 is indicated, however, at 54 and in Fig. 2 is shown as partly concealed behind the controlling-solenoid 25, while the armature 55, controlled by this magnet, is in like manner partially concealed behind the same solenoid.

The connection of the controlling-solenoid 25 and of the magnets 48 and 54 will now be readily understood by referring back to Fig. 1, in which the winding 25 represents the controlling-solenoid 25 in Fig. 2, while the windings 48 and 54 represent, respectively, the correspondingly-designated magnets in Fig. 2.

Fig. 2 shows the parts in the position they occupy when the potential of the mains 1 2 is of normal value. When, however, the potential varies from normal, the main contact 35 is shifted either to the right or the left, as the case may be, and engages one of the retreating contacts 44 45. Supposing, for example, the main contact 35 is moved to the right and engages the retreating contact 45, immediately upon this engagement a circuit is closed from the main 1, through the mag-

net 54, through the magnet 20, and back to the main 2. The valve 9 then commences to open under the action of the magnet 20, while at the same time the retreating contact 45 moves backward through the energizing of the magnet 54. The retreating contact thereby acts to open the circuit which it has previously helped to close and through the resulting deënergizing of its controlling-magnet 54 is immediately allowed to return toward its normal position, thereby again coming in contact with the main contact 35, whereupon the retreating action is repeated, the series of resulting advances and retreats of the retreating contact constituting a continued oscillation or vibration which serves to transmit to the valve 9 of the mechanical controlling device a sort of series of taps, as it were, which allows a just sufficient regulating effect to take place and checks this regulating effect as soon as it has attained the proper amount. Without this series of impulses it would be necessary for the regulating effect to slightly overstep the amount required to bring the mains back to normal potential before the main contact would return, thereby necessitating a reversal of the regulating action, which is apt to continue through a series of oscillations before the final regulation is secured. The arrangement shown is particularly effective in preventing this objectionable seesawing effect, and this is due to the fact that as the regulating action proceeds the main contact moves back toward its normal position, thereby increasing the amplitude of movement of the coöperating contact, the oscillations of which thereby become longer and longer and finally cease when the desired regulating effect has been secured.

In adjusting the regulators in practice I prefer that the main contact 35 and the cooperating contacts 44 45 should be so related that a very small percentage variation of the quantity to be regulated will be sufficient to cause the main contact to move into engagement with one of the coöperating contacts. A vibratory action of the last-mentioned contact will then take place and a resulting regulation follow, as above described. In case, however, of a comparatively large variation of the quantity to be regulated the main contact will follow the receding coöperating contact to such an extent as to maintain a continuously-closed circuit between them, the result being a quick and uninterrupted regulating action nearly sufficient to restore normal conditions, whereupon the contacts separate and the last stages of the regulating action are completed without overstepping the mark through the sensitive making and breaking of the controlling-circuit already described.

Although I have illustrated but a single arrangement for carrying out my invention, it will of course be evident that many modifications thereof and variations therefrom may be made without departing from the spirit of my invention, for which reason I do not wish to be limited to the particular details shown. Moreover, although I have shown my invention as arranged to regulate an electric system, it is obvious that it is applicable as well to the regulation of steam or water pressure, the speed of engines or water-wheels, and the like, pressure or speed indicators being in such cases employed to control one of the contacts of the regulating device.

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

1. In an electric regulating apparatus, the combination of an electrically-actuated main contact, and an electrically-controlled vibratory contact coöperating therewith.

2. In an electric regulating apparatus, the combination of a main contact controlled by the quantity to be regulated, and an electrically-actuated and mechanically-retracted vibratory contact coöperating therewith.

3. The combination of an electrically-actuated main contact, and an electrically-vibrated coöperating contact.

4. In an electric regulator, the combination of a main contact controlled by the quantity to be regulated, and an electrically-vibrated coöperating contact.

5. In an electric regulator, the combination of a main contact controlled by the quantity to be regulated, a coöperating contact, and means controlled by the engagement of said contacts for electrically vibrating said coöperating contact.

6. In an electric regulating apparatus, the combination of a main contact controlled by the quantity to be regulated, and a coöperating contact normally stationary but adapted when engaged by the main contact to be withdrawn electrically from engagement with said main contact and returned mechanically as soon as such engagement is broken.

7. In an electric regulating apparatus, the combination of a circuit controlling a regulating mechanism, two contacts for making and breaking said circuit, one under the control of the quantity to be regulated and the other actuated electromagnetically by current in said circuit, and means for restoring the latter contact upon the interruption of said current.

8. In an electric regulator, the combination of a circuit to be regulated, a vibratory circuit-closing device coöperating therewith, and means controlled by said device for regulating said circuit.

9. In an electric regulating apparatus, the combination of a controlling-circuit, a contact controlled by the quantity to be regulated for closing said circuit, and a contact for opening said circuit electrically actuated in one direction and mechanically actuated in the other.

10. In an electric regulating apparatus, the combination of coöperating circuit-closing contacts, one moved in response to variation of the quantity to be regulated and the other

in one direction by a spring and in the opposite direction by a magnet energized in response to engagement of said contacts.

11. In a regulator, the combination of circuit-controlling contacts, means for causing a vibratory engagement of said contacts when the quantity to be regulated varies slightly from normal, and means for causing an uninterrupted engagement of said contacts upon a greater variation from normal of the quantity to be regulated.

12. The combination of a mechanically-actuated electric regulating mechanism, a magnetic actuating means for controlling said mechanism, and a controlling device coöperating with said magnetic actuating means and consisting of a main contact controlled by the quantity to be regulated, a coöperating contact or contacts, and a magnet or magnets energized through the engagement of the main contact with the said coöperating contact or contacts and controlling said coöperating contact or contacts.

In witness whereof I have hereunto set my hand this 20th day of July, 1901.

JAMES B. FOOTE.

Witnesses:
CHARLES ZANG,
R. E. SEARLS.