May 4, 1948. J. L. CREVELING 2,441,059

ELECTRIC REGULATION

Filed June 12, 1944

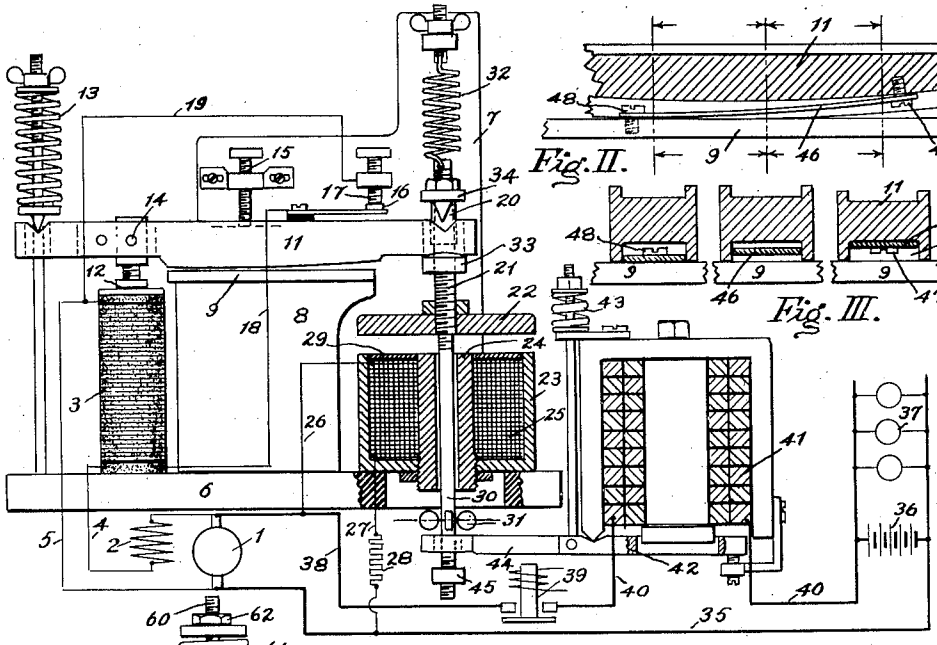


Fig. I.

Fig. II.

Fig. III.

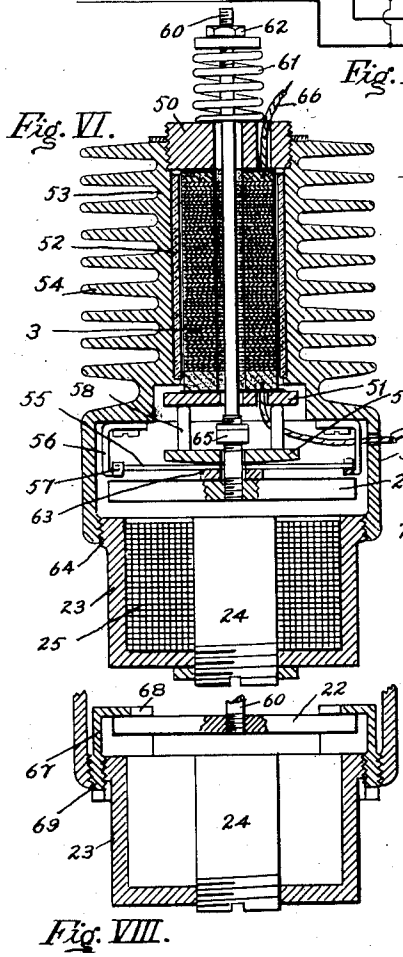


Fig. VI.

Fig. VIII.

