May 20, 1930. G. E. GREENLEAF ET AL 1,759,551

CONTROL SYSTEM

Filed April 20, 1923 3 Sheets-Sheet 1

FIG. 7.

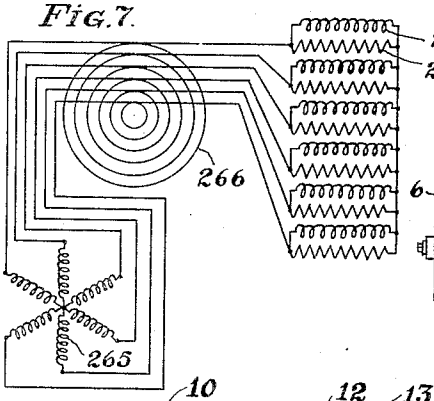


FIG. 1.

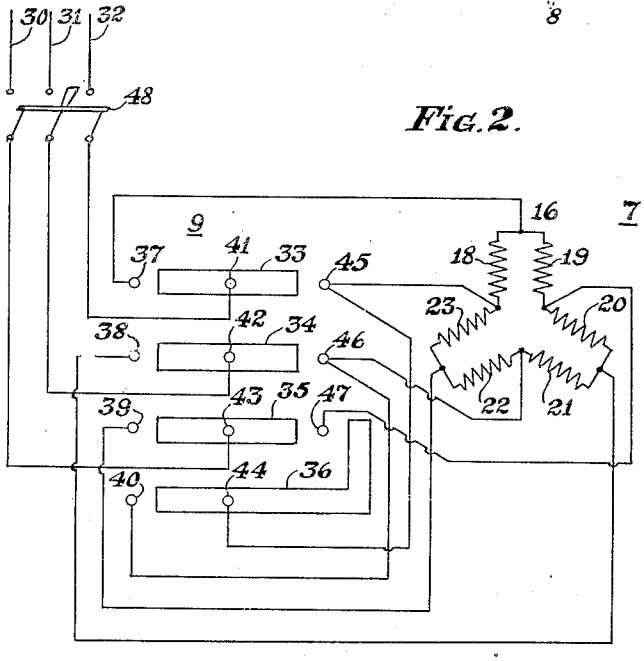


FIG. 2.

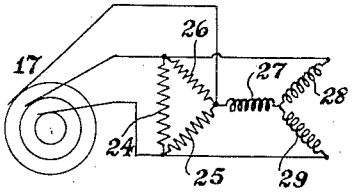
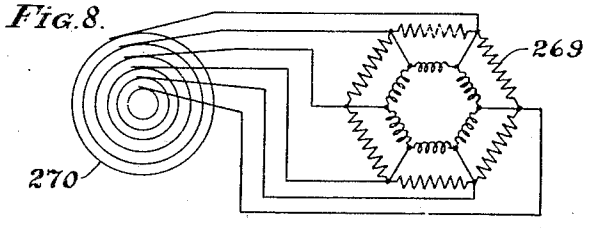


FIG. 8.



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CONTROL SYSTEM

Filed April 20, 1923 3 Sheets-Sheet 2

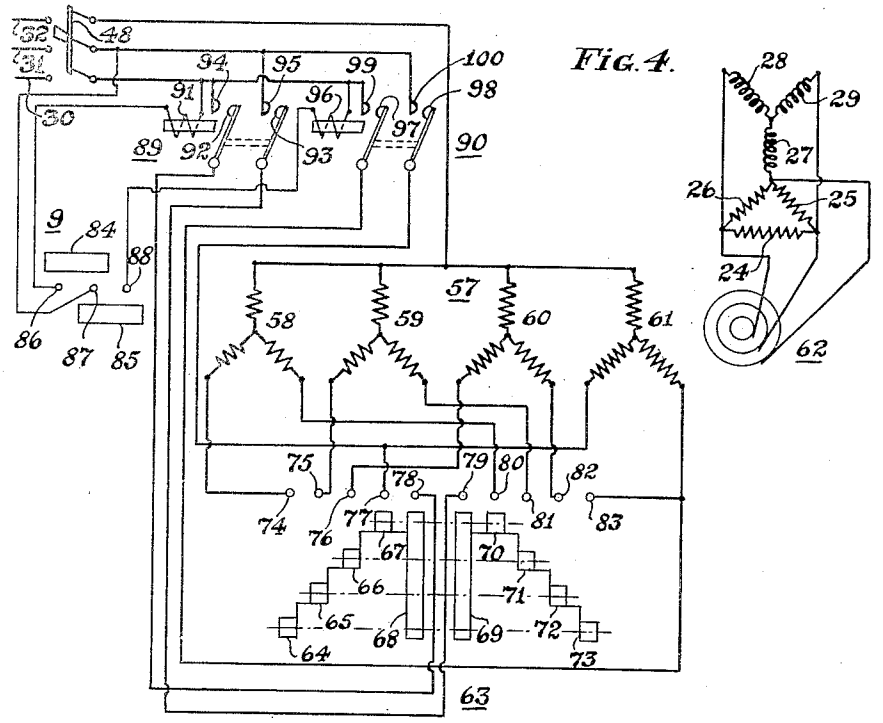


Fig. 4.

