

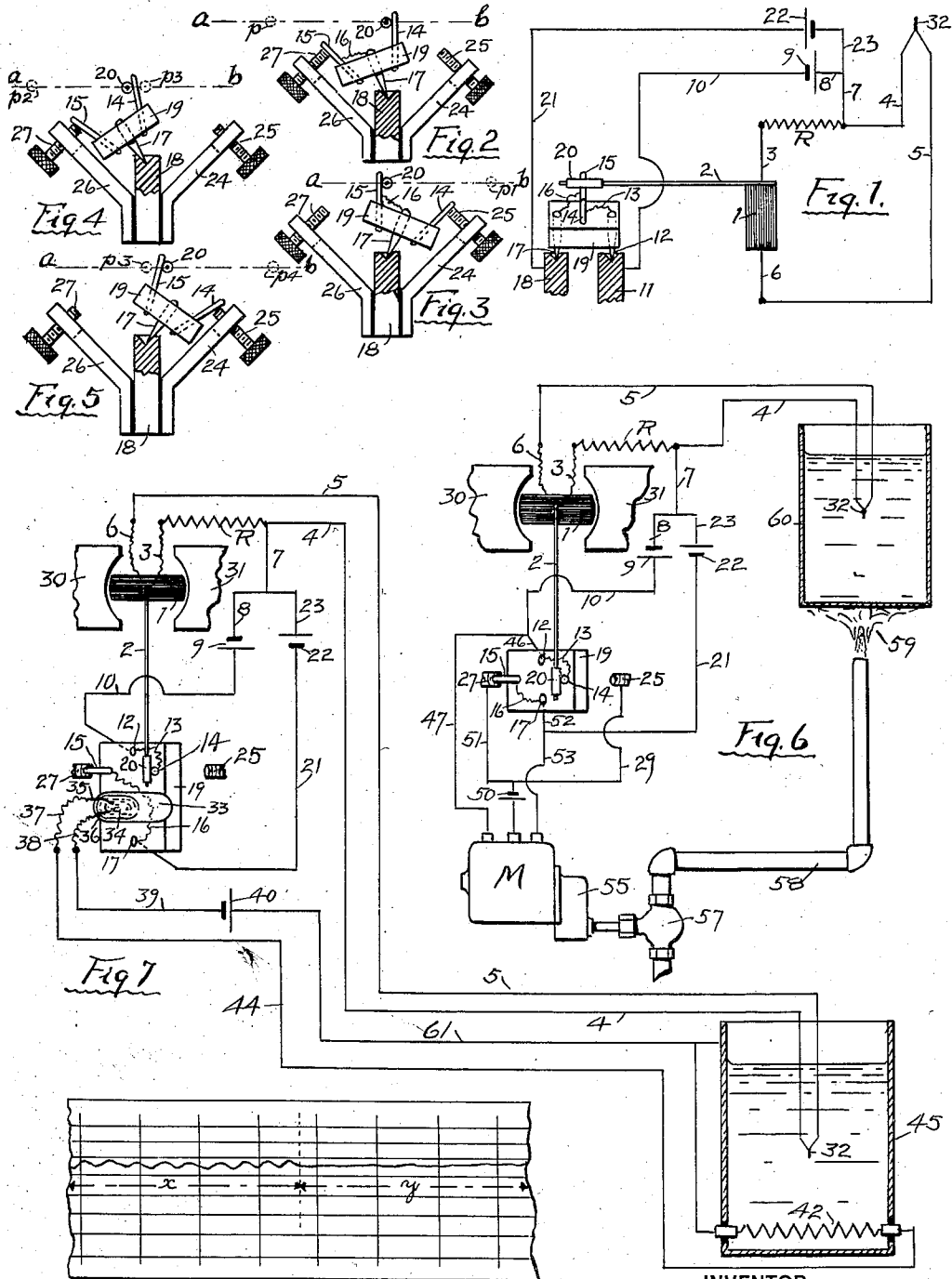
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TEMPERATURE CONTROL APPARATUS

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TEMPERATURE CONTROL APPARATUS

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This invention relates to means, controlled by a thermocouple, for automatically maintaining a constant temperature for the medium in which one of the junctions of the couple is located. One of the features of the invention is a novel utilization of the indicating needle of a galvanometer to close and to open circuits as required to maintain the desired temperature. Furthermore, in order to close said circuits, the needle of the galvanometer, which is actuated by the thermocouple, makes electrical contact with movable contact pieces all in the manner as hereinafter described.