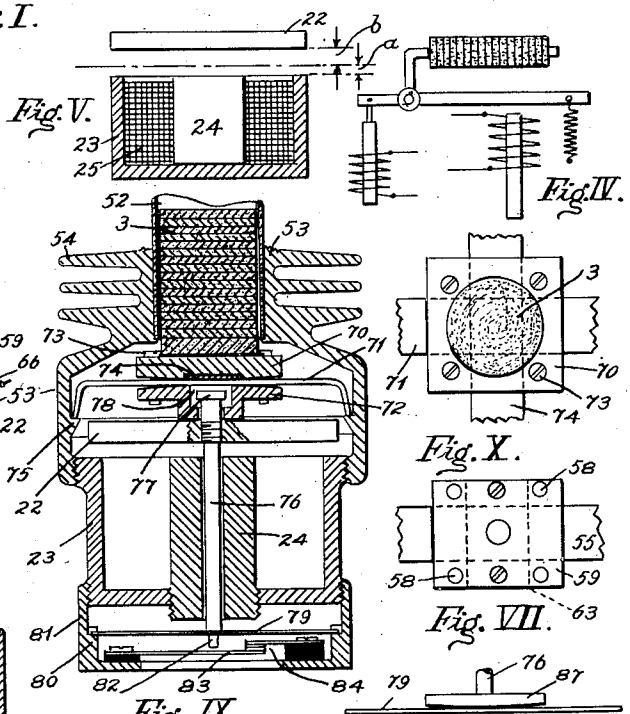


Fig. V.

Fig. IV.

Fig. IX.

Fig. X.

Fig. VII.

Fig. XII.

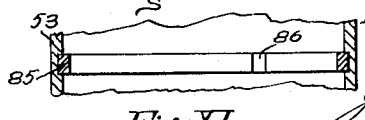


Fig. XI.

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ELECTRIC REGULATION

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Application June 12, 1944, Serial No. 539,931

22 Claims. (Cl. 322—25)

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My invention pertains to that class of electric regulation wherein the voltage upon or the current in an electric circuit is to be controlled automatically.

An object of my invention is to provide a sensitive regulator having relatively wide range which may be of small dimensions and cheaply built.

Another object is to provide an automatic regulator which shall come into action only when its services are required. Other objects will be pointed out in the specification or obvious therefrom to those skilled in the art.

As my invention is particularly applicable to systems wherein the dynamo or generator subject to intermittent operation and wide changes in speed is employed to charge a storage battery and supply lamps or other translating devices it will be described with particular reference to such a system.

Fig. I is a more or less diagrammatic representation of a system included in my invention, showing some parts in elevation, some in section, and some in diagram.

Figs. II and III are partial sections and partial elevations of a portion of the structure of Fig. I on larger scale portraying features which cannot be seen in Fig. I.

Figs. IV and V are mere diagrams of conventional devices which will be used in pointing out some of the particular features of the present invention.

Fig. VI is a partial section and partial elevation of one type of structure included in my invention.

Fig. VII is a top plan of a portion of the structure of Fig. VI.

Fig. VIII shows a modification that may be made in the structure generally portrayed in Fig. VI.

Fig. IX is a partial elevation and partial section of a portion of a structure included in my invention and in many respects similar to that of Fig. VI.

Fig. X is a top plan of a portion of the structure of Fig. IX.

Fig. XI is a section showing a modification that may be made in the structure of Fig. IX.

Fig. XII shows a modification that may be made in the structure of Fig. IX.

Referring to Fig. I of the drawing which includes a structure I have found very useful in laboratory work on account of its general flexibility and easy adjustability, 1 represents a generator or dynamo subject to intermittant operation and varying speed.

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The generator 1 is shown as provided with a field coil 2 having connected in series therewith the carbon pile 3 as by wires 4 and 5.

The carbon pile 3 is mounted upon the base 6 of insulating material and is preferably held in proper position by vertical insulating rods (not shown). Base 6 is provided with a back plate or vertical member 7 and support member 8 provided with a metal plate 9 having a smooth upper surface which serves as a bearing for the rocker shaped portion of lever 11 pivotally carrying the adjustable pressure plate 12 bearing upon the pile 3. The adjustable spring 13 tends to depress the left hand end of lever 11 and compress the pile 3 and, when the generator is idle or running at sufficiently low speed and the elements of the structure are in the positions indicated, to revolve the lever about the pivot 14 and thus to lift the rocker portion from the bearing plate 9 until arrested by the adjustable screw 15. Under these conditions the pile 3 will be tightly compressed and of low resistance and may even be short circuited as by contact members 16 and 17 and wires 18 and 19 by proper adjustment of screw 17.

