Dec. 11, 1945. J. F. KOVALSKY 2,390,796

REGULATING APPARATUS

Filed Aug. 26, 1942 2 Sheets-Sheet 1

Fig. 1.

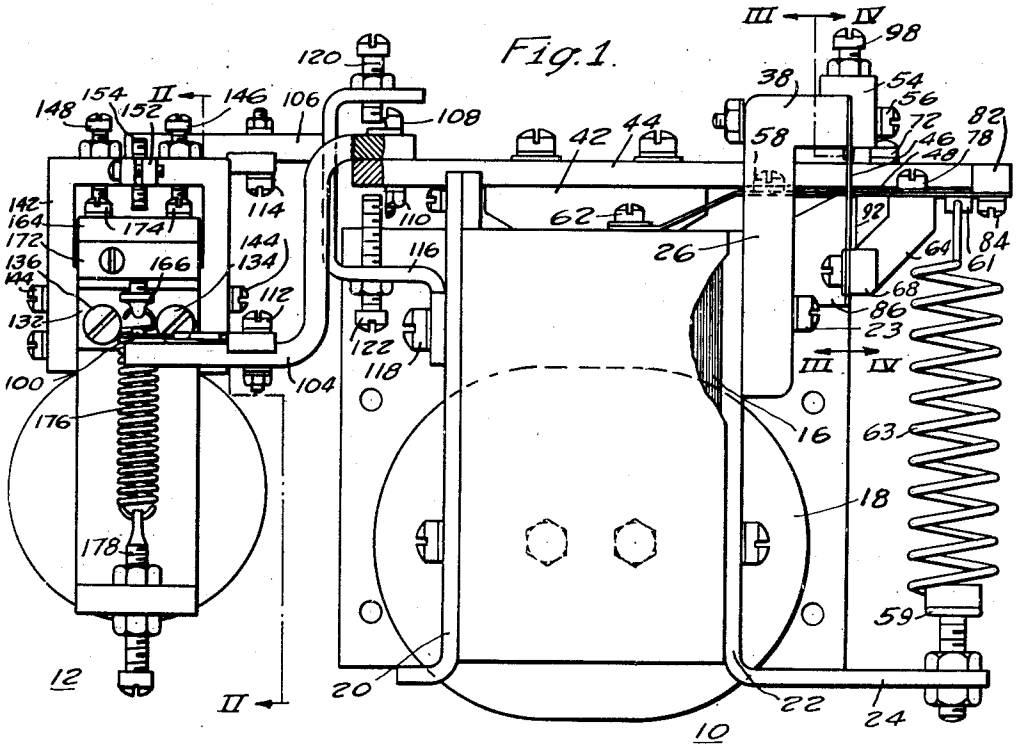
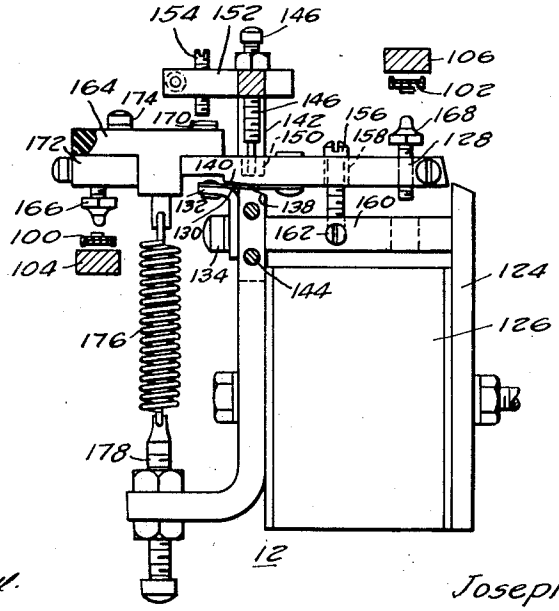


Fig. 2.



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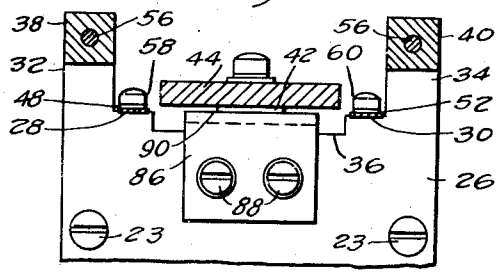
REGULATING APPARATUS

Filed Aug. 26, 1942 2 Sheets-Sheet 2

Fig. 3.



