

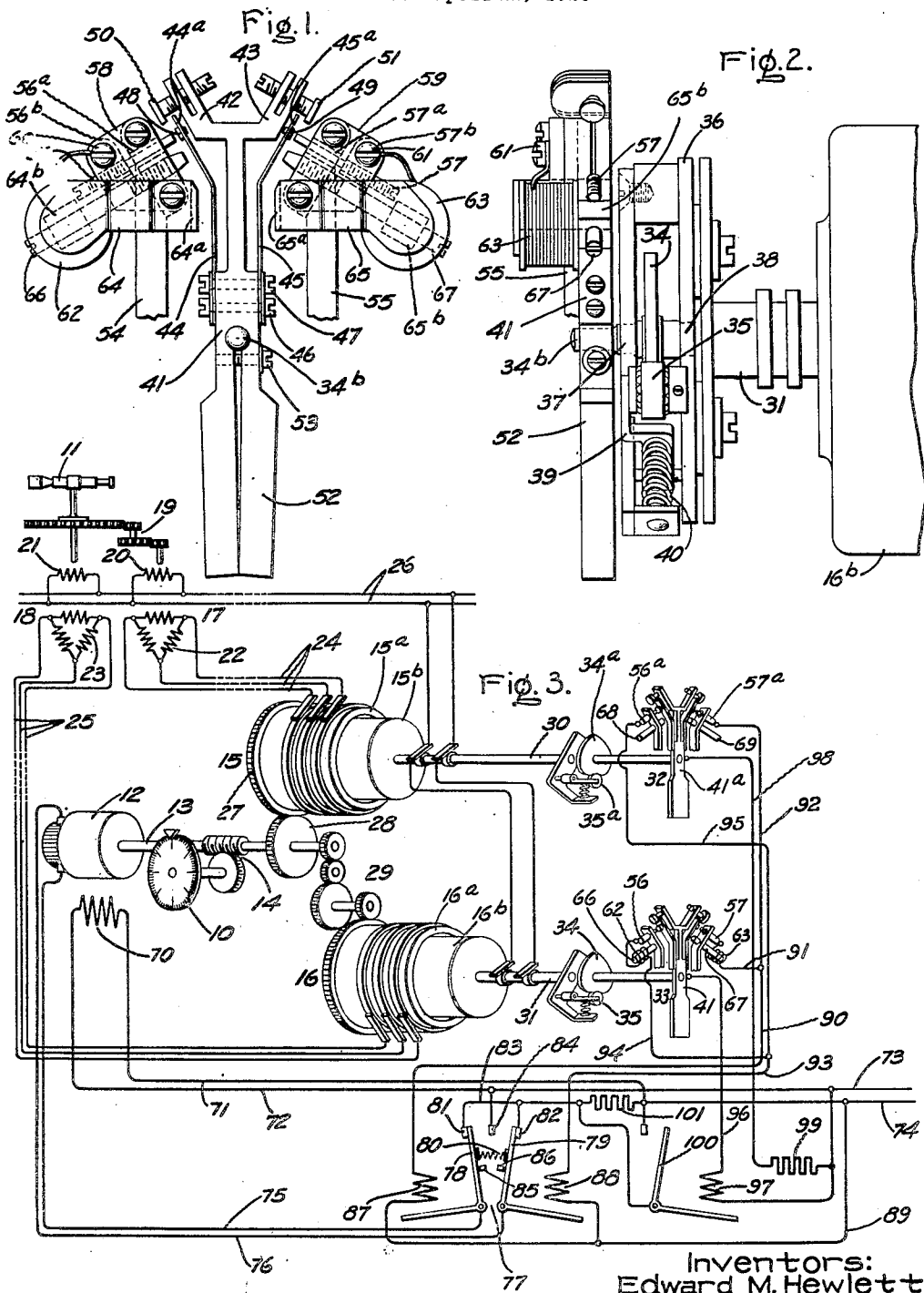
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MEANS FOR REPRODUCING POSITION

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UNITED STATES PATENT OFFICE.

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MEANS FOR REPRODUCING POSITION.

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This invention relates to means for reproducing position and has for its object the provision of improved means for maintaining one object in positional agreement with a second object constituting a controlling object.

