

F. W. MERRILL.
ELECTRICAL REGULATOR.
APPLICATION FILED DEC. 6, 1913.

1,220,255.

Patented Mar. 27, 1917.
3 SHEETS—SHEET 1.

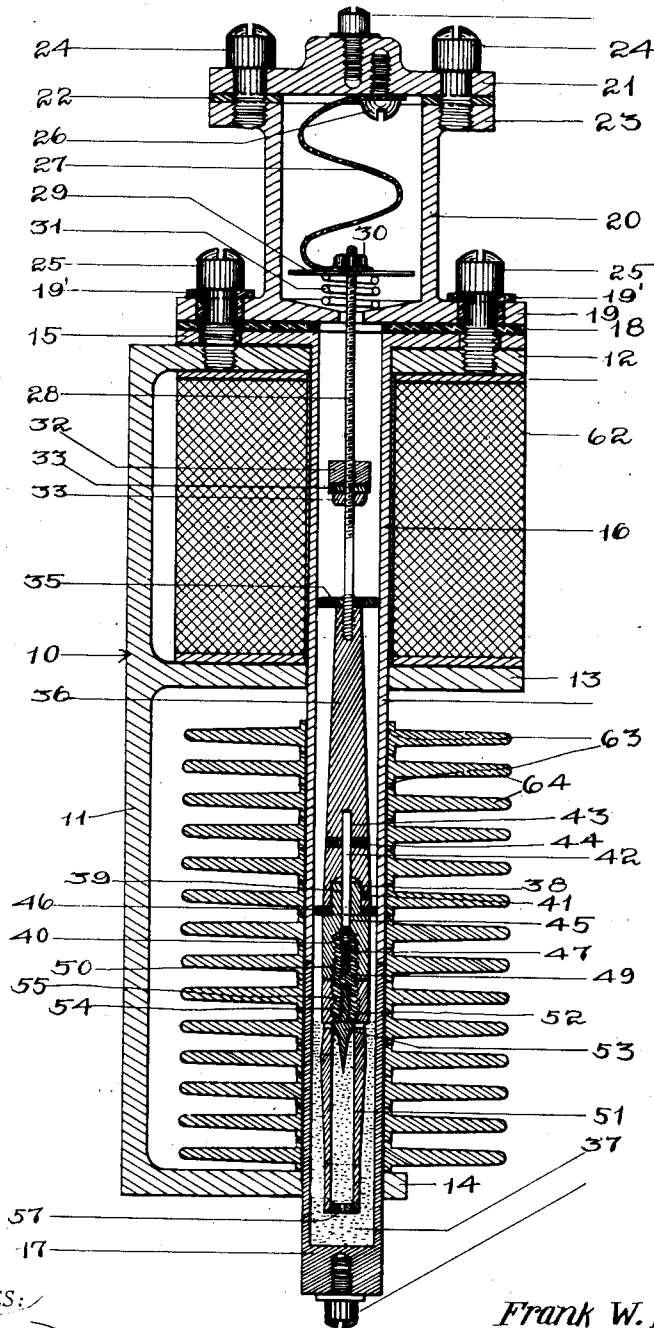


FIG. 1

WITNESSES:

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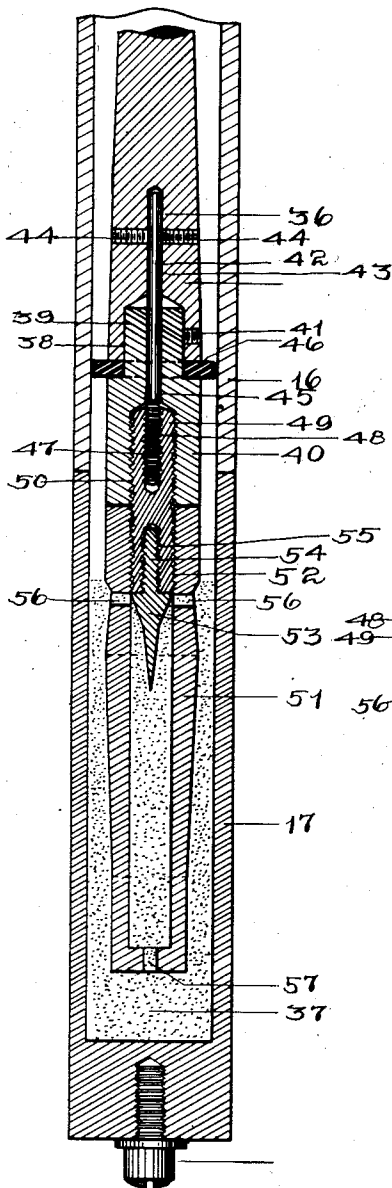


FIG. 2.

