

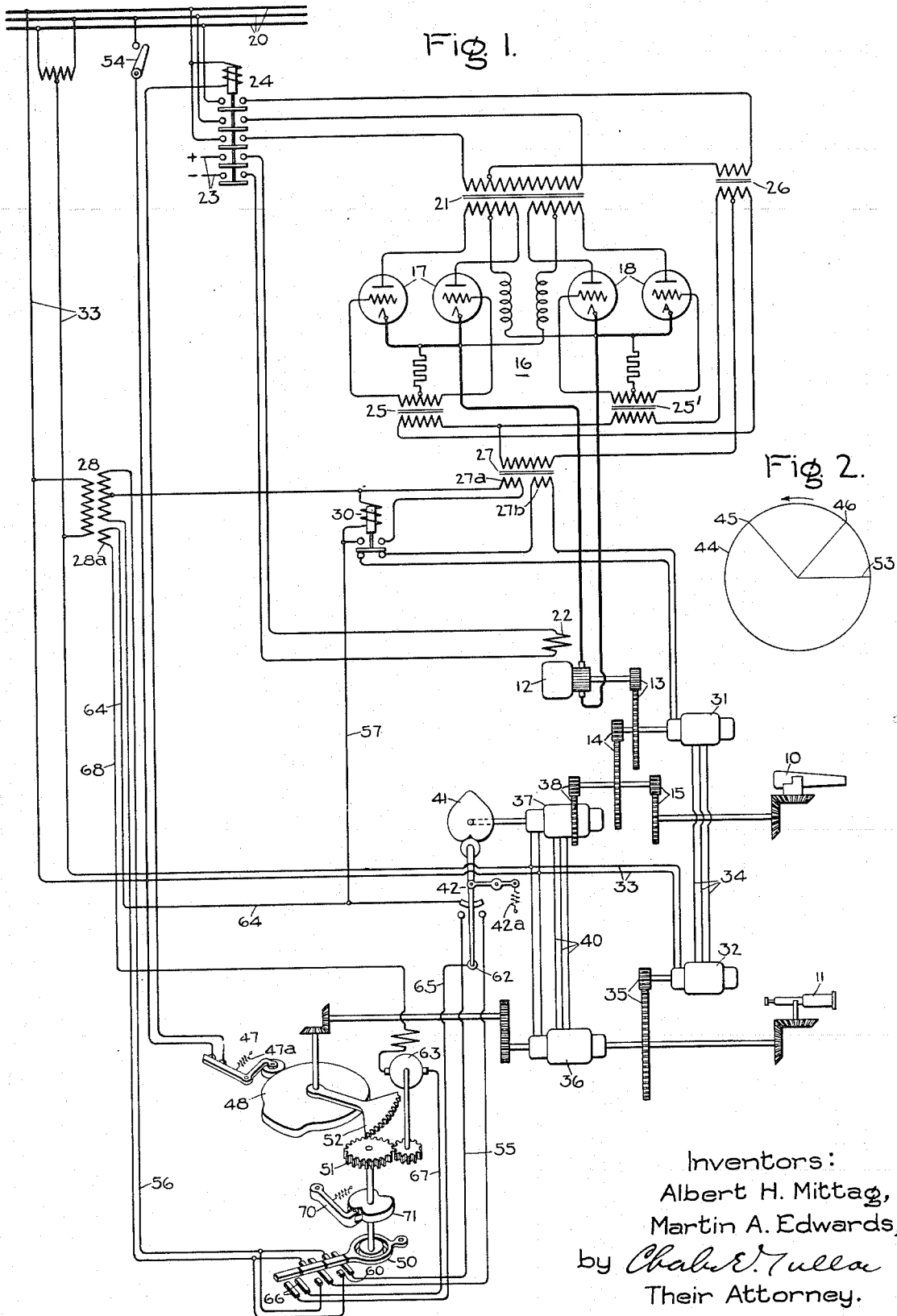
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CONTROL SYSTEM

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CONTROL SYSTEM

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This invention relates to control systems, more particularly to follow-up systems in which a relatively heavy object is driven into positional agreement with a pilot device, and it has for an object the provision of a simple, reliable and improved system of this character.