More specifically this invention relates to means for driving an object into positional agreement with a remotely situated controlling object of the type in which the driving object is actuated by an electric motor which is controlled by the controlling object through the agency of one or more receivers of the movements of the controlling object. A system of this character is described and claimed, for example, in a patent to Edwin J. Murphy and Leonard P. Hutt, No. 1,559,525 of Oct. 27, 1925, and assigned to the same assignee as this invention. Our invention is particularly useful in reproducing at a distance the position of an object having angular motion, such as a telescope.

Where the motion of the controlling object is transmitted by means of low speed and high speed systems, this motion being reproduced by low speed and high speed receivers, it is important for successful operation of the system that the low speed receiver retain control of the servo motor until the control mechanism operated by the high speed receiver has turned to such a position that it may take over the control. In the aforesaid copending application contact arms are connected to the receivers through heart-cam couplings by means of which the contact is reversed each half revolution. With this control mechanism the contact arm must be turned to some point within the correct revolution with relation to the high speed receiver in order that the high speed receiver can properly control the motor. If this condition does not exist the high speed receiver will cause the motor to run to a wrong position.

Where the driving means for the transmitter of the low speed receiver has an appreciable error, it may happen that the control will be given over to the high speed receiver too soon, due to the effect of this error. This is especially true where the high speed receiver operates at a high ratio such as 72:1 with relation to the low speed receiver. In such case it will be observed that the low speed receiver must retain control to some point within $2\frac{1}{2}^\circ$ from its ac-

curate position to be within 180° from the accurate position of the fine receiver. It will be observed that if there should be an error which is cumulative in the driving connection of the transmitter of the low speed receiver, the low speed receiver must retain control to a point which is $2\frac{1}{2}^\circ$ minus the amount of error from its true position in order that the high speed receiver may be in position to take up the control. Under these conditions, if the low speed receiver gives up control at the $2\frac{1}{2}^\circ$ point, then the high speed receiver will not operate the motor correctly.

In carrying out our invention we provide means for prolonging the control by the low speed receiver in such manner that the low speed receiver must turn very near its accurate position before the control is turned over to the high speed receiver.

For a more complete understanding of our invention, reference should be had to the accompanying drawing in which Fig. 1 is an end elevation view of a control device embodying our invention; Fig. 2 is a side elevation view of Fig. 1; while Fig. 3 is a view showing in diagrammatic fashion a system for reproducing position involving our invention.

Referring to Fig. 3 of the drawing, we have shown our invention in one form as applied to a system for driving an indicating dial 10 in accordance with the movements in a substantially horizontal plane of a remotely situated telescope 11. The dial 10 is turned by means of an electric servo motor 12, the shaft 13 of which is geared to the dial through a worm gear connection 14. The servo motor 12 is controlled by means of two receivers or reproducers of angular motion 15 and 16, which are electrically connected respectively to transmitters 17 and 18 operated by the telescope. As shown, the transmitter 17 is connected to the telescope through a suitable gear train 19 to operate at a suitable high speed ratio such as 72:1 with the movement of the telescope, while the transmitter 18 is driven in a 1:1 ratio with the telescope.

The receiving and transmitting instruments 15 to 18 inclusive may be of any suitable type. Preferably an alternating current type is used, each instrument being provided with a polycircuit armature winding and a field winding. As shown, the trans-

mitters 17 and 18 are provided with field windings 20 and 21 on their rotor members and with delta connected, bi-polar, three phase armature windings 22 and 23 on their stator members. The receivers 15 and 16 are similar in construction to the transmitter. Like points of the armature windings of the receiver 15 and the transmitter 17 are connected by means of three conductors 24, and in similar manner like points of the armature windings of the receiver 16 and the transmitter 18 are connected by three conductors 25. The field windings of all four devices are connected to a single phase alternating current supply source 26.

In the operation of systems of this character for transmitting angular motion, electromotive forces are induced in the armature windings of the transmitting and receiving devices by the cooperating field windings. These voltages result in an exchange of current between the armature windings whereby the rotor of the receiver is turned to a position corresponding to the position of the transmitter in which position the voltages in the two armature windings are equal and opposite. Any movement applied to the transmitter results in an unbalanced voltage condition whereby the receiver is caused to follow. It is a characteristic of instruments of this type that if the receiver lags more than 180° behind its transmitter, its torque will be reversed and be in a direction to cause it to turn into angular agreement by completing a whole revolution of lag.

