

Feb. 4, 1947.

R. H. HILL ET AL

2,415,170

MOTOR CONTROL CIRCUIT

Filed Oct. 23, 1942

2 Sheets-Sheet 1

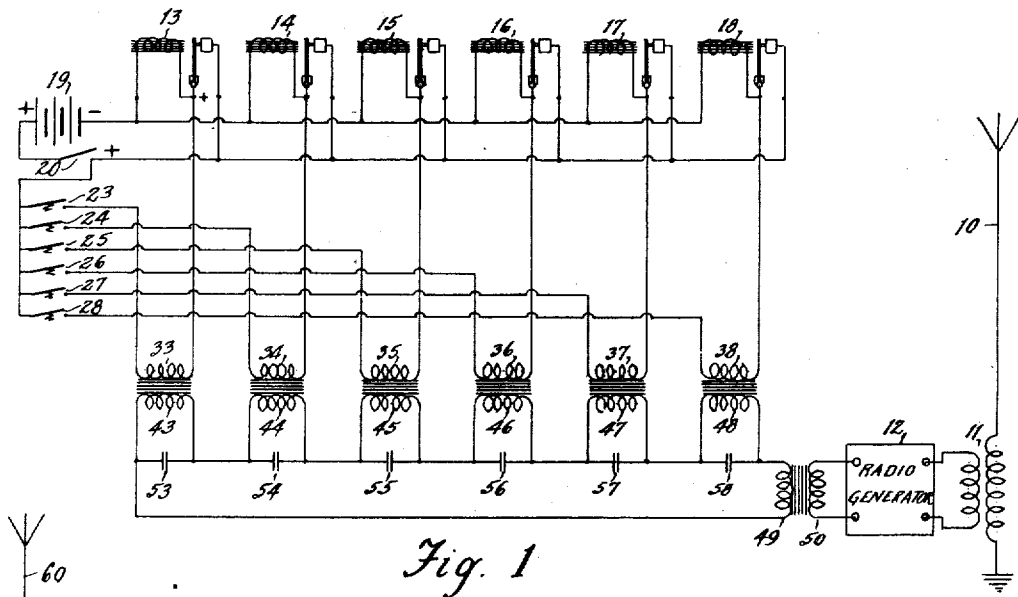


Fig. 1

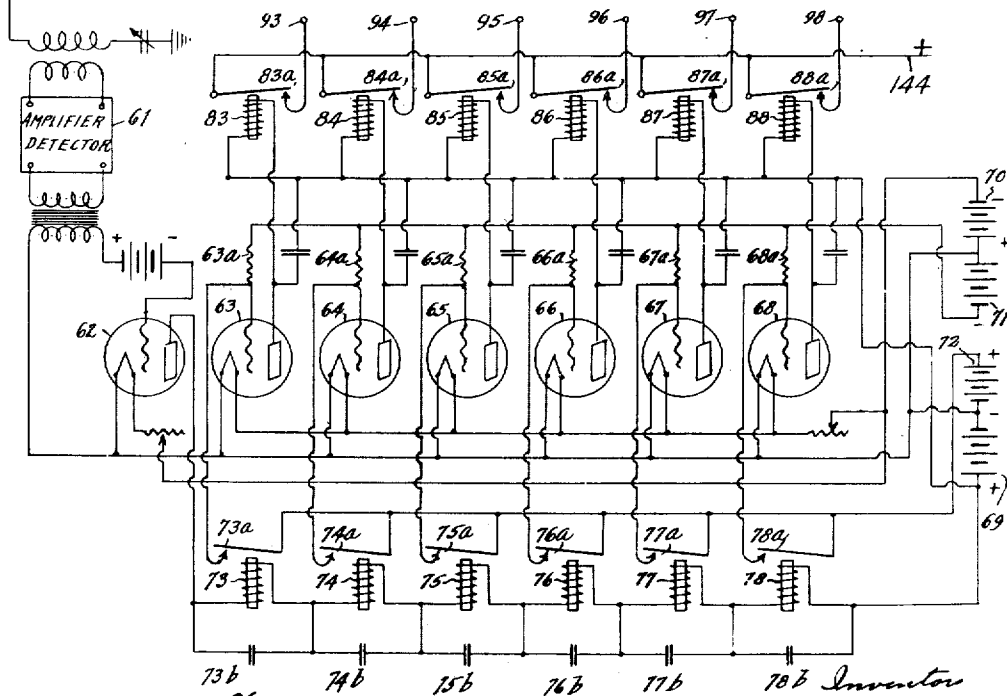


Fig. 2

15b 16b 17b 18b Inventor
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their attorneys

