March 6, 1951 M. N. YARDENY ET AL 2,543,950

COARSE-FINE ELECTRIC MOTOR CONTROL SYSTEM

Filed May 29, 1948 2 Sheets-Sheet 1

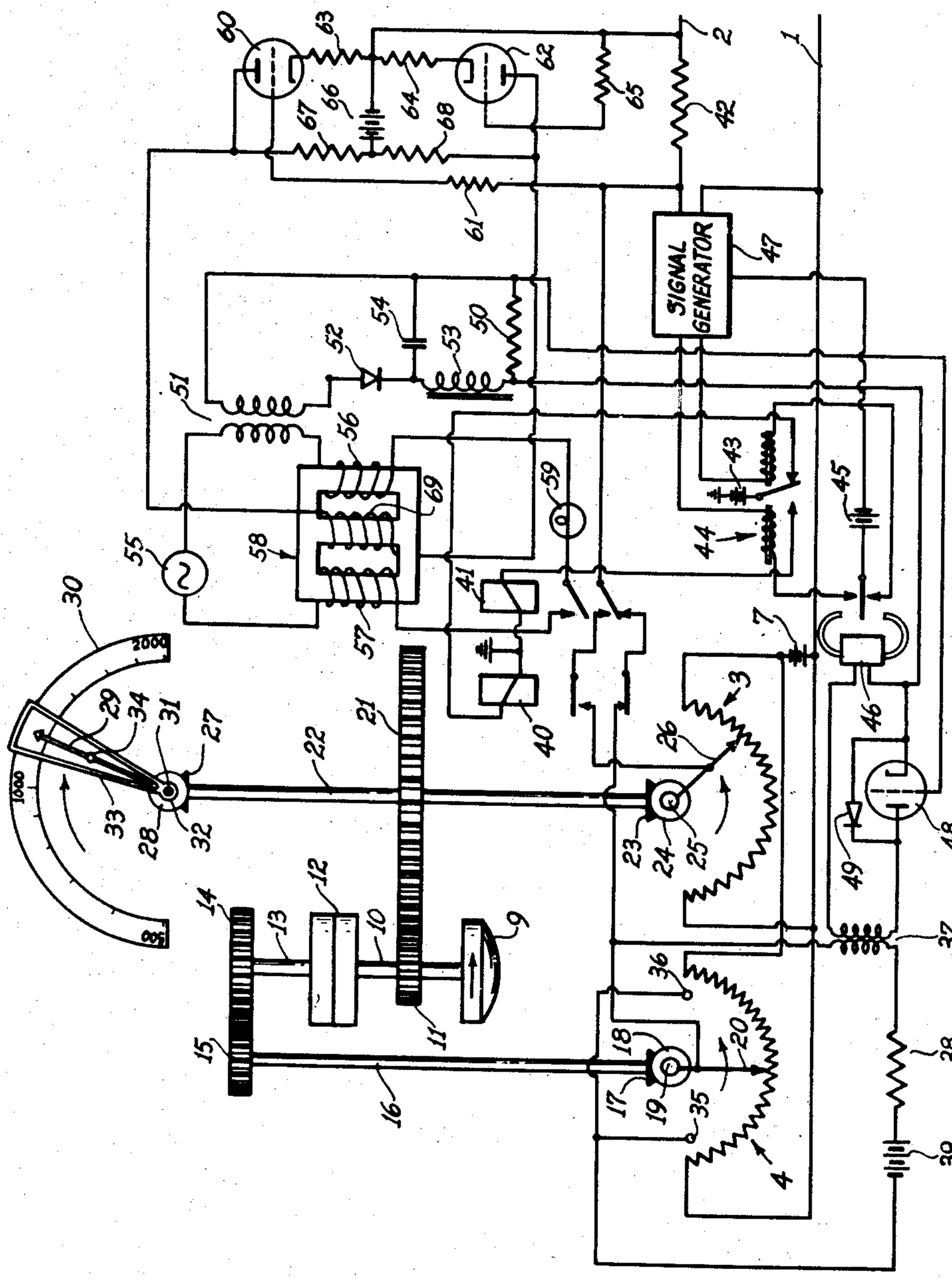

FIG. 1

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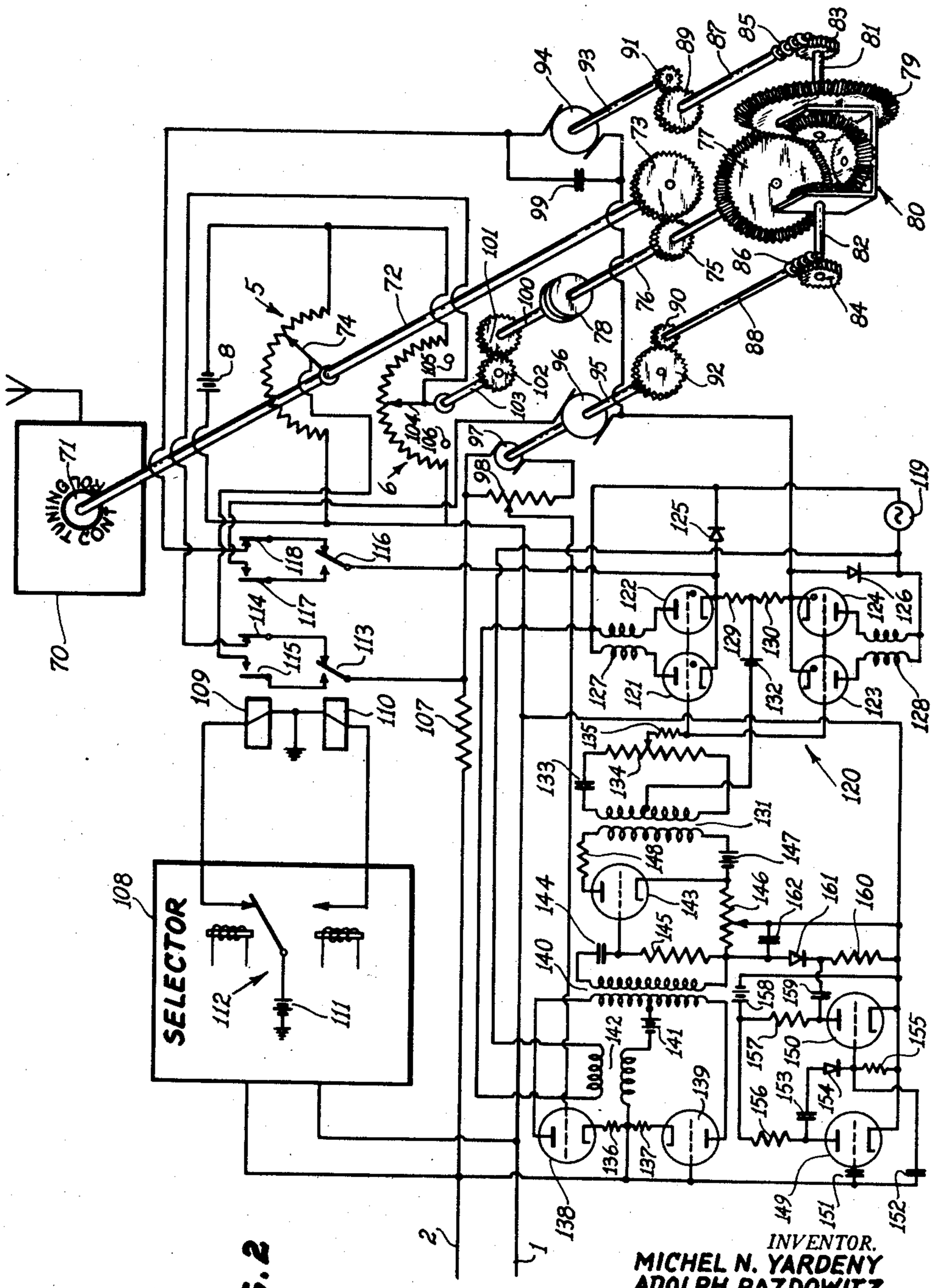

FIG. 2

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COARSE-FINE ELECTRIC MOTOR CONTROL SYSTEM

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15 Claims. (Cl. 318—29)

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The present invention relates to remote control systems and, more particularly, to control systems of the coarse-fine type wherein a preliminary setting and a vernier setting are to be given to a load located at a remote station.

The invention is particularly, though not exclusively, applicable to remote control systems of the type described generally in the co-pending United States patent application of Michel N. Yardeny and Robert Bernas, Ser. No. 5,276, filed January 30, 1948, now abandoned, and more specifically in our co-pending United States patent application Ser. No. 22,863, filed April 23, 1948, now Patent No. 2,531,187, granted November 21, 1950.

While the invention may be utilized for the purpose of controlling any type of load located at a remote station, a now preferred field of application thereof is the remote actuation of the tuning control of a radio receiver.

An object of the present invention is to provide a control system of the character set forth wherein coarse as well as fine control are effected by the manipulation of a single operating member (e. g. tuning knob).

Another object of the invention is to provide a coarse-fine system wherein the switching from coarse to fine control will be automatically effected upon reversal of the sense of actuation of a control member, while the return to coarse control will be automatically effected whenever the range for fine control is exceeded.

A further object of the invention is to provide, in a remote control system of the character described utilizing a transmission channel which is also used for the transmission of other signals (such as set forth in the co-pending applications referred to), means for preventing false operation of the system by rendering the same insensitive to such other signals.

Still another object of the invention is to provide, in a coarse-fine control system, means for preventing false operation by disabling the vernier control until the preliminary positioning of the load or controlled device has been completed.

According to one of the features of the invention, there is provided, in a control system of the character described, an actuating member at a local station, first control means positively connected with said actuating member, second control means frictionally entrainable by said actuating member, stop means for arresting the second control means when the displacement of the latter surpasses predetermined limits, and switch means arranged to render the first control means

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effective in the arrested condition of the second control means to cause the displacement of a load at a remote station and to render the second control means similarly effective during entrainment thereof by said actuating member.

According to another feature of the invention, there is provided, in a system of the character set forth above, a load-positioning member at a remote station actuatable under the control of either of two follower means arranged to respond to signals from a respective control means at the control station, said two follower means including coarse follower means positively connected to and fine follower means frictionally coupled with said load-positioning member. Preferably, the two control means and the two follower means comprise two pairs of correlated potentiometers operating in the manner described in our aforesaid Patent No. 2,531,187.

According to a further feature of the invention, the two stations may be interconnected by a transmission channel to which said control means may be alternately connected, signal generator means operable simultaneously with said switch means being provided at the control station to indicate at the remote station which one of said control means is connected to said channel.