The stator members 15^a and 16^a of the receivers 15 and 16 are rotatably mounted and are connected to the servo motor 12, the stator 15^a having secured to it a gear 27 which meshes with a gear 28 on the shaft 13 of the motor; while the stator 16^a is connected to the shaft 13 through a reducing gear train 29. The driving ratios of these connections between the stators and the shaft 13 are such that the stators are driven in a 72:1 ratio, the stator 15^a having the higher speed.

The rotors 15^b and 16^b of the receivers have their shafts 30 and 31 connected to contact devices 32 and 33 respectively, whereby the starting, stopping and direction of rotation of the servo motor is controlled in accordance with the movement of the receivers. The contact devices are connected to the receiver shafts through yieldable couplings comprising heart shaped cams 34 and 34^a , with which cooperate spring pressed rollers 35 and 35^a respectively, whereby the receivers are free to turn around immediately, under the small restraint offered by the couplings, to their proper positions independently of the contact devices. The contact devices operated by the receivers 15 and 16 are somewhat similar in construction and conse-

quently only one will be described in detail, i. e., the device driven by the low speed receiver 16.

Referring to Figs. 1 and 2, a frame or support 36 is secured to the end of the rotor shaft 31 of the low speed receiver. The heart shaped cam 34 is rotatably mounted in this frame 36 on a shaft 34^b which is mounted in bearings 37 and 38 so that its axis of rotation is coincident with the axis of shaft 31. The roller 35 is carried on the end of an arm 39, which is pivotally mounted on the frame 36. Bearing against the arm 39 is a helical spring 40 which forces the arm toward the heart-cam and thereby maintains the roller in engagement with the cam. The heart-cam is constructed and arranged on its shaft 34^b in such manner that the roller 35 is caused by the spring 40 to seek a position of rest at the base of the cam, as shown in Fig. 3.

The outer end of the cam shaft 34^b projects beyond the frame 36, and has secured to it a contact arm 41. This contact arm is provided with two branches 42 and 43 on its upper end extending in directions to form an acute angle with each other. On opposite sides of the contact arm are secured resilient contact members 44 and 45, made of a suitable magnetic material, such as steel. These members are secured to the contact arm at their lower ends only, for example, by means of bolts 46 and 47, and are provided on their upper ends with contacts 48 and 49. Upper portions 44^a and 45^a of the contact members are bent outwardly in parallelism with the branches 42 and 43. The upper ends of the members 44 and 45 terminate substantial distances below the ends of the branches 42 and 43, and extend under stops 50 and 51 carried by the branches.

As shown, these stops consist of headed members which are threaded and screwed into tapped bores in the branches 42 and 43. As shown, the upper ends of the branches 42 and 43 may be bifurcated to form two resilient prongs which are sprung together slightly so that the stops when screwed into them are secured in any adjusted position. The upper ends of the members 44 and 45 project under the heads of the stops 50 and 51, which, therefore, limit the outward movement of the members with relation to the contact arm.

The lower end of the contact arm is provided with a weight 52, and is also bifurcated so that the two portions thereby formed may be drawn together by means of a screw 53, and the contact arm thereby clamped securely on the shaft 34^b of the heart-cam.

Closely adjacent the contact arm on opposite sides thereof are two stationary contact members 54 and 55, the upper ends of which extend substantially parallel with the

branches 42 and 43. On the upper ends of the stationary contact members in insulated relation therewith are contact screws 56 and 57, the inner ends of which terminate opposite the contacts 48 and 49 respectively and form cooperating contacts therewith. The inner ends of the contact screws 56 and 57 are of reduced size and extend through electrically insulating bushings 56^a and 57^a. As shown, the larger outer ends of the screws are threaded and secured in tapped holes in blocks 56^b and 57^b, made of a suitable electrically conducting material such as brass, and these blocks 56^b and 57^b are secured in turn to insulating plates 58 and 59 which are mounted on the upper ends of the members 54 and 55, the various mechanical connections being made by suitable screws. The plates 58 and 59 may be made of any suitable electrically insulating material, such as bakelite. The screws 60 and 61 securing the blocks 56^b and 57^b respectively to the plates 58 and 59 are also utilized as binding posts for making electrical connections with the contact screws 56 and 57.

