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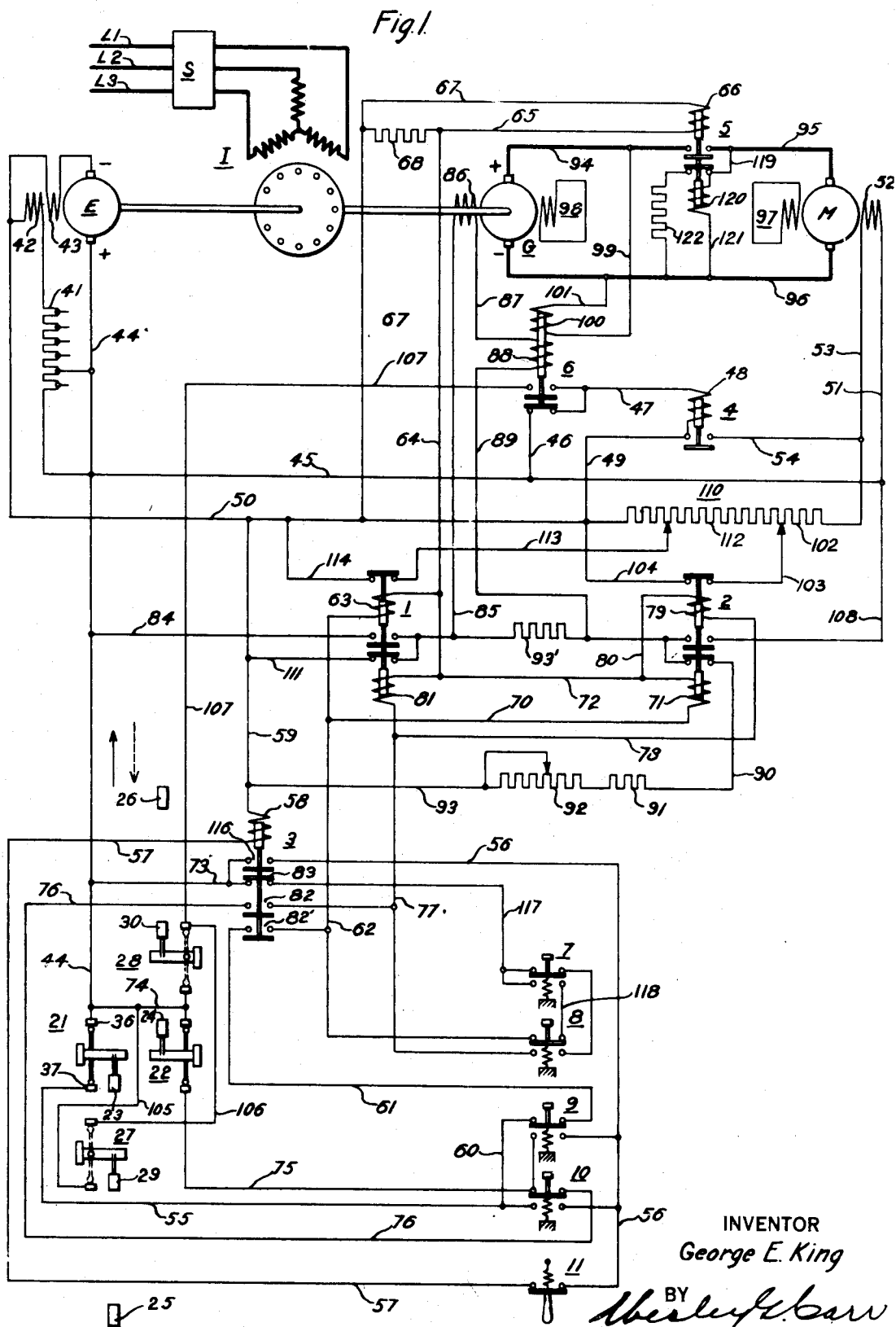
G. E. KING

