Oct. 11, 1966 H. M. COOK 3,278,820

MOTOR CONTROL CIRCUIT

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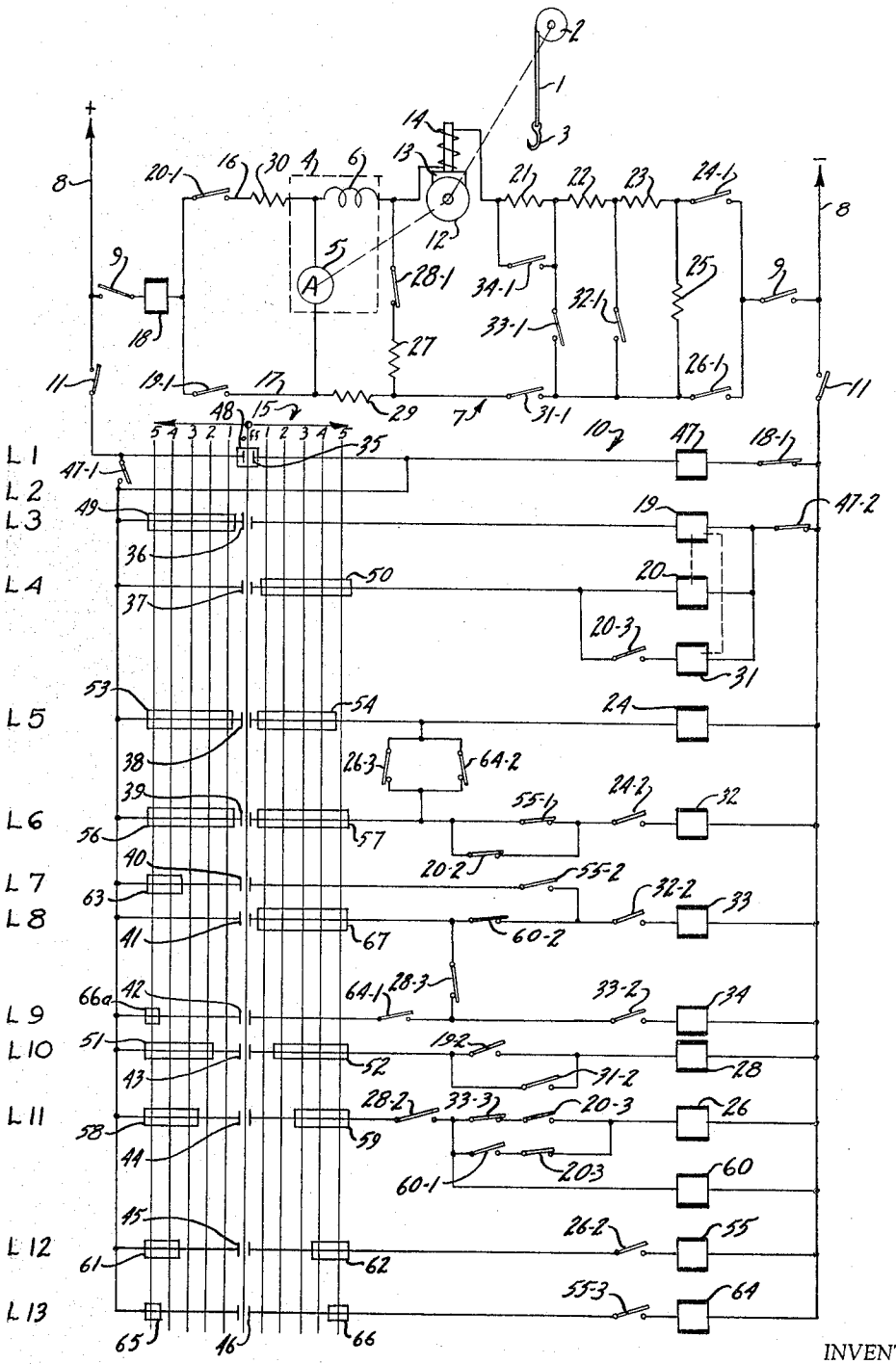



Fig. 1

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Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9



Fig. 10



Fig. 11

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# MOTOR CONTROL CIRCUIT

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2 Claims. (Cl. 318—270)

This invention relates to a motor control circuit particularly for controlling the electric motor of an electrically operated hoist unit.

In the control of cranes and hoisting apparatus, both A.C. (alternating current) and D.C. (direct current) control systems are employed. The present invention is directed to an electrically operated hoist wherein a direct current motor is drivingly connected to a hoist cable winding drum to raise and lower a work member or support carried on the end of a flexible cable. A master controller is provided for operating a plurality of electromagnetic contactors having contacts for selectively inserting and removing of resistance from the motor power or operating circuit and thereby varying the speed of the motor and the hoist unit. Generally, crane controls to meet industry standards must have smooth operating characteristics with circuitry and components of long, trouble-free life and a very minimum of maintenance while providing a high degree of safety and reliability. For practical application, the mechanical and electrical wearing of parts should be minimized. Further, when maintenance is required, the circuitry and components must be such that they allow performance thereof quickly and easily by personnel of reasonable skill in order to avoid expensive down time. The control should also be designed to minimize the effort and skill required of the operator such that the operator is free to concentrate on the other necessary decisions which he must make during the movement and operation of the crane and hoist mechanism. Extremely highly satisfactory crane controls have been provided employing direct current motors adapted to be operated as either a D.C. series motor during a hoisting operation and a D.C. shunt motor during the lowering operation. For example, a highly satisfactory circuit is shown in U.S. Patent 2,902,635 which issued Sept. 1, 1959, to Kai-Kobad S. Kuka.