More specifically the invention relates to follow-up systems in which the driven object is prevented from following the pilot device into a predetermined portion of its path of rotation, and a further object of this invention is the provision of means for preventing the driven object from following the pilot device into this predetermined portion of the path of rotation, and a further object of this invention is the provision of means for preventing the driven object from following the pilot device into this predetermined portion of the path and for driving the driven object into positional agreement with the pilot device when it again emerges from this restricted portion of the path.

In carrying the invention into effect in one form thereof the control device is rotatable to all positions in a closed path and means are provided for arresting the following motion of the driven object at either limit of a restricted portion of the path while the pilot device continues on through the restricted portion, and means are also provided for causing the driven object to rotate in the reverse direction into correspondence with the control device when the latter emerges from this restricted portion of its path at the opposite limit.

In illustrating the invention in one form thereof, it is shown as embodied in a follow-up control system in which a gun is caused to follow the motion of a directing telescope and in which the gun is prevented from following the telescope into a corresponding portion of its travel, usually referred to as a "blind" for preventing the gun from firing in a certain area; for example to prevent the gun from firing into the superstructure of a ship on which it is mounted, or for preventing the gun from striking a part of the ship.

For a better and more complete understanding of the invention reference should now be had to the following specification and to the accompanying drawing in which Fig. 1 is a simple diagrammatical representation of an embodiment of the invention applied to the above-mentioned gun-fire problem and in which Fig. 2 is a diagram serving to explain the operation.

Referring now to the drawing a relatively heavy object, such for example as a naval gun 10 is rotated in train with a control or pilot device

represented by the telescope 11. The gun 10 is driven by any suitable driving means such for example as the direct current electric motor 12 to the drive shaft of which the gun mounting platform is connected by suitable reduction gearing 13, 14 and 15. Direct current is supplied to the armature of this motor by any suitable means such for example as the electric valve apparatus 16 illustrated as comprising a pair of electric valves 17 for supplying direct current in one direction to the armature of the motor 12 and a second pair of electric valves 18 for supplying current to the armature in the reverse direction. The electric valve apparatus is in turn supplied from a suitable source of alternating voltage, represented by the three-supply lines 20 through a suitable supply transformer 21, the primary winding of which is connected to the upper and middle supply lines 20 and the secondary windings of which are connected to the anodes of the electric valve apparatus. The direct current motor 12 is provided with a separately excited field winding 22 which is supplied from any suitable separate source of direct current such for example as that represented by the supply lines 23. A suitable electromagnetic switching device 24 is provided for the purpose of establishing and interrupting the connections from the sources 20 and 23 to the electric valve apparatus 16 and the motor field winding 22 respectively.

Although the electric valves may be of any suitable type, they are preferably of the three-electrode type, into the envelope of which a small quantity of an inert gas such for example as mercury vapor is introduced after exhaust; the presence of the mercury vapor within the tubes serving to change the usual electronic discharge into an arc stream thereby constituting the tubes grid controlled arc rectifiers. As is well understood by persons skilled in the art, the average value of the current flowing in the anode circuit of electric valves of this character can be varied by varying the phase relationship between the voltages applied to the grids and to the anodes respectively. When the grid voltage is substantially in phase with the anode voltage, the current flowing in the anode circuit is maximum and when the grid voltage is 90° lagging with respect to the anode voltage, the current flowing in the anode circuit is substantially zero. For intermediate phase relationships, the current flow has corresponding intermediate values.