The right hand end of lever 11 is perforated to allow the sleeve 20 to pass therethrough without contact while the sleeve in turn is bored to slide over the threaded stem 21 carrying the armature 22 operated by an electro-magnet, in this instance shown as of the iron-clad type having the shell 23, adjustable core 24 and voltage winding 25. The magnet is secured to the base 6 as by screws (not shown) and is here shown as having the winding 25 connected across the generator circuit as by wires 26 and 27 through a resistor 28 which may be used for adjustment or to provide temperature compensation in a manner now well known in the art. The magnet is also here shown as provided with a magnetic shunt 29 which, by being made of material having its permeability decreased by increase in temperature, may be employed for temperature compensation in a now well known manner if desired.

The magnet core 24 is shown as tubular while the stem 21 has a tail rod 30 passing through the bore thereof for holding the armature in proper alignment throughout operation, the tail rod being here indicated as held in central position with respect to the bore by guide rollers 31 supported in any suitable manner (not shown). The adjustable spring 32 tends to raise the stem 21 and parts carried thereby and, when the elements are in the position shown in the drawing, to rotate lever 11 about the contact with screw

15 and thus assist spring 13 in compressing the pile 3, owing to contact of the adjustable ball faced nut 33 with the end of the lever 11. The sleeve 23 carries a member 34 provided with knife edges on opposite sides of the sleeve adapted to engage suitable notches on each side of lever 11 when the stem 21 is moved downwardly so that when sufficient downward movement has been given to armature 22 any further movement will draw lever 11 downwardly about pivot 14 and break contact with screw 15 and bring the rocker portion of the lever to bear upon the plate 9, whereupon any further downward movement of the armature 22 will cause the short-circuit contact 16—17 to be broken and the pressure upon pile 3 to be decreased in an obvious manner.

Therefore, proper operation of the armature 22 may be caused to regulate the generator for constant voltage throughout speed changes above the minimum speed required to generate the voltage desired to carry.

In Fig. I the generator is shown as having its lower brush connected by wire 35 with one side of storage battery 36 and lamps or other translating devices 37 while the upper brush is shown as connected as by wire 38 with one side of any suitable automatic switch, the mere presence of which is indicated at 39, which has its opposite side connected with the free terminals of the battery and translating devices as by wire 40. Wire 40 has in series therewith the current coil 41, of a clapper type magnet supported in any suitable manner (not shown) and having the armature 42 which, when attracted may rotate against the effort of adjustable spring 43 to bring the lever 44 in contact with the adjustable nut 45 upon the tail rod 30 and thus assist the magnet 23—24—25 and lower the voltage upon the generator in such manner as will prevent the desired maximum current to be delivered by the generator from being exceeded.

The lever 11 is maintained in proper relation to the other parts by means of the flexible strip 46 shown in Fig. II having its upper right-hand end attached to the lever by screw 47 and its left-hand end attached to the plate 9 by the screw 48. The strip 46 is confined within the channel 49 shown more plainly in the sections appearing in Fig. III, which are taken along the lines appearing above the same in Fig. II and viewed in the directions indicated by the arrows. This arrangement permits the lever to rock freely upon the plate 9 and even to be lifted a limited distance above the same as indicated in Fig. I. As the lever 11 is rocked upon the plate 9 under the influence of armature 22 its point of contact changes so as to change the position of the fulcrum of the lever in such manner as to compensate for the changes in pull exerted by the magnet 23—24—25 due to approach of the armature and also to compensate for any changes in the effect of the springs 13 and 32 as well as the elasticity of the pile.

Fig. VI shows a more compact commercial type of voltage regulator wherein the carbon pile 3 is shown as compressed between the adjustable plug 50 and the pressure plate 51 and insulated therefrom as indicated.

The pile is held in position by the surrounding tube 52 having thin walls of ceramic or other insulating material capable of withstanding relatively high temperatures without losing its insulating character.