Magnet coils 62 and 63 are secured to the upper ends of the members 54 and 55 respectively. These magnet coils are provided with cores of suitable material, such as iron. The cores consist of plates 64 and 65 secured to the members 54 and 55 and having their inner ends bent over to provide pole faces 64^a and 65^a adjacent and opposite the members 44 and 45 respectively. The outer ends of the plates 64 and 65 terminate at the sides of the coils respectively, and carry core members 64^b and 65^b which extend through the coils. The remaining portions of the cores for the coils are formed by screws 66 and 67 which extend through the members 64^b and 65^b and terminate adjacent the members 44 and 45 respectively, thus forming the opposite poles of the electromagnets. The screws 66 and 67 are mounted in tapped holes in the members 54 and 55 and can be adjusted as desired. One terminal of the coil 62 is connected to the contact screw 56 by means of the screw 60, and one terminal of the coil 63 is connected to contact screw 57 by means of the screw 61.

The contact device 32, operated by the high speed receiver 15 differs from the contact device 32 shown in Figs. 1 and 2 mainly in that no electromagnets are used. If desired, bar magnets 68 and 69 may be provided for the purpose of effecting quick make and break of the contacts, as shown in Fig. 3. These bar magnets, however, are not the equivalents of the electromagnets of the device 33.

Referring now to Fig. 3, the servo motor 12 is shown as a shunt type motor having its field winding 70 permanently connected through conductors 71 and 72 to the supply

current supply source. The armature winding of the motor is connected to the supply mains 73 and 74 through conductors 75 and 76 and a relay switch 77 comprising two pivoted contact arms 78 and 79 which are normally forced apart by an insulated spring 80 into engagement with the fixed contacts 81 and 82 respectively, as shown in the drawing. When the contact arms are in these positions, the armature is short circuited through a conductor 83 connecting the contacts 81 and 82 together, and also connecting them to the supply main 74. Between the contact arms is a stationary contact 84 which is electrically connected to the supply main 73. By moving the contact arm 78 into engagement with contact 84, the armature of the motor 12 is connected across the supply means 73 and 74 for operation in one direction, while by moving the contact arm 79 into engagement with contact 84 the armature is connected across the supply mains with the opposite polarity for operation in the opposite direction. Insulated stops 85 and 86 are provided on the contact arms respectively, and are arranged to engage with each other when one of the contact arms is in engagement with contact 84 and thereby insure that when one of the contact arms is in engagement with contact 84 the other shall remain in contact with 81 or 82, as appropriate.

The contact arms 78 and 79 are operated by magnet coils 87 and 88 respectively. One terminal of each of the coils is connected through a conductor 89 to the supply main 74. The remaining terminal of the coil 87 is connected by means of conductors 90 and 91 through the magnet coil 63 to the stationary contact screw 57, and also by means of a conductor 92 leading from conductor 91 to the contact screw 57^a of the contact device 32. The remaining terminal of the coil 88 is connected by means of conductors 93 and 94 through the magnet coil 62 to the contact screw 56, and also by means of a conductor 95 connecting with the conductor 93 to the contact screw 56^a of the contact device 32. It will be understood that the contact screws 56^a and 57^a associated with the contact device 32 correspond respectively with the contact screws 56 and 57 associated with the contact device 33. The contact arm 41 is connected by means of a conductor 96 through a magnet coil 97 to the supply main 73, while the corresponding contact arm 41^a of device 32 is connected through a conductor 98 and a resistance 99 to the supply main 73.

The magnet coil 97 operates a switch 100 and when energized closes the switch 100, thereby short circuiting a resistance 101 which is connected in the circuit between the stationary contacts 81 and 82 and the

supply main 74. The resistance 99 is substantially of the same value as the resistance of the magnet coil 97. It is provided to prevent short circuiting and consequent de-energization of the coil 97 in case the two are connected in parallel through the contact devices.