1,955,334

VARIABLE VOLTAGE REVERSING PLANER CONTROLLER

Filed Dec. 19, 1930

2 Sheets-Sheet 1



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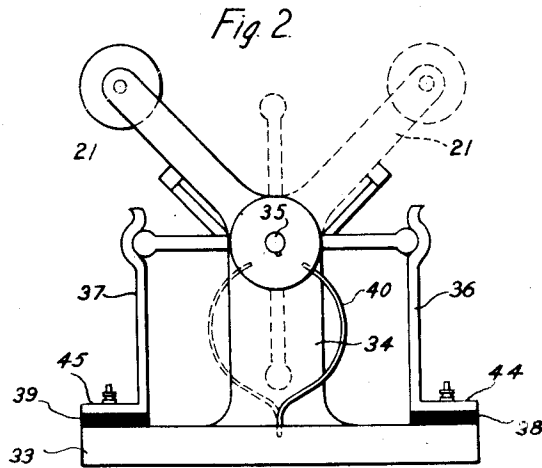
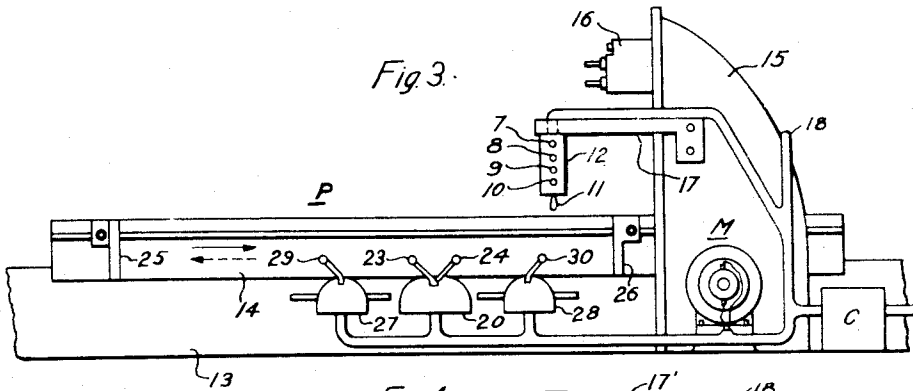
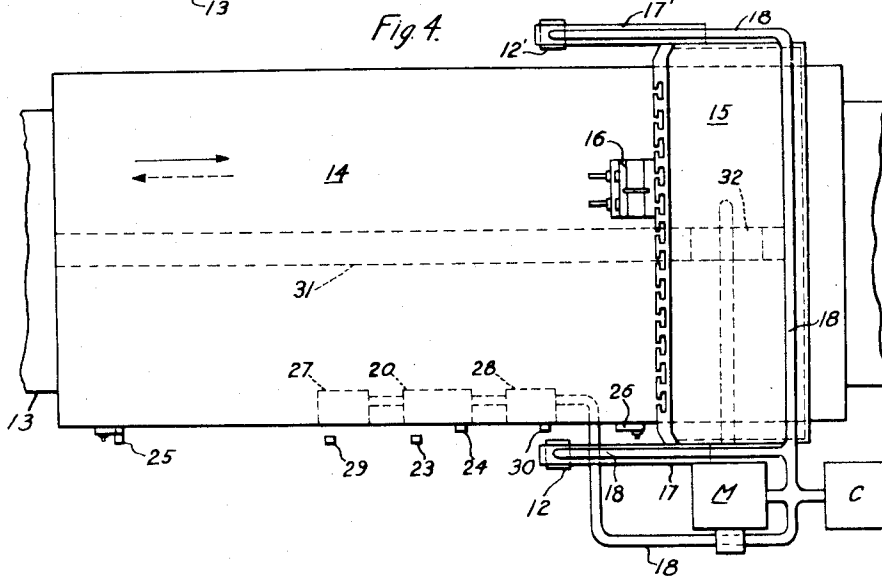
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VARIABLE VOLTAGE REVERSING PLANER CONTROLLER

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2 Sheets-Sheet 2



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1,955,334

VARIABLE-VOLTAGE REVERSING-PLANER
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pany, a corporation of Pennsylvania

Application December 19, 1930, Serial No. 503,463

8 Claims. (Cl. 172-240)

This invention relates to control systems and particularly to control systems for automatically controlling the operation of variable-voltage reversing motors used to drive reciprocating mechanisms, such as planers, drawcut shapers, roll grinders, transfer tables, etc.

The devices for reciprocating machines made according to the teachings of the prior art embody either a reversing gear, a reversing belt or the combination of a reversing motor with a tumbler mechanism.

The use of a reversing belt to reverse a machine requires a constant-speed overhead shaft and gives very poor control of the limits of travel of the reciprocating member. Furthermore, acceleration cannot be controlled because of belt slippage and the ever-changing belt tension, and the belt slippage makes considerable noise. The reversing gear is inherently subject to clashing and grinding.

A reversing motor having a tumbler mechanism is objectionable because the tumbler mechanism is cumbersome, expensive, dangerous, noisy, subject to premature operation because of ships falling into it, and, for slow speeds, it frequently fails to establish the motor circuit necessary to effect the reverse movement. To provide for stopping the reciprocating member within desired limits, in the event of voltage failure, elaborate brakes are required and, in some instances, it is necessary to utilize dynamic braking. When dynamic-braking circuits are provided, if the line contactors weld and fail to function, the article being worked may shift on the platen, with consequent damage to the article or to the machine or to both.

This invention has, for one of its objects, the provision of electrical means, subject, selectively, to either manual or automatic control, for determining the distance of travel of a reciprocating member, and to fix the stopping position of such member when moving either in a forward or in a reverse direction.