Figure 1 is a diagrammatic view of some of the more important elements of the invention, and shows the coil of the galvanometer, its indicating needle, and the movable contact pieces in elevation.

Figures 2, 3, 4 and 5 show the movable contact pieces in different positions with respect to the indicating needle of the galvanometer.

Figure 6 is also a diagrammatic view of the invention with more of the elements shown, and includes a plan view of the galvanometer coil, the indicating needle, and the movable contact pieces as illustrated in elevation by Figure 1.

Figure 7 illustrates diagrammatically another application of the invention.

Figure 8 illustrates a graphical record of the controlled temperature, part of which was made with one setting of the movable contact pieces, and part of which was made with another setting of the movable contact pieces.

Similar numerals represent similar parts throughout all of the illustrations.

A thermo-junction 32, Figure 1, forms part of an electric circuit which includes a resistance R and the coil 1 of the galvanometer, said coil being rotatably mounted between the north and south poles 30 and 31 of a permanent magnet as diagrammatically shown in Figure 6. The coil 1 may be pivoted in the customary manner, not shown. A needle 2 which is fastened to the coil is electrically connected with the wire 3, and will obviously be deflected in one direction or the other depending upon changes in the electromotive force of the junction 32. In order to insure a good contact surface, the needle 2 is forced through a small silver tube 20, as illustrated, and is electrically connected therewith. Two contact pieces 14 and 15, Figures 1, 3 and 6, are insulated from each other and fastened to a block 19. The block 19 is tiltably mounted on two uprights 11 and 18 (Figure 1) by means of two pins 12 and 17 which are insulated from each

other and fastened to the block 19. The pivoted ends of the pins rest respectively in conical sockets at the top of the uprights 11 and 18 and form a fulcrum about which the block 19 with its contact pieces 14 and 15 may be tilted in the manner to be presently described.

Figures 2 and 3 represent views of the tiltable block 19 when looking at the extreme end of the needle 2 along a line which coincides with the axis of the needle. The plane in which the needle 2 may be deflected is illustrated by the line a—b. The center of gravity of the block 19 with its contact pieces 14 and 15 is above the fulcrum previously referred to, so that when the block with its contact pieces is pushed toward the left, Figure 2, the contact piece 15 will rest against an adjustable screw 27 which is fastened to a fixed bracket 26 as illustrated. Similarly when the block 19 is tilted to the right, Figure 3, the contact piece 14 will rest against an adjustable screw 25 which is fastened to a fixed bracket 24, as illustrated. The brackets 26 and 24 are insulated from each other. Contact between the screw 27 and the contact piece 15, Figure 2, closes a circuit, Figure 6, which includes the screw 27, wire 51, a battery 50, a motor M, wires 53 and 52, the pin 17, wire 16, and the contact piece 15. The motor M is connected with a valve 57 through a reduction gear 55 and is so wound that when the circuit through the motor which includes the screw 27 and the contact piece 15 is closed, the motor will operate to close the valve. Similarly, contact between the screw 25 and the contact piece 14, Figure 3, closes a circuit, Figure 6, which includes the screw 25, wire 29, the battery 50, the motor M, wires 47 and 46, the pin 12, wire 13, and the contact piece 14. The circuit which is thus closed when the contact piece 14 rests against the screw 25, Figure 3, will operate the motor M, Figure 6, to open the valve 57. The purpose of the valve 57 is to throttle the flow of gas through a pipe 58, thereby decreasing or increasing the intensity of a flame 59 depending upon whether the contact piece 15 touches the screw 27 or whether the contact piece 14 touches the screw 25. A vessel 60 which contains a liquid is placed over the flame 59, as illustrated, while the position of the needle 2 of the galvanometer and its contact surface 20 is determined by the temperature of the junction 32 which is located in the liquid.

