G. D'EUSTACHIO & P. VON LEHOCZKY.

AUTOMATIC VOLTAGE REGULATOR.

APPLICATION FILED NOV. 14, 1905. RENEWED MAR. 15, 1911.

1,005,107. Patented Oct. 3, 1911.

3 SHEETS—SHEET 1.

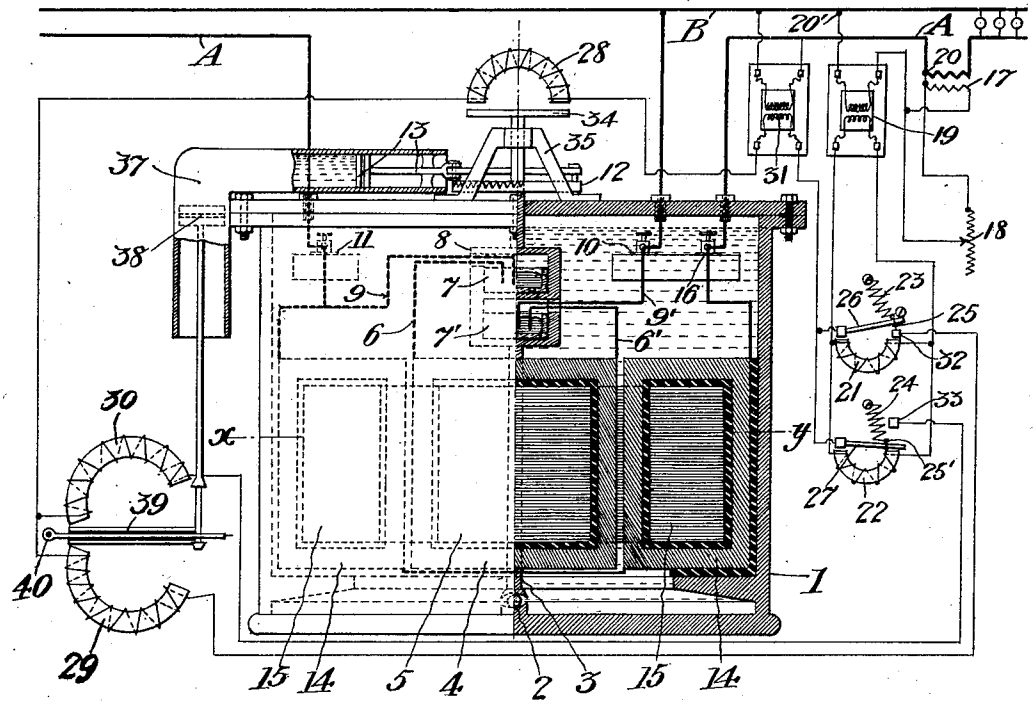

Fig. 1.

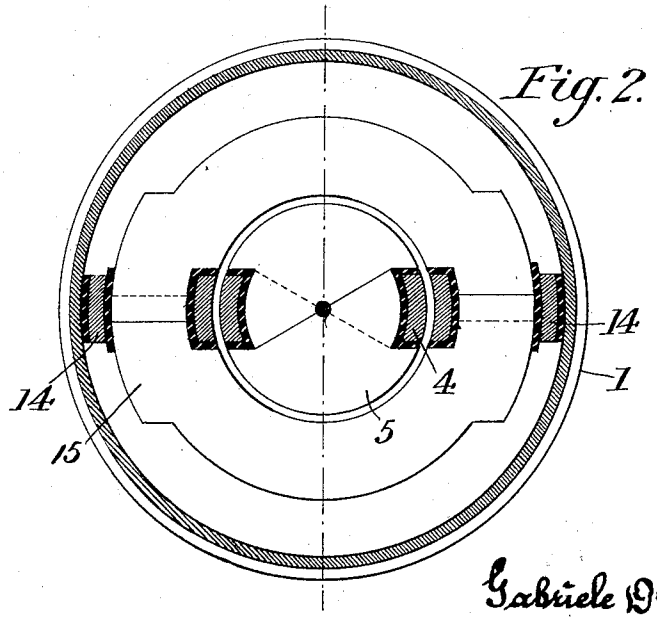

Fig. 2.

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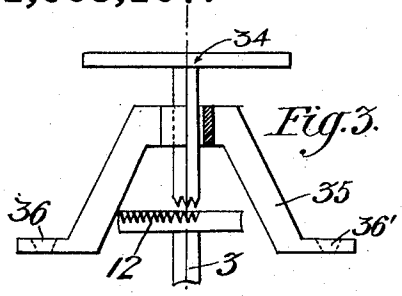


Fig.3.