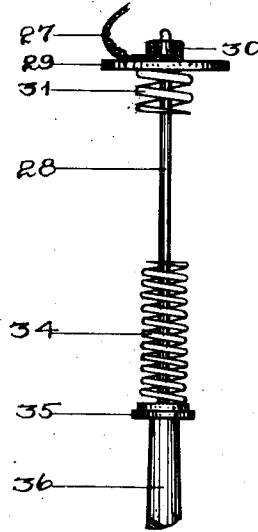


FIG. 6.

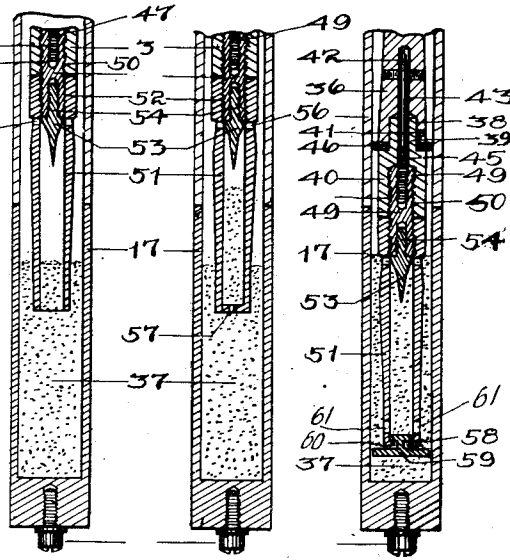


FIG. 3.

FIG. 4.

FIG. 5.

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3 SHEETS—SHEET 3.

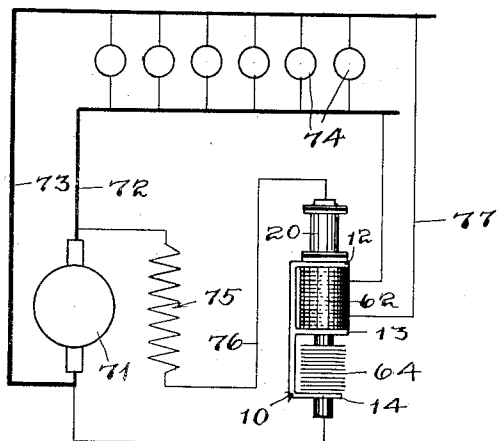
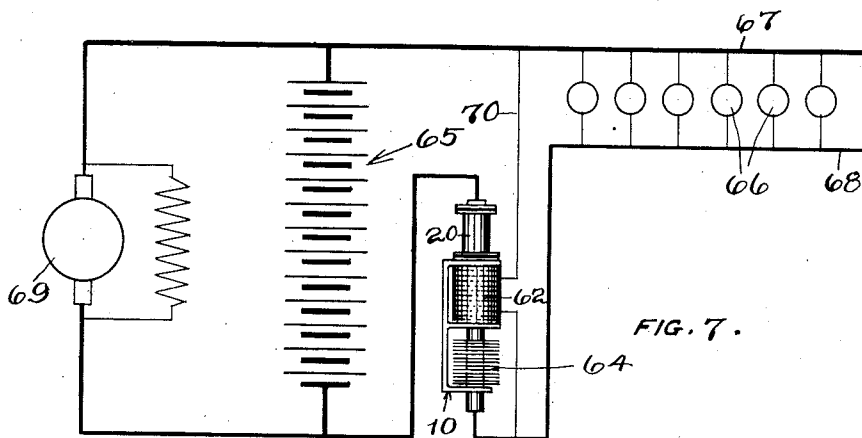


FIG. 8.

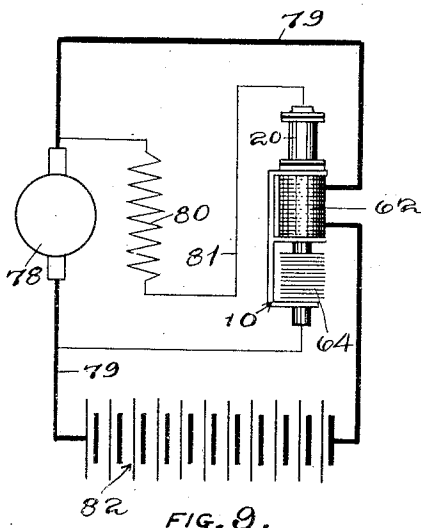


FIG. 9.

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UNITED STATES PATENT OFFICE.

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ELECTRICAL REGULATOR.

1,220,255.

Specification of Letters Patent.

Patented Mar. 27, 1917.

Application filed December 6, 1913. Serial No. 805,049.