The above and other features and objects will become apparent and the invention will be better understood from the following description of an embodiment thereof, reference being had to the accompanying drawing in which:

Fig. 1 is a circuit diagram of a control station according to the invention, and

Fig. 2 is a circuit diagram of a remote station according to the invention.

Referring to the drawing, there is shown a control station (Fig. 1) and a remote station (Fig. 2) interconnected by a transmission channel shown in this exemplification as a two-wire transmission line 1, 2. Conductor 1 of this line is connected at the control station to the positive terminals of two potentiometers 3, 4 in parallel and at the remote station to the positive terminals of two similar potentiometers 5, 6 in parallel. Potentiometers 3, 4 are energized from a battery 7 and potentiometers 5, 6 are energized from a battery 8.

Turning now to the control station (Fig. 1), there is provided an actuating member in the form of a knob 9 which is fixed to a shaft 10 carrying a pinion 11 as well as the lower coupling half of a clutch 12. The upper coupling half of the clutch 12 is mounted on a shaft 13 carrying a gear 14 which meshes with another gear 15

fixed to a shaft 16. The rotation of the shaft 16 is transmitted by means of two bevel gears 17, 18 to a shaft 19 carrying the wiper 20 of "fine" potentiometer 4.

The pinion 11 meshes with a gear 21 which is mounted on a shaft 22. The rotation of the shaft 22 is transmitted by means of two bevel gears 23, 24 to a shaft 25 carrying the wiper 26 of "coarse" potentiometer 3. Shaft 22 also carries a bevel gear 27 which meshes with a bevel gear 28 integral with a pointer 29, the latter cooperating with a scale 30. The gear 28 is rotatably mounted on a stationary pin or stud shaft 31 on which there is frictionally held a collar portion 32 of a frame 33 which brackets the pointer 29. It will be understood that the frame 33 will be entrained by the pointer 29, e. g. by being engaged by a projection 34 thereof, whenever the pointer tends to move beyond the area defined by the sides of the frame, yet will remain at rest as long as the movements of the pointer are confined to this area.

If the ratio of gears 14 and 15 is 2:1 and that of gears 11 and 21 is 1:5, then each quarter turn of the knob 9 will displace the wipers 20 and 26 by 180 and 18 degrees, respectively, pointer 29 undergoing the same displacement as wiper 26. The movement of the wiper 20 and, with it, of the shaft 16 is limited to a range of approximately 180 degrees by means of stops 35, 36, further rotation of the knob 9 causing the friction clutch 12 to slip while wiper 26 and point 29 continue to advance. By making the angle of the apertured sector of frame 33 equal to 18 degrees, this sector will always indicate the range within which operation of the "fine" potentiometer 20 will be possible.

Connected between the stops 35, 36 in parallel, on the one hand, and the wiper 20, on the other hand, is a series circuit comprising the primary of a transformer 37, a resistance 38 and a battery 39. Wiper 20 is also connected to the front contact of the lower armature of a "fine" relay 40, the circuit being extended by said armature to the back contact of the lower armature of a "coarse" relay 41 and thence, over the last-mentioned armature, to the left-hand terminal of a resistor 42 in series with line conductor 2. Wiper 26 is connectable to the same terminal of resistor 42 by way of the back contact and upper armature of "fine" relay 40 and the front contact and lower armature of "coarse" relay 41. The energizing circuits for each of these two relays include a battery 43, the armature of a side-stable relay 44 and a respective contact of the last-mentioned relay engageable by said armature. The term "side-stable relay" imports that this relay is of a type which has no unoperated or released position and whose armature does not comprise a restoring spring, thereby remaining in engagement with one or the other of its two contacts, depending on which one of its two windings has been energized last.

Relay 44 has two windings energizable from a battery 45 over an armature and respective contacts of a polarized relay 46. The energizing circuits for these windings also lead over a signal generator 47 whose function it is to send a suitable impulse to the line 1, 2 whenever one of these windings becomes energized. Signal generator 47 may be of any well known and suitable design, yet we prefer to use a pair of self-locking relays each adapted to break the holding circuit for the other, when actuated, and to send a signal pulse to line which is generated by the current surge in its own holding circuit. An arrangement of this description has been fully disclosed in connection with Fig. 1 of our aforementioned Patent No. 2,531,187.

Polarized relay 46 is connected across the secondary of transformer 37 in series with a triode 48 which is shunted by a rectifier 49. The grid and the cathode of tube 48 are connected across a resistor 50 which in turn is connected in series with the secondary of a transformer 51 and a rectifier 52 by way of a smoothing network comprising an audio frequency choke 53 and a condenser 54. The primary of transformer 51 is connected across an alternating-current generator 55 in series with the windings 56, 57 of a saturable-core reactor 58, an indicator lamp 59 and the front contact and upper armature of "coarse" relay 41. The rectifier 52 is poled so that any alternations induced in the secondary of transformer 51 will apply a negative bias to the control grid of triode 48.

The left-hand terminal of resistor 42 is connected to the grid of a vacuum tube 60 by way of a grid resistor 61, its right-hand terminal being connected to the cathodes of this tube and of a companion tube 62 by way of respective cathode resistors 63, 64. The common terminal of these resistors is connected to the grid of tube 62 by way of a resistor 65. A battery 66 supplies space current to the tubes 60, 62 by way of respective plate resistors 67, 68. The plates of these tubes are also connected across the central winding 69 of reactor 58. Tubes 60, 62 and their respectively associated resistors are preferably identical, so that substantially no current will flow through winding 69 when the voltage drop across resistor 42 is zero.