Let us assume that the temperature of the liquid in the vessel 60 is to be maintained at 200 degrees F. and that the galvanometer is so adjusted to permit a deflection of the needle 2 and

its contact surface 20 to the position illustrated in Figures 6 and 2 when the temperature of the liquid is slightly below 200 degrees. In this position the contact surface 20 will just touch the contact piece 14, thereby closing the circuit, Figure 6, which includes the contact surface 20, the needle 2, the wire 3, the resistance R, wires 7 and 8, a battery 9, wires 10 and 46, the pin 12, wire 13, and contact piece 14. The contact thus established between the contact piece 14 and the contact surface 20 will obviously be very delicate. Regardless, however, of the minuteness of the pressure with which the contact surface 20 rests against the contact piece 14, some current will flow through the circuit which includes the battery 9 and the resistance R. The battery 9 is of the proper polarity to cause a drop in potential across the resistance R in the right direction to cause a current to flow through the wire 3, the coil 1, wires 6 and 5, the junction 32, and wire 4, to cause a deflection of the needle in a counter-clockwise direction. This tendency of the needle to deflect in a counter-clockwise direction will cause a greater pressure between the contact surface 20 and the contact piece 14, thereby decreasing the contact resistance and increasing the current from the battery 9 through the resistance R. This increased flow through the resistance R will obviously still further increase the drop in potential across the resistance, thereby similarly increasing the current through the coil 1 and forcing the contact surface 20 still tighter against the contact piece 14. This will again decrease the contact resistance between 20 and 14 thereby still further increasing the drop across the resistance R and causing still more current to flow through the coil 1 which in turn causes a still greater pressure against the contact piece 14. This pressure of the needle against the contact piece 14 will thus continue to build up almost instantaneously until there is enough power to push the block 19 with its contact pieces 14 and 15, Figure 2, to the position illustrated in Figure 3. The inertia of the needle as acquired while pushing the block to its new position will cause the needle to move to some position $p-1$, Figure 3. It will, however, promptly return to the position determined by the electro-motive force of the thermo-junction 32 as soon as this inertia has been dissipated.

Similarly let us assume that the temperature of the liquid in the vessel 60 is slightly above 200 degrees F. in which case the needle with its contact surface 20 will have returned to the position illustrated in Figure 3. In this position the contact surface 20 will just touch the contact piece 15, thereby closing the circuit, Figure 6, which includes the needle 2, the wire 3, the resistance R, wires 7 and 23, a battery 22, wires 21 and 52, the pin 17, wire 16, contact piece 15 and the contact surface 20, Figure 3. The contact thus established between the contact piece 15 and the contact surface 20 will obviously be very delicate. Regardless, however, of the minuteness of the pressure with which the contact surface 20 rests against the contact piece 15, some current will flow through the circuit which includes the battery 22, and the resistance R. The battery 22 is of the proper polarity (opposite to that of battery 9) to cause a drop in potential across the resistance R in the right direction to cause a current to flow through the wire 3, the coil 1, wires 6 and 5, the junction 32 and wire 4, to cause a deflection of the needle in a clockwise direction. This tendency of the needle to de-

flect in a clockwise direction will cause a greater pressure between the contact surface 20 and the contact piece 15, Figure 3, thereby decreasing the contact resistance and increasing the current from the battery 22 through the resistance R. This increased flow through the resistance will obviously still further increase the drop in potential across the resistance, thereby similarly increasing the current through the coil, and forcing the contact surface 20 still tighter against the contact piece 15. This will again decrease the contact resistance between 20 and 15, thereby still further increasing the drop across the resistance R and causing still more current to flow through the coil 1 which in turn causes still greater pressure against the contact piece 15. This pressure of the needle against the contact piece 15 will thus continue to build up almost instantaneously until there is enough power to push the block 19 with its contact pieces 14 and 15, Figure 3, to the position illustrated in Figure 2. The inertia of the needle as acquired while pushing the block to its new position will cause the needle to move to some position p , Figure 2. It will, however, promptly return to the position determined by the electro-motive force of the thermo-junction 32 as soon as this inertia has been dissipated.

It thus follows that as soon as the temperature of the junction is slightly above 200 degrees the block with its contact pieces 14 and 15 will be forced from the position illustrated in Figure 3 to the position illustrated in Figure 2. In the latter position, as previously stated, the electric circuit through the screw 27 will be closed to actuate the motor M to reduce the intensity of the flame 59. This will obviously cause a reduction in the temperature of the junction 32 and when this temperature has reached a point slightly below 200 degrees F. the block with its contact pieces 14 and 15 will be forced from the position illustrated in Figure 2 to the position illustrated in Figure 3. In the latter position, as previously stated, the electric circuit through the screw 25 will be closed to actuate the motor M to increase the intensity of the flame 59. This will obviously increase the temperature of the junction 32 and when this temperature has reached a point slightly above 200 degrees F. the block with its contact pieces 14 and 15 will again be forced from the position illustrated in Figure 3 to the position illustrated in Figure 2 to again actuate the motor M to reduce the flame intensity. In other words, in the manner above described, the block 19 with its contact pieces 14 and 15 will be forced to the position illustrated in Figure 2 or to the position illustrated in Figure 3 depending upon whether the temperature of the liquid in the vessel 60 is above or below 200 degrees, or above or below any other temperature for which the galvanometer has been adjusted.