To all whom it may concern:

Be it known that I, FRANK W. MERRILL, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Electrical Regulators, of which the following is a specification.

This invention relates to improvements in electrical regulators, for automatically maintaining constant, substantially, the voltage or amperage, or both, of an electric current.

An important object of the invention is to provide means of the above mentioned character, which are so constructed that upon the rise of amperage or voltage of the current, the same will automatically operate to restore the amperage or voltage by gradually introducing resistance, in a novel manner, into the circuit.

A further object of the invention is to provide means of the above mentioned character, which are accurate and reliable in operation, strong, durable, and not liable to derangements.

A further object of the invention is to provide means of the above mentioned character, which are simple in construction, comparatively inexpensive to manufacture and convenient in use.

Other objects and advantages of this invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification and in which like numerals are employed to designate like parts throughout the same,

Figure 1 is a central longitudinal sectional view through a regulator embodying my invention,

Fig. 2 is an enlarged central longitudinal sectional view through the conductor portion of the regulator,

Fig. 3 is a similar view through a slightly different form of conductor member,

Fig. 4 is a similar view through a different form of conductor member,

Fig. 5 is a similar view through a still different form of conductor member,

Fig. 6 is a fragmentary view of the upper end of the conductor member, showing a different form of shock absorbing means carried thereby,

Fig. 7 is a diagrammatic view of a circuit,

showing my improved regulator connected therein,

Fig. 8 is a similar view of a different circuit with my regulator connected therein, and,

Fig. 9 is a similar view of a still different circuit with my improved regulator connected therein.

In the drawings, wherein is illustrated a preferred embodiment of my invention, attention being first called to Fig. 1, the numeral 10 designates a casting or support, including a preferably vertically arranged body portion 11, carrying laterally extending horizontal arms 12, 13 and 14. Arranged upon the upper arm 12 is a plate 15, which is preferably formed of a non-magnetic material, such as copper. Depending from this plate and preferably formed integral therewith is a tube 16, also formed of non-magnetic material, such as copper. The tube 16 passes through openings formed in the arms 12 and 13 and is securely held in place thereby. Arranged below and in alinement with the tube 16 is a second tube 17, which is preferably formed of a metal which will not be readily affected by the action of mercury, the same being preferably formed of iron. The lower end of the iron tube 17 is closed, as shown. The contiguous ends of the copper and iron tubes 16 and 17 are preferably connected by being welded together. The function in forming the tube 16 of copper is to prevent the same from interfering with the action of the winding of a solenoid, to be described. Copper is also preferred over other non-magnetic metals, since it is only slowly acted upon by mercury, and the same has a coefficient of expansion closer to that of iron, than any other non-magnetic metal which is slowly acted upon by mercury, that I am aware of. The specific location of the welded joint between the two tubes will be discussed later, as the same has a particular function. From the foregoing it is obvious that the two tubes 16 and 17 are securely held in place by the arms 12, 13 and 14, and may be readily removed when desired.

Arranged upon the plate 15 is an insulating ring 18, upon which is mounted an apertured plate 19. This insulating ring 18 also serves to exclude dampness, air or oxygen

from the interior of the tubes 16 and 17, for preventing the deterioration of a resistor, to be described. Upon this plate is formed an upstanding housing or dome 20, preferably cast integral therewith. The upper end of the housing or dome 20 is preferably formed open and is closed by a removable cap 21. A packing ring 22, preferably formed of rubber or the like, is interposed between the cap 21 and the flanged end 23 of the housing or dome 20, to effectually exclude dampness, atmosphere, or oxygen from the interior of the housing or dome 20. The cap 21 is detachably clamped to the flanged end 23 by screws 24. The plate 19 is detachably clamped to the upper arm 12 by screws 25, which are thoroughly insulated from the plate 19, as shown at 19', whereby the plate 19 and arm 12 are thoroughly insulated. In the preferred construction, these screws 25 have screw-threaded engagement with the arm 12 and pass through enlarged openings formed in the plates 15, as shown.