Alternating voltage is supplied to the grids of the pairs of electric valves 17 and 18 by means

of grid transformers 25 and 25' respectively, the primary windings of which are connected in series relationship with the secondary windings of a grid biasing transformer 26, one terminal of the primary winding of which is connected to the lower supply line 20 and the opposite terminal of which is connected to an intermediate point of the primary winding of the supply transformer 21. This intermediate connection serves to bias the grid voltages of the electric valve apparatus approximately to the 90° relationship with respect to the anode voltages so that neither of the pairs of valves 17 supplies current to the armature of the motor 12.

For the purpose of varying this phase relationship of the grid and anode voltages a component voltage is supplied to the grid circuit by means of a transformer 27, one terminal of the secondary winding of which is connected to a midpoint between the primary windings of the grid transformers 25 and 25' and the opposite terminal of the secondary winding of which is connected to a mid-point of the secondary winding of the bias transformer 26. This component voltage is substantially in phase with the anode voltage of one pair of valves 180° out of phase with the anode voltage of the other pair of valves, and thus it will be seen that by varying the magnitude of this component voltage the phase relationship of the resulting grid voltage, i. e., the vectorial sum of the component voltage and the grid bias voltage may be varied as desired and the magnitude of the current supplied to the electric motor 12 correspondingly varied. As will be observed the transformer 27 is provided with two primary windings 27a and 27b. The primary winding 27a is connected to the supply source 20 through a supply transformer 28 and supplies a component voltage of constant magnitude to the grid circuit of the electric valve apparatus when the electromagnetic switching device 30 is operated to its upper position, whilst when the switch 30 is operated to its lower position, the primary winding 27b is connected to the source 20 through rotary induction devices 31 and 32 respectively under the control of the driven object 10 and the pilot device 11 by means of which the component voltage supplied to the grid circuit of the electric valve apparatus is varied in magnitude in proportion to the angular disagreement of the control device and the driven object.

The rotary induction device 32 usually referred to as the transmitter comprises a rotor member provided with a single phase winding (not shown) the terminals of which are connected to the supply source 20 by means of conductors 33 and further comprises a stator member provided with a distributed three-element winding (not shown) which is physically similar to the three-phase winding of a poly-phase dynamo-electric machine. The rotary induction device 31 usually termed the receiver is in all respects identical with the transmitter 32, and its single phase winding is connected with the terminals of the primary winding 27b whilst its three-element winding is connected to the three-element winding of the transmitter 32 by means of the three conductors 34. The primary winding of the transmitter 32, when energized, produces an alternating magnetic field by means of which a voltage is induced in the stator winding thereby causing current to flow in the stator windings of the receiver 31 and in turn producing an alternating magnetic field by means of which a voltage is induced in the single phase winding of the rotor member of the

receiver. When the axis of the single phase winding of the receiver 31 is at right angles to the axis of the magnetic field produced by the stator windings no voltage is induced in the single phase winding, whilst when the axis of this winding is substantially parallel with the axis of the magnetic field of the stator windings, a maximum voltage is induced in the single phase winding and applied to the grid circuit of the electric valve apparatus. Rotation of the rotor member of the transmitter causes the axis of its magnetic field to rotate in space and similarly to produce a rotation in space of the magnetic field produced by the stator windings of the receiver 31. Thus a rotation of the rotor member of the transmitter 32 results in a variation in the magnitude of the voltage supplied to the grid circuit of the electric valve apparatus.

In order that a very small rotation of the telescope 11 shall produce a comparatively large variation in the voltage applied to the grid circuit of the electric valve apparatus, gearing 35 having a large ratio, for example 36:1 is interposed in the connections between the telescope turntable and the rotor of the transmitter 32. When the driving ratio of 36:1 is employed between the telescope and the transmitter the rotor of the transmitter rotates 180° while the telescope rotates 5° and consequently if the telescope becomes slightly more than 5° out of correspondence with the gun 10 the axis of the single phase winding of the receiver 31 becomes slightly more than 180° out of correspondence with the axis and of the alternating magnetic field of the stator windings and the voltage induced in this winding is reversed with the result that the electric valve apparatus reverses the current supplied to the motor 12 tending to cause the latter to reverse and drive the gun to a position 10° out of correspondence with the telescope. In order to prevent this condition, an electrical motion transmitting and receiving system comprising a transmitter 36 and a receiving device 37 directly connected to the telescope 11 and the gun 10 with a 1:1 driving connection is provided for the purpose of taking over the control before the telescope 11 and the gun 10 become 5° out of correspondence with each other.