This tube which may be a mere coat of heat resisting enamel is carried by the body portion 53 having heat conducting and dissipating fins

54 to hold the temperature of the pile as low as possible and thus increase its regulating capacity.

The plate 51 is pressed upwardly by the leaf spring 55 which is shown as supported and held in place by the somewhat flexible brackets 56 provided with upturned ears 57. While spring 55 is here shown as substantially flat, it would, if free, appear arched and is shown in its present position as forced downwardly by the reaction of the pile 3 through the contact of plate 51 with the posts 58 carried by the member 59 (shown in Fig. VII) bearing upon the upper side of spring 55.

The armature 22 is here shown as carried by the rod 60 passing through the perforated discs of pile 3 and drawn upwardly by the compression spring 61 acting against the adjusting nut 62 and, as the member 63 (shown in dotted lines in Fig. VII) bears upon the lower side of spring 55, spring 61 tends to assist spring 55 in compressing the pile 3.

The voltage winding 25 is here shown as surrounding the adjustable solid core 24 carried by the shell 23 which may be adjusted with respect to the armature as by the threads at 64 engaging the body portion 53. If armature 22 is drawn downwardly my magnet 23—24—25 it will be opposed only by spring 61 until the adjustable nut 65 strikes the upper side of member 59 and then further downward movement will be opposed by spring 55 and tend to release the pressure upon the pile so as to raise its resistance to control the generator voltage if connected in series with its field as by means of pigtails 66. The member 59 has its lower surface so formed that as it is drawn downwardly it extends its bearing from the center of the spring toward the ends thereof in such manner as to increase the resistance offered by the spring to compensate for the increase in pull of the armature due to approach toward the magnet.

In Fig. VIII there is shown an adustable magnetic shunt 67 which may be incorporated in the structure of Fig. VI and which has portions 68 extending around the outer edge of the armature as far as desired. This tends quite strongly to hold the armature from being drawn downwardly during the initial energization of the magnet while the armature is in the position shown. The position of the shunt may be adjusted by means of the threaded arrangement at 69.

In Fig. IX a portion of the carbon pile is shown at 3 as contained within the tube 52 which is carried by the body portion 53 and the pile may have its position adjusted as by a screw plug similar to 50 in Fig. VI. Here the pile is shown as of relatively thick discs as used for relatively lower voltage and as resting upon the member 70, shown in top plan in Fig. X. Member 70 rests upon the spring 71 and is connected with member 72 as by screws 73 while a flexible member 74 at right angles to spring 71 is clamped together with spring 71 between members 70 and 72. The flexible member 74 may be either another spring similar to 71 or merely a readily bendable member serving principally to maintain the parts in central positions as desired.

Spring 71 and member 74 have depending portions which rest upon the ledge 75 and together tend to compress the pile 3. The armature 22 is carried by the rod 76 passing through the hollow magnet core 24 and provided with a head 77 within the pocket 78 in the member 72. The armature is pressed upwardy by the leaf spring

79 which holds the armature 22 in the position shown when the winding (not shown) within the shell 23 is deenergized.

The leaf spring 79 rests upon ledges 80 of the shell 81 and is perforated to receive the tail rod 82 of rod 76 to hold the latter in central position while the tail rod 82 if depressed will strike the flexible member 83 and break the contact at 84 which may be connected to short-circuit the pile in an obvious manner if desired. In this structure member 70 has its lower surface so formed as to increase its bearing upon spring 71 and member 74 to compensate for approach of the armature toward the magnet.

In Fig. XI there is shown another means of supporting the spring 71 of Fig. IX which may be used instead of the ledge 75 of Fig. IX. Here a spring ring 85, split as indicated at 86, is sprung into an annular channel in the body portion 53.

Before taking up the operation of the present invention it will be noted that, with a carbon pile regulator of conventional prior art type as indicated in Fig. IV, if we consider both the solenoids deenergized the pile will of course be under the maximum pressure and its resistanec will be at its minimum value. In a system employing a generator which operates intermittently and at variable speed it is of course very desirable that the pile shall remain under maximum compression until the voltage or current to be limited by the regulator reaches the full maximum desired value, so as to allow the field to build up rapidly in starting and to obtain full generator output at as low speed as possible.