The numeral 26 designates a clamping screw, mounted upon the inner face of the cap 21 and serving to electrically connect therewith a longitudinally extensible or "pig tail" conductor wire 27. The lower end of this longitudinally extensible conductor wire is electrically connected with a depending reciprocatory rod 28, formed of non-magnetic material, preferably such as copper. Having screw-threaded engagement with the upper end of the rod 28 is a non-magnetic disk 29, preferably formed of copper and serving to support upon its upper surface the longitudinally extensible or "pig tail" conductor wire 27. Having screw-threaded engagement with the upper end of the rod 28 is a clamping nut 30, preferably formed of copper, which serves to hold the lower end of the extensible conductor wire 27 upon the disk 29 and to lock the disk 29 in adjustment in desired longitudinal positions with relation to the rod 28, said disk being longitudinally adjustable with relation to the rod 28 so that the extent of longitudinal movement of the rod in one direction may be regulated. The rod 28 passes through the central aperture in the plate 19 and is surrounded above this plate by a suitably stiff compressible spring 31, serving to support the rod 28 and associated elements when they occupy their lowermost position and as shock absorbing means when moved to such lowermost position. Instead of employing a spring as shock absorbing means, other suitable material, such as felt or rubber may be advantageously used. The upward movement of the rod 28 is yieldingly limited by an elastic stop or buffer 32, surrounding the rod and supported by a pair of clamping or locking nuts 33, having screw-threaded engagement with a portion

of the rod 28. It is thus seen that the stop or buffer 32 may be properly longitudinally adjusted with relation to the rod 28. The clamping nuts 33 are formed of non-magnetic material, preferably copper. Instead of forming the elastic stop or buffer of felt, I may construct the same, as shown in Fig. 6, of a coil spring 34, which is formed of non-magnetic material, preferably copper. When the spring construction is used, the same is preferably supported by an insulating spacing ring 35, operating within the copper tube 16. This insulating spacing ring 35 while preventing undue lateral movement of the rod 28, has its diameter sufficiently smaller than the interior diameter of the tube 16, whereby the same will not create vacuums in the tube 17, upon opposite sides thereof, or having binding action with the tube 17.

Connected with the lower end of the rod 28 is a magnetic plunger-core 36, preferably formed of iron, the same being preferably connected with the rod by having screw-threaded engagement therewith, the screw-threaded end of the rod 28 preferably extending into a screw-threaded opening in the plunger-core 36. Particular attention is called to the fact that the plunger-core 36 is conical or tapered, decreasing in diameter upwardly, for a purpose to be fully explained. The lower large end of the plunger-core 36, when occupying its lowermost position, is suitably spaced from the upper end of the iron tube 17, to prevent this tube from exerting an undue magnetic influence upon the plunger-core. If the upper end of the iron tube 17 is too near the lower end of the plunger-core 36, there will be had a bad magnetic locking effect, which causes the plunger to remain in the lower position, when the same should rise, said plunger-core being magnetized, as will be apparent. It has been found that satisfactory results are obtainable by having the distance between the plunger-core and the magnetic or iron tube 17 substantially equal to the diameter of the lower end of the plunger-core, but it is to be understood that the invention is in no sense restricted to this precise distance. At this point it might be well to state that the iron or magnetic tube 17 is partially filled with mercury 37, the upper end or level of the mercury being spaced a suitable distance from the lower end of the copper tube 16, as shown. The function of spacing the lower end of the copper tube 16 from the level or upper end of the mercury 37 is to prevent the mercury from coming in contact, in excess, with the copper tube. It has been found by experience that the continued action of mercury vapor, or an occasional splash of the liquid mercury will not injure the copper, but if the liquid mercury is allowed to be in con-

tact with the copper tube for a considerable time, the same will eat clear through the tube and destroy it. It has also been found that satisfactory results are obtainable by having a distance between the lower end of the copper tube 16 and the upper end or level of the mercury 37 equal to substantially one and one-fourth of the diameter of the tube 16. However it is to be distinctly understood that the invention is in no sense restricted to this precise distance.

As more clearly shown in Fig. 2, the plunger-core 36 is provided at its lower end with a socket 38, receiving a reduced extension or shank 39 of a combined spacing and connecting element 40 preferably formed of carbon having a low electrical resistance. The shank 39 is held within the socket 38 by a clamping screw 41. The numeral 42 designates a rod, preferably formed of iron, extending within an axial opening 43 of the plunger-core 36 and through the socket 38, the same being held within the opening 43 by clamping screws 44. This rod 42 also extends through a longitudinal opening 45 in the shank 39, as shown. Arranged between the adjacent ends of the plunger-core 36 and the combined connecting and spacing element 40 is an insulating spacing ring 46, identical with the upper insulating spacing ring 35 and serving the same purpose. The lower end of the iron rod 43 is screw-threaded, as shown at 47, and passes into a screw-threaded opening 48 of a coupler 49, which is preferably formed of iron. This coupler is externally screw-threaded with its upper portion extending into a screw-threaded opening 50 of the element 40, the lower portion thereof extending downwardly below such element. The numeral 51 designates a tubular resistor, preferably formed of carbon having a high electrical resistance. The resistor 51 is tubular, extends into the mercury, and is vertically movable, whereby the resistance that the same will offer to the passage of the current will be increased as the same moves upwardly. The upper end of the tubular resistor 51 is internally screw-threaded, as shown at 52, for engagement with the lower screw-threaded portion of the coupler 49. Considerable heat is generated in the vicinity of the resistor 51, by current passing therethrough, which tends to cause the elements constituting the joint between the element 40 and the resistor, to expand. A particular advantage is therefore gained in connecting the element 40 and resistor 51 by the internally arranged coupler 49 of iron, the iron having a greater coefficient of expansion than the carbon element 40 and carbon resistor 51, whereby upon heating, the expansion of the coupler 49 serves to increase clamping engagement of the same with the element 40 and the resistor 51, for

effecting a more perfect electrical connection between these parts.

