Aug. 12, 1947. J. W. ALLEN 2,425,296

VOLTAGE REGULATOR FOR GENERATORS

Filed April 23, 1945

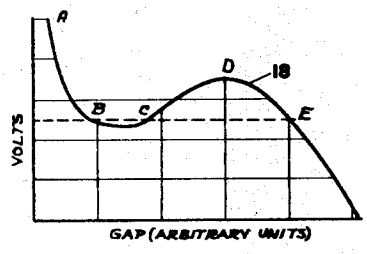


Fig. 1

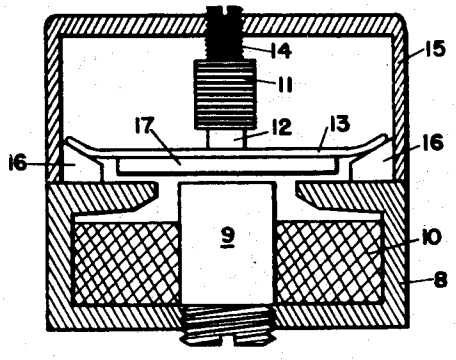


Fig. 2

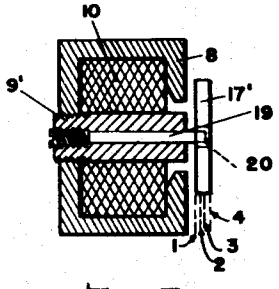


Fig. 3

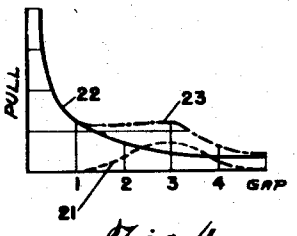


Fig. 4

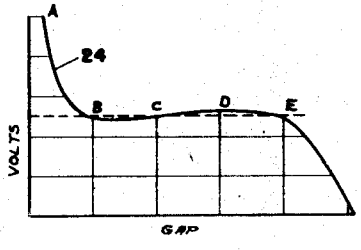


Fig. 5

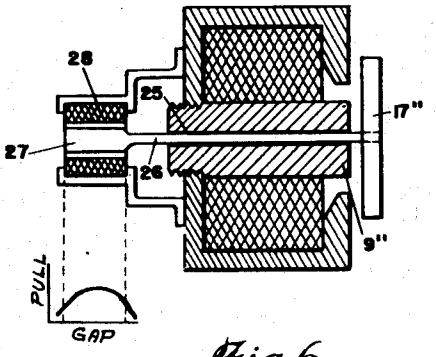


Fig. 6

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Patented Aug. 12, 1947 2,425,296

# UNITED STATES PATENT OFFICE

2,425,296

## VOLTAGE REGULATOR FOR GENERATORS

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Application April 23, 1945, Serial No. 589,832

6 Claims. (Cl. 201—51)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This invention relates to voltage regulators of the carbon pile type, and more particularly to means for maintaining a uniform pressure on the discs of the carbon pile as the discs are reduced in thickness by wear.

Among the several objects of this invention are:

To provide means to compensate for the varying resultant pressure on the carbon pile discs as the gap increases between the voltage coil and the armature attached to the spring which presses the discs together;

To device a voltage regulator capable of holding the output voltage of a generator at a more nearly uniform value through greater wear of the carbon pile discs than do prior art devices known to me.

In the drawings:

Fig. 1 shows the relation between the voltage of the generator and the gap, in arbitrary units, between the armature attached to the pressure spring and the voltage coil;

Fig. 2 is an axial section of the essential parts of ordinary type of carbon pile regulator;

Fig. 3 is an axial view of the parts of a carbon pile regulator with which my invention is most immediately concerned but with the spring and carbon pile omitted for clearness;

Fig. 4 shows the relation between the pull on the armature and the gap between the armature and the coil and the modification thereof effected by my invention;

Fig. 5 is a graph showing the voltage-gap characteristic of a voltage regulator modified according to my invention;

Fig. 6 is an axial section of a further embodiment of my present invention.