If we assume the pile of Fig. IV connected as is pile 3 in Fig. I and the solenoid at the left connected across the generator as is the winding 25 in Fig. I and the right-hand solenoid inoperative, then, as the generator voltage rises from zero to its desired maximum value some of the pressure upon the pile will be relieved throughout this process, even though no very marked change in the position of the lever may be noticed, and this drawback of course is aggravated by the elasticity of the pile. This is a great disadvantage in this type of regulator.

If we assume the left-hand solenoid to be inoperative and the one at the right to be connected as above mentioned then the pile will remain at maximum compression untill sufficient voltage is reached to lift the core into contact with the lever, but from this point on the action will be the same as in the previous case. As it is desired that the maximum pressure upon the pile shall be quite heavy this means that the solenoid core will encounter considerable resistance to upward movement when it comes in contact with the lever and on this account must be brought into contact at a voltage usually very much below that to be limited and that, therefore, throughout a large portion of the rise in voltage to full value the pressure upon the pile will be relieved as in the first case, even though this is not true at the very lowest speeds, at which time the voltage is nowhere near the value to be limited, and the effect even upon a connected core like the one at the left would be the least and of little moment.

Now, if we increase the power of the solenoid, and therefore its size, it will be affected less by the added load upon contact with the lever and may be arranged to bring its core into contact at more nearly the voltage value to be limited and thus grow better and better as a regulator as the size of the solenoid is increased. However, there is a practical limit to size and power of the solenoid which necessitates the core acting against the lever for a considerable portion of the time while the voltage is rising to full value and this at the most undesirable time when the voltage is approaching full value and the solenoid is thus strongest and most able to hold the voltage from reaching its full value at the instant speed.

Now, in the structure of the present invention, instead of the usual solenoid as the one at the right in Fig. IV, having substantially constant force throughout its useful range for a given excitation, there is employed an iron-clad magnet of the general type indicated in Fig. V. This type of magnet is capable of exerting a very strong pull upon its armature throughout a very limited distance and as here used manipulates the pile to perform its regulating function by slight movement of the armature while separated from the magnet by a small airgap, say for example, while the armature has its lower face within the space indicated as *a* in Fig. V.

Thus, while the magnet is actually performing regulation it is caused to do so against heavy spring pressure capable of compressing the pile sufficiently to lower its resistance to very low value when not affected by the magnet which of course is a very valuable feature. On the other hand, since the pull upon the armature decreases so rapidly upon its movement away from the magnet, a relatively light spring is capable of holding the armature from approaching the magnet if the air gap is increased only a reasonable amount, as for example, when the armature occupies the position indicated in Fig. V. These features are utilized in the present invention to make the regulator perform much as the one shown in Fig. IV would, if the lefthand solenoid were suppressed and the right-hand one were of reasonable dimensions as usual until the core came in contact with the lever and then were transformed into a very powerful one capable of at once operating against a heavy spring to affect the pile upon very slight increases in excitation.

That is, if the armature be in the position shown in Fig. V it can be held in that position by a light spring until the voltage across the magnet reaches substantially the value to be limited, and when this value is reached it will be descend, and while passing through the space indicated at *b* the pull per ampere turn will be transformed from weak to strong and the magnet will be capable of at once operating to effect the regulation against a strong spring upon very slight changes in excitation, as will be seen from the following description of the operation of the invention.

An operation of the system of Fig. I is substantially as follows:

With the generator at rest and the parts in the positions shown in the translating devices may be supplied by the battery in the usual manner.

