F. A. H. HARLÉ.

MECHANISM FOR CONTROLLING MOVEMENT.

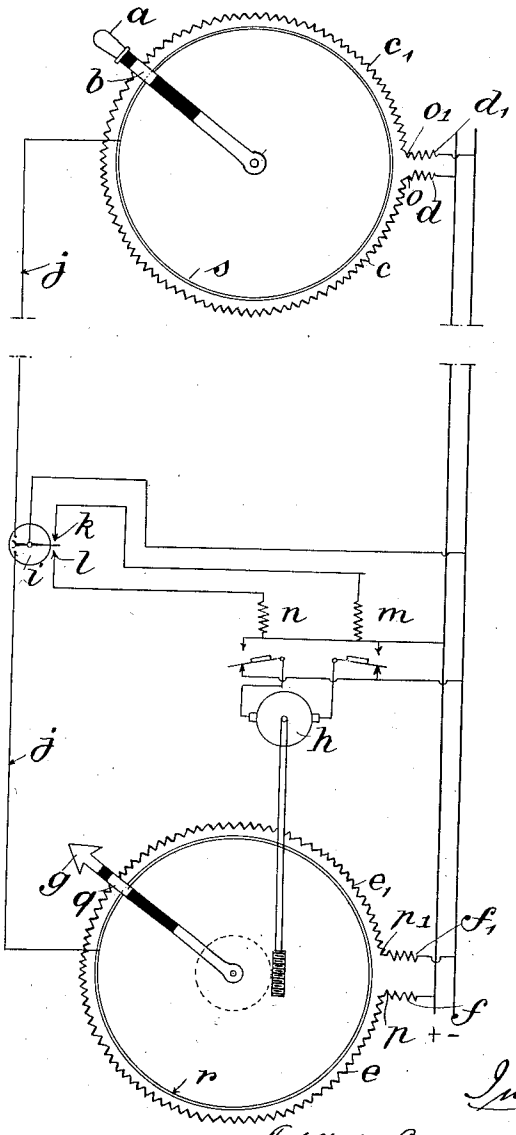
APPLICATION FILED JULY 21, 1914.

1,268,712.

Patented June 4, 1918.

8 SHEETS—SHEET 1.

Fig. 1.



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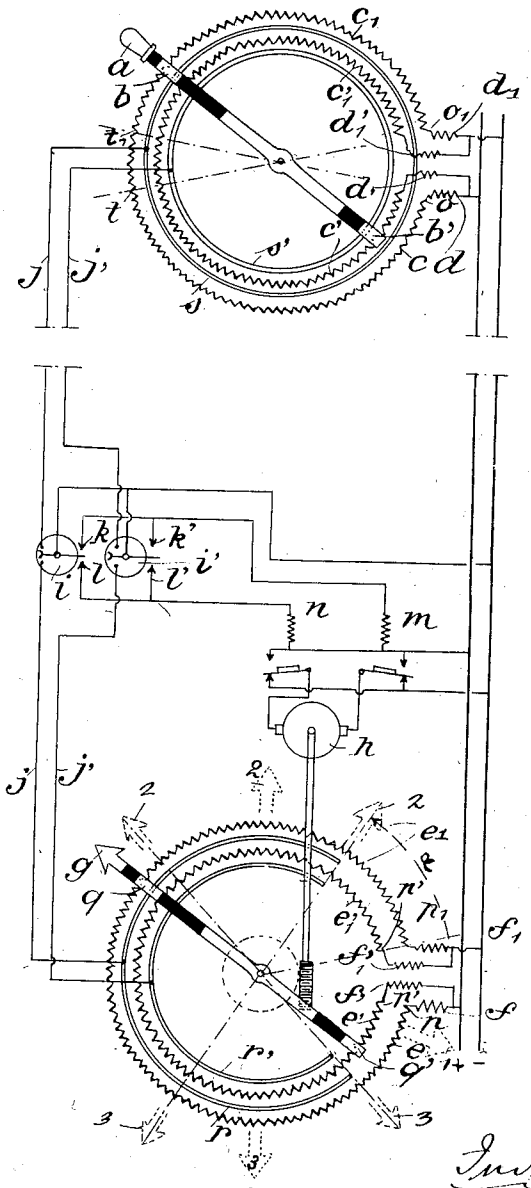
8 SHEETS—SHEET 2.

Fig. 2.



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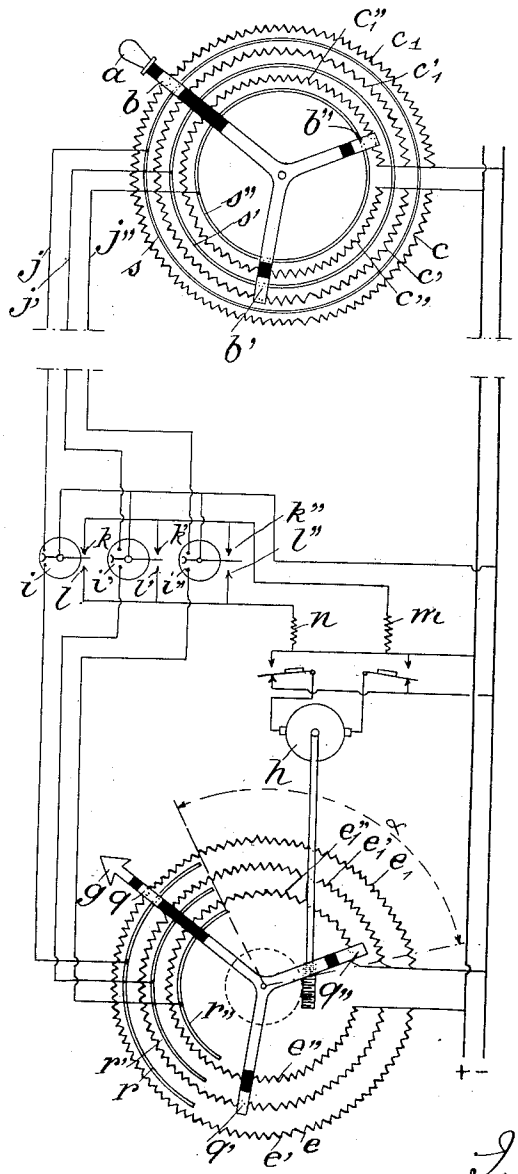
8 SHEETS—SHEET 3.

