

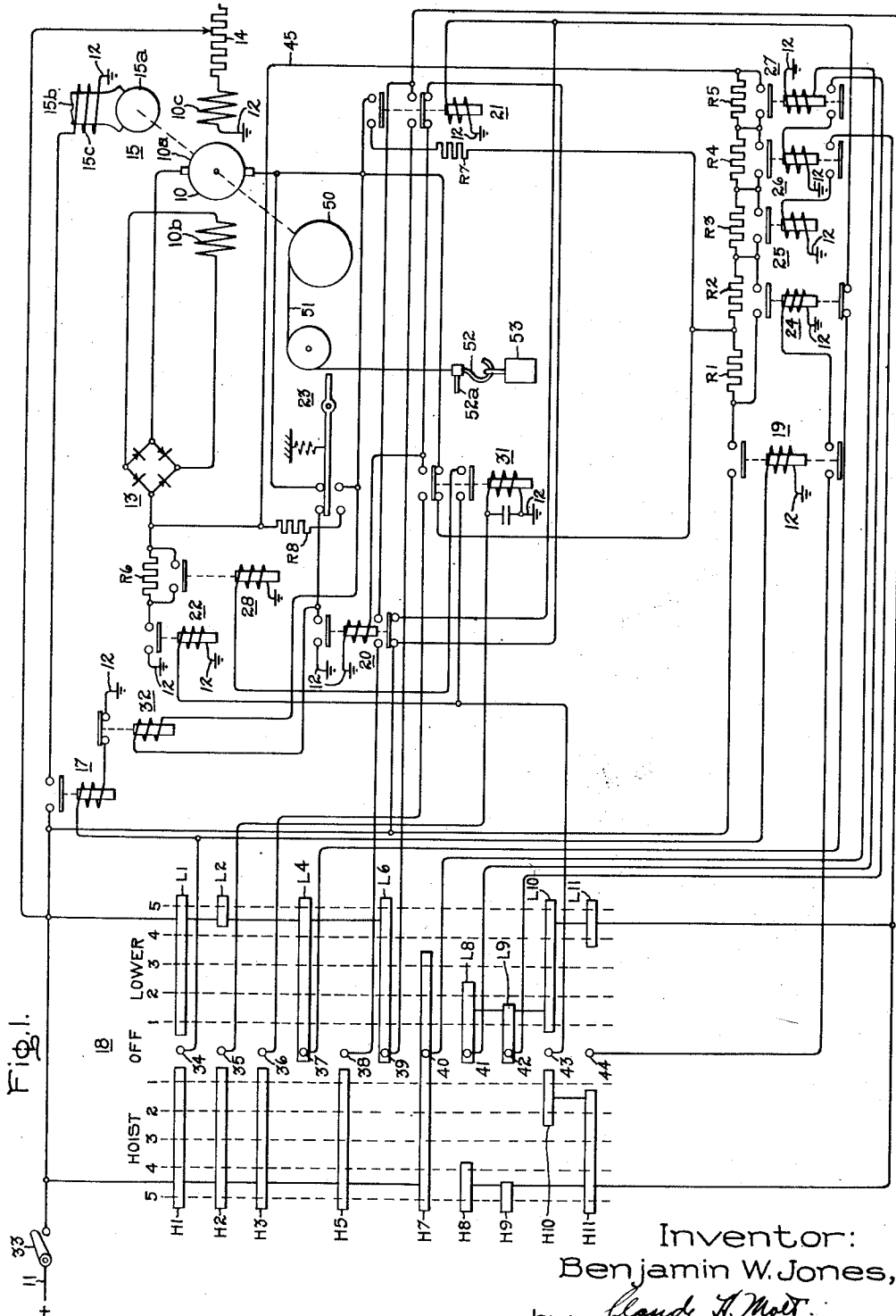
Sept. 25, 1951

B. W. JONES
CONTROL SYSTEM

2,569,317

Filed Dec. 30, 1949

3 Sheets-Sheet 1



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Fig. 2.

