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VARIABLE RESISTANCE DEVICE

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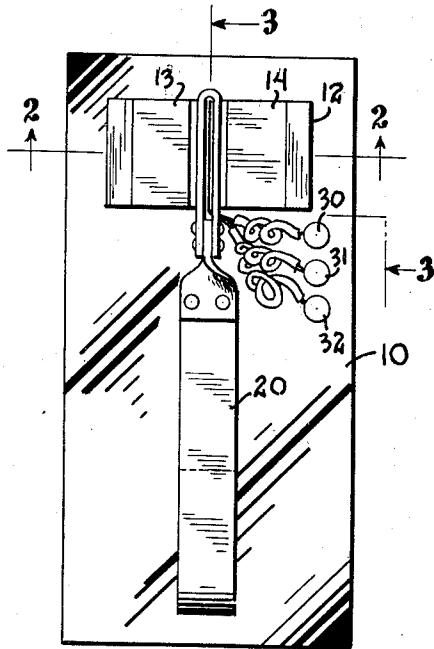


Fig. 1

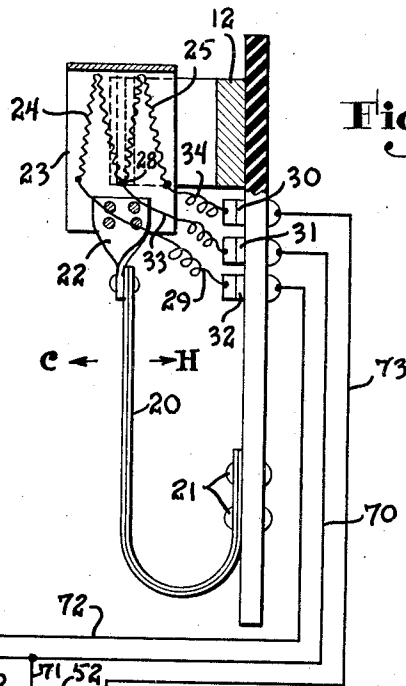


Fig. 3

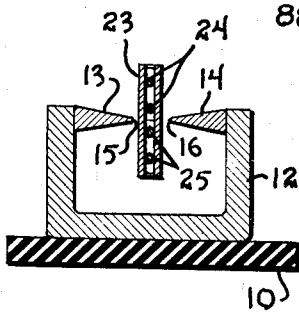
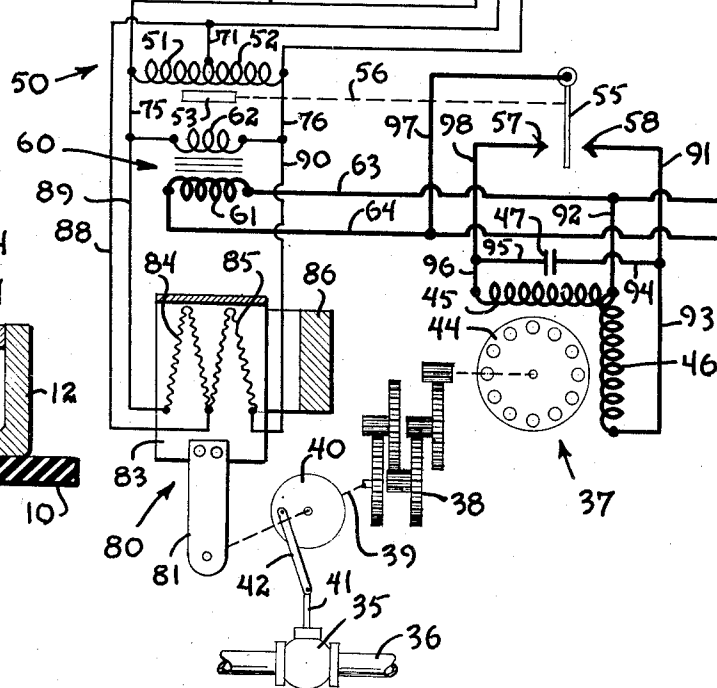


Fig. 2



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VARIABLE RESISTANCE DEVICE

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4 Claims. (Cl. 201—55)

An object of the present invention is to provide a variable resistance device and more particularly one particularly adapted to actuation by a condition control device.