It is also an object of this invention to provide a control system wherein the line contactor for the variable-voltage reversing motor, during the starting operation, will not close on the motor-armature circuit when the generator voltage is high; wherein the line contactor, during the stopping operation, will not open when the generator voltage is high; and wherein the line contactor will be forced to open position if it fails to open by gravity, upon deenergization of the main control means for the line contactor.

A further object of this invention is to automatically and successively reverse the motor by producing smooth yet very effective regenerative braking of the motor, by strengthening the motor field and by weakening the generator field during the change of polarity of the generator supplying the motor.

Other objects of the invention are the provision of limit switches actuated directly by dogs on the planer platen, and the provision of a single pendant station from which complete control of the reversing motor may be had, or the provision of a plurality of such pendant stations from each of which complete control of the reversing motor may be had.

A more specific object of this invention is to supply a rapidly rising voltage to the reversing motor while decreasing the field excitation thereof, whereby the motor may be very rapidly accelerated; in supplying a rapidly decreasing voltage to the reversing motor while the field excitation of the motor is increased to stop the motor by regenerative braking; in reversing the polarity of the voltage supplied to the motor and then supplying a rapidly rising voltage to the motor while the excitation of the motor is rapidly decreased, whereby the motor may be rapidly accelerated in the opposite direction.

A further object of this invention is the provision of a control system whereby the motor is always stopped dynamically when voltage fails or when the stop push-button or the inch push-button is actuated.

Other objects of the invention are the provision of a limit switch which will have its contacts so placed by the action of a driven reciprocating member that, if travel of the member ceases within the limits of extreme travel the member may be again set in motion in the desired direction from either of two push-buttons or some equivalent control device, or multiples thereof, and the provision of means whereby the initial direction of travel of the member will be selectively controlled from a single station or a number of stations, regardless of the position of the reciprocating member.

A further object of this invention is the provision of a reversing motor for driving a reciprocating platen, wherein the speeds of the motor for the forward or cut direction and for the return direction may be adjusted over wide and overlapping ranges, thereby providing a cutting speed in excess of the minimum return speed or a cutting speed that is low relative to the return speed.

In the following discussion, the invention is treated in connection with a planer and, more particularly, the planer platen, but the invention is not limited in its use to the control of planers but may be applied generally where rapid reversal of a motor-driven machine is desired.

The novel features of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment, when read in

connection with the accompanying drawings, wherein:

Figure 1 is a diagrammatic representation showing, in operative relation, the parts of an electrical control system embodying the invention;

Fig. 2 is an end view of one of the limit and slow-down switches;

Fig. 3 is a side view of the subject matter of the invention, as applied to a planer, and

Fig. 4 is a plan view of the subject matter of the invention shown in Fig. 3.

Referring more particularly to Fig. 1, L₁, L₂ and L₃ represent the supply lines of a suitable source of alternating-current power for driving the induction motor I. The alternating-current line starter S is disposed between the supply lines and the induction motor and, by proper manipulation, insures proper starting and stopping of such motor. Since the starter S is of conventional design and function and per se, does not constitute a part of this invention, no detailed description and showing thereof is necessary.

The alternating-current line starter S incorporates conventional low-voltage, high voltage, and over-load protecting devices. When any one of these devices functions, the motor I slows down and, in consequence, the voltage of exciter E decreases, the result being that the control system for motor M operates to stop the motor so that the planer platen does not overtravel the limits for which it is adjusted. The stopping of motor M is thus similar, in every respect, to the stopping operation hereinafter discussed in connection with the inching operation of the planer platen.

The control panel C, shown in Figs. 3 and 4, carries the main-line contactor 5 for the motor G, the directional contactor relays 1 and 2, the full motor-field control relay 4 and the control relays 3 and 6.

The pendant switch 12, from which complete control of the motor is had, includes the inch cut push-button switch 7, the inch return push-button switch 8, the automatic-cut push-button switch 10, the automatic-return push-button switch 9 and the stop lever 11. It is to be noted that the depending stop lever 11 is the most accessible part of the pendant switch, and, since the pendant switch is itself located conveniently on the planer, the planer may be stopped very readily. The stopping, whether caused by the stop lever or because of voltage failure, is always accomplished by the establishment of the same dynamic-braking circuit for the motor, as will be pointed out more in detail hereinafter.

A pendant switch of any suitable type may be utilized but, preferably, a switch like that disclosed in the patent to Phelan McShane, No. 1,736,746, granted April 29, 1929, will be employed.

In Figs. 3 and 4, the motor M is shown associated with the control panel C, the planer P, including among other elements, the table 13, platen 14, crossbar standard 15 and tool holder 16. On the crossbar standard 15 or any other convenient part of the planer, are supported one or more pendant-switch stations 12 and 12', from each of which complete control of the motor M may be had. The pendant-switch stations are mounted, in the most accessible places for the attendant, by means of brackets 17 and 17' which also carry portions of the conduit 18 provided for the conductors leading from the re-

spective pendant-switch stations to the motor M and the control panel C.