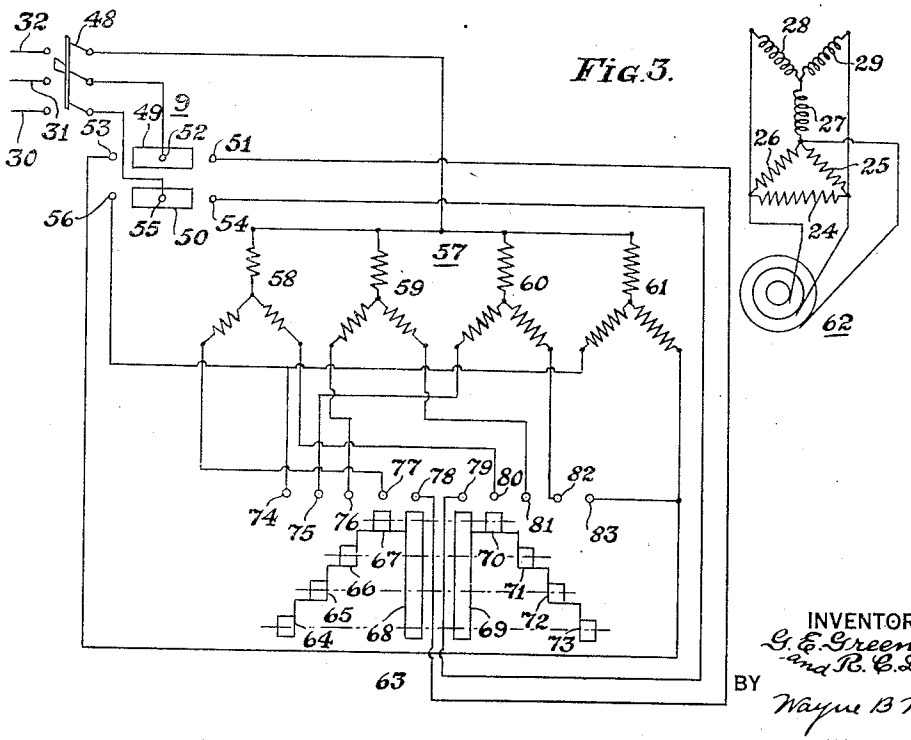


Fig. 3.

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CONTROL SYSTEM

Filed April 20, 1923 3 Sheets-Sheet 3

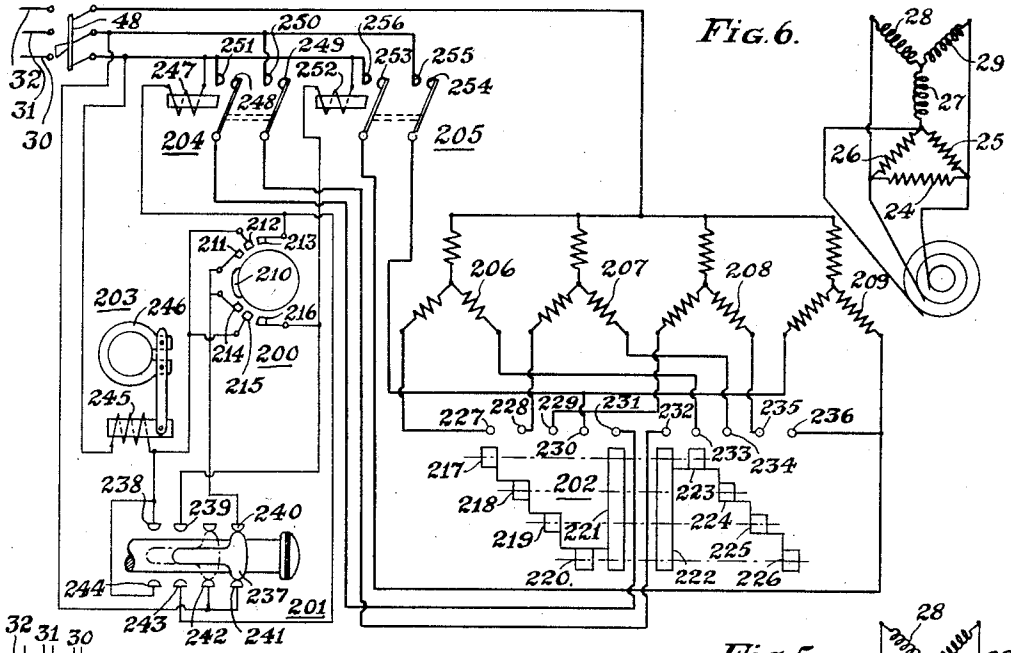


Fig. 6.