Fig. 3.



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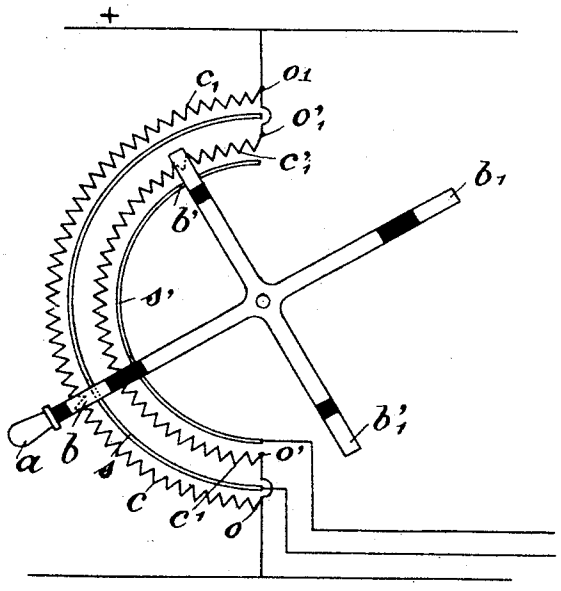
8 SHEETS—SHEET 4.

Fig. 4.



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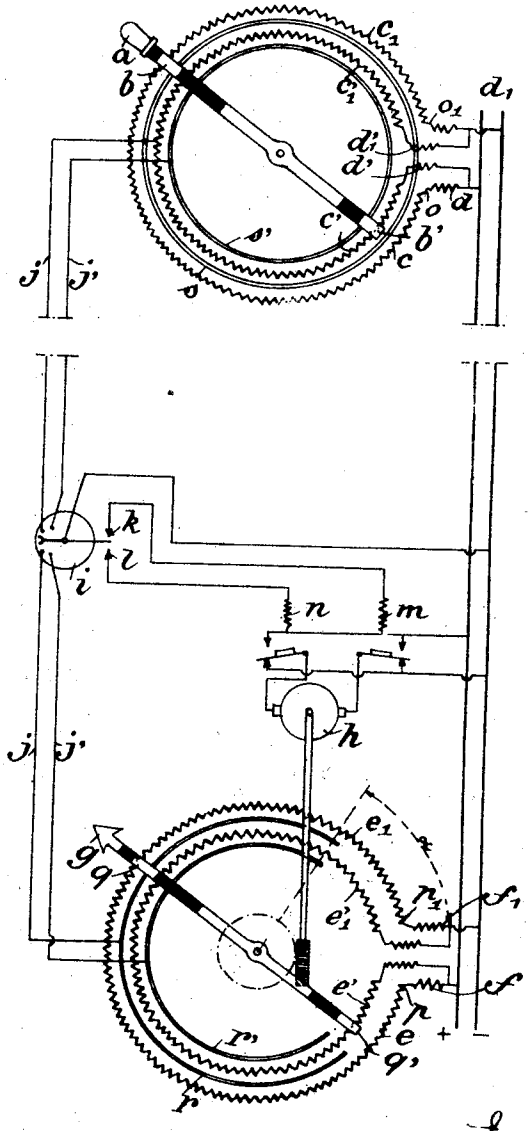
8 SHEETS—SHEET 5.

fig. 5.



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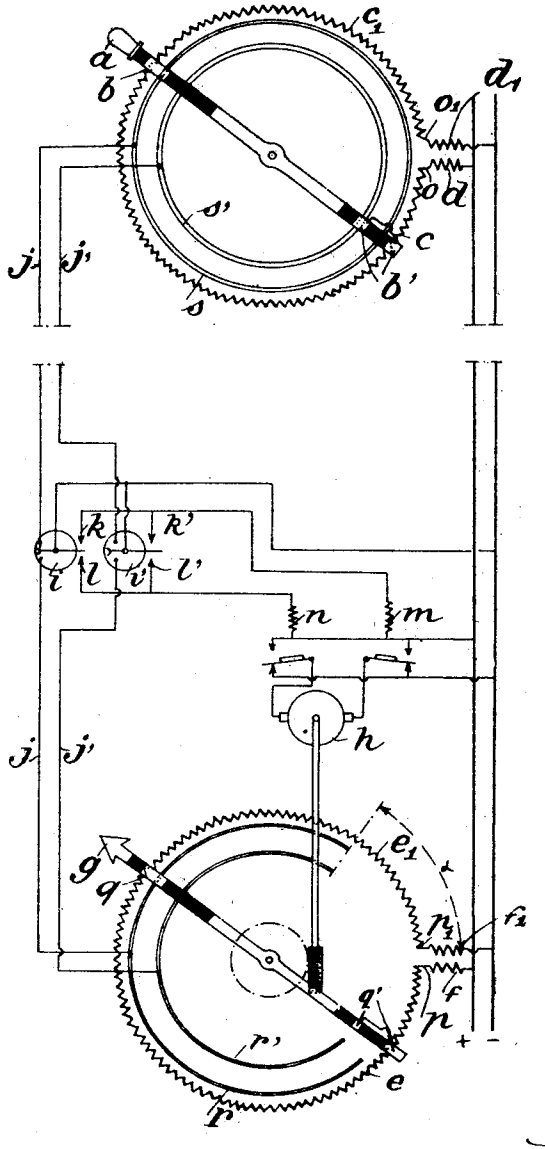
8 SHEETS—SHEET 6.