In practically all types of heaters there is an inherent lag between the change of heat input and the resulting change in temperature of the medium heated. It is for this reason that when the heat input is increased to a point where the temperature is slightly below the desired temperature, and decreased to a point where the temperature is slightly above the desired temperature, a record of the controlled temperature would take the form illustrated by that part of the graph over the distance x in Figure 8. In other words the wavy record is caused by the lag in the heater which permits too long a period of high flame intensity and too long a period of

low flame intensity before the required change in temperature is affected. To eliminate this difficulty and to permit the maintenance of a more even temperature, I have made the screws 25 and 27 adjustable. In Figures 4 and 5, for example, the screws have been turned down further to permit the block 19 with its contact pieces 14 and 15 to tilt in either direction to a greater angle than illustrated in Figures 2 and 3. The position $p-3$ of the needle of the galvanometer, Figures 4 and 5, is the position it would assume when the temperature of the junction 32 is 200 degrees, namely the temperature at which the liquid in the vessel 60 is to be maintained, and for which the galvanometer has been adjusted. Let us assume that the temperature is considerably below 200 degrees, in which case the contact surface 20 of the indicating needle, Figure 5, would be at the right of the contact piece 15. As soon as the temperature has risen sufficiently to cause a slight contact between the contact surface 20 and the contact piece 15, the block 19 with its contact pieces 14 and 15 will, in the manner already stated, be forced to a new position illustrated in Figure 4. It will be noted, however, that by virtue of the position of the contact piece 15, Figure 5, which is further to the right than that illustrated in Figure 3, the block will be forced to its new position considerably before the junction 32 has reached the temperature corresponding to the position $p-3$ of the needle. The inertia which the needle gained in forcing the block to the new position, Figure 4, will cause it to deflect to some position $p-2$. It will, however, promptly return to the position determined by the electro-motive force of the thermo-junction 32, as soon as this inertia has been dissipated. As soon as the temperature has dropped sufficiently to cause a slight contact between the contact surface 20 and the contact piece 14, Figure 4, the block 19 with its contact pieces 14 and 15 will, in the manner already stated, be forced back to its former position illustrated in Figure 3. It will be noted, however, that by virtue of the position of the contact piece 14, Figure 4, which is further to the left than that illustrated in Figure 2, the block will be forced to its previous position, Figure 5, considerably before the junction 32 has reached the temperature corresponding to the position $p-3$, Figure 4, of the needle. In other words, when the screws 25 and 27 are set as illustrated in Figures 2 and 3, the block 19 with its contact pieces 14 and 15, Figure 2, will be forced to the right only when the temperature of the junction 32 is slightly less than 200 degrees, and the block, Figure 3, will be forced to the left only when the temperature of the junction 32 has slightly exceeded 200 degrees. On the other hand with the adjustment of the screws 25 and 27 as illustrated in Figures 4 and 5, the block with its contact pieces 14 and 15, Figure 4, will be forced to the right when the temperature of the junction 32 is considerably above the 200 degrees, and will be forced to the left, Figure 5, when the junction is at a temperature considerably less than 200 degrees. It must be kept in mind that the temperature of 200 degrees for which the galvanometer is adjusted, Figures 4 and 5, is represented by the position $p-3$ of the indicating needle. With the adjustment of the screws 25 and 27 as illustrated in Figures 4 and 5, it is obvious that the flame intensity will be increased before the temperature of the thermo-junction actually drops to the temperature for

which the galvanometer is adjusted, and the intensity of the flame will be decreased before the actual temperature of the junction reaches the temperature for which the galvanometer is adjusted. It is the proper adjustment of these screws, for the particular characteristics of the heater, which will cause a more even temperature as illustrated by the distance y of the graph in Figure 8.