The present invention is directed to a simplified multiple speed motor control, particularly for a hoist unit, in which all the advantages of the more complex system are retained providing a multiplicity of speeds for hoisting and lowering within a predetermined operating range and without any tendency for erratic or overlapping speed movement. The present invention incorporates excellent utilization of power contactors for varying the motor operating circuit with a minimum of mechanical and electrical wear on the contactors. The contactors are interconnected in the circuit such that each contactor is operated only once in the total multiple positions or points of operation in either of the hoisting or lowering motor energization and different contactors distributed the current in the respective two-high speed position. A very simple and logical contactor sequence is provided thus permitting ready understanding by those with a minimum skill and quick determination of malfunction of any component.

The present invention also provides for acceleration control during both the hoisting and lowering movement with time relays which operate in identical sequence in the two movements. This also permits quick determination of a fault location. In the lowering power circuit, the successive speed characteristics are provided by stepped insertion of power resistance sections in the field circuit without cross connecting or transferring of armature resistance sections on the high speed points. This



prevents loss of hoist control during lowering as a result of malfunction in the control.

The drawings furnished herewith illustrate the best mode presently contemplated for carrying out the invention and disclose the advantages heretofore discussed as well as other advantages which will be clear from the following description of the illustrated embodiment.

In the drawings:

FIG. 1 is a schematic circuit diagram showing the motor operating circuit and a control circuit for adjusting the motor to five different speeds during hoisting and during lowering;

FIGS. 2–11 constitute point-by-point power diagrams for hoisting and lowering positions of the five-speed system shown in FIG. 1, and more particularly;

FIG. 2 illustrates the first hoist position;

FIG. 3 illustrates the second hoist position;

FIG. 4 illustrates the third hoist position;

FIG. 5 illustrates the fourth hoist position;

FIG. 6 illustrates the fifth hoist position;

FIG. 7, which is placed adjacent FIG. 2, illustrates the first lowering position;

FIG. 8 illustrates the second lowering position;

FIG. 9 illustrates the third lowering position;

FIG. 10 illustrates the fourth lowering position; and

FIG. 11 illustrates the fifth lowering position.

Referring to the drawings and particularly to FIG. 1, a hoist cable 1 is shown adapted to be wound and unwound on a cable drum 2. A hook 3 is secured to the lower end of the cable for attachment to a suitable load. A D.C. hoist motor 4 is diagrammatically shown having a rotating armature 5 and a fixed field 6 connected in a motor operating circuit 7. Incoming D.C. power leads 8, one of which is labeled positive (+) and the other of which is labeled negative (—), are connected to the motor operating circuit 7 through a double-pole, single-throw power switch 9. A control circuit 10 is also connected to the incoming power lines 8 by a double-pole, single-throw control switch 11.

The illustrated control circuit 10 is generally of an across-in-line variety wherein the several lines which extend between the extension of power lines 8 have been identified respectively as lines L–1 through L–13, respectively, for clarity and simplicity of the subsequent description. The control circuit actuates contactors for the various control contacts in the motor operating circuit 7 for selective insertion of resistance in the circuit of the armature 5 and field 6 for controlling the speed as more fully developed hereinafter.

A friction brake drum 12 is connected in common with the armature 5 and the drum 2, as shown diagrammatically by the broken line. A brake shoe 13 is urged into frictional braking engagement, by any suitable means, with drum 2. A brake release winding 14 is connected in the motor operating circuit 7 and electromagnetically coupled to brake shoe 13 for releasing thereof.

The main control of the cable 1 and cable drum 2 is under the control of an operator through a drum controller 15. Generally, drum controllers of the variety illustrated are well known and the diagrammatic illustration of FIG. 1 is for purposes of more clearly showing the functioning and circuit connections. Generally, the controller includes a plurality of axially spaced contacts and which are selectively movable to opposite sides of a central off-position for operation by suitable bar actuators as hereinafter described to establish hoisting and lowering of hook 3. In the illustrated embodiment of the invention, the drum is rotated towards the right in FIG. 1 to five successive lowering points numbered 1 through 5 on the corresponding vertical lines or towards the left to five successive hoisting points numbered 1 through 5 on corresponding vertical lines.

In the illustrated embodiment, motor operating circuit 7 has been simplified by elimination of safety circuits which are normally provided to more clearly and fully illustrate the present invention. For example, the limit switches and the protective relay circuit shown in U.S. Patent 2,902,635 previously referred to, the protective relay circuitry of the copending application of Harry M. Cook and Christian Chermely entitled "Electric Motor Control," filed on July 20, 1961 with Serial No. 122,817 or some similar circuitry may and will normally be provided. However, as such circuitry forms no part of the present invention other than as in combination with the circuit hereinafter described provides a highly practical system, it has not been included.

The illustrated motor operating circuit 7 includes a pair of branch motor lines 16 and 17 connected in parallel between the incoming power lines 8. The armature 5 is connected between the branch lines 16 and 17 such that if current is supplied from the positive power line 8 through branch line 17, the current flows through armature 5 and field 6 in line 16 to establish a series motor operation. Current supplied via line 16, however, divides at the connection of armature 5 and field 6 to provide a shunt motor operation during the lowering cycle because if driven, generator action results and produces a retarding and self-limiting torque to match the overhauling load. The ends of branch lines 16 and 17 are interconnected to power lines 8 by main control switch 9 with an overload protective relay 18 in the one power line connection. Overload protective relay 18 illustrates a protective device which is normally provided in circuits of this nature.

The power supply path to motor 4 is selectively controlled by a hoisting contactor 19 and a lowering contactor 20 of control circuit 10 having corresponding hoisting contacts 19–1 in branch line 17 and lowering contacts 20–1 in branch line 16.

