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VOLTAGE REGULATING RELAY

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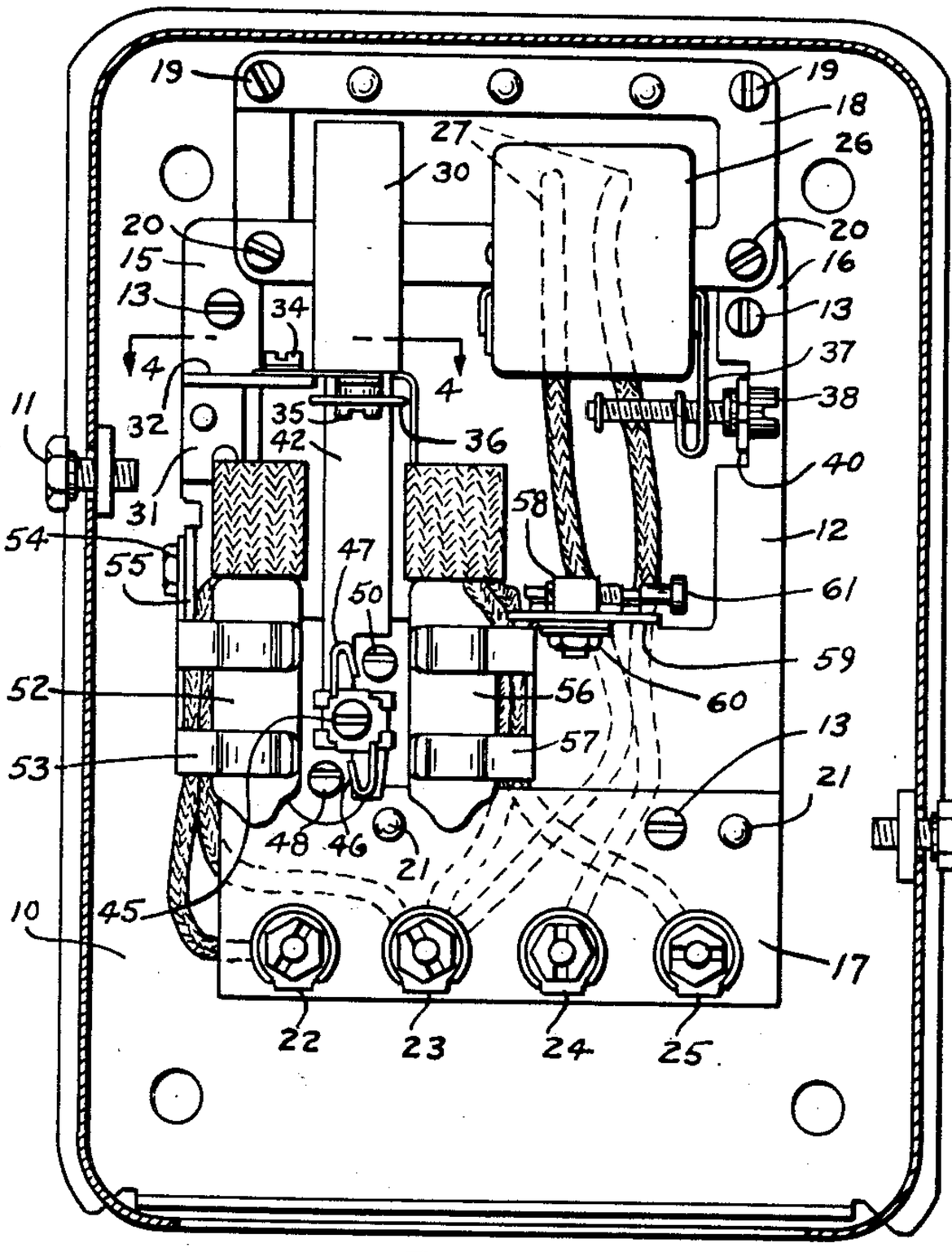

