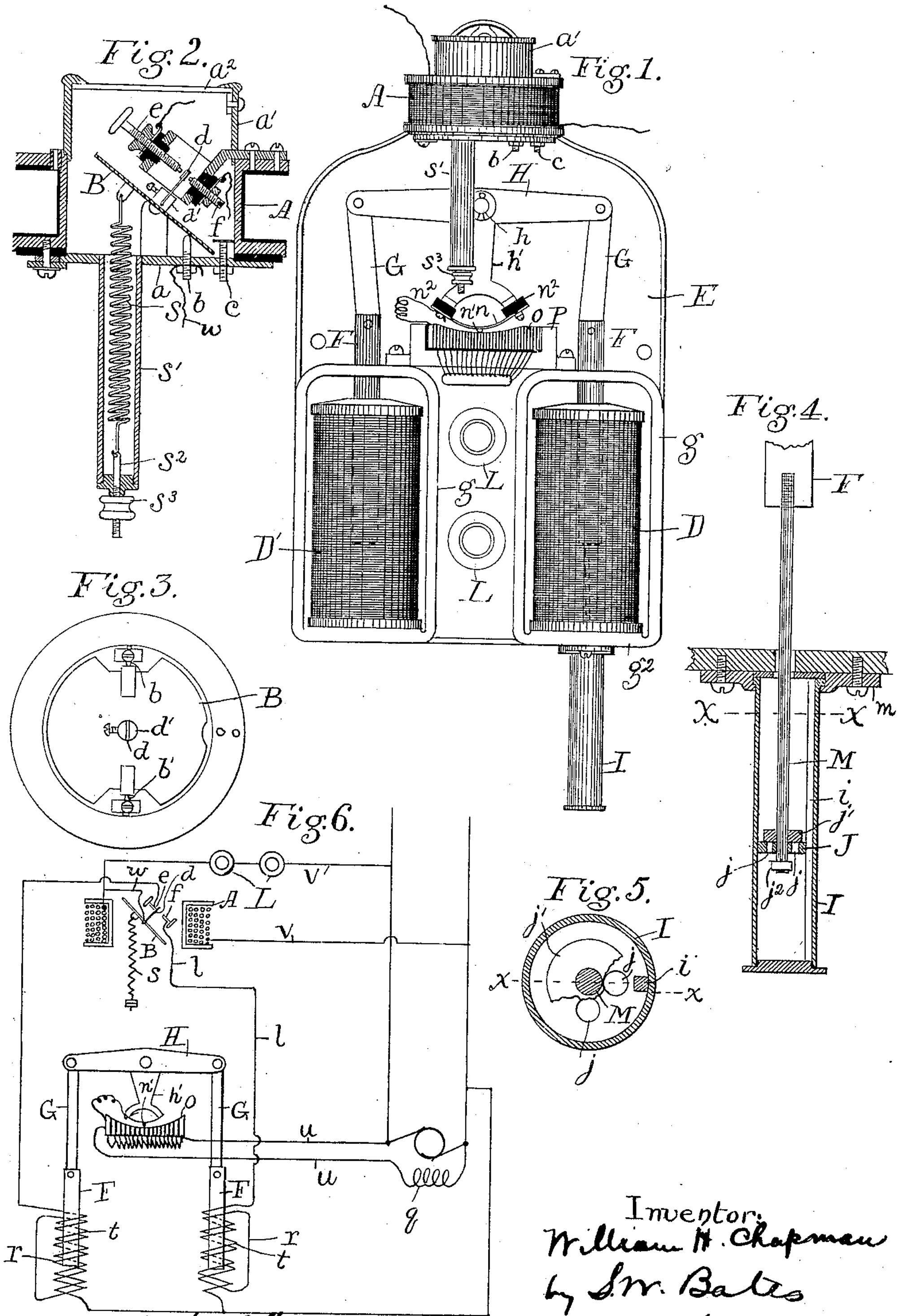
No. 648,388. Patented May 1, 1900.

# W. H. CHAPMAN.
## VOLTAGE REGULATOR.

(Application filed Feb. 23, 1900.)

(No Model.) 2 Sheets—Sheet 1.




Witnesses: Frank H. Colley. L. M. Godfrey.