The transmitting device 36 is in all respects identical with the transmitter 32 and the receiver 37 differs from the receiver 31 in that its stator is rotatably mounted in ball bearings and is rotated once for each rotation of the gun 10 to which it is connected through the 1:1 driving connections 38 and 15. The single phase rotor windings of the transmitter and receiver 36 and 37 are both connected to the conductors 33 so as to be supplied with single phase alternating voltage whilst the three-element stator windings are connected together by means of the conductors 40. When the axes of the rotor windings of the transmitter 36 and receiver 37 are in correspondence with each other, the voltages induced in the stator windings of both devices are equal and opposite with the result that substantially no current flows in the conductors 40 whilst when the rotor of the transmitter is rotated with respect to the stator the voltages induced in the stator windings of these devices become unbalanced with the result that a current flows from one device to another through the conductors 40 which produces a torque between the rotor and stator members of the receiver tending to rotate the rotor member of the receiver in a direction to restore the condition of correspondence between the axes of the

rotor members of both devices and also to restore the balanced condition between the voltages induced in the stator windings of both devices. A heart-shaped cam member 41 is mounted on the shaft of the rotor of the receiver 37 and engages with the cam follower of a switching device 42 so as to operate the contact arm of the latter from its central or neutral position to engage the right or left hand cooperating stationary contacts depending upon the direction of rotation of the cam member 41. When the movable contact arm of the switching device 42 is in engagement with either stationary contact the switching device 30 is energized and operated to the upper position in which it takes the control of the electric valve apparatus away from the high speed transmitter and receiver 32, 31 and transfers this control to the single speed system 36, 37.

The telescope 11 is rotatable into any desired position of a closed circular path such for example as that represented by the circle 44 of Fig. 2. The gun 10 must not follow the telescope 11 into a certain restricted portion of this circular path such for example as the arc subtended by the radial lines 45, 46 in order, as previously pointed out, to prevent the gun from firing into the superstructure of the ship upon which it is mounted or from striking some portion of the ship. In order to prevent the gun from following the telescope into this restricted area, a switching device 47, operated by a cam 48 driven by the telescope 11 serves to deenergize the electric valve apparatus 16 and the gun driving motor 12 when the telescope 11 enters the restricted area between the lines 45, 46. Similarly a cam operated switching device 50 actuated by the cam 48 to which it is connected by means of gear 51 and gear sector 52 serves when the telescope enters the lines to reverse the connections of the primary winding 27a of the grid transformer 27 so that after the telescope 11 has continued through this line and emerged at the opposite limit and the electric valve apparatus 16 is again energized it will supply current in the reverse direction to motor 12 and thereby cause the latter to drive the gun 10 in the reverse direction into correspondence with the telescope 11.

With the above understanding of the apparatus and connections and their organization in the completed system, the operation of the system itself will readily be understood from the detailed description which follows:

