Dec. 11, 1945. K. A. OPLINGER 2,390,809

CIRCUIT-CONTROLLING APPARATUS

Filed Jan. 26, 1943

Fig. 1.

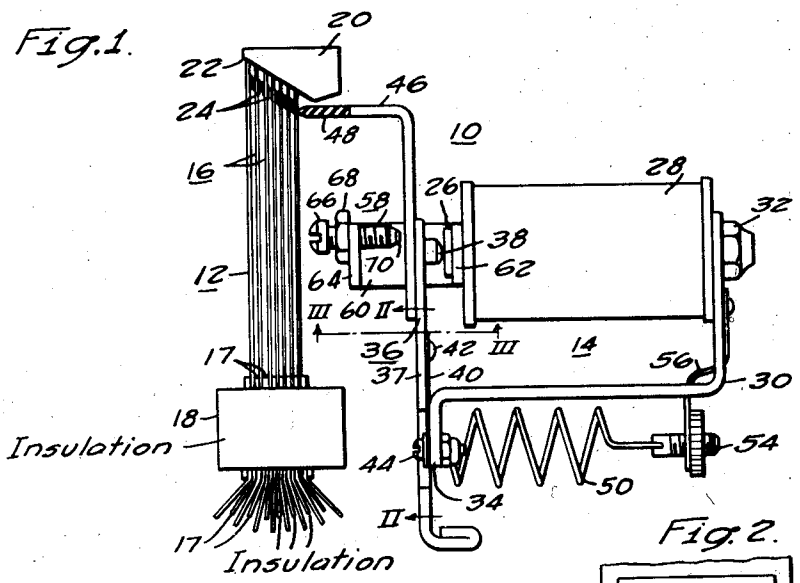


Fig. 2.

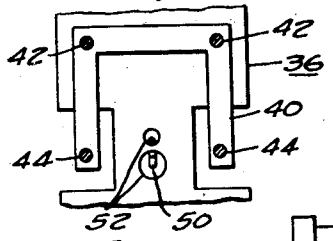


Fig. 3.

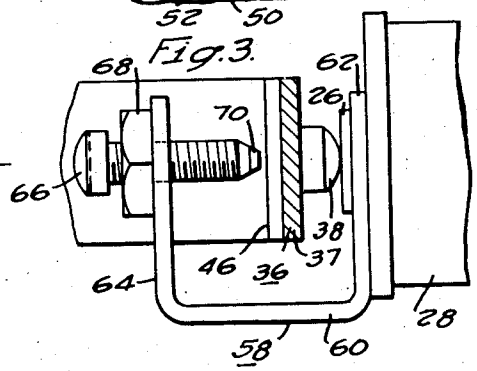
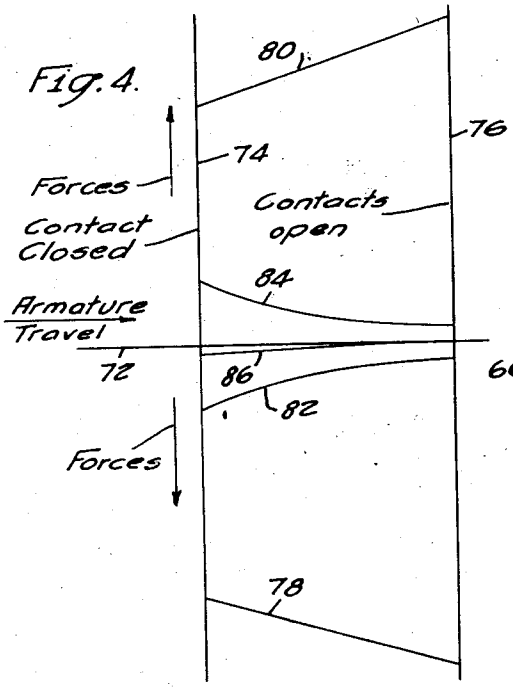


Fig. 4.



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CIRCUIT-CONTROLLING APPARATUS

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Application January 26, 1943, Serial No. 473,582

6 Claims. (Cl. 200—104)

This invention relates to electrical apparatus and, in particular, to circuit controlling apparatus.

This application is a continuation-in-part of my copending application, Serial No. 416,171, filed October 23, 1941.

In electrical systems, switches and electromagnetic operating devices therefor have been utilized for controlling and establishing given circuits. The electromagnetic devices usually consist of a core member, a winding disposed to be energized magnetically associated therewith, and an armature disposed for movement for actuating the switch to effect a switching operation when the winding is energized.