Inventor: William H. Chapman by S. W. Bates Attorney

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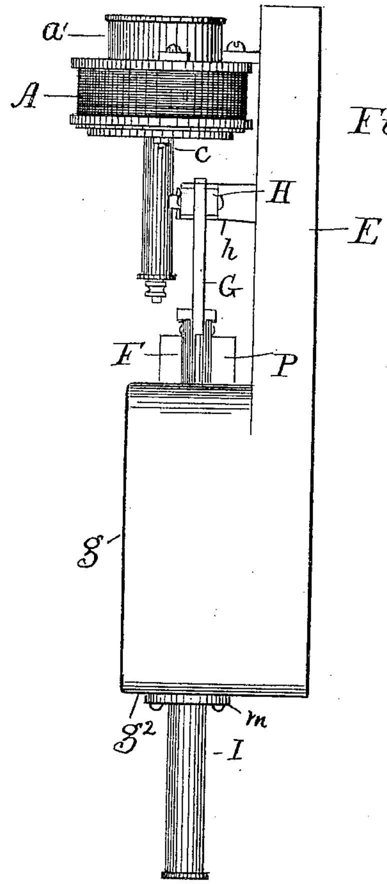


Fig. 7.

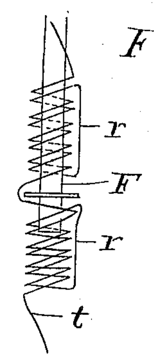


Fig. 8.

Witnesses:
Frank H. Colby
L. M. Godfrey

Inventor:
William H. Chapman
by S. W. Bates
Attorney

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# UNITED STATES PATENT OFFICE.

WILLIAM H. CHAPMAN, OF PORTLAND, MAINE.

## VOLTAGE-REGULATOR.

SPECIFICATION forming part of Letters Patent No. 648,388, dated May 1, 1900.

Application filed February 23, 1900. Serial No. 6,197. (No model.)

*To all whom it may concern:*

Be it known that I, WILLIAM H. CHAPMAN, a citizen of the United States of America, and a resident of Portland, Maine, have invented certain new and useful Improvements in Voltage-Regulators, of which the following is a specification.

My invention relates to devices for automatically maintaining a constant voltage or a constant current at some prescribed point in an electric circuit; and one object is to provide an apparatus sensitive to detect slight changes and at the same time powerful in its movements to correct those changes, one that shall be accurate and reliable in its action when subjected to heavy jarring or vibratory motions, as on a railway-train, and one that shall be consuming no current in its working solenoids or magnets during the time that no changes are occurring in the current to be regulated.

A further object of the invention is to so construct the working solenoids or magnets that sparking will be avoided at the switch.

The device by which I accomplish these objects consists of, first, a relay for the detection of slight changes in the current to be regulated and for admitting a current to or cutting it off from the working solenoids or magnets by a switch operated by the relay; second, working solenoids or magnets adapted to do the work of operating a rheostat or other current-adjusting device and which have two equal and parallel windings, one for energizing the iron core of the solenoids or magnets when a contact is established at the relay and the other winding having its ends connected or short-circuited to form a complete circuit within the solenoid for the purpose of absorbing the induction-current when a contact is broken at the relay, thus avoiding a spark at the contact-points, and, third, a current-adjusting device, such as a rheostat or a choke-coil, adapted to be operated by the working solenoids or magnets and placed either directly in the circuit to be regulated or in the field-magnet circuit of a dynamo which is supplying the circuit to be regulated.

I illustrate my invention by means of the accompanying drawings, in which—

Figure 1 represents a front view of my device in its commercial form. Fig. 2 is a vertical central section through the relay-solenoid. Fig. 3 is a plan view of the same with the upper casing and certain parts removed. Fig. 4 is a section through the dash-pot, taken on the line $x$ $x$ of Fig. 5. Fig. 5 is an enlarged section on the line $x$ $x$ of Fig. 4. Fig. 6 is a diagram for illustrating the operation of the device. Fig. 7 is a side view of the completed regulator as shown in Fig. 1, and Fig. 8 is a diagram showing an alternate form of winding.

A is a brass spool of comparatively-large diameter wound full of insulated copper wire to form a relay-solenoid. Inside of the spool is placed a thin iron disk or armature B, hung on pivots which are set in a line at right angles to the axis of the spool and midway between its two ends.