5 In the condition controlling art, it is often necessary to employ variable resistance devices, the values of which are varied in accordance with a controlling condition. Such devices are often used as the control elements of electrical follow-up systems, which in turn control the position of valves or other devices capable of regulating the condition in question. One difficulty which has always been encountered with such arrangements is that, due to the necessarily extreme sensitivity of the condition responsive element, the variable resistance device required an excessive amount of operating power. In other words, in the case of an ordinary type of variable resistance with a contact sliding over the turns of a wire resistance, it was either necessary to sacrifice on the accuracy of the instrument by having too much contact pressure for the condition responsive element to actuate the contact properly, or it was necessary to sacrifice on the reliability of the device by having too little contact pressure to assure a firm contact at all times.

10 An object of the present invention is to provide a condition responsive variable resistance device in which there is no contact between the relatively movable elements of the variable resistance.

15 A further object of the present invention is to provide a variable resistance device employing a resistance element of a material the resistance of which is varied when subjected to a magnetic material, and means for varying the intensity of the magnetic field to which this element is subjected.

20 A further object of the present invention is to provide such an arrangement in which the means for varying the intensity of the field to which the element is subjected is a condition responsive one.

25 A further object of the present invention is to provide an arrangement of the type set forth in the previous objects in which the intensity of the magnetic field to which the element is subjected is affected by movement of the element relative to the magnetic field.

30 A further object is to provide such an arrangement in which two such resistance elements are used and the relative position of these to the magnetic field are varied.

35 Other objects of the invention will be apparent from a consideration of the accompanying specification, claims and drawing, of which

Figure 1 is a front elevational view of the improved variable resistance device;

60 Figure 2 is a sectional view taken along the line 2—2, and

Figure 3 is a schematic view of a control system employing the improved variable resistance device and showing a side elevational view of the device with a portion thereof taken in section along the line 3—3.

5 Referring to the drawing, the device in question is shown as employing an insulating base 10 upon which the various elements are mounted. Secured to the upper portion of this base is a horseshoe magnet 12 which has secured to the forward extremities of the legs thereof pole pieces 13 and 14 of material of high permeability, such as soft iron. These pole pieces are tapered so as to provide very sharp edges 15 and 16 facing each other. Due to the extremely high permeability of the pole pieces 13 and 14 and to the extremely small cross section thereof at the edges 15 and 16, the flux in these points is extremely highly concentrated.

10 Also secured to the base 10 is a bimetallic element 20, which bimetallic element is bent so as to be U-shaped at its lower end and is secured to the base by suitable fastening means 21. At its upper end, bimetallic element 20 has secured thereto a strip 22 of metal which is twisted at an angle of 90°. Secured to the upper end of this strip is a doubled-over strip 23 of sheet copper, which strip serves as a support for two non-inductively wound coils 24 and 25. These coils 24 and 25 are formed of a material whose resistance varies when placed in the magnetic field and varies with the intensity of such field. The material which exhibits this property to the most marked degree is bismuth although nickel and some other metals exhibit the same properties to a somewhat lesser degree. The resistance elements 24 and 25 may be formed in any suitable manner so as to be non-inductive. The non-inductive winding of the resistances is particularly necessary when the apparatus is used with alternating current. When the apparatus is used with direct currents of small magnitude, the windings may be inductive. These coils are so located in the support 23 that in the normal position of bimetallic element 20 they are disposed on substantially opposite sides of a plane passing through the edges 15 and 16 of the pole pieces 13 and 14. This is most clearly shown in Figures 2 and 3. The resistance elements 24 and 25 are connected together at their ends, the junction being indicated by the reference numeral 28. Three terminals 30, 31, and 32 are located on the base 10. The junction 28 is connected through a conductor 33 to terminal 31, the center one of these three terminals, and the outer terminals of coils 24 and 25 are connected to the remaining two terminals 30 and 32 by wires 29 and 34, respectively.