Turning now to Fig. 2, there is shown a radio receiver 70 provided with a tuning control 71 which is mounted on a shaft 72, the latter carrying a gear 73 as well as the wiper 74 of "coarse" potentiometer 5. Gear 73 meshes with a pinion 75 which is fixed to a shaft 76, the latter having mounted thereon a bevel gear 77 as well as one of the coupling halves of a clutch 78 which is similar to clutch 12 in Fig. 1. Bevel gear 77 meshes with a similar gear 79 fixed to the housing of a conventional differential gearing 80 whose two planet gears are mounted on respective stud shafts 81, 82 each carrying a worm wheel 83, 84 which is engaged by a worm 85, 86, respectively. The worm-carrying shafts 87, 88 each have mounted thereon a respective pinion 89, 90 meshing, respectively, with pinions 91, 92. Pinion 91 is mounted on the shaft 93 of a D.-C. motor 94, while pinion 92 is similarly mounted on the shaft 95 of another D.-C. motor 96; shaft 95 is also connected to a small damping generator 97 having a load resistor 98 connected across its terminals. A condenser 99 is bridged across the armature of motor 94.

The other coupling half of clutch 78 is fixed to a shaft 100 carrying a gear 101 which meshes with a gear 102, the latter being mounted on a common shaft 103 with the wiper 104 of "fine" potentiometer 6. Two stops 105, 106 limit the displacement of wiper 104 to an angle of substantially 180 degrees, in the same manner as the movement of wiper 20 (Fig. 1) is limited by stops 35 and 36.

It will be understood that, in the embodiment illustrated, the ratio of gears 101, 102 on the one hand and gears 73, 75 on the other should be selected so that the angular velocity of wiper

104 (when disengaged from the stops 105, 106) will be ten times that of wiper 74, in order to duplicate the conditions existing at the local station (Fig. 1). Worm drive 84, 86 is driven over a high-speed gearing 90, 92 from "coarse" motor 96, while worm drive 83, 85 is driven over a reduction gearing 89, 91 from "fine" motor 94. The two worm drives represent respective self-locking inputs to the differential 80, each being adapted to effect the rotation of shaft 76 when the other drive is unoperated.

The upper terminal of load resistor 98 is connected to the right-hand terminal of a control resistor 107 which is in series with line conductor 2. Connected across the line 1, 2 ahead of this resistor is a selector 108 whose function it is to respond to the impulses transmitted over the line by the signal generator 47 (Fig. 1). Selector 108 may be of any well-known and suitable design, depending upon the nature of the impulses produced by the generator 47, but preferably comprises a pair of selectively biased thyratrons responsive to positive D.-C. pulses of different magnitudes; such an arrangement has been fully disclosed in connection with Fig. 2 of our Patent No. 2,531,187. The selector controls the operation of a pair of relays 109, 110, the energizing circuits for these relays including a battery 111 as well as an armature and respective contacts of a side-stable relay 112 included in the selector.

The right-hand terminal of control resistor 107 is connected to the armature 113 of "coarse" relay 110, the circuit being extended by way of the back contact of this armature and front contact and armature 114 of "fine" relay 109 to the wiper 104 of "fine" potentiometer 6. Wiper 74 of "coarse" potentiometer 5 is connectable over back contact and armature 115 of "fine" relay 109 and front contact and armature 113 of "coarse" relay 110 to the same terminal. Armature 116 of relay 110 and armatures 117, 118 of relay 109 serve to effect the selective energization of motors 94, 96, depending on which one of the two relays is operated. These motors are energized from a source of alternating current 119 by way of a rectification network 120 which includes a first pair of parallel thyratrons 121, 122 and a second pair of parallel thyratrons 123, 124, the two pairs being connected with opposite polarity across the source 119. A rectifier 125 is bridged across the thyratrons 121, 122 while a rectifier 126 is similarly bridged across the thyratrons 123, 124. Connected to the plates of the first pair, in series with the source 119, are respective windings of a synchronizing transformer 127 and to the plates of the second pair, in similar manner, respective windings of a synchronizing transformer 128.

Each pair of thyratrons are provided with a common cathode resistor 129, 130, respectively, the common terminal of the two resistors being connected to the midpoint of the secondary of an input transformer 131 by way of a biasing battery 132. The circuit of this secondary is completed by a condenser 133 in series with a resistance 134, a tap on this resistance being connected to the grids of all thyratrons in parallel by way of a current-limiting resistor 135.

Conductor 2 is connected to the common terminal of the cathode resistors 136, 137 of a pair of vacuum tubes 138, 139 whose plates are connected across the primary of a transformer 140, the midpoint of this primary being connected to said common terminal by way of a battery 141 in series with the secondary of a transformer 142; the primary of the latter transformer is connected directly across the source 119. The upper terminal of the secondary of transformer 140 is connected to the grid of an amplifier tube 143 by way of a coupling condenser 144, its lower terminal being connected to the junction of two series resistors 145, 146 inserted as a grid leak between the grid and the cathode of tube 143. The load circuit of tube 143 includes the primary of input transformer 131 in series with a battery 147 and a load resistance 148.