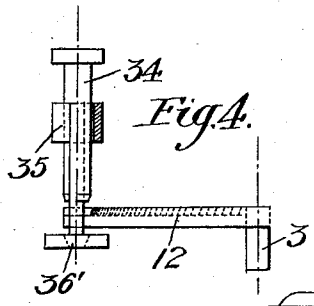


Fig.4.

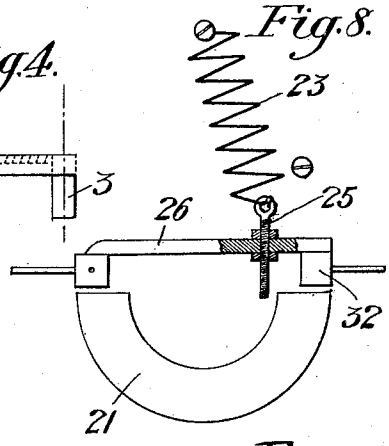


Fig.8.

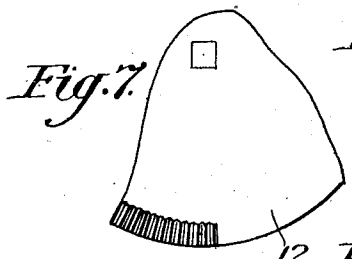


Fig.7.

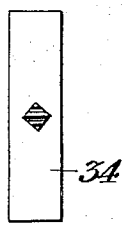


Fig.5.

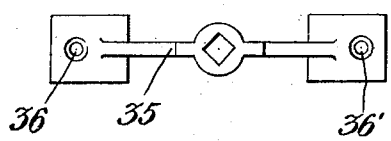


Fig.6.

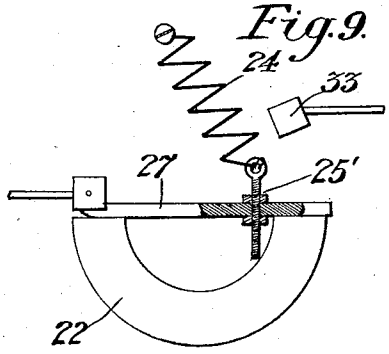
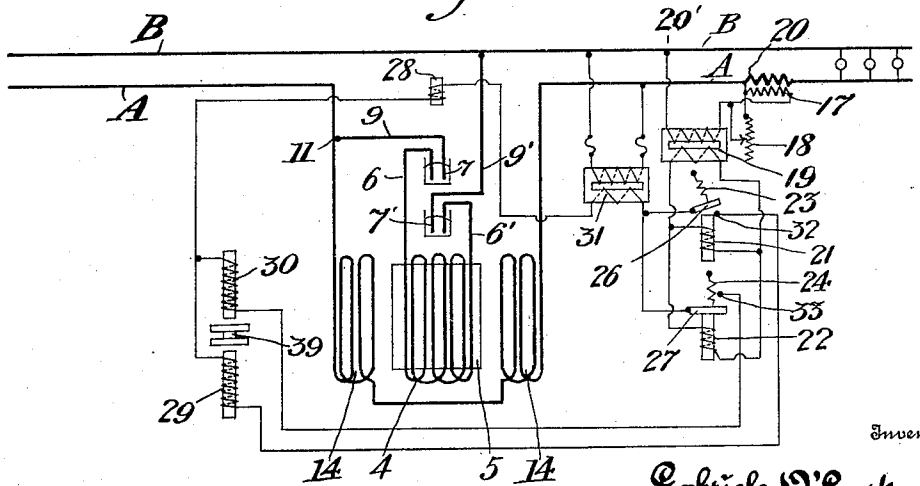


Fig.9.

Fig.10.