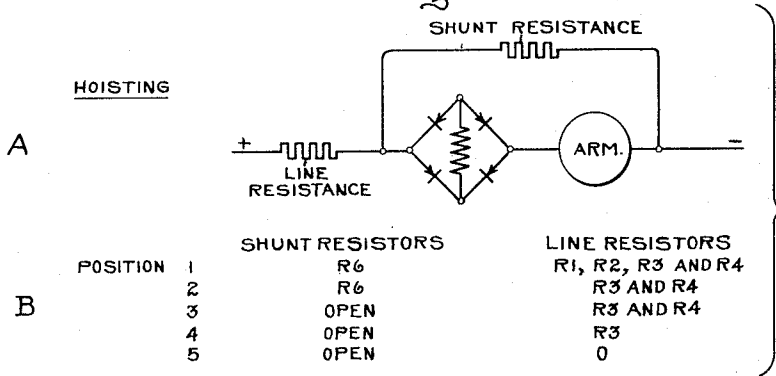
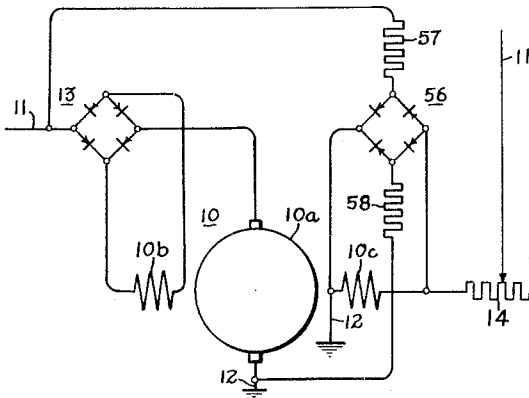
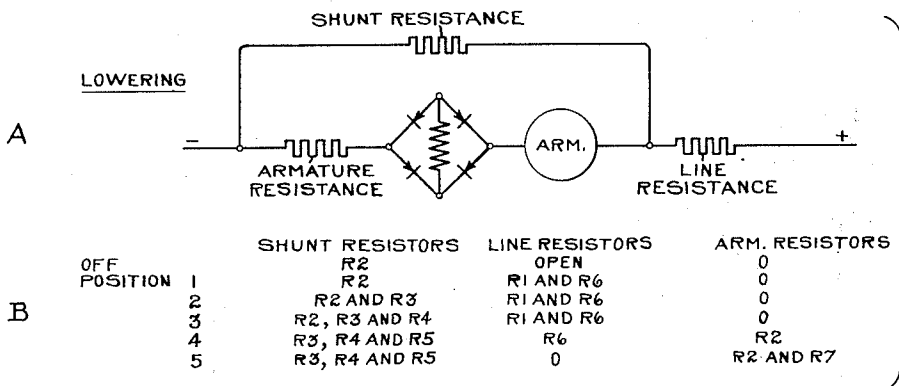


Fig. 3.



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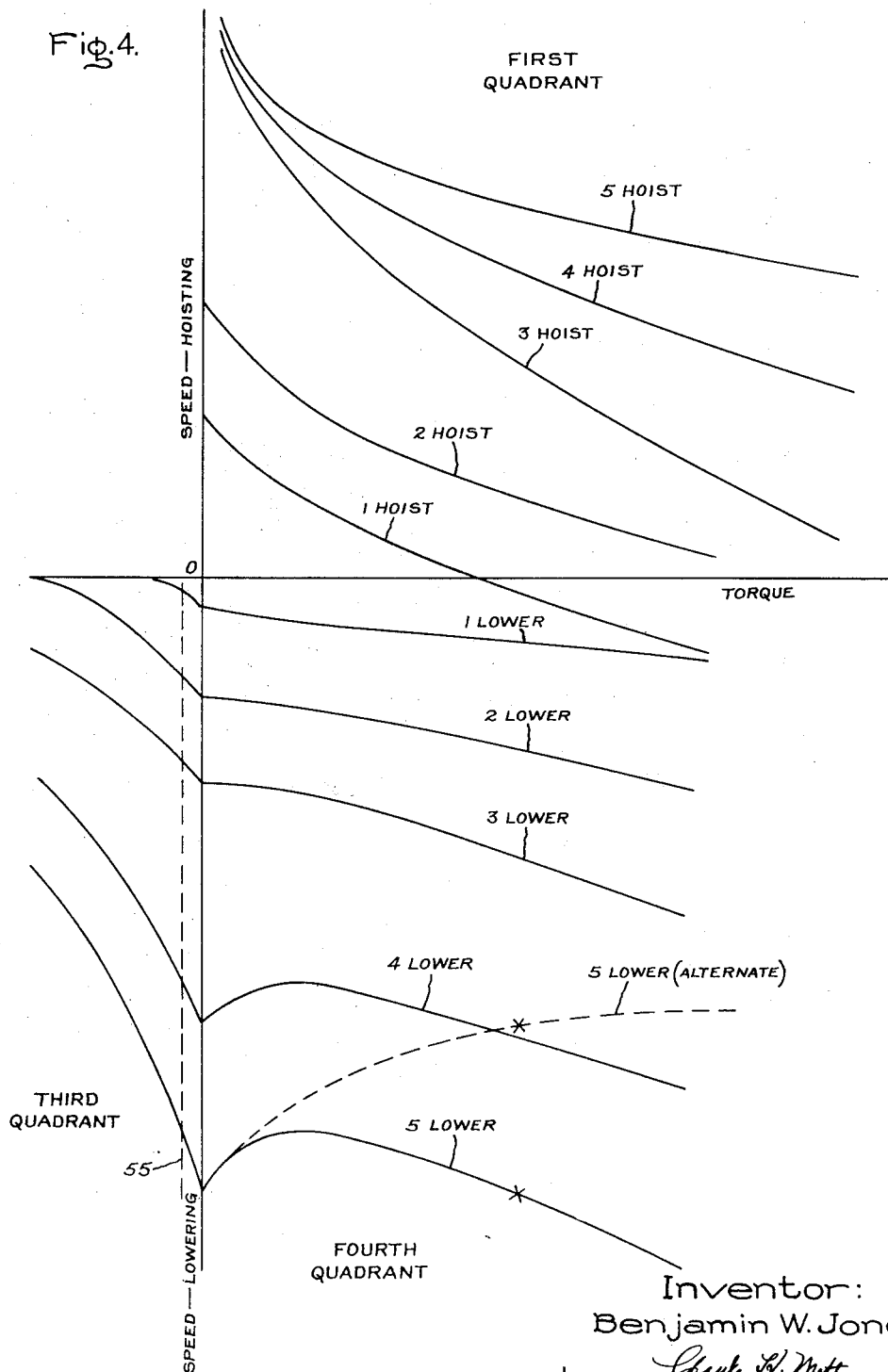
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,569,317

CONTROL SYSTEM

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Application December 30, 1949, Serial No. 135,950

12 Claims. (Cl. 318—154)

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This invention relates to control systems and more particularly to systems for controlling dynamoelectric machines for the operation of crane hoists and the like.