It is obvious that, in order to produce a practically straight line record, it may be necessary to adjust the screws 25 and 27 to entirely different positions for different types of heaters, depending upon the relation between the heating characteristics of the heater and the cooling characteristics of the heater. As a matter of fact in order to maintain a very even temperature it may be necessary in some cases to adjust the screw 27 as illustrated in Figure 2, while the screw 25 is adjusted as illustrated in Figure 5. Again in another case it may be necessary to adjust the screw 27 to the position illustrated in Figure 4, while the screw 25 is adjusted to the position illustrated in Figure 3. The adjustment of the screw 25 determines a temperature at which the intensity of the flame is reduced before the actual temperature of the junction, for which the galvanometer has been adjusted, has been reached. Similarly the adjustment of the screw 27 determines a temperature at which the intensity of the flame is increased before the actual temperature of the junction, for which the galvanometer has been adjusted, has been reached. Increase in the flame intensity or a lowering of the flame intensity can thus be anticipated or delayed depending upon the position of the screws 27 and 25 which may be adjusted to suit the characteristics of the heater involved so that a record of the control temperature will be practically a straight line.

Another form of the invention is illustrated in Figure 7, whereby the temperature of a medium contained in a vessel 45 is maintained constant by means of an electric heater 42, the current through which heater is furnished by a battery 40 and is turned off or on by a mercury switch 33 fastened to the tiltable block 19. In this case the screws 25 and 27 determine the degree of anticipation the same as illustrated in Figures 4 and 5 but they are not included in any other circuits as illustrated in Figure 6. When the temperature of the medium in vessel 45 is above the control point, the block 19 with the mercury switch 33 will be tilted to the right, in the manner already stated, thereby breaking the circuit through the heater 42, and when the temperature in the vessel 45 is below the predetermined temperature, the block 19 including the mercury switch 33 will, in the manner already stated, be tilted to the left, thereby closing the circuit through the switch to reenergize the heater.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a device of the class described, the combination with a galvanometer having an indicating needle, said indicating needle moving in a horizontal plane, of tiltable block located below the path of the needle, a bearing for the block, a second bearing for the block insulated from the first bearing, an extension from the block electrically connected with the first bearing, which extension extends above the path of the needle and against which the needle normally rests when the block is in one of its tilted posi-

tions, a stop against which the extension rests when the block is in the second of its tilted positions as determined by the stop, a second extension from the block electrically connected with the second bearing, which second extension extends above the plane of the needle and against which the needle normally rests when the block is in said second tilted position, a second stop against which the second extension rests when the block is in its first tilted position as determined by the second stop, an electric circuit which is closed by contact between the needle and the first extension, said circuit including the first bearing, a second circuit which is closed by contact between the needle and the second extension said circuit including the second bearing, a third circuit which includes the galvanometer and a source of electrical energy for deflecting the needle against one or the other of said extensions, an independent source of electrical energy in the first circuit said source having a given polarity, a second independent source of electrical energy of opposite polarity in the second circuit, a common resistance included in the first, second and third circuits, the drop across which resistance (when the first circuit is closed) energizes the galvanometer to force the needle against the first extension to tilt the tiltable block in one direction, and the drop across which resistance (when the second circuit is closed) energizes the galvanometer to force the needle against the second extension to tilt the tiltable block in the opposite direction, and a switch mechanism actuated by the tiltable block.

2. In a device of the class described, the combination with a galvanometer, of a resistance, a circuit which includes the galvanometer and the resistance in parallel, a second circuit which includes the galvanometer and the resistance in parallel, a battery in the first circuit with the proper polarity to deflect the galvanometer in a clockwise direction, a battery in the second circuit with the proper polarity to deflect the galvanometer in the opposite direction, a needle actuated by the galvanometer, a tiltable element, a contact piece extending from the tiltable element against which contact piece the needle may deflect in a clockwise direction to close the first circuit thus energizing the galvanometer to force the needle with sufficient power to tilt the tiltable element in said direction, a second contact piece extending from the tiltable element against which second contact piece the needle may deflect in a counter-clockwise direction to close the second circuit thus energizing the galvanometer to force the needle with sufficient power to tilt the tiltable element in said direction, and a thermo-couple for energizing the galvanometer to deflect the needle against one or the other of said contact pieces, said couple being in parallel with the resistance and in series with the galvanometer in both the first and second circuits.