Fig. 1

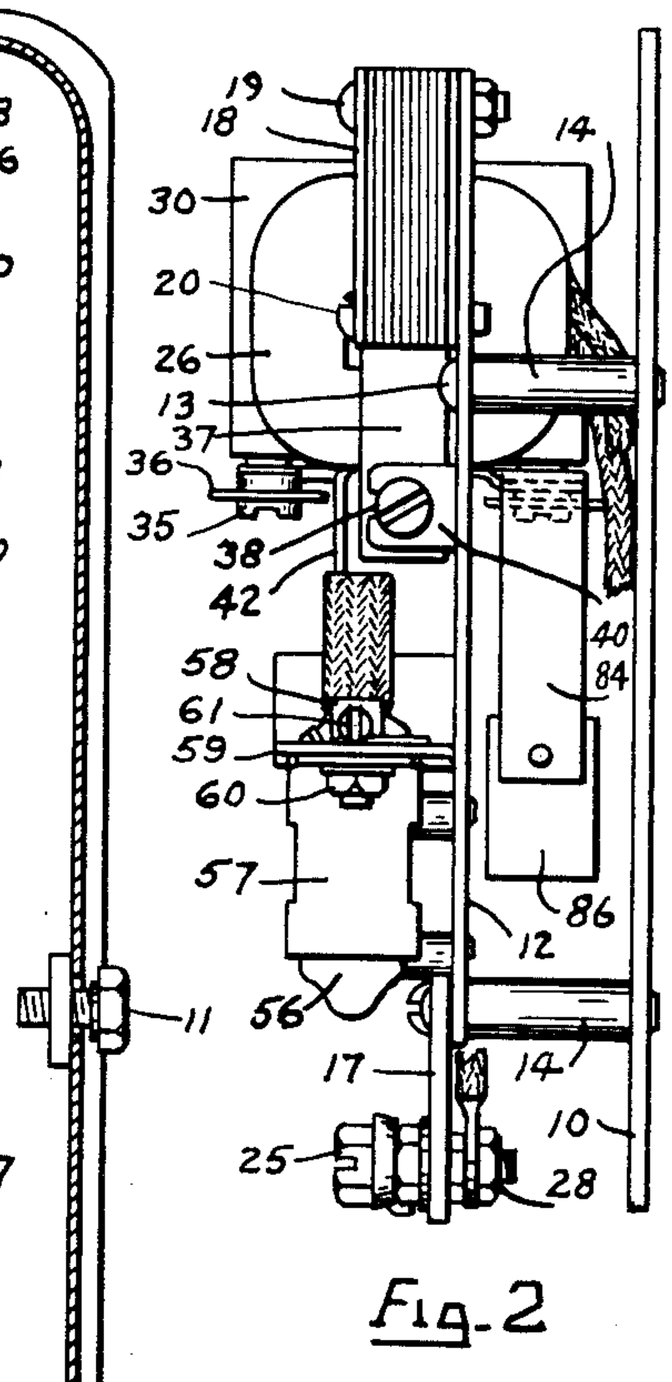

Fig. 2

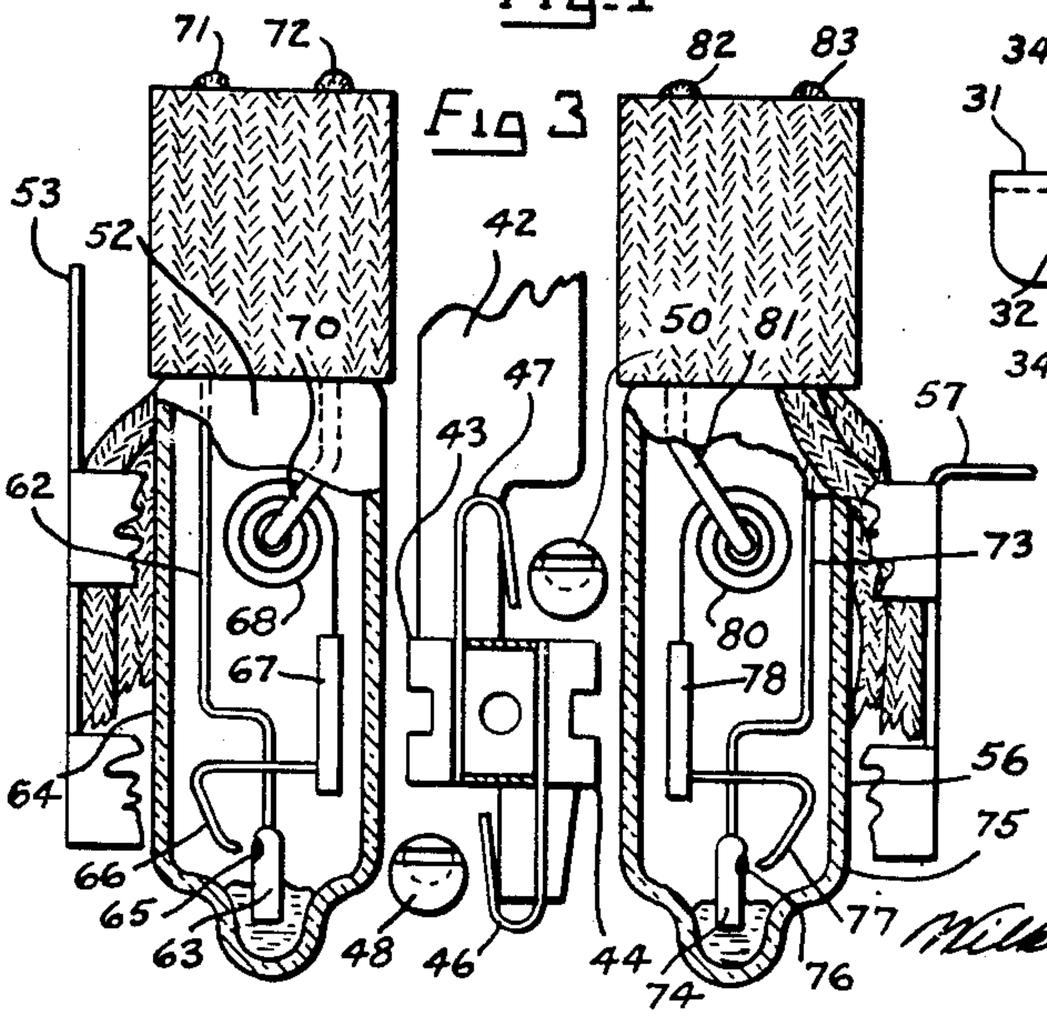

Fig 3

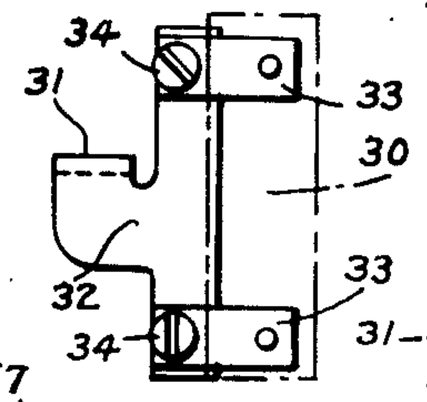

Fig. 4

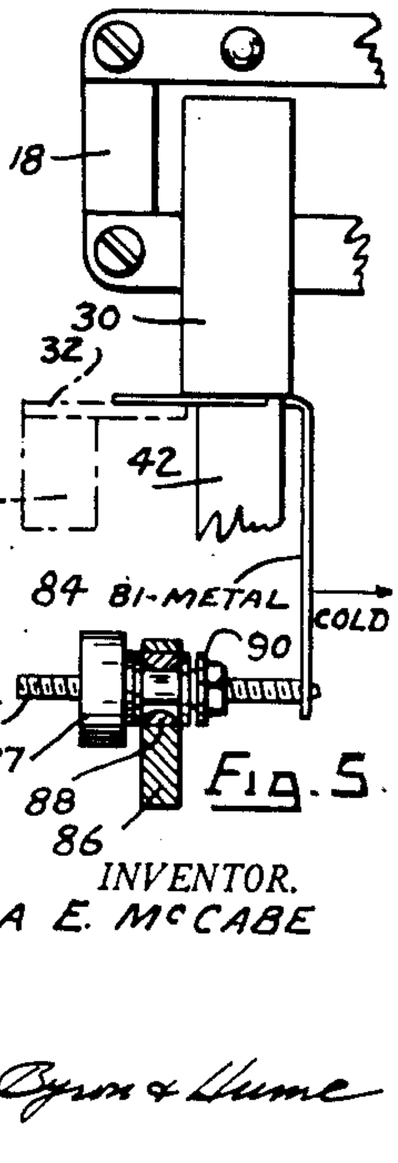

Fig. 5

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VOLTAGE REGULATING RELAY

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6 Claims. (Cl. 200—102)

1

The invention relates to electrical regulating devices of the relay type and has reference more particularly to an improved voltage regulating relay which will be sensitive to small changes in operating voltage to open and close the relay contacts of said device. Apparatus of this character is employed in control equipment for regulating electric power supplies and similar apparatus is employed in the control of conveyor systems.

In connection with providing satisfactory electrical service to consumers of electricity, the maintenance of a substantially constant voltage on the service line becomes a critical and important factor in maintaining customer satisfaction and economy of operation for the power company. For control of the supply through the feed circuits various types of automatic feeder-voltage booster regulators are employed. Forming part of the control mechanism of certain regulators are relay devices which are sensitive to slight variations in the load circuit whereby the devices respond to effect operation of the regulator to step up or down the voltage of the outgoing feeder to compensate for the variable line drop or variable bus voltage and thus maintain a constant voltage at the center of distribution of the particular feeder. Generally rheostats are employed to set the operating voltage of the relay and as such they represent an item offering need of improvement in the development of relay control to which this invention is directed.

Further need for simplicity of adjustment and more satisfactory performance of voltage control devices is evidenced in their application to control of belt conveyor systems. In one such system the relay is energized from a tachometer-generator which may be driven through speed change mechanism operated by a conveyor belt. In the system, the relay contacts are connected to the control circuit of a feeding conveyor so as to stop its movement should the main conveyor speed drop below a preselected speed. Operation of the relay results from a voltage drop which occurs as the tachometer-generator speed is reduced by the slowing down of the main conveyor upon which it depends for operation.

Accordingly an object of this invention is to produce a relay device for the above and other related and similar uses which will possess a sensitivity of operation, simplicity of adjustment, and an elimination of the effect of vibration upon the contact controlling elements such as will improve the function and performance of the apparatus with which it is used.