If the generator be started and its speed gradually increased, the field will build up quite rapidly as the pile 3 is short circuited and the generator voltage will soon equal that of the battery and cause the switch 39 to close and connect the generator with the battery and translating devices, whereupon the generator may take part in supplying current to the load. As the speed increases further the voltage will increase and, by proper adjustment of spring 32 and the air gap be-

tween the armature 22 and the magnet, I can cause the armature to be drawn downwardly and the knife edges 20 to be brought into contact with the lever 11 at a voltage slightly below, equal to, or slightly above the maximum desired to have held across the generator. When this occurs, lever 11 will be drawn down into contact with the plate 9, breaking the short circuit at 16—17 and the pile 3 will now be able to control the generator voltage throughout further increases in speed if properly manipulated. The pull upon the armature per ampere turn in the magnet may now be several times that when the armature was in the position shown in the figure and therefore if properly utilized will cause the regulator to respond to very small changes in voltage across the magnet, while able to operate against quite strong pressure exerted by spring 13 capable of placing the pile 3 under heavy compression when allowed to do so.

I now so adjust the member 12 that the contact of the lever 11 with the plate 9 is at such point as properly to compensate for further approach of the armature toward the magnet and adjust the spring 13 to give the desired voltage and this will be held constant within very narrow limits throughout further changes in speed so long as they take place above that speed necessary to generate the chosen value. If at any time the chosen voltage tend to cause a greater current than desired, the series coil 41 will rotate its armature against the effort of spring 43 and cause lever 44 to engage nut 45 and assist magnet 23—24—25 and lower the voltage to prevent the maximum desired current from being exceeded.

It is here to be noted that the screw 15 has a support which is adjustable upon the upright 7 so that the screw may have such position as not to interfere with the rocking movement of lever 11 within the limits of useful operation, and that no attempt has been made in the drawing to portray the exact curvature of the lever 11 or the exact position of the armature 22 with respect to the magnet.

If the parts are so arranged and adjusted that the armature 22 moves the knife edges 20 into contact with the lever 11 at a voltage slightly below the full value to be maintained, a slight rise in voltage to full value will take place before the magnet assumes the regulation, while if the above armature action takes place at the desired maximum voltage, the magnet will at once take up the regulation while if the voltage be allowed slightly to exceed the desired value before the said armature action takes place, it may be caused to at once lower the voltage to the proper value and hold it within very narrow limits.

In the structure of Fig. VI the initial movement of the armature 22 proceeds as in Fig. I until the nut 65 strikes the member 59 and then the relatively strong spring 55 is encountered and the regulation brought about in a manner believed obvious in view of the foregoing. Here the shaping of the lower side of the member 59 causes it so to vary the action of the spring as to effect much the same result as the shifting of the point of contact of lever 11 in Fig. I while sliding of the ends of the spring upon its support is avoided by the flexibility of the brackets 56.

In the modification shown in Fig. VIII the excitation required to bring the armature into operative position may be materially modified by the magnetic shunt 67—68 which will tend to hold

the armature in its inoperative position until overpowered and then will suddenly release the same and have little further effect upon its operation if properly proportioned.

The operation of the structure of Fix. IX is believed to be so plain from the foregoing that it is only necessary to point out that the armature has its initial movement opposed by the spring 78 against the effort of which it brings the head 77 of the rod 76 into contact with the lower portion of member 72 to affect the action of spring 72 and 74 upon the pile and that during its initial movement it opens the contact at 84 which may be used to short-circuit the pile in an obvious manner if desired. In this embodiment sliding action of spring 74 upon its supports is avoided by the shaping of the spring as indicated.

In Fig. XII the rod 76 is shown as resting upon the member 87 which in turn rests upon the spring 78 and has its lower surface so shaped as to compensate as much as desired for the increase in pull upon the armature due to approach toward the magnet. And, it is of course plain that instead of an ordinary tension spring at 32 in Fig. I and an ordinary compression spring at 61 in Fig. VI, I may use any desired type of spring mechanism which will bring about the same action as the member 87 shown in Fig. XII if desired so to do.

I do not here limit myself to any of the exact constructions shown nor to any of the particular modes of operation herein described, which have been set forth merely to illustrate a few embodiments of my invention, which is as set forth in the following claims.

I claim:

1. Regulating means including a regulating element, means tending to reduce the resistance of said element, means for increasing the resistance of said element and automatic means including a magnetic shunt for rendering said resistance increasing means inoperative under predetermined conditions.