Assume that the telescope 11 and the gun 10 are in correspondence with each other as represented by the horizontal line 53. The manually operated switch 54 is first operated to the closed position establishing an energizing circuit for the operating coil of switching device 24 which circuit is readily traced from the upper supply line of the source 20 through the operating coil 24 and the contacts of switching device 47 to the middle supply line of the source 20. The switching device 24 in response to the energization of its operating coil is moved to the upper position in which its upper three contacts connect the terminals of the anode supply transformer 21 and the grid bias transformer 26 to the three supply lines 20 and in which its lower pair of contacts connects the direct current field winding 22 of the gun driving motor 12 to the supply lines 23. Rotation of the telescope 11, for example, in a counter clockwise direction as seen in Fig. 2 causes the phase relationship of the resultant voltage applied to one of the pairs of electric valves 17, 18 to be advanced with respect to the

anode voltage and to be retarded with respect to the anode voltage of the other pair of valves, as a result of which current is supplied to the electric motor 12 in such a direction as to cause the latter to drive the gun 10 in a counter clockwise direction following the telescope 11. If the telescope should become as much as 5° out of correspondence with the gun 10, the cam 41 actuates the cam follower of the switching device 42 to the right or left hand side (depending upon the direction of correspondence) establishing an energizing circuit with the operating coil of the switch 30 that is readily traced from the mid point of the secondary winding of the transformer 28 through the operating coil of the switch, thence by conductors 57, 55 (assuming the switch 42 to be operated to the left hand position) and conductor 56 to the upper terminal of the secondary winding of transformer 28. Switch 30 in responding to the energization of its operating coil moves to the upper position in which it interrupts the connection between the single phase winding of the receiver 31 and the primary winding of the grid transformer 27a and connects the primary winding 27a from the mid point of the secondary winding of transformer 28 to the upper terminal thereof through conductors 57, 55 and 56. As a result of the energization of the primary winding 27a a component voltage of constant magnitude is applied to the grid circuit of the electric valve apparatus such as to cause the motor 12 to drive the gun 10 at maximum speed toward correspondence with the telescope 11.

The rotation of the gun 10 rotates the stator member of the receiver 37 in a direction opposite to that in which the rotor is rotated by the rotation of the telescope 11, thereby tending to rotate the cam 41 back to its original position in which it is illustrated in the drawing. When the gun 10 is again within 5° of correspondence with the telescope 11 the heart cam 41 is rotated backwards by an amount sufficient to allow the switch 42 to be actuated to its central or neutral position by its operating spring 42a, as a result of which the switch 30 is deenergized and the control of the electric valve apparatus transferred from the single speed system 36, 37 to the high speed system 32, 31. Assume now that the telescope 11 approaches the limit 46 of the "blind" into which the gun 10 must not enter. As the telescope 11 enters the "blind" the raised portion of the cam member 48 engages the cam follower of the switching device 47 causing it to disengage the movable contacting member of the switching device from its stationary contact and thereby interrupting the energizing circuit for the operating coil of the switching device 24 the switch thereupon descending to its lower position in which it disconnects the valve apparatus 16 from the source 20 and disconnects the field winding 22 from the source 23.

As a result of the deenergization of the gun driving motor 12, the gun 10 is brought to rest at the limit 46 of the "blind". As the telescope 11 continues on through the "blind" in the direction indicated by the arrow, it becomes more than 5° out of correspondence with the gun and since the stator member of the receiver 37 is no longer rotated in the opposite direction from that in which its rotor member is rotating in correspondence with the rotor member of the transmitter 36, the heart cam 41 actuates the movable contact member of the switch 42 into engagement with the cooperating left-hand stationary

contacts. And thereafter, the gear sector 52 engages the gear 51 and operates the movable contact member of switch 50 in a counter clockwise direction from the normal position in which it is illustrated to a position in which it engages the stationary contact member 60, thereby reversing the connections between the primary winding 27a of the grid transformer and the secondary winding 28 of the grid supply transformer. In its left hand position, the movable contact member of the switch 42 completes an energizing circuit for the operating coil of the switch 30 (previously traced) as a result of which the switch is operated to its upper position completing the connections to the primary winding 27a of the transformer 27.