The principal object of the invention is the provision of a control system of this character which provides improved speed-torque characteristics.

Another object of the invention is the provision of such a control system in which the speed-torque characteristic curves for lowering operation may be provided with positive or negative slopes of varying degrees.

A specific object of the invention is the provision of a control system for crane hoist apparatus for operation from a substantially constant potential source in which, for a given control position, the lowering speed may be made to decrease for an increased overhauling load, thus providing a speed-torque curve having a negative slope or, as it is often called, a drooping characteristic.

Another object of the invention is to provide limit switch means in a crane hoist control system which is capable of stopping the dynamoelectric machine with a minimum of overtravel when it is operating as a motor at full speed hoisting, and retaining the load in the stopped position with a magnetic brake until the controller is moved to a lowering position.

Another object of the invention is to provide means for preventing failure of the shunt field of a compound wound dynamoelectric machine, in the event that the shunt field winding becomes disconnected from its normal source of current.

A still further object of the invention is to provide improved dynamic braking means for crane hoist control systems.

In carrying my invention into effect in one form thereof, a compound wound direct current dynamoelectric machine for operating a crane hoist is connected to a source of direct current of substantially constant potential. The dynamoelectric machine is connected for self-excitation, the series field being connected in series with the armature, while the shunt field is connected directly across the supply lines in the conventional manner. A bridge type rectifier is connected in circuit with the series field in a manner such that, regardless of the direction of current through the armature, the current through the series field remains unchanged in direction. This results in improved speed-torque relationships for both hoisting and lowering operation, the exact relationships depending upon the values of shunt resistance, line resistance, and armature resistance which are used in the system.

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For a better and more complete understanding of the invention, reference should be had to the accompanying drawing, Fig. 1 of which is a diagrammatical illustration of a preferred embodiment of the invention; Figs. 2A, 2B, 3A and 3B depict schematically and in chart form details of the operation of the control system illustrated in Fig. 1 to facilitate an understanding thereof; Fig. 4 illustrates typical speed-torque characteristic curves which are obtainable by the use of my invention; while Fig. 5 illustrates a protective circuit which may be incorporated in the control system of the invention.

Referring to Fig. 1 of the drawing, a dynamoelectric machine 10, which may, for example, drive a hoist, is supplied from a suitable source of substantially constant potential unidirectional current represented by supply lines 11 and 12. Line 12 is shown at ground potential, in order to simplify the drawing, and other devices in the control system which are connected to this supply line are shown in a similar manner. The dynamoelectric machine 10 is illustrated as a compound wound motor having an armature 10a, a series field winding 10b and a shunt field winding 10c.

A bridge type rectifier 13, composed of four unidirectional conducting devices, is connected in circuit with the armature 10a of motor 10. Series field winding 10b is connected to opposite constant polarity terminals of rectifier 13 in a manner such that the direction of the current through winding 10b remains unchanged, in spite of reversals of current through armature 10a, while the variable polarity terminals of the rectifier are connected in the armature circuit. The shunt field winding 10c of the motor is connected directly across the supply lines with a variable resistor 14 being provided for adjustment of the shunt field current. The machine 10 is provided with a shunt brake 15 having a brake wheel 15a directly coupled to the shaft of armature 10a and a magnetically operated shoe portion 15b. The operating coil 15c of the brake is connected to the supply lines through a contactor 17, which is provided for releasing the brake during operation of the motor, the brake being set during the time that the motor is not in operation.

The machine 10 may, for example, operate a hoist comprising a hoist drum 50 connected directly to the shaft of the machine, a rope 51 which is wound and unwound on the drum, a hoist hook 52, and a load 53 supported by the hook.

Suitable means are provided for controlling the direction of rotation of machine 10 to operate the hoist in either the hoisting or lowering direc-

tion. These means are illustrated as a multi-point reversing type controller 18 and four magnetic contactors 19, 20, 21 and 22, which are under the control of the master switch. The controller, or master switch 18, is provided with an off position and five positions each for hoisting and lowering, as indicated on the drawing, with a plurality of segments H1—H11 being provided on the hoist side of the master switch, and a plurality of segments L1—L11 on the lowering side of the master switch, to engage contact fingers 34—44, respectively, at selected positions of the master switch. Contactor 19 is the main power supply contactor for the armature of machine 10. Contactor 20 is the main hoisting contactor while contactors 21 and 22 may be designated as the lowering contactors.

The control system includes seven resistors R1—R7 inclusive, which serve in various combinations and capacities during hoisting and lowering to provide line, shunt, and armature resistances for the dynamoelectric machine. Also included in the control system is an overhoist limit switch 23, a magnetic relay 32, and an additional resistor R8, which cooperate to provide dynamic braking in the event that the hoist is raised beyond a predetermined limit.

In addition to the foregoing elements, the control system also includes four contactors 24—27 inclusive, associated with resistors R1—R5, a contactor 28 associated with resistor R6, and a dynamic braking contactor 31 which provides dynamic braking in the lowering direction.