The operation of contactors 19 and 20 is hereinafter described in connection with the description of the control circuit 10. Throughout the description herein, the various contactors and relays are numbered with the contacts associated therewith similarly numbered and distinguished by a sub-number 1, 2, 3 etc. for each of the several contacts operated by the corresponding contactor or relay for simplicity and clarity of explanation.

In both circuits, the hoisting and lowering circuits, the brake release winding 14 is connected in series with the field 6 and thus energized to release the brake partially or completely to provide controlled movement of the motor 5 with the exact speed being determined by the interconnection of the following resistors in the circuit.

Three accelerating resistors 21, 22 and 23 are series connected in branch line 17 between winding 14 to the negative power line 8. A set of normally open contacts 24–1 of an acceleration control contactor 24, which is connected in line L–5 of the control circuit 10, is inserted in branch line 16 between resistor 23 and the common connection to negative power line 8. An accelerating resistor 25 is also connected in the circuit between the branch lines 16 and 17 with the one end connected between the resistor 23 and contacts 24–1 and the opposite end connected to the branch line 17. A set of normally open contacts 26–1 of a second accelerating control contactor 26 is connected in the branch line 17 between the connection of resistor 25 and the common connection to branch line 16.

The accelerating resistors 21 through 23 ad 25 are selectively connected in the circuit to provide timed accelerated movement of the motor 5 at relatively high speed of the hoist cable.

A dynamic braking circuit is also provided and employed to control initial variations in the speed of the motor in the low speed range as hereinafter described. The dynamic braking circuit includes a resistor 27 selectively connected in parallel with the armature 5 and the field 6 by a set of contacts 28–1 of a dynamic brake contactor 28. The contactor 28 is connected in line L–10 of control circuit 10 for selective energization and opening of contacts 28–1, as hereinafter described.



In addition, the illustrated circuit includes a resistor 29 in line 17 between the connection to the armature 5 and the dynamic braking resistor 27. A further lowering resistor 30 is inserted in branch line 16 between the main lowering contactor contacts 20–1 and the connection to the armature 5 and field 6.

A set of normally open contacts 31–1 of a shunt contactor 31 is also connected in branch line 17 for selectively connecting the armature to the negative power line 8 through the branch line 17 for shunt motor operation. Contactor 31 is connected in the control circuit in parallel with the contactor 20 in line L–4 and is energized only during a setting of the control circuit for a lowering operation as hereinafter developed.

During the lowering or hoisting operation, the accelerating resistors 21–23 and 25 are selectively inserted in the circuit through the controlled operation of the contactors 24, 26 and 28 and additionally three accelerating contactors 32, 33 and 34 forming a part of the control circuit in lines L–6, L–8 and L–9, respectively. The contacts 32–1 of contactor 32 are connected between the branch lines 16 and 17 with the connection to branch line 16 made between the accelerating resistors 22 and 23. Contacts 33–1 of acceleration contactor 33 are similarly connected with the connection to branch line 16 being made between resistors 21 and 22. Normally open contacts 34–1 of acceleration contactor 34 are connected directly across the resistor 21.

The motor operating circuit 7 and control circuit 10 in FIG. 1 are shown in a standby or de-energized position with the switches 9 and 11 open.

Generally, the control circuit includes the drum controller 15 which includes the spatially axially distributed contacts 35 through 46 in lines L–1 and L–3 through L–13, respectively, for controlling the several contactors and control relays. The several contacts 35 through 46 and their interconnection in the circuit will be separately described in connection with the hoisting and lowering positioning of the drum controller 15.

The first set of contacts 35 are connected in series with an interlocking off relay 47 and the relay contacts 18–1 in line L–1. A set of normally open contacts 47–1 of the relay 47 is connected in the positive power line 8 to all of the other cross lines of the control circuit 10. A contact bar 48 of the drum controller 15 is aligned with contacts 35 in only the off position of the controller 15 such that power to relay 47 is only provided when the drum controller 15 is set in the off position and further the overload relay contacts 18–1 of relay 18 in the connection of motor operating circuit 7 to the positive power line 8 are closed. Any other suitable protective devices can also be included for example an overhauling protective relay system such as shown in the previously referred to copending application of Cook and Chermely may be provided with a relay connected in the motor operating circuit to control a set of contacts in line L–1.

Energization of relay 47 closes contacts 47–1 and establishes a holding circuit via line L–2 which is connected in parallel with contacts 47–1 and 35. Drum controller 15 can then be moved to the hoist or lower positions opening contacts 35 without de-energizing interlock relay 47.

Relay 47 controls a second set of normally open contacts 47–2 connected in line L–3 in series with the hoisting contactor 19 as well as the lowering contactor 20 and shunt contactor 31 which are connected through line L–4 to the positive power line 8 and through contacts 47–2 to the negative line 8.

The motor 4 can then be operated to raise or lower the cable 1 through proper positioning of the drum controller 15.

Drum controller 15 provides for 5 different hoisting and lowering speeds. The control circuit 10 is described as controller 15 moves progressively to the several hoisting positions and thereafter as it moves to the several lowering positions.

In the off position contactor 47 is energized to provide power to lines L–3 through L–13 but the circuits therethrough are held open by normally open drum controller contacts therein. The drum controller 15 is then turned to place the several switches 35–46 in the first vertical hoist position which results in the motor operating circuit 7 of FIG. 2. In FIGS. 2–11, the solid lines are current conducting lines and the dotted lines are non-conducting or open circuits.

In the first hoist position, a contact bar 49 of controller 15 is aligned with and closes contacts 36 in line L–3 thereby establishing a complete circuit through the hoisting relay 19. The contact bar 49 spans all five hoisting positions and holds the contacts 36 closed during all hoist positions, maintaining contactor 19 energized and power contacts 19–1 of motor operating circuit 7 closed. Current flows through armature 5 and field 6 in series and motor 4 operates as a series D.C. motor.