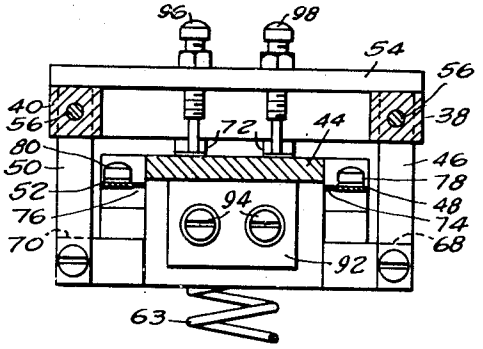
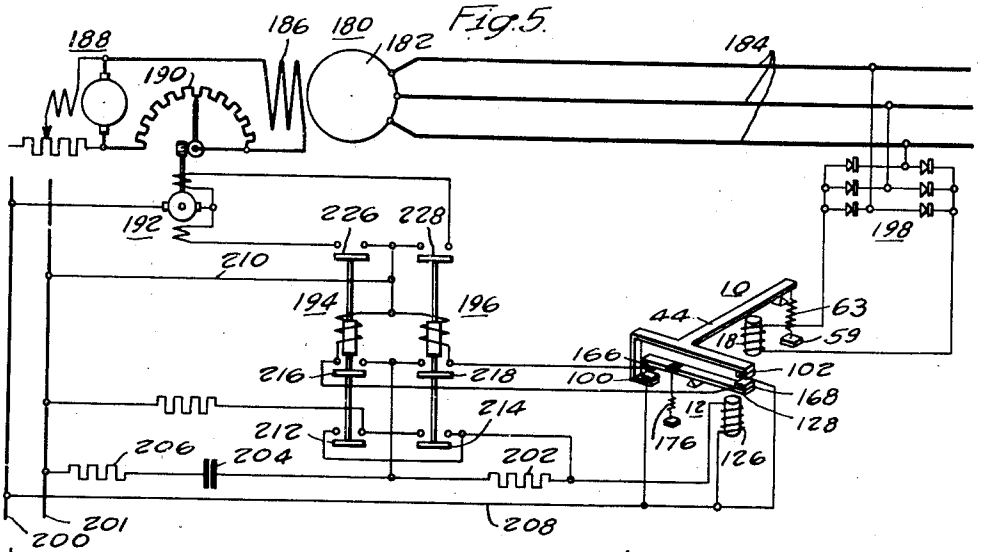


Fig. 4.

Fig. 5.



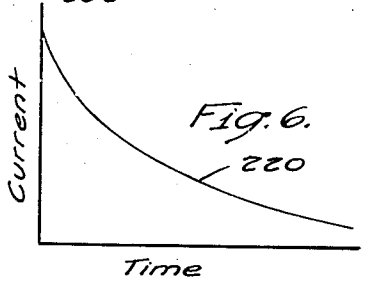


Fig. 6.

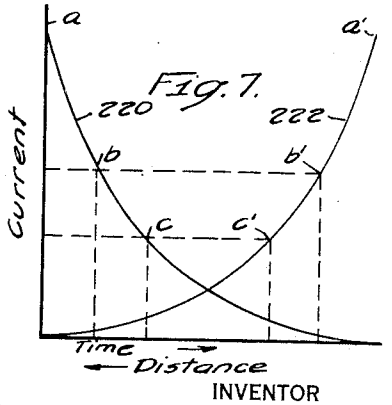


Fig. 7.

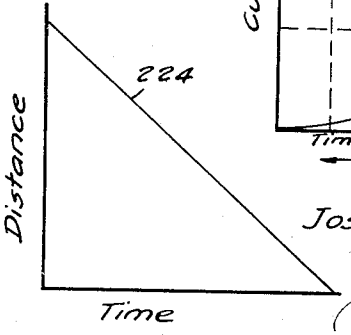


Fig. 8.

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Patented Dec. 11, 1945

2,390,796

UNITED STATES PATENT OFFICE

2,390,796

REGULATING APPARATUS

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Application August 26, 1942, Serial No. 456,188

12 Claims. (Cl. 200—98)

This invention relates to electrical apparatus, and it has particular relation to regulators.

It is known to utilize anti-hunt type of regulators of the exciter rheostat type to prevent overshooting of the corrective action where such regulators are employed for regulating a given characteristic of a dynamo-electric machine. One well known form of anti-hunt means is illustrated and claimed in my patent No. 2,140,363, assigned to the assignee of this invention and comprising a sensitive electromagnetic device having contact spreading action in accordance with the amount required for different time constants and a slow return action of the contact members insured by means of dashpots. Such regulators have proven to be reliable and stable for many different applications including certain Navy applications where the regulator is subjected to 150 foot pounds of shock. However, it has been found that such regulators cannot be employed for all Navy applications as they are not sufficiently stable or rugged enough to withstand the high impact shock test of 2000 foot pounds, as now required by the Navy for combat service.

It is, therefore, an object of this invention to provide an improved sensitive and rugged regulator having anti-hunt characteristics which is capable of withstanding high impact shocks.