Below the planer platen 14, and at the side of the table 13, is positioned a unitary structure 20 containing limit switches 21 and 22 having projecting levers 23 and 24, respectively. At the side of the platen are positioned a pair of lugs 25 and 26 which may be adjusted longitudinally of the platen 14 within grooves of T shape. The lugs and projecting levers are so disposed that lug 25 engages lever 23, and lug 26 engages lever 24 when the platen is reciprocating.

A pair of slow-down limit switches 27 and 28 are mounted on each side of the structure 20. Slow-down limit switch 27 has a projecting lever 29 disposed ahead of projecting lever 23 and directly in line with the lug 25 and the projecting lever 23. Slow-down limit switch 28 has a projecting lever 30 disposed ahead of the projecting lever 24 and directly in line with the lug 26 and the projecting lever 24. It is obvious, from the disposition of the slow-down switches, that the lug 25, during movement of the platen 14 in the cut direction, will engage lever 29 and thereafter lever 23, and that lug 26, during movement of the platen in the return direction, will engage lever 30 and thereafter lever 24.

The slow-down limit switches control the field excitation of the motor M to slow down the motor just prior to the changing of the polarity of the generator G by the controlling action of the limit switches 21 and 22. To accomplish the slow-down effect in a variable manner, the slow-down limit switches 27 and 28 are adjustably mounted on table 13 so that the distance between 27 and 20 and 28 and 20 may be varied at will. The adjusting means are of conventional design and need not be described. The adjustable slow-down effect may, of course, be attained electrically and I do not wish to be limited to the mechanical means suggested, however, in the preferred embodiment, elements 27 and 28 are adjustable relative to the unitary switch structure 20. On the lower face of the platen 14 is positioned a rack 31 meshing with the bull-gear 32 driven by the variable voltage reciprocating motor M.

If it be assumed that the planer platen moves to the right, or in the cut direction, lug 25 actuates projecting lever 29 which changes the field connection of motor M to increase its excitation. The motor thus decreases in speed very rapidly. A moment later, the lug 25 actuates lever 23 which causes interruption of the field connection of the generator G. Since the limit switch 22, under these conditions, will be in the position shown, the field connection of the generator field is reversed, and the generator G supplies low voltage of opposite polarity to the motor M, as pointed out more in detail hereinafter.

As the planer platen moves to the left, or in the return direction, lug 26 again actuates lever 23 and then lever 29 to set them to their original positions. A similar function is performed by lug 26 in connection with the projecting levers 24 and 30. It will thus be apparent that projecting levers 23, 24, 29 and 30 are always in given positions, the set positions, when the planer platen is in a position intermediate the limits of travel determined by the positions selected for the lugs 25 and 26. When projecting levers 23 and 24 are in set positions, their contact members are in circuit-closing positions, but when projecting levers 29 and 30 are in their set posi-

tions, their contact members will be in open-circuit positions. In this connection, see Fig. 1.

The limit switches and slow-down limit switches are similar in structure, and a better understanding of their function may be had from a study of Fig. 2 which shows a more detailed end view of limit switch 21. The switch comprises a base 33 supporting a bearing standard 34. Within the bearing is mounted a shaft 35 carrying the contact member (shown in full and broken lines, respectively) of the limit switch mounted at one end and the projecting lever 21 near the other end. The stationary contact members 36 and 27 are mounted, by means of insulating blocks 38 and 39, on the base 33 in position to be engaged by the movable contact members of the limit switch. To hold the movable contact member either in the full-line or in the broken-line positions, over-center spring 40 is secured to the base 33 and to the shaft, respectively. Different springs from those shown may, of course, be employed or the springs may be dispensed with entirely if the projecting lever 21 and the roller usually mounted on this lever are designed to be sufficiently heavy.

The various electrical devices shown in Fig. 1 are shown in the positions they would occupy if no energy were supplied to the induction motor I, that is, the alternating-current starter S has not been operated.

Upon actuation of the starter S, energy is supplied to the induction motor I to actuate it to normal speed for operating exciter E and generator G. The exciter supplies the energy for the control circuits and the field windings of the generator G, motor M and exciter E. When exciter E and generator G are operating at normal speed, energy is supplied from the positive terminal of the exciter, through conductor 44 the adjustable field rheostat 41, the shunt field windings 42 of the exciter and the series field windings 43, to the negative terminal of the exciter.

A circuit is also established from the positive terminal of the exciter, through conductors 44, 45 and 46, back contact members of control relay 6, conductor 47, actuating coil 48 of full-field relay 4, conductors 49 and 50 and the series field of the exciter, to the negative exciter terminal. Energization of the coil 48 causes closing of the contact members of the control relay 4, whereby a circuit is established from the positively energized conductor 44, through conductors 45 and 51, the shunt field winding 52 of the motor M, conductors 53 and 54, the contact members of full-field relay 4 and conductor 49, to the negatively energized conductor 50. It will be noted that the circuit just traced includes no shunt-field rheostat for the shunt field of the motor M, the excitation of the motor thus being a maximum even before energy is supplied to the armature of the motor. At the instant energy is supplied to the motor M, the acceleration thereof will not be at an undesirable rate and the mechanical parts are not subject to undue strain.