In the operation of the system it will be understood that when the telescope is moved to a new bearing the rotors of the receivers reproduce this movement in their respective ratios whereby the contact arms 41 and 41^a are actuated. Assume, for example, that the telescope is rotated rapidly through a considerable angle in such direction that the contact arm 41 is thrown into engagement with contact 56, the contact arm 41^a being thrown into engagement with contact 56^a. A control circuit is thereby closed from the supply main 74 through conductor 89, the magnet coil 88, conductors 93 and 94, contact arm 41, conductor 96 and coil 97 to the supply main 73. This energizes coil 88 which throws the contact arm 79 into engagement with the stationary contact 84 whereby a circuit is closed for the armature of the servo motor 12 from supply main 74 through contact arm 78, conductor 75, the armature, conductor 76, and contact arm 79 to the supply main 73. The servo motor is thus caused to rotate in a direction to cause the dial 10 to follow the telescope. By reason of the fact that coil 97 is energized, the resistance 101 is short circuited during the operation of the motor under the control of contact arm 41, and the motor consequently operates at high speed. The motor 12 at the same time drives the stators 15^a and 16^a in directions opposite to the movements of their rotors whereby the rotors are carried back toward their original angular positions.

As the motor continues to rotate the dial and the stators, it will be observed that the rollers 35 and 35^a will gradually move back toward their seats at the bases of the heart-cams and finally, when the dial 10 has been driven into angular agreement with the telescope within the limit of the accuracy of the low speed receiver 16, contact arm 41 will be moved to disengage contact 56, thus transferring the control to the high speed receiver for the accurate adjustment of the dial. The contact arm 41^a will then be in engagement with contact 56^a whereby a circuit is maintained for the coil 88, this circuit being from supply main 74 through conductor 89, the coil 88, conductors 93 and 95, contact arm 41^a, conductor 98 and resistance 99 to the supply main 73. The motor circuit is thus maintained and the motor continues the adjustment of the dial, the circuit of coil 88 being broken by contact arm 41^a when the dial has been moved into accurate angular agreement. It will be understood that when

the circuit of the coil 88 is broken the contact arm 79 is thrown into engagement with contact 82 by the spring 80 to short circuit the armature of the motor and bring it to rest quickly by dynamic braking.

It will be observed that when the high speed receiver 15 has control, the coil 97 is not energized and the resistance 101 is, therefore, included in the armature circuit of the motor and consequently the motor operates at a slower speed, and can, therefore, be stopped much quicker than would be possible when operating at high speed under the control of the low speed receiver. This facilitates the stopping of the dial in accurate angular agreement with the telescope.

When the telescope is moved in the opposite direction the contact arms 41 and 41^a are also moved in the opposite direction whereby the armature circuit is closed in the reverse direction, the low speed receiver making the coarse adjustment of the dial and the high speed receiver making the accurate adjustment substantially as previously described. In this case, the contact arm 41 engages the contact 57, thereby closing a circuit from supply main 74 through conductor 89, coil 87, conductors 90 and 91, contact arm 41 and coil 97 to the supply main 73. Upon the completion of the coarse adjustment the control is taken over as before by the high speed receiver, contact arm 41^a then being in engagement with contact 57^a, whereby a circuit is closed from the supply main 74 through conductor 89, coil 87, conductors 90 and 92, contact arm 41^a, conductor 98 and resistance 99 back to the supply main 73.

The heart-cam couplings between the contact arms 41 and 41^a and their respective receivers permit the receivers to turn at once to positions of angular agreement with their transmitters, as previously noted. This feature is of particular importance where the receivers are switched on the transmitters with the dial considerably out of angular agreement with the telescope. If a rigid connection were provided, so that the receivers would be prevented from snapping at once into angular agreement with their transmitters, excessive current flow and consequent overheating of the transmitting and receiving instruments would result, and furthermore the accuracy of other receiving instruments which might be operating on the same circuit would be seriously affected.