Fig. 6



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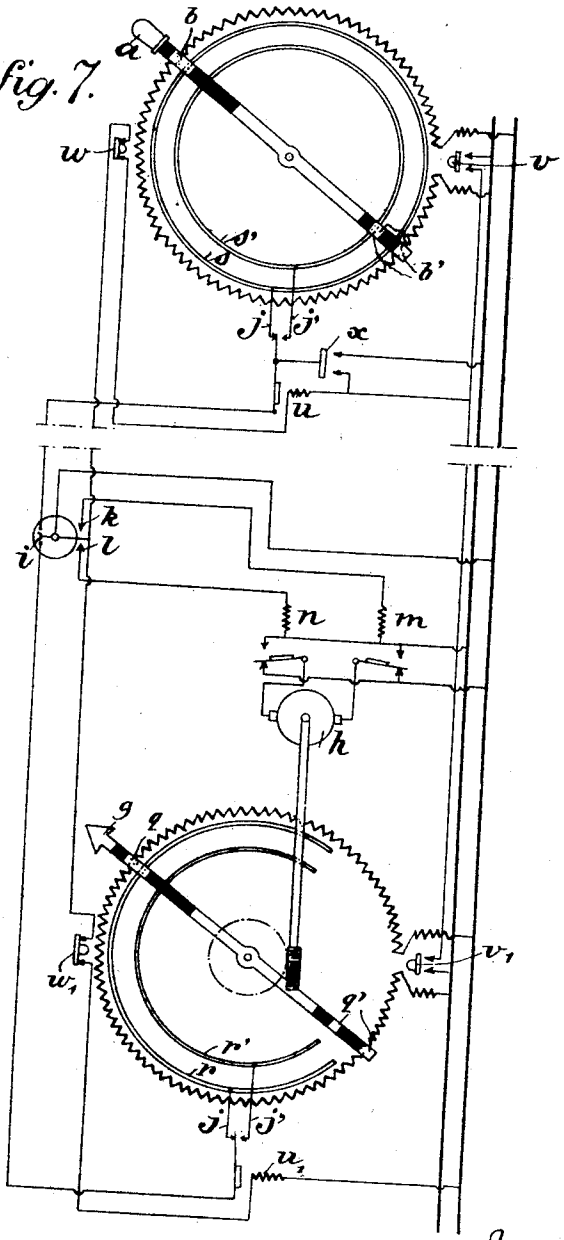
8 SHEETS—SHEET 7.

Fig. 7.



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1,268,712.

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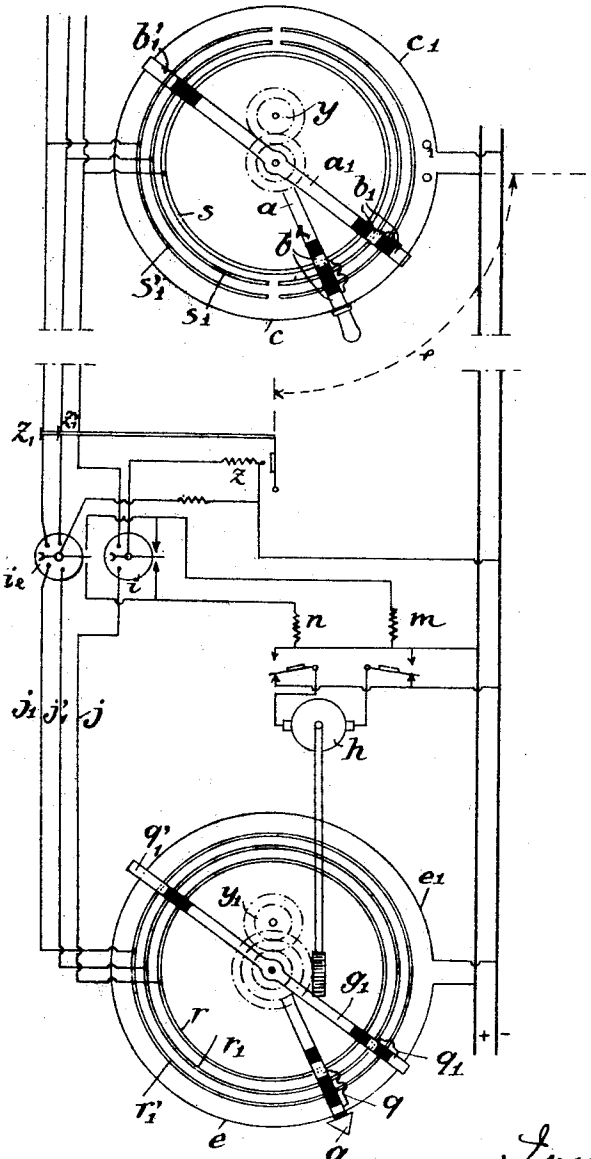
8 SHEETS—SHEET 8.

Fig. 8.



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UNITED STATES PATENT OFFICE.

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MECHANISM FOR CONTROLLING MOVEMENT.

1,268,712. Specification of Letters Patent. Patented June 4, 1918.

Application filed July 21, 1914. Serial No. 852,161.