Another object of this invention is to provide a sensitive regulator having a minimum of pivots supplemented with auxiliary rigid pivots for use under predetermined conditions of shock.

A more specific object of this invention is to provide in a regulator having its moving parts mounted on floating pivots for auxiliary rigid pivots as supplements thereto for preventing damage to the floating pivots when subjected to shock.

Other objects of this invention will be best understood from the following description when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a view in elevation and partly in section of the regulating apparatus of this invention;

Fig. 2 is a view in elevation and partly in section taken along the line II—II of Fig. 1;

Fig. 3 is a view of a part of the apparatus of Fig. 1 taken along the line III—III;

Fig. 4 is a view of another part of Fig. 1 taken along the line IV—IV thereof;

Fig. 5 is a diagrammatic representation of apparatus and circuits showing the improved apparatus of this invention as applied to a regulating system for a dynamo-electric machine;

Fig. 6 is a graph, the curve of which illustrates the decrease in the charging current with respect to time of the capacitor utilized in the circuit of Fig. 5;

Fig. 7 is a graph, the curves of which represent the charging current versus time and the corresponding decrease in the magnetic pull of the electromagnetic means in circuit therewith versus the distance or movement of the armature member of the electromagnetic means; and

Fig. 8 is a graph, the curve of which represents the movement of the armature member with respect to time as the charging current of the capacitor of the circuit of Fig. 5 is decreased.

Referring to Fig. 1, this invention is illustrated by reference to a primary control relay 10 and a secondary control or anti-hunt relay 12. The primary control relay 10 comprises a core member 16 of magnetic material and an energizing coil or winding 18 carried thereon, the core member 16 being carried between end flanges 20 and 22 provided for mounting the assembly on a panelboard (not shown). The end flange 22 has an outwardly extending lower end 24 and carries a substantially U-shaped bracket 26 at its upper end. The bracket 26 is of some light-weight metal, such as aluminum, and is secured to the end flange 22 by screws 23.

Referring to Fig. 3, the bracket 26 is better illustrated as having benches 28 and 30 formed between the vertical legs 32 and 34 and spaced from the upper edge 36 of the connecting portion of the bracket. At the upper end of each of the vertical legs 32 and 34, an outwardly extending lug 38 and 40 respectively, is provided.

Again referring to Fig. 1, an armature 42 is provided for cooperating with the core member 16. The armature 42 is carried by an elongated arm 44 disposed for pivotal movement about a floating pivot formed by two spaced pairs of cross springs 46—48 and 50—52, as more clearly shown in Fig. 4. One end of the vertical springs 46 and 50 is fixedly secured to the lugs 38 and 40, respectively, by means of the L-shaped elongated bar 54 which extends between the lugs 38 and 40, being secured thereto by means of the screws 56. Each of the horizontal spring members 48 and 52 is fixedly secured to the benches 28 and 30 respectively, by screws 58 and 60 respectively, their ends extending to and being also secured to the core member 16 by screws 62.

In order to secure the arm 44 for pivotal movement, a bracket 64 is secured to the arm by screws 72, the lower outer edges of the bracket being provided with outwardly extending lugs 68 and 70 for receiving the lower ends of the vertical

springs 46 and 50 respectively. As illustrated benches 74 and 76 are provided adjacent the upper edge of the bracket 64 for receiving the horizontal springs 48 and 52, respectively, which are secured thereto by means of the screws 78 and 80 respectively. The outer edges of the horizontal spring members 48 and 50, however, extend beyond the benches formed on the bracket 64 and are secured to a cross-bar 82 carried by the end of the arm 44 by means of the screws 84. By anchoring the horizontal springs 48 and 52 in this manner, the elongated spring members 48 and 52 are strengthened against torsional movement about the elongated axis. A spring member 63, having one end secured by the adjustable retainer 59 carried by the lower end 24 of end flange 22 and the other end secured to the lug 61 carried by the arm 44, is provided for biasing the arm 44 in the clockwise direction about its pivot formed by the cross-springs.

As illustrated in Figs. 1 and 3, a block 86 of light-weight metal is secured to the bracket 26 carried by the end frame member 22 by means of the screws 88, and is so disposed as to have an upper bearing edge 90 adjacent the pivot formed by the two pairs of cross-springs so as to form an auxiliary rigid bearing support for the arm 44 under predetermined conditions of shock. In practice, the bearing edge 90 of the rigid bearing support 86 is positioned at a distance of not more than .01 inch from the pivot formed by the cross-springs, so that under conditions of shock tending to distort the floating pivot in a direction towards the fixed ends of the horizontal springs maintained by the screws 58 and 60, the arm will seat against the bearing edge 90 and substantial distortion or buckling of the horizontal spring members 46—52 will be prevented. As an auxiliary to the rigid bearing member 86, the main body portion of the bracket 64 carried by the arm 44 is also provided with a plate member 92 secured thereto by means of the screws 94, as illustrated in Fig. 4, which tends to seat against the rigid bearing member 86 under predetermined conditions of shock to further prevent substantial distortion or buckling of the spring members.