With the foregoing understanding of the various elements of the control system, the operation of the system will be readily understood from the following detailed description. It should be noted that all elements of the control system are shown in Fig. 1 of the drawing in their inoperative positions. A control switch 33 is first closed to connect the motor and the other elements of the control system to line 11, which is illustrated as the positive side of the supply source. This energizes hoisting segments H1, H2, H3, H5 and H7 and lowering segments L1, L2, L4 and L6 of master switch 18, and the shunt field winding 13c of machine 10. It also energizes the coil of magnetic contactor 21 through a circuit which includes the lower auxiliary contacts of contactor 24 and finger 37 which is engaged by segment L4 in the off position of the master switch. Segment L6 likewise engages finger 39 on the off position, thereby energizing segments H8 to H11 inclusive, and L8 to L11 inclusive, of the master switch through the now closed center auxiliary contacts of contactor 21. In addition, the coils of contactors 25, 26 and 27 are energized in the off position; contactor 27 is energized directly from finger 40 which is in engagement with segment H7, contactor 26 is energized through a circuit including the now closed lower auxiliary contacts of contactor 27 and finger 41 which is engaged by segment 41, while contactor 25 is energized through a circuit including the lower auxiliary contacts of contactor 26 and finger 42 which is engaged by segment 42 on the off position of the master switch.

In order to begin operation of the dynamoelectric machine 10 as a motor in the hoisting direction, the master switch 18 is moved to position 1 hoist. This brings segment H1 into engagement with contact finger 34, which energizes the coil of contactor 17, causing the shunt brake to release, and also operates main power supply contactor 19, which energizes the armature of

the machine through a suitable amount of line resistance. The movement of the master switch to position 1 in the hoist direction also causes segment H2 to engage finger 35, which energizes the coil of contactor 31, thereby opening the center contacts and closing the upper and lower pairs of contacts. Segment H3 engages finger 36 in this position also, which energizes the coil of hoisting contactor 20 through the now closed upper contacts of contactor 31. Segment H5 likewise engages finger 38, which energizes hoisting segments H8, H9, H10 and H11 and lowering segments L8, L9, L10 and L11 through the now closed upper auxiliary contacts of contactor 20. These upper auxiliary contacts are located immediately below the coil of contactor 20. Segment H10, which is now energized through segment H5 instead of segment L6 as on the off position, engages finger 42 and energizes the coil of contactor 22, thereby providing a shunt resistance circuit for the motor through R6. The movement of the master switch to the first hoist position disengages segments L8 and L9 from fingers 41 and 42, respectively, thus deenergizing contactors 26 and 25; contactor 27 remains energized because segment H7 remains in engagement with finger 40. The armature 10a of the motor is now energized through a circuit which may be traced from supply line 11 through contactor 19, resistances R1—R4 inclusive, contactor 27, a conductor 45, rectifier 13 and series field winding 10b, thence through armature 10a of the motor and through the upper contacts of switch 23 and contactor 20 to the other supply line 12. The motor, therefore, rotates in the hoisting direction at a speed corresponding to the resistance values which are employed in this circuit and the load on the hoist.

To increase the speed of the motor, the master switch is moved to the second hoist position. This causes segment H11 to engage contact finger 44, which energizes contactor 24, thereby providing a shunt around resistances R1 and R2. This decreases the amount of line resistance in circuit with the motor and causes the speed of the motor to increase.

To increase the speed of the motor still further, the master switch 18 is moved to the third hoist position, at which point segment H10 is disengaged from contact 43, thereby deenergizing contactor 22 and opening the shunt resistance circuit through R6. The removal of the shunt resistance from the system causes a further increase in the speed of the motor.

When master switch 18 is moved to the fourth hoist position, segment H8 engages finger 41, which results in the energizing of contactor 26 through the closed lower auxiliary contacts of contactor 27. This shunts resistance R4, leaving only R3 as line resistance in circuit with the armature and thereby increasing the speed still further.

On the fifth and highest speed hoist position, segment H9 engages finger 42, which energizes contactor 25 through a circuit including the lower auxiliary contacts of contactor 26. This shunts resistance R3 and allows the dynamoelectric machine to operate as a motor directly across the line without line or shunt resistance.

In Fig. 2A on the accompanying drawing is shown a schematic diagram of the connections of the basic elements of the control system during hoisting operation, while in Fig. 2B there is shown a chart indicating the resistors which are connected in shunt and in the line on each of

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the five hoist positions just described. It should be understood that the dynamoelectric machine may be operated on any of the hoist positions, depending upon the size of the load and the speed desired.

If, while the apparatus is operating on any of the five hoist positions, the hoist should travel beyond a predetermined upper limit, a projection 52a on the hoist hook engages the pivoted operating member of limit switch 23. This opens the upper contacts of switch 23, which disconnects the armature of the machine from the line, and closes the lower contacts of switch 23. The latter establishes a low resistance dynamic braking circuit around the armature and series field of the machine through resistance R8 and, at the same time, energizes the coil of relay 32 and opens the contacts of this relay, thereby deenergizing contactor 17, which deenergizes the magnetic brake 15 and causes it to set. Thus, through the combination of two braking actions, the upward motion of the hoist is arrested quickly and without a momentary dropping back of the hoist, regardless of the position of the master switch. If the hoist should then start downward for any reason, the current through the armature 10a of the machine would be reversed, but the direction of current through series field winding 10b would remain the same, due to rectifier 13; therefore, dynamic braking action would be provided in the downward direction also through resistor R8, as an added protection. In order to lower the hoist out of engagement with the limit switch, it is necessary only to move controller, or master switch, 18 to one of the five lowering positions and the hoist moves downward at a speed corresponding with the setting of the master switch and load on the hoist. The manner in which this is accomplished will be understood from the following explanation of the operation of the apparatus in the lowering direction.