Another function of the heart-cam coupling is to cause the dial to be driven through the shortest angle into positional agreement. For example, in case the dial should lag more than 180°, for any reason whatever, as might occur if the telescope were swung around with great rapidity, it will be observed that the roller 35 connected to the low speed receiver will pass over the point

of its heart-cam 34, thus reversing the armature circuit of the motor and causing it to reverse and drive the dial in the opposite direction into angular agreement by completing a revolution of lag.

When the low speed receiver has control, the rotor of the high speed receiver may and probably will be turned with its stator by the motor through a number of complete revolutions, the roller 35^a then moving over its heart-cam 34. When this takes place it will be observed that the contact arm 41^a will be reversed each half revolution of the receiver 15 due to the effect of the heart-cam, but this has no effect on the operation of the motor since the stops 85 and 86 prevent the operation of both of the contact arms 78 and 79 at the same time, and consequently prevent the high speed receiver from taking control as long as the low speed receiver has control.

Ordinarily during the usually relatively slow training of the telescope, the dial is caused to follow the telescope under the control of the high speed receiver only, and it is only when switching or high speed training is done that the low speed receiver is called upon to take control. The adjustment of the contact devices 32 and 33 is such that just before the lag of the dial is sufficient to cause the roller 35^a to move over the point of the heart-cam 34^a the contact arm 41 will make contact so that should the roller 35^a move over the point of the heart-cam 34^a and reverse the contact arm 41^a, the motor circuit will be maintained in the proper direction by the contact arm 41.

It will be observed that due to the reversing effect of the heart-cam coupling each half revolution, the low speed receiver must adjust the dial with sufficient accuracy to bring the roller 35^a onto the correct revolution of the heart-cam 34^a, i. e., within 180° of its correct position on the heart-cam, before the high speed receiver takes control. If this condition is not established when the high speed receiver takes control, the motor will be reversed and the dial driven in the wrong direction. With the 72:1 speed ratio for the high speed receiver previously assumed, this means that the low speed receiver must maintain control until the dial has been moved to some point less than 2½° from its accurate position. No difficulties would be encountered in making the proper adjustments of the contact devices 32 and 33 to bring this about, provided there are no inaccuracies in the various driving connections for the transmitting and receiving devices. Ordinarily, such inaccuracies are due to inaccuracies in manufacture, wear, etc. The driving connection between the telescope and the transmitter 18 may have an appreciable error, and ordinarily the driving gear train between the motor and the stator 16^a

of the low speed receiver will have an appreciable error. Such errors, particularly in gear trains, are cumulative in some positions and subtractive in other positions, and consequently the control mechanism must be adjusted accordingly.

Let it be assumed that the inaccuracy in the driving connections of the low speed receiver amounts to 1¼°. When this error is cumulative, the low speed receiver must take the control at a point somewhat less than 2½° minus 1¼° or 1¼° from the accurate position of the dial in order that the high speed receiver may operate properly, but when this error is subtractive the low speed receiver must take control at a point greater than 1¼° from the accurate position of the dial, else it may take control and operate the dial due to error displacement. It is obvious from this that with an error of 1¼° which may be either cumulative or subtractive, it would be impossible to correctly adjust the contact mechanism of the low speed receiver as long as the control is given up at approximately the same point as it is taken over. It is the function of the electromagnets 62 and 63 to permit such an adjustment, whereby the control, once taken at the proper point, will be retained until the dial is very close to its accurate position.

It will be observed that since the magnet coils 62 and 63 are connected in the control circuits they are not energized until their particular control circuit is closed by the contact arm, and consequently the electromagnets do not exert any attractive force on the arms 44 and 45 before contact is actually made. Thus, when the contact arm engages the contact 56 the magnet coil 62 is energized and maintains the contacts in engagement until they are positively separated by the engagement of stop 50 with the end of member 44. The separation of the contacts, however, opens the circuit of the magnet coil 62 whereby the member 44 is released. The effect of magnet coil 63 on member 45 is similar. Where the error is plus or minus 1¼° in the driving connections, the adjustment of the contacts 56 and 57 would be such that contact would be made when the dial is somewhat more than 1¼° but less than 2½° from its accurate position, and the adjustment of the screws 66 and 67 and the stops 50 and 51 would be such that the contact once made would not be broken until the dial had been turned to a position less than 1¼° from its accurate position.