Assuming that the planer platen is in the return position, and the attendant wishes to start the planer platen for automatic operation in the cut direction, which, in this embodiment, is toward the right in Figs. 3 and 4 and in the direction indicated by the full-line arrow in Fig. 1, then the attendant depresses push-button switch 10, thereby establishing a circuit from the positively energized conductor 44, through the contact members of the limit switch 21, conductor 55, the lower or normally open contact members

of automatic-cut push-button switch 10, conductor 56, stop switch 11, conductor 57, actuating coil 58 of control relay 3 and conductor 59, to the negatively energized conductor 50.

Operation of the control relay 3 establishes a circuit from the positively energized conductor 55, through conductor 60, upper or normally closed contact members of the automatic return push-button switch 9, conductor 61, the lowermost contact members 82' of control relay 3, conductor 62, actuating coil 63 of forward directional contactor 1, conductors 64 and 65, actuating coil 66 of the line contactor 5 and conductor 67, to the negatively energized conductor 50.

At the same instant that actuating coil 63 is energized, the back contact coil 71 of the reverse directional contactor 2 is energized by a circuit extending from the positively energized conductor 62, through conductor 70, back contact coil 71 and conductor 72, to the conductor 64. Energization of coil 71 prevents operation of the reverse directional contactor upon subsequent energization of the actuating coil of this contactor. Attention is also called to the resistor 68 in parallel with the actuating coil 66 of the line contactor 5. The resistance value of this resistor is so selected that the sum of the currents passing through coils 63 and 71 actuates the line contactor an instant after the operation of the directional contactor 1.

At the instant the circuits just described are established by the control relay 3, a holding circuit is also established for the actuating coil 58 of this relay. This circuit may be traced from the positively energized conductor 44, through conductor 73, the uppermost contact member 116 of the control relay 3, conductor 56, stop switch 11, conductor 57, actuating coil 58 and conductor 59, to the negatively energized conductor 50. Upon the establishment of this holding circuit for the control relay 3, the automatic-cut push-button switch 10 may be released.

When the push-button switch 10 is released, a circuit is established from the positively energized conductor 44, through conductor 74, the contact members of the limit switch 22, conductor 75, the upper or normally closed contact members of automatic-cut push-button switch 10, conductor 76, contact member 82 of control relay 3, conductors 77 and 78, actuating coil 79 of reverse directional contactor 2 and conductor 80, to the conductor 72 and thence to the negatively energized conductor 50 through the circuit above traced in connection with line contactor 5. Energization of coil 79 at this time can have no effect, since back contact coil 71 of the same contactor is energized and, since the back contacts of reverse directional contactor 2 are already "sealed in", prevents operation of this contactor. Energization of coil 79 is of value though during a subsequent operation, as will be apparent as the description proceeds.

Operation of the control relay 3 also causes the opening of its back-contact members 83. Opening of contact members 83 renders the inch-cut and inch-return push-button switches ineffective, whereby an unauthorized or inadvertent actuation of these push-button switches will not establish a control circuit which will interfere with automatic operation.

Operation of the forward directional contactor 1 establishes a circuit from the positively energized conductor 44, through conductor 84, upper of "make" contact members of the forward directional contactor 1, conductor 85, shunt field

windings 86 of the generator G, conductor 87, lower coil 88 of control relay 6, conductor 89, lower or back-contact member of directional contactor 2, conductor 90, permanent resistor 91, adjustable resistor or generator cut-rheostat 92, and conductors 93 and 59, to the negatively energized conductor 50.

Opening of the uppermost contact member of the contactor 1 produces no effect since the full-field relay 4 is still energized, thus shunting the rheostat or resistor and supplying the motor M with a heavy field excitation. At the same time, it will be noted, the field excitation of the generator G is accomplished through the permanent resistor 91 and the generator cut-rheostat 92. The result is that the generator voltage is low, while the motor field excitation is high at the instant the line contactor 5 establishes the armature circuit for the motor M.

A very short interval after the operation of the directional contactor 1, the motor-armature circuit is established from the positive terminal of the generator, through conductor 94, the contact members of line contactor 5, the armature of motor M, and conductor 96, to the negative terminal of the generator G. The series field windings 97 of the motor M and the series field windings 98 of the generator G are merely to provide a damping effect on these machines.

Since the generator voltage is low and the motor-field excitation high, the motor does not start with a jolt but starts smoothly. After a short interval of time, depending on the time it takes for the generator voltage to build up after the closing of the field connection of the generator, the control relay 6 operates to interrupt the circuit for the full-motor-field control relay 4.