Line L–4 which includes the lowering contactor 20 and paralleled shunt contactor 31 are controlled by the drum controller contacts 37. A contact bar 50 spans all five lowering positions and is effective to provide current flow through line L–4 only when drum controller 15 is moved to a lowering position.

Simultaneous energization of hoist contactor 19 with contactors 20 and 31 is prevented by mechanical interlocks separately provided between contactor 19 and the contactors 20 and 31, as diagrammatically shown by broken coupling lines between the coils. The mechanical coupling is of any suitable variety and no further showing thereof is necessary for those skilled in the art.

Energization of contactor 19 closes a second set of contacts 19–2 in line L–10 in series with controller contacts 43 for conditioning the circuit of contactor 28. Contacts 43 are controlled in the respective hoist and lowering positions by contact bars 51 and 52, respectively, which only span the positions 2 through 5 inclusive and thus in the initial or first position, the dynamic brake contactor 28 remains de-energized. The associated contacts 28–1 in the motor operating circuit 7 remain closed to maintain current from contacts 19–1 through resistor 29, resistor 27 and contacts 28–1 in parallel with armature 5 and field 6 of motor 4 which operates as a series motor with a motor shunt.

The current continues through the brake winding 14 in branch line 16, accelerating resistors 21, 22 and 23 to normally open contacts 24–1 of contactor 24.

Referring to the control circuit 10 and particularly line L–5, contactor 24 is energized upon movement of the drum controller 15 to the first hoist position through the drum controller contacts 38. The normally open contacts 38 are respectively controlled in the hoist and lowering positions by the contact bars 53 and 54. Contact bar 53 spans all hoist positions. Contactor 24 is thus energized in the first hoist position to close the contacts 24–1 and complete the previously described circuit to the negative side of the power line 8 via switch 9.

Energization of contactor 24 further closes a set of normally open contacts 24–2 in line L–6 which includes contactor 32 and the normally open contacts 39 of the drum controller 15. The contacts 39 are controlled by a pair of contact bars 56 and 57, which respectively span all five hoisting positions and lowering positions. When contactor 24 closes contacts 24–2 in line L–6, a circuit is completed from the positive power line 8 through contacts 39, a set of normally closed timing contacts 55–1 of a timing relay 55 in line L–12, the now closed contacts 24–2 and contactor 32 to the negative power line 8. Contactor 32 then closes the normally open contacts 32–1



of the motor operating circuit 7 and connects the accelerating resistor 25 in parallel with the accelerating resistor 23. In summary, in the first hoist position, the contactors 19, 24 and 32 are energized to establish the circuit of FIG. 2. In this position, it is seen that the motor 4 is energized with a shunt as a result of the closed dynamic braking contacts 28–1 and with the accelerating resistors 23 and 25 in parallel. This constitutes the highest series resistance connection in the hoist position and establishes the minimum speed and holding torque. As a result, in the first position, a low creeping movement of the motor 4 and the coupled drum cable 2 is established.

In proceeding through the positions 2–5 of the hoisting circuit, it will be noted that the contactors 19, 24 and 32 are maintained in the energized state and thus the contactors are only actuated once for the complete five point operation.

FIG. 3 illustrates the second hoist position where in addition to energization of contactors 19, 32 and 24, contactor 28 is energized. The contacts 19–2 in line L–10 are closed by the continued energization of contactor 19 in line L–3. In the second position, the contact bar 51 closes the contacts 43 and completes the circuit to the contactor 28 through the closed contacts 19–2.

Energization of contactor 28 open contacts 28–1 and removes the motor shunt of resistors 29 and 27 previously described and shown in FIG. 2. Consequently, the series resistance is reduced and the motor 4 operates at a higher speed and with a substantially higher holding torque somewhat less than but approaching 100%. In moving from the first hoisting position to the second hoisting position, the single contactor 28 has been actuated and is maintained energized for the subsequent hoist positions.

Moving of drum controller 15 to the next or third hoist position establishes the motor operating circuit 7 shown in FIG. 4. In this position, the previously described energization of the contactors 19, 32, 24 and 28 is maintained and additionally, acceleration control contactor 26 in line 11 is energized, as follows. Drum controller contacts 44 in line L–11 are controlled by contactor bars 58 and 59, respectively, for hoisting and lowering and each of the bars span the corresponding drum positions 3–5, inclusive. The contactor 26 and a timing relay 60 are connected in parallel circuit to the contacts 44 in series with the contacts 28–2 of the dynamic braking contactor 28 in line 10. Contacts 28–2 are closed as a result of the energization of contactor 28 in the hoist positions 2–5. When the drum controller 15 is placed in the third speed position, the contact bar 58 engages and closes contacts 44 to connect the positive power line 8 to a point through the contacts 28–2 and through timing relay 60 which has its opposite side connected directly to the negative power line 8. The circuit to contactor 26 is held open by a set of normally open contacts 60–1 of the timing relay 60. After a predetermined time period, the relay 60 closes the associated normally open contacts 60–1 and completes the circuit through contactor 26 through a set of normally closed contacts 20–3 of the lowering contactor 20. After the selected time period, the contactor 26 is energized and closes the associated contacts 26–1 in branch line 17 of the motor operating circuit 7 which completes a direct bypass or shorting circuit to the negative power line 8 about the accelerating resistors 23 and 25. The balance of the circuit of FIG. 4 corresponds to that of FIG. 3. The series motor resistance is therefore reduced, establishing a higher speed and an increased torque by the actuation of the single contactor 26.