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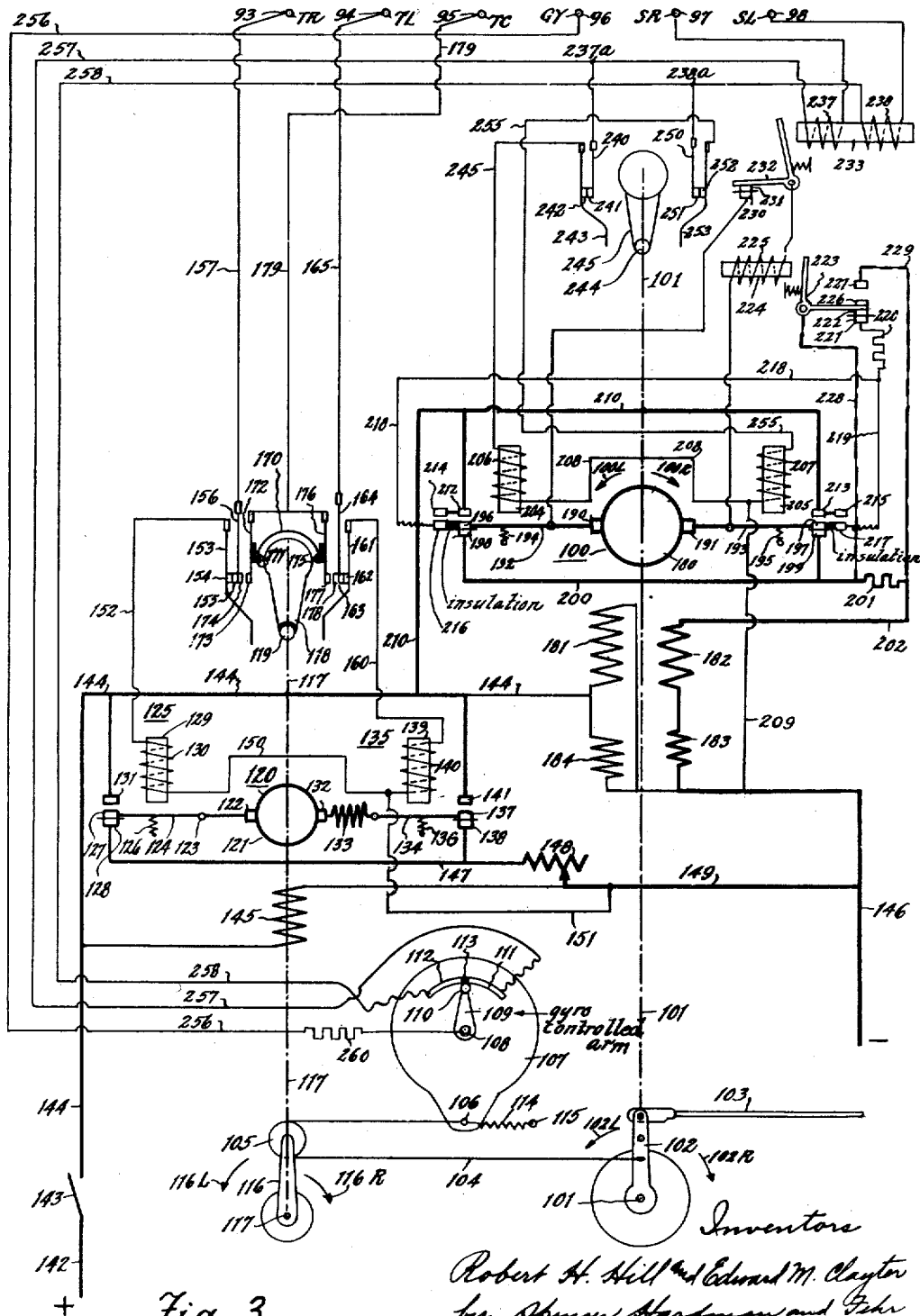


Fig. 3

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UNITED STATES PATENT OFFICE

2,415,170

MOTOR CONTROL CIRCUIT

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18 Claims. (Cl. 172-282)

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This invention relates to remote control by radio of aircraft and other vehicles.

An object of the present invention is to provide electric motor operated means for actuating the steering mechanism and other controls of the airplane and to provide a system of control therefor whereby the functions of the electric motor operated means may be controlled from a distance. This object is accomplished by a system of motor control the several functions of which are caused to become operative respectively in response to the operation of relays of a radio receiver which are tuned to different frequencies. The radio transmitter employs a single wave length or carrier wave which is modulated by one, and sometimes two, of a plurality of different frequencies corresponding to the functions to be controlled. In case two functions of the motor control are to become operative at the same time, the carrier wave is modulated by a frequency combination such that the tuned relays, which are selected to operate simultaneously, may effectively separate the modulating wave into its two components.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred embodiment of the present invention is clearly shown.

In the drawings:

Fig. 1 is a wiring diagram of the control apparatus at the radio transmitting station.

Fig. 2 is a wiring diagram of the control apparatus at the radio receiving station.

Fig. 3 is a wiring diagram of the electric motor control apparatus which functions in cooperation with the radio transmitter shown in Fig. 1 and the radio receiver shown in Fig. 2.

The motor control system shown in Fig. 3 is for example adapted to be operated by the radio transmitter and receiver disclosed in Mirick Patent 1,597,416, granted August 24, 1926, and shown in Figs. 1 and 2.

Referring to Fig. 1, a broadcast antenna 10 is connected by a transformer 11 with a generator 12 which provides a radio carrier wave. The means for modulating the carrier wave includes a plurality of vibrators 13, 14, 15, 16, 17, 18 energized by a battery 19, the circuit of which is controlled by a main switch 20. The vibrators are adjusted independently to different frequencies. These vibrators are connected respectively by push buttons or keys 23, 24, 25, 26, 27, 28 with transformer primaries 33, 34, 35, 36, 37, 38 whose secondaries 43, 44, 45, 46, 47, 48 are connected

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with a transformer primary 49, whose secondary 50 is connected with the radio wave generator 12. If for example key 23 is pressed, a wave having the frequency of the vibrator 13 will be superimposed on the carrier wave and the modulated carrier wave will be radiated from the antenna 10 and will be picked up by antenna 60 of the receiving apparatus located on the airplane. The signal received by antenna 60 passes to amplifier detector 61 which causes the low frequency signal to pass through the input of a relay apparatus comprising a master tube 62 and a plurality of tubes 63, 64, 65, 66, 67, 68 corresponding in number to the number of control circuits at the transmitter. Tuned resonant relays 73, 74, 75, 76, 77, 78 are constructed to respond respectively, to the frequency of the vibrators 13, 14, 15, 16, 17, 18 of the transmitter. These relays are connected in series in the plate circuit of the master tube 62 supplied by B-battery 69. When key 23 is pressed to connect vibrator 13 with radio generator 12, resonant relay 73 responds to control the input circuit of tube 63, the output of which is connected with a secondary relay 83 which then operates to close a switch 83a and thus make a connection between a positive battery wire 144 and a terminal 93. Similarly, when key 24 of the transmitter is pressed, vibrator 14 is connected with radio generator 12; and resonant relay 74 and tube 64 function to effect the response of secondary relay 84 and the closing of the switch 84a to connect battery lead 144 with a terminal 94. Similarly, the other keys 25 through 28 respectively control tuned relays 75 through 78 to cause the tubes 65 through 68, respectively, to effect the operation of secondary relays 85 through 88, respectively, and the connection of battery wire 144 with terminals 95 through 98, respectively.

