April 16, 1935.

D. J. STEWART

1,997,604

AUTOMATIC CONTROL DEVICE

Original Filed May 16, 1930

Fig. 1.

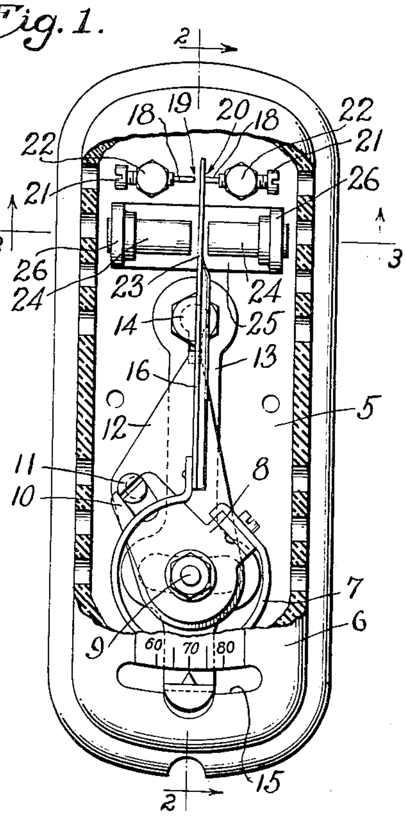


Fig. 2.

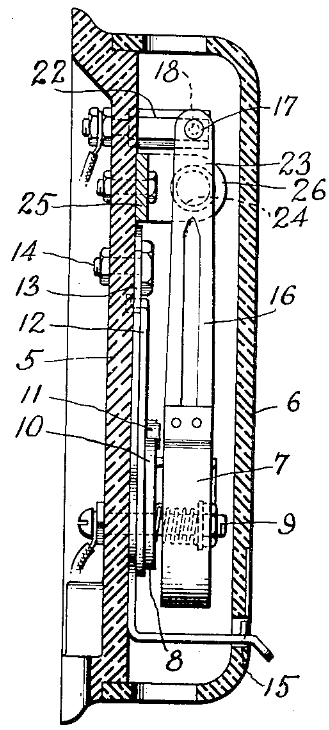


Fig. 3.

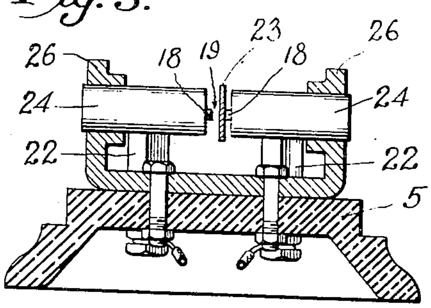
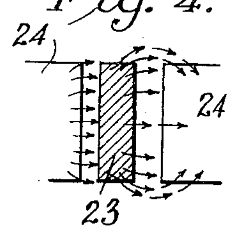


Fig. 4.



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AUTOMATIC CONTROL DEVICE

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9 Claims. (Cl. 200—139)

This invention relates to sensitive automatic control devices such as humidostats and thermostats and has more particular reference to devices for controlling electric circuits.

In devices of the above character, the motion of the sensitive control element resulting from changes in temperature or other conditions of the surrounding air is applied to a control switch through the medium of a member which is made relatively long and of light construction in order to properly augment the motion of the sensitive element and cause the switch to be opened or closed with the required accuracy. In view of this necessarily delicate and flexible mounting, jarring of the supports for the instrument or vibration thereof such as is often encountered in service will produce sufficient movement of the switch actuating member to open and close the switch against the action of the sensitive element and at a rapidly recurring rate. As a result, objectionable and prolonged sparking frequently takes place at the contact points which become burned off and disfigured to such an extent as to impair the sensitivity of the device. Such sparking is also objectionable in that it seriously interferes with the operation of radio receiving sets in the vicinity of the instrument.

The primary object of the present invention is to provide an automatic switch controlling instrument such for example as a thermostat having a magnetic detent associated therewith in a novel manner such as to produce a quick and positive closure of the controlling switch without materially reducing the sensitivity of the instrument as a whole.

The invention also resides in the novel and compact manner in which the magnet is associated with the control instrument.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawing, in which

Figure 1 is a front elevational view of a thermostat embodying the features of the present invention, the cover being broken away to show the working parts.