Where weight is a consideration in the type of circuit-controlling device utilized, an electromagnetic apparatus of the type having a variable magnetic gap between the armature and the core member is employed as the actuating mechanism in contrast with the type of electromagnetic apparatus having an overlapping gap. The variable magnetic type of electromagnet is usually smaller and less complicated than the overlapping gap type of electromagnetic devices.

Where the variable gap type of electromagnetic devices are employed with a plurality of switches for effecting progressive switching operations, it is found that the opposing forces of the switches and the operating device are unbalanced during operation, and that stability of operation is not obtained. Further, the electromagnetic device will not have the voltage sensitivity over its working range required for sensitive operations such as in voltage regulators for aircraft applications.

An object of this invention is to provide in a circuit-controlling apparatus having a plurality of spring biased progressively operated switches for compensating for the change in forces of the spring biased switches as the switching operations are effected to give a substantially uniform stability of operation of the switches.

A more specific object of this invention is to provide in an electromagnetic device disposed for actuating a plurality of spring biased progressively operated switches for compensating for the change in balance of the forces of the electromagnetic device and the switches resulting from the operation of the switches.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawing, in which:

Figure 1 is a view in elevation of the circuit-controlling apparatus of this invention;

Fig. 2 is a view of a part of the electromagnetic device of Fig. 1 taken along the line II—II thereof;

Fig. 3 is a plan view, greatly enlarged, of another part of the electromagnetic device of Fig. 1 taken along the line III—III thereof; and

Fig. 4 is a graph, the curves of which represent the opposing forces which are balanced in the circuit-controlling apparatus of this invention.

Referring to Fig. 1, this invention is illustrated as applied to a circuit-controlling device 10 comprising the switching apparatus 12 and an electromagnetic device 14 disposed to control the operation of the switching apparatus 12.

The switching apparatus 12 illustrated comprises a plurality of elongated self-biased spring leaf members 16 having one of their ends insulated from each other by means of layers 17 of suitable insulating material, such as fishpaper, and fixedly supported with respect to each other in an insulating clamping member 18, the details of which are not shown. The other ends of the spring leaf members 16 are free to move away from an adjustable stop 20, the stop being provided with a beveled or sloped surface 22 for receiving and spacing the ends of the biased members 16 for limiting their movement in the self-biasing direction.

Each of the spring leaf members 16 is of good conducting material, such as beryllium copper alloy, and carries a contact button 24 near its free end. The contact buttons 24 are so positioned that as the spring leaf members 16 are actuated away from the sloped surface 22 of the stop 20, the contact buttons are progressively actuated into engagement. In practice, the projecting ends of the fixed spring leaf members 16 are connected to different sections of a resistor (not shown) by suitable conductors, so that as the spring members 16 are actuated to the circuit closing position, the sections of the resistor are progressively shunted by the progressively closed contact buttons 24 carried by the spring leaf member 16.

For a more complete description of the details and construction of the switching apparatus 12, reference may be had to Patent No. 2,246,301 which issued June 17, 1941, to C. R. Hanna et al. and which is assigned to the assignee of this invention.

The electromagnetic device 14 may be of any form, and as illustrated comprises a core member 26 having an energizing winding 28 mounted thereon, the winding 28 being disposed to be energized in a predetermined manner from a suitable source of power (not shown).

A bracket 30 of non-magnetizable material is carried by the electromagnetic device 14, and is secured thereto as by means of the screw 32. As illustrated, the bracket 30 is provided with spaced depending legs 34 disposed or positioned for mounting an armature member 36 thereon.

The armature member 36 is of elongated form being formed of the long thin members 37 and 46 and carries a contact button 38 of non-magnetizable material at the upper end of the member 37, and is disposed to be pivotally secured to the depending legs 34 of the bracket 30 by means of the spring pivot member 40. The positioning of the armature member 36 and the function of the button 38 in the structure of this invention will be explained more fully hereinafter. As more clearly illustrated in Fig. 2, the spring pivot member 40 is of substantially U-shape, the base of the pivot member 40 being secured to the armature member 36, as by means of the rivets or screws 42, or where desired, as by means of copper brazing. The legs of the spring pivot member 40 are spaced in the same manner as the divided legs 34 of the bracket 30, and are secured to the legs 34 by means of the screws 44.

Referring again to Fig. 1, the member 46 of the armature member 36 constitutes a driving member disposed to actuate the spring leaf members 16 to effect progressive switching operations as the armature member 36 is moved. The tip 48 of the driving member 46 is of insulating material for insulating the armature member 36 from the conducting spring leaf members 16.