The filament electrodes of the tubes are energized by battery 70. A constant negative potential is maintained on the grids of tubes 63 through 68 from battery 71 connected across the input circuit of each of these tubes to resistances 63a through 68a. The independent resonant relays 73 through 78 are provided, respectively, with pairs of contacts 73a which are normally open; but, when any particular relay becomes energized, these contacts are closed and charge the grids of the respective tubes with positive polarity derived from battery 72 causing a plate current to flow in the particular tube and in the secondary relay in the plate circuit to be actuated. Normally when the contacts of the resonant relays are open, the grids are charged negatively;

and, accordingly, there will be zero plate current through that particularly circuit so that a maximum value of plate current will be obtained upon the closing of the contacts of the resonant relays.

While separate batteries are indicated for supplying negative grid bias and positive charging potential, a separate plate battery for the master tube 62 and a separate plate battery for the relay tubes 63 through 68, it will be understood that this is represented for the sake of clearness and that common source of potential may be employed.

As will be described later, it is necessary to operate two modulating vibrators simultaneously in order to effect the operation of two functions of the motor control system simultaneously. For example, the function of the motor control system controlled by vibrator 13 may be required concurrently with the function controlled by vibrator 16; the function controlled by vibrator 14 may be required concurrently with the function controlled by vibrator 16; and the function controlled by vibrator 15 may be required concurrently with the function controlled by vibrator 16. This means that tuned relays 73 and 76 must operate simultaneously, or tuned relays 74 and 76 must operate simultaneously, or tuned relays 75 and 76 must operate simultaneously. In securing this simultaneous action of these tuned relays, two conditions are essential. One condition is that the wave form of the resultant E. M. F. derived from the simultaneous operation of two oscillators must approach that of a wave in which instantaneous values of E. M. F. due to each one singly are added algebraically. Such a resultant is obtained by placing the transformer secondaries 43 through 48 in series as shown in Fig. 1. The second condition is that the waves to be combined should be as nearly as possible of pure sine form without harmonics. This condition is approached by using condensers 53 through 58 to tune the circuits electrically to the periods of the oscillators and resonant relays of the receiving apparatus tuned by condenser 73b through 78b.

The terminals 93 through 98 of Fig. 2 appear also at the top of Fig. 3 with the following additional designations: 93 is designated TR, meaning trim motor right or clockwise; 94 is designated TL, meaning trim motor left or counterclockwise; 95 is designated TC to designate the trim motor centering or returning to center position; 96 is designated GY, meaning gyroscope control; 97 is designated SR, meaning servomotor right or clockwise; 98 is designated SL, meaning servomotor left or counterclockwise.

The trim motor and the servomotor and controller therefor will now be described with reference to Fig. 3 in which the heavy lines indicate the armature circuits of the motor 100 and the servomotor 120 and the series field circuit of the servomotor. Servomotor 100 drives a shaft represented by a dot-dash line 101. Shaft 101 operates an arm 102 connected by link 103 with mechanism for operating a rudder or elevator or other part of an airplane to be controlled. A cable 104 is connected with arm 102 and passes around a pulley 105 and is attached at 106 to a plate 107 rotatable coaxially with a shaft 108 connected to a metallic arm 109 carrying a metallic contact or roller 110 for engaging either of two conductor segments 111 or 112 or an intermediate insulating segment 113 carried by plate 101. Shaft 108 is operated by a gyro (not shown).

The slack in the cable 104 is taken up by spring 114 connected with pin 106 and with a stationary stud 115. Pulley 105 is carried by an arm 116 attached to a shaft 117 driven by an electric motor 120 called a trim motor and carrying a limit switch operating arm 118 and a centering switch operating cam 170. The function of the trim motor is to set a course to be maintained automatically by the gyro.

The trim motor 120 has an armature 121 connected by brush 122 with a pivot 123 for the armature 124 of a relay 125. Armature 124 is urged downwardly by a spring 126 so that contact 127 on the armature 124 normally engages a contact 128. The relay 125 has a core 129 surrounded by a magnet coil 130 which, when energized, causes armature 124 to be attracted upwardly to cause contact 127 to be separated from contact 128 and to engage contact 131. Brush 132 is connected with a magnet coil 133 (which controls a brake) and with an armature 134 of relay 135 having a core 139 surrounded by the magnet coil 140 which, when energized, attracts armature 134 against the action of spring 136 and causes contact 137 (on the armature 134) to separate from contact 138 and to engage contact 141. A wire 142 leading from the plus pole of a battery is connected by switch 143 with the wire 144. The relay contacts 131 and 141 are directly connected to wire 144. A shunt field winding 145 is connected between wire 144 and wire 149 connected with wire 146 leading to the minus pole of the battery. Contacts 128 and 138 are connected by wire 147 and variable resistance 148 with wire 149.