2

A further object is to provide a voltage regulating relay of the repulsion type, employing separate and independent coils of wire mounted on an iron core and which are relatively adjustable to vary the gap between them whereby the relay device can be set for different operating voltages between maximum and minimum values as determined by said adjustability.

Another object of the invention is to provide a voltage regulating relay incorporating adjustable means for adjusting the position of one of the relay contacts whereby to increase or decrease the spread as regards the fluctuations in the operating voltage required to cause opening of one relay contact and closing of the other.

In connection with the adjustability of one of the relay contacts another object of the invention is to provide eccentric abutments adjustable by rotation of the same to increase or decrease the amplitude of movement of the magnet carrier arm between the abutments, whereby as regards the mercury switches providing the relay contacts it is possible to secure that relationship of the magnets therewith for the most efficient and sensitive operation.

A further object is to provide a voltage regulating relay as described which will additionally embody novel and improved temperature compensating means for compensating for ambient temperature changes or for temperature changes caused by the operation of the device itself.

A still further object is to provide a relay device for the voltage regulation of feeder lines which will be highly sensitive in operation by reason of the improved pivot mounting of the movable coil, which will embody temperature compensating means carried by the movable coil in a manner for modifying the action of the same, and which will be positive in operation since the relay contacts in the form of mercury switches are actuated by magnets carried by an arm depending from the movable coil.

With these and various other objects in view, the invention may consist of certain novel features of construction and operation, as will be more fully described and particularly pointed out in the specification, drawings and claims appended hereto.

In the drawings which illustrate an embodiment of the device and wherein like reference characters are used to designate like parts—

Figure 1 is a front elevational view of a voltage regulating relay embodying the improved structural features of the present invention;

Figure 2 is a side elevational view of the apparatus shown in Figure 1;

Figure 3 is an enlarged fragmentary view with parts in section to better illustrate the construction of the switch contacts and the manner in which they are actuated by the magnet carrier arm;

Figure 4 is a detail plan view illustrating the structure for pivotally supporting the movable coil of the relay means; and

Figure 5 is a fragmentary view with parts in section to illustrate the construction of the compensating means for modifying the action of the movable coil in accordance with temperature changes.

Referring to the drawings, the illustrated embodiment of the invention is housed within a container or box providing a base pate 10 having securing means such as the threaded screws 11 for releasably fastening a cover to the base plate. A metal supporting plate 12 is fixedly secured in spaced relation to the base plate 10 by means of the fastening screws 13 which carry sleeves or spacing elements 14 for maintaining the supporting plate in proper spaced relation. The upper central portion of plate 12 is cut away to provide spaced supporting arms 15 and 16, which arms have fixedly secured thereto the iron core 18 of any preferred form either as a bar or as a continuous rectangular core, as best shown in Figure 1. The iron core is formed of laminations which are riveted together except at the corners where bolts 19 and 20 are employed for purposes of assembly. In the present instance the bolts 20 serve to secure the iron core to the arms 15 and 16. A fiber terminal plate 17 is secured by the rivets 21 to the bottom edge of the plate 12 and a plurality of posts 22, 23, 24 and 25 are secured to the terminal plate, each being suitably insulated from the other by the insulating character of the plate itself.

Separate and independent coils are mounted for movement on the lower horizontal bar of the iron core 18. The said coils comprise a repulsion type relay which operates to open and close certain relay switch contacts in accordance with fluctuations in an operating voltage. A multi-turn coil 26 of wire is mounted on the bottom horizontal bar of the iron core 18 in a manner to permit right and left hand movement of the same for adjusting the repulsion type relay for different operating voltages. The coil 26 is provided with terminals 27 which are electrically connected to the posts 23 and 24, said posts extending through the fiber terminal plate to the underside of the same, the threaded extremity of each post receiving a nut 28 for releasably securing the terminals such as 27 to their respective posts.

Numeral 30 indicates the movable coil of the relay and which may comprise a multi-turn coil of wire such as 26 or the said movable coil may constitute a single turn coil of aluminum or copper in accordance with the disclosure of Figure 1. The movable coil is pivotally supported for oscillating movement by improved means which renders the movable coil extremely sensitive to fluctuations in the voltage of the current traversing coil 26. The bracket 31, suitably secured to leg 15, provides a flat horizontally disposed supporting portion 32, Figure 4, which in turn supports the movable coil 30 through the instrumentality of thin flexible blades 33. Two such blades are shown in Figure 4 although more may be employed. Said blades, which may consist of flexible material such as a .003'' beryllium copper, are secured at one end to the support 32 by means of the screws 34 and at their other end to the bottom surface of the movable coil 30 by the screws 35 which provide the flanged head 36 in spaced relation with respect to the bottom surface of the movable coil. The relationship of the movable coil and the support therefor when joined by the flexible blades is such as to cause the adjacent edges of the support and coil to slightly overlap, as is evident from Figure 4, to provide a fulcrum edge for operation. Vertical movement of the coil 30 is limited by the flanged heads 36 on the screws 35, each flanged head being of such diameter as to extend under the support 32 a distance sufficient to limit upward movement of the coil 30. When the normal gap exists between flanged heads 36 and the support 32 there is no interference with the oscillating movement of the coil.