Figs. 2 and 3 are sectional views taken respectively along the lines 2—2 and 3—3 of Fig. 1.

Fig. 4 is an enlarged fragmentary view of certain of the magnetic parts.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawing and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

In the form shown in the drawing, the invention is embodied for the purpose of illustration in a thermostat, the operating parts of which are housed within a casing formed by a flat elongated base 5 and a removable perforated cover 6 therefor. The sensitive element, which is adapted to respond to temperature changes in the surrounding air, is in the form of a coiled bimetallic strip 7 adjustably supported at the lower end of the base in a manner well known in the art. For this purpose, one end of the strip is secured to a bell-crank 8 pivoted on a stud 9 and having an arm 10 connected through the medium of an eccentric screw 11 to a lever 12 also fulcrumed on the stud 9 and extending upwardly along the base 5. At its upper end, the lever 12 is connected to a lever 13 adjacent the latter's fulcrum which is formed by a stud 14. The lower end of the second lever projects through a slot 15 in the cover 6 and may be swung in one direction or the other to shift the supported end of the strip 7 and thereby change the setting of the thermostat.

Lateral flexure of the free end of the thermostatic strip 7 in response to temperature changes in the surrounding air operates a switch actuating element in the form of an elongated tongue 16 rigidly attached to the free end of the strip. The tongue extends longitudinally of the base 5 and carries at its upper end an electrical contact 17 which cooperates with two adjustable contacts 18 to form control switches 19 and 20. The contacts 18 are arranged in opposed relation on opposite sides of the tongue contact and are carried by adjusting screws 21 threading through studs 22 which constitute binding terminals for the two switches. For thermostats of this character, the contacts 18 are spaced to give the common contact 17 a total range of movement of approximately 0.002 inch. While it is desirable in order to obtain optimum sensitivity to maintain such a small range of movement of the switch arm 17, this range of movement may be increased slightly without danger of increasing the sensitivity of the instrument to an objectionable degree. Such increase, for example, may occur by reason of deterioration or burning off of the contact surfaces in service use. With the parts thus arranged, it will be apparent that one control switch will be opened and the other closed when the temperature rises above or falls below the value predetermined by the combined settings of the screw 11 and the adjusting lever 13.

The present invention contemplates the use, in a control device of the general character above described, of a single permanent magnet having its opposite poles disposed on opposite sides of an armature which moves with the switch actuating member or tongue 16. The armature is formed herein by the upper end portion 23 of the tongue which, for this purpose, is composed of magnetic material and made relatively thin and flat.

In the present instance, the magnet proper comprises two pole pieces 24 arranged in end-to-end relation on opposite sides of the armature with their adjacent end faces disposed parallel to each other and to the coacting armature surfaces. For a purpose which will more fully appear later, the pole faces are spaced somewhat farther apart than the contact points 18, being $\frac{3}{16}$ of an inch in the present instance as compared with the present armature thickness of $\frac{1}{32}$ of an inch. Therefore, as shown in Figs. 1 and 3, the contact points 18 constitute stops for preventing the armature 23 from coming in contact with or approaching very near to the pole faces. The armature is thus confined to a narrow range of movement which, in the present instance, is 0.002 of an inch and occupies the central zone of the gap between the pole faces.

The remote ends of the pole pieces are joined by a magnetic member in the form of a U-shaped yoke 25 composed of soft readily workable magnetic iron and having its flat intermediate portion secured against the base 5 immediately below the contacts 18. The parallel legs 26 of the yoke project forwardly from the base on opposite sides of the armature and are formed with apertures into which the remote ends of the pole pieces are pressed and thereby firmly supported. By employing a separately formed yoke for connecting and supporting the pole pieces 24, the latter may be formed conveniently in the desired cylindrical shape and composed of cobalt steel which will retain a high degree of permanent magnetism but cannot be machined readily or otherwise worked into the shape required in the present instance in order to aline the pole projections in end-to-end relation on opposite sides of the armature.