As illustrated in Fig. 4, the cross bar 54 also carries adjustable screw members 96 and 98 disposed to project therethrough with their ends adjacent the arm 44. These adjustable screw members, when properly positioned with respect to the arm 44, also provide a rigid bearing support which is auxiliary to the floating pivot formed by the two pairs of cross-springs and prevents substantial distortion or buckling of the cross-springs under other predetermined conditions of shock. Thus, as shock is encountered tending to distort or buckle the vertical spring members 46 and 50, the arm 44 seats against the ends of the screws 96 and 98 to prevent further vertical movement of the floating pivot and consequently, distortion of the spring members forming the floating pivot.

At the other end of the arm 44 a plurality of contact members 100, 102 are disposed in offset, spaced but facing relation and carried by the arms 104 and 106, respectively, the arms terminating in a base which is secured to the arm 44 as by means of the bolt 108 and nut 110. The contact members 100, 102 are suitably spring mounted, as illustrated, being secured to the arms 104, 106 by the screws 112 and 114, respectively. The relative spacing and positioning of the contact members 100 and 102 are better illustrated in Fig. 2.

In order to limit the pivotal movement of the arm 44, a substantially U-shaped bracket 116 is carried by the end frame 20 and secured thereto as by means of the screw 118, the bracket 116 extending upwardly between the spread arms 104 and 106 which carry the contact members. As illustrated, opposed adjustable set screws 120 and 122 are carried by the upper and lower legs respectively of the bracket 116. By adjusting the position of the ends of the set screws 120 and 122 with respect to the arm 44, the pivotal movement of the arm 44 about its floating pivot or the auxiliary rigid pivots may be limited to any required amount.

Referring to Fig. 2 of the drawings, the secondary relay 12 is illustrated as comprising the core member 124 having a winding 126 disposed thereon with an elongated cooperating armature member 128 disposed for pivotal movement about a spring pivot 130. As illustrated, the spring pivot member 130 is an elongated leaf spring having one end fixedly secured to a flange 132 carried by the frame member of the relay 12 and being secured thereto by the screws 134 and 136. The upper end of the frame member adjacent the leaf spring 130 is provided with a beveled surface 138 terminating in an edge adjacent the pivot formed by the spring member 130. Likewise, the elongated armature member 128 is provided with a beveled surface 140 terminating in an edge adjacent the normal pivot formed by the spring 130, these beveled surfaces 138 and 140 cooperating with the spring member 130 to permit pivotal movement of the armature member 128. In addition, the bearing edge of the frame adjacent the floating pivot of the spring member 130 functions as an auxiliary rigid bearing support for the armature member 128 under predetermined conditions of shock, such as would tend to distort or buckle the spring member 130 towards its end which is secured to the flange member 132.

In order to limit distortion or buckling of the spring 130 under other predetermined conditions of shock, in which the armature member 128 would tend to be lifted further from the extreme position, as shown in Fig. 2, a bracket 142 is provided and secured to the frame member as by means of the screws 144, set screws 146 and 148 being carried by the bracket 142, having their ends disposed to seat in recesses 150 provided in the armature member 128. The set screws 146 and 148 are adjusted as illustrated in Fig. 2, so that their ends seat against the armature member 128 under predetermined conditions of shock, and thereby provide the required rigid auxiliary pivot.

In order to prevent excessive pivotal movement of the armature member 128, the bracket 142 is provided with a split lug 152 in which is carried an adjustable set screw 154 disposed to seat against the armature member on one side of the pivot formed by the spring 120, thereby preventing excessive pivotal movement in the clockwise direction, as viewed in Fig. 2. In addition to the stop 154, a stop 156 is also provided on the other side of the pivot disposed to prevent excessive counterclockwise pivotal movement of the armature member 128. The stop 156 in the present embodiment, is in the form of an adjustable screw projecting through an enlarged opening 158 in the armature member 128 and secured to a support member 160 of the core member 124 by means of the set screw 162 with the head of the screw 156 disposed to seat against the upper edge of the armature member 128.