S is a spring which tends to pull the disk against the force exerted by the solenoid or to a position where its plane would be at right angles to the axis of the spool. Two stop-screws $b$ and $c$ are provided to limit the movement of the disk B to a comparatively-small arc. On the upper side of the disk B is secured a brass stud $d'$, which is slit for the reception of the contact-spring $d$. The contact-spring $d$ has small pieces of platinum attached to its free end to serve as contact-surfaces. $e$ and $f$ are platinum-tipped contact-screws set at either side of the contact-spring $d$. They are mounted on a brass piece attached to the spool A, but insulated therefrom by rubber bushings. The spool A is supported on a lug cast onto the back or supporting plate E of the regulator. A casing $a'$, with glass top $a^2$, fits on the upper end of the solenoid A and serves to inclose and protect the contact-points from dust or mechanical injury.

At each end of the regulator and at the lower end are two working solenoids set with their axes parallel and inclosed on all sides except the front by the cast-iron back plate and flanges or projections $g$ $g$, cast with it. Each solenoid has an iron core F, which is attached by a connecting-rod G to the beam-lever H. The cores are preferably made a little longer than the coils, and the connection-rods are of such a length that when the lever H is in a horizontal position the lower ends of the two cores are situated at a point about two-thirds of the way through their respective solenoids from the top toward the bottom. Each working solenoid is mounted on a brass spool the lower head of which is secured to projections or shelves cast on the back plate. The solenoids are wound with parallel and insulated wire, and as I prefer to construct them each solenoid-coil is made up of two strands of insulated copper wire wound onto the spool together and at the same time, but kept insulated from each other, forming two equal and parallel wires. One of these strands, which may be called the "primary," has one of its ends connected to one of the contact-screws of the relay and acts as an energizing or exciting coil, while the other strand has its two ends connected together to form a complete wire-circuit through the solenoid and may be called the "secondary coil," because it can only get induction or secondary currents, since it is not connected into circuit with any other part of the apparatus. Instead of winding the wires onto the solenoids together, so that they will be equal in length, they may be wound in layers or otherwise, as desired.

In order to retard the action of the cores, so that they will not act too suddenly, means are provided for checking any sudden movement. For this purpose I place just below one of the working solenoids a dash-pot or liquid-cylinder composed of a brass tube I, designed to be filled with a suitable liquid, as alcohol. A piston-rod M, secured to the lower end of the core F, extends down into the dash-pot, and on the lower end of the rod is a piston secured thereon by means of a screw-thread, so that as it is turned it will move up and down on the rod. The tube I is secured to the under side of the shelf $g^2$ on the back plate in line with the center of the solenoid. The dash-pot is so constructed that the resistance of the piston as it passes up and down through the liquid may be easily regulated. For this purpose the tube I is so connected with the under side of the shelf that it can be readily turned on its own axis by hand. With this end in view the upper end of the tube is provided with a flange, over which fits a collar $m$, secured to the under side of the shelf $g^2$, and the tube I turns freely within this collar. The tube I is connected with the piston by means of a spline, so that as it turns the piston turns and moves longitudinally on the rod. As here shown, the tube I has inside of it a projection or feather $i$, extending nearly its whole length from top to bottom and engaging with a notch cut in the periphery of the piston J. The piston, fitting loosely on this projection as well as in the tube, slides freely up and down when the tube is turned. The piston J has ports through it for the passage of the liquid used in the dash-pot, and the passage of liquid through these ports is regulated by a disk $j'$, rigidly secured to the rod M above the piston and of a diameter large enough to close the ports of the piston when the latter is up against it. A lower stop $j^2$ on the end of the rod is of small enough diameter to leave the holes open when the piston is up against it.

The stops $j'$ and $j^2$ are located far enough apart so that the piston will have sufficient movement to open and close the ports to their full extent. As the tube is turned the piston is caused to approach or recede from the upper stop, according to the direction in which it is turned, and thus the freedom of passage for the liquid in the dash-pot through the piston is adjusted for the purpose of securing a greater or less retarding effect on the moving parts of the regulator. The two cores of the solenoids are connected to opposite ends of the beam-lever H, so that as each is drawn down by the action of its solenoids it will move the lever in a different direction. The lever H is pivoted on a hub $h$, attached to the back plate E, and has an arm $h'$ projecting downward, to which is attached the spring $n$, having contact-shoe $n'$ attached to its lower side. The spring $n$ is insulated from the lever H by fiber pieces $n^2$ $n^2$. Coöperating with the swinging arm of the lever H is a rheostat or current-regulating device of any desired construction, the movement of the arm operating the rheostat to increase or diminish the current passing through it in the well-known manner.