Subsequent to the assembly of the pieces 24 in the yoke, the magnet thus formed is polarized in a well-known manner whereupon the adjacent ends of the pieces become poles of opposite polarity and constitute sources of permanent magneto-motive forces which cause a magnetic flux to thread the gap between the two pole faces and a highly permeable return path. As shown in Fig. 3, this return path is spaced from the armature 23 when the magnet is mounted as above described and extends through the yoke 25 between the outer end of the pole pieces. Thus the magnetic flux threads the armature in a direction substantially perpendicular thereto as is shown by the arrows in Fig. 4. Since both pieces 24 constitute parts of the same magnetic circuit, they act cumulatively in contributing to the total magneto-motive force regardless of the fact that they may be polarized to different degrees. Because of the low reluctance of the magnetic circuit as a whole, a strong magnetic field is produced with a relatively small magnet.

The armature 23, it will be observed, is flexibly supported by the strip 7 and tongue 16 for broadwise movement longitudinally of the gap in the magnetic circuit and therefore is under the influence of two oppositely acting forces which are due to the respective poles and which vary in magnitude according to the spacing of the armature relative to the poles. Thus, when the armature is displaced to one side of the magnetic center of the gap, the attractive force of the nearer pole predominates and the resultant force firmly maintains the armature in a limiting position spaced from the pole and determined by the associated stationary contact 18. This force decreases as the armature moves to its other limiting position and as the armature passes beyond the magnetic center, the oppositely acting force due to the other pole becomes the predominating force and serves to hold the tongue against the other stationary contact thereby effectually maintaining the other switch closed.

The strip 7 permits or resiliently resists movement of the armature by the resultant of the two attractive forces depending on the existing temperature. Thus, as the temperature change reverses after movement of the tongue against one stop 18, the strip becomes strained, the energy at first stored being insufficient to move the tongue but eventually increasing with the temperature change to a value sufficient to overcome the magnetic force tending to hold the switch closed. When the attractive force is finally overcome, the tongue moves quickly and with a snap action to its opposite limiting position.

As a result of this snap action, the opening and closure of both control switches is made to occur positively and accurately and with a slight blow at the contact points which are thereby cleared of any detrimental particles of foreign material. The contacts of the closed switch are always drawn together firmly under sufficient pressure, due to the predominating magnetic influence, to prevent their separation as an incident to jarring or other vibration of the thermostat. Moreover, when the switch opening movement of the tongue has been initiated by the building up of the required amount of energy in the resilient strip 7, completion of the switch opening is completed rapidly and reclosure of the switch cannot take place. Sparking at the contact points and the consequent deterioration thereof are effectually minimized.

From the foregoing considerations it will be apparent that the present thermostat is well adapted for the control of oil burners and the like where only one switch is required and this must be operated to start the burner at a temperature slightly lower than that at which it is operated to stop the burner. With the present thermostat this differential temperature range may be varied as desired by changing the strength of the magnet or the position of the tongue stops.

The desirable snap action in the movement of the thermostatic tongue between its limiting positions as above described is obtained with the present magnetic structure by taking advantage of the fact that the two opposing magnetic forces acting on the tongue armature change at a more rapid rate due to movement of the armature than does the tension on the thermostatic strip. Thus, according to a well known law, the attractive force exerted on the armature by each pole is equal to

$$\int^{a} (B \cos x)^2 da,$$

where B is the flux density over each incremental area da of the armature surface threaded by the magnetic field and x is the angle at which the flux lines enter or leave the armature. In one limiting position of the armature, as shown in Fig. 4, the lines of force thread the narrower gap between the armature and the nearer pole substantially at right angles to the armature surface as indicated by the arrows. In this case, the average value of cosine x for determining the attractive force due to the nearer pole is greater than for the farther pole and the average value of the flux density B is also greater for the nearer pole.

The other pole is spaced substantially farther from the armature which allows the magnetic lines greater opportunity to spread out and take longer paths rather than to create high flux densities in the short path directly between the pole and armature. Such spreading action is illustrated on an exaggerated scale in Fig. 4 and causes the average value of the flux density B to be diminished with displacement of the armature away from the pole. Since this quantity is squared in the above equation, it will be apparent that a relatively large change in the attractive force exerted by either pole will result from a slight displacement of the armature. The decrease in the average value of cosine x as the armature moves away from the pole causes a further decrease in the attractive force. Moreover, the force due to one pole decreases as the other increases, thereby further multiplying the change in the resultant magnetic force for a given displacement of the armature. On the other hand, the change in the tension of the thermostatic strip is more nearly proportional to the displacement of the armature. From this it follows that whenever enough energy has been stored in the strip 7, due to temperature changes, to initiate movement of the tongue 16 away from its engaged contact, the movement will continue and the tongue will be carried throughout its entire range of movement into engagement with the other contact.