2. Regulating means including a regulating element, means tending to reduce the resistance of said element, means tending to increase the resistance of said element in response to an increase in an electrical quantity, and means for rendering said resistance increasing means inoperative also affected by changes in said quantity and including a magnetic shunt.

3. Means for regulating a generator including a regulating element for affecting the output of a generator, means tending to affect said element to increase the generator output, means for varying the effect of said last mentioned means in response to fluctuations in a function of said output and separately movable automatically operated means for affecting the element and simultaneously delaying the action of said varying means also affected by said function.

4. Regulating means including a regulating element, means for affecting said element in a given sense, electro-magnetic means for affecting said element in an opposite sense, and means for opposing the operation of the electro-magnetic means affecting the element and responsive to the effect of excitation of the electro-magnetic means.

5. Regulating means including a regulating element, resilient means for affecting said element in a given sense, electro-magnetic means for affecting the element in an opposite sense against the effort of the resilient means and means for opposing the initial operation of the electro-

magnetic means affecting the element and responsive to an effect produced by excitation of the electro-magnetic means.

6. Regulating means including a regulating element, resilient means for affecting said element in a given sense, electro-magnetic means for affecting the element in an opposite sense against the effort of the resilient means, means for controlling the initial operation of the electro-magnetic means responsive to the effect of excitation of the electro-magnetic means and means automatically affecting the further operation exerted by the electro-magnetic means by varying the opposition of the resilient means.

7. Regulating means including an element the effect of which is varied by variations in pressure thereupon, means tending to exert pressure upon said element and means for controlling the pressure thus exerted comprising an electro-magnet having a useful field of rapidly diminishing strength with respect to distance, an armature for said magnet, means for exerting pressure upon the element and holding said armature in a relatively weak portion of the field of said magnet including a lost motion device permitting the armature to move into a strong portion of said field upon predetermined excitation of said magnet and means whereby the armature may affect the element while in said strong portion of the field.

8. Regulating means including an element the effect of which is varied by variations in pressure thereupon, means tending to exert pressure upon said element and means for controlling the pressure thus exerted comprising an electro-magnet having a useful field of rapidly diminishing strength with respect to distance, an armature for said magnet, means for compressing said element and holding said armature in a relatively weak portion of the field of said magnet permitting the armature to move into a strong portion of said field upon predetermined excitation of said magnet and means whereby the armature may affect the element only while in said strong portion of said field.

9. Regulating means comprising a carbon pile, means for exerting pressure upon said pile, means for controlling said pressure including an electro-magnet having a useful field of which different portions vary materially in strength per ampere turn, an armature within the field of said magnet means whereby the armature may affect the pressure, means for holding said armature in a weak portion per ampere turn of said field until a predetermined field strength has been reached and then allowing the armature to move into a strong portion per ampere turn of said field to render operative the means whereby said armature may affect the pressure upon said pile while in said strong field.

10. Means for regulating a generator, comprehending an element for affecting a generator output in response to changes in pressure applied to said element, means for exerting pressure upon said element, and means for modifying the pressure exerted thereby including a magnet affected by a function of the generator output, an armature affected by said magnet, means for preventing said armature from affecting said pressure upon said element below a predetermined value of said function and then permitting said armature to move into pressure relieving position, said change in position greatly increasing the magnetic effect per degree of fluctuations in said function in said magnet upon the armature.

11. In a regulator including a carbon pile, a spring, a member bearing upon said spring and transmitting pressure to said pile, said member extending its bearing upon said spring to increase the effect of said spring upon movement of said member to decrease the pressure upon said pile.

12. An electric regulator comprising a carbon pile, a spring, a member bearing upon and transmitting pressure from said spring to said pile, an armature for affecting said member, an electro-magnet for affecting said armature, said member being adapted progressively to vary its effect upon said spring when said member is moved by said armature.