3. In a device of the class described, the combination with a galvanometer having the usual pivoted coil and indicating needle, said needle being deflectable by means of a source of electrical energy included in a circuit with the coil, of a tiltable block, a contact piece fastened to the block, said contact piece being in the path of the needle when the block is tilted clockwise and out of the path of the needle when the block is tilted counter-clockwise, a second contact piece fastened to the block said second contact piece being in the path of the needle when the block is tilted counter-clockwise and out of the path of

the needle when tilted clockwise, a second circuit which includes the coil and which is closed by contact between the needle and the first contact piece when the needle is deflected in a given direction against said contact piece by the current flowing through the coil from said source of electrical energy, a second source of electrical energy in the second circuit which, when said second circuit is thus closed, energizes the coil in the proper direction to force the needle against the first contact piece with sufficient power to tilt the block counter-clockwise, a third circuit which includes the coil and which is closed by contact between the needle and the second contact piece when the needle is deflected in the opposite direction against said contact piece by the current flowing through the coil from the first source of electrical energy, a third source of electrical energy in the third circuit which, when said third circuit is thus closed, energizes the coil in the proper direction to force the needle against the second contact piece with sufficient power to tilt the block clockwise.

4. The means set forth in claim 3 with the addition of a switching mechanism actuated by the tiltable block.

5. In a device of the class described, the combination with a galvanometer having a movable coil, of a resistance, a circuit which includes the coil and the resistance, a movable contact piece, a second movable contact piece, a needle fastened to the coil for moving the movable contact pieces, an independent source of electrical energy in said circuit for energizing the coil to deflect the needle against one or the other of said contact pieces, a second circuit which is closed by contact between the needle and the first movable contact piece, said second circuit including the resistance, the drop across which resistance, when the second circuit is closed, energizes the coil to move the first movable contact piece, and a third circuit which is closed by contact between the needle and the second movable contact piece, said third circuit including the resistance, the drop across which resistance, when the third circuit is closed, energizes the coil to move the second movable contact piece.

6. In a device of the class described, the combination with a coil movably mounted between the north and south poles of a permanent magnet, of an arm fastened to the coil, a thermo-couple for energizing the coil to deflect the arm, a movable contact piece which intercepts the arm when deflected in one direction, a second movable contact piece which intercepts the arm when deflected in the opposite direction, a resistance, a circuit which includes the thermo-couple, the resistance and the coil, a second circuit which is closed by contact between the arm and the first movable contact piece, said second circuit also including the resistance, a battery in the second circuit for causing a drop across the resistance, said drop supplying energy to the coil to force the arm with sufficient power to move the first movable contact piece, a third circuit which is closed by contact between the arm and the second movable contact piece, said third circuit also including the resistance, and a second battery in the third circuit for causing a drop across the resistance, said drop supplying energy to the coil to force the arm with sufficient power to move the second movable contact piece.

7. In a device of the class described, the combination with a galvanometer having a movable coil, of a resistance, a circuit which includes the

coil and the resistance, a contact piece fastened to a tiltable element, a second contact piece fastened to the tiltable element, an arm extending from the coil, a thermo-couple in the circuit for energizing the coil to deflect the arm against one or the other of said contact pieces, a second circuit which is closed by contact between the arm and the first contact piece said second circuit also including the resistance, a source of electrical energy in the second circuit for causing a drop across the resistance, said drop energizing the coil to force the arm against the first contact piece with sufficient power to tilt the tiltable element in a given direction, a third circuit which is closed by contact between the arm and the second contact piece, said third circuit also including the resistance, and a source of electrical energy in the third circuit for causing a drop across the resistance to force the arm against the second contact piece with sufficient power to tilt the tiltable element in the opposite direction.

8. In a device of the class described, the combination with a galvanometer having a movable coil, of a resistance, a circuit which includes the coil and the resistance, a contact piece fastened to a movable element, a second contact piece fastened to the movable element, an adjustable screw for limiting the motion of the movable element in one direction, a second adjustable screw for limiting the motion of the movable element in the opposite direction, an arm which extends from the galvanometer coil for making electric contact with one or the other of said contact pieces, a thermo-couple in the circuit for energizing the coil to deflect the arm against one or the other of said contact pieces, a second circuit which is closed by contact between the arm and the first contact piece, said second circuit also including the resistance, a source of electrical energy in the second circuit for causing a drop in potential across the resistance said drop supplying auxiliary energy to the coil to force the arm against the first contact piece with sufficient power to move the movable element in a given direction, a third circuit which is closed by contact between the arm and the second contact piece, said third circuit also including the resistance, and a second source of electrical energy in the third circuit for causing a drop in potential across the resistance said drop supplying auxiliary energy to the coil to force the arm against the second contact piece with sufficient power to move the movable element in the opposite direction.