As illustrated, an insulating member 164 is provided for separating the contact members 166 and 168 carried by the armature member 128. The insulating member 164 is in the form of a T-shaped block and is secured to the armature member 128 as by means of the screws 170, and to the conducting block 172 which carries the contact member 166 by the screws 174. The contact members 166 and 168 are disposed on opposite sides of the spring pivot 130 disposed to face in opposite directions and align with the offset contact members 100 and 102 respectively. In order to maintain the armature member 128 in a predetermined position, a spring member 176 is secured at one of its ends to the insulating block 164 with its other end secured to the frame member of the relay 12 by means of the adjustable screw member 178.

As illustrated in Fig. 1, the armature members of the primary relay 10 and the secondary relay 12 are disposed at right angles to each other with their contact members aligned. Likewise, each of the relays 10 and 12 has a substantially floating pivot for the armature members with auxiliary rigid bearing supports supplementing the floating pivots for preventing distortion or buckling of the spring members forming the floating pivots under predetermined conditions of shock. With the armature members mounted as described at substantially right angles to each other, there is no necessity for a complicated pivotal support of the various contact members as a simple pivotal movement of each of the armature members will effect a required circuit closing or circuit opening of the contact members.

Referring to Fig. 5, there is illustrated a regulating system utilizing the apparatus of this invention for maintaining constant the voltage on a generator 180, the armature windings 182 of which are directly connected to the conductors 184 of an output circuit and the field winding 186 of which is connected to receive exciting current from a suitable source of direct-current voltage, such as the exciter 188. A field rheostat 190 is connected in the field circuit for adjusting the excitation of the generator 180, the rheostat being arranged to be operated by an electric motor 192 which is respectively controlled in its voltage lowering and raising directions by a pair of relay devices 194 and 196 respectively. Each of the relay devices 194 and 196 is of usual construction having an energizing winding and a plurality of contact members for establishing predetermined circuits.

The primary relay 10 described hereinbefore is disposed with its energizing winding 18 connected to the conductors 184 through the rectifying device 198 while the secondary relay 12 is disposed with its energizing winding 126 connected to a suitable source of energy such as the supply conductors 200, 201, one end of the winding 126 being directly connected to conductor 200, and the other end of the winding being connected through resistor 202, capacitor 204 and resistor 206 connected in series circuit to the other supply conductor 201. As illustrated, the contact members 100 and 102 of the primary relay 10 are connected through a conductor 208 to supply conductor 200, while contact member 166 of the secondary relay 12 is connected through the energizing winding of the relay 196 and conductor 210 to supply conductor 201. Contact member 168 of the secondary relay 12 is connected through the energizing winding of relay 194 and conductor 210 to the supply conductor 201. Thus the primary relay 10 and the secondary relay 12 are disposed to selectively energize the windings of the relays 194 and 196 to control the operation of the motor 192.

As illustrated, the contact members 212 and 214 of the relays 194 and 196, respectively, are disposed when actuated to shunt the capacitor 204 from the energizing winding of the secondary relay 12, while contact members 216 and 218 of the relays 194 and 196, respectively, are disposed to connect the capacitor 204 in series with the energizing winding of the relays for effecting a time delay in the decrease of the energization of the respective relays.

The characteristics of the secondary relay 12 of this invention are such that if the current is reduced after the winding 126 is energized, the armature member does not follow the initial change in current on account of the hysteresis of the core member. Consequently, in order to obtain a gradual return of the armature member 128 to a predetermined position, it is necessary to compensate or adjust the energizing circuit to provide a maximum energization of the winding 126 equivalent to the current necessary for permitting the return of the armature member to its given position. This is obtained by so adjusting the total resistance of the energizing circuit constituting the resistors 202, 206, capacitor 204, and the winding 126, that the rate of charging current of the capacitor 204 when the energizing circuit is established will be of the order shown by the curve 220 of Fig. 6. By properly adjusting either of the resistors 202 or 206, the charging current can be so adjusted that, as illustrated in Fig. 7, the movement of the armature with respect to the current will be as illustrated by curve 222, this curve being equal but opposite to the decay of the charging current as represented by the curve 220. From the curves 220 and 222 of Fig. 7, the curve 224 of Fig. 8 can be established illustrating the armature travel with respect to time as the capacitor 204 is charged to capacity. The utilization of this characteristic in the regulating circuit shown in Fig. 5 will be better understood from the following description of the operation thereof.

Assuming that the generator 180 is supplying a given load and that the spring member 63 has been adjusted to maintain a given position of the armature arm 44 of the primary relay 10, and the spring member 176 of the secondary relay 12 has been so adjusted together with the resistance of the energizing circuit of the winding 126 thereof, that the armature member 128 is balanced in a given stationary position, then if for any reason the voltage of the generator 180 changes, the energization of the winding of the primary relay 10 is changed to upset the initial balanced condition of the primary relay 10 and the secondary relay 12.