A two-stage amplifier comprising vacuum tubes 149, 150 has the grids of both of its stages connected in parallel to the conductor 2 over respective coupling condensers 151, 152. The plate of tube 149 is also connected to the grid of tube 150 over a coupling condenser 153 in series with a rectifier 154 and a grid leak 155. The plate resistors of tubes 149, 150 are indicated at 156, 157 and are connected in parallel to a battery 158. The plate of tube 150 is connected over a coupling condenser 159 to a load resistance 160, the latter being in series with a rectifier 161 and with a portion of resistor 146 which is shunted by a condenser 162; this condenser and the said resistor portion form a time constant circuit connected across the series combination of rectifier 161 and load resistance 160.

The operation of the control system just described is as follows:

Let us assume that the pointer 29 at the indicator of the control station is positioned substantially midway within the open sector of frame 33, wiper 20 at the same time contacting the mid-portion of potentiometer 4 as shown. With the armature of side-stable relay 44 in the position illustrated, due to a previous energization of the right-hand winding of that relay, "fine" relay 40 will be operated and the wiper 20 of "fine" potentiometer 4 will be connected to line conductor 2 over a front contact of relay 40, a back contact of relay 41 and resistor 42. At the remote station, the upper winding of side-stable relay 112 in selector 108 will have previously responded to a signal from generator 47, thereby placing its associated armature in the position illustrated in which an energizing circuit is closed for "fine" relay 109. Thus at the remote station, too, the wiper 104 of the "fine" potentiometer 6 is connected to conductor 2 over a front contact of "fine" relay 109, a back contact of "coarse" relay 110 and resistor 107.

When the wipers 20, 104 are in corresponding positions, the system is in balance and nothing further will happen until the operator displaces the knob 9 to select a different position of the indicator 28, 30. Assuming that the knob 9 is actuated in the sense of the arrow, then the wipers 20, 26 as well as the pointer 29 will also be rotated in the directions indicated by the respective arrows. After a rotation of the knob 9 through approximately 45 degrees, the wiper 20 will strike the stop 36 while projection 34 on pointer 28 will simultaneously abut the right-hand side of frame 33. A circuit is closed from battery 39 through resistance 38, primary of transformer 37, wiper 20 and stop 36, sending a current pulse through the secondary of transformer 37 which (for reasons subsequently to become apparent) should be of such polarity as to pass the rectifier 49 and energize polarized relay 46 to move the latter's armature upward. An energizing circuit is now closed for the left-hand armature of relay 44, swinging its armature over

to the left so as to restore "fine" relay 40 and operate "coarse" relay 41. At the same time the generator 47 will send a "coarse tuning" pulse to line, this pulse being preferably of the opposite polarity as the voltage applied to the line by potentiometer 3 or 4. Wiper 20 is now insulated from resistor 42 which is instead connected to wiper 26 over a back contact of relay 40 and a front contact of relay 41.

At the remote station, the arrival of the "coarse tuning" selection pulse causes the reversal of the position of the armature of relay 112 and operates "coarse" relay 110, releasing "fine" relay 109. This insulates wiper 104 from resistor 107 while connecting thereto the wiper 74 over a front contact of relay 109 and a back contact of relay 110. Since the two potentiometers 3, 5 are now in unbalance, wiper 26 having been displaced toward the more negative end of the potentiometers, current will now flow from right to left through resistors 107 and 42 in series.

Tubes 138, 139 are designed so that no current will flow in the secondary of transformer 140 when zero signal is applied to the grid of tube 138. It will be seen that the grid of tube 139 is connected directly to the common terminal of cathode resistors 136, 137 while that of tube 138 is connected to the right-hand terminal of control resistor 107 over a portion of load resistor 98. The unbalance current flowing through resistor 107 will drive the grid of tube 138 positive with respect to that of tube 139, thereby unbalancing the primaries of transformer 140 and giving rise to an output current in the secondary of this transformer. The oscillations corresponding to this output current are applied to the secondary of input transformer 131 after amplification in tube 143.

It will be understood that the output of amplifier tube 143 will be in step (that is, either in phase or in phase opposition) with the output of generator 119 but that both the amplitude and the polarity of control oscillations set up in transformer 131 will depend upon the magnitude and the sense of the current flow through resistor 107. In a coarse-fine tuning drive as herein contemplated, however, it is desirable to use a D.-C. motor whose speed may be regulated according to the amount of unbalance, whereby a more accurate setting will be obtainable and "hunting" will be virtually eliminated as will more fully appear hereinafter. Accordingly, the output of generator 119 is applied to the armature of a respective D.-C. motor 94, 93 after rectification in the network 120 under the control of the output of tube 43; network 20 operates as follows:

Since the control oscillations from transformer 131 are applied to the grids of all thyratrons 121 through 124 in parallel, and since the output of source 119 is applied to the plates of the two pairs of thyratrons in push-pull, the signal on the grids of one pair (disregarding for the moment the phase shift introduced by the circuit 133, 134) will be in phase with the corresponding plate potential while that of the grids of the other pair will be in phase opposition with respect to the potential on the associated plates. Accordingly, only one pair of thyratrons (say, the tubes 121 and 122) will fire, during alternate half-cycles, when the current through resistor 107 flows in a given direction. We can now trace an operating circuit for the motor 96 (which is the "coarse" motor) from generator 119, thyratrons 121 and 122 in parallel, armature 116 and front contact of relay 110, armature 117 and back contact of relay 109, armature of motor 96, through rectifier 126 back to the generator 119. Had the voltage drop across resistor 107 been of opposite polarity, then the operating circuit for the motor would have included the thyratrons 123, 124 and the rectifier 125 instead of the corresponding elements referred to.