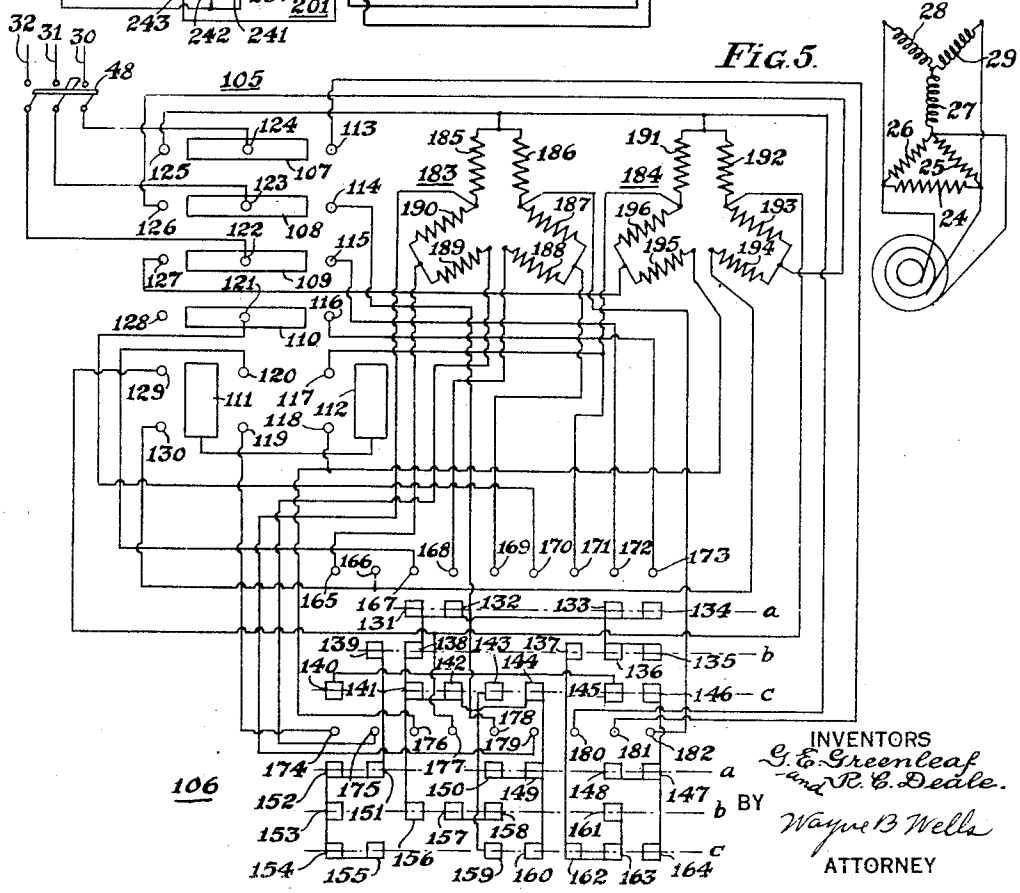


Fig. 5.

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UNITED STATES PATENT OFFICE

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CONTROL SYSTEM

Application filed April 20, 1923. Serial No. 633,510.

Our invention relates to control systems for operating machines having reciprocating members and particularly to control systems for operating planers and other machine tools.

One object of our invention is to provide a control system having an alternating current motor that shall operate a reciprocating member at different speeds in opposite directions and that shall insure a good starting torque.

Another object of our invention is to provide a control system comprising a wound-rotor induction motor, means for varying the poles of the primary winding to govern the motor speed, and impedance elements connected to the secondary winding to prevent an excessive current flow through the motor during reversing and starting and to develop a relatively high starting torque.

Another object of our invention is to provide a planer control system that shall embody an induction motor for reciprocating the planer table, the primary winding of the motor being controlled to vary the motor speed and to obtain a quick return of the table, and impedance elements connected to the motor secondary winding for so governing the secondary circuit as to offer relatively large opposition to the high frequency current flowing through the secondary winding during reversing and starting and to offer substantially little opposition to the low frequency current flowing through the secondary circuit when the motor is operating at a normal speed.

A further object of our invention is to provide a planer control system that shall comprise an alternating current motor having a primary and a secondary winding, a transfer switch for changing the primary winding of the motor to determine the motor speed, means comprising a pilot switch operated by the planer table for reversing the primary connections to reciprocate the table and to effect return of the table at a relatively rapid rate, and impedance elements inserted in the secondary winding of the motor for limiting the current flow through the motor during starting and reversing and for effecting substantially short circuit conditions in the secondary circuit when operating the motor at normal speed.

Heretofore, it has been customary to operate machine tools, such for example, as planers, either by a direct current motor or by some form of mechanical drive. Although it has been very desirable, in many cases, to operate planers by alternating current motors, it has been impossible to utilize such motors by reason of the difficulty in varying the speed of such motors and also by reason of the difficulty in effecting a quick reversal of the rotation of such motors.

In a control system constructed in accordance with our invention, the primary winding of an induction motor is so varied as to effect operation of the motor at various speeds in a forward direction and to effect operation of the motor at high speed in a reverse direction. Thus, the cutting stroke of a planer may be varied in accordance with the material being cut and the return stroke may be effected at a very rapid rate. Moreover, impedance elements are connected in the secondary circuit of the motor to prevent an excessive flow of current during starting and reversing and to develop a relatively high starting torque. For a complete description of the connecting of various impedance elements in the secondary circuit of a planer control system, reference may be had to the application of Chester L. Seymour and Robert C. Deale, Serial No. 500,997, filed September 15, 1921.

When starting an induction motor, the frequency of the current developed in the secondary circuit approaches the frequency of the current supplied to the primary circuit from the source of supply. The frequency of the current developed in the secondary circuit is gradually lowered during acceleration until a minimum low frequency is reached when the motor is operating at normal speed. In the construction above set forth, it is apparent that the inductive elements offer a relatively large opposition to the high frequency current during starting, and consequently the majority of the starting current passes through the resistors. Thus, the motor is started with a relatively high torque while

using a relatively small starting current. The frequency of the secondary current is lowered in accordance with the acceleration of the motor and accordingly the opposition of the inductive elements to the secondary current is lowered in accordance with the increase in speed of the motor. Such action by the impedance elements permits a gradual acceleration of the motor to full speed. When the motor is operated at normal speed, the frequency of the secondary current is very low and accordingly the inductive elements offer little or no opposition to the flow of such current. Consequently, when the motor is operating at normal speed the resistors carry little secondary current and the secondary circuit is substantially short-circuited through the inductive elements. In many cases, it may be desirable to include capacity elements in the secondary circuit in order to make the reactance portion of that circuit resonant to the frequency developed when the motor is operating at normal speed, and consequently still further reduce the current through the resistors while the motor is running at normal speed.

As above set forth, planer control systems heretofore provided have been connected to direct current supply circuits. When alternate-current power only is available, it has been customary to operate the planer by direct current supplied by a motor generator set. In operating a planer, it is very desirable to operate the table at different speeds during the cutting stroke and to effect a rapid return of the table. If the planer table is directly geared to an electric motor, it is necessary to brake the motor and reverse its direction of rotation at each end of the planer stroke. A direct current motor can be quickly stopped by completing a dynamic braking circuit through it and moreover the speed of a direct current motor can be easily controlled. When the movement of a direct current motor and a table is stopped, such motor can be quickly accelerated in a reverse direction. Accordingly, as before set forth, machine tools such as planers have been generally operated by direct current motors.

In the accompanying drawings:

Figure 1 is a partial side elevational view of a planer provided with a control system constructed in accordance with our invention.