50 While the sizes and spacings of the various elements have been exaggerated in order to more clearly illustrate the invention, the space be- 60

tween the edges 15 and 16 and the supporting element 23 is relatively small in actual practice in order to decrease as much as possible the leakage of the magnetic flux. For the same reason, the support 23 and the resistance elements 24 and 25 have much smaller dimensions so that the entire assemblage consisting of the support and the resistance elements is relatively thin. It is also to be understood that the conductors of the resistance elements 24 and 25 are insulated throughout their length so as to prevent any short circuiting thereof by the copper supporting member 23.

The supporting member 23, as previously indicated, is made of copper or other material of high heat conductivity. The purpose of this is to insure that the heat generated in the bismuth resistance wires be carried away as rapidly as possible. Bismuth has a relatively low melting point, and it is only by reason of the provision of the retainer 23 of a high heat conductivity that the use of the bismuth wire is possible, unless a very low voltage and a low operating current is employed.

As will be observed from Figures 2 and 3, the supporting member 23 is disposed transversely to the plane passing through the edges 15 and 16 of the pole pieces 13 and 14. Any movement of support 23 in a direction transverse to this plane causes one of the coils to be moved further away from the region of greatest magnetic intensity and the other coil towards this region. In this manner, it is possible to vary the relative resistance values of the resistance elements 24 and 25. The bimetallic element 20 is effective for this purpose as a change in the temperature to which the bimetallic element is subjected causes the upper end of the bimetallic element 20 to move in a plane perpendicular to the base and perpendicular to the plane passing through the pole pieces 13 and 14 of the magnet. Consequently, such movement of bimetallic element 20 is effective to cause a shifting in the positions of coils 24 and 25 relative to the plane of greatest magnetic intensity. As will be illustrated in Figure 3, the variation in resistance arising as the result of the shifting of coils 24 and 25 relative to the magnetic field can be used to exert a controlling action upon a regulating device for a condition changing means. In the particular illustration, this regulating device is a valve controlling a steam line.

Referring to Figure 3, a valve is generally designated by the reference numeral 35. This valve is used to control the flow of steam through a pipe 36 leading to a radiator, or other similar heating device. A motor generally indicated by the reference numeral 37 operates the valve. The motor drives, through a reduction gear train 38, a shaft schematically shown in the drawing and indicated by the reference numeral 39. Secured to this shaft is a crank-disc 40 and connecting this crank-disc 40 to the valve stem 41 is a link 42.

The motor 37 comprises a rotor 44 and a pair of field windings 45 and 46. Associated with the motor 37 is a condenser 47. This condenser is adapted to be connected in series with one or the other of the two field windings to displace the phase of the current passing therethrough with respect to that passing through the other. When the condenser is connected in series with one field winding, the motor is caused to rotate in one direction and when connected in se-

ries with the other is caused to rotate in the opposite direction.

A relay generally indicated by the reference numeral 50 is used to control the energization and the method of connection of transformer 47. This relay consists of a pair of oppositely connected relay coils 51 and 52 which are connected together at their mid point. These two relay coils control the position of an armature member 53 which is connected to a switch blade 55 through any suitable connecting means 56. The switch blade 55 is adapted to engage either of two contacts 57 or 58. As will be apparent from the drawing, the position of core 53 and consequently switch blade 55 is determined by the relative energization of coils 51 and 52. When coil 51 is more highly energized than coil 52, the armature 53 is drawn to the left moving switch blade 55 into engagement with contact 57. When relay coil 52 is more highly energized than relay coil 51, the opposite movement of armature 53 takes place and switch blade 55 is moved into engagement with contact 58.

A step-down transformer 60 is provided for the purpose of supplying low voltage power for the operation of the control system. This transformer comprises a line voltage primary 61 and a low voltage secondary 62. The primary 61 is connected to line wires 63 and 64 leading to any suitable source of power (not shown).