In order to balance the magnetic pull on the armature member 36 when the winding 28 is energized, a coil spring member 50 is provided. One end of the coil spring 50 is secured to the lower end of the armature member 36, as illustrated in Fig. 2, the end of the spring 50 being hooked through suitable openings 52 in the armature 36. The other end of the spring 50 is secured to an adjustable screw 54 which is carried on one end of the bracket 56, the other end of the bracket 56 being secured to the bracket member 30 in any suitable manner. By adjusting the position of the screw 54, the tension of the coil spring 50 may be so adjusted that the force of the spring will balance the magnetic pull of the electromagnetic device 14 throughout the operating range of the armature 36.

As the spring leaf members 16 are progressively actuated to their circuit closing position, the stiffness of the spring leaf members 16 increases, depending upon the number of spring leaf members 16 that form the switching assembly. This stiffness or resistance of the spring leaf members 16 to the actuating force for effecting a circuit closing operation is a variable, varying over the operating range of the armature member 36. In order to offset the variable stiffness factor of the spring leaf assembly, a magnetic trimmer 58 is provided for cooperating with the electromagnetic device 14 for compensating for the change in balance of the forces of the circuit-controlling apparatus due to the change in the stiffness factor of the switching members as switching operations are effected.

As more clearly shown in Fig. 3, the magnetic trimmer 58 comprises a substantially U-shaped member 60 of magnetizable material having one of its legs 62 secured to the core member 26 of the electromagnetic device 14 as by means of a close press fit. The other leg 64 of the U-shaped member 60 terminates opposite the core member 26 on the opposite side of the armature 36. Thus, as the armature member 36 moves within the gap between the legs of the U-shaped member 60, a variable gap is provided on both sides of the armature member 36.

In order to adjust the variable gap between the legs 64 and the armature member 36, a screw 66 of magnetizable material is adjustably carried by the leg 64, a nut 68 being provided for securing the screw 66 in any given position. The screw 66 terminates in an end cap 70 of non-magnetizable material, such as brass or the like which is brazed to the screw 66. The size of the screw 66 and the air gap between the screw and the armature member determines the magnetic pull applied to the armature member by the magnetic trimmer in opposition to the main magnetic pull of the electromagnetic device. In this embodiment, the screw 66 has a small surface area as compared to the surface area of the main core member 26 and the gap between the screw 66 and the armature member 36 is maintained relatively small as compared with the gap between the armature member 36 and the main core member 26.

As illustrated in Fig. 1, and more clearly shown in Fig. 3, the contact button 38 carried by the armature member 36 is of a size sufficient to insure that the armature member 36 is maintained in a position where the air gap between the adjusting screw 66 and the armature member 36 is smaller than the air gap between the armature member 36 and the main core member 26 when the button 38 is seated against the core member and for all operative movement of the armature member 36 over the working range of from "open" to "closed" positions of the leaf spring members 16. By positioning the armature member in this manner, a small air gap between the armature member 36 and the adjusting screw 66 provides for applying a magnetic force to the armature member 36 which increases in a non-linear relation as the armature member approaches the screw 66, such increasing force being substantially equal but opposite to the bias or stiffness of the leaf springs 16 as they are actuated to a circuit closing position.

The operation of the circuit-controlling apparatus of this invention can be best explained by reference to the curves of Fig. 4. In this graph, the horizontal line 72 represents the armature travel from a position where the contacts are closed to the position where the contacts are open, as represented by the vertical lines 74 and 76, respectively. Forgetting for the moment the presence of the magnetic trimmer 58, the magnetic pull of the electromagnetic device 14 on the armature member 36 as the armature travels from the circuit closed position to the circuit open position is represented by the curve 78. In the graph, this curve 78 is represented as a negative force as opposed to the forces which will be illustrated above the horizontal line 72.

Opposing the magnetic pull 78 is the force of the spring pivot 40 and the force of the adjustable spring 50, as represented by the curve 80. As is evident, these opposing forces represented by the curves 78 and 80 substantially balance each other throughtout the operating range or path of movement of the armature 36. The matching of the substantially linear forces represented by the opposed curves 78 and 80 is made possible by maintaining a large gap between the armature member 36 and the core member 26, so that the movement of the armature member 36 is in response to a change of only the linear portion of the normal magnetic force curve for

movement of the armature member 36 through the total air gap between the screw 66 and the core member 26 if such movement were permitted. However, the button 38 limits the movement as described.