In order to cause the hoist to move in the lowering direction at the lowest speed, master switch 18 is moved through the off position to restore the connections previously described for this position, and then to position 1 lower. This brings segment L1 into engagement with contact finger 34, thereby energizing contactor 17, which releases the brake, and also energizing main power supply contactor 19. At the same time, segment L10 engages finger 43, which energizes contactor 22, in order to complete the circuit through the armature 10a to the negative side of the power supply to cause the dynamoelectric machine 10 to lower. This circuit may be traced from the main upper contacts of contactor 19 through resistor R1 and the center contacts of contactor 31, thence through the armature 10a, through rectifier 13 and the series field winding 10b, resistor R6 and contactor 22 to the negative side of the power supply. R1 and R6 thus serve as line resistances, as indicated in Fig. 3A, which shows schematically the connections for lowering. In addition, a shunt circuit is provided around the armature of the machine 10 in this position to provide for dynamic braking as well as speed control, and this shunt circuit may be traced from the junction of resistors R1 and R2 through the latter resistor and through the upper contacts of contactors 25, 26 and 27 and conductor 45.

To increase the lowering speed, the master switch is moved to the second lowering position, which results in segment L9 being disengaged

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from contact 42. This deenergizes contactor 25 through a circuit including the lower auxiliary contacts of contactor 26. Deenergizing contactor 25 opens the shunt around resistor R3, thereby inserting this resistor in series with resistor R2 in the shunt circuit around the machine armature, which increases the voltage across the machine and results in a speed increase. The line resistance remains the same on position 2 as on position 1.

On the third lowering position of the master switch, the line resistance again remains the same as on the two previous positions, but an additional resistance is inserted in the motor armature shunt circuit to cause a further speed increase by further increasing the voltage across the machine. This results from segment L8 being disengaged from contact 41, thereby deenergizing contactor 25 through a circuit including the auxiliary contacts of contactors 27. This opens the shunt around resistor R4 and places this resistor in series with resistors R2 and R3.

On the fourth lowering position, segment H7 is disengaged from finger 40, thereby deenergizing contactor 27, which opens the shunt around resistor R5 and inserts this resistor in the armature shunt circuit. At the same time, however, segment L11 engages contact finger 44, which energizes contactor 24 through the closed lower auxiliary contacts of contactor 19. The energizing of contactor 24 removes resistor R2 from the armature shunt circuit and places it in series with the armature 10a through a circuit which includes the center contacts of contactor 31. At the same time, resistor R1 is removed from the line; therefore, the dynamoelectric machine 10 is provided on this position with shunt resistance composed of resistors R3, R4 and R5, line resistance composed of resistor R6, and armature resistance composed of resistor R2.

The highest speed lowering position is number 5 on the master switch. In this position, segment L2 engages finger 35, thereby energizing contactor 31. This opens the direct circuit from resistance R2 to the armature 10a through contactor 31 and diverts the current through another circuit which includes resistor R7 and the upper contacts of contactor 21. At the same time, the closing of the lower contacts of contactor 31 results in the energizing of contactor 23, thus shunting resistor R6. Thus, on position 5, resistors R3, R4 and R5 remain in the armature shunt circuit and the line resistance is reduced to zero while the armature resistance is composed of R2 and R7. Fig. 3B of the drawing provides a chart showing the disposition of the various resistors for the off position and the five lowering positions.

Typical speed-torque curves for this control system are shown in Fig. 4 of the accompanying drawing. These curves are labeled to show the relationships of speed and torque output of the dynamoelectric machine for the various hoisting and lowering positions of the master switch. The curves for hoisting operation lie generally in the first quadrant, while the curves in the third quadrant are for light hook lowering and accelerating lowering, and those in the fourth quadrant are for lowering under overhauling torque conditions. It will be noted that all of the lowering curves provide for an approximately uniform speed, for a given controller position, regardless of the torque, in this typical case. However, these curves were chosen principally

for psychological reasons, and their slopes may be varied in accordance with this invention to give substantially any desired positive or negative slope. A positive slope is referred to herein as one which illustrates the speed varying directly with the torque, while with a negative slope the speed varies inversely with the torque. In conventional crane hoist control systems for operation from a constant potential source, the lowering speed for a given master switch position is inherently greater for larger torques and cannot be made otherwise, or, in other words, the slope of the characteristic curves is inherently positive. By the use of this invention, however, the slopes of the lowering curves can be changed, if desired, so that a larger torque results in a smaller lowering speed, or, in other words, to provide a negative, or drooping, speed-torque characteristic. As an example, if the value of armature resistance on point 5 lower is decreased by reducing the resistance values of R2 and R7, or by eliminating one or both of these resistors from the armature circuit, the curve for point 5 lower can readily be changed to that indicated by the dotted line in Fig. 4.