Fig. 2 is a diagrammatic view of an alternating-current control system operating the main motor at different speeds in opposite directions.

Fig. 3 is a diagrammatic view of an alternating-current control system adapted to operate the main motor at four different speeds in one direction and at a relatively high rate of speed in an opposite direction.

Fig. 4 is a diagrammatic view of a modification of the system shown in Fig. 3.

Fig. 5 is a diagrammatic view of a modification of our invention.

Fig. 6 is a diagrammatic view of another modification of our invention having a pendent switch for controlling the main motor.

Fig. 7 is a diagrammatic view of a portion of a control system having a six phase secondary circuit.

Fig. 8 is a modification of the system shown in Fig. 7.

Referring to Fig. 1 of the drawings, a planer 1 having a bed 2, a table 3 and uprights 4 is adapted to be operated by a control system constructed in accordance with our invention. The uprights 4 carry a rail 5 which supports a tool head 6. The table 3 is connected to an alternating current motor 7 through a set of gearing 8. The motor 7 is controlled by a pilot switch 9 which is of any suitable type. Two adjustable dogs 10 and 11, which are adjustably secured to the table 3, serve to effect operation of the pilot switch 9 at each end of the table stroke. The dogs 10 and 11 respectively engage levers 12 and 13 which are directly connected to the pilot switch 9 by means of suitable links 14 and 15. Near the end of the table stroke towards the right, as shown in Fig. 1 of the drawings, the dog 10 engages the lever 12 for so moving the pilot switch 9 as to reverse the direction of rotation of the motor. The planer table 3 is moved towards the left. When near the end of such movement, the dog 11 engages the lever 13 for again operating the pilot switch 9 to reverse the direction of rotation of the motor 7. The motor 7 is preferably an induction motor of the wound-rotor type.

Referring to Fig. 2 of the drawings, a control system is shown for operating a planer table during the cutting stroke at a predetermined speed and for effecting a return movement of the table at substantially twice the speed during the cutting stroke. In Fig. 2 as well as in the systems disclosed in the other figures to be described, similar parts to those shown in Fig. 1 will be indicated by like reference characters. The motor 7 comprises a primary winding 16 and a secondary winding 17. The primary winding 16 is divided up into portions 18, 19, 20, 21, 22 and 23. The secondary winding 17 is connected through slip rings to impedance elements comprising resistors 24, 25 and 26 and inductors 27, 28 and 29. The resistors 24, 25 and 26 are preferably connected to the slip rings in delta arrangement and the inductors 27, 28 and 29 are preferably connected to the slip rings in Y arrangement. It is to be understood, however, that the arrangement of the impedance elements in the secondary circuit may be varied as desired.

The pilot switch 9, which is operated by the dogs 10 and 11 on the planer table, serves to connect the primary winding 16 to

supply conductors 30, 31 and 32. The pilot switch comprises contact segments 33, 34, 35 and 36 which are adapted to engage contact fingers 37 to 47 inclusive.

When the pilot switch 9 is moved towards the left, as shown in Fig. 2 of the drawings, to connect the contact segments 33 to 36 inclusive, respectively, with the contact fingers 37 to 40 inclusive, the primary winding 16 of the motor 7 is connected across the supply conductors 30, 31 and 32 to effect movement of the table 3 towards the left, as shown in Fig. 1 of the drawings at a relatively rapid rate. The contact segment 33, which bridges contact members 37 and 41, connects the supply conductor 32 to the junction point between the portions 18 and 19 of the primary winding. The contact segment 34 bridges the contact fingers 38 and 42 for connecting the supply conductor 31 to the junction point between the portions 20 and 21 of the primary winding. The contact segment 35 bridges the contact fingers 39 and 43 for connecting the supply conductor 30 to the junction point between the portions 22 and 23 of the primary winding. The contact segment 36 bridges the contact fingers 40, 44 and 47 and serves to interconnect the junction point between the portions 18 and 23 of the winding, the junction point between the portions 21 and 23 of the winding and the junction point between the portions 19 and 20 of the winding. Such connections are made in order to vary the poles of the primary winding and increase the speed of the motor.

Near the end of the movement of the planer table 3 towards the left, as shown in Fig. 1 of the drawings, the dog 11 engages the lever 13 to reverse the position of the pilot switch 9. The contact segments 33 to 36, inclusive, disengage the contact fingers 37 to 40, inclusive, and the contact segments 33 to 35, inclusive, engage the contact fingers 45, 46 and 47. The bridging of the contact fingers 41 and 45 by the contact segment 33 serves to connect the supply conductor 32 to the junction point between the portions 18 and 23 of the primary winding. The bridging of the contact fingers 42 and 46 by the contact segment 34 serves to connect the supply conductor 31 to the junction point between the portions 21 and 22 of the primary winding. The bridging of the contact fingers 43 and 47 by the contact segment 35 serves to connect the supply conductor 30 to the junction point between the portions 19 and 20 of the primary winding. The direction of rotation of the induction motor is reversed and the speed thereof is reduced substantially one-half. Accordingly the planer table 3 is moved towards the right, as shown in Fig. 1 of the drawings, at substantially one-half the speed of the return movement. The impedance elements 24 to 29 inclusive, which are included in the secondary circuit 17 of the motor, serve to limit the current flow through the motor during the reversing operation thereof. When the induction motor is reversed, the frequency of the current induced in the secondary circuit approaches twice the frequency of the current impressed upon the primary winding. Accordingly, at such time, the inductors 27, 28 and 29 in the secondary winding offer great opposition to the flow of current through the secondary circuit. The resistors 24, 25 and 26 permit a limited amount of the high frequency current to flow through them and thus develop a relatively high torque during starting and reversing. When the motor is operated at normal speed, the inductors 27, 28 and 29 offer substantially negligible opposition to the flow of current through them. Such impedances are preferably tuned to the frequency of the current induced in the secondary winding when the motor is operating at normal speed. Such impedance elements also permit a steady and even acceleration of the motor to full speed.