However, when a plurality of spring biased progressively operated switch members, such as represented by the spring leaf members 16, are to be actuated through progressive switching operations, the stiffness factor of the spring members 16 introduces a force which unbalances the heretofore balanced forces of the electromagnetic device 14 and the opposing pivot member 40 and spring member 50. This stiffness factor of the spring leaf members 16 is represented in the graph by the curve 82, and as illustrated opposes the forces represented by the curve 80. Thus, in effect, the forces of the pivot member 40 and the adjustable spring member 50 are opposed throughout the operating range of the armature 36 from the circuit closed position to the circuit opening position by the sum of the forces represented by the curves 78 and 82. The non-linear force of the leaf spring 16 as represented by the curve 82 is, however, a small portion of the total force opposing the force of the pivot and main spring represented by the curve 80. In practice, it is impossible to so adjust the tension of the spring 50 to balance these opposing forces even though the force of the leaf springs 16 is small to give a substantial linear stability or relation between the voltage and deflection of the armature member 36 over the entire range of travel of the armature.

By adding the magnetic trimmer 58, which constitutes an extension of the core member 26, it is found that the magnetic pull of the leg 64 of the U-shaped member 60 and the magnetizable screw 66 carried thereby on the armature member 36 is a variable, depending upon the position of the armature with respect to the screw member 66 and the size of the screw, the magnetic pull of the trimmer increasing as the armature 36 approaches the screw member 66 and as the magnetic pull of the core member 26 on the armature 36 decreases. The magnetic pull of the trimmer through the screw 66 on the armature member 36 in opposition to the main force represents a small percentage of the main force applied to the armature member by the main core member 26. The magnetic pull of the trimmer on the armature member 36 may be varied by adjusting the position of the screw member 66 to vary the size of the air gap between the screw 66 and the armature 36.

As described hereinbefore the leaf springs 16 have a non-linear stiffness factor or force as represented by the curve 82 of Fig. 4. The travel of the armature member 36 is limited to that small amount required for actuating the leaf spring 16 from "open" to "closed" positions, and it is necessary, therefore, to provide a positive force for only that travel which will be in opposition to the non-linear force of the leaf springs 16. This is accomplished by the use of the trimmer described hereinbefore, the screw 66 and a small air gap provided thereby giving a small non-linear force which is in opposition to the stiffness factor of the leaf springs 16.

Thus, by suitably adjusting the screw member 66, a magnetic pull curve 84, as represented in Fig. 4, may be obtained which is in opposition to but which will substantially match the non-linear curve 82 representing the stiffness factor of the progressively operated switching members 16. The magnetic trimmer thus compensates for any change in the balance between the pulls exerted on the armature resulting from a progressive operation of the spring biased switch members 16, and results in the obtaining of a stable operating curve, as represented by 86, which is substantially linear with respect to the movement of the armature throughout the operating range of the armature.

The net force represented by curve 86 is always in one direction to tend to effect an operation of the leaf springs 16 toward an open position in opposition to the force of the pivot and main spring which tend to operate the leaf spring 16 to a circuit closing position. In other words, by positioning the armature member 36, as described hereinbefore, so that the gap between the screw 66 and the armature member 36 is smaller than the gap between the armature member 36 and the core member 26, that is, with the armature member 36 maintained to one side of the center line of the air gap between the screw 66 and the core member 26, the trimmer applies a definite positive force in one direction to the armature member 36 at all times while the energizing winding 28 is energized. This positioning of the armature member 36 in the gap insures a gradual movement of the armature member 36 to actuate the leaf spring members 16 in response to a slight decrease in the energization of the energizing winding 28.

Through the use of the magnetic trimmer, it is possible to operate a larger number of the progressively operated spring biased switching members 16, as the magnetic pull of the trimmer can be matched against the stiffness factor of the biased switching members regardless of the number of switching members employed. Further, since all the forces of the circuit-controlling apparatus are in substantial balance regardless of the number of switching operations effected, an increased voltage sensitivity response of the circuit-controlling apparatus is obtained, it being found that substantially the same voltage change is required for each switching operation throughout the progressive operation of the switching members. Further, where, in service, it is found necessary to make changes in the switching members, the circuit-controlling apparatus of this invention can be readily adjusted by adjusting the position of the screw 66 with respect to the armature member to give a substantially perfectly balanced circuit-controlling apparatus.