As above explained, establishment of the field connection for the generator also caused energization of lower coil 88 of control relay 6. As the generator voltage builds up, the upper coil of this same relay is energized more and more by the circuit extending from the positive terminal of the generator G, through conductors 94 and 99, upper coil 100 of control relay 6 and conductors 101 and 96, to the negative terminal of the generator G. Coils 88 and 100, during acceleration, operate additively and at some definite generator voltage, the circuit for coil 48 is interrupted, whereby the shunt field excitation for the motor M then takes place from the field windings 52, through conductor 53, resistor section 102, conductor 103, the uppermost contact members of the directional contactor 2 and conductor 104, to the negatively energized conductor 50. The motor then accelerates to the full cutting speed, depending on the adjustment of conductor 103 along resistor 102 and also on the adjustment of the generator-cut rheostat 92.

By properly adjusting the generator-cut rheostat 92, the voltage of the generator may be kept low enough to prevent the operation of the control relay 6 during the cutting stroke. By this use of the generator field rheostat, a great speed range may be obtained for the cutting stroke. It is, of course, obvious that, instead of adjusting the rheostat 92, the control relay 6 may be provided with means for varying its sensitivity. In any case, if the circuit for coil 48 is not interrupted, the motor-field excitation remains a maximum, and the cutting speed is obviously a minimum. The resistor 93 merely serves as a discharge resistor for the generator field when on open circuit.

Assuming that control relay 6 operates during the cutting stroke, then the resistor 102 will be in series with the motor field 52, and the planer platen will move toward the right at its maximum cutting speed. This speed may be too high to permit reversal of the field connections for the generator G and, to slow down the motor, slow-down switch 27 is provided.

As the planer platen moves to the right, the lug 25 engages the projecting lever 29, moving it to the right and thereby establishing a circuit from the positive conductor 44, through conductors 74 and 105, the contact members of the slow-down limit switch 27, conductors 106 and 107, the upper contact members of control relay 6, conductor 47, coil 48 of control relay 4 and conductor 49, to the negatively energized conductor 50. Operation of control relay 4 establishes a shunt circuit for the motor-shunt-field rheostat 110 through conductor 54, contact members of control relay 4 and conductor 49. As the field excitation builds up, the motor speed decreases.

Further movement of the platen to the right or in the direction of the full-line arrow (see Figs. 1, 3 and 4, respectively) causes operation of limit switch 21 through the lug 25 and the projecting operating lever 23 of limit switch 21. Operation of the limit switch 21 interrupts the circuit for coils 63 and 71 at 36 and 37. De-energization of coils 63 and 71 causes interruption of the field connections of the generator for an instant. The field excitation decreases and discharges through the resistor 93.

A very short interval of time after this open-circuit condition of the generator field 86, the reverse directional contactor 2 operates to reverse the field connections for the generator G. Since the motor-field excitation is high, control relay 4 having operated as above explained, a regenerative-braking effect takes place in motor M, the motor actually returning energy to the generator G for a short interval.

Since the adjustments of the various elements for any given operation is fixed, the motor M will stop in a substantially fixed time after operation of the limit switch 21 and, consequently, it will stop the planer platen within a substantially fixed distance. For the end of the return stroke, the operation is similar to that just explained, and it is, therefore, apparent that the planer equipment, and the lugs 25 and 26, may be made to travel within predetermined limits.

The circuit for the generator field, after operation of the directional contactor 2, may be traced from the positively energized conductor 44, through conductors 45 and 108, the contact member of directional contactor 2, conductor 89, lower coil 88 of control relay 6, generator field windings 86, conductor 85, the back contact members of directional contactor 1 and conductors 111 and 59, to the negatively energized conductor 50. It will be noted from this circuit, that coil 88 is energized oppositely to its original energization. The result is that control relay 6 drops open during regenerative braking, since coils 88 and 100 are differentially energized. Control relay 4 is thus energized regardless of the position of the slow-down switch 27, with the result that motor M has maximum excitation.

The generator-field connections for the return movement include no resistor, with the result that the generator voltage builds up rapidly and soon regenerative braking ceases, and the motor speed for the cut direction becomes zero. At this in-

stant, since the generator voltage is now higher than it was for the cutting stroke, the control relay 6 operates. This does not affect full field relay 4 because slow-down switch 27 has not yet been moved to open-circuit position. It is thus apparent that the motor begins to accelerate in the reverse direction on a heavy field. The operation of the motor in the reverse direction is thus initiated in a smooth and continuous manner.

Shortly after the planer platen starts moving to the left (Figs. 3 and 4) or in the direction of the dotted arrow (Fig. 1) the lug 25 resets limit switch 21 to circuit-closing position and, a moment later, the lug 25 resets slow-down limit switch 27 to open-circuit position.