The use of two thyratrons in parallel is dictated by the necessity to prevent overloading of the tubes where the motor is liable to draw a large starting current; if this is not the case, each of the two pairs of thyratrons may be replaced by a single tube. Note that the transformers 127, 128 insure the simultaneous firing of the tubes of each pair, their windings being of course arranged so that a current surge through either winding will increase the positive potential of the anode connected to the other winding.

As the voltage drop across resistor 107 decreases, the amplitude of the control oscillations set up in transformer 131 will diminish and the firing point of the thyratrons 121, 122 (in the case assumed) will be more and more delayed, resulting in progressively shorter ionization periods during each half cycle of oscillation; hence the period of current flow per cycle and, thereby, the average current density will decrease. Actually, the provision of condenser 133 and resistor 134 causes the grid voltage to lag behind the associated plate voltage, so that the two voltage peaks will not coincide and the bias of battery 132 will not be overcome unless the control oscillations exceed a predetermined amplitude. The sensitivity of the thyratrons may, of course, be varied by displacing the tap on the resistor 134 to which the grids of the thyratrons are connected.

It will be noted that the energizing circuit for the motor, whether including one or the other pair of thyratrons, is always shunted by the two cathode resistors 129, 130 in series. If, as the amplitude of the control oscillations decreases and the average current through the motor is reduced, the latter should fail to decelerate sufficiently, then the counter-e. m. f. built up by its armature will appear as a voltage drop across the two cathode resistors which will tend to overcome the negative signal on the grids of the opposite pair of thyratrons (e. g. tubes 123 and 124), leading to their ionization and energetically plugging the motor. It will thus be seen that the network 120 represents an effective anti-hunting device, capable of reducing to a minimum the time required to obtain a desired setting.

A further means for reducing hunting is represented by the generator 97 which is driven through the shaft 95 regardless of whether or not motor 96 is energized. The output of generator 97 produces a voltage drop across the tapped-off portion of resistor 98 which opposes the voltage drop across resistor 107. The magnitude of this opposing voltage drop is selected so as to be small enough to be without appreciable effect during high-speed operation but to become effective upon approach to balanced condition in order to prevent the motor from overshooting its mark.

It is desirable that the transmission of transient voltages over the line 1, 2 (e. g. the arrival of selection pulses from signal generator 47) have no disturbing effect upon the setting of the tuning drive shaft 72. This is accomplished by the provision of a transient blanking network which comprises the two-stage amplifier 149, 150

and its associated circuits. This network will be nonresponsive to D.-C. voltages, due to the provision of blocking condensers 151, 152, but will operate in response to transients by blocking the input to the network 120. If, for example, a positive pulse appears across the line (conductor 2 positive relative to conductor 1), then the grids of both tubes 149, 150 will be driven positive; due to the provision of rectifier 154, however, the negative anode swing of tube 149 will have no effect upon tube 150 whose plate potential will drop in response to the positive pulse applied to its grid. This drop in plate potential produces a current surge through resistor 160 which will pass the rectifier 161 and build up a voltage drop across the tapped-off portion of resistor 146 which is shunted by condenser 162, this voltage drop being of such polarity as to bias the tube 143 beyond cutoff. If, on the other hand, a negative transient had been applied to the grids of tubes 149, 150, then the positive anode swing of tube 149 would have overcome the negative grid swing of tube 150, due to the transient, and again a drop in the plate potential of tube 150 would have been the result. It will be seen that the period during which tube 143 remains blocked will depend upon the time constant of the circuit 146, 162.

Let us now assume that, at the control station, the operator has moved the pointer 29 past the desired setting and reverses the rotation of knob 9. Immediately, the primary circuit of transformer 37 is broken and a current surge opposite to that previously described is induced in its secondary, its polarity being such that the current will be blocked by the rectifier 49 but may pass through the tube 48. The armature of relay 40 is now moved downward for the duration of this surge, energizing the right-hand winding of relay 44 and actuating the signal generator 47 to send a "fine tuning" selection pulse to line. Relay 40 operates and relay 41 releases, thus restoring the conditions initially described.

At the remote station, the arrival of the appropriate selection pulse energizes the lower winding of relay 112 which moves its armature upward, operating relay 109 and releasing relay 110. With the wiper 104 reconnected to the line in lieu of the wiper 74, motor 94 now operates over an energizing circuit which is similar to that previously described for motor 96 but includes armature 116 and a back contact of relay 110 as well as armature 118 and a front contact of relay 109. Note that the "fine" motor 94 has its armature shunted by condenser 99 which acts to reduce the voltage input to this motor, thus allowing the latter to follow all voltage changes across the resistor 107 at a relatively slow rate and affording very precise tuning.