Controlling the output voltage of a generator having a shunt field winding, by means of a carbon pile regulator, is well known. In such devices a pile of thin carbon discs is connected in series with the shunt field winding, with a spring to hold the discs in firm contact together. A voltage coil opposes the action of the spring, and the parts are so adjusted that the flow of current through the carbon pile and through the field is such as to give the desired output voltage. When the voltage rises, for any reason, the voltage coil exerts a greater pull in opposition to the spring, the pressure on the discs is diminished and the increased resistance of the pile cuts down the field current until the voltage is reduced to the normal working value.

However, the effective pull of the voltage coil on the armature decreases rapidly as the gap between the armature and coil increases. The result is that after the discs have worn to a certain extent the armature is at such a distance from the coil that the latter does not sufficiently offset the pressure of the spring, the discs are pressed together too tightly and the voltage rises, sometimes to a value that damages the equipment. After further wear of the discs the strain in the spring is released to such an extent that the pressure on the discs is reduced so the resistance of the pile increases and the voltage drops. It is thus apparent that the difference between the pull of the coil and the force exerted by the spring first increases to a maximum value and then decreases as the displacement of the armature from its original position with respect to the coil becomes greater.

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The present invention provides means to secure more nearly uniform voltage regulation over the whole range of movement of the armature due to the wear of the discs. This is effected by auxiliary means that give increasing pull on the armature up to the point that the preponderance of spring pressure over pull of the voltage coil begins to decrease and then itself decreases.

Fig. 2 depicts the essential parts of a type of voltage regulator in wide use. Centrally disposed in the housing 8 is a core 9 in threaded engagement with the housing to provide for adjustment of the position of the core. Coil 10 is disposed in housing 8 around core 9 and is connected across the generator, providing an electromagnetic device that is responsive to voltage changes in the output of the generator. The pile 11 of carbon discs is held under pressure between a member 12 carried by spring 13 and a screw 14 threaded into closure 15 secured to housing 8. Spring 13 is supported at its ends on sloping abutments 16 and carries an armature 17. The strain in spring 13 is adjusted by means of screw 14 to obtain the pressure on pile 11 that will provide in pile 11 the proper resistance to maintain the desired output voltage. It is, of course, understood that the actual pressure exerted on pile 11 is the preponderance of the thrust of spring 13 over the opposing pull on armature 17 due to the flux set up by coil 10, which is connected as a voltage coil across the generator.

Fig. 1 shows diagrammatically the characteristics of a regulator like that above described, with the desired voltage value indicated by the dotted line through B, C and E. Curve 18 shows the output voltage in relation to the gap between armature 17 and core 9. When screw 14 is adjusted to make the gap very small, the spring 13

is considerably strained and, since it follows Hooke's law, reacts strongly on pile 11 so that the flux of coil 10 does not sufficiently reduce the pressure on the pile and the voltage is high, but decreases rapidly and non-linearly from A to B as the backing off of screw 14 permits widening of the gap. It is to be understood that the units of gap width have an arbitrary assigned value. The usual adjustment is such that the voltage is held substantially uniform during such wear of the discs of pile 11 as changes the gap through the distance between the points B and C, Fig. 1. It will be observed that from point C the voltage increases rather rapidly to the point D. This is because the width of the gap reduces the effect of coil 10 in opposing spring 13 and the pressure applied to pile 11 so reduces the resistance of the pile that the field current is augmented and the voltage builds up.

The gap increasing from three units, due to further wear of the discs, the strain in spring 13 is increasingly released and insufficient pressure is applied to the pile 11 to keep the voltage up. It is apparent from curve 18 that the device of Fig. 2 does not operate satisfactorily when wear of the discs has proceeded past the stage that gives a gap width much beyond the value represented at the point C.