To all whom it may concern:

Be it known that I, FRÉDÉRIC AUGUSTE HENRI HARLÉ, of 26 Avenue de Suffren, Paris, France, engineer, have invented new and useful Improvements in Mechanism for Controlling Movement, which improvements are fully set forth in the following specification.

In electric control apparatus it has already been proposed to control a motor actuating the controlled member by the balance current of an electric arrangement identical with or similar to a Wheatstone bridge. When the balance is upset to a given extent at the control station, the current thus generated in the balance wire sets the motor running until it reëstablishes equilibrium by acting upon the relation of the resistances of the other arm of the bridge.

A known arrangement of control is illustrated diagrammatically in Figure 1.

At the control station a handle a has on it a contact b which moves in a circular path to vary the resistance of the two arms c c_1 of a Wheatstone bridge provided if desired with resistances d and d_1.

The two other arms e e_1 of the bridge are similarly arranged and provided if desired with resistances f f_1 at the controlled station whose index or controlled member g carrying contact q is moved by a motor h.

The motor h is controlled by a galvanometer relay i interposed in the bridge balance wire j connected to the contact bars s and r; this relay has contacts k and l which control through relays m n the movement of the motor in one or other direction.

Under these conditions when the handle a at the control station is moved the motor h starts running and brings the index g at the controlled station into the corresponding position. So soon as such position is reached the motor h stops.

A control of this type has the defect that when the handle a is moved so that its contact b comes to either of the extreme ends o or o_1 of the resistances c c_1 and moves on across to the other extreme end the index g at the controlled station does not follow this movement; instead of passing through the corresponding points p p_1 it turns in the reverse direction and regains the position of balance at the other side; this is due to the fact that when the contact b reaches the point o or o_1 the current in the balance wire j changes in direction thus reversing the movement of the galvanometer relay i and consequently the direction in which the motor h turns.

In order to avoid this according to this invention several Wheatstone bridges are employed the action of each being eliminated at the points at which such reversal could take place.

The accompanying drawings illustrate diagrammatically several ways of carrying out the invention.

Figs. 2, 3 and 4 differ from each other in the number or arrangement of the bridges.

Fig. 5 shows a modification of the galvanometer relay.

Fig. 6 shows a modification as regards the arms of the bridges.

Figs. 7 and 8 show a modification as regards the method of putting the bridges out of action at the desired moment.

Fig. 2 shows two bridges connected in parallel. One bridge comprises the same elements as shown in Fig. 1, that is to say, at the control station there are resistances c, c_1 connected with the mains, if desired through resistances d, d_1, the resistances c, c_1 being varied by movement of the contact b, carried on handle a, over the contact bar s, said contact bridging the resistances and bar as shown. At the controlled station there are resistances e, e_1 connected with the mains, if desired through resistances f, f_1, the resistances e, e_1 being varied by movement of the index g carrying contact q over the contact bar r, said contact being designed to bridge the resistances and bar as shown. Balance wire j is connected with the contact bars r and s, and interposed therein is the galvanometer relay i for controlling the operation of the motor h which moves the index g.

In parallel with the above bridge circuit is a second bridge circuit comprising at the control station the resistances c', c'_1 connected to the mains, if desired through the resistances d', d'_1, the resistances c', c'_1 being varied by movement of the contact b', which may be conveniently carried on the opposite end of the handle a, along the contact bar s', this contact bridging the resistances c', c'_1, and the bar s'. At the controlled station are the resistances e', e'_1 connected to the mains, if desired through the resistances f', f'_1, the resistances e', e'_1 being varied by contact q', which may be conveniently carried on the opposite end of index g, along the contact

bar r', said contacts bridging the resistances e', e'_1, and the bar r'. The contact bars s' and r' are connected by the balance wire j' in which is interposed the galvanometer relay i'. The motor h is controlled through the relays m and n by the relays i and i', the latter relays being constructed to close contacts k or l and k' or l' respectively.

To cut out the wire j when the contact q is near points p and p_1, the contact bar r does not extend through a complete circle as does the contact bar s, but only through a little more than a semicircle, as clearly shown on the drawing. Similarly, to cut out the balance wire j' when the contact q' is near the points p' or p'_1, the contact bar r' is similarly limited to a little more than a semicircle, as shown.

In this arrangement no reversal will take place by movement of the handle a from point o to point o_1, or vice versa, provided the handle a be moved approximately at the speed with which the motor h drives the index g; or otherwise expressed, so long as the relative angularity of the handle a to the index g does not exceed the angle between the radii connected respectively to the end of the contact bars r and r' and the points p_1 or p'_1, designated on the drawing as α. Thus, assuming the parts to be in the position shown in full lines in Fig. 2, contact q' is not in engagement with contact bar r' and balance wire j' is therefore cut out. Assuming that the handle a is moved in a clockwise direction at approximately the speed at which the motor h can drive the index g, as the handle a is moved toward the point o_1 index g will follow in the same direction and contact q' will come into engagement with contact bar r'. By the time contact b has engaged point o_1, contact q is ready to pass out of engagement with contact bar r. Consequently, as the contact b is moved from point o_1 to point o, balance wire j is cut out and the motor h is under the control solely of the balance wire j' which, as will be apparent, will maintain the motor running in the same direction. Obviously the same result will occur if the contact b be moved from the point o to point o_1 in an anti-clockwise direction.