By providing two magnetic poles on opposite sides of the armature, a strong magnet and therefore a rapid change in the magnetic force for a small armature displacement may be provided for without placing the thermostatic strip under such strain as to impair the sensitivity and accuracy of the thermostat. Thus it will be apparent that the oppositely acting forces due to the magnet, tend to neutralize each other with the result that the thermostatic strip is not under any stress due to the presence of the magnet when the armature is on the magnet center. This condition substantially prevails through the narrow range of movement of the armature with the result that the stresses set up in the strip are due practically entirely to temperature changes.

The desirable snap action above described within the extremely narrow range of the tongue movement provided for and effective equalization of such action for both directions of movement of the tongue is rendered possible, in the present instance, by constituting the opposite magnetic poles parts of the same magnetic circuit. Since the flux threading each pole is derived from the same source of permanent magnetism, that is, the pieces 24, the poles may be made of equal strength simply by constructing the pole faces of equal area. With the poles of equal strength, the magnetic center of the gap between them coincides with the space center of the gap which greatly facilitates setting of the thermostat so that the opposing pole actions will be substantially balanced. Such setting may be effected simply and conveniently by locating the magnet armature on the space center of the gap when the armature is disposed on the space center between the two limit stops formed by the contact points 18.

The initial or factory adjustment of the thermostat is effected as follows: First the tongue armature is located exactly midway between the pole faces by inserting plates of equal thickness in the two air gaps between the armature and the poles. Then the limit stops for the armature are set by turning the screws 21 so that the contact end of each is accurately spaced 0.001 inch from the opposing surface of the tongue contact. A 0.002 inch range of movement is thereby established for the armature and this range is located centrally of the gap between the poles. After removal of the gage plates, the screw 11 is adjusted so that the tongue will respond to the prevailing temperature when the adjusting lever is set for such temperature.

The magnet constructed as above described, renders the factory adjustment of the thermostat simple and reliable and forms an exceedingly compact structure which can be mounted within the ordinary thermostat casing without enlargement thereon.

With the magnet constructed and the limit stops 18 and the pole faces spaced relative to the armature in the manner above described, the desired snap or detent action is obtained without materially reducing the sensitivity of the instrument. This result is obtained by the novel arrangement of the magnet, the limit stops 18, the contact arm and the magnet armature whereby the attractive forces acting on the armature are relatively weak but the rate of change of these forces by displacement of the armature is so great as to produce the desired detent action, even though the range of movement of the armature is very narrow. The use of a strong magnet producing relatively weak attractive forces which change in magnitude at a rapid rate during displacement of the armature is made possible by locating the magnet poles on opposite sides of the armature and spaced a substantially greater distance from the armature than the total range of movement of the latter. This rate of change of the attractive forces is increased to a maximum by positioning the limit stops and pole faces relative to the armature so that when the latter is disposed on the magnetic center of the gap between the poles, the contact arm will be disposed midway between the limit stops.

I claim as my invention:

1. In an automatic control device, the combination of a base plate, an elongated laterally movable switch actuating element movably mounted on said base plate and extending parallel thereto, said element having a magnetic armature movable therewith, a permanent magnet secured to said base plate and comprising a bar extending transversely of said element between the element and said base plate, legs projecting from opposite ends of said bar substantially perpendicular to said base plate and disposed on opposite sides of said armature and alined arms projecting toward each other from the projecting ends of said legs and defining pole faces on opposite sides of the armature.

2. In an automatic control device, the combination of a base plate, an elongated substantially straight tongue of magnetic iron constituting an armature, means associated with one end of said tongue and supporting the same on said base plate in parallel relation thereto, a stationary contact cooperating with the opposite end of said tongue to form a switch, and a permanent magnet comprising a bar supported from said base and extending transversely of said tongue adjacent said contact, legs projecting from opposite

ends of the bar substantially perpendicular to said base plate, and arms extending at right angles to the projecting ends of said legs and defining poles having faces disposed on opposite sides of said tongue.