While we have described our invention as embodied in concrete form and as operating in a specific manner in accordance with the provisions of the patent statutes, it should be understood that we do not limit our invention thereto, since various modifications thereof will suggest themselves to those skilled in the art without departing from the

spirit of our invention, the scope of which is set forth in the annexed claims.

What we claim as new and desire to secure by Letters Patent of the United States is:—

5 1. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, a motor for driving said driven object, control means for said motor actuated in accordance with the movements of said objects
10 arranged to operate said motor upon the occurrence of a predetermined positional disagreement between said objects, and auxiliary means responsive to a condition of operation of said motor for maintaining said motor in operation until said driven object has been moved to a predetermined relative position in which the positional disagreement between said objects is less than that required to start said motor.

2. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, control means for said motor, operating connections between said control means and said objects whereby said motor is caused to drive said driven object into positional agreement with said controlling object, and auxiliary means responsive to a condition of operation of said motor associated with said control means for maintaining said control means in closed circuit position until said driven object has been moved to a predetermined position after said control means would otherwise be in open circuit position.

3. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, means operated by said controlling object for closing the circuit of said motor upon a predetermined angular disagreement between said objects whereby said motor is caused to drive the driven object into angular agreement with said controlling object, holding means responsive to the closing of said motor circuit for maintaining said circuit closed as said driven object is moved toward angular agreement with said controlling object, and means operated by said controlling object for opening said motor circuit when said driven object has assumed a predetermined position with relation to said controlling object, whereby said holding means is rendered ineffective.

4. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, means operated by said controlling object for closing a control circuit for said motor, auxiliary means responsive to the closing of said circuit for maintaining said circuit closed, and means operated by said

controlling object for opening said circuit when said driven object has assumed a predetermined position with relation to said controlling object.

5. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, a pair of spaced contacts, a contact arm movable between said contacts to control the circuit of said motor for either direction of rotation, driving connections between said contact arm and said objects whereby said contact arm is moved to engage one of said contacts to start said motor upon movement of said controlling object and moved toward an intermediate position between said contacts in response to movement of said driven object so that said motor is caused to drive said driven object into positional agreement with said controlling object, and means responsive to a condition of the motor circuit whereby contact once established is maintained until said contact arm has been moved toward an intermediate position between said contacts a predetermined distance from the position in which contact was established.

6. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, a control device for said motor operated in accordance with the movements of said objects provided with a resilient contact member, a magnet coil energized upon the closing of a circuit by said contact member arranged to exert an attractive force on said contact member to maintain said circuit closed, and means for moving said contact member against the pull of said magnet coil to open the circuit of said motor.

7. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, a pair of spaced contacts, an arm movable between said contacts in accordance with the movements of said objects, resilient contact members carried by said arm arranged to engage said contacts to control the circuit of said motor for either direction of rotation, magnet coils in the circuits with said contacts, each coil being arranged to exert an attractive force on one of said resilient contact members when its circuit is closed by said resilient member and thereby maintain said motor circuit closed when said arm is moved toward an intermediate position between said contacts, and stops carried by said arm arranged to move said resilient members against the pull of said magnet coils to open the circuit therethrough.

8. Means for reproducing position comprising in combination with a controlling

movable object and a driven movable object, an electric motor for driving said driven object, a fixed contact, a resilient contact member made of magnetic material operated
 5 by said controlling object arranged to close a control circuit for said motor when moved into engagement with said fixed contact upon movement of said controlling object, a magnet coil in said control circuit arranged
 10 to exert an attractive force on said contact member to maintain said circuit closed, and means operated by said driven object co-operating with said contact member to open said circuit against the pull of said magnet
 15 coil when said driven object has assumed a predetermined position with relation to said controlling object.

9. Means for reproducing position comprising in combination with a controlling
 20 movable object and a driven movable object, an electric motor for actuating said driven object, a pair of spaced fixed contacts, an arm actuated in accordance with the movements of said objects, a pair of resilient contact members made of magnetic material
 25 on said arm movable by said controlling object into engagement with one or the other of said fixed contacts to close control circuits for said motor for both directions of rotation, magnet coils adjacent said fixed contacts connected in said control circuits arranged to exert an attractive force on their
 30 respective contact members when energized by the closing of a control circuit thereby and maintain said circuit closed when said arm is turned toward an intermediate position between said fixed contacts as said driven object is moved toward positional agreement
 35 with said controlling object, and means carried by said arm for engaging said resilient members to open the control circuit when said driven object has assumed a predetermined position with relation to said controlling object.