Similarly, in moving from the third hoist position to the fourth position, a single contactor 33 is actuated with all previous contactors being maintained in the position established in the third hoist position, shown by the comparison of FIGS. 4 and 5.

Referring particularly to FIG. 1, when the drum controller 15 is moved to the fourth hoist position, the circuits through line L–7 and L–12 change as follows.

In line L–12, the normally open drum controller contacts 45 are controlled by contact bars 61 and 62 in the hoisting and lowering movements, respectively. In moving to the fourth hoisting position, contact bar 61 engages contacts 45 and completes the circuit therethrough for controlling energization of the timing relay 55. The circuit is completed through the normally open contacts 26–2 of acceleration control contactor 26 which was energized in the third hoist position and is maintained energized through the fifth hoist position. As a result, immediately upon moving to the fourth hoist position, the timing relay 55 is energized and begins timing. After a predetermined time period, the relay 55 actuates associated contacts. A first set of normally closed contacts 55–1, in line L–6, opens to break the circuit therethrough to the contactor 32. However, energization thereof is maintained by the set of normally closed contacts 20–2 of the lowering contactor 20, which is never energized in the hoisting movement of drum controller 15. In effect, contacts 55–1 are operative, as hereinafter described, in the several lowering positions of the drum controller 15. A set of normally open contacts 55–2, in line L–7, are also closed. Contacts 55–2 are connected in parallel with a portion of line L–8 to control energization of the accelerating control contactor 33 in series with the normally open contacts 32–2 of contactor 32. As just described, contactor 32 is maintained energized in the fourth hoist position to hold the contacts 32–2 closed and upon the closing of contacts 55–2, conditions the circuit through line L–7 for energization of the contactor 33. The circuit is completed through the normally closed contacts 40 which are controlled by a contact bar 63 of the drum controller 15. The contact bar 63 spans the fourth and fifth hoist positions and thus in moving to the fourth hoist position, establishes the energizing circuit for contactor 33 upon the timed closing of the contacts 55–2.

Energizing of the accelerating control contactor 33 closes the normally open contacts 33–1 of the motor operating circuit 7 and establishes a shunt or bypass circuit about the resistor 22 and the closed contacts 32–1 forming a part of the third hoist position of FIG. 4. As a result, the circuit in the fourth hoist position is as shown in FIG. 5. The elimination of the resistor 22 further reduces the series resistance and establishes a higher motor speed. Thus, the resistance of the motor circuit is less, the current increases and the motor accelerates to a still higher speed.

FIG. 6 shows the final or fifth hoist position providing maximum hoisting speed.

In the final hoisting position, a timing relay 64 in line L–13 is actuated to control operation of the third accelerating contactor in line L–9 as follows. In line L–13, normally open contacts 46 of drum controller 15 are controlled by contact bars 64 and 65, during the hoisting and lowering positioning, respectively, of the drum controller 15. Each of the contact bars 64 and 65 spans only the fifth operating position of the drum controller and as a result, contacts 46 are maintained open until the drum controller is placed in the fifth position. Contacts 46 then are closed to establish a circuit for energizing relay 64. A set of normally open contacts 55–3 of the timing relay 55, in line L–12, are connected in line L–13 to prevent energization of the timing relay 63 without the timed energization of relay 55 in the fourth hoist position. Assuming the proper energization of the timing relay 55, when the drum controller 15 is moved to the fifth hoist position, the timing relay 64 is energized and closes contacts 64–1 in line L–9 after a predetermined time.

Contactor 34 is connected in line L–9 in series with contacts 64–1 and drum controller contacts 42. A single contact bar 66*a* is provided in the fifth hoist position only and contacts 42 are closed thereby in the fifth hoist position. Moving to the fifth hoist position establishes a timed closing of contacts 64–1 and energization of contactor 34. As a result, contacts 34–1 of the motor operating circuit 7 are then closed and bypass or shunt current about the accelerating resistor 21, and motor operating circuit 7 is as shown in FIG. 6. All resistance cut is removed from the series motor circuit and the maximum hoist speed is established.

The corresponding lowering sequence is shown in FIGS. 7–11 wherein it will be noted from the following description that the speed is increased as a result of progressive insertion of power resistance sections only in contrast to removal of resistance sections and the cross connecting and transfer of armature resistance section on the fast speed points 3–5 of drum controller 15.

Referring particularly to FIG. 7, wherein the motor operating circuit 7 is illustrated with the drum controller 15 in the first lowering position, operation of the device is described.

Contactor 47 is energized to complete the power connection to the control circuit as previously described.

The hoist contactor 19 is de-energized as a result of opening of contacts 36 in line L–3 with the movement of the drum controller 15 to the off position and then to the lowering position. In moving to the first lowering position, the contact bar 50 engages the contacts 37 in line L–4 of drum controller 15 and establishes the energizing circuit for contactor 20 through the closed contacts 37, contactor 20 and the interlock contacts 47–2. As a result, contacts 20–1 and branch line 16 of motor operating circuit 7 close to provide current connection between the positive power line 8 to the junction of the armature 5 and the series field 6 of the motor 4.

Energization of the contactor 20 also closes a set of normally open contacts 20–3 connected in series with the shunt contactor 31 across the contactor 20. The normally open shunt contacts 31–1 in line 17 of the motor operating circuit 7 close to complete a current path to the normally open contacts 26–1 and to normally open contacts 24–1 through the shunted accelerating resistor 25 whereby motor 4 operates as a shunt motor.

The contactor 24 in line L–5 is energized in the first lowering position as a result of engagement of contacts 38 by contact bar 54 which spans the first four lowering positions of the drum controller 15. Consequently, contactor 24 is energized to close the contacts 24–1 in the motor operating circuit 7 and completes the circuit to the negative power line 8 for the excitation of the armature 5.