The energization of the relay 50 is controlled in part by the improved variable resistance device described previously. The terminal 31, as indicated previously, is connected through conductor 33 through the junction 28 to the two resistances 34 and 35. This terminal is connected through conductors 70 and 71 to the junction of relay coils 51 and 52. The outer terminal of resistance 24 is connected through conductor 29, terminal 32, and conductor 72 to the left-hand end of relay coil 51. Similarly, the outer terminal of resistance 25 is connected through conductor 34, terminal 30, and conductor 73 to the left-hand end of relay coil 52. In view of the fact that the two outer terminals of relay coils 51 and 52 are connected through conductors 75 and 76 to the secondary 62, it will be seen that resistance coils 24 and 25 are connected to the source of power in parallel with relay coils 51 and 52 and act as a voltage divider to control the relative energizations of the two coils. Thus when the coil 24 is shifted so as to lie more in the plane extending between the pole pieces 13 and 14 than resistance element 25 so as to increase the resistance value of resistance element 24 and decrease the value of resistance element 25, the voltage impressed across coil 51 becomes greater than that across coil 52 changing the relative energization of these two coils in like proportions. The effect of this is to cause relay coil 53 to be drawn to the left moving the switch blade 55 into engagement with contact 57. On the other hand, when the resistance element 25 is moved more into the plane extending between the pole pieces 13 and 14 than resistance element 24, relay coil 52 becomes more highly energized than relay coil 51 and causes the armature 53 to move switch blade 55 into engagement with contact 58. As previously indicated, this movement of coils 24 and 25 relative to the magnet 12 is effected by means of bimetallic element 20. The direction of movement of bimetallic element 20 upon a given temperature change can be so selected as to be in either direction. For use in the present system, it is desirable that upon a

temperature fall the support 23 for the resistance elements 24 and 25 will be moved to the left, and that upon a temperature rise be moved to the right.

Also controlling the energization of the relay 50 is a second variable resistance device generally indicated by the reference numeral 80. This device is fundamentally similar to that previously described and shown in Figures 1 and 2 but differs therefrom in that the supporting element for the coils is secured to a member 81, which in turn is secured to the shaft 39 driven by the motor 37. The arm 81 has secured thereto a doubled strip of copper 83 which is similar in function to member 23. In this member 83 is a pair of resistance elements 84 and 85 corresponding to elements 24 and 25. These elements like elements 24 and 25 are non-inductively wound and are made of a material whose resistance varies with the intensity of the magnetic field to which it is subjected. Cooperating with the resistance elements 84 and 85 is a magnet 86, which it is to be understood is identical in construction and in its arrangement relative to the resistance elements 84 and 85 to magnet 12 of the controlling variable resistance device. By reason of member 81 being connected to shaft 39, the position of the supporting member 83 and consequently the position of resistance coils 84 and 85 relative to the poles of magnet 86 is varied as the motor is rotated to position the valve.

The purpose of this second variable resistance device 80 is to effect a rebalance of the energization of relay coils 51 and 52 after the same have been unbalanced by a movement of bimetallic element 20. The junction of resistance elements 84 and 85 is connected through conductors 88 and 71 to the junction of relay coils 51 and 52. Similarly, the outer terminals of resistance elements 84 and 85 are connected through conductors 89 and 75 on the one hand and 90 and 76 on the other hand, to the outer terminals of relay coils 51 and 52. It will be noted that resistance elements 84 and 85 are connected in parallel with resistance elements 24 and 25 to the relay coils 51 and 52. Consequently, the effect of a change in the relative resistance values of resistance elements 84 and 85 is the same as that of a change in the relative resistance values of elements 24 and 25. Thus, any increase in the value of resistance 84 relative to that of resistance element 85 causes an increase in the energization of relay coil 51 and a decrease in the energization of relay coil 52. Upon an opposite change in the relative values of resistances 84 and 85, an opposite change occurs in the relative energization of relay coils 51 and 52. The apparatus is so interconnected that the movement of the motor produced by a given deflection of bimetallic element 20 is always such as to cause an opposite movement of arm 81, and consequently the movement of coils 84 and 85 in a direction opposite to the movement of coils 24 and 25 which initiated operation of the motor. Thus, after a predetermined movement of the motor and the valve operated thereby, the position of coils 84 and 85 will be shifted relative to the magnet 86 sufficiently to rebalance the relay 50 and to deenergize the motor, as will be more clear from the subsequent operation.