Near the end of the cutting stroke, the dog 10 engages the lever 12 to again reverse the position of the pilot switch 9 and to repeat the above cycle of operations. A suitable switch 48 is provided for connecting the pilot switch 9 to the supply conductors. In the system shown in Fig. 2 the speed of the motor is controlled by varying the poles of the single primary winding.

Referring to Fig. 3 of the drawings, a modified control system is illustrated wherein the pilot switch 9 comprises two contact segments 49 and 50. The contact segment 49 is adapted to engage contact fingers 51, 52 and 53. The contact segment 50 is adapted to engage contact fingers 54, 55 and 56. The primary circuit 57 of the induction motor comprises windings 58, 59, 60 and 61 of different number of holes. Such windings 58, 59, 60 and 61 are preferably connected in Y arrangement but if so desired such windings may be connected in delta arrangement. The secondary circuit 62 of the motor is connected to impedance elements comprising resistors 24, 25 and 26 and inductors 27, 28 and 29 in the same manner as the secondary circuit shown in Fig. 2 of the drawings.

A transfer switch 63 is provided for varying the speed of the motor during the cutting stroke. The transfer switch illustrated is adapted to effect four different speeds of the motor during the cutting stroke. The transfer switch comprises contact segments 64 to 73 inclusive which are adapted to engage contact fingers 74 to 83 inclusive.

When the pilot switch 9 is moved towards the left, as shown in Fig. 3 of the drawings, the contact segment 49 bridges the contact

fingers 52 and 53 and the contact segment 50 bridges the contact fingers 55 and 56 to connect the winding 61 to the supply conductors 30, 31 and 32. The motor is operated in a direction to move the table 3 towards the left, as shown in Fig. 1 of the drawings, at a relatively rapid rate. Near the end of the return movement, the dog 11 operates the pilot switch in the manner heretofore set forth to move the switch towards the right, as shown in Fig. 3 of the drawings. The contact segment 49 disengages the contact finger 53 and bridges the contact fingers 51 and 52. The contact segment 50 disengages the contact finger 56 and bridges the contact fingers 54 and 55. The contact fingers 51 and 54 of the pilot switch are directly connected to the contact fingers 78 and 79 of the transfer switch 63.

The transfer switch 63 may be moved to four different positions for effecting four different speeds during the cutting stroke of the planer. In the first position of the transfer switch, the contact segments 67, 68, 69 and 70 respectively engage the contact fingers 77, 78, 79 and 80 for connecting the winding 58 of the primary circuit to the supply conductors 30, 31 and 32. The motor is operated at a limited speed when the winding 58 is connected to the supply conductors.

In the second position of the transfer switch, the contact segments 66, 68, 69 and 71 respectively engage the contact fingers 76, 78, 79 and 81 for connecting the winding 59 of the primary circuit to the supply conductors 30, 31 and 32. In the third position of the transfer switch, the contact segments 65, 68, 69 and 72 respectively engage the contact fingers 75, 78, 79 and 82 for connecting the winding 60 of the primary circuit across the supply conductors 30, 31 and 32. In the fourth position of the transfer switch, the contact segments 64, 68, 69 and 73 respectively engage the contact fingers 74, 78, 79 and 83 for connecting the winding 61 across the supply conductors 30, 31 and 32. The windings 59, 60 and 61 progressively increases the speed of the motor and in the fourth position of the transfer switch the cutting stroke is effected at the same speed as the return stroke.

The impedance elements, which are included in the secondary circuit of the motor, operate in the same manner as set forth in describing the circuit disclosed in Fig. 2 of the drawings. In operating the system disclosed in Fig. 3 the transfer switch is set in accordance with the speed desired during the cutting stroke and the system is then operated automatically in accordance with the movement of the planer table.

Referring to Fig. 4 of the drawings, a system very similar to the system shown in Fig. 3 is provided with electro-magnet switches which are controlled by the pilot switch. Similar parts in the system shown in Fig. 4 to those in the system shown in Fig. 3 will be indicated by like reference characters. The pilot switch 9 comprises two contact segments 84 and 85 which are adapted to engage contact fingers 86, 87 and 88. The pilot switch 9 controls two electro-magnet switches 89 and 90 which serve to connect the windings 58, 59, 60 and 61 through the transfer switch 63 to the supply conductors 30, 31 and 32.

The electro-magnet switch 89 comprises a coil 91 and two movable contact members 92 and 93. The contact members 92 and 93 are adapted to engage stationary contact members 94 and 95. The electro-magnet switch 90 comprises coil 96 and two movable contact members 97 and 98. The movable contact members 97 and 98 are adapted to engage two stationary contact members 99 and 100.

Upon movement of the contact segment 85 to bridge the contact members 87 and 88, a circuit is completed across the supply conductors 31 and 30 for operating the switch 90. Upon operation of the switch 90, the contact members 97 and 98 respectively engage contact members 99 and 100 for connecting the winding 61 of the primary circuit across the supply conductors 30, 31 and 32. The motor 7 is operated at a relatively rapid rate for moving the table 3 towards the left, as shown in Fig. 1 of the drawings. Near the end of the movement of the planer table towards the left, as shown in Fig. 1 of the drawings, the dog 11 engages the lever 13 for reversing the position of the pilot switch. Thereupon, the contact segment 85 disengages the contact members 87 and 88 and the contact segment 84 bridges contact segments 86 and 87. Thereupon, the coil 91 of the switch 89 is connected acros the supply conductors 30 and 31. The contact members 92 and 93 engage contact members 94 and 95 for selectively connecting the primary windings 58, 59, 60 and 61 through the transfer switch 63 to the supply conductors. The transfer switch 63 is operated in the manner set forth in describing the system disclosed in Fig. 3 of the drawings.