Relay coils 130 and 140 are connected with wire 149 by wires 150 and 151. Relay coil 130 is connected by wire 152 with resilient blade 153 carrying a contact 154 for normally engaging a contact 155 carried by resilient blade 156 connected by wire 157 with terminal 93, TR. When sending key 23 (Fig. 1) is pressed, terminal 93 becomes connected with positive battery lead 144. Therefore relay 130, which is connected with battery negative lead 146 through wire 150, wire 151 and wire 149, is energized to attract armature 124 upwardly to separate contact 127 from contact 128 and to cause contact 127 to engage contact 131, thereby causing current to flow from the battery through armature 121 in such direction as to cause arm 116 to move toward the right or clockwise as indicated by arrow 116R in Fig. 3. So long as switch 23 is closed, clockwise movement of arm 116 will continue but not farther than is determined by a limit switch in a manner to be described. During operation of the motor 120 a motor brake (not shown) is held disengaged against the action of a brake applying spring (not shown) by an electromagnet whose coil 133 is then in circuit with the motor armature 121. When switch 23 is opened relay 130 is deenergized and the armature 124 returns to the position shown, thereby causing motor armature 121 to be short-circuited and the armature shaft to be brought quickly to rest by dynamic braking. The armature shaft and hence the arm 116 will be held in position by a friction brake which then is permitted to be engaged by a spring since the electromagnet coil 133 is then ineffective. During the first part of the period of deceleration of the armature shaft, the friction brake is ineffective to assist in stopping because the magnet 133 is sufficiently energized to overcome the force of the brake spring. During the end of this period, the magnet coil becomes sufficiently deenergized

to allow the spring force of the brake to be effective. Then the friction brake can assist dynamic braking. The principal function of the friction brake is to prevent creeping of the armature shaft and of arm 116. The friction brake spring is adjusted so that when the trim motor is normally loaded, the coil 133 can overcome the spring and release the brake. If key 23 is pressed long enough to cause arm stud 119 to strike blade 153, then contacts 154 and 155 are separated and armature circuit 130 is interrupted and the motor 120 will stop.

Relay magnet 140 is connected by wire 160 with spring blade 161 carrying a contact 162 engaging a contact 163 on a spring blade 164 connected by wire 165 with terminal 94, TL. When sending key 24 is pressed, terminal 94 will be connected with battery positive lead 144 and relay coil 140 will be energized since it is connected through wire 151 to the battery negative lead 146. Then armature 134 will be attracted upwardly to disengage contact 137 from contact 138 and to move contact 137 into engagement with contact 141, thereby connecting the motor armature 121 with wires 144 and 147 to cause the arm 116 to rotate counter-clockwise or to the left as indicated by arrow 116L in Fig. 3. So long as key 24 is pressed, counterclockwise rotation of arm 116 will continue, and when the key 24 is released rotation will stop. However if key 24 is held down long enough for insulated pin 119 on arm 118 to engage blade 161, then contact 162 will be separated from contact 163 and the relay 140 will be deenergized and rotation will stop.

The shaft 117 carrying arms 116 and 118 does not rotate at the same speed as the motor armature 121, but at a very much reduced speed, there being a train of speed reducing gears (not shown) between armature 121 and the shaft 117. Shaft 117 carries a cam 170 for engaging a cam follower 171 carried by resilient arm 172 which carries a contact 173 for engaging a contact 174 carried by arm 156. Cam 170 also engages a follower 175 on a resilient arm 176 which carries a contact 177 for engaging a contact 178 on arm 164. When arm 118 is in the exact central position shown, cam 170 permits both pairs of contacts 173, 174 and 177, 178 to be opened. If arm 116 has been moved toward the right by motor 120, cam 170 will be rotated clockwise to close contacts 177, 178. If it is desired to restore arm 116 to central position from some position toward the right of that shown in Fig. 3, the key 25 is depressed thereby causing terminal 95, TC to be connected with battery positive lead 144; therefore relay coil 140 is energized since it is then connected with terminal 95 through wire 160, contacts 162, 163, contacts 178, 177, blade 176 and wire 179 leading to terminal 95. Relay magnet coil 140 being energized, motor 120 will rotate arm 116 to rotate counterclockwise to central position. When central position of arm 116 is reached, cam 170 will permit contacts 177, 178 to be separated. Since relay 135 may have a slight time lag, the motor will not immediately come to rest but will cause arm 116 to move slightly to the left of central position and arm 118 slightly to the right and the cam 170 will so move as to cause contacts 173, 174 to be engaged whereupon relay coil 130 becomes energized while the magnetic flux in relay 135 is decaying. Relay 130 being energized, the motor will rotate clockwise and arm 166 will move toward the right, thereby causing contacts 173 to be disengaged, but since relay 130 has a time lag, arm

118 will not stop moving toward the left until it has caused contacts 177, 178 to be engaged. Therefore there will be an oscillatory motion of arms 116 and 117 through a small angle on each side of central position. This oscillatory centering movement will continue so long as the centering switch or key 25 is pressed. The foregoing obtains where extremely close centering is desired. If approximate centering will suffice, then more clearance can be provided between the cam followers 171, 175 and the cam 170 in the central position of the cam; and there will be no oscillation of the trim motor.

The servomotor 100 comprises an armature 180, a shunt field 181 connected between wire 144 and wire 146 and a series field 182 connected with wire 202 and connected with wire 146 through a brake magnet coil 183 which performs the same function as brake magnet coil 133 of trim motor 120. Clutch magnet coil 184 is in parallel with the shunt field 181. Brake coil 183 functions when the motor is operating to overcome a brake spring (not shown). The brake may be either the shoe type or disc type. The clutch magnet coil 184 and the shunt field 181 are operative when switch 143 is closed. Clutch coil 184, when energized, causes a clutch (not shown) to connect the shaft 101, driven at a reduced speed by the motor 100 through reduction gearing (not shown), with the arms 182 and 245. When the circuit of motor 100 is interrupted to stop the motor, brake magnet coil 183 is inoperative so that the motor-driven shaft 101 is frictionally prevented from creeping. The shunt field 181 and the clutch coil 184 are energized so long as the switch 143 in positive battery lead 142 is closed.