The field 6 is energized in a shunt circuit, as follows.

The previously described energization of the contactor 24 also results in closing of the contacts 24–2 in line L–6 for energizing contactor 32. Contacts 39 of the drum controller 15 are engaged by the control bar 57 in all lowering positions and closing of contacts 24–2 completes the energizing circuit to contactor 32 through the normally closed timed relay contacts 55–1. When contactor 32 is energized, the contacts 32–1 are closed and connect the accelerating resistor 23 in parallel with the resistor 25 in the armature circuit.

Further, in the first lower position, the drum controller contacts 41 of line L–8 are engaged by a contact bar 67 which spans all five lowering positions of the drum controller 15. This completes a relay circuit to the contactor 33 through a set of normally closed timed contacts 60–2 of timing relay 60 and a set of normally open contacts 32–2 of the accelerating contactor 32. The accelerating contactor 32 is energized however as described immediately above and as a result, contactor 33 is energized on the first lowering position of the drum controller 15 to close the contacts 33–1, as shown in FIG. 7. Further, a circuit is established to the contactor 34 from line L–8 and contacts 41 through a set of normally closed dynamic braking contacts 28–3 of the contactor 28 which is connected in a jumper lead between the lines L–8 and L–9, as shown. The circuit to the contactor 34 also includes normally open contacts 33–2 of contactor 33. These contacts are closed upon energization of the contactor 33

as described immediately above. As a result, in the first lowering position of the drum controller 15, the contactor 34 is also energized and closes the shunting contacts 34–1 across resistor 21 of the motor operating circuit 7.

In summary, in the first lowering position, the contactors 20, 31, 24, 32, 33 and 34 are all energized and hoist contactors 19 accelerating contactor 26 and dynamic brake contactor 28 are de-energized as are the timing relays 55, 60 and 64. As a result, the circuit of FIG. 7 is established with the armature circuit including positive power line 8, switch 9, contacts 20–1, resistor 30, armature 5, resistor 29, shunt contacts 31, and then the parallel resistors 23 and 25, contacts 24–1 and main contact switch 9 to the negative power line 8.

The field circuit includes the contacts 20–1, resistor 30, field 6 and then, in parallel, the release brake winding 14 and the dynamic braking resistor 27 to branch line 17 with the completion of the circuit through the parallel resistors 23 and 25 in common with the armature circuit. This establishes the minimum field resistance employed in the five positions and establishes a relatively strong field. The circuit of FIG. 7 constitutes the maximum armature resistance in lowering and thus a relatively low armature voltage. The combination produces a relatively low or creeping speed.

In moving to the second lower position of drum controller 15, the circuit of FIG. 8 is established. The several contactors remain in the condition of position 1 with the exception of dynamic braking contactor 28 and contactor 34.

In the second lower position, the contact bar 52 in line L–10 engages and closes the contacts 43 and thereby establishes a circuit to energize dynamic braking contactor 28 through the contacts 31–2 of the shunt contactor 31. The shunt contacts 31–2 are energized as a result of the continued energization of contactor 31 through line L–4 during the complete lowering cycle. The result of energizing contactor 28 is to open the contacts 28–1 of the motor operating circuit 7 to remove the motor shunt from the circuit.

Energization of the contactor 28 also opens the associated contacts 28–3 in the jumper lead between cross lines L–8 and L–9 through which contactor 34 was energized in the first lower position. As a result, contactor 34 drops out and contacts 34–1 of the motor operating circuit 7 open. Opening of the contacts 34–1 inserts the accelerating control resistor 21 in series with the field 6 of the motor 4 and weakens the strength of field 6, thereby increasing the speed of motor 4.

FIG. 9 illustrates the condition of operating motor circuit 7 in the third lower position of drum controller 15.

Referring to FIG. 1, it will be noted that the only change in the condition of the circuitry in the third lower position is the closure of contacts 44 by contact bar 59 in line L–11. The contacts 28–2 in line 11 are closed as a result of the previous energization of the dynamic braking contactor 28 and the maintenance of the energization of the contactor 28 for all positions of 2 through 5, inclusive, by the contact bar 52. The circuit is then established through the normally closed contacts 33–3 of contactor 33 and the now closed contacts 20–3 to energize the contactor 26. Energization of contactor 26 results in closing of contact 26–1 and the connection of the branch line 17, following the shunt contacts 31–1, directly to the negative power line 8. As a result, the resistors 23 and 25, which were previously connected in parallel in the circuit through the contacts 24–1 are disconnected from the circuit.

The timing relay 60 which is also connected in line L–11 in parallel with the contactor 26, the contacts 33–3 and contacts 20–3, is energized simultaneously with the contactor 26 and begins to time out. After the selected time period, contacts 60–2 open in line L–8 to de-energize contactor 33 and thereby open the contacts 33–3 in the circuit for contactor 26. However, simultaneously the timer contacts 60–1 close and complete a parallel latching circuit connected directly across or in parallel with the contacts 33–3 and 20–3 in line L–11. As a result, contactor 26 is maintained energized while contactor 33 is de-energized.

De-energization of the contactor 33 opens the contacts 33–1 and opens the direct connection between branch lines 16 and 17 of motor operating circuit 7 between the resistors 21 and 22. As a result, the resistor 22 is connected in series with resistors 21 and 23, the release brake winding 14 and the series field winding 6 to establish the circuit of FIG. 9. In FIG. 9, the additional resistor 22 in the field circuit causes a resultant weakening of the field and an increase in the motor speed.

In the third lowering position, contactor 26 is energized and contactor 33 is de-energized being the first actuation of these contactors following the first lowering position. They are maintained in this single actuated position for the fourth and fifth lowering positions to be presently described.