Referring to Fig. 5 of the drawings, an alternating-current control system is shown for operating the main motor at three different speeds in a cutting or forward direction and one speed in a return direction. The speed of the motor during the return stroke is relatively rapid. The system comprises a pilot switch 105 and a transfer switch 106. The pilot switch 105 comprises contact segments 107 to 112 inclusive, which are adapted to engage contact fingers 113 to 130 inclusive.

The transfer switch 106 comprises contact segments 131 to 164 inclusive, which are adapted to engage contact fingers 165 to 182

inclusive. The primary circuit of the motor comprises two windings 183 and 184. The winding 183 is divided up into portions 185 to 190 inclusive and the winding 184 is divided up into portions 191 to 196 inclusive.

Assuming the transfer switch to be in the off position, as shown in Fig. 5 of the drawings, the motor is rotated in a direction to move the table towards the left as shown in Fig. 1 of the drawings, when the pilot switch 105 is moved towards the left, as shown in Fig. 5 of the drawings. The pilot switch 105 is moved towards the left by the dog 10, shown in Fig. 1 of the drawings, engaging the lever 12. When the pilot switch is so operated, a circuit is completed from the supply conductor 30 through the contact fingers 124 and 125, which are ridged by the contact segment 127, to the junction point between the portions 191 and 192 of the winding 184. The supply conductor 31 is connected through the contact fingers 123 and 126, which are bridged by the contact segment 108, to the junction point between the portions 193 and 194 of the winding 184. The supply conductor 32 is connected through the contact fingers 122 and 127, which are bridged by the contact segment 109 to the junction point between the portions 195 and 196 of the winding 184.

The pilot switch not only connects the primary winding 184 to the supply conductors 30, 31 and 32 in the manner above set forth but also interconnects the remaining junction points between the portions of the primary winding 184. Such interconnection of the portions of the primary winding is effected by the contact segment 111 bridging the contact fingers 129 and 130 and the contact segment 112 bridging the contact fingers 117 and 118. The connecting of the primary winding 184 in such manner serves to operate the motor at a rapid rate and to effect a quick return stroke of the planer table.

Upon movement of the planer table to the extreme left, as shown in Fig. 1 of the drawings, the dog 11 engages the lever 13 to reverse the position of the pilot switch. The pilot switch 105 is moved toward the right, as shown in Fig. 5 of the drawings. Assuming the transfer switch 106 to be in the first position, as indicated by reference character *a*, a circuit is completed from the supply conductor 30 through the contact fingers 124 and 113, which are bridged by the contact segment 107, and the contact fingers 181 and 182, which are bridged by the contact segments 148 and 147, to the junction point between the portions 186 and 187 of the winding 183. A circuit is completed from the supply conductor 31 through the contact fingers 123 and 114, which are bridged by the contact segment 108, and the contact fingers 178 and 179, which are bridged by the contact segments 150 and 149, to junction point between the portions 185 and 190 of the winding 183. A circuit is completed from the supply conductor 32 through the contact fingers 122 and 115, which are bridged by the contact segment 109, and the contact fingers 172 and 168, which are bridged by the contact segments 132 and 133, to one terminal of the portion 188 of the winding 183. The supply conductor 32 and the terminal of the portion 188 of the winding 183 are connected through the contact segment 131, contact finger 167, contact fingers 120 and 119, which are bridged by the contact segment 111, contact finger 174, contact segment 152, contact segment 151, and the contact finger 175 to one terminal of the portion 189 of the winding 183. When the winding 183 of the motor is so connected to the supply conductors 30, 31 and 32, the motor is operated at a relatively low speed.

When the transfer switch 106 is in the second position as indicated by the reference character *b*, the supply conductor 30 is connected through the contact fingers 124 and 113, which are bridged by the contact segment 107, and the contact fingers 181 and 171, which are bridged by the contact segments 161 and 137 to the junction point between the portions 191 and 196 of the winding 184. The supply conductor 31 is connected through the contact fingers 123 and 114, which are bridged by the contact segment 108, and the contact fingers 178 and 177, which are bridged by the contact segments 158 and 157, to the junction point between the portions 192 and 193 of the winding 184. The supply conductor 32 is connected through the contact fingers 122 and 115, which are bridged by the contact segment 109, contact finger 172, contact segment 136, contact segment 138, contact finger 167, contact fingers 120 and 119, which are bridged by the contact segment 111, and the contact fingers 174 and 166 which are bridged by the contact segments 152 and 139, to one terminal of the portion 194 of the winding 184. The supply conductor 32 is also connected to one terminal of the portion 195 of the winding 184. The circuit may be traced from the contact finger 172 through the contact segments 136 and 156, and the contact finger 176 to one terminal of the portion 195 of the winding 184. When the primary winding 184 of the motor is so connected to the supply conductors 30, 31 and 32, the motor is operated to effect a cutting stroke at the second speed.