Armature 180 is connected through a commutator with brushes 190 and 191 connected respectively with the pivots of relay armatures 192 and 193 urged downwardly by springs 194 and 195, respectively, and carrying contacts 196 and 197, respectively, engageable with contacts 198 and 199, respectively, connected with a wire 200 leading to a resistance unit 201 connected by wire 202 with series field coil 182. Armatures 192 and 193 move upwardly toward relay cores 204 and 205, respectively, when their surrounding magnet coils 206 and 207, respectively, are energized. Coils 206 and 207 are connected by wires 208 and 209 with battery negative lead 146. A wire 210 is connected with wire 144 and with contacts 212 and 213 with which the armature-carried contacts 196 and 197, respectively, engage, when the armatures 192, and 193, respectively, move upwardly. Contacts 212 and 213 are connected with contacts 214 and 215, respectively, adapted to be engaged by contacts 216 and 217, respectively, carried by armatures 192 and 193, respectively, and insulated from said armatures and from said contacts 196 and 197. Contacts 216 and 217 are connected respectively to wires 218 and 219 leading to a resistance 220 connected with a contact 221 normally engaged by a contact 222 carried by bell-crank armature lever 223 which is attracted toward a relay core 224 when its surrounding coil 225 is energized. Armature lever 223 carries a contact 226 for engaging a contact 227. Lever 223, which is electrically connected with contacts 222 and 226, is connected by wire 228 with the junction of wire 290 and resistance 201, the other end of which is connected by wire 229 with contact 227. Therefore so long as contacts 226 and 227 are separated, resistance 201 is effective to reduce

the C. E. M. F. of the armature and to reduce the speed of the armature. The engagement of contacts 221 and 222 provides a circuit connection by which the resistance 220 is placed in parallel with the armature, said paralleling circuit being completed through either set of contacts 214, 216 or 215, 217. The relay coil 225 is a counter E. M. F. coil. It is connected in parallel with the armature 180 through a pair of normally closed contacts 230 and 231, the latter being carried by bell crank armature lever 232 which will move toward relay core 233 whenever either of its surrounding magnet coils 237, 238 are energized. One end of coil 237 is connected with terminal SR, 97 and the other end is connected with a terminal 237a. Likewise the coil 238 is connected between terminal SL, 98 and a terminal 238a. Terminal 237a is connected with a spring blade 240 carrying a contact 241 normally engaging a contact 242 carried by spring blade 243 having its free end located in the path of movement of an insulated pin 244 on an arm 245 driven by shaft 191. Blade 243 is connected by wire 245 with relay coil 206. Similarly terminal 238a is connected with spring blade 250 carrying a contact 251 normally engaging a contact 252 carried by spring blade 253 having its free end located in the path of movement of the pin 244. Blade 253 is connected by wire 255 with relay coil 207.

Terminal GY, 96 is connected by wire 256 with a resistance 265 connected with a gyro-controlled arm 109. Terminal 237a is connected by wire 257 with segment 111 which is mounted on the plate 107. Terminal 238a is connected by wire 258 with segment 112 located on plate 107.

The operation of the motor-controlled system will now be described. When it is desired to effect a direct manual control of the servomotor 100 (not through the use of the gyro) to effect clockwise rotation of motor 100 as indicated by 100R as shown in Fig. 3, the key 27 is pressed thereby causing the relay 87 to operate to connect terminal 97 with the positive battery wire 144, Fig. 2. This causes the following circuit to be established: wire 144, Fig. 2, connected with terminal 97, relay coil 237, normally closed limit switch contacts 241, 242, wire 245, relay coil 206, wires 208 and 209, negative battery lead 146. Then armature 192 moves up to cause contact 196 to be separated from contact 198 and to engage contact 212 and contact 216 to move up to engage contact 214. The following armature circuit is then established: wire 144, wire 210, contact 212, contact 196, armature 192, brush 190, armature 180, brush 191, armature 193, contact 197, contact 199, resistance 201, wire 202, series field 182, brake coil 183, negative battery lead 146. The shunt field 181 and the clutch magnet coil 184 are energized by the closing of switch 143. Therefore the motor 180 operates as a compound wound motor to rotate arm 102 in the direction 102R, the power being transmitted by clutch (not shown) which is effective when clutch magnet coil 184 is energized. The motor 100 will continue to rotate in this direction so long as key 27, Fig. 1, is closed but not further than determined by the limit switch in a manner to be described. During the running of the motor the brake coil 183 is energized to cause separation of the brake shoes or discs, not shown. When key 27 is opened the brake coil 183 will be deenergized to allow brake parts to be engaged through the action of a spring, thereby assisting in the stopping of the motor and holding the

motor armature in its stopped position. If however the key 27 is held down long enough for the arm 245 to carry its pin 244 into engagement with blade 243 and to cause separation of contacts 242 and 241, then coil 206 will be disconnected and armature 192 will move downwardly under the action of spring 194 to interrupt the circuit from the battery lead 142 to the armature 180.

Hand control of rotation of arm 102 counterclockwise as indicated by arrow 102L is effected in a similar manner, except that key 28 is pressed to cause terminal SL, 98 to be connected with positive battery lead 144 of Fig. 2. In this case relay coil 207 (instead of 206 as in the case of clockwise rotation) is effective to attract armature 193 upwardly to cause contact 197 to be separated from contact 199 and to engage contact 213 thereby causing current to flow through the armature 180 in the opposite direction to give counterclockwise rotation. Counterclockwise rotation is limited by engagement of pin 244 of arm 245 with switch blade 253 to cause separation of contacts 252 and 251.