Operation of the system

The various elements of Figure 3 are shown in the position which they occupy when the temperature to which bimetallic element 20 is re-

sponsive is approximately at the desired value. Let it be assumed now that the temperature decreases so as to cause the upper end of bimetallic element to move to the left, as viewed from Figure 3. The movement to the left of bimetallic element causes the bismuth resistor 25 to be moved into the plane passing through the edges 15 and 16 of pole pieces 13 and 14, the resistor 24 to be moved farther away from this plane. The result is that resistance 25 will be increased in value and resistance 24 decreased in value. This results, as previously explained, in relay coil 52 becoming more highly energized than relay coil 51, which in turn causes switch blade 55 to engage contact 58. As soon as this takes place, a circuit is established to field winding 46 of motor 37 as follows: from line wire 64 through conductor 97, switch blade 55, contact 58, conductor 91, field winding 46, and conductor 92 to the other line wire 63. At the same time a circuit is established to the other field winding 45 as follows: from line wire 64 through conductor 97, switch blade 55, contact 58, conductors 91 and 94, condenser 47, conductors 95 and 96, field winding 45 and conductor 92 to the other line wire 63. It will be noted that as a result of the circuits just traced, field winding 46 is connected directly across the line wires whereas field winding 45 is connected through the condenser 47. The current through field winding 45 accordingly leads that through field winding 46 and a definitely rotating field is produced which causes rotation of rotor 44. This rotation is in a direction such as to cause clockwise rotation of shaft 39. The clockwise rotation of shaft 39 acts through the crank-disc 40 to move the valve 35 towards open position which results in steam being admitted to the radiators.

At the same time that the shaft 39 moves the valve to open position, such rotation also causes movement of arm 81 and consequently resistor support 83 to the right so as to bring resistor 84 into the plane passing through the pole pieces of magnet 86 and resistor 85 farther away from such plane. As previously pointed out, the effect of this is to tend to increase the energization of relay coil 51 and decrease that of relay coil 52. It will be obvious that after this movement has been carried sufficiently far the effect of such movement upon the energizations of coils 51 and 52 will counterbalance the effect of the movement of resistors 24 and 25 which initially upset the balance of the energization of the relay coils. The variable resistance device 80 accordingly operates to stop further movement of the motor and consequently of the valve after a movement corresponding to the deflection of bimetallic element 20 has taken place.

Let it be assumed now that the further opening of valve 35 caused by the deflection of bimetallic element 20 to the left results in slightly more heat being admitted than is necessary so that the temperature begins to rise. This will cause bimetallic element to be deflected to the right moving resistor 24 nearly into the plane passing through pole pieces and resistor 25 away from such plane. This has, as its result, an increase in the energization of relay coil 51 and a decrease in energization of relay coil 52, as previously explained. The effect of this change in the relative energization of relay coils 51 and 52 is to cause switch blade 55 to be moved into engagement with contact 57. As soon as this takes place, the following circuit is established to field winding 45: from line wire 64 through conductor 97

97, switch blade 55, contact 57, conductors 98 and 96, field winding 45, and conductor 92 to the other line wire 63. At the same time, a circuit is established to the other field winding 46 as follows: from line wire 64 through conductor 97, switch blade 55, contact 57, conductors 98 and 95, condenser 47, conductors 94 and 93, field winding 46, and conductor 92 to the other line wire 63. It will be noted that in the present instance, condenser 47 is connected in series with field winding 46 whereas field winding 45 is directly connected across the line wires. Accordingly, the current through field winding 46 will now lead that through field winding 45 so that the rotor will rotate in a direction opposite to that in which it rotated when switch blade 55 was in engagement with contact 58. The result of this is that shaft 39 will now be rotated in a counter clockwise direction so as to cause valve 35 to be moved towards closed position reducing the supply of steam to the radiators. At the same time, the arm 81 is moved to the left so as to move resistor 85 into the plane passing through the poles of magnet 86 and resistance 84 farther away from such plane. This causes the resistance of element 85 to be increased in value and the resistance of element 84 to be decreased in value. The effect of this is to increase the energization of relay coil 52 relative to relay coil 51. It will be obvious that after this movement has continued sufficiently far, the system will be rebalanced and switch blade 55 will be moved to the position shown in the drawing wherein the motor is deenergized.