The primary or adjustable coil 26 provides a depending bracket 37 which is U-shaped at its lower end, the same having threaded engagement with a rotatable screw 38. The screw 38 is suitably mounted for rotation in the upstanding flange 40 struck from the supporting plate 12 and coil 26 can be adjustably positioned with respect to movable coil 30 by rotation of said screw 38. The U-shaped end of bracket 37 applies sufficient tension upon the screw threads to maintain the movable coil in its adjusted position.

The carrier arm 42 is suitably secured to movable coil 30 in depending relation therewith whereby the carrier arm oscillates in accordance with similar movement of the coil. The magnets 43 and 44 are suitably secured by the screw 45 to the terminal end of said carrier arm 42 and the structure for fixedly securing the magnets to the arm, see Figure 3, additionally provides resilient contact elements 46 and 47. Said resilient contact elements are adapted to engage eccentric abutment members 48 and 50 positioned on respective sides of the carrier arm in the vicinity of magnets 43 and 44. The abutments 48 and 50 consist of eccentric members rotatably mounted in the plate 12 and by rotation of said members it is possible to control the amplitude of movement of the carrier arm. When arm 42 swings to the left contact element 46 will engage the abutment 48 and movement of the arm in this left hand direction can be adjusted within limits by rotation of said abutment 48. In a similar manner when carrier arm 42 swings in a direction toward the right contact element 47 will engage the abutment 50 and movement of the arm in this direction can be adjusted within limits by rotation of the abutment 50.

A pair of mercury switches provide the relay contacts of the present device, each mercury switch providing a normally open switch contact which is adapted to be actuated into a closed position by its respective magnet carried by arm 42. The electric switches are adapted to control the operation of a tap changer motor for varying the turn ratio on the regulating transformer, thus maintaining a substantially constant voltage in the load circuit. In other applications of the device, however, only one mercury switch may be employed, such as in the aforementioned system of conveyor belt control. The mercury switch 52 is suitably supported by the member 53 which is secured by screw 54 to bracket 55 bent from the metal of plate 12. The position of switch 52 is fixed, the same being located to the left of the carrier arm, and the switch contact provided thereby being actuated by magnet 43. A similar mercury switch 56 is located to the right of the carrier arm and the switch contact provided by this switch is actuated by

magnet 44. The member 57 supports the switch 56 in a manner providing for adjustment of the switch toward and from 52. For said adjustment a carriage 58 is provided, the same extending through a slot in bracket 59 and having the nut 60 threaded to the end thereof for securing member 57 to the bracket in a manner permitting adjustment of said member and thus the switch. The carriage 58 is adjustably supported by the threaded screw 61 which is suitably mounted for rotation, being suported by bracket. By rotation of screw 61 the carriage 58 can be moved in either a right or left hand direction and similar movement is imparted to switch 56.

The mercury switches 52 and 56 are of the capillary tube type such as disclosed and claimed in my Patent 2,325,785 granted August 3, 1943, and entitled Enclosed Mercury Switch. The fixed electrode 62 of mercury switch 52 is provided at its lower end with a capillary tube 63, which tube dips into the mercury pool at the bottom of the glass container 64. Said tube provides a meniscus of mercury as at 65 for contact by the movable electrode 66. Said movable electrode 66 includes the armature 67 and the tension spring 68, one end of which is fixed to the armature 67 for supporting the armature and the movable electrode 66, whereas the other end of the spring 68 is fixed to support 70. When armature 67 is attracted by magnet 43 the movable contact 66 is caused to move toward capillary tube 63 and eventually contact will be made between the same and the meniscus of mercury 65 provided by said capillary tube. This action of the movable contact will close an electric circuit connecting with terminals 71 and 72 of the mercury switch 52.

The construction of switch 56 is similar, the same including a fixed electrode 73 supporting at its lower end the capillary tube 74 which dips into the mercury pool at the base of the glass container 75 and provides a meniscus of mercury at 76. The movable electrode 77 additionally includes the armature 78 and the tension spring 80 having one end secured to the armature and its other end secured to support 81. The switch 56 is provided with terminals 82 and 83 and when armature 78 is attracted by magnet 44 the movable electrode 77 closes the electric circuit by contact with the meniscus of mercury in the capillary tube 74.