13. An electric regulator, including an electro-magnet having a field of rapidly diminishing strength per ampere turn at distances therefrom, an armature in said field, means for moving said armature away from said magnet and holding said armature in a weak portion of said field per ampere turn until said field attains a certain strength and then permitting said armature to move into a strong portion of said field per ampere turn and means whereby said armature may perform a regulating function only while in said strong portion of said field in response to fluctuations in the strength of said portion of said field.

14. For use in an electric system having a generator and a load circuit supplied thereby, a regulating element for affecting the output of the generator, means for operating said element including an electro-magnet having a field affected by a function of said output, an armature in said field, means tending to hold said armature in a weak portion of said field and allowing it to move into a strong portion thereof only upon predetermined strength of said field, means whereby said armature may affect said element only while in the stronger portion of said field, means opposing movement of said armature only while in said strong portion of the field, and movable means whereby said opposing means increases its opposition as said movable means is moved toward said magnet.

15. For use in an electric system having a generator and a load circuit supplied thereby, a regulating element for affecting the output of the generator, means for operating said element including an electro-magnet having a field affected by a function of said output, an armature in said field, means tending to hold said armature in a weak portion of said field and allowing it to move into a strong portion thereof only upon predetermined strength of said field, means whereby said armature may affect said element only while in the stronger portion of said field, means opposing movement of said armature only while in said strong portion of the field, means whereby said opposing means increases its opposition as said means is moved toward said magnet, and means for assisting said magnet in response to another function of said output.

16. An electric regulator including a regulating element responsive to changes in pressure thereupon, a spring supported substantially at its ends, a member bearing upon said spring at substantially its mid-portion and transmitting pressure to said element, and electro-magnetic means for moving said member to alter the pressure upon said element, said member being adapted to alter its bearing upon said spring when said member is affected by said electro-magnetic means.

17. An electric regulator including a regulat-

ing element responsive to changes in pressure thereupon, a spring supported substantially at its ends, a member bearing upon said spring at substantially its mid-portion and transmitting pressure to said element, and electro-magnetic means for moving said member to alter the pressure upon said element, said member being adapted to alter its bearing upon said spring during said movement.

18. Regulating means including a regulating element, a strong spring affecting said element, an electro-magnet having a field of rapidly diminishing strength with respect to distance from said magnet, an armature in said field, means operated by said armature capable of affecting said element only when the armature is in a strong portion of said field, relatively weak means for holding the armature in a weak portion of said field until a strong portion of said field is substantially capable of operating the armature against the effort of the above mentioned strong spring and then allowing the armature to move into said strong portion to affect the regulating element against the effort of the strong spring upon slight changes in the excitation of said magnet.

19. Regulating means including a regulating element, main and auxiliary means each capable of automatically increasing the initial pressure upon said element, an electro-magnet, and an armature for said magnet the movement of which in response to attraction by the magnet is opposed first by one and then by both of the compressing means.

20. Regulating means including a regulating element, main and auxiliary means each reducing the initial resistance of said element, an electro-magnet, and an armature for said magnet the movement of which in response to attraction by the magnet is opposed first by one and then by both of the resistance reducing means.

21. Regulating means including a regulating element, means for reducing the electrical resistance of said element offering strong mechanical resistance against movement to cause increase in the electrical resistance of said element, an electro-magnet having a field of rapidly decreasing strength per ampere turn with respect to distance from said magnet, an armature in said field, means whereby motion of the armature may increase the resistance of the regulating element, means for holding said armature in a relatively weak portion of said field per ampere turn until a strong portion of said field per ampere turn is substantially capable of operating the armature to affect the element against the strong mechanical resistance and then permitting the armature to move into said strong portion of said field per ampere turn to become able to operate the resistance increasing means.

22. A compressible pile type of regulator, including means for exerting heavy pressure upon the pile, means for controlling the pressure including an armature, a magnet having a field with rapid decrease in strength with respect to distance capable of attracting the armature to overcome the pressure exerting means only when in a strong portion of said field and means for holding said armature in a weak portion of said field until said strong portion is of substantially sufficient strength to affect the compressing means and then allowing the armature to move into said strong portion of the field, to become able to affect the compressing means.

JOHN L. CREVELING.

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