Witnesses

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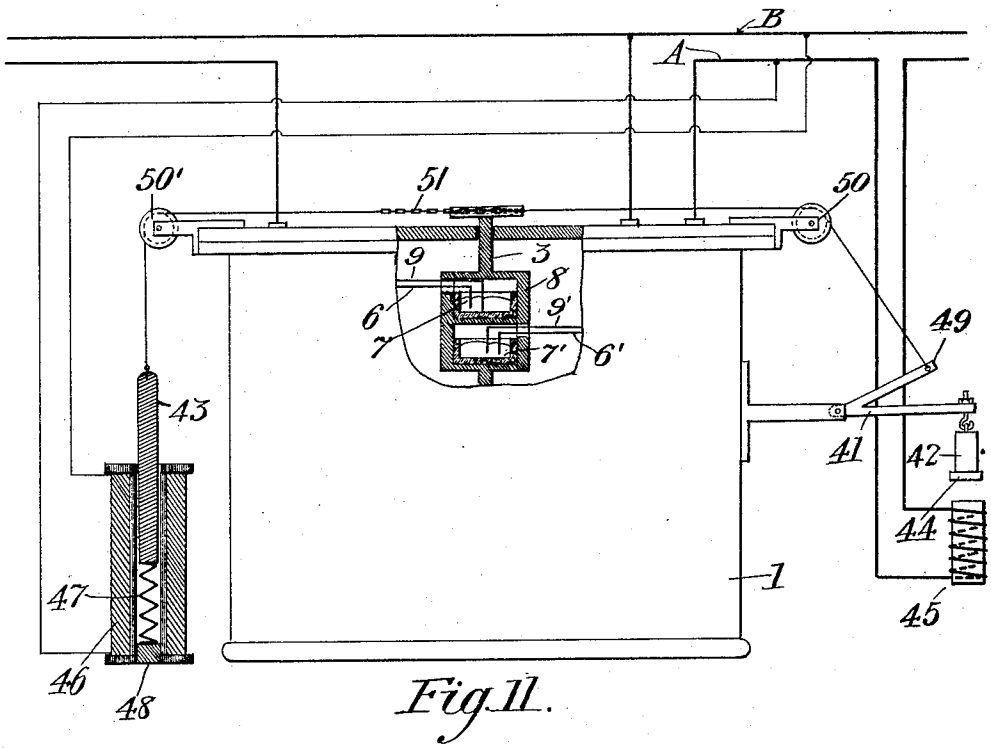

Fig. 11.

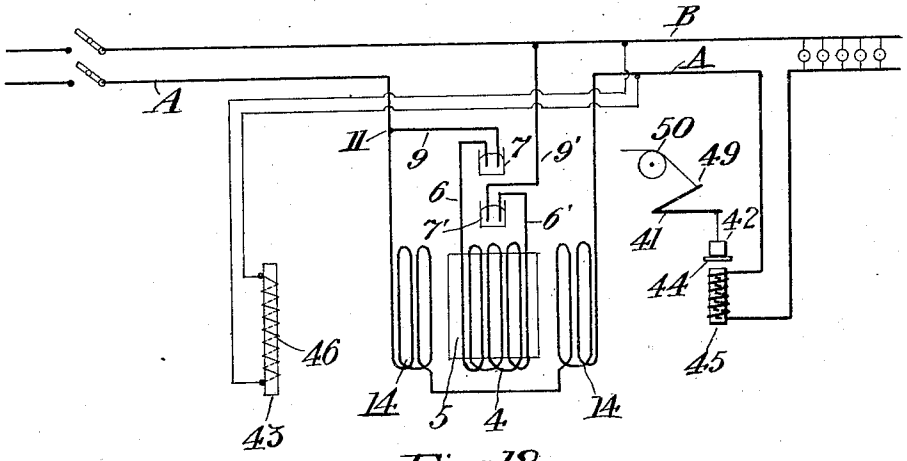

Fig. 12.

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UNITED STATES PATENT OFFICE.

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AUTOMATIC VOLTAGE-REGULATOR.

1,005,107. Specification of Letters Patent. Patented Oct. 3, 1911.

Application filed November 14, 1905, Serial No. 287,260. Renewed March 15, 1911. Serial No. 614,700.

To all whom it may concern:

Be it known that we, GABRIELE D'EUSTACHIO and PAUL von LEHOCZKY, subjects, respectively, of the King of Italy and the Emperor of Austria-Hungary, residing at Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Automatic Voltage-Regulators, of which the following is a specification, reference being had therein to the accompanying drawing.

Our invention relates to appliances for automatically regulating the voltage in alternating current circuits at the feeding points or centers of load, independently (within certain limits) of the voltage at the generating station and of the load at the feeding point.