In the embodiment of the invention which is illustrated and described herein, the slopes of the lowering speed-torque curves were chosen so that an increased torque, due to a heavier load on the hoist, results generally in a slightly greater lowering speed. This was done because crane hoist operators are accustomed to the operating characteristics which are typified by such curves. By the use of this invention, however, it is possible to adjust the slopes of the lowering curves so that they are more nearly parallel to each other and to the horizontal axis in the fourth quadrant than is possible with conventional constant potential crane hoist control systems, thereby providing improved operating characteristics and, at the same time, having the resulting apparatus acceptable to operators who are accustomed to conventional crane hoist apparatus. To illustrate what is meant by the operating characteristics just discussed, the fifth and highest speed lowering curve may be followed from the left extremity in the third quadrant towards its right extremity in the fourth quadrant. As the lowering of a load is begun, the speed of the dynamoelectric machine running as a motor accelerates along curve 5 through the third quadrant until the vertical axis between the third and fourth quadrants is reached. Then, as the curve is followed into the fourth quadrant, the speed is reduced slightly at first, but thereafter increases again until a point, which may be at "X," for example, is reached where the regenerative torque of the machine acting as a generator equals the torque of the load, after which the lowering speed remains constant as long as the master switch remains on the fifth lowering position. If the slope of this curve is changed by reducing or eliminating the armature resistance as described above, the speed follows the dotted alternative curve until equilibrium is reached at point "X" on this curve. It will be noted in the latter case that the speed decreases as the torque increases, giving a negative slope to the curve.

An advantage of this invention is that it provides a light hook, or no load lowering speed which is substantially the same as the corresponding loaded lowering speed. This is illustrated by the line 55 in Fig. 4 which represents the amount of torque required to move the light hook downward. The intersection of line 55 with

each of the lowering curves therefore represents the amount of motoring torque which machine 10 must furnish to operate the light hook downward at each of the respective controller positions. It will be seen that the light hook lowering speed in each case, and particularly on the fifth position which is used most for light hook lowering, is approximately the same as the corresponding loaded lowering speed in the fourth quadrant. It is important to have the no load, or light hook lowering speed relatively high because in most hoist applications the apparatus operates under this condition for approximately one half of each cycle, and my invention fulfills this need. At the same time, however, it also is important to have stable and uniform no load lowering speeds, and my invention also provides these through use of a compound wound dynamoelectric machine. The use of a compound wound machine having a rectified series field means that the speed-torque curves are continuous from the third to the fourth quadrant, whereas if a series wound machine is used the curves are not continuous. With a series wound machine it is necessary to change either the armature or series field connections in order to go from the third to the fourth quadrant. Also, as is well known, the slope of the speed-torque curve of a series motor is very steep under light load conditions as it approaches the vertical axis, and, therefore, a slight change in torque causes a large change in speed. In the present system, however, the slope of the curve is moderate under corresponding light load conditions so that the light hook lowering speed may be accurately predetermined even though the torque varies from one operation to the next.

Another advantage of this invention is that it eliminates the critical torque limit point which is encountered on conventional crane hoist apparatus at a value of torque somewhat greater than that for point "X," beyond which point the machine becomes unstable and may run away. Due to the use of the rectified series field of this invention, there can be no such critical condition, because the currents in the armature and the series field winding are always the same and, therefore, cannot become unbalanced.

Another advantage of the invention is that it makes practical the use of a compound wound motor for crane hoist service. A series motor, when hoisting an empty hook on the highest speed hoisting position, may attain speeds that are excessive, but the shunt field winding of a compound wound motor prevents such an excessive speed, as is illustrated by the curve of Fig. 4 for the number 5 hoist position.

Another advantage of this invention is that it makes it possible to employ dynamic braking for a compound wound dynamoelectric machine as simply as it has heretofore been employed with a shunt wound machine, because the direction of the current through the series field is always the same, such that the resulting flux boosts the shunt field flux, regardless of the direction of the current through the armature.

It will be noted from Figs. 2A and 3A of the drawing that this control system may be considered as a potentiometer circuit. Looking at the armature and the series field winding with its rectifier as a unit, it can be seen that they serve as a part of a potentiometer circuit for accomplishing the requirements of a hoist control system, namely, to operate in either direction, to have a wide range of controlled speeds, and always to have a local dynamic braking circuit in

the lowering direction to remove the possibility of the power source becoming disconnected and allowing the motor to run away. In this connection, it will be noted from Fig. 1 that in the event of failure of the power supply during lowering, a dynamic braking circuit including one or more resistors is always formed immediately in series with the armature and the series field winding, regardless of the position of the controller. For example, on the fifth lowering position, resistors R7, R2, R3, R4 and R5 form a dynamic braking circuit immediately that contactor 19 is energized, and even though contactors 21 and 31 are subsequently deenergized, all the resistors except R7 remain in the circuit.

It will be readily understood by those skilled in the art that additional protective circuits or protective devices may be employed in this control system, if desired, without departing from the scope of the invention. As examples, plugging may be provided to provide more rapid braking in the event of an emergency, and accelerating relays may be provided to prevent the operator from accelerating the hoist too rapidly in either the hoisting or lowering direction. In addition, protective features such as the overhoist limit switch 23 and its associated devices may be eliminated from the circuit, if desired, without affecting the improved speed-torque relationships which are obtained by the use of this invention.