When the transfer switch 106 is in the third position, as indicated by the reference character *c*, the speed of the driving motor is further increased. In such position of the transfer switch, the supply conductor 30 is connected through the contact fingers 124 and 113, which are bridged by the contact segment 107, and the contact fingers 181 and 180, which are bridged by the contact seg-

ments 163 and 162, to the junction point between the portions 185 and 186 of the winding 183. The supply conductor 31 is connected to the contact fingers 123 and 114, which are bridged by the contact segment 108, and the contact fingers 178 and 169, which are bridged by the contact segments 159 and 143, to the junction point between the portions 187 and 188 of the winding 183. The supply conductor 32 is connected through the contact fingers 122 and 115, which are bridged by the contact segment 109, and the contact fingers 172 and 165, which are bridged by the contact segments 145 and 140, to the junction point between the portions 189 and 190 of the winding 183. The junction point between the portions 186 and 187, the junction point between the portions 185 and 190, and one terminal of each of the portions 188 and 189 of the primary winding 183 are connected together through the transfer switch 106 in its third position. The junction point between the portions 186 and 187 of the winding 183 is connected through the contact finger 182, contact segments 164 and 146, contact finger 173, contact fingers 116 and 121, which are bridged by the contact segment 110, contact finger 170, contact segments 144 and 160, and the contact finger 179 to the junction point between the portions 185 and 190 of the winding 183. The contact finger 170 is also connected through contact segments 144 and 142 and the contact finger 168 to one terminal of the portion 188 of the winding 183. A third connection from the contact finger 170 is effected through the contact segments 144 and 141, contact finger 167, contact fingers 120 and 119, which are bridged by contact segment 111, and the contact fingers 174 and 175, which are bridged by the contact segments 154 and 155, to one terminal of the portion 189 of the winding 183. When the primary winding 183 is so connected to the supply conductors, the motor is operated at a relatively high speed.

Impedance elements are included in the secondary circuit of the motor in the same manner as in the circuits heretofore described. It is deemed unnecessary to explain the operation of such impedance elements in connection with the present system.

In Fig. 6 of the drawings, an alternate-current control system is illustrated for operating the motor at four cutting speeds and one return speed. The system comprises a pilot switch 200 which is operated automatically by the planer table, a pendant switch 201 which may be operated at will, a transfer switch 202, a no-current brake 203 and two electro-magnetic switches 204 and 205.

The primary circuit of the motor comprises windings 206, 207, 208 and 209. The secondary circuit of the motor is preferably the same as the secondary circuits of the systems heretofore described. The pilot switch 200 comprises a contact segment 210 and contact fingers 211 to 216, inclusive. The contact segment 210 bridges the contact fingers 211, 212 and 213 during the cutting stroke of the planer table and bridges the contact fingers 214, 215 and 216 during the return stroke of the table. The transfer switch 202 comprises contact segments 217 to 226, inclusive, which are adapted to engage contact fingers 227 and 236 inclusive. The pendant switch 201 comprises a contact segment 257 which is adapted to engage contact fingers 238 to 244, inclusive.

The no-current brake comprises an electro-magnet 245 which is adapted to operate a suitable brake 246. The brake 246 is connected to the motor in any suitable manner. The electro-magnet switch 204 comprises a coil 247, two movable contact members 248 and 249, and two stationary contact members 250 and 251. The electro-magnet switch 205 comprises a coil 252, two movable contact members 253 and 254 and two stationary contact members 255 and 256. The electro-magnet switch 205 is operated either by the pendant switch or the pilot switch to effect a return movement of the planer table and the electro-magnet switch 204 is operated by the pendant switch or the pilot switch to effect a cutting movement of the planer table.

Assuming the pilot switch 200 to be operated by the dog 10 to bridge the contact fingers 214, 215 and 216 by the contact segment 210, a circuit is completed for operating the electro-magnet switch 205. The circuit for operating the electro-magnet switch 205 extends from the supply conductor 31 through the contact fingers 240 and 242, which are bridged by the contact segment 237 of the pendant switch, contact fingers 214 and 216, which are bridged by the contact segment 210 of the pilot switch, and the coil 252 to the supply conductor 30.

The electro-magnet switch 205 is operated for connecting the primary winding 209 to the supply conductors 30, 31 and 32. One terminal of the winding 209 is connected directly to the supply conductor 32. The other two terminals of the primary winding are connected through the contact members 253 to 256 inclusive of the switch 205 to the supply conductors 31 and 30. The motor is operated at a relatively high speed to effect a return stroke of the planer table. Such movement of the planer table is continued until the dog 11 engages the lever 13 to reverse the position of the pilot switch. The contact segment 210 is moved out of engagement with the contact fingers 214, 215 and 216 and into engagement with the contact fingers 211, 212 and 213. It should be noted that at the same time a circuit is completed through the coil 252 of the switch 205, a second circuit is completed through the coil 245 of the no-current brake. Thus during the operation of the motor, the

brake is released and whenever the pilot switch is moved to reverse the rotation of the motor, such brake assists the impedance elements included in the secondary circuit to effect a quick stopping of the motor. The no-current brake may be of any suitable type and may be connected to the motor in any suitable manner.

When the pilot switch is moved to bridge the contact fingers 211, 212 and 213 by the contact segment 210, a circuit is completed for operating the electro-magnet switch 204. The circuit for operating the electro-magnet switch 204 extends from the supply conductor 31 through the contact fingers 241 and 240, which are bridged by the segment 237 of the pendant switch, contact fingers 211 and 213, which are bridged by the contact segment 210 of the pilot switch, and the coil 247 to the supply conductor 230. The electro-magnet switch 204 is operated for connecting the supply conductor 31 through the contact fingers 249 and 250 to the contact finger 232 of the transfer switch and to connect the supply conductor 30 through the contact fingers 251 and 248 to the contact finger 231 of the transfer switch.

In the first position of the transfer switch, the contact segments 221 and 222 engage the contact fingers 231 and 232 and the contact segments 217 and 223 engage the contact fingers 227 and 233 for connecting the primary winding 206 across the supply conductors 30, 31 and 32. In such position of the transfer switch, the motor is operated at a relatively slow speed. In the second position of the transfer switch, the contact segments 217 and 223 disengage the contact fingers 227 and 233 and the contact segments 218 and 224 engage the contact fingers 228 and 234. In such position of the transfer switch the primary winding 207 is connected across the supply conductors to operate the motor at an increased speed. In the third position of the transfer switch, the contact segments 218 and 224 disengage the contact fingers 228 and 234 and the contact segments 219 and 225 engage the contact fingers 229 and 235. In such position of the transfer switch, a further increase in the speed of the motor is effected.