A regulator to be employed in the consumer's house must occupy very little room, must be automatic, accurate, efficient, not a fire hazard and simple in its mechanism so it can be sold at a very low price. Such a regulator is needed in the consumer's house, because using the best method of regulation in the sub-stations, the voltage can be kept constant at the centers of distribution, but there is always a variation of voltage of at least 3% in the consumer's transformer and a drop of about 2% in the consumer's house, with another drop in the mains from no load to full load, which means a variation of at least 5% in the voltage at the terminals of the lamps. An increase of 3% in voltage halves the life of a lamp while 6% increase reduces the life by two-thirds and a decrease of 3% in the voltage reduces the efficiency of the lamp about 16% (see H. A. Foster, *Electrical Engineers' Pocket Book*, 1904, pages 405 and 407).

Our invention has for its object to meet the requirements and to obviate the objections thus recognized.

To these ends the invention consists in the provision of a self acting regulator or regulators, and the general mode of operation thereof is substantially as hereinafter fully described in the accompanying specification and shown in the drawings, in which—

Figure 1 is a front view partly in section of our apparatus; Fig. 2 is a horizontal section of said apparatus through line x—y; Figs. 3, 4, 5, 6, 7, 8 and 9 are details of Fig. 1. Fig. 10 is a diagram showing the arrangement of the circuits. Fig. 11, represents one of the modifications of the apparatus shown in Figs. 1 and 2 and is a front view partly in section of our apparatus that can be used in the consumer's house and Fig. 12 is a diagram showing the arrangement of the circuits of said modification.

Referring to the drawings 1 is a case of cast metal, with removable cover and filled with good transformer oil; 2 is a ball-bearing, carrying shaft 3. On said shaft is fastened coil 4 and a core of laminated iron 5. The ends 6 and 6′ go in cups 7 and 7′ containing mercury. Said cups are held in the frame 8, fastened on the shaft 3. Two leads 9 and 9′ electrically connect the ends 6 and 6′ to binding posts 10 and 11 through the mercury contained in cups 7 and 7′ and binding posts 10 and 11 are electrically connected across line B and A; in other words coil 4 is shunted across the line A. B. through the mercury contacts. The shaft 3 carries on the upper end of a wheel 12. The left hand upper half surface of the wheel is corrugated as shown in Fig. 7. Said wheel is driven by piston rod 13, and so arranged that it can rotate through an angle of about 160 degrees carrying in its rotation coil 4.

14 is a stationary coil mounted on the ring 15 of laminated iron. Said coil 14 is electrically connected in series with line A through binding posts or terminals 11 and 16. A current transformer 17 is connected in series on the circuit which it is desired to regulate. The secondary of said series transformer is connected to an adjustable resistance 18. This resistance can be adjusted in such a way that the drop of potential in itself will be equal to the drop in the line A. B. from no load to full load. In series with said resistance 18 is connected the primary of the potential transformer 19, which primary is connected across line A. B. at the points 20 and 20′. The voltage across the adjustable resistance 18 counteracts against the voltage across the points 20 and 20′, so the voltage applied at the terminals of the primary of transformer 19 is equal to the voltage across points 20 and 20′ less the drop in the line A. B. from no load to full load from station or center of distribution to feeding point.

In the present specification we have supposed that the ratio of transformer 19 is equal to the ratio of the transformers used to supply current at low voltage to the different consumers connected on the line A. B., but the ratio of transformer 19 can be any

suitable one and in this case the drop across the terminals of the adjustable resistance 18 must be adjusted. The current of the secondary of transformer 19 is used to energize the two electromagnets 21 and 22. If the voltage across the line A. B. at the feeding point increases or decreases it is clear that the voltage of the secondary of transformer 19 increases or decreases also and such variation of voltage will increase or decrease the exciting current of the electromagnets 21 and 22, making them stronger or weaker. The tension of springs 23 and 24 is so regulated by adjusting screws 25 and 25′ (see Figs. 1, 8 and 9) that when the voltage at the feeding point is the one required by the apparatus in use (lamps or other load) spring 23 overcomes the strength of the electromagnet 21, keeping armature 26 open, while electromagnet 22 overcomes the tension of spring 24 and keeps armature 27 closed. Should the voltage at the feeding point increase, electromagnet 21 becomes stronger and overcomes the tension of spring 23, closing the armature. If the voltage decreases electromagnet 22 becomes weaker, spring 24 overcomes electromagnet 22 and armature 27 opens. Electromagnets 28 and 29 are controlled by armature 26, *i. e.* when armature 26 is closed electromagnets 28 and 29 are energized, because when armature 26 is closed, it makes a closed electrical circuit through the secondary of transformer 31, armature 26, contact 32, coils of electromagnets 29 and 28 and back to the secondary of transformer 31. Electromagnets 28 and 30 will be energized when armature 27 is open, because when armature 27 is open it makes a closed electrical circuit through the secondary of transformer 31, armature 27, contact 33, coils of electromagnets 30 and 28 and back to the secondary of transformer 31.