Among the protective features which may be incorporated in the system, if desired, is a novel circuit which is illustrated in Fig. 5 of the drawing. This circuit is useful particularly when connections are made to the armature and field windings of the dynamoelectric machine through individual trolleys where there is a possibility that one of the trolleys connecting the shunt field to the source of power may become disengaged, and it is desired to provide an alternate stand-by source of excitation for the shunt field. In analyzing Fig. 5, it should be assumed that all connections of the control system remain the same as in Fig. 1, with the addition of a second bridge type rectifier 56 and two resistors 57 and 58. The reversible potential terminals of the rectifier are permanently connected in shunt with the armature 10a and the series field winding 10b with its rectifier 13. Resistors 57 and 58 are connected in this circuit to limit the current, which flows through it continuously as long as the dynamoelectric machine 10 is energized. The constant polarity terminals of rectifier 56 are connected to the two terminals of shunt field winding 13c. During normal operation, the shunt field winding is supplied with current from supply line 11 through the variable resistor 14 in the same manner as described in connection with Fig. 1. If, for any reason, line 11 or the other supply line 12 should be disconnected from the shunt field, then the shunt field winding is supplied with current through rectifier 56 and this current is in the proper direction, regardless of the direction of current flow through dynamoelectric machine 10 at that time. Thus, means are provided to prevent a complete failure of the shunt field which would cause machine 10 to operate as a series wound machine.

Although in accordance with the provisions of the patent statutes this invention is described as embodied in concrete form and the principle is explained together with the best mode in which it is now contemplated applying that principle, it will be understood that the specific elements and connections shown and described are merely

illustrative and that the invention is not limited thereto, since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of the invention or from the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A hoist control system for a dynamoelectric machine having an armature and shunt and series field windings comprising, connections for separately energizing said shunt field winding, reversing means for selectively energizing said series field winding and said armature in series with each other whereby said machine operates respectively as a motor for hoisting and as a regenerator for lowering, rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, dynamic braking means, and means for connecting said dynamic braking means to supplement the regenerative braking provided during lowering operation.

2. A hoist control system for a direct current dynamoelectric machine having an armature and shunt and series field windings comprising, connections for separately energizing said shunt field winding, means for energizing said series field winding and said armature in series with each other with either polarity whereby said machine operates respectively as a motor for hoisting and as a generator for lowering, rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, a plurality of resistors, means operated by said series energizing means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of hoisting speeds, and means operated by said series energizing means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of lowering speeds.

3. A hoist control system for a self-excited direct current dynamoelectric machine having an armature and shunt and series field windings comprising, connections for separately energizing said shunt field winding, circuit means including a reversing controller for selectively energizing said series field winding and said armature in series with each other with either polarity whereby said machine operates respectively as a motor for hoisting and as a motor and generator for lowering dependent upon load requirements, a plurality of resistors, means operated by said controller means for selectively connecting selected ones of said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of hoisting speeds, means operated by said controller means for selectively connecting selected ones of said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of lowering speeds, and rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, whereby said lowering speeds are provided with speed-torque char-

acteristic curves having a selected sense and degree of slope.

4. A hoist control system for a direct current dynamoelectric machine having an armature and shunt and series field windings comprising, connections for separately energizing said shunt field winding at a substantially constant potential, reversing controller means having a plurality of positions for selectively energizing said series field winding and said armature in series with either polarity whereby said machine operates respectively as a motor for hoisting and as a motor and generator for lowering, a plurality of resistors, means operated by said controller means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of hoisting speeds, means operated by said controller means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of lowering speeds, and rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, the resulting rectified series field current producing excitation flux for said machine which cooperates with the flux produced by said shunt field winding to maintain the lowering speed on any selected controller position approximately uniform independently of the load on the hoist.

5. A hoist control system comprising a direct current dynamoelectric machine having an armature and shunt and series field windings, connections for separately energizing said shunt field winding at a substantially constant potential, means including a reversing controller for selectively energizing said armature and said series field winding in series at a substantially constant potential with either polarity, said controller having an off position and five positions each for hoisting and lowering, a bridge type rectifier having four legs each including a unidirectional conducting device forming two variable polarity terminals and two constant polarity terminals, said rectifier having its variable polarity terminals connected in circuit with said armature and its constant polarity terminals connected to said series field winding whereby the current through said series field winding remains unchanged in direction despite reversals of the current through the armature, seven resistors, means operated by said controller on the off position thereof for connecting the second resistor in shunt with said armature and said series field winding, means operated by said controller on the first hoist position thereof for connecting the sixth resistor in shunt with said armature and said series field winding and resistors 1-4 inclusive in circuit with said energizing means, means operated by said controller on the second hoist position for connecting the sixth resistor in shunt with said armature and said series field winding and for connecting resistors 3 and 4 in circuit with said energizing means, means operated by said controller on the third hoist position for connecting the third and fourth resistors in circuit with said energizing means, means operated by said controller on the fourth hoist position for connecting the third resistor in circuit with said energizing means, and means operated by said controller on the fifth hoist position for connecting said armature and said series field winding directly to

said energizing means without series or shunt resistance, means operated by said controller on the first lowering position for connecting the second resistor in shunt with said armature and said series field winding and for connecting the first and sixth resistors in circuit with said energizing means, means operated by said controller on the second lowering position for connecting the second and third resistors in shunt with said armature and said series field winding and for connecting the first and sixth resistors in circuit with said energizing means, means operated by said controller on the third lowering position for connecting the second, third and fourth resistors in shunt with said armature and said series field winding and the first and sixth resistors in circuit with said energizing means, means operated by said controller on the fourth lowering position for connecting the third, fourth and fifth resistors in shunt with said armature and said series field winding for connecting the sixth resistor in circuit with said energizing means and for connecting the second resistor in series with said armature and said series field winding, and means operated by said controller on the fifth lowering position for connecting the third, fourth and fifth resistors in shunt with said armature and said series field winding and the second and seventh resistors in series with said armature and said series field winding.