One of the important features and advantages of my regulator is the fact that the resistor 51, operates to increase the resistance continually or uniformly, without sudden increases or steps, whereby exceeding fineness in the adjustment of the resistance may be obtained. In order that the apparatus may operate in the manner above stated, or substantially so, a shunt resistor 53 is used, preferably located within the tubular resistor 51 and provided with a screw-threaded extension or stem 54, extending into a screw-threaded opening 55 of the coupler 49. The shunt resistor 53 is formed of low resistance carbon, preferably of one-tenth the resistance of the resistor 51 and is tapered, or conical, and decreases in diameter downwardly, whereby its resistance rapidly increases as it is moved away from the surface of the mercury. The resistor 51 is provided adjacent the upper end of the shunt resistor 53 with openings 56 whereby the mercury 37 can freely pass into the upper end of the tubular resistor 51, to engage the shunt resistor. This shunt resistor 53 prevents the resistance of the tubular resistor 51 from being too suddenly brought into circuit, when the same is first moved upwardly. It is obvious that upon the upward movement of the tubular resistor 51, the shunt resistor 53 still contacts with the mercury, the resistance of the shunt resistor however, rapidly increasing as it is moved upwardly, until it disengages the mercury, at which time the circuit will be completed through the tubular resistor 51, of high resistance.

The tubular resistor 51, shown in Figs. 2 and 4, has its lower end closed and provided with a contracted outlet opening 57, whereby when the resistor 51 is elevated, as shown in Fig. 4, the mercury contained within the tubular resistor will be temporarily held therein until the same gradually flows through the contracted opening 57, whereby the resistance of the resistor is more gradually thrown into circuit. The type of resistor shown in Figs. 2 and 4 is employed when it is desired that the change in resistance in the circuit be accomplished more gradually. This type of resistor gives the plunger-core 36 time to become steady and locate itself in the proper place to regulate the resistance of the circuit. In Fig. 3, the tubular resistor 51 has its lower end opened entirely open, whereby the mercury contained therein will pass out of the same, upon being raised. This is a quicker acting resistor. In Fig. 5, mechanical means are shown, for causing the resistance of the resistor 51 to be gradually thrown into circuit. This type of resistor is particularly suitable for operation in places where the apparatus

might be subjected to sudden jars and jolts, such as upon vehicles or automobiles. This resistor 51 has its lower end formed closed and provided with a contracted opening 58, within which is loosely mounted a depending headed pin 59, having attached thereto an exterior damper-disk or plate 60. The resistor 51, in Fig. 5, is provided near and spaced from its lower end, preferably at diametrically opposite points with relatively large outlet openings 61, which permit the mercury to freely pass out of the lower end of the resistor when it is elevated. It is thus seen that the damper-disk 60, coöperates with the tube 17 containing the mercury, forming in effect a dash-pot, to retard or dampen the movement of the resistor in either direction, whereby the effect of the inertia of the resistor 51 is reduced to a minimum, and "hunting" prevented. Particular attention is called to the fact that by pivotally connecting the damper-disk 60 with the lower end of the resistor 51, as explained, no additional side strains will be transmitted to the resistor, from the tube 17.

The numeral 62 (see Fig. 1) designates a solenoid winding, which surrounds the upper portion of the copper tube 16, between the arms 12 and 13 and is supported thereby. Particular attention is called to the fact that this solenoid winding is not supported by the tube 16, whereby the same is relieved from unnecessary strains. At this point it is thought proper to call attention to the fact that the upper end of the plunger-core 36, when in its lowermost position, extends for a comparatively short distance into the axial opening of the solenoid winding 62. It has been found by experience, that satisfactory results are obtainable by having substantially one-fourth of the plunger-core extending into the solenoid winding, while of course the invention is not solely restricted to this specific arrangement. By these means the working stroke of the plunger-core is below the uniform pull zone of the solenoid winding. As a result of this, as the plunger-core moves upwardly, the pull of the solenoid winding rapidly increases and then gradually becomes constant as the plunger-core reaches or nears the uniform pull zone of the solenoid winding. This increase of the pull of the solenoid winding upon the plunger-core is also due to the tapered shape of the plunger-core.