The lower part of armature 34 is corrugated and said armature 34 is held by 35 so that it cannot rotate, but can only move up when electromagnet 28 is energized, and down when electromagnet 28 is not energized (see Figs. 3, 4, 5, and 6). Casting 35 is fastened to case 1 by screws 36 and 36′. As the upper part of wheel 12 is corrugated and armature 34 rests upon said wheel, when electromagnet 28 is not energized it is clear that by adjusting the weight of armature 34 the friction between it and wheel 12 can be made great enough to overcome the force of attraction or repulsion of coils 14 and 4. When electromagnet 28 is energized armature 34 does not rest on wheel 12, so it can rotate and the angle of the planes of coils 4 and 14 can be varied. Armature 39 is pivoted at point 40. Piston 13 is air tight in the chamber 37 and the other opening of said chamber is closed air tight by piston 38. Chamber 37 is filled by a suitable fluid and the ratio of the surfaces of pistons 13 and 38 is such that when armature 39 moves from the upper ends of electromagnet 29 to the lower ends of the electromagnet 30, the movement of piston 13 will cause a rotation of coil 4 of about 160 degrees.

The E. M. F. induced by coil 4 in the coil 14 can be indicated by the formula K. cos. a in which a is the angle between the planes of coils 4 and 14 and K is a constant depending only upon the ratio of the number of turns of coils 4 and 14, the reluctance of the magnetic circuit, the voltage applied to the terminals of coil 4, etc., *i. e.*, all constant quantities. Varying a from 0 degrees to 180 degrees, cos. a will vary from +1 to −1 and the E. M. F. induced in coil 14 will vary from +K to −K, passing through the infinite number of values between +K and −K. If V is the voltage of line A. B. at the generating station, the voltage of said line at the center of distribution can be varied continuously between V+K and V−K, or the voltage at the center of distribution can be kept constant (*i. e.* equal to V) while the voltage at the generating station varies between V+K and V−K. If (with no load in the circuit A. B.) V is such a voltage that applied to the terminal of transformer 19, electromagnet 22 is just strong enough to overcome tension of spring 24 and electromagnet 21 is just strong enough to be overcome by the tension of spring 23, and the resistance 18 is adjusted as above specified and K is the constant of our regulator, the voltage at the center of distribution will be automatically kept continuously at V, while the load in the line A. B. varies and the voltage at the generating station varies between V+K and V−K.

In our drawings we have shown transformer 31 used to supply energy for electromagnets 28, 29 and 30, but any independent circuit (carrying A. C. or D. C. current) can be used.

Fig. 11 shows a modification of the apparatus shown in Fig. 1 and can be used in the consumer's houses to regulate the drop in the mains and transformers. On such apparatus lever 41 and the adjustable weight 42 are used to balance the weight of plunger 43. Weigh 42 is made of iron and at the bottom has a plate 44 of non-magnetic substance. 45 is an electro-magnet, whose ampereturns vary as the current in the line A. B. 46 is a solenoid shunted across line A. B. Spring 47 acts against the downward motion of the plunger 43, while the current flowing through the winding of solenoid 46 tends to pull same plunger 43 nearer core 48. The attraction and repulsion between coils 4 and 14, (whose attraction and repulsion varies with the load used in the line A. B., and the angle of said coils 4 and 14) is overcome by the attraction of electro-magnet 45 on the iron weight 42, (whose

attraction varies with the load used in the line A. B., and with the distance between weight 42 and electro-magnet 45). A cord or metal wire fastened at point 49 of lever 41 goes over pulley 50 and is fastened to one end of chain 51 and another cord or metal wire goes from the other end of chain 51 to pulley 50′ and is fastened to plunger 43. As the voltage in line A. B. changes either solenoid 46 overcomes the tension of spring 47, or vice versa, and the position of plunger 43 varies and chain 51 acting on driving wheel 52 varies the angle of the two coils 4 and 14 so that the voltage in line A. B. will be kept constant. A series transformer can be used to energize electro-magnet 45.