It is furthermore to be noted that handle a may be moved, however quickly, within certain limits of its circle of movement and be followed by the index g in the same direction. Thus the handle a may be moved rapidly from a position wherein contact q' is out of engagement with bar r', as shown in full-line position in Fig. 2, in a clockwise or anti-clockwise direction to any portion of the greater arc between t_1 and t, and be followed by the index g in the same direction because, at starting, the balance wire j' is cut out (since contact q' is not in engagement with contact bar r') and when this balance wire is cut in, it will not within these limits undergo a change in the direction of the current flowing therethrough. Similarly, if the index g be moved from a position wherein contact q is out of engagement with bar r as shown in the dotted-line position indicated at 1 in this figure, the handle a may be moved rapidly in a clockwise or anti-clockwise direction to any portion of the greater arc between o_1 and o, and be followed by the index g in the same direction because, at starting, the balance wire j is cut out (since the contact q is not in engagement with bar r) and when the balance wire j is cut in, it will not within these limits undergo a change in the direction of the current flowing therethrough. Similarly, if the index g is in any of the positions indicated in dotted lines at 2, handle a may be moved rapidly in either direction to any portion of the arc o_1—t_1, and if the index g is in any of the positions indicated in dotted lines at 3, handle a may be moved rapidly to any point in the arc o—t, and be followed by the index g in the same direction, because, while the motor may be under the control of both balance wire j and j' within these limits, neither will undergo a change in the direction of current flowing therethrough.

Therefore, by the construction of Fig. 2, the handle a may be moved through one or more revolutions and be followed by the index g in the same direction of rotation through the same number of revolutions if the angularity between the two be kept within the angle α as explained.

In place of two bridges, as in Fig. 2, three may be employed as illustrated in Fig. 3. Similar parts are indicated by similar letters, the characters designating the second and third bridge elements being differentiated from those designating the first bridge elements by one and two primes respectively.

As shown, this arrangement comprises three galvanometer on relays i i' i'' acting upon the motor h through relays m and n.

Contact bars r r' r'' are also provided which do not make a complete circle. As illustrated the angle α is larger than in the arrangement of Fig. 2 nevertheless one bridge at least is always in circuit.

A greater number of bridges may be provided on the same principle.

It is not necessary that a bridge should extend through the entire circle as in Figs. 1, 2 and 3; an arrangement in which it extends through a half circle only is illustrated in Fig. 4.

In this figure there are two bridges c c_1 and c' c'_1; the elements and their working are the same as in Fig. 2 except that the handle carries two pairs of contacts b b' and

b_1 b'_1 90° apart one or the other of which come alternately into contact with the bridges. At the controlled station the bridges may be arranged as in Figs. 2, 3 or 4 or as in Fig. 6 hereinafter described.

Referring to Fig. 3, it has been supposed that there are galvanometer relays i i' i'', one on each of the balance wires j j' j''.

While a bridge is out of action by reason of the corresponding contact on the index not engaging one of the contact bars r r' r'', its galvanometer relay comes back to zero. As this relay possesses a certain inertia this movement takes place with a certain lag. This may be avoided by replacing the galvanometer relays by a single relay comprising as many windings as there are bridges, two in Figs. 2 and 4 and three in Fig. 3.

Fig. 5 illustrates the employment of a single galvanometer relay i having two windings which may be applied to the constructions of Figs. 2 or 4.

The Wheatstone bridges as previously illustrated are distinct one from the other. Consequently for example as in Fig. 2, when the current is broken in the balance wire j by the disengagement of the contact q from contact bar r no variation occurs in the balance current of the wire j' and therefore no disturbance in the working of the relay i' or in the working of the motor.

If as a modification of this invention the bridges are not distinct but utilize, for example as in Fig. 6, the same resistance c c_1 as a bridge arm, the relays i and i' must have a great electrical resistance in order that the balance current in the wire j may be small enough for its variations to be without substantial influence upon the value of the current in j' and reciprocally.

Referring to Fig. 6, the control station has two resistances c, c_1 connected to the mains, if desired through resistances d, d_1. The handle a is provided with a contact b to connect the resistances to a contact bar s and with a pair of separated but electrically connected contacts b' to connect the resistances to a second contact bar s', the insulation intermediate said contacts b' insulating the same from the contact bar s. The controlled station has resistances e, e_1 connected to the mains, if desired through resistances f, f^1. The index g is provided with a contact q to connect the resistances and a contact bar r, and with a pair of separated but electrically-connected contacts q' adapted to connect the resistances to a second contact bar r', the insulation between said contacts q' insulating the same from the contact bar r. The contact bars r and s are connected by the balance wire j in which is the galvanometer relay i, and the contact bars r' and s' are connected by the balance wire j' in which is the galvanometer relay i'. The relays i and i' respectively control contacts k, l and k', l' in circuit with the relays m and n which control the operation of the motor h, as in the modification of Fig. 2. The contact bars r, r' at the controlled station extend through less than a complete circle as in the modification of Fig. 2, while the corresponding bars s, s' at the control station extend through a complete circle. It is evident that the equivalent result could be obtained by making the contact bars r, r' a complete circle and the contact bars s, s' less than a complete circle.

Assuming the parts to be in the position shown in full-lines in Fig. 6, the balance wire j' is cut out as the contacts q' are out of electrical connection with the contact bar r'. A movement of the handle a will be followed by a corresponding movement of the index g precisely as in the modification of Fig. 2, the elements operating as described in connection with that construction. When the contacts q' electrically connect the resistances with the contact bar r', there will be corresponding reductions in the two currents flowing through the resistances c and e to and from the contacts b and q respectively, as part of the current will flow through contacts b' and bar s' and through contacts q' and bar r' and through the balance wire j'. The index g is now under the control of the two bridge circuits which operate in precisely the same way as in the modification of Fig. 2. When the contact q passes out of engagement with contact bar r, the balance wire j is cut out, but the two contacts b' cooperating with resistances c, c_1 and contact bar s' and the two contacts q' coöperating with resistances e, e_1 and contact bar r', operate to control the galvanometer relay i, in precisely the same way as when the contacts b and q in the modification of Fig. 2 are out of contact with contact bars s and r respectively.