In the form of my invention here shown I provide a series of copper or brass segments $o$, insulated from each other and from the containing-frame P. These segments are connected in the usual manner to a set of resistance units placed on the back side of the back plate E and not here shown. The resistance units and segments $o$ and contact-shoe $n'$ and spring $n$, together with lever H, constitute a rheostat which is adapted to be operated by the working solenoids.

The operation of the device and the connection of the various parts are illustrated in diagram shown in Fig. 6. In this diagram the rheostat part of the regulator is placed in the field-magnet circuit of the dynamo which is supplying the circuit to be regulated.

The action of the apparatus is as follows: A small current is continually flowing through the coil on the spool A over the circuit-wires $v$ $v$, which tends to move the iron disk or armature B to a position where its plane will be in the line of the axis of the spool, while the spring $s$ is continually pulling the armature the other way. Normally these two forces are balanced and the contact-spring $d$ stays half-way between the contact-screws $e$ and $f$ without touching either of them. If the voltage of the circuit to be regulated should rise above normal from any cause, the armature would be overbalanced by the force of the coil on spool A and contact would be made with the screw $f$. This would admit a current which may be either a derived current from the main current or an independent current to the right-hand working solenoid over the connecting-wires $l$ and $w$. This causes the solenoid to pull its core downward, moving the lever H and the arm $h'$, with the contact-shoe $n'$, toward the left, where it will put more resistance in the field-magnet circuit. Thus the force in the supplying-circuit will be weakened, and when the voltage has been brought down again to normal the contact with screw $f$ will be interrupted. At the instant of interruption a secondary current will be generated in the secondary winding $r$ of the working solenoid, which will maintain the magnetic condition of the core to about its full strength during an appreciable interval of time while the contact-spring is separating from the contact-screw, and thus an induction-spark is avoided, which might otherwise burn the contacts at the instant of interruption. If the voltage of the supply-circuit becomes lower than the normal from any cause, the force of the coil on the spool A becomes less and the spring $d$ makes contact with the screw $e$, which admits current to the left-hand working solenoid. This causes it to pull its core downward, moving the lever H and the contact-shoe $h'$ toward the right, and resistance is thereby cut out of the field-magnet circuit until the voltage is again brought to normal. The contact of spring $d$ with screw $e$ will now be interrupted, and the interruption will also be sparkless because of the current generated in the secondary winding of the working solenoid.

In the circuit of the coil on spool A is placed a resistance, which is usually greater than the resistance of the coil itself. This outside resistance is made of some material whose temperature coefficient is very small, like German silver, or negative, like carbon, and in that way any error due to rise of temperature of the relay-coil is greatly reduced. For convenience I have made use of incandescent lamps L L for resistance in the relay-coil circuit. The projections or flanges $g$ $g$ from the cast-iron back E serve a useful purpose in improving the magnetic circuit of the solenoids. The magnetic flux in the cores has to have a return-circuit somewhere, and if there is no iron in the vicinity to form a return-circuit then it must go through the air the whole length of the solenoid; but air has a very high reluctance and the placing of iron in proximity to the solenoid is a great help to the magnetic circuit and increases the force exerted by the solenoid.

In cases where high voltages are used in operating the working solenoids it is often expedient to divide up the winding into two or more sections, so as to avoid excessive strains on the insulation of the wires. The several sections of primary winding $t$ are in this case all connected in series with each other, while the several sections of secondary winding are entirely separated from each other; but the two ends of each section are connected together by themselves. This is illustrated by diagram Fig. 8, where the winding is divided into two sections.

The relay-coil may be wound in various ways to suit various purposes for which the regulator may be applied. If the regulator is to be used to maintain a constant voltage on a pair of mains at the point where it is located, then it should have a winding of fine wire connected in series with a resistance forming a circuit which is connected as a shunt across the pair of mains; but if the regulator is to be used to maintain a constant current in a line the relay-coil should be wound with a coarse wire connected in series with the line, and if the regulator is to be used to maintain a constant voltage at some distant point on a pair of mains the relay-coil should have a fine winding connected, as in the first case, in a circuit which is a shunt to the two mains at a point near where the regulator is located and also a few turns of coarse wire connected in series with the mains; but whatever be the winding adopted on the relay for specific purposes the general principle of operation is the same. The relay responds to slight changes of electrical conditions occurring on the circuit to be regulated and causes a contact to be made admitting a current to one or the other of two working solenoids, which in turn operates the rheostat part of the device in a manner to compensate for the change that has occurred.