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 circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to be energized to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising an extension of the core member of the electromagnetic means disposed to exert a magnetic pull on the armature member in opposition to an inversely varying with the magnetic pull of the core of the electromagnetic means, the extension and core member being disposed on opposite sides of the armature member to pro-

vide a predetermined gap therebetween, means disposed to limit the movement of the armature member towards the core member when the electromagnetic means is energized, said limiting means cooperating with the extension to provide an air gap between the extension and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by the extension in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of the extension compensating for the change in balance between the forces of the biased switches, armature biasing spring and the magnetic pull of the electromagnetic means exerted on the armature member resulting from the progressive release of the spring biased switches.

2. In a circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to be energized to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising a substantially U-shaped member of magnetizable material having one of its legs disposed on one side of the armature member secured to the core member and the other leg terminating opposite the core member on the opposite side of the armature member, means disposed to limit the movement of the armature member away from said other leg towards the core member and said one leg when the electromagnetic means is energized, said other leg of the U-shaped member exerting a magnetic pull on the armature member in opposition to the magnetic pull of the core and said one leg, said limiting means cooperating with said other leg to provide an air gap between said other leg and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by said other leg in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of the extension compensating for the change in balance between the forces of the biased switches, armature biasing spring and the magnetic pull of the electromagnetic means exerted on the armature member resulting from the progressive release of the spring biased switches.

3. In a circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to be energized to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising an extension of the core member of the electromagnetic means disposed to exert a magnetic pull on the armature member in opposition to an inversely varying with the magnetic pull of the core of the electromagnetic means, the extension and core member being disposed on opposite sides of the armature member to provide a predetermined gap therebetween, means disposed to limit the movement of the armature member towards the core member when the electromagnetic means is energized, said limiting means cooperating with the extension to provide an air gap between the extension and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by the extension in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of the extension compensating for the change in balance between the forces of the biased switches, armature biasing spring and the magnetic pull of the electromagnetic means exerted on the armature member resulting from the progressive release of the spring biased switches, and means for manually adjusting the extension to adjust the gap and effect an adjustment in the magnetic pull of the extension on the armature member.

4. In a circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to be energized to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising a substantially U-shaped member of magnetizable material having one of its legs disposed on one side of the armature member secured to the core member and the other leg terminating opposite the core member on the opposite side of the armature member, means disposed to limit the movement of the armature member away from said other leg towards the core member and said one leg when the electromagnetic means is energized, said other leg of the U-shaped member exerting a magnetic pull on the armature member in opposition to the magnetic pull of the core and said one leg, said limiting means cooperating with said other leg to provide an air gap between said other leg and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by said other leg in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of the extension compensating for the change in balance between the forces of the biased switches, armature biasing spring and the magnetic pull of the electromagnetic means exerted on the armature member resulting from the progressive release of the spring biased switches, and means carried by said other leg for manually adjusting the magnetic pull by said other leg on the armature member.

5. In a circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, the spring biased switches exerting a non-linear force in opposition to the armature member as they are moved to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising a substantially U-shaped member of magnetizable material having one of its legs disposed on one side of the armature member secured to the core member and the other leg terminating opposite the core member on the opposite side of the armature member,

means carried by the armature member disposed to limit the movement thereof away from said other leg toward the core member and said one leg when the electromagnetic means is energized, said limiting means cooperating with said other leg to provide an air gap between said other leg and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by said other leg in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of said other leg being substantially equal but opposite in force to the non-linear force exerted by the spring biased switches.

6. In a circuit-controlling apparatus, in combination, a plurality of spring biased switches, a spring biased armature member for actuating progressively the spring biased switches to closed positions, the spring biased switches exerting a non-linear force in opposition to the armature member as they are moved to closed positions, electromagnetic means comprising a core member and a winding thereon disposed to exert a magnetic pull on the armature member to actuate it to progressively release the spring biased switches, means comprising a substantially U-shaped member of magnetizable material having one of its legs disposed on one side of the armature member secured to the core member and the other leg terminating opposite the core member on the opposite side of the armature member, means carried by the armature member disposed to limit the movement thereof away from said other leg toward the core member and said one leg when the electromagnetic means is energized, said limiting means cooperating with said other leg to provide an air gap between said other leg and the armature member that is smaller at all times than the air gap between the core member and the armature member to insure the exertion of a continuous non-linear magnetic pull by said other leg in one direction on the armature member when the electromagnetic means is energized, the non-linear magnetic pull of said other leg being substantially equal but opposite in force to the non-linear force exerted by the spring biased switches, and means carried by said other leg for manually adjusting the magnetic pull thereof to insure maintaining the force of the magnetic pull equal but opposite to the non-linear force of the spring biased switches as they are actuated from closed to released positions.

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