Fig. 3 illustrates one embodiment of the present invention for favorably modifying the undesirable characteristics of the regulator above described. For simplicity of drawing there are shown on the armature and the electromagnetic portion of the unit, but it is to be understood that in practice the armature 17' is attached to a spring such as 13 in Fig. 2. Core 9' has an axial bore tapped at one end to receive and to have threaded engagement with auxiliary core 19 that is adjusted to project beyond the face of core 9' into an opening 20 in armature 17'.

The variation of pull exerted upon armature 17' by auxiliary core 19 depends upon the extent to which the auxiliary core is inserted into the hole in the armature as is well known to those skilled in the art, and is shown graphically by dotted curve 21 in Fig. 4, the gap units being arbitrary. The gap-pull characteristics of the flux set up by coil 10 acting upon armature 17' is illustrated by full line curve 22 in Fig. 4 and the resultant of adding curves 21 and 22 is depicted in dot-and-dash line 23 in Fig. 4. The points on curves 21, 22 and 23 where these curves intersect vertical lines 1, 2, 3 and 4 in Fig. 4 give the values of the pull on armature 17' when the face thereof adjacent housing 8 is at the positions respectively indicated by the same numerals in Fig. 3. It will be noted that the resultant pull on armature 17' is uniform, for all practical purposes, from position 1 to position 3. This device will thus give a substantially constant pull throughout a considerable degree of wear of the discs after which the pull will decrease at the time the pressure of the spring is appreciably diminished.

The curve 18 of Fig. 1 is thus modified to the curve 24 in Fig. 5, so that the voltage remains substantially constant throughout the wear of the discs covered by Fig. 5 from B to E, and thereafter it decreases, indicating the need of replacing the discs, without the dangerous rise in voltage shown by Fig. 1.

The regulator is assembled with the end of auxiliary core 19 flush with the face at the free end of the core 9' and the latter is adjusted to give the characteristic shown by curve 18, Fig. 1.



The auxiliary core 19 is then screwed into core 9' to cause the auxiliary core to extend into armature 17' to give the characteristic shown by curve 24, Fig. 5.

Another embodiment of my invention is depicted in Fig. 6. The core 9'' is provided with an axial bore 25 through which passes a stem 26 having fixed on one end thereof an armature 17'' and on the other end a magnetic plunger 27 which is movable in solenoid coil 28 connected to a source of excitation, which may be the generator.

The regulator is adjusted so that the longitudinal center of plunger 27 coincides with that of coils 28 when the armature 17'' is set at a point corresponding to B, Fig. 5. As shown in the small graph in Fig. 6, the pull on plunger 27 by solenoid 28 increases as wear of the carbon discs permits the plunger to be displaced more and move toward the right by the spring (not shown). When half the length of the plunger is out of the coil the pull begins to decrease and practically vanishes when the plunger leaves the coil. The proportioning of plunger 27 and coil 28 to obtain the desired gap-pull characteristic through the working range of the device is well known to those skilled in the art. Thus a voltage-gap characteristic similar to curve 24 can be obtained and the useful operational life of a pile of carbon discs can be greatly extended.

As the discs wear, permitting greater displacement of armature 17'' from core 9'', thereby diminishing the pull exerted upon the armature by coil 10, there is augmented pull applied to the armature by solenoid 28 and plunger 27 to balance the effect of the spring. The position of plunger 27 in solenoid 28 at which the pull begins to decline is such that the effort of the spring tending to move armature 17'' away from core 9'' also lessens and thus there is applied to the carbon discs a pressure that is substantially uniform for all practical purposes.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. In a voltage regulator having a carbon pile, a spring mounted to apply pressure thereto, an armature fixed to the spring, and a voltage coil disposed to attract the armature in opposition to the spring when the coil is energized; an axially bored core in said coil, a stem extending through the core and fixed at one end to the armature, a solenoid plunger fixed to the other end of the stem, and a solenoid disposed around the plunger and connected across a source of energizing current as a voltage coil, whereby said solenoid and plunger oppose the action of the spring when the plunger is moved toward the pile from its equilibrium position in the solenoid and having a pull characteristic that initially increases to a maximum as the plunger is shifted from said position by movement of the armature away from the coil and then decreases upon continued movement of the armature, so that the effective pressure of the spring upon the carbon pile is substantially the same in all positions of the armature at equal output voltages.