As in the case of the trim motor 120, the stopping of the servomotor 100 from either direction of rotation is hastened chiefly by dynamic braking and the friction brake released by magnet 183 (when sufficiently deenergized) assists in stopping and then prevents creeping of the armature shaft and arm 102.

Whenever operation of the servomotor 100 is effected by pressing either of the keys 27 or 28 to cause terminals 97 or 98 to be connected with the battery, then one or the other of the relay coils 237 or 238 is energized to effect the attraction of armature lever 232 to separate contacts 231 from contact 230. Therefore whenever the servomotor is controlled by hand through the keys 27 or 28, the relay coil 225 is inoperative and contacts 221 and 222 remain closed so that the resistance 220 remains in parallel with the armature 180 when either one of the armatures 192 or 193 is up and the other one is down. Under these conditions the resistance 220 is a bypass around the armature 180 and the speed of the armature is thereby limited as well as by the effect of the resistance 201 in series with the series field 182. When the servomotor 180 is controlled by the gyro, neither of the coils 237 or 238 is effective. Therefore contacts 230, 231 remain closed and the coil 225 operates as a counter E. M. F. coil; and voltage thereon will build up to a certain value as the speed of the motor increases until finally the armature 223 will be attracted toward the core 224 and the contacts 221 and 222 will be separated and the contacts 226 and 227 will be engaged, thereby rendering both resistances 220 and 201 ineffective, whereupon there is an abrupt increase in motor speed. This increase in motor speed is desirable when controlling the servomotor by gyro control.

To obtain gyro control, the operator presses key 26, Fig. 1, thereby connecting positive battery wire 144 with terminal GY, 96 which is connected with gyro-controlled arm 109. As long as conductor roller 110 is on the dead spot 113 of plate 107, the servomotor 100 will not operate. However, if the plane should swerve from its course there will be relative rotation between the arm 109 and the segments 111 and 112. If for example the deviation from course would be such as to cause segment 111 to be engaged by roller 110, then there will be a connection between terminal 96 and terminal 237a whereupon

relay coil 296 will be energized to cause the servomotor to turn the arm 102 in the direction of the arrow 102R. This will effect a pull in a direction to cause clockwise rotation of plate 107 and hence segment 111 in the R direction until such time as the dead spot 113 engages the roller 110. Then the motor 100 stops and the arm 102 remains in a fixed position. If the deviation from course is in the opposite direction such that segment 112 engages roller 110, then terminal 238a becomes connected with terminal GY, 95, thereby effecting energization for relay coil 207 thereby causing motor 100 to rotate the arm 102 counterclockwise or in the direction of arrow 102L thereby effecting counterclockwise rotation of plate 107 in order to bring the dead spot 113 again into engagement with the roller 110. Since there is a certain time lag in the relay system it is evident that the plate 107 must overtravel the roller slightly therefore there will be an oscillation of the arm 102 through an angle approximately 1° so long as the gyro is controlling the servomotor.

During the 1° oscillation, the acceleration of the servomotor in either direction is insufficient to cause the counter E. M. F. relay 225 to close. Therefore the oscillation occurs at slow speed. Resistor 201, being in series with the servomotor, prevents destructive peak currents therein as the motor reverses. Oscillation of the servomotor could be avoided by using a wide nonconducting segment 113; but that would result in wider deviation from the set course than might be desirable.

The gyro controlled arm 109 so controls the servomotor 100 as to automatically maintain the airplane on a definite course either up or down or left or right. It will be understood of course that the rod 103 is adapted to control a rudder or ailerons. To provide for control of both rudder and ailerons, the apparatus shown in Fig. 3 will be duplicated and the radio controller will be equipped for transmitting 12 different frequencies which are picked up by tuned relays in the receiver.

The course which is automatically kept by the gyro controller of the servomotor is established by the trim motor 120. If for example one wishes to establish a course to the right of the course which had been maintained, the key 23 is pressed to effect clockwise rotation of arm 116 in the direction of arrow 116R in the manner which has been described. When the arm 116 so moves, the spring 114 causes the plate 107 to move counterclockwise to bring the segment 111 into engagement with the roller 110 on the gyro controlled arm 109 whereupon the servomotor 100 will cause the arm 102 to move to the direction 102R to effect a change in course to the right. Arm 109 and its contact 110 are held in fixed relation to the earth by the gyro. Plate 107 is moved by the plane when it deviates from course, or by the trim motor when desired. The change in course will cause the plate 107 to rotate clockwise relative to the arm 109 until the dead spot 113, hits the roller 110; then the change in course is thereafter maintained by the gyro. The extent of change in course to the right will depend on the duration of closing of the key 23. Likewise if it is desired to change the course toward the left, the key 24 is pressed to cause the arm 116 to move counterclockwise as indicated by arrow 116L, thereby causing clockwise rotation of plate 107 to bring segment 112 into engagement with roller 110, thereby causing the servomotor 100 to move arm 102 counterclockwise as indi-

cated by arrow 102L. This will change the course to the left and the plate 107 will rotate counterclockwise to carry the dead spot 113 into contact with the roller 110 on gyro arm 109. The extent of change of course to the left depends upon the duration of closing of switch 24. When either of the switches 23 or 24 are open, the plate 107 remains in the adjusted position set by the trim motor. Thereafter the gyro controls the servomotor 100 to maintain the course determined by the trim motor.

The functioning of the system with respect to changing the course letter to right or to left applies equally well to changing the angle of flight to up or to down. As stated before, for complete control for left and right and up and down, the system shown in Fig. 3 would be duplicated, one system for direction and the other for angle of flight and the transmitter would provide for sending twelve different frequencies and the receiver would provide for picking up those frequencies and causing the proper tuned relay to be responsive thereto. Obviously the sending and receiving apparatuses must take care of at least two frequencies at the same time since key 26 of gyro-controller is held down while either of keys 23, 24, 25 is operated.