Having thus described our invention, what we claim and desire to secure by Letters Patent is:

1. In a regulating device, the combination with a fixed coil, and a movable coil, of a cylinder, pistons therein, one of which is connected directly to said movable coil, a fluid body between said pistons, a device for actuating one of said pistons and thus the fluid body and the other piston, whereby the inductive relation of the coils is changed, means controlling the action of the aforesaid device, and means to decrease the potential to said controlling means.

2. In a regulating device for alternating current circuits, a fixed current coil, a movable potential coil, electromagnetic means separate from both coils for actuating the movable coil, and electromagnetic locking means in circuit with the actuating means and adapted to release said movable coil when the actuating means becomes active.

3. In a regulating device for alternating circuits, a fixed current coil, a relatively movable potential coil, electromagnetic means for actuating said movable coil to change the inductive relation between the two coils, and locking means comprising a toothed segment secured to said movable coil, and a toothed member engaging said toothed segment, the latter being locked by the toothed member when the actuating means is idle but unlocked thereby when the actuating means becomes active.

4. In a regulating device, the combination with a fixed coil, of a movable coil, means for varying the inductive relation of said coils, means for controlling said means, a toothed segment carried by said movable coil, means for engaging said toothed segment to lock said coil from movement, and means for retracting said locking means.

5. In a regulating device, the combination with a fixed coil, of a movable coil, means for varying the inductive relation of said coils, means for controlling said means, a toothed segment secured to said movable coil, a toothed member engaging said toothed segment to lock said coil from movement, and a magnet controlling the action of said toothed member.

6. In a regulating system for alternating current work circuits, a transformer having a relatively good magnetic circuit, with a yoke and one coil fixed, a second coil in inductive relation to the first and rotatable around a common central axis, separate electromagnetic means for rotating the second coil with relation to the first, whereby the magnetic flux in the one coil can be changed from positive maximum through zero to negative maximum, producing an E. M. F. in the other coil which will vary correspondingly, and electromagnetic locking means for the movable coil becoming active to lock the same when the actuating means is idle and vice versa.

7. In a voltage regulator for alternating current circuits, an inclosing casing, a fixed coil and a laminated core therefor, a movable coil in inductive relation to the fixed coil, means to move said coil, a pair of mercury troughs, and terminals for the line and for the movable coil, maintained in connection through the mercury in all positions of the coil.

8. In a voltage regulator for alternating current circuits, a casing containing oil, an iron yoke or core carrying a fixed coil and supported within said casing, a movable coil on a vertical spindle within said fixed coil, said spindle having a foot-step bearing at its lower end and a crank disk at its upper end outside the casing, means to convey current to the fixed coil through fixed terminals, and to convey current to the movable coil in all positions, mechanical means communicating motion to the spindle crank disk or wheel, and electromagnetic means responsive to changes in voltage in the work circuit, to actuate said mechanical transmitting means.

9. In a voltage regulating system for alternating current circuits, a main supply circuit and a consumption circuit, a transformer regulator having a movable coil, electromagnetic means for controlling the regulator, means for supplying current to the latter from the consumption circuit, and a variable resistance connected so as to adjust the current in the said electromagnetic controlling means.

10. In a regulating device for alternating current work circuits, a fixed coil, a rotatable coil, a shaft supporting said rotatable coil, mechanical actuating means connected to said shaft, electromagnetic means controlling said mechanical means, means for producing variations of current in said electromagnetic means in response to variations in the work circuit, and a locking device for the shaft becoming active when the actuating means is idle and vice versa.

11. In a regulating device, the combination with a fixed coil, a shaft, a movable coil carried thereon in inductive relation to said fixed coil, a mechanical locking member on said shaft, an electromagnet having an armature extension coöperating therewith, and other electromagnets for regulating the movement of said movable coil.

12. In a regulating device, the combination with a fixed coil, a movable coil in inductive relation thereto, mechanical means for actuating said movable coil, electromagnetic means acting thereon in response to variations in voltage, said means acting independently of the mutual attraction and repulsion between the two coils, and electromagnetic locking means for the movable coil, arranged to hold said movable coil stationary when the coil actuating means is idle, and to release it when the coil actuating means becomes active.

In testimony whereof we affix our signatures in presence of two witnesses.

GABRIELE D'EUSTACHIO.
PAUL VON LEHOCZKY.

Witnesses:
H. N. MÜLLER,
A. E. ECKLUND.