The function in having the plunger-core 36 tapered and increasing in diameter downwardly, is to provide means whereby the pull or lifting force of the solenoid winding 62 thereon, will increase, as the plunger-core rises. Upon the upward movement of the resistor 51 the buoyant or lifting force of the mercury 37 thereon, decreases, as is obvious. There are three forces in the same straight line, to wit, (1) the weight of the plunger

core 36 and resistor 51 acting downwardly, (2) the magnetic pull of the solenoid winding 62 acting upwardly upon the plunger core with increasing force, according to the degree of taper of the plunger core and to the distance which the plunger core has entered the solenoid winding, and (3) the buoyant or lifting force of the displaced mercury, acting upwardly upon the resistor 51 with decreasing force as the stroke proceeds. It is desired that the force (1) be balanced at all times by the sum of the forces (2) and (3), which result is accomplished by the predetermined shapes of the plunger-core and resistor, and the starting position of the plunger-core with relation to the solenoid winding. By this means the solenoid winding 62 will move the plunger-core 36 upwardly, upon a very slight increase of the current passing therethrough.

Surrounding the lower portion of the tube 16 and the upper portion of the tube 17 is a tubular radiator, embodying a plurality of separate superposed rings 63, carrying annular flanges or fins 64. These rings 63 are entirely supported by the lower arm 14, whereby undue strain is taken off of the tubes 16 and 17. The function of the radiator is to remove heat from the resistor 51 and closely associated elements.

In Fig. 7, the numeral 65 designates a storage battery feeding current to lamps 66, through wires 67 and 68. The storage battery 65 may be charged by a generator 69. The variable resistance element of my regulator, including the resistor 51, is connected in series with the wire 68, while the solenoid winding 62 is connected across wires 67 and 68 by a wire 70. It is thus seen that as the voltage rises between the wires 67 and 68, current will pass through solenoid winding 62, whereby the resistor 51 will be elevated, to increase the resistance of the wire 68, thus keeping the voltage on the lamps 66, constant.

In Fig. 8, the numeral 71 designates the armature of a shunt wound generator or dynamo, feeding current through wires 72 and 73, to lamps 74. The numeral 75 designates the shunt field winding of the generator. The variable resistance member embodying the resistor 51 is connected in series with the field winding 75 by a wire 76, while the solenoid winding 62 is connected across the wires 72 and 73 by a wire 77. It is thus seen that as the voltage on the lamps 74, increases, current will pass through the solenoid winding 62, increasing the magnetism thereof, whereby the resistor 51 will be elevated, and an increased resistance added to the shunt field of the generator. In this manner the voltage on the lamps 74 is maintained constant.

In Fig. 9, the numeral 78 designates the armature of a shunt wound generator or

dynamo, feeding current through wires 79. 80 is the shunt field of the generator, which is connected in series by wire 81 with the variable resistance member of the regulator including the resistor 51. In this instance the generator 78 is supplying current to a storage battery 82 for charging the same. When used in this capacity, my regulator has its solenoid winding 62 wound for controlling the amperage of the current. It is thus seen that when the amperage of the current increases, the solenoid winding 62 will elevate the resistor 51, whereby a corresponding resistance is added to the field winding 80. In this manner the amperage of the current generated by the dynamo 78 is maintained constant. It is thought that no further explanation of the apparatus is necessary.

It is to be understood that the form of my invention herewith shown and described is to be taken as a preferred example of the same, and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

Having described my invention, I claim:—

1. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a relatively high resistance resistor substantially vertically movably mounted within the receptacle, a relatively low resistance shunt resistor electrically connected with the first named resistor and adapted to be vertically moved, and means to move said resistors.

2. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a relatively high resistance resistor vertically movably mounted within the receptacle, a relatively low resistance shunt resistor electrically connected with the first named resistor and movable substantially vertically within the receptacle, and means to move the first named resistor.

3. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a relatively high resistance resistor vertically movably mounted within the receptacle, a relatively low resistance shunt resistor connected with the first named resistor and terminating at a point considerably spaced from the lower end thereof, and means to move the resistors.

4. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a relatively high resistance resistor substantially vertically movably mounted within the receptacle to contact with the liquid electrical conductor, a relatively low

resistance shunt resistor, connected with the first named resistor, extending longitudinally thereof, terminating at a point remote from the lower end of said first named resistor, and increasing in resistance toward its lower end, and means to move the resistors.

5. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a relatively high resistance tubular resistor vertically movably mounted within the receptacle, a relatively low resistance tapered resistor mounted within the tubular resistor, decreasing in diameter downwardly, and terminating at a point remote from the lower end of the first named resistor, and means to move the resistors.