Assuming that the telescope 11 is continued on through the "blind" in the same direction, the cam follower of the switch 47 rides off the raised portion of the cam 48 as the telescope emerges from the "blind" at the opposite limit 45, thereby allowing the spring 47a of the switch 47 to operate the movable contact of the switch into engagement with its cooperating stationary contacts to recomplete the energizing circuit for the operating coil of the switch 24. As a result of the energization of its operating coil, the switch 24 moves to its upper position in which it reestablishes the supply connections to the electric valve apparatus 16 and to the field winding 22 of the motor 12. Due to the reversal of the connections to the primary winding 27a of the grid transformer, the phase relationship between the grid and anode voltages of the previously energized pair of valves is retarded, whilst the phase relationship between the grid and anode voltages of the previously deenergized pair of valves is advanced thereby causing the valve apparatus 16 to supply current to the motor 12 in the reverse direction. The gun 10 is now driven in a clockwise direction from the limit 46 of the blind toward the limit 45, and when the gun arrives within 5° of correspondence of the telescope 11, the heart cam 41 is again in such a position that it allows the spring 42a to return the movable contact arm of the switch 42 to the central position in which it is illustrated in the drawing. This operation of the switch 42 to its central position interrupts the energizing circuit for the switch 30 thereby permitting its contact member to descend to its lower position in which it interrupts the connections to the primary winding 27a and reestablishes the connections to the primary winding 27b thereby returning the control of the electric valves to the high speed system 32, 31. When the gun reaches the position of correspondence with the telescope 11, the rotor member of the receiver 31 is at right angles to the magnetic field of the stator winding and as a result the component voltage supplied to the grid circuit of the electric valve apparatus becomes zero, the electric valve apparatus is deenergized and the motor is stopped. Thereafter the gun 10 follows the movements of the telescope as previously described.

The operation of the movable contact member of the switch 42 from its left hand position to its central position in engagement with the cooperating stationary contact member 62 simultaneously completes an energizing circuit for the electric motor 63 that is readily traced from the upper terminal of the secondary winding 28a of the transformer 28 by conductors 64 and 65, contacts 66 (bridged by a contact member of switch 50) conductor 67, armature and field winding of mo-

tor 63 and thence by conductor 68 to the lower terminal of secondary winding 28a. The gear sector 52 has by this time passed out of engagement with gear 51 and the electric motor 63 rotates the gear 51 and the switch 50 from the position to which it was previously operated to the position in which it is illustrated. As the contact arm of switch 50 is disengaged from the stationary contacts 66 the circuit of the motor 63 is interrupted and the spring pressed arm 70, which is provided with a cam follower engaging a cam 71 on the shaft of the switch 50 snaps the latter into its normal position and maintains it in this position. Simultaneously, the conductor 55 is reconnected to the conductor 56 again reversing the connections to the primary winding 27a of grid transformer so that if the single speed system 36, 37 is again called upon to take control the rotation of the motor 12 will be in the correct direction.

If the telescope 11 should enter the "blind" from the limit 45, the operation will be substantially the same as that above described and will be readily understood from the above description in connection with the operation following upon entering the "blind" from the limit 46.

Although in accordance with the provisions of the patent statutes, this invention is described as embodied in concrete form it will be understood that the apparatus and connections as shown are merely illustrative and that the invention is not limited thereto, since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or the scope of the annexed claims.

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

1. A follow-up system comprising a pilot device rotatable in a closed path, a driven object, driving means for said object, means for controlling said driving means to drive said object into positional agreement with said device, means for deenergizing and stopping said driving means to prevent said driven object from entering a predetermined portion of its path, means for reversing said controlling means to provide for rotation of said object in the reverse direction, and means for reenergizing said driving means when said pilot device emerges from a portion of its path corresponding with said predetermined portion so that said driven object is driven into correspondence with said pilot device.