I am aware of the fact that many electric regulators have been constructed in which a relay solenoid or magnet is employed to operate a set of contact-points which admit current to other solenoids or magnets which do the work of operating a rheostat. In many of these regulators no special means is applied to prevent sparking at the contact-points of the relay due to the inductance in the coils of the working solenoid or magnet, and in this way they are defective, because the resulting corrosion of the contact-points renders them unreliable in action. In other regulators a differential winding is applied to the working solenoid or magnet for the purpose of obviating the spark. I myself have been the inventor of two regulators of this nature, described in Patents No. 599,892, dated March 1, 1898, and No. 613,853, dated November 8, 1898. In regulators of this latter kind an electric current is continuously maintaining the magnetization of the iron core, and when the relay makes a contact there is a partial neutralization of magnetism in the core, so that when the interruption of contact occurs there is a rise of magnetization which tends to neutralize the spark. In my present invention I obviate the necessity of maintaining a current continuously in any portion of the windings of my working solenoids, and no current is applied to them until they are called upon to operate the rheostat-arm, and, furthermore, I attain a perfect neutralization of spark by reason of the fact that my two windings are practically coincident with each other, being wound at the same time with their successive convolutions side by side.

I claim—

1. In a voltage-regulator, the combination of a relay-solenoid for switching an electric current into one of two regulating-circuits, consisting of a spool wound with insulated wire and having a pivoted core connected with the circuit, said core having its pivotal axis substantially at right angles to the axis of the spool, a spring for holding said core at an inclination to the axis of the spool, a pair of contact-points electrically connected with two regulating-circuits, a moving electric contact connected with said core and adapted to vibrate between said contact-points to throw the current one way or the other.

2. In a voltage-regulator, the combination of a relay-solenoid for switching an electric current into one of two regulating-circuits, consisting of a spool wound with insulated wire and having a core formed of a disk pivoted at opposite edges and connected with the main circuit, said disk having its pivotal axis substantially at right angles to the axis of the spool, a spring for holding said core at an inclination to the axis of the spool, a pair of contact-points electrically connected with the two regulating-circuits, a moving electrical contact connected with said disk and adapted to vibrate between said contact-points and to throw the current one way or the other.

3. In a voltage-regulator, the combination of a relay-solenoid for switching an electric current into one of two regulating-circuits, consisting of a spool wound with insulating-wire and having a core formed of a disk pivoted at opposite edges and connected with the main circuit, said disk having its pivotal axis substantially at right angles to the axis of the spool, an adjustable spiral spring attached to one side of said disk for holding the same at an inclination with the axis of the spool, a pair of contact-points electrically connected with the two regulating-circuits, a contact-spring extending out from the face of said disk to a point between said contact-points to form a moving contact.

4. In a voltage-regulator the combination of a rheostat, a solenoid for operating the same having a longitudinally-movable core, an extension-rod on said core, a piston secured to said rod by means of a screw-thread, ports in said piston, a disk on said rod above said piston adapted to close said ports when in contact with the piston, a stop on the end of the rod to limit the motion of the piston in that direction, a liquid-cylinder or dash-pot in which said piston moves, adapted to be turned on its axis and a spline connecting the piston with the inner surface of the cylinder.

5. In a voltage-regulator, the combination of a solenoid wound with two parallel insulated wires one of which carries the operating-current and connects with contact-points adapted to be opened or closed when the current to be regulated changes its voltage, the other wire having its ends connected to form a complete circuit within the solenoid whereby the magnetism of the core is prevented from dropping too suddenly and causing a spark at the contact-points.

6. In a voltage-regulator, the combination of a rheostat, solenoids for operating the same, an iron supporting or back plate to which said solenoids are secured said plate having projecting flanges forming recesses for containing said solenoids.

7. In a voltage-regulator, the combination of a rheostat, a solenoid for operating the same having a longitudinally-movable core, an extension-rod on said core, a piston threaded on said rod, ports leading by said piston from one side to the other and adapted to be opened and closed by the movement of the piston on the rod, a dash-pot in which said piston moves, adapted to be turned on its axis a spline connecting said dash-pot with said piston.

Signed at Portland, Maine, this 14th day of February, 1900.

WILLIAM H. CHAPMAN.

Witnesses:
S. W. BATES,
L. M. GODFREY.