45 10. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, a motor for driving said driven object, control means for said motor, low and high
 50 speed receivers of angular motion responsive to the movements of said controlling object, operating connections between said receivers and said control means whereby said motor is operated under the control of
 55 said low speed receiver for a coarse adjustment and under the control of said high speed receiver for a fine adjustment so as to drive said driven object into positional agreement with said controlling object, said
 60 control means being arranged to operate said motor under the control of said low speed receiver upon the occurrence of a predetermined positional disagreement between said objects, and auxiliary means responsive

to a condition of the motor circuit for causing said low speed receiver to retain control until said driven object has been moved to a predetermined relative position in which the positional disagreement between said objects is less than that required to
 65 cause said low speed receiver to take control.

11. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object,
 75 a motor for driving said driven object, controlling means for said motor, low and high speed receivers of angular motion responsive to the movements of said controlling objects, operating connections between said receivers
 80 and said control means, and between said driven object and said control means, whereby said motor is operated under the control of said low speed receiver for a coarse adjustment and under the control of
 85 said high speed receiver for a fine adjustment so as to drive said driven object into positional agreement with said controlling object, said control means being arranged to operate said motor under the control of
 90 said low speed receiver upon the occurrence of a predetermined positional disagreement between said objects, holding means responsive to the control of said motor by said low speed receiver causing said low speed receiver to retain control until said objects are
 95 in closer positional agreement than when said motor was started, and means for transferring the control of said motor to said high speed receiver when said driven object
 100 has assumed a predetermined position with relation to said controlling object, whereby said holding means is rendered ineffective.

12. Means for reproducing position comprising in combination with a controlling
 105 movable object and a driven movable object an electric motor for driving said driven object, low and high speed receivers of angular motion responsive to the movements
 110 of said controlling object, control means operated by said receivers and by said driven object for opening and closing control circuits for said motor so that said motor is operated under the control of said low speed
 115 receiver for a coarse adjustment and under the control of said high speed receiver for a fine adjustment and thereby caused to drive said driven object into positional agreement with said controlling object,
 120 means responsive to the closing of a control circuit by said low speed receiver for maintaining said circuit closed, and means for opening said control circuit when the driven object has assumed a predetermined position
 125 with relation to said controlling object in which the positional disagreement between said objects is less than when said motor

was started, whereby the control of said motor is turned over to said high speed receiver.

13. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, low and high speed receivers of angular motion responsive to the movements of said controlling object, control devices for said motor operated by said receivers respectively, a resilient contact member for the control device operated by said low speed receiver, a magnet coil energized on the closing of a circuit by said contact member arranged to exert an attractive force on said contact member to maintain said circuit closed, and means for moving said contact member against the pull of said magnet coil to open said circuit, whereby the control of said motor is turned over to said high speed receiver.

14. Means for reproducing position comprising in combination with a controlling movable object and a driven movable object, an electric motor for driving said driven object, low and high speed receivers of angular motion responsive to the movements of said controlling object, said receivers having their

stators rotatably mounted, arms movable by said receivers respectively between pairs of spaced contacts to start said motor, driving connections between said motor and said stators arranged to turn said receivers in directions opposite to the movements of their rotors and thereby move said arms toward intermediate positions between said pairs of spaced contacts to stop said motor, resilient contact members carried by the arm operated by said low speed receiver, and magnet coils in the circuits with said contact members, each coil being arranged to exert an attractive force on one of said contact members when its circuit is closed and thereby cause the low speed receiver to retain control of said motor when said low speed receiver arm is moved toward an intermediate position between said contacts, and stops carried by said arm arranged to move said resilient members against the pull of said magnet coils to open the circuit there-through, whereby the control is turned over to said high speed receiver.

In witness whereof, we have hereunto set our hands this 21st day of April, 1925.

EDWARD M. HEWLETT.
WALDO W. WILLARD.