Assuming that the change in voltage is an increase in voltage, then the winding 18 of the primary relay 10 is so energized as to actuate the contact member 102 into engagement with the contact member 168 of the secondary relay to establish a circuit which extends from supply conductor 200, through conductor 208, contact members 102—168, the energizing winding of relay 194, and conductor 210 to the other supply conductor 201. The energization of the winding of relay 194 immediately actuates its contact member 226 to its circuit closing position to so energize the motor 192 as to operate the rheostat 190 to connect additional sections of the rheostat 190 in circuit with the field winding 186 of the

generator 180 and thereby decrease the energization of the generator 180.

At the same time that the corrective operation of the rheostat motor 192 is initiated, contact members 212 and 216 of the relay 194 are also actuated to their circuit closing position, the contact member 212 effectively shunting the capacitor 204 from circuit with the energizing winding 126 of the secondary relay 12, the energizing circuit thus established extending from the supply conductor 200, through conductor 208, winding 126 of the relay 12, through contact member 212 of the relay 194 to the other supply conductor 201.

By removing the capacitor and the resistors 202 and 206 from the energizing circuit, the energization of the winding 126 is suddenly increased and the armature member 128 is actuated about its pivot against the pull of the spring 176 to abruptly separate the contact members 102 and 168 to interrupt the energizing circuit to the winding of the relay 194. However, since capacitor 204 is at the same time connected in series circuit with the winding of the relay 194 by the contact member 216, the capacitor 204 is discharged through the winding of the relay 194 to momentarily energize it and prevent the immediate operation of the relay 194 to open the circuits established by its contact members. This insures a regulating operation of the rheostat motor 192 to initiate a regulation of the generator 180.

As soon as the condenser 204 is discharged to a point where the winding of relay 194 is sufficiently deenergized, then the contact members 212, 216 and 226 of the relay 194 drop to their circuit opening position to connect the capacitor 204 in circuit with the winding 126 of the secondary relay 12. When thus connected the charging current for the capacitor 204 is so large as to maintain the winding 126 sufficiently energized and prevent a quick or sudden movement of the armature member 128 about its pivot to again effect engagement of the contact members 168 and 102. As the capacitor is charged and the charging current is decreased, the energization of the winding 126 is also decreased as shown by the curve 220 of Fig. 7, and the armature member 128 is permitted to move about its pivot due to the bias of the spring member 176, as represented by the curve 222 so that, in effect, the movement of the contact member 168 to its circuit closing position to engage contact member 102 is in accordance with the curve 224 of Fig. 8.

If the initial corrective action of the motor 192 is insufficient to correct the increase in voltage of the generator 180, the contact member 168 again engages the contact member 102 before the contact member 168 is returned to its initial stationary position and the winding of the relay 194 is again so energized as to establish the circuits and initiate operation of the motor 192 as described hereinbefore. The rate of initiated operations of course depend on the voltage change. If the voltage change is large, the primary relay is continuously energized to circuit closing position to effect the continuous operation of the motor, whereas if the voltage change is small the secondary relay controls the energization of the rheostat motor to limit the corrective operation. Thus the secondary relay controls the regulating operations in accordance with the change in the voltage.

On the other hand, if the voltage of the generator is decreased, then the winding 18 of the primary relay 10 is so deenergized that the spring member 63 effects a pivotal movement of the arm 44 in a direction to actuate the contact member 100 into engagement with the contact member 166 of the secondary relay 12 to establish a circuit which extends from supply conductor 200, through conductor 208, contact members 100, 166, the energizing winding of relay 196 and conductor 210 to supply conductor 201 to energize the relay 196. The energization of the winding of the relay 196 actuates the contact member 228 to a circuit closing position to effect the operation of the motor 192 in a direction to shunt a number of the sections of the field rheostat 190 from circuit with the field 186 and thereby reduce the energization of the generator 180 to effect a decrease in its voltage. At the same time, the contact member 214 of the relay 196 shunts the capacitor 204 from the energizing circuit of the winding 126 of the secondary relay 12 and the contact member 28 connects the capacitor 204 in series circuit relation with the energizing winding of relay 196. The shunting of the capacitor 204 from circuit with the winding 126 by contact member 214 effects a sudden increase in the energization of the winding 126 of the relay 12 to actuate the armature member 128 against the bias of its spring member 176 to effect an abrupt separation of the contact members 100 and 166.

However, because of the capacitor 204 is connected in series with the winding of the relay 196, the energization of the winding is momentarily maintained due to the discharge of the capacitor to prevent the actuation of the contact members of the relay 196 to their open circuit position, thereby insuring a regulating operation of the motor 192. As soon as the capacitor 204 is sufficiently discharged as to decrease the energization of the winding of relay 196 a predetermined amount, the contact members of the relay 196 drop to their open circuit position, thereby connecting the capacitor 204 in the energizing circuit of the winding 126 of relay 12. Again, the large charging current for the capacitor 204 maintains the winding 126 so energized for a period of time as to permit only a gradual return of the contact member 166 towards its circuit closing position with the contact member 100 of primary relay 10. Repeated operations of the relays 10 and 12 are effected until the voltage of the generator 180 is corrected.