It will be observed that the switch contacts are located on the respective sides of the magnet carrier arm and that said switch contacts are normally open, this being the normal position of the movable contact of the switch owing to the tension imparted thereto by resilient parts 68 and 80. The switch contacts are closed by movement of the same toward each other and which is effected by the magnets carried by arm 42. However, the magnets will actuate only one switch contact at a time so that when 66 is closed contact 77 is open and when the arm moves to the right to close contact 77 it will be understood that contact 66 will automatically open. The terminals of the respective switches are connected to the posts in a manner as shown in Figure 1, with the terminals 71 and 72 of switch 52 being connected to posts 22 and 23 and terminals 82 and 83 of switch 56 being connected to posts 23 and 25. When switch 52 is actuated to close, the circuit connecting with the terminals 71 and 72 is energized and the same results in an increase in the voltage of the load circuit of the regulating transformer as is well known in the art. When switch 56 is actuated to close, the circuit connecting with the terminals 82 and 83 is energized and a decrease in the voltage of the load circuit results.

In this embodiment of the invention it is possible to adjust the primary coil 26 for an operating voltage ranging from forty to sixty-five volts. As described, the coil is moved toward or from movable coil 30 by turning the screw 38, the adjustment varying the gap between the coils. A particular voltage in the current traversing the primary coil 26 requires a particular position of the coil to insure operation of the relay switches. The total voltage change for effecting an opening of one switch and closing the other, may be adjusted in the present relay device to a minimum of three volts. Switches 52 and 56, as determined by the position of the abutment members 48 and 49 adjacent thereto, may each operate on a one volt change in the primary voltage. Switch 56 is supported by the adjustable carriage structure so that this switch may be adjusted for predetermined voltage conditions. When screw 61 is rotated to increase the distance between the switches the effect is to increase the spread as regards the fluctuations in the primary voltage such as will result in the opening of switch 52 and closing of switch 56. In making an adjustment of the carriage 58 it should be accompanied by an adjustment of the abutment 50 so as to increase the amplitude of movement of carrier arm 42 to maintain the proper relationship of the magnets with the switches for their most efficient and satisfactory operation.

Energization of the relay as a result of current flow in the primary coil 26 and flow of induced current in the movable coil 30, results in an increase in the temperature of the unit. This temperature increase together with the effect of ambient temperatures may result in a change in the resistance of the primary coil. With the device calibrated for a particular operation in response to a variation in voltage in the primary coil under normal operating conditions it is apparent that with the change of a few volts effecting switch operation, a change in temperature from that prevailing at the time of calibration could produce operation of the device when not desired.

The invention provides means compensating for those temperature changes which tend to affect operation of the device at voltage values other than those for which it has been set. In other words, if under normal operating conditions the device is calibrated to operate the switch contacts over a predetermined voltage range, a change in voltage as a result of temperature changes will not produce an operation of said contacts owing to said compensating means. An extreme condition may be best exemplified by considering the difference in temperature between that representing normal operating temperatures and that prevailing when the device is energized "cold" after a period of inactivity. When "cold" the repelling force of coil 26, due to its low resistance, is greater than its repelling force when the coil attains its normal operating temperature. This is due to the fact that the temperature rise increases the voltage drop in the coil and so decreases the magnetic effect of the current flowing through the same. The result is that the force operating on movable coil 30 is correspondingly decreased. The compensating means of the invention compensates for temperature changes

by means of a weight suspended from the movable coil by means of a bi-metallic element.

As best shown in Figures 2 and 5, the bi-metallic strip **84** is suitably secured to movable coil **30** so as to depend therefrom, the strip being located and having movement with the coil in the space between plates **10** and **12**. The threaded stud **85** is fixed to the lower depending end of the bi-metallic strip and projects horizontally in a direction toward the left as viewed in Figure 5. The weight **86** is supported by the rotatable member **87** which is threaded on **85** and accordingly the weight can be positioned for securing the desired operation of the compensating means by rotation of **87** which adjusts its position on **85**. Said weight **86** is provided with the fiber insert **88** and the same is retained on member **87** by the snap washer **90**. The bi-metallic element **84** is so constructed and the weight **86** so balances the movable coil **30**, that with a predetermined voltage impressed on the primary coil **26** and with normal operating temperatures prevailing, the carrier arm **42** is positioned by the movable coil in its repelled state with the magnets **43** and **44** centered between the switches with both switch contacts in open position. When the voltage of the current traversing coil **26** drops to a predetermined level, switch **52** is actuated to close since this voltage drop will reduce the repelling force on coil **30** and the carrier arm will move to the left. Upon an increase in the primary voltage to a predetermined level the repelling force is increased to an extent causing movement of carrier arm **42** to the right whereby switch **56** is caused to close. Should a temperature condition exist differing from that at the time of calibration, the bimetallic element **84** will flex due to the change in temperature to thereby shift the weight **86** so that its action with respect to movable coil **30** will compensate for such temperature change. For example, should the temperature of the relay increase, the compensator will flex in a direction toward the left to compensate for a reduction in the repelling force acting on movable coil **30** and in a similar manner, should the temperature of the relay drop, the bi-metallic element **84** will flex in a direction toward the right to compensate for an increase in the repelling force. The temperature compensating means may be adjusted over a wide range and in accordance with the invention the weight is loosely supported by member **87** to provide a dampening effect on the oscillating movements of the movable coil.