It will be noted that by the reason of the use of the improved variable resistance device of the present invention, the system of Figure 3 operates without the use of any sliding contactors whatsoever. This is extremely important inasmuch as the presence of any such contactors introduces either the possibility of a poor contact or inaccuracy due to too heavy contact pressure. The danger of a poor contact where a conventional type potentiometer is used is quite serious in such a system inasmuch as the controller loses control as soon as the contact is electrically separated from the resistance at any point. Furthermore, it is impossible to have any great amount of contact pressure inasmuch as an element such as the bimetallic element 20, if it is to be at all sensitive, is not capable of exerting a very great force.

While I have shown my improved variable resistance device as applied to a control system of the so-called "proportioning" type, it is to be understood that the present invention is not limited to this use of the variable resistance device. Moreover, while I have shown the resistance elements actuated by a bimetallic element, it is to be understood that other condition responsive elements could be employed to actuate the resistance elements. Thus it would be possible, if desired, to employ hair or other humidity responsive devices for controlling the position of the resistance elements. In general while I have shown a specific embodiment of my invention for purposes of illustration, it is to be understood that the invention is limited only by the scope of the appended claims.

I claim as my invention:

1. A variable resistance device consisting of an element the electrical resistance of which is varied when subjected to a magnetic field in accordance with the intensity of said field, a

magnet comprising straight spaced pole pieces of slender form having a common center plane longitudinally of said pole pieces, a support for said element for causing it to extend between said pole pieces and for holding said element in the magnetic field between said pole pieces at an angle of less than forty-five degrees with respect to said center plane, and means for relatively moving said support and said magnet perpendicularly to said center plane.

2. A variable resistance device consisting of a pair of spaced resistance elements of a material the electrical resistance of which is varied when subjected to a magnetic field in accordance with the intensity of said field, a magnet comprising straight spaced pole pieces of slender form having a common center plane longitudinally of said pole pieces, a support for said resistance elements for disposing said elements between the spaced pole pieces of said magnet with said elements normally spaced equal distances on either side of the center plane of the pole pieces of said magnet and disposed at an angle of less than forty-five degrees with respect to said center plane, a condition responsive element associated with said support and adapted upon changes of condition to vary the relative distance of said elements from said center plane by moving said resistance elements at an angle greater than forty-five degrees with respect to said center plane, and means associated with said resistance elements for dissipating the heat generated by current flowing through said elements.

3. A variable resistance device consisting of a pair of spaced resistance elements of a material the electrical resistance of which is varied when subjected to a magnetic field in accordance with the intensity of said field, a magnet comprising straight spaced pole pieces of slender form having a common center plane longitudinally of said pole pieces, a support for said resistance elements for causing them to extend between said pole pieces with said elements normally disposed at substantially the same distance on each side of said center plane and within the magnetic field between said pole pieces, said elements being disposed at an angle of less than forty-five degrees with respect to said center plane, and means for moving said support at an angle greater than forty-five degrees with respect to said center plane to vary the relative distance of said elements from said center plane.

4. A variable resistance device consisting of a pair of spaced resistance elements of a material the electrical resistance of which is varied when subjected to a magnetic field in accordance with the intensity of said field, a magnet comprising straight spaced pole pieces of slender form having a common center plane longitudinally of said pole pieces, a support for said resistance elements for causing them to extend between said pole pieces with said elements normally disposed at substantially the same distance on each side of said center plane and within the magnetic field between said pole pieces, said elements being disposed at an angle of less than forty-five degrees with respect to said center plane, and a bimetallic element associated with said support and adapted upon temperature variation to move the support at an angle greater than forty-five degrees with respect to said center plane to vary the relative distance of said elements from said center plane.

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