Other arrangements may also be employed for putting a bridge out of action. Fig. 7 shows one example and comprises two relays u u_1 in series, one at the control station the other at the controlled station.

When excited they cut out the balance wire j and connect the galvanometer relay i to the wire j'; when they are not excited they cut out the wire j' and connect the relay i to j.

The relays u, u_1 are controlled by press buttons v, v_1 and w, w_1 in circuit therewith, the buttons v, v_1 being normally held open to maintain the circuit through the relays open, and the buttons w, w_1 being normally held closed to maintain the circuit through the relays closed. Said buttons are positioned in the path of and designed to be operated by the heads of the handle a and index g.

Assuming the parts to be in the position

shown in Fig. 7 with the balance wire j in circuit with the galvanometer relay i, if the handle a be swung through 180° in a clockwise direction, it will close the button v as is passes over the same. Current will now flow from the main through button v, relay u, the normally closed buttons w, w_1 and relay u_1, back to the other main. The relays u and u_1 operate the contacts to cut balance wire j out of circuit with relay i and to cut the balance wire j' into circuit with said relay. The operation of the relay u will also bridge the contacts at x so as to maintain a circuit through the relays u and u_1, and the parts in the position to which they have been moved, even though the button v be again opened. Obviously the same could be accomplished by closing the button v_1. If the handle a be then swung through 180° in an anti-clockwise direction, it will open the button w in passing the same and break the circuit through the relays u and u_1. The balance wire j' will now be cut out of circuit with relay i and the balance wire j will be cut into said circuit. This operation of relay u also breaks the electrical connection at x, and the circuit will not be completed if the button w be again closed. Obviously the same effect could be accomplished by opening the button w_1.

If the handle a and index g are in the position shown in this figure and the handle is moved suddenly clockwise through 180°, the motor h, if controlled solely by balance wire j, would be reversed. Owing to the closing of the button v and the consequent cutting out of balance wire j and cutting in of balance wire j', no reversal takes place however. Similarly, if the handle a were swung through 180° in an anti-clockwise direction, and the motor h were controlled solely by the balance wire j', it would be reversed. Owing to the opening of the button w and the consequent cutting out of balance wire j' and cutting in of balance wire j, however, no reversal takes place.

It will therefore be observed that so long as handle a is moved at such a speed as not to make with index g an angle greater than 180°, there will be no reversal of the motor h and the index g will follow the handle a through one or more turns in the same direction. Furthermore, the handle a may be moved quickly through an arc of less than 180° and it will be followed by the index g rotating in the same direction.

As such control arrangement has no dead point it is capable of numerous applications other than that of a single control at a distance. For example Fig. 8 indicates its application to increase the precision of a control in accordance with Fig. 1.

Referring to this figure, which has been somewhat simplified for the sake of clearness, the resistances c, c_1 at the control station and e, e_1 at the controlled station are represented by smooth semicircles, the points o, o_1 being indicated at the control station. Handle a is provided with two separated contacts b in electrical connection designed to connect the resistances to the contact bar r. At the controlled station index g is provided with separated electrically-connected contacts q designed to connect the resistances with the contact bar r. The contact bars s and r are connected by the balance wire j through the relay i as heretofore described.

At the control station a second contact member a_1 is mounted concentrically with the handle a and is driven therefrom through the speed-increasing gearing y. Contact member a_1 carries a pair of separated electrically-connected contacts b_1 to connect the resistances with contact bar s_1, and a contact b'_1 to connect the resistances with contact bar s'_1. Similarly at the controlled station a second contact member g_1 is mounted concentrically with the index g to be driven therefrom through the speed-increasing gearing y_1. The two sets of speed-increasing gearing y, y_1 have the same ration. Contact member g_1 carries two separated electrically-connected contacts q_1 designed to connect the resistance with contact bar r_1 and a contact q'_1 designed to connect the resistances with contact bar r'_1. Contact bars r_1 and s_1 and r'_1 and s'_1 are respectively connected by the balance wires j_1, j'_1 which include separate coils of a double winding of the galvanometer relay i_2 as described in connection with Fig. 5.

Relays i and i_2 respectively control the motor h through the relays m and n, as heretofore disclosed. The circuit through the relays m and n, which includes the relay i, additionally includes a relay z which is designed to operate a pair of contact members z_1, z'_1 in the balance wires j_1, j'_1.

When the handle a and the index g are relatively at a small angle the current which passes through the wire j is too small to move the galvanometer relay i. Therefore, without the aid of the bridges including the balance wires j_1, j'_1 the motor h would not be put into action, and the small error would persist. Owing to the speed increasing gearing between the handle a and the contact member a and between the index g and the contact member g_1, the small angle between the handle a and index g is considerably multiplied as between the contact members a_1 and g_1, so that the current passing through the wires j_1, j'_1 is much larger than that passing through the wire j. The galvanometer relay i_2 will therefore control the motor h and the accuracy of control will be increased.

When the handle a and the index g are at a larger angle, the current flowing through the balance wire j is sufficient to actuate the relay i. The closing of the circuit through the relays m and n by the relay i also closes the circuit through the relay z, whereupon contact members z_1, z'_1 are moved to cut out the balance circuits through the wires j_1, j'_1. This prevents the possibility of a reversal of the motor which might be produced by the bridges including the balance wires j_1, j'_1 if, as described in connection with Fig. 2, the contact members a_1 and g_1 should be at an angle greater than α.