In compensating for the effect of temperature changes upon the operation of the relay, due to energization of the relay and ambient temperatures, whereby to maintain a constant voltage at the center of distribution of a particular feeder, such compensation may be varied throughout a predetermined range of temperature, including atmospheric temperatures, so as to over compensate at various stages of temperature change to the extent that under certain conditions transformer capacity may be increased within its design limitations. As is well known, transformer capacities are limited by their abiilty to dissipate heat generated under load demands and as affected by weather conditions. Thus their capacity is governed in part by the effect of the range of atmospheric temperatures through which the transformer will be subjected in use. Since the rate of transformer capacity is thus based with consideration to the highest temperatures to which it may be subjected, it follows that at very low atmospheric temperatures, when increased dissipation of heat lowers the transformer temperature, the transformer will be operating below its design capacity.

In the use of electrical energy for heating purposes and particularly with respect to the increasing use of the improved forms of electrical radiant heating units now making their appearance on the market for house heating, it is apparent that the load demands of such heating systems are greatest at a time when cold temperatures prevail and which have an effect upon the capacity of power transformers, constituting the source of electrical energy, to permit an increase in their capacity without exceeding their design limitations. Thus, there is available from such transformers a potential power output in cold weather in excess of its rated capacity, which increase under such conditions could be used to meet electric heating demands.

In these situations where excessive demands upon transformer installations are potentially existent and directly related to temperature the present invention may incorporate the compensating structure, so designed as to be responsive to temperature changes, that control of the outgoing voltage of the transformer may be accomplished to raise or lower the voltage as a direct result of atmospheric temperature changes and in proportion to the effect of said temperatures upon the capacity of the transformer within its designed limitations.

From the drawings and description preceding it is apparent that the bi-metallic compensator may be made so responsive to temperature conditions that as a result of changes therein the weight may be shifted to require the voltage impressed upon the primary coil to be greater or less in order to cause such repulsion of the movable coil as will actuate the switch contacts controlling the apparatus regulating the voltage output of the transformer. Since load demand represents an ever increasing problem to the power company, the present improved voltage regulating relay offers a means of satisfying certain load demands without an expensive outlay of additional equipment.

Whether for the limited purpose of compensating sufficiently within a range of temperature change to nullify the effect of such changes upon the operating values of the relay or in the broader form such as to compensate to the extent that the relay operating values are varied with changing temperatures, the present invention may provide for the accomplishment of either objective through proper design and selection of materials comprising the bi-metallic compensator. In either case, however, the sensitivity of the relay to variations in the operating voltage which effects the operation of either switch and one with respect to the other, remains the same, and as made adjustable by the abutment members **43** and **50** for the arm **42** and the adjustable carriage for switch **56**.

The invention is not be limited to or by details of construction of the particular embodiment thereof illustrated by the drawings as various other forms of the device will of course be apparent to those skilled in the art without departing from the spirit of the invention or the scope of the claims.

What is claimed is:

1. In a relay for controlling an electric circuit, a pair of coils mounted upon a core and adapted for energization from a source of electrical en-

ergy, one of said coils having a stationary position on the core with respect to the second coil, and said second coil being mounted for oscillating movement as a result of variations in the voltage of the current traversing the stationary coil, supporting means for the movable second coil comprising thin flexible spring members having connection to a support providing an edge fulcrum for flexing the spring members, a pair of electric switches disposed in spaced relation and each switch providing a normally open switch contact, a carrier arm fixed to the movable coil and extending between the electric switches, magnetic means fixed to the carrier arm on respective sides of the same, whereby the switch contacts of the electric switches are actuated by the magnetic means one at a time to cause them to close as the carrier arm is oscillated by movement of the movable coil, a resilient stop element also fixed to the carrier arm in associated relation with each of said magnetic means, and adjustable abutment posts located on respective sides of the carrier arm for engagement with the resilient stop elements to limit oscillating movement of the carrier arm in both directions.

2. In a voltage regulating device for controlling the voltage of an electric circuit, a repulsion type relay including an adjustable coil and a movable coil, said movable coil having movement as a result of voltage variations in the current traversing said adjustable coil, an adjustable member for varying the position of the adjustable coil with respect to the movable coil whereby to vary the spread as regards the variations in the voltage of the current traversing said adjustable coil required to effect actuation of said movable coil, supporting means for the movable coil comprising thin flexible spring members having connection to a support providing an edge fulcrum for flexing the spring members, a pair of electric switches disposed in spaced relation and each switch providing a normally open switch contact, a carrier arm fixed to the movable coil and extending between the electric switches, magnetic means fixed to the carrier arm on respective sides of the same whereby the switch contacts of the electric switches are actuated by the magnetic means one at a time to cause them to close as the carrier arm is oscillated by movement of the movable coil, and adjustable means including a carriage supporting one of said electric switches for movement toward or away from the other electric switch, whereby the amplitude of movement of the carrier arm for effecting actuation of the switch contacts thereof is varied.