Resetting of the limit switch 21 merely again energizes coils 63 and 71, but, since directional contactor 2 has already operated, no effect is at present produced. Energization of coils 63 and 71 does, however, reduce the time interval for changing the field connections for the generator G. Movement of the slow-down limit switch to its set or open-circuit position interrupts the circuit for coil 48 of the full-field-control relay. Deenergization of coil 48 causes interruption of the shunt for the motor-field rheostat 110.

The field excitation of the motor for the return stroke thus takes place through a circuit that may be traced from the motor field windings 52, through conductor 53, resistor sections 102 and 112, conductor 113, the uppermost contact of directional contactor 1 and conductor 114, to the negatively energized conductor 50. The motor thus accelerates to full return speed.

By the provision of the higher generator voltage for the return stroke and by a proper adjustment of the position of the conductor 113 on the resistor segment 112, a very wide speed range, and a relatively high speed, may be had for the return stroke.

As the planer platen 14 nears the end of the return stroke, the lug 26 engages the projecting lever 30, thus moving the slow-down limit switch 28 to circuit-closing position and establishing an energizing circuit for the full-field relay 4. This circuit extends from the positively energized conductor 44, through conductor 74, the contact members of the slow-down limit switch 28, conductor 107, the upper contact members of control relay 6, conductor 47, actuating coil 48 of full-field relay 4 and conductor 49 to the negatively energized conductor 50. Operation of the control relay 4 establishes a shunt circuit for the motor-field resistor 110. The motor-field excitation is thus built up to a maximum for slowing down the planer platen before lug 26 engages the projecting lever 24 of the limit switch 22.

The instant the lug 26 operates the limit switch 22, the energizing circuit for coils 79 and 81 is interrupted and, in consequence, the field connections for the generator are interrupted. Since the limit switch 21 is in circuit-closing position, coils 63 and 71 are energized in consequence, but a short interval of time is required for the directional contactor 1 to operate to reverse the connection of the generator field windings for operation of the planer platen in the cut direction. The motor M, after a substantially predetermined interval of time, is stopped by regenerative braking and is accelerated in the cut direction similar in every respect to the reversing operation above discussed for the limit of travel of the planer platen in the cut direction.

If the attendant desires to inch the planer platen either in the forward or reverse direction

the motor M, if operating automatically, is stopped by striking the depending stop lever 11, which causes deenergization of the actuating coil 58 of control relay 3. As the armature of control relay 3 drops to inoperative position, as shown in Fig. 1, the holding circuit for coil 58 and the circuits for coils 63 and 71 and 79 and 81 are interrupted at 116 and 82' and 82, respectively. It is thus apparent that coils 63 and 71 and 79 and 81 can not be energized by operation of the limit switches 21 and 22.

Deenergization of control relay 3 also causes closing of contact members 83. If the inch-cut push-button 7 be depressed, a circuit is established from the positively energized conductor 44, through conductor 73, contact members 83, conductor 117, the inch cut push-button switch 7, conductor 118, the inch-return push-button switch 8, conductor 62, actuating coil 63 of directional contactor 1, conductors 64 and 65, actuating coil 66 of line contactor 5 and conductor 67, to the negatively energized conductor 50. A circuit in parallel to coil 63 is also established for coil 71. In this connection, see conductor 70, coil 71 and conductor 72.

Energization of coils 63 and 66 causes the establishment of the field connection of the generator for the cut direction and the establishment of the motor-armature circuit similar in every respect to automatic operation. The motor M, as for automatic operation, also starts accelerating in the inch-cut direction on maximum field excitation, which is then changed to a lower excitation by the control relay 6.

Near the limits of travel, the slow-down limit switches function as for automatic operation, but, since the operation of the limit switches does not affect the inching operation, no automatic reversing takes place at the limits of travel for which lugs 25 and 26 should happen to be adjusted. Inching may thus be effected to any desired distance in either the cut or the return direction, but, in any case, inching takes place slowly beyond the limits of travel, since the motor-field excitation will always be high.

Reversing is accomplished differently during inching operation than it is during automatic operation. If the attendant releases the push-button switch which he may have been operating, the line contactor 5 and the energized directional contactor are deenergized, whereby the circuit connecting the motor M to the generator G is interrupted.

The momentum of the motor armature and the planer platen 14 causes the motor to operate as a generator. The lower coil 120 of the line contactor 5 is thus energized from the upper terminal of the motor M, through conductors 95 and 119, coil 120, and conductors 121 and 96, to the lower terminal of the motor. Energization of coil 120 makes it certain that the main-line contactor does not remain closed by reason of its residual magnetism and, at the same time, establishes a low resistance dynamic-braking circuit for the motor. This circuit may be traced from the upper terminal of the motor, through conductors 95 and 119, the lower contact members of line contactor 5, dynamic-braking resistor 122 and conductor 96, to the lower motor terminal.