It may occur that, at the time when the rotation of knob 9 is reversed, the wiper 74 of "coarse" potentiometer 5 has not had time to occupy a position corresponding to that of wiper 26 at the control station; hence any switch at this instant to "fine" control would result in a misadjustment. In order to prevent this from happening an interlocking circuit is provided at the control station which will maintain "coarse" potentiometer 3 effective until complete balance is obtained. Referring again to Fig. 1, the load circuit of A.-C. generator 55 includes the impedance of reactor 58 which normally is sufficiently high to limit the amplitude of the oscillations in transformer 51 to such an extent that the bias voltage for tube 48, developed across resistor 58, will be less than that necessary to bias this tube to cutoff. If, however, a voltage drop exists across the line resistor 42, the tubes 60 and 62 will have unbalanced outputs and a voltage drop will exist across the series combination of plate resistors 67 and 68, giving rise to a biasing current through the center winding 69 of reactor 58. This biasing current, in turn, decreases the reactance of the two windings 56 and 57, tube 48 will become blocked, and the relay 46 will not be energized when the wiper 20 leaves stop 35 or 36. Consequently, the "coarse" relay 41 will remain operated and the "fine tuning" signal will not be given.

Indicator lamp 59 in series with windings 56, 57 apprises the operator of the fact that an unbalance exists between the two "coarse" potentiometers, preventing the switch-over to "fine" control. This lamp will not function during "fine" control operations, its circuit being open at the upper armature of relay 41.

While the invention has been described with reference to a single, now preferred embodiment, it is to be understood that it is capable of numerous modifications without departing from its spirit or exceeding its scope.

What we claim as novel, and desire to secure by Letters Patent, is the following:

1. In a control system, in combination, an actuating member, first control means positively connected with said actuating member, second control means frictionally entrainable by said actuating member, stop means for arresting said second control means in either of two limiting positions between them defining a predetermined range, a load, load-actuating means operable to change the position of said load, switch means selectively operable to render either of said control means exclusively effective to operate said load-actuating means and reversing means for said switch means actuated by said second control means in either of said limiting positions to place said load-actuating means under the control of said first control means, said switch means being effective in all other positions of said second control means to place said load-actuating means under the control of said second control means.

2. In a remote control system, in combination, a control station, a remote station, transmission means interconnecting said two stations, an actuating member at the control station, first control means positively connected with said actuating member, second control means frictionally entrainable by said actuating member, stop means for arresting said second control means in either of two limiting positions between them defining a predetermined range, switch means selectively operable to connect either of said control means to said transmission means to the exclusion of the other control means, reversing means for said switch means actuated by said second control means in either of said limiting positions to effect the connection of said first control means to said transmission means said switch means being effective in all other positions of said second control means to connect said second control means to said transmission means, a load at said remote station, load-actuating means operable to change the position of said load, and circuit means for connecting said load-actuating means to said transmission means to effect a displacement of the load in response to signals from either one of said control means.

3. In a remote control system, in combination,

a control station, a remote station, a transmission channel interconnecting said two stations, an actuating member at the control station, first control means positively connected with said actuating member, second control means frictionally entrainable by said actuating member, stop means for arresting said second control means in either of two limiting positions between them defining a predetermined range, switch means selectively operable to connect either of said control means to said transmission channel to the exclusion of the other control means, reversing means for said switch means actuated by said second control means in either of said limiting positions to effect the connection of said first control means to said channel, said switch means being effective in all other positions of said second control means to connect said second control means to said channel, signal generating means operable simultaneously with said switch means to signal to said remote station which one of said control means is connected to said channel at said control station, a load at said remote station, first and second load actuating means alternatively operable to change the position of said load, first and second follower means at the remote station each adapted to control the operation of a respective one of said load-actuating means, and selector means at the remote station operable under the control of said signal generating means to connect a respective one of said follower means to said transmission channel depending on which one of said control means is thus connected at the control station.

4. In a control system, in combination, preliminary control means displaceable over a predetermined range, vernier control means displaceable over a fraction of said range, a load, load-actuating means operable to change the position of said load, stop means for arresting said vernier control means in an extreme position, switch means having a first condition for rendering said preliminary control means effective to operate said load-actuating means and a second condition for rendering said vernier control means similarly effective, and circuit means including said stop means and controlled by said vernier control means to place said switch means in said first condition upon engagement of said stop means by said vernier control means and to place said switch means in said second condition upon disengagement of said vernier control means from said stop means.

5. In a remote control system, in combination, a control station, a remote station, transmission means interconnecting said two stations, an actuating member at the control station, first control means positively connected with said actuating member, second control means frictionally entrainable by said actuating member, stop means for arresting said second control means when the displacement of the latter surpasses a predetermined range, circuit means for connecting said control means to said transmission means, first and second follower means at the remote station, a load positively connected with said first follower means and frictionally coupled with said second follower means, drive means arranged to displace said load until said first and second follower means occupy positions corresponding to those of said first and second control means, respectively, and stop means for limiting the displacement of said second follower means to a range corresponding to that of said second control means.