As but single sets of resistances are employed as in the modification disclosed in Fig. 6, it will be understood that when the motor is under the control of the bridges including balance wires j_1 j'_1 the motor is controlled in the same manner as described with respect to said figure. Furthermore, as in the construction shown in Fig. 1, the motor h will not be reversed when controlled solely by the relay i so long as the contact b does not pass from one extreme position o to the other extreme position o_1, or vice versa, but will possess greater accuracy of control because of the multiplied movement given contact members a_1 and g_1 by the speed-increasing gearing y and y_1 between said members and the handle a and index g respectively.

It will be apparent that the accuracy of control may be still further increased by increasing the number of contact members at the two stations, and by the selection of proper speed-increasing gearing which will make the contact members move at different speed ratios. As in Fig. 8, the motor-control circuits of such a construction would include relays to cut out the balance circuits in succession.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of balance circuits between said sets of resistances, movable contacts in electrical connection with said first-named resistances and said balance circuits for varying the resistances at the control station, movable contacts in electrical connection with said last-named resistances and said balance circuits for varying the resistances at the controlled station, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

2. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of balance circuits between said sets of resistances, movable contacts in electrical connection with said first-named resistances and said balance circuits for varying the resistances at the control station, movable contacts in electrical connection with said last-named resistances and said balance circuits for varying the resistances at the controlled station, means for predeterminately cutting out each of said balance circuits, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

3. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable contacts at the control station for connecting the resistances to the respective contact bars at said station, movable contacts at the controlled station for connecting the resistances to the respective contact bars at said station, a plurality of balance circuits connecting the contact bars at the two stations, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

4. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable contacts at the control station for connecting the resistances to the respective contact bars at said station, movable contacts at the controlled station for connecting the resistances to the respective contact bars at said station, a plurality of balance circuits connecting the contact bars at the two stations, means whereby each of said balance circuits is predeterminately cut out by the movement of one of said sets of movable contacts, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

5. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable contacts at the control station for connecting the resistances to the respective contact bars at said station, movable contacts at the controlled station for connecting the resistances to the respective contact bars at said station, a plurality of balance circuits connect-

ing the contact bars at the two stations, each of said contact bars of one set being broken whereby the corresponding movable contacts predeterminately cut out each of said balance circuits, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

6. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of balance circuits between said sets of resistances, movable circumferentially-spaced contacts in electrical connection with said first-named resistances and said balance circuits for varying the resistances at the control station, movable circumferentially-spaced contacts in electrical connection with said last-named resistances and said balance circuits for varying the resistances at the controlled station, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

7. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of balance circuits between said sets of resistances, movable circumferentially-spaced contacts in electrical connection with said first-named resistances and said balance circuits for varying the resistances at the control station, movable circumferentially-spaced contacts in electrical connection with said last-named resistances and said balance circuits for varying the resistances at the controlled station, means for predeterminately cutting out each of said balance circuits, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

8. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable circumferentially-spaced contacts at the control station for connecting the resistances to the rerspective contact bars at said station, movable circumferentially-spaced contacts at the controlled station for connecting the resistances to the respective bars at said station, a plurality of balance circuits connecting the contact bars at the two stations, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

9. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable circumferentially-spaced contacts at the control station for connecting the resistances to the respective contact bars at said station, movable circumferentially-spaced contacts at the controlled station for connecting the resistances to the respective bars at said station, a plurality of balance circuits connecting the contact bars at the two stations, means whereby each of said balance circuits is predeterminately cut out by the movement of one of said sets of movable contacts, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

10. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a plurality of contact bars at the control station, a plurality of contact bars at the controlled station, movable circumferentially-spaced contacts at the control station for connecting the resistances to the respective contact bars at said station, movable circumferentially-spaced contacts at the controlled station for connecting the resistances to the respective bars at said station, a plurality of balance circuits connecting the contact bars at the two stations, each of said contact bars of one set being broken whereby the corresponding movable contacts predeterminately cut out each of said balance circuits, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

11. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a rotatable handle at the control station, concentric contact bars at the control station coaxial with said handle, a rotatable index at the controlled station, concentric contact bars at the controlled station coaxial with said index, movable circumferentially-spaced contacts carried by said handle and index respectively for connecting the respective resistances to the respective bars, a plurality of balance circuits connecting the contact bars at the two stations, a motor for moving said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

12. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a rotatable handle at the control station, concentric contact bars at the control station coaxial with said handle, a rotatable index at the controlled station, concen-

tric contact bars at the controlled station coaxial with said index, movable circumferentially-spaced contacts carried by said handle and index respectively for connecting the respective resistances to the respective bars, a plurality of balance circuits connecting the contact bars at the two stations, means for predeterminately cutting out each of said balance circuits, a motor for moving said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

13. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a rotatable handle at the control station, concentric contact bars at the control station coaxial with said handle, a rotatable index at the controlled station, concentric contact bars at the controlled station coaxial with said index, movable circumferentially-spaced contacts carried by said handle and index respectively for connecting the respective resistances to the respective bars, a plurality of balance circuits connecting the contact bars at the two stations, means whereby each of said balance circuits is predeterminately cut out by the movement of one of said sets of movable contacts, a motor for moving said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

14. In control apparatus, Wheatstone bridge mechanism comprising resistances at a control station, resistances at a controlled station, a rotatable handle at the control station, concentric contact bars at the control station coaxial with said handle, a rotatable index at the controlled station, concentric contact bars at the controlled station coaxial with said index, movable circumferentially-spaced contacts carried by said handle and index respectively for connecting the respective resistances to the respective bars, a plurality of balance circuits connecting the contact bars at the two stations, each of said contact bars of one set being broken whereby the corresponding movable contacts predeterminately cut out each of said balance circuits, a motor for moving said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

15. In control apparatus, a plurality of Wheatstone bridge circuits in parallel, means for varying the resistances of said circuits, said circuits and resistance-varying means being so related that the dead-points of the respective circuits are non-coincident, and relay mechanism controlled by the balance circuits of said bridge circuits.