The regulating operation of the apparatus of this invention is very sensitive while the apparatus, of itself, is so rugged as to be capable of withstanding shocks of upwards of 2000 foot pounds. Further, because the apparatus is balanced and is free of dash pots it can be operated in any position required for any given installation. Since a minimum of pivots are provided for the apparatus of this invention, it is apparent that there are only a minimum of wearing parts and that, therefore maintenance will be held to a minimum. Further, the apparatus can easily be adjusted to fit the characteristics of any given dynamo-electric machine.

Although this invention has been described with reference to a particular embodiment thereof, it is, of course, not to be limited thereto except insofar as is necessitated by the scope of the appended claims.

I claim as my invention:

1. In a regulator, in combination, a control relay having an energizing winding and an arma-

ture member, means comprising a spring mounting for providing a floating pivot for the armature member, and means associated with the armature member and the spring pivot mounting disposed to limit buckling and distortion of the spring pivot mounting under predetermined conditions of shock, said means providing a rigid auxiliary pivot for receiving the armature member under the predetermined conditions of shock to assure operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot.

2. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a spring mounting for providing a floating pivot for the armature member, a member having an edge associated with the armature member and the spring pivot mounting disposed to receive the armature member and provide a rigid bearing support therefor under predetermined conditions of shock which effect a movement of the floating pivot a predetermined distance, and means disposed to limit the movement of the armature member in a direction away from the floating pivot and the rigid bearing support under other predetermined conditions of shock, said limiting means providing another rigid bearing support for the armature member, the rigid bearing supports assuring the operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot.

3. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a spring mounting for providing a floating pivot for the armature member, a member having a bearing edge associated with the armature member and the spring pivot mounting, the bearing edge being disposed not more than .01 of an inch from the spring pivot to provide a rigid bearing support for the armature member under predetermined conditions of shock which effect a movement of the floating pivot a predetermined distance, and means disposed to limit the movement of the armature member in a direction away from the floating pivot and the rigid bearing support to provide another rigid bearing support therefor under other predetermined conditions of shock, said limiting means providing another rigid bearing support for the armature member, the rigid bearing supports assuring the operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot.

4. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a spring mounting for providing a floating pivot for the armature member, a member having a bearing edge associated with the armature member and the spring pivot mounting, the bearing edge being disposed not more than .01 of an inch from the spring pivot to provide a rigid bearing support for the armature member under predetermined conditions of shock which effect a movement of the floating pivot a predetermined distance, means disposed to limit the movement of the armature member in a direction away from the floating pivot and the rigid bearing support to provide another rigid bearing support therefor under other predetermined conditions of shock, said limiting means providing another rigid bearing support for the armature member, the rigid bearing supports assuring the operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot, and means associated with the armature member disposed to limit the extent of the pivotal movement thereof about the spring pivot and the rigid bearing supports when the winding is energized.

5. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a cross-spring mounting for providing a floating pivot for the armature member, each of the cross springs having a fixed end, a member having an edge associated with the armature member and the spring pivot, the edge of the member being disposed in proximity to the pivot to provide a rigid auxiliary pivot for the armature member when the cross-spring mounting is distorted under predetermined conditions of shock to move the floating pivot towards the fixed end of one of the springs, and means disposed to limit the movement of the armature member and provide a second rigid auxiliary pivot therefor when the cross-spring mounting is distorted under other predetermined conditions of shock to move the floating pivot towards the fixed end of the other of the springs, the rigid auxiliary pivots cooperating with the floating pivot to maintain substantially stable operation of the relay and prevent damage to the cross spring mounting when exposed to physical shock.

6. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a cross-spring mounting for providing a floating pivot for the armature member, each of the cross-springs having a fixed end, a member having an edge associated with the armature member and the spring pivot, the edge of the member being disposed in proximity to the pivot to provide a rigid auxiliary pivot for the armature member when the cross-spring mounting is distorted under predetermined conditions of shock to move the floating pivot towards the fixed end of one of the springs, means disposed to limit the movement of the armature member and provide a second rigid auxiliary pivot therefor when the cross-spring mounting is distorted under other predetermined conditions of shock to move the floating pivot towards the fixed end of the other of the springs, the rigid auxiliary pivots cooperating with the floating pivot to maintain substantially stable operation of the relay and prevent damage to the cross-spring mounting when exposed to physical shock, and means associated with the armature member disposed to limit the extent of the pivotal movement thereof about the spring pivot and the cooperating rigid bearing supports when the winding is energized in a predetermined manner.

7. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a cross-spring mounting for providing a floating pivot for the armature member, each of the cross-springs having a fixed end, a member having a bearing edge associated with the armature member and the spring pivot mounting, the bearing edge being disposed not more than .01 of an inch from the spring pivot to provide a rigid auxiliary pivot for the armature member when the spring mounting is distorted under predetermined conditions of shock to move the floating pivot towards the fixed end of one of the springs, and means disposed to limit the movement of

the armature member and provide another rigid auxiliary pivot therefor when the spring mounting is distorted under other predetermined conditions of shock to move the floating pivot towards the fixed end of the other of the springs, the rigid auxiliary pivots cooperating with the floating pivot to maintain substantially stable operation of the relay and prevent damage to the cross-spring mounting when exposed to physical shock.

8. In a regulator, in combination, a primary control relay and an auxiliary control relay, each of the relays having an armature member and a winding disposed to be energized to control the movement of the related armature member, each of the relays having a spring mounting disposed to provide a floating pivot for each of the armature members, the armature members being longitudinally disposed for pivotal movement through arcs which are substantially at right angles to one another, a pair of oppositely disposed contact members carried by each of the armature members, the contact members carried by the primary armature member being disposed to selectively engage the contact members carried by the auxiliary armature member in response to a predetermined change in the energization of the winding associated therewith, the winding of the auxiliary control relay effecting a pivotal movement of the auxiliary armature member when energized to abruptly separate the contact members of the relays, and means associated with the armature member and spring pivot mounting of each of the relays disposed to limit buckling and distortion of the spring pivot mounting under predetermined conditions of shock, said means providing rigid auxiliary pivots for receiving the armature members under the predetermined conditions of shock to assure operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivots.

9. In a regulator, in combination, a primary control relay and an auxiliary control relay, each of the relays having an armature member and a winding disposed to be energized to control the movement of the related armature member, each of the relays having a spring mounting providing a floating pivot for each of the armature members, the armature members being longitudinally disposed for pivotal movement through arcs which are at substantially right angles to one another, a pair of contact members carried by each of the armature members, the contact members of the primary armature member being disposed at one side of the pivot therefor in offset, spaced and facing relation to one another, the contact members of the auxiliary armature member being disposed on opposite sides of the pivot therefor to face in opposite directions and align with the offset contact members of the primary armature member, the armature member of the primary control relay being disposed for pivotal movement in response to a predetermined change in the energization of the winding associated therewith to effect the engagement of one of the contact members carried thereby with its cooperating contact member of the auxiliary control relay, the winding of the auxiliary control relay effecting a pivotal movement of the auxiliary armature member when energized to abruptly separate the contact members of the relays.

10. In a regulator, in combination, a primary control relay and an auxiliary control relay, each of the relays having an armature member and a winding disposed to be energized to control the movement of the related armature member, each of the relays having a spring mounting providing a pivot for each of the armature members, the armature members being disposed at substantially right angles to one another, a pair of contact members carried by each of the armature members, the contact members of the primary armature member being disposed at one side of the pivot therefor in offset, spaced and facing relation to one another, the contact members of the auxiliary armature member being disposed on opposite sides of the pivot therefor to face in opposite directions and align with the offset contact members of the primary armature member, the armature member of the primary control relay being disposed for pivotal movement in response to a predetermined change in the energization of the winding associated therewith to effect the engagement of one of the contact members carried thereby with its cooperating contact member of the auxiliary control relay, the winding of the auxiliary control relay effecting a pivotal movement of the auxiliary armature member when energized to abruptly separate the contact members of the relays, and means associated with the armature member and spring mounting of each of the relays disposed to limit buckling and distortion of the spring pivot mounting under predetermined conditions of shock, said means providing rigid auxiliary pivots for receiving the armature members under the predetermined conditions of shock to assure operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivots.

11. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a spring mounting for providing a floating pivot for the armature member, a rigid pivot for the armature member, the rigid pivot being disposed to receive the armature member when the shock conditions move the floating pivot a predetermined distance thereby to limit the load imposed on the floating pivot and to assure operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot.

12. In a regulator, in combination, a control relay having an energizing winding and an armature member, means comprising a cross-spring mounting for providing a floating pivot for the armature member, a rigid pivot for the armature member, the rigid pivot being disposed closely adjacent the spring mounting to receive the armature member when the shock conditions move the floating pivot a predetermined distance thereby to limit the load imposed on the floating pivot and to assure operation of the regulator when the shock conditions become greater than can safely be carried by the floating pivot.

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