3. In a relay for controlling an electric circuit, a pair of coils mounted upon a core and adapted for energization from a source of electrical energy, one of said coils having a stationary position on the core with respect to the second coil, and said second coil being mounted for oscillating movement as a result of variations in the voltage of the current traversing the stationary coil, supporting means for the movable second coil comprising thin flexible spring members having connection to a support providing an edge fulcrum for flexing the spring members, a pair of electric switches disposed in spaced relation and each switch providing a normally open switch contact, a carrier arm fixed to the movable coil and extending between the electric switches, magnetic means fixed to the carrier on the respective sides of the same, whereby the switch contacts of the

electric switches are actuated by the magnetic means one at a time to cause them to close as the carrier arm is oscillated by movement of the movable coil, temperature compensating means for modifying the action of the movable coil to compensate for temperature changes, said compensating means including a biasing weight and a bi-metallic element securing the weight in depending relation to the movable coil, and adjustable means for adjusting the position of the weight with respect to the coil to thereby vary the modifying action of the weight on the coil.

4. In a voltage regulating device for controlling the voltage of an electric circuit, a repulsion type relay including an adjustable coil and a movable coil, said movable coil having movement as a result of voltage variations in the current traversing said adjustable coil, an adjustable member for varying the position of the adjustable coil with respect to the movable coil whereby to vary the spread as regards the variations in the voltage of the current traversing said adjustable coil required to effect actuation of said movable coil, supporting means for the movable coil comprising thin flexible spring members having connection to a support providing an edge fulcrum for flexing the spring members, a pair of electric switches disposed in spaced relation and each switch providing a normally open switch contact, a carrier arm fixed to the movable coil and extending between the electric switches, magnetic means fixed to the carrier arm on respective sides of the same whereby the switch contacts of the electric switches are actuated by the magnetic means one at a time to cause them to close as the carrier arm is oscillated by movement of the movable coil, adjustable means including a carriage supporting one of said electric switches for movement toward or away from the other electric switch, whereby the amplitude of movement of the carrier arm for effecting actuation of the switch contacts thereof is varied, temperature compensating means for modifying the action of the movable coil to compensate for temperature changes, said compensating means including a biasing weight and a bi-metallic element securing the weight in depending relation to the movable coil, and adjustable means for adjusting the position of the weight with respect to the coil to thereby vary the modifying action of the weight on the coil.

5. In a voltage regulating relay for controlling the voltage of an electric current, the combination with an elongated metal core, of a primary coil in encircling relation with said metal core, a movable coil also in encircling relation with the metal core and positioned in associated relation with respect to the primary coil, means supporting the movable coil for limited oscillating movement as a result of voltage variations in the current traversing the primary coil, means for adjusting the position of the primary coil toward and away from the movable coil, a carrier arm fixed to and depending from said movable coil, magnetic means secured to the free end of said arm, an electric switch disposed on each side of the carrier arm and each switch providing a switch contact positioned for actuation by the magnetic means, an adjustable carriage supporting one of said electric switches whereby adjustment of the carriage varies the spaced relation between the electric switches, resilient stop elements fixed to the carrier arm, adjustable abutment posts located on respective sides of the carrier arm and adapted for contact by the resilient stop elements to limit the oscillating movement

of the carrier arm in both directions, and compensating means including a biasing weight and a bi-metallic element securing the weight in depending relation to the movable coil, said compensating means modifying the action of the movable coil to compensate for temperature changes such as effect a change in voltage of the current traversing the primary coil.

6. In a voltage regulating relay for controlling the voltage of an electric current, the combination with an elongated metal core, of a primary coil in encircling relation with said metal core, a movable coil also in encircling relation with the metal core and positioned in associated relation with respect to the primary coil, means supporting the movable coil for limited oscillating movement as a result of voltage variations in the current traversing the primary coil, means for adjusting the position of the primary coil toward and away from the movable coil, a carrier arm fixed to and depending from said movable coil, magnetic means secured to the free end of said arm, an electric switch disposed on each side of the carrier arm and each switch providing a switch contact positioned for actuation by the magnetic means, an adjustable carriage supporting one of said electric switches whereby adjustment of the carriage varies the spaced relation between the electric switches, resilient stop elements fixed to the carrier arm, and adjustable abutment posts located on respective sides of the carrier arm and adapted for contact by the resilient stop elements to limit the oscillating movement of the carrier arm in both directions.

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