6. In apparatus of the character described, the combination with a solenoid winding, of a core for movement within the opening of the winding and provided near its lower end with a socket, a carbon connecting element provided with a reduced shank to extend within the socket and provided with a longitudinally extending opening, a carbon resistor provided in its end adjacent the connecting element with a longitudinal opening, a coupler mounted within the longitudinal openings of the connecting element and conductor and formed of a metal having a coefficient of expansion greater than carbon, and a mercury containing receptacle for receiving the resistor.

7. In apparatus of the character described, the combination with a solenoid winding, of a core for movement within the opening of the winding, a carbon connecting element connected with the core and provided with a screw-threaded longitudinal opening, a resistor having its end adjacent the connecting element provided with a screw-threaded longitudinal opening, an exteriorly screw-threaded coupler mounted within the screw-threaded longitudinal openings of the connecting element and resistor, and formed of a metal having a coefficient of expansion greater than carbon, a receptacle for receiving the resistor therein, and mercury contained within the receptacle.

8. In apparatus of the character described, a core, a solenoid winding, a carbon connecting element connected therewith and provided with a screw-threaded longitudinal opening, a carbon resistor having its adjacent end provided with a longitudinal screw-threaded opening, an iron coupler externally screw-threaded to enter the longitudinal screw threaded openings of the carbon connecting element and carbon resistor and provided with longitudinally extending screw-threaded openings, an iron rod having one end screw-threaded and extending into one screw-threaded opening of the iron

coupler, means connecting the opposite end of the iron rod with the core, a shunt resistor provided with a screw-threaded shank extending into the other screw-threaded opening of the iron coupler, and a mercury containing receptacle for receiving the resistors.

9. In apparatus of the character described, an iron receptacle, mercury contained therein, a copper receptacle connected with the upper end of the iron receptacle, a longitudinally movable core mounted within the copper receptacle with its lower end spaced from the upper end of the iron receptacle when the core is in its lowermost position whereby the iron receptacle will not exert undue magnetic influence upon the core, a resistor mounted within the iron receptacle in contact with the mercury and spaced from the lower end of the core, connecting means between the resistor and core, and a solenoid winding for moving the core.

10. In apparatus of the character described, a lower metallic receptacle to hold mercury and adapted to withstand the action thereof, mercury contained therein, a non-magnetic receptacle connected with the upper end of the lower metallic receptacle, a longitudinally movable core mounted within the non-magnetic receptacle with its lower end spaced from the upper end of the lower metallic receptacle when the core is in its lowermost position whereby the lower metallic receptacle will not exert undue magnetic influence upon the core, a non-magnetic resistor mounted within the lower metallic receptacle in contact with the mercury and spaced from the lower end of the core, connecting means between the resistor and core, and a solenoid winding surrounding the non-magnetic receptacle to move the core.

11. Apparatus of the character described, comprising a lower iron receptacle, an upper copper receptacle which is welded to the iron receptacle, mercury contained within the iron receptacle with its upper end surface suitably spaced from the lower end of the copper receptacle, a resistor contacting with the mercury, and means to move the resistor.

12. In apparatus of the character described, the combination with a receptacle, of a liquid electrical conductor contained therein, a tapered tubular resistor decreasing in diameter downwardly mounted to reciprocate within the receptacle in engagement with the liquid electrical conductor contained therein and having its lower end provided with a permanently uncovered restricted outlet opening of a substantially smaller diameter than the bore of the tubular conductor whereby the liquid electrical conductor may enter the interior of the

tubular conductor and discharge therefrom in a retarded manner upon the upward movement of the tubular resistor, and electrically operated means to move the tubular resistor upwardly.

13. Apparatus of the character described, comprising a tubular shell having its lower portion formed of a material which is not acted upon by mercury and its upper portion formed of a non-magnetic metal, a non-magnetic resistor adapted to operate within the lower portion of the shell, a liquid electrical conductor contained within the lower portion of the shell, a magnetic core operating within the upper non-magnetic portion of the shell and connected with the resistor, and a solenoid winding surrounding the upper non-magnetic portion of the shell to move the core.

14. In apparatus of the character described, the combination with a receptacle of a liquid electrical conductor therein, a tapered tubular resistor of high resistance mounted to reciprocate within the receptacle in engagement with the liquid electrical conductor, a shunt resistor mounted within and connected with the tubular resistor and having a lower resistance and tapered at a greater angle and decreasing in diameter downwardly, and means to move the tubular resistor.