Referring particularly to FIG. 10, which is the fourth lower position, the circuit essentially corresponds to that of FIG. 9 with the exception that the accelerating control resistor 23 has been inserted in the circuit by the opening of the contacts 32–1. These contacts are open in timed relation in the following manner.

Referring to FIG. 1 and particularly the illustration of the drum controller 15, it is to be noted that in the position of FIG. 10 the various circuits correspond to the position of the third lower position with the exception that at line 12, contact bar 62 engages and closes contacts 45 thereby conditioning the circuit for energizing timing relay 55. Connected in circuit with the timing relay 55 and the contacts 45 are the second set of normally open contacts 26–2 of contactor 26 shown connected in line L–11. Contactor 26 was energized in the third position and is maintained energized in the fourth position by the actuation of the contact bar 59 in the previously described circuitry. As a result, timing relay 55 is energized and begins to time out. After the selected timing period, the contacts 55–1 in line L–6 open and break the circuit to the contactor 32. As a result, contacts 32–1 open in the motor operating circuit 7 and break the shunt path from the resistor 22 to the branch line 17 about the resistor 23. As a result, the circuit for armature 5 is maintained the same as in the third position. However, the field circuit is weakened by the insertion of the resistor 23 and results in an increased speed in accordance with known operation of shunt motors.

The fifth and final lower position of the operating circuit 7 is shown in FIG. 11. The circuit corresponds to that of FIG. 10 with the addition of the accelerating control resistor 25 in the field circuit.

Referring particularly to FIG. 1, the drum controller varies the condition of the contacts in line L–5 and L–13.

In line L–13, the contact bar 66 engages and closes the contacts 46 completing the circuit for the timing relay 64. The normally open timing contacts 55–1 were previously closed as a result of the positioning of the fourth lower position of the drum controller 15 to energize the timing relay 55. Thus, the movement from the fourth to the fifth position can only be effected after a predetermined timed setting in the fourth position. Assuming proper operation, the relay 64 is energized and closes contacts 64–1 in line L–9 and contacts 64–2 between lines L–5 and L–6.

Closing of contacts 64–1, which are only effective in the hoisting cycle, is ineffective as a result of the open drum contacts 42.

The positioning of the drum controller 15 removes the contact bar 54 from the contacts 38 in line L–5 and thereby opens that circuit to the contactor 24. The normally closed contacts 64–2 which are connected directly between lines L–5 and L–6 maintain the circuit for contactor 24 for the timed period of relay 64.

The contactor 64 in line L–13 thus after a predetermined time period times out and opens the contacts 64–2

whereupon the contactor 24 is de-energized and the contacts 24–1 of the motor operating circuit 7 open. As a result, current cannot flow directly from the branch line 17 from the negative side of the resistor 23 to the negative power line 8 but is diverted or shunted downwardly through the accelerating resistor 25 into the negative line 8 through the closed contacts 26–1. As a result, resistor 25 is inserted in series with the field 6 in addition to the previously inserted resistors 21, 22 and 23. This provides maximum series resistance in the field circuit with a maxmum weakening of the field. As a result, motor 4 operates at a maximum speed as a shunt motor.

It is noted from FIGS. 7–11 that the control of the motor 4 in the lowering position is effected by the selective insertion of accelerating resistors 21, 22, 23 and 25 in the field circuit for the second, third, fourth and fifth lowering positions, respectively. This provides an extremely safe lowering power circuit as a result of the elimination of any cross connection and transfer of armature resistance section, particularly on the fast feed points.

Thus, if any contactor malifunctions, the resistance of the field circuit is maintained at the higher value to hold the speed of the hoist. This eliminates the danger of losing complete control of the load during lowering.

Further, it is noted that the operation of the contactor sequence on lowering is substantially the opposite of that of the hoisting sequence. Thus, in the hoisting sequence, the contactors 32, 33, and 34 are actuated in that order whereas in the lowering sequence they are operated in the reverse order. In both hoisting and lowering each contactor is operated only once being either energized or de-energized in the total five point operation of either hoisting or lowering. Thus, the first position establishes energization or de-energization of certain relays or contactors and thereafter these contactors are only actuated once during the complete following cycle.

Another particularly advantageous operation of the illustrated control is the operation of the time relays 55, 60 and 64. Thus, during a hoisting operation, they are operated in the sequence of relay 60, relay 55 and relay 64. The relay sequence is identical for the lowering operation. The circuit thus provides three point timed acceleration in both hoisting and lowering and minimizes the location of fault in the control circuit for maximum usage and utility.

The circuit thus provides a logical and readily understood control sequence which can be maintained and checked in the event of any breakdown with a minimum of skill.

The circuit minimizes both the electrical and mechanical wear on contactors such that the control will operate surely and safely over long periods with minimum maintenance. Thus, each contactor is operated once, being either energized or de-energized, in completing the five point operation in either the hoist sequence or lower sequence. In the respective fifth or maximum speed point of hoisting and lowering, the running current is distributed through different contactors with only the one contactor 26 being common.

Further, this simplified circuit also provides a safe stop at the off setting of controller 15 from fast lowering to immediately stop the hoist unit as the complete circuit drops out at the off position. The circuit can employ a protective relay such as shown in the previously referred to copending application of Cook et al. to assure setting of the brake upon entering an overhoist power-type limit switch, even in the event the operator mistakenly places the controller in a lowering position from a hoist position.

The present invention, in summary, provides a relatively simple control system providing excellent utilization of the power contactors with a minimum actuation thereof during any contactor sequence.