2. A follow-up control system comprising a pilot device rotatable in a closed path, a driven object, an electric motor for driving said object into positional correspondence with said pilot device, means for deenergizing and stopping said motor to prevent said driven object following said pilot device for a predetermined portion of its path, means for reversing and reenergizing said motor to provide for rotation of said object in the reverse direction so that said driven object is driven into correspondence with said pilot device as said device emerges from said predetermined portion of its path.

3. A follow-up control system comprising a pilot device rotatable in a closed path, a driven object, an electric motor for driving said object, supply means for said motor comprising electric valve means for supplying current to said motor in one direction and additional electric valve means for supplying current to said motor in the reverse direction, each of said valve means being provided with a grid control circuit, control means and

connections controlled thereby for energizing one of said grids to cause said motor to drive said object into positional correspondence with said pilot device, means responsive to arrival of said pilot device at a limit of a predetermined portion of its travel for deenergizing said valve apparatus and for reversing said grid connections, and responsive to arrival of said pilot device at the opposite limit of said portion of its travel for reenergizing said valve apparatus whereby said motor is caused to drive said object in the reverse direction into correspondence with said pilot device.

4. A follow-up control system comprising a pilot device, a driven object, an electric motor for driving said driven object, supply means for said motor comprising electric valve apparatus provided with a control grid, electrical connections for energizing said grid, fine control means for said grid for causing said valve apparatus to supply a current to said motor proportional to the disagreement of said pilot device and driven object, coarse control means for supplying a voltage of constant magnitude to said grid to cause said motor to drive said object at a maximum speed, means responsive to arrival of said pilot device at a limit of a predetermined portion of its travel for deenergizing said valve apparatus to stop said motor and for reversing said grid connections, and responsive to arrival of said pilot device at the opposite limit of said portion of its travel for reenergizing said valve apparatus and said coarse control means whereby said motor is controlled to drive said object into positional agreement with said pilot device at maximum speed.

5. In a follow-up system having a control device and a driven object movable in corresponding closed paths, an electric motor for driving said object, supply means for said motor comprising electric valve apparatus provided with a control grid, means responsive to positional disagreement of said device and said object and electrical connections to said grid controlled thereby for causing said motor to drive said object into positional agreement with said device, and switching means operated in response to arrival of said device at a limit of a predetermined portion of its travel for deenergizing said valve apparatus and reversing said grid control connections and responsive to departure from said portion at the opposite limit thereof for reenergizing said valve apparatus to effect operation of said motor to drive said object in the reverse direction into agreement with said device.

6. In a follow-up system provided with a control device and a driven object rotatable in corresponding closed paths, an electric motor for driving said driven object, means responsive to positional disagreement of said device and said object and electrical connections controlled thereby for causing said motor to drive said object into correspondence with said device, and means for preventing said object from following said device into a predetermined portion of its travel in either direction comprising a switching device in the supply connections to said motor, a reversing switch in said control connections provided with an actuating gear and a device actuated by said control device provided with a member for actuating said switching device to deenergize said motor when said device enters said portion of its travel and to reenergize said motor upon emerging therefrom and provided with a gear sector for engaging said gear to operate said reversing switch to reverse said control connections when said control device enters said predetermined portion of its travel.

7. In a follow-up system having a control device and a driven object movable in corresponding paths, an electric motor for driving said object, supply means for said motor comprising electric valve apparatus provided with a control grid, means responsive to positional disagreement of said device and said object comprising an electrical motion transmitting device actuated by said control device and an electrical motion receiving device actuated by said transmitting device and electrical connections to said grid controlled by said receiving device for causing said motor to drive said object into positional correspondence with said control device, a switching device provided with a gear and having a normal position and a reversing position included in said connections, a second switching device included in the supply connections to said valve apparatus, and a device provided with a gear sector arranged to engage said gear to actuate said first switching device to said reversing position when said control device enters a predetermined portion of its travel at either of opposite limits and provided with a cam for engaging said second switching device to deenergize said valve apparatus when said control device enters said portion of its travel and reenergize said valve apparatus when said control device emerges therefrom.

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