9. In a device of the class described, the combination with a galvanometer having a movable coil, of a resistance, a circuit which includes the coil and the resistance, a tiltable block, a contact piece fastened to the block, a second contact piece fastened to the block, an arm fastened to the galvanometer coil for making electric contact with one or the other of said contact pieces, a source of electrical energy in the circuit for energizing the coil to deflect the arm against one or the other of said contact pieces, a second circuit which is closed by contact between the arm and the first contact piece, said second circuit also including the resistance, a source of electrical energy in the second circuit for causing a drop in potential across the resistance said drop supplying auxiliary energy to the coil to force the arm against the first contact piece with sufficient power to move the tiltable block in a given direction, a third circuit which is closed by contact between the arm and the second contact piece, said third circuit also including the resistance,

and a second source of electrical energy in the third circuit for causing a drop in potential across the resistance said drop supplying auxiliary energy to the coil to force the arm against the second contact piece with sufficient power to move the tiltable block in the opposite direction.

10. In a device of the class described, the combination with a galvanometer having a movable coil, of a resistance, a circuit which includes the coil and the resistance, an arm fastened to the coil, a thermo-junction in the circuit for energizing the coil to deflect the arm, a tiltable block the center of gravity of which is above a fixed bearing on which it is tiltable mounted, two contact pieces extending upward from the block, an adjustable screw against which the first of said contact pieces is held by gravity when the block is tilted counter-clockwise, and in which tilted position the first contact piece is below the path of the deflectable arm and the second contact piece in the path of said arm, a second adjustable screw against which the second of said contact pieces is held by gravity when the block is tilted clockwise and in which tilted position the second contact piece is below the path of the deflectable arm and the first contact piece in the path of said arm, a second circuit which is closed by contact between the first contact piece and the first adjustable screw, a third circuit which is closed by contact between the second contact piece and the second adjustable screw, a fourth circuit which is closed by contact between the arm and the first contact piece said fourth circuit also including the resistance, a source of electrical energy in the fourth circuit for causing a drop across the resistance, said drop supplying auxiliary energy to the galvanometer coil to force the arm against the first contact piece with sufficient power to tilt the block counter-clockwise, a fifth circuit which is closed by contact between the arm and the second contact piece said fifth circuit also including the resistance, and a second source of electrical energy in the fifth circuit for causing a drop across the resistance, said drop supplying auxiliary energy to the galvanometer coil to force the arm against the second contact piece with sufficient power to tilt the block clockwise.

11. In a device of the class described, the combination with a circuit, of a second circuit, a tiltable frame, a switch in the first circuit which is closed by the tiltable frame when tilted clockwise and opened by said frame when tilted counter-clockwise, a second switch in the second circuit which is closed by the tiltable frame when tilted counter-clockwise and opened thereby when tilted clockwise, a galvanometer, a needle which is deflected by the galvanometer, a resistance, a third circuit which includes the galvanometer and the resistance, a thermo-couple in the third circuit for energizing the galvanometer to deflect the needle, a contact piece on the tiltable frame, a second contact piece on the tiltable frame, a fourth circuit which is closed by contact between the needle and the first contact piece said fourth circuit also including the resistance, a source of electrical energy in the fourth circuit for causing a drop across the resistance, said drop supplying current from said source to the galvanometer to force the needle against the first contact piece with sufficient power to tilt the tiltable frame clockwise, a fifth circuit which is closed by contact between the needle and the second contact piece said fifth circuit also including the resistance, a second

source of electrical energy in the fifth circuit for causing a drop across the resistance, said drop supplying current from the second source to the galvanometer to force the needle against the second contact piece with sufficient power to tilt the tiltable frame counter-clockwise.

12. In a device of the class described, the combination with a tiltable block, of two bearings each insulated from the other and on which the tiltable block is mounted, a contact piece extending from the block and electrically connected with the first bearing, a second contact piece extending from the block and electrically connected with the second bearing, a galvanometer having an indicating needle which needle may be deflected against one or the other of the contact pieces, a resistance, a circuit which is closed by contact between the needle and the first contact piece said circuit including the resistance and the first bearing, a second circuit which is closed by contact between the needle and the second contact piece said second circuit including the resistance and the second bearing, a third circuit which includes the galvanometer and the resistance, a source of electrical energy in the third circuit for deflecting the needle against one or the other of said contact pieces, a second source of electrical energy in the first circuit for causing a drop across the resistance thereby energizing the galvanometer to force the needle against the first contact piece with sufficient power to tilt the block clockwise, and a third source of electrical energy in the second circuit for causing a drop across the resistance thereby energizing the galvanometer to force the needle against the second contact piece with sufficient power to tilt the block counter-clockwise.