2. In a voltage regulator having a carbon pile, a spring mounted to apply pressure thereto, an armature fixed to the spring, and a voltage coil disposed to attract the armature in opposition to the spring when the coil is energized; an axially bored core in said coil, a stem extending

through the core and fixed at one end to the armature, a solenoid plunger fixed to the other end of the stem, and a solenoid disposed around the plunger and connected to a source of energizing current, whereby said solenoid and plunger opposes the action of the spring when the plunger is moved toward the pile from its equilibrium position in the solenoid and having a pull characteristic that initially increases to a maximum as the plunger is shifted from said position by movement of the armature away from the coil and then decreases upon continued movement of the armature, so that the effective pressure of the spring upon the carbon pile is substantially the same in all positions of the armature at equal output voltages.

3. In a voltage regulator having a carbon pile, a spring mounted to apply pressure thereto, an armature fixed to the spring, and a voltage coil disposed to attract the armature in opposition to the spring when the coil is energized: a stem connected at one end to the armature and having a solenoid plunger at its other end, and a solenoid disposed around the plunger and connected to a source of energizing current, whereby said solenoid and plunger applying to the armature a pull in opposition to the spring when the plunger is moved toward the pile from its equilibrium position in the solenoid, said pull varying as a function of the extent of such movement to maintain normally a substantially constant difference between the force exerted by the spring on the one hand and the sum of the attraction of said coil and the pull of said plunger and solenoid on the other hand.

4. In a voltage regulator having a pressure-controlled variable resistance unit, a spring mounted to apply pressure thereto, an armature fixed to the spring, and a voltage coil disposed to attract the armature in opposition to the spring when the coil is energized: a stem connected at one end to the armature and having a solenoid plunger at its other end, and a solenoid disposed around the plunger and connected to a source of energizing current, whereby said solenoid and plunger apply to the armature a pull in opposition to the spring when the plunger is moved



toward the pile from its equilibrium position in the solenoid, said pull varying as a function of the extent of such movement to maintain normally a substantially constant difference between the force exerted by the spring on the one hand and the sum of the attraction of said coil and the pull of said plunger and solenoid on the other hand.

5. In a voltage regulator having a pressure-controlled variable resistance unit, a spring mounted to apply pressure thereto, and a voltage coil disposed to attract the armature in opposition to the spring when the coil is energized: an armature having a hole therethrough, and an auxiliary magnetic element mounted to extend into the hole in the armature when the armature is an initial position said element to be of such a length that its extremity appears at the mouth of said hole when the armature is intermediate said initial position and the position of maximum displacement of the armature away from the coil, whereby the pull of said auxiliary element being additive to that of the coil and augmenting as the displacement of the armature increases to approximately said intermediate position and thereafter decreasing to said position of maximum displacement to maintain normally over the whole range of displacement of the armature a substantially uniform difference between the pull of the coil and that of the auxiliary element on the one hand and the force exerted by the spring on the other hand.

6. The apparatus as described in claim 5, wherein the pressure-controlled variable resistance unit is a carbon pile.

JOSEPH W. ALLEN.


REFERENCES CITED

The following references are of record in the file of this patent:

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## Certificate of Correction

Patent No. 2,425,296. August 12, 1947.

JOSEPH W. ALLEN

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 1, line 13, for "device" read *devise*; column 3, line 33, for "on the" read *only the*; column 4, line 14, for "coils" read *coil*; column 5, line 26, claim 3, for "applying" read *apply*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of December, A. D. 1947.

[SEAL]

THOMAS F. MURPHY,
*Assistant Commissioner of Patents.*