In the fourth and last position of the transfer switch, the contact segments 219 and 225 disengage the contact fingers 229 and 235 and the contact segments 220 and 226 engage the contact fingers 230 and 236. In such position of the transfer switch the primary winding 209 is connected across the supply conductors 30, 31 and 32. In the fourth and last position of the transfer switch, the cutting speed is the same as the speed of the motor during the return stroke.

In case it is desired to operate the motor by the pendant switch 201 independent of the pilot switch 200, the contact segment 237 of the pendent switch is moved to break the circuit between the contact fingers 240 and 241. If it is desired to effect a return movement of the planer table, the contact segment is moved to bridge the contact fingers 238 and 239. A circuit for operating the electro-magnet switch 205 is completed which extends from the supply conductor 32 through the contact fingers 242 and 239, which are bridged by the contact segment 237 of the pendent switch, and the coil 252 to the supply conductor 30. Thus, the electro-magnet switch 205 is operated to effect a return movement of the planer table. The coil 245 of the no-current brake is connected to the supply conductor 31 through contact fingers 238 and 242.

If it is desired to operate the electro-magnet switch 204 to effect a cutting stroke of the table, the pendant switch is so operated as to bridge the contact fingers 243 and 244 by the contact segment 237. A circuit is completed for operating the switch 204 which extends from the supply conductor 31 through contact fingers 242 and 244, which are bridged by contact segment 237, and the coil 247 to the supply conductor 30. The electro-magnet switch 204 is operated and the circuits for the motor are completed through the transfer switch 202 in the manner heretofore set forth.

It is to be understood that if so desired, a number of three phase windings with a corresponding number of impedance elements may be utilized in the secondary circuit. It is deemed unnecessary to illustrate such construction inasmuch as it would be a duplication of the circuits already shown. In some cases, it may be desirable to utilize one or more six phase windings in the secondary circuit with a corresponding number of impedance elements. In Fig. 7 of the drawings, a six phase secondary star-connected winding 265 is shown connected to slip rings 266. Impedance elements comprising inductance elements 267 and resistors 268 are also shown connected to the slip rings 266. In Fig. 8 of the drawings, a six phase mesh connected secondary winding 269 is shown connected to slip rings 270. Any suitable arrangement of impedance elements as for example the arrangement shown in Fig. 7 may also be connected to the slip rings 270 for short-circuiting the secondary winding. It is also apparent that if desired other desired number of phases may be utilized in the secondary circuit which may be desirable from a standpoint of construction of the motor. Moreover, such windings may be connected in such manner as may be desirable.

Although our invention has been described by means of a control system for a machine tool and particularly a planer, it is to be understood that our invention is applicable to any alternating current control system wherein an alternating current motor is started and reversed and particularly wherein a rela-

tive large starting torque is required with different speeds in different directions.

Modifications in the systems, and in the arrangement and location of parts may be made within the spirit and scope of our invention and such modifications are intended to be covered by the appended claims.

What we claim is:

1. In a control system for a machine tool, the combination with a reciprocating member, a polyphase motor having a primary and a secondary winding for operating said reciprocating member, automatic means comprising a pilot switch operated by the reciprocating member for controlling said primary winding to reverse the direction of rotation of the motor and to operate the motor at different speeds in different directions, and a manually operable switch connected to said pilot switch for rendering the pilot switch ineffective and for controlling the motor independently of the pilot switch, of impedance elements connected to the motor secondary winding for limiting the current flow during reversing of the motor connections and for effecting substantially short circuit conditions in the secondary winding when the motor is operating at normal speed.

2. In a control system for a machine tool, the combination with a reciprocating member, a polyphase induction motor for operating said reciprocating member, automatic means operated by said reciprocating member for reversing the primary connections of said motor to change the direction of rotation thereof, and a manually operable switch for rendering said automatic means ineffective and for controlling said motor independently of said automatic means, of means for varying the motor primary winding to operate the motor at different speeds, means comprising impedance elements connected across the secondary winding for offering small opposition to the current at the frequency flowing through the secondary winding when the motor is operating at normal speed and for limiting the current flow through the motor at each reversal thereof, and an electrically operated brake for assisting in effecting a quick stopping of the motor at each reversal thereof.

3. In a control system for a machine tool, the combination with a reciprocating member, a polyphase induction motor for operating said reciprocating member, a pilot switch operated by said reciprocating member for reversing the direction of rotation of the motor, and a manually operable switch for rendering the pilot switch ineffective and for controlling the motor independently of the pilot switch, of means comprising impedance elements connected across the secondary winding for effecting a quick reversal of the motor and for limiting the starting current to develop a relatively high starting torque, and means comprising an electrically operated brake for assisting in effecting a quick stopping of the motor during reversing.

4. In a control system for a machine tool, the combination with a reciprocating member, a polyphase induction motor for operating said member, means comprising a pilot switch operated by the reciprocating member for reversing the motor connections to effect rotation of the motor in opposite directions, and means comprising a portable manually operated switch for rendering the pilot switch ineffective and for controlling the motor independently of the pilot switch, of means comprising impedance elements connected across the motor secondary winding for limiting current flow upon reversal of the motor connections, and means comprising an electrically operated mechanical switch for assisting in stopping the motor under certain conditions.

In testimony whereof, we hereto affix our signatures.

GEORGE E. GREENLEAF.
ROBERT C. DEALE.

CERTIFICATE OF CORRECTION.

Patent No. 1,759,551. Granted May 20, 1930, to

GEORGE E. GREENLEAF ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 110, for the word "holes" read "poles"; page 5, line 18, for "ridged" read "bridged"; page 6, line 75, for the word "and" read "to"; page 7, line 16, before the word "segment" insert the word "contact"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of July, A. D. 1930.

(Seal)

Wm. A. Kinnan,
Acting Commissioner of Patents.