6. In a remote control system, in combination, a control station, a remote station, a transmission channel interconnecting said two stations, an actuating member at the control station, a first control potentiometer at the control station, said potentiometer having a first wiper positively connected with said actuating member, a second control potentiometer at the control station, said second potentiometer having a second wiper frictionally coupled with said actuating member, relay means operable to connect either of said wipers to said transmission channel, circuit means connecting a terminal of each of said potentiometers to said transmission channel, stop means engageable by the wiper of said second potentiometer in either of two limiting positions, switch means operable upon engagement of said stop means by the second wiper to actuate said relay means so as to disconnect said second wiper from said transmission channel while connecting said channel to the first wiper, said switch means being further operable upon disengagement of said second wiper from said stop means to actuate said relay means so as to disconnect said first wiper from said channel while connecting said channel to said second wiper, impulse generator means operable upon connection of said first or second wiper to said channel to send a first or second signal, respectively, to said remote station, a first follower potentiometer at said remote station, a second follower potentiometer at said remote station, a load at said remote station, said first follower potentiometer having a third wiper positively connected with said load, said second potentiometer having a fourth wiper frictionally coupled with said load, relay means at said remote station operable to connect either of the last-mentioned wipers to said transmission channel, circuit means connecting a terminal of each of said follower potentiometers to said channel, a control impedance connected to said channel so as to register a voltage drop unless the setting of a follower potentiometer connected across said channel bears a predetermined relationship to the setting of a control potentiometer simultaneously connected across said channel, drive means connected with said load and adapted to displace the latter in response to a voltage drop across said control impedance, stop means adapted to arrest said fourth wiper in either of two limiting positions bearing a predetermined relationship to the limiting positions of said second wiper, and selector means arranged to actuate said relay means so as to connect either said third or said fourth wiper to said transmission channel in response to said first and second signal, respectively.

7. The combination according to claim 6, further comprising a control resistance connected to said transmission channel at the control station, and an interlocking circuit connected across said control resistance, said interlocking circuit being arranged to inactivate said switch means in response to a voltage drop across said control resistance occurring while said first and third wipers are connected to said channel.

8. The combination according to claim 7 wherein said interlocking circuit comprises a balanced amplifier, input means connecting said amplifier across said control resistance so as to produce a D.-C. output in response to a voltage drop across said control resistance, a source of alternating current, a saturable-core reactor in series with said source, circuit means for apply-

ing said D.-C. output to said reactor so as to decrease the reactance of the latter, an electric discharge device, said device forming part of a circuit for operating said switch means upon engagement of said stop means by said second wiper, and biasing means for said discharge device, said biasing means being energizable from said reactor so that a bias tending to block said device will be developed when said reactance is reduced.

9. In a control system, in combination, control means, follower means, a load coupled with said follower means, circuit means interconnecting said control means and said follower means, said circuit means including a control impedance connected so that a voltage drop is produced thereacross when the positions of said control means and said follower means bear any but a predetermined relationship, a D.-C. motor coupled to said load, and energizing means arranged to maintain said motor operated until the voltage drop across said control impedance is substantially zero, said energizing means including a source of alternating current, balanced amplifier means connected across said source so as normally to have substantially zero output, circuit means connecting said control impedance to said amplifier means so that a finite output in step with the output of said source will be produced in response to a voltage drop across said impedance, and a rectification network connecting said source to said motor, said network including two thyratrons connected in series with opposite polarity, input means connecting the grids of said thyratrons in parallel to the output of said amplifier means, circuit means connecting said source differentially across the plates of said thyratrons, and a pair of rectifiers each in series with a respective one end shunted across the other of said thyratrons.

10. The combination according to claim 9 wherein said input means comprises a phase shifting network arranged to introduce a lagging phase shift between the output of said amplifier means and the grids of said thyratrons.

11. The combination according to claim 9, further comprising a pair of cathode resistors serially connected between the cathodes of said thyratrons in parallel with said motor, the magnitude of said cathode resistors being selected so that excessive counter-E. M. F. generated by said motor will result in the flow of current tending to stop the motor.

12. In a remote control system, in combination, a control station, a remote station, a transmission line interconnecting said two stations, control means at said control station arranged to apply a D.-C. potential to said line, follower means at said remote station arranged to apply a balancing potential to said line, drive means for said follower means adapted to displace the latter, in response to any difference between said two potentials, until said transmission line is in balance,

a load coupled with said follower means for simultaneous displacement by said drive means, transient blanking means, said blanking means being arranged temporarily to inactivate said drive means, and an operating circuit for said transient blanking means reactively coupled to said line, thereby responding to the appearance of a transient voltage across said line.

13. The combination according to claim 12 wherein said transient blanking means comprise an amplifier, input means including D.-C. blocking means connecting said amplifier across said line, and a time constant circuit connected across the output of said amplifier, said drive means comprising a motor, an energizing circuit for said motor including an amplifier tube, and biasing means for said amplifier tube including at least part of said time constant circuit connected so as to bias said tube beyond cutoff in response to a momentary change in the output of said amplifier.

14. The combination according to claim 13 wherein said amplifier has a first and a second stage, said D.-C. blocking means comprising condenser means connecting said two stages in parallel across said line, and a coupling between said stages, said coupling including a rectifier connected in such manner that transients of either polarity will result in an output pulse of predetermined polarity from the second stage.

15. In a control system, in combination, control means, follower means, a load coupled with said follower means, a motor coupled with said load and said follower means, and energizing means arranged upon displacement of said control means to cause operation of said motor until said follower means occupies a position bearing a predetermined relationship to that of said control means, said energizing means comprising a source of alternating current and a rectification network, said network including at least two thyratrons connected in parallel across said source and a synchronizing transformer having two inductively coupled windings each connected between said source and the plate of a respective thyratron so as to increase the potential of the associated plate in response to an increase in current through the other winding.

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