Various modes of carrying out the invention are regarded as being within the scope of the following claims, particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. In a motor control circuit for controlling energization from a current source of the field and armature of a direct current motor having a pair of operational conditions one of which creates a series motor and the other of which creates a shunt motor, the motor operating circuit including first and second branch lines connected in parallel to a current source with the armature connected between said branch lines and the field serially connected in the first branch line and series-motor contact means and shunt-motor contact means respectively connecting the second and first branch lines to one power line of the current source, the improvement comprising,

(a) three acceleration resistance means connected in series in the second branch between the field and the second power line,

(b) a resistance means connected between the branch lines to the end of acceleration resistance means opposite the field connection,

(c) a dynamic braking resistance means connected across the armature and field,

(d) first contact means connected in parallel with the first resistance means,

(e) second contact means connected between the first and second branch lines between the first and second resistance means,

(f) third contact means connected between the first and second branch lines between the second and third resistance means,

(g) acceleration contact means connecting the first branch line to the second power line,

(h) acceleration contact means connecting the second branch line to the second power line,

(i) a contactor for each of said contacts connected to the power line, and

(j) multiple position control switch means to selectively actuate said contactors, said switch means having a position for each speed of the motor in each of the operational connections thereof and actuating each of said contactors only once in moving through the operating positions for each of said operational connections.

2. A hoist control having a direct current hoist motor operating circuit including,

(a) A hoist circuit including said motor connected for series motor operation with hoist contacts of a hoist contactor between a first power line and the motor and a plurality of accelerating control resistors and a motor shunt resistor between a second power line and the motor,

(b) a lowering circuit including said motor connected for shunt motor operation with lower contacts of a lower contactor between the first power line and the motor and the accelerating resistors and said motor shunt resistor between the second power line and the motor,

(c) said accelerating resistors including first, second and third accelerating resistors connected in series and a fourth accelerating resistor connected in parallel with the third accelerating resistor to form a single effective resistor,

(d) contactors having contacts interconnected to operably insert and remove the accelerating resistors and shunt resistor from the circuit,

(e) said contactors being sequentially actuated during a hoisting sequence first to connect said accelerating resistors in series with the motor field and said motor shunt resistor in parallel with the motor, secondly to disconnect said motor shunt resistor, third to bypass said single effective resistor, fourth to shunt the second accelerating resistor and fifth to shunt said first accelerating resistor,

(f) said contactors being sequentially actuated during a lowering sequence first to connect said motor shunt resistor in parallel with the motor and said effective resistor in series with the motor, second to remove said motor shunt resistor and insert said first accelerating resistor in series with the field, third to remove the effective resistor and insert the second accelerating resistor in series with the field, fourth to insert the third accelerating resistor in series with the field and fifth to insert the fourth accelerating resistor in series with the field,

(g) said contactors including individual contactors for actuating dynamic braking contacts of a dynamic brake contactor in series with said motor shunt resistor, first accelerating contacts of a first accelerating contactor in parallel with said first accelerating resistor, second accelerating contacts of a second accelerating contactor in parallel with a series connection of the second, third and fourth accelerating resistors, third accelerating contacts of a third accelerating contactor in parallel with said third and fourth accelerating resistors, fourth accelerating contacts of a fourth accelerating contactor between the third accelerating resistor and the second power line, fifth accelerating contacts of a fifth accelerating contactor between the fourth accelerating resistor and the second power line, shunt motor contacts of a shunt contactor between the fifth accelerating contacts and the armature of the motor, and

(h) a contactor control circuit having a controller including a plurality of individual contact means selectively actuated, said contact means being connected to control the contactors and divided into a pair of five similar controller positions one each for a hoisting sequence and a lowering sequence, said controller control circuit including a first control branch including a hoist controller contact means holding the hoist contactor energized for the hoisting sequence, a second control branch including lower controller contact means holding the lower contactor energized for the lowering sequence, said shunt contactor being connected in series with a set of lower contactor contacts across the lower contactor, a third control branch including accelerating controller contacts holding the fourth accelerating contactor energized for all hoist positions and the first four lower positions, a fourth control branch including accelerating controller contacts conditioning the third accelerating contactor for energization in all hoisting and lower positions, contacts of the lower contacts contactor and the fourth accelerating contactor being connected in series therewith, a fifth control branch including controller contacts conditioning the second accelerating contactor for energization in the last two hoist positions, a sixth control branch including controller contacts conditioning the second and third accelerating contactors for energization in all lower positions, separate contacts of the third accelerating contactor being in series with the second accelerating contactor and separate contacts of the second accelerating contactor being in series with the third accelerating contactor, a seventh control branch including controller contacts conditioning the third accelerating contactor for energization in series with said last-named contacts of the second accelerating contactor in the last hoist position only, an eighth control branch including controller contacts conditioning the dynamic braking contactor for energization in series with paralleled contacts of the hoist contactor and lower contactor in the last four hoist and lower positions, a ninth branch line including controller contacts conditioning the fifth accelerating contactor for energization in series with dynamic braking contactor contacts and second accelerating contactor contacts and lower contactor contacts in the last three hoist and lower positions, a timing relay connected in parallel with the fifth accelerating contactor and contacts of the lower contactor and second accelerating contactor, a latching circuit including contacts of the timing relay and the lower contactor connected in parallel with the contacts of the lower contactor and the second accelerating contactor, a tenth branch line including controller contacts conditioning a second timing relay for energization in series with contacts of the fifth accelerating contactor, said second timing relay having contacts in said fourth and fifth branch line, an eleventh branch line including controller contacts conditioning a third timing relay for energization in series with contacts of said second timing relay in the last hoist and lower position, said third timing relay including contacts connecting the third and fourth branch lines and contacts in the seventh branch line for controlling said second accelerating contactor in the last hoist position.



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