3. In an automatic control device such as a thermostat, the combination of a base, an elongated laterally movable switch-actuating element extending along the base and providing a flat magnetic armature adjacent its free end, a pair of stops disposed on opposite sides of said element adjacent said free end and acting to limit the movement of the end in opposite directions, a pair of longitudinally alined magnetic poles adjacent said stops providing two opposed parallel faces of equal area disposed on opposite sides of said armature and spaced apart a distance greater than said stops, a member of magnetic material connecting said poles at points spaced from said faces and extending crosswise of said element adjacent said stops, the magnet formed by said poles and said member being supported by said base.

4. In an automatic electric control device of the general character described, the combination of a substantially rigid arm supported from one end for lateral movement of the opposite end, a sensitive control element responsive to changes in the condition of the surrounding air and arranged to actuate said arm, a pair of closely spaced stationary stops engageable with said arm to limit the movement of the arm in opposite directions, said arm having rigid therewith a contact engageable directly with one of said stops to form an electric control switch and also a magnet armature with oppositely facing surfaces, and a permanent magnet having poles disposed on opposite sides of said armature with end faces opposing said armature surfaces and each spaced from the adjacent armature surface a distance substantially greater than the range of movement of the arm whereby said pole faces will be spaced substantial distances from said armature surfaces in the limit positions of said arms.

5. In the automatic electric control device of the general character described, the combination of a substantially rigid arm supported for lateral movement of one of its ends, a sensitive control element arranged to actuate said arm, a pair of stationary stops engageable with said arm to limit the movement of the arm in opposite directions to a range of a few thousandths of an inch, said arm having a contact thereon engageable directly with one of said stops to form an electric control switch and having rigid therewith a magnet armature with oppositely facing magnetic surfaces, and a permanent magnet having poles disposed on opposite sides of said armature with end faces each spaced from the opposed armature surface a distance at least ten times as great as the spacing of the corresponding stop and said arm in either limit position of the arm.

6. An automatic control device having, in combination, an arm, means responsive to changes in the condition of the surrounding air for moving the arm laterally back and forth, a pair of closely spaced stationary stops engageable with said arm and acting to limit the movement thereof in opposite directions to a narrow range, one of said stops cooperating with a contact rigid with said arm to form an electric switch, and said arm having thereon a magnet armature with oppositely facing surfaces adjacent said stops, and a permanent magnet having poles disposed on opposite sides of said armature and having substantially parallel end faces each spaced from said armature a distance substantially greater than the range of movement of said arm, said stops and pole faces being so spaced relative to each other that said armature will be disposed on the magnetic center of the gap between the pole faces when said arm is disposed equidistant from said stops.

7. An automatic control device having, in combination, an arm, means responsive to changes in the condition of the surrounding air for moving the arm laterally back and forth, a pair of closely spaced stationary stops disposed on opposite sides of said arm and acting to limit the movement thereof in opposite directions to a narrow range, one of said stops cooperating with a contact rigid with said arm to form an electric switch, and said arm having thereon a magnet armature with oppositely facing surfaces adjacent said stops, and a permanent magnet having poles disposed on opposite sides of said armature and having substantially parallel end faces each spaced from said armature a distance substantially greater than the range of movement of said arm, said pole faces being of equal areas so that the space center between the faces coincides with the magnetic center of the magnet, and said stops and pole faces being so spaced relative to each other that said armature will be disposed exactly midway between the pole faces when said arm is equidistant from said stops.

8. In an automatic control device of the general character described, the combination of a member mounted for movement in opposite directions, a sensitive control element arranged to move said member back and forth in response to changes in the condition of the surrounding air, stop means operating to limit the range of movement of the member in opposite directions to a few thousandths of an inch, said member carrying means coacting with said stop means to form a control device and also carrying a magnet armature with oppositely facing surfaces, and a permanent magnet having poles disposed on opposite sides of said armature with end faces opposing said armature faces and each spaced from the adjacent armature face in the limit positions of said member a distance several times as great as the range of movement of the member.

9. An automatic control device having, in combination, a member mounted for movement back and forth, actuating means for said member adapted to apply a relatively small actuating force to said member for moving the same in one direction or the other, stop means operating to limit the movement of said member in opposite directions within a range of a few thousandths of an inch, said member carrying means coacting with said stop means to form a control device and also carrying a magnet armature with oppositely facing surfaces, and a permanent magnet having poles disposed on opposite sides of said armature and having substantially parallel end faces spaced from said armature a distance such that the total nonmagnetic gap between the armature surfaces and said pole faces is at least several times as great as the total range of movement of said member.

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