6. A hoist control system comprising a dynamoelectric machine having an armature and shunt and series field windings, connection means for separately energizing said shunt field winding, polarity reversing means for energizing said armature and said series field winding in series with each other with either polarity to provide for the operation of said machine as a motor for hoisting and as a regenerator for lowering, rectifier means connected in circuit with said series field winding whereby current flows through said series field winding in the same direction for both polarities of said energizing means, and means including a plurality of resistors connected in circuit with said dynamoelectric machine to provide said machine with speed-torque characteristic curves for lowering operation having a selected sense and degree of slope.

7. A control system comprising a direct current motor having an armature and shunt and series field windings, connections for separately energizing said shunt field winding, reversible polarity means for energizing said armature and said series field winding in series, rectifier means connected in circuit with said series field windings whereby current flows through said series field windings in the same direction for both polarities of said energizing means, limit switch means, a brake on said motor, and means responsive to said limit switch means for operating said brake and simultaneously disconnecting said armature and said series field winding from said energizing means.

8. A hoist control system comprising a compound wound direct current motor having an armature and shunt and series field windings, means for separately energizing said shunt field winding, means including a reversing controller for selectively energizing said series field winding and said armature in series with each other with either polarity, a bridge type rectifier having four legs each including a unidirectional conducting device, said rectifier having variable polarity terminals connected in circuit with said armature and constant potential terminals connected to said

series field winding whereby the current through said series field winding remains unchanged in direction despite reversals of current through the armature, limit switch means, dynamic braking means operated by said limit switch means, a brake on said motor, and means responsive to said limit switch means for disconnecting said armature and said series field winding from said energizing means and simultaneously operating said brake and said dynamic braking means.

9. A hoist control system comprising a direct current dynamoelectric machine having an armature and shunt and series field windings, connections for separately energizing said shunt field winding, means for selectively energizing said series field winding and said armature in series with each other with either polarity whereby said machine operates respectively as a motor for hoisting and as a motor and generator for lowering, rectifier means connected in circuit with said series field winding whereby the current through said series field winding remains unchanged in direction despite reversals of current through the armature, a plurality of resistors, means associated with said energizing means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of hoisting speeds, means associated with said energizing means for selectively connecting said resistors in series with said armature and said series field winding and in shunt therewith to provide a plurality of lowering speeds, an overhoist limit switch, a magnetically operated brake on said machine, a dynamic braking resistor, means operated by said overhoist limit switch for setting said brake and simultaneously disconnecting said armature and said series field winding from said energizing means and connecting them to said dynamic braking resistor, and means associated with said energizing means for connecting said machine for lowering operation at a selected one of said lowering speeds after the operation of said limit switch.

10. A control system comprising a direct current dynamoelectric machine having an armature and shunt and series field windings, connections for energizing said shunt field winding to provide the primary source of excitation thereof, means for selectively energizing said series field winding and said armature in series with each other to operate said machine selectively as a motor and as a generator, rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, and alternate means for the excitation of said shunt field winding including resistor means and second rectifier means in circuit with said shunt field winding connected in shunt with said armature and said series field winding.

11. A hoist control system comprising a self-excited compound wound direct current dynamoelectric machine having an armature and shunt and series field windings, means for selectively energizing said series field winding and said armature in series with each other with either polarity whereby said machine operates respectively as a

motor for hoisting and as a motor and generator for lowering, means for normally energizing said shunt field winding for separate excitation when said machine is operating as a motor, connections for normally energizing said shunt field winding from the machine itself when said machine is operating as a generator, rectifier means connected in circuit with said series field winding in a manner such that the current through said series field winding remains unchanged in direction despite reversals of current through the armature, second rectifier means, at least one resistor, and stand-by means for providing shunt field excitation in the event the said shunt field is disconnected from said normal energizing means including said second rectifier means and said resistor connected in circuit with said shunt field winding, said resistor and said second rectifier means being connected in shunt with said armature and said series field winding.

12. A hoist control system comprising a direct current dynamoelectric machine having an armature and shunt and series field windings, connections for separately energizing said shunt field winding to provide a primary source of excitation therefor, circuit means including a reversing controller for selectively energizing said series field winding and said armature in series with each other with either polarity whereby said machine operates respectively as a motor for hoisting and as a motor and generator for lowering, a first bridge type rectifier having four legs each including a unidirectional conducting device forming two reversible polarity terminals and two constant polarity terminals, said first rectifier having its reversible polarity terminals connected in circuit with said armature and its constant polarity terminals connected to said series field winding whereby the current through said series field winding remains unchanged in direction despite reversals of the current through the armature, a pair of resistors, a second bridge type rectifier having four legs each including a unidirectional conducting device forming two reversible polarity terminals and two constant polarity terminals, means for connecting said shunt field winding to the constant polarity terminals of said second rectifier, and means for connecting the reversible polarity terminals of said second rectifier through said resistors to said armature and said series field winding so that the circuit including said second rectifier and said shunt field winding is in shunt to said armature and said series field winding, whereby a continuously connected alternate source of excitation is provided for said shunt field winding in the event that said primary source becomes disconnected.

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