Whenever it is desired to return to the course originally set, the key 25 is pressed while key 26 is pressed to cause the trim motor to return to center position, thereby centering the arm 116 and the plate 107 thereby causing the gyro to control the servomotor for a course straight ahead.

The function of the resistance 260 connected with gyro controlled arm 109 is to produce a voltage drop equal to the voltage drop across either of relay coils 237 or 238. In this way the voltage drop across either of relay coils 206 or 207 is the same whether they operate in series with coils 237 or 238, respectively, as in case of direct control of the servomotor 100, or whether they operate in series with the resistance 260, as in case of gyro control of the servomotor.

From the foregoing description of the construction and mode of operation of the servomotor control system, it is apparent that we provide for direct manual control of the servomotor for slow speed operation in either direction. This is an advantage because there will be less danger of getting too much deviation from course by the direct manual control. In other words, the manual control is less sensitive, and a lesser degree of skill is required to operate it. We have provided gyro automatic control by which the servomotor maintains a course. During oscillation of the servomotor between close limits, the acceleration of the motor is low and the motor is protected by a resistance which prevents overheating. The course to be maintained by the gyro is determined by the trim motor. If the deviation from course is to be small the adjustment made by the trim motor is small and the servomotor operates at slow speed. If the deviation from course is relatively great requiring larger adjustment by the trim motor, the servomotor accelerates to top speed in order to effect its control of the steering apparatus quickly.

To recapitulate, applicants' invention relates to a remote control of a steering part of a vehicle. For example, applicants' invention is adapted to operate and control the adjustment of the rudder of an airplane. An electric servomotor 100 provides the motive power to adjust the rudder. A series of local push buttons are provided of

which buttons 27 and 28, when pressed, complete remote controlling circuits for effecting rotation of the motor in one or the other direction respectively. For instance when button 27 is closed the motor operates to adjust the rudder to the right, and when button 28 is closed the motor adjusts the rudder to the left. Limit switches stop motor operation when the rudder has been adjusted through a predetermined range of movement in either direction. The speed of the servomotor during these adjusting cycles is held at a reduced speed by the provision of a relay controlled resistance circuit across the armature of the motor.

During flight of the airplane a gyroscope is adapted to maintain the airplane in a substantially constant direction. When gyro control is to be instituted, push button 26 is pressed rendering the gyro controlled circuits to the servomotor effective. Now any deviation of the airplane from the set course in one direction or the other will cause the gyro control to become effective automatically to cause the servomotor to operate and adjust the rudder in one direction or the other to return the airplane from its veered course to the set course. The relay controlled resistance circuit is opened and thus the motor is adapted to operate at full speed while under gyro control.

The course which is automatically kept by the gyro controller of the servomotor is established by the trim motor 120. If, for example, the operator desires to establish a course to one or the other side of the course then maintained by the gyro, either push button 23 or 24 is depressed while the push button 26 is depressed. When push button 23 is closed the trimmer motor 120 is caused to rotate in the one direction which will rotate the gyro plate 107 in one direction causing said gyro to become effective to render the servomotor operative to adjust the rudder so that the airplane is now brought into the newly set course in which the gyro will maintain it. To change the course of the airplane to the opposite side of the set course, button 24 is pressed which effects rotation of the trimmer motor 120 in the other direction, adjusting the gyro so that the servomotor is rendered effective to adjust the rudder for the newly set course in which the airplane is maintained by said gyro. Limit switches control the operation of the trim motor so that it may actuate the gyro adjusting mechanism at a predetermined distance only in either direction.

In the claims which follow, the term automotive vehicle embraces land, water and air vehicles. The term course as applied to air vehicles includes an upwardly or downwardly course as well as a directional course.

While the embodiment of the present invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, relay switches having magnet coils for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the relay switches and having a gyro-controlled contact and two spaced contacts respectively connected with the magnet coils of the relay switches, a movable plate supporting the two spaced con-

tacts, means for causing the plate to move in accordance with movements of the steering member and manually controlled means for establishing connection between a current source and the relay magnet coils through the two-way switch.

2. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, relay switches having magnet coils for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the relay switches and having a gyro-controlled contact and two spaced contacts respectively connected with the magnet coils of the relay switches, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing connection between a current source and the relay magnet coils through the two-way switch, and manually controlled means for effecting movement of the plate.

3. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, means for connecting a current source with either of the devices, means responsive to the operation of a gyro for controlling the connecting means, means responsive to the operation of the servomotor for controlling said connecting means, a reversible trim motor, means for effecting a control of the connecting means by movements of the trim motor in either direction, and manually controlled means for effecting operation of the trim motor in either direction.

4. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, relay switches having magnet coils for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the relay switches and having a gyro controlled contact and two spaced contacts respectively connected with the magnet coils of the relay switches, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing connection between a current source and the relay magnet coils through the two-way switch, a reversible trim motor, means for effecting movement of the plate in response to movements of the trim motor in either direction, and manually controlled means for effecting operation of the trim motor in either direction.

5. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering members, and manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch.

6. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, elec-

trically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch, and manually controlled means for moving the plate in either direction.

7. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch, a reversible trim motor, means for effecting movement of the plate in response to movements of the trim motor in either direction, and manually controlled means for effecting operation of the trim motor in either direction.

8. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, a spring for urging the plate in one direction, a cable connecting the plate with the steering member operated by the servomotor and held taut by the spring, a bodily movable pulley around which the cable passes, manually controlled means for moving the pulley in either direction, and manually controlled means for establishing through the two-way switch a connection between a current source and the electrical devices which control the servomotor.

9. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, a spring for urging the plate in one direction, a cable connecting the plate with the steering member operated by the servomotor and held taut by the spring, a bodily movable pulley around which the cable passes, a reversible trim motor for moving the pulley in either direction, manually controlled means for effecting operation of the trim motor in either direction, and manually controlled means for establishing through the two-way switch a connection between a current source and the electrical devices which control the servomotor.

10. A motor control system for use with vehicle steering apparatus comprising a reversible

servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, means for connecting a current source with either of the devices, means responsive to the operation of a gyro for controlling the connecting means, means responsive to the operation of the servomotor for controlling said connecting means, a reversible trim motor, means for effecting a control of the connecting means by movements of the trim motor in either direction, manually controlled means for effecting operation of the trim motor in either direction from a normal status, and manually controlled means for effecting an operation of the trim motor reverse to that just previously effected and then causing the trim motor to stop after returning to normal status.

11. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices throughout the two-way switch, a reversible trim motor for moving the pulley in either direction, manually controlled means for effecting operation of the trim motor in either direction from a normal status, manually controlled means for effecting an operation of the trim motor reverse to that just previously effected and then causing the trim motor to stop after returning to normal status and manually controlled means for establishing through the two-way switch a connection between a current source and the electrical devices which control the servomotor.

12. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, a spring for urging the plate in one direction, a cable connecting the plate with the steering member operated by the servomotor and held taut by the spring, a bodily movable pulley around which the cable passes, a reversible trim motor for moving the pulley in either direction from an intermediate location, manually controlled means for effecting operation of the trim motor in either direction, manually controlled means for effecting an operation of the trim motor reverse to that just previously effected and then causing the trim motor stop in response to return of the pulley to said intermediate location, and manually controlled means for establishing through the two-way switch a connection between a current source and the electrical devices which control the servomotor.

13. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices

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and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch, the spacing between the plate-supported contacts of the two-way switch being relatively short whereby the steering member is given an oscillatory movement by the servomotor which is caused to rotate alternately in opposite directions through control by the two-way switch, and means for preventing the rise of destructive peak currents due to reversals of the servomotor.

14. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch, whereby the two-way switch operates through its gyro-controlled contact and its servomotor operated plate to maintain a course within certain limits, and means for shifting the plate in order to set the control system for changing the course, and means for causing the servomotor to operate at less than full speed when the amount of course change is relatively small or at full speed when the amount of course change is relatively great.

15. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch whereby the two-way switch operates through its gyro-controlled contact and its servomotor operated plate to maintain a course within certain limits, and means for shifting the plate in order to set the control system for changing the course, means for limiting the speed of the servo-motor to less than full speed and means responsive to a predetermined duration of the operation of the servo-motor for rendering inoperative the speed limiting means in order that the servo-motor will operate at full speed, whereby the servo-motor operates at less than full speed when the amount of course change is relatively small or at full speed when the amount of course-change is relatively great.

16. A motor control system for use with vehicle steering apparatus comprising a reversible servo-motor, a steering member operated thereby, electrically operated devices for causing rotation of the servo-motor in opposite directions, a two-way switch for controlling the electrical devices

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and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch whereby the two-way switch operates through its gyro-controlled contact and its servo-motor operated plate to maintain a course within certain limits, and means for shifting the plate in order to set the control system for changing the course, a servo-motor-armature by-passing resistance circuit for limiting the speed of the servo-motor to less than full speed, and a counter E. M. F. relay connected with the servo-motor-armature for rendering said resistance circuit ineffective after a predetermined duration of the operation of the servo-motor in order that the servo-motor will operate at full speed, whereby the servo-motor operates at less than full speed when the amount of course change is relatively small or at full speed when the amount of course-change is relatively great.

17. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for establishing a connection between a current source and the electrical devices through the two-way switch whereby the two-way switch operates through its gyro-controlled contact and its servomotor operated plate to maintain a course within certain limits, and means for shifting the plate in order to set the control system for changing the course, means for limiting the speed of the servomotor to less than full speed and means responsive to a predetermined duration of the operation of the servomotor for rendering inoperative the speed limiting means in order that the servomotor will operate at full speed, whereby the servomotor operates at less than full speed when the amount of course-change is relatively small or at full speed when the amount of course-change is relatively great, and manually controlled means for directly connecting the electrically operated controlling devices of the servomotor with a current source and for rendering inoperative the means which is responsive to a predetermined duration of the servomotor for rendering inoperative the speed-limiting means of the servomotor whereby the servomotor will operate only at reduced speed when only the direct manual control is effected.

18. A motor control system for use with vehicle steering apparatus comprising a reversible servomotor, a steering member operated thereby, electrically operated devices for causing rotation of the servomotor in opposite directions, a two-way switch for controlling the electrical devices and having a gyro-controlled contact and two spaced contacts respectively connected with the electrical devices, a movable plate supporting the two spaced contacts, means for causing the plate to move in accordance with movements of the steering member, manually controlled means for

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establishing a connection between a current source and the electrical devices through the two-way switch whereby the two-way switch operates through its gyro-controlled contact and its servomotor operated plate to maintain a course within certain limits, and means for shifting the plate in order to set the control system for changing the course, a servomotor-armature by-passing resistance circuit for limiting the speed of the servomotor to less than full speed, and a counter 10 E. M. F. relay connected with the servomotor-armature for rendering said resistance circuit ineffective after a predetermined duration of the operation of the servomotor in order that the servomotor will operate at full speed, whereby the servomotor operates at less than full speed when the amount of course-change is relatively small or at full speed when the amount of course-change is relatively great and manually con-

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trolled means for directly connecting the electrically operated controlling devices of the servomotor with a current source and for rendering inoperative the counter E. M. F. relay whereby 5 the servomotor will operate only at reduced speed when only the direct manual control is effective.

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