15. In apparatus of the character described, the combination with a solenoid winding, of a core for movement within the opening of the winding and provided near its lower end with a socket, a carbon connecting element provided with a reduced shank to extend within the socket and provided with a longitudinally extending opening, a carbon resistor provided in its upper end adjacent the connecting element with a longitudinal opening, a coupler mounted within the longitudinal openings of the connecting element and conductor and formed of a metal having a coefficient of expansion greater than carbon and having screw-threaded engagement with these elements, and a mercury containing receptacle receiving the resistor.

16. Apparatus of the character described, comprising a lower iron receptacle, an upper copper receptacle arranged in end to end relation to the iron receptacle and welded thereto, mercury contained within the iron receptacle with its level spaced a substantial distance from the lower end of the copper receptacle, a resistor engaging with the mercury, and means to move the resistor.

17. Apparatus of the character described, comprising a vertical solenoid winding, a mercury containing receptacle arranged below the solenoid winding, a tapered metallic magnetic core increasing in diameter downwardly with its reduced upper end extending into the opening of the solenoid winding

only for a short distance when the core is in the lowermost position, and a tapered resistor decreasing in diameter downwardly, connected with the core and movable in engagement with the mercury.

18. Apparatus of the character described, comprising an upstanding support provided with a plurality of apertured substantially horizontal laterally extending arms, a tubular casing extending through the apertured arms and provided at its upper end with an outwardly extending flange engaging the uppermost arm to be supported thereby, mercury contained within the lower end of the tubular casing, a movable resistor mounted within the tubular casing to engage with the mercury, a core connected with the resistor to move the same, a solenoid winding to move the core, surrounding the upper portion of the tubular casing and arranged between two of the arms to be held in place and supported thereby, and a plurality of radiator rings surrounding the lower portion of the tubular casing in proximity to the resistor and entirely supported by the lowermost arm.

19. Apparatus of the character described, comprising an upstanding support provided with a plurality of apertured laterally extending arms, a tubular casing extending through the apertured arms and held in place thereby, mercury contained within the lower end of the tubular casing, a resistor to contact with the mercury, a core connected with the resistor to move the same, a solenoid winding to move the core, surrounding the upper portion of the tubular casing and entirely supported by one arm, and a tubular radiator surrounding the lower portion of the tubular casing in proximity to the resistor and entirely supported by the lowermost arm.

20. Apparatus of the character described, comprising a support, a plate mounted upon the support and provided with a depending tube, a shell arranged near and above the plate, insulating packing arranged between the lower portion of the shell and the plate, clamping means connecting the lower portion of the shell with the support, a longitudinally movable rod extending into the shell, a longitudinally extensible conductor element connected with the rod, a plunger-core connected with the rod, a solenoid winding surrounding the depending tube to move the plunger core, mercury contained within the lower portion of the tube, a resistor to contact with the mercury, and connecting means between the resistor and the plunger core.

21. Apparatus of the character described,

comprising a support, a tubular casing connected therewith, a shell connected with the support and having communication with the tubular casing, a rod extending through a portion of the tubular casing and passing into the shell, a longitudinally extensible conductor connected with the upper portion of the shell and the upper end of the rod, a disk connected with the rod below and adjacent the longitudinally extensible conductor to support the turns of the same upon the upward movement of the rod, a solenoid winding surrounding a portion of the tubular casing, a plunger-core to be moved by the solenoid winding when the same is energized, a liquid electrical conductor contained within the lower portion of the tubular casing, and a resistor to contact with the liquid electrical conductor and connected with the plunger-core.

22. In apparatus of the character described, the combination with a solenoid winding, of a receptacle arranged near the winding, a liquid electrical conductor contained within the receptacle, a resistor arranged within the receptacle to engage with the liquid electrical conductor, and a core arranged for movement within the winding and so shaped that as the core is drawn upwardly into the winding the increasing upward force of the solenoid upon the core plus the decreasing upward force of the displaced liquid electrical conductor upon the resistor is equal, at all points of the stroke with the same current flowing in the solenoid winding, to the downward force of gravity upon the core, resistor, and associated moving elements.

23. In apparatus of the character described, the combination with a solenoid winding, of a core arranged for movement within the winding, a receptacle arranged near the winding, a liquid electrical conductor contained within the receptacle, and a resistor attached to the core, of such shape that as the core is drawn upwardly into the winding the decreasing upward force of the displaced liquid electrical conductor upon the resistor plus the increasing upward force of the solenoid pull upon the core, as it enters farther into the coil, is equal at all points of the stroke with the same current flowing in the solenoid winding to the downward force of gravity upon the core, resistor and associated moving elements.

In testimony whereof I affix my signature in presence of two witnesses.

FRANK WINTHROP MERRILL.

Witnesses:

HIRAM L. WALKER,

J. L. ARTHUR.