From the foregoing discussion, it will be apparent that the desirable functions accomplished by the lower coil 120 are the interruption of the motor-generator circuit, whereby the motor M is not subject to a slow progressive movement

caused by the residual field of the generator, and the establishment of a low-resistance dynamic-braking circuit for the motor, whereby the motor may be brought to rest within a very short interval of time after the attendant releases the push-button switch he is operating.

If the system be operating automatically, voltage failure or striking of the stop lever 11, through control relay 3, causes interruption of the circuits for the coils 63 and 71, 79 and 81, and 66, and the motor then stops by the dynamic-braking operation above discussed.

The invention is not to be restricted to the specific structural details, arrangement of parts of circuit connections herein set forth, as various modifications thereof may be effected without departing from its spirit and scope, and it is desired that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In an electrical control system, in combination, a reciprocating member, a variable-voltage motor for driving the member, means for variably exciting the motor, a source of power of variable voltage for the motor, means for varying the voltage of said source of power, control means for the motor, a limit switch disposed to be operated by the member and so positioned by the member, when intermediate its limits of travel, that the member may be started, as desired, in either a forward or a reverse direction by the control means and means for controlling the motor excitation varying means and the power voltage varying means in inverse order during acceleration and deceleration of said motor.

2. In an electrical control system, in combination, a reciprocating member, a variable-voltage motor for driving the member, excitation varying means for the motor, a variable-voltage generator, voltage varying means for the generator, a main-line switch for connecting the motor to the generator, means for controlling the excitation and voltage varying means reversing switches for reversing the polarity of the generator, control means, and a limit switch actuated by the member, when reciprocating, to cause a reversal of the motor and always so actuated to such position by the member that, if the member has ceased movement intermediate its limits of travel, said member may be again set in motion in the desired direction by the control means.

3. In an electrical control system, in combination, a reciprocating member, a variable-voltage driving motor for the member, a variable-voltage generator, a main-line switch for connecting the motor to the generator, reversing switches for reversing the motor by changing the field connection of the generator, a push-button control station, and a forward limit switch actuated by the member when moving in a forward direction to cause a reversal of the member, said limit switch being also actuated to set position during initial stages of reverse movement, whereby said member, if it ceases moving intermediate its limits of travel, may be again started, at will, in either a forward or a reverse direction by said control station.

4. In an electrical control system, in combination, a reciprocating member, a variable-voltage driving motor for the member, a variable-voltage generator, a main-line switch for connecting the motor to the generator, reversing switches for reversing the motor by changing the field connection of the generator, a push-button control station, a slow-down limit switch actuated

by the member, when moving in a forward direction, to cause slowing down of the motor, a forward limit switch actuated by the member an instant after actuating the slow-down limit switch for causing a reversal of the member, said slow-down limit switch and limit switch being also actuated to set position during initial stages of reverse movement, whereby said member, if it ceases moving intermediate its limits of travel, may be again started, at will, in either a forward or a reverse direction by said control station.

5. In an electrical control system, in combination, a reciprocating member, a variable-voltage motor for operating the member, a variable-voltage generator, a contactor for connecting the motor to the generator slow-down means operated by the reciprocating member for slowing down the motor as the reciprocating member approaches its limit of travel in a given direction, limit means operated by the reciprocating member for reversing the operation of the motor, and means mounted on the reciprocating member for resetting the slow-down means and the limit means to non-operated position during initial stages of reverse movement.

6. The method of reversing a motor during operation which consists in increasing the excitation of the motor from a given positive value to a given higher positive value during a substantially definite interval of time, decreasing the voltage supplied to the motor from a given positive value to zero during a substantially definite interval of time, the said voltage decreasing operation being initiated at any instant during the change in motor-field excitation, decreasing the voltage supplied to the motor from zero to a given negative value during a substantially definite interval of time, decreasing the excitation of the motor from the given higher positive value to the given positive value during a substantially definite interval of time, said decreasing of the excitation of the motor being initiated at any instant during the voltage change from zero to the given negative value.

7. The method of reversing a motor which consists in varying the voltage supplied to the motor from a given positive value to a given negative value different in absolute value from the given positive value, said variation taking place during a substantially predetermined interval of time, and in varying the field excitation of the motor from a given positive value to a given higher positive value and back to some value other than the given positive value, said variation of the motor-field excitation taking place during substantially the same interval of time mentioned.

8. The method of reversing a motor which consists in decreasing the voltage supplied to the motor from a predetermined positive value to zero during a substantially definite interval of time, increasing the field excitation of the motor, during the time interval just mentioned, from a predetermined positive value to a predetermined higher positive value, decreasing the voltage supplied to the motor from zero to a predetermined negative value greater in absolute value than the predetermined positive voltage value, said decreasing operation taking place during a substantially definite interval of time, and decreasing the field excitation of the motor during this last mentioned time interval from the predetermined higher positive value to a predetermined value lower than the predetermined positive field excitation above mentioned.