16. In control apparatus, a plurality of Wheatstone bridge circuits, means for varying the resistances of said circuits, said circuits and resistance-varying means being so related that the dead-points of the respective circuits are non-coincident, means for cutting out one of said circuits while another of said circuits is closed, and relay mechanism controlled by the balance circuits of said bridge circuits.

17. In control apparatus, a plurality of Wheatstone bridge circuits, means for varying the resistances of said circuits, said circuits and resistance varying means being so related that the deadpoints of the respective circuits are non-coincident, means for cutting out each of said circuits when a resistance-varying element thereof approaches or reaches a dead-spot of said circuit, and relay mechanism controlled by the balance circuits of said bridge circuits.

18. In control apparatus, a plurality of parallel Wheatstone bridge circuits each comprising resistances at a control station, resistances at a controlled station and a balance circuit connecting said sets of resistances, movable contacts at each of said stations in electrical connection with the respective resistances and balance circuits for varying the respective resistances at the two stations, said circuits and resistance-varying means being so related that the dead-points of the respective circuits are non-coincident, and relay mechanism controlled by the balance circuits of said bridge circuits.

19. In control apparatus, a plurality of parallel Wheatstone bridge circuits each comprising resistances at a control station, resistances at a controlled station and a balance circuit connecting said sets of resistances, movable contacts at each of said stations in electrical connection with the respective resistances and balance circuits for varying the respective resistances at the two stations, said circuits and resistance-varying means being so related that the dead-points of the respective circuits are non-coincident, means for cutting out each of said circuits as a resistance-varying means thereof reaches or approaches a dead-point therein, and relay mechanism controlled by the balance circuits of said bridge circuits.

20. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of contact bars at said station, movable contacts for connecting said pairs of resistances to said bars respectively, a plurality of pairs of resistances at a controlled station, a plurality of contact bars at said station, movable contacts for connecting said last-named pairs of resistances to said last-named bars respectively, a plurality of balance circuits connecting respective bars at the two stations, means for cutting out each of said balance circuits as a contact in electrical

connection therewith reaches or approaches a dead-point in the corresponding resistances, and relay mechanism controlled by said balance circuits.

21. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of contact bars at said station, movable circumferentially-spaced contacts for connecting said pairs of resistances to said bars respectively, a plurality of pairs of resistances at a controlled station, a plurality of contact bars at said station, movable circumferentially-spaced contacts for connecting said last-named pairs of resistances to said last-named bars respectively, a plurality of balance circuits connecting respective bars at the two stations, means for cutting out each of said balance circuits as a contact in electrical connection therewith reaches or approaches a dead-point in the corresponding resistances, and relay mechanism controlled by said balance circuits.

22. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of contact bars at said station, movable contacts for connecting said pairs of resistances to said bars respectively, a plurality of pairs of resistances at a controlled station, a plurality of contact bars at said station, movable contacts for connecting said last-named pairs of resistances to said last-named bars respectively, a plurality of balance circuits connecting respective bars at the two stations, the contact bars at one of said stations being broken whereby each of said balance circuits is cut out as a contact in electrical connection therewith reaches or approaches a dead-point in the corresponding resistances, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

23. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of contact bars at said station, movable circumferentialy-spaced contacts for connecting said pairs of resistances to said bars respectively, a plurality of pairs of resistances at a controlled station, a plurality of contact bars at said station, movable circumferentially-spaced contacts for connecting said last-named pairs of resistances to said last-named bars respectively, a plurality of balance circuits connecting respective bars at the two stations, the contact bars at one of said stations being broken whereby each of said balance circuits is cut out as a contact in electrical connection therewith reaches or approaches a dead-point in the corresponding resistances, a motor for moving said last-named contacts, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

24. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of pairs of resistances at a controlled station, a plurality of concentric contact bars at each of said stations, a rotatable handle carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resistanes at the control station to the respective contact bars, a rotatable index carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resistances at the controlled station to the respective contact bars, a plurality of balance circuits connecting respective contact bars at the two stations, a motor for rotating said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

25. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of pairs of resistances at a controlled station, a plurality of concentric contact bars at each of said stations, a rotatable handle carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resistances at the control station to the respective contact bars, a rotatable index carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resinstances at the controlled station to the respective contact bars, a plurality of balance circuits connecting respective contact bars at the two stations, means for predeterminately cutting out each of said balance circuits as a contact in electrical connection therewith reaches or aproaches a dead-point in the corresponding resistances, a motor for rotating said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

26. In control apparatus, Wheatstone bridge mechanism comprising a plurality of pairs of resistances at a control station, a plurality of pairs of resistances at a controlled station, a plurality of concentric contact bars at each of said stations, a rotatable handle carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resistances at the control station to the respective contact bars, a rotatable index carrying a plurality of circumferentially-spaced contacts for connecting the pairs of resistances at the controlled station to the respective contact bars, a plurality of balance circuits connecting respective contact bars at the two stations, the contact bars at one of said stations being broken whereby each balance circuit is cut out as a contact

in electrical connection therewith reaches or approaches a dead-point in the corresponding resistances, a motor for rotating said index, and relay mechanism controlled by said balance circuits for controlling the operation of said motor.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

FRÉDÉRIC AUGUSTE HENRI HARLÉ.

Witnesses:
DE WITT C. POOLE, Jr.
FRÉDÉRIC HARLÉ.