13. In a device of the class described, the combination with a galvanometer, of an indicating needle for the galvanometer which needle is moved by the galvanometer in a given horizontal plane, a tiltable block located below the plane, a bearing for the block located below the center of gravity of the block, a stop for limiting the motion of the block in one direction and against which it is normally held by gravity when tilted in said direction, a second stop for limiting the motion of the block in the opposite direction, and against which it is normally held by gravity when tilted in said opposite direction, an extension from the block which extends into the plane of the needle and against which the needle normally rests when the block is in one of its extreme positions, a second extension from the block which extends into the plane of the needle and against which the needle normally rests when the block is in its other extreme position, and means for energizing the galvanometer to force the needle against one or the other of the extensions to tilt the block.

14. In a device of the class described, the combination with a galvanometer, of a resistance, a circuit which includes the galvanometer and the resistance in parallel, a second circuit which includes the galvanometer and the resistance in parallel, a battery in the first circuit with the proper polarity to deflect the galvanometer in a clockwise direction, a battery in the second circuit with the proper polarity to deflect the galvanometer in the opposite direction, a needle actuated by the galvanometer, a tiltable element, a contact piece extending from the tiltable element against which contact piece the needle may deflect in a clockwise direction to close the first

circuit thus energizing the galvanometer to force the needle with sufficient power to tilt the tiltable element in said direction, a second contact piece extending from the tiltable element against which second contact piece the needle may deflect in a counter-clockwise direction to close the second circuit thus energizing the galvanometer to force the needle with sufficient power to tilt the tiltable element in said direction, and a thermo-couple for energizing the galvanometer to deflect the needle against one or the other of said contact pieces, said couple being in parallel with the resistance and in series with the galvanometer in both the first and second circuits.

15. In a device of the class described, the combination with an electrical resistance, of a circuit which includes the resistance and a battery with a given polarity, a second circuit which includes the resistance and a second battery of opposite polarity, a shunt across the resistance which shunt includes a galvanometer and a thermo-couple for energizing the galvanometer independently of the batteries, a needle actuated by the galvanometer, a movable contact piece against which the needle may be deflected by the galvanometer in a given direction to close the first circuit thus causing a drop across the resistance which energizes the galvanometer to force the needle with sufficient power to move said movable contact piece, and a second movable contact piece against which the needle may be deflected by the galvanometer in the opposite direction to close the second circuit thus causing a drop across the resistance which energizes the galvanometer to force the needle with sufficient power to move said second movable contact piece.

16. In a device of the class described, the combination with a galvanometer, of a thermo-couple for energizing the galvanometer, a circuit which includes the galvanometer and the thermo-couple, an indicating needle actuated by the galvanometer, a tiltable element, a contact piece on the tiltable element against which the needle may be deflected by the galvanometer in one direction, a second circuit which includes the galvanometer and a resistance in parallel and which circuit is closed by contact between the needle and the contact piece to supply auxiliary energy from a battery in said second circuit to force the needle to tilt the tiltable element in a given direction, a second contact piece on the tiltable element against which the needle may be deflected by the galvanometer in the opposite direction, a third circuit which includes the galvanometer and the resistance in parallel and which third circuit is closed by contact between the needle and the second contact piece to supply auxiliary energy from a second battery in said third circuit to force the needle to tilt the tiltable element in the opposite direction, a stop on each side of the tiltable element for limiting the tilting in either direction, means for adjusting each stop, and a multiplicity of circuits which are opened and closed by the tiltable element.

17. In a device of the class described, the combination with a galvanometer, of an indicating needle for the galvanometer which needle is moved by the galvanometer in a given horizontal plane, a tiltable block located below the plane, a bearing for the block located below the center of gravity of the block, a stop for limiting the motion of the block in one direction and against which it is normally held by gravity when tilted

in said direction, a second stop for limiting the motion of the block in the opposite direction and against which it is normally held by gravity when tilted in said opposite direction, an extension 5 from the block which extends into the plane of the needle and against which the needle normally rests when the block is in one of its extreme positions, a second extension from the block which extends into the plane of the needle 10 and against which the needle normally rests when the block is in its other extreme position, means for energizing the galvanometer to force

the needle against one or the other of the extensions to tilt the block, and a mercury switch fastened to the block, said mercury switch consisting of the usual glass envelope into which envelope two electrodes are sealed, and which envelope contains a globule of mercury for electrically connecting the electrodes when the block is tilted in one direction and electrically disconnecting them when tilted in the opposite direction. 5 10

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