

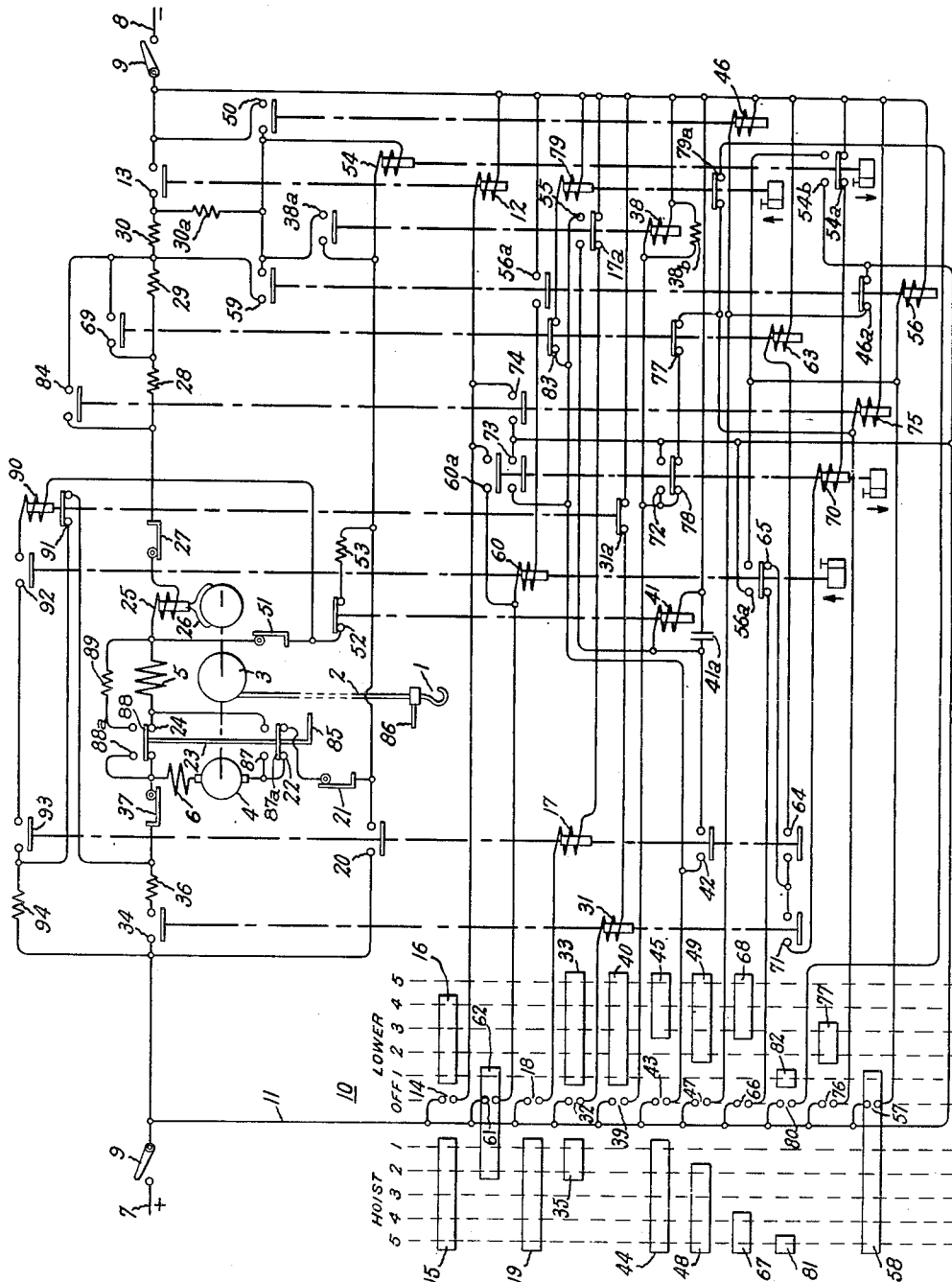
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CONTROL SYSTEM

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CONTROL SYSTEM

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Our invention relates to systems for controlling the operation of electric motors and has for an object the provision of a reliable and improved control system of this character.

More specifically, our invention relates to motor control systems for crane hoists and the like in which the hoist is driven by a series motor and in which a power type limit switch is provided for disconnecting the motor from the source when the hook arrives at the overhoist limit.

A further object of our invention is the provision of means for overcoming certain objectionable operating features which are encountered in control systems of this character.

In a large percentage of hoist cranes, the circuit established in lower position 1 of the master switch includes the series connection of the motor armature and a resistance connected in parallel with a unit comprising the motor field and a unit resistance connected in series with each other. As the master switch is turned to higher speed positions in the lowering direction, other units of resistance are added in series with the field. Circuits for the still higher speed lowering positions are formed by disconnecting the armature resistance from series connection with the armature and in some cases reconnecting it in another portion of the circuit.

The connecting and disconnecting of the armature resistance in series with the armature of the motor affects the speed-torque characteristics of the hoist so that the changes in speed with respect to torque in the lowering positions of the master switch do not occur at the same rate. For instance, in some hoist cranes at a particular torque load the speed in lower position 4 is greater than in lower position 5 so that when the operator shifts the controller to decrease the lowering speed of the load, he finds that the speed of the load is actually increased. This condition is manifestly disconcerting to the operator and may be very dangerous. Accordingly, another object of our invention is to cause circuits to be established in the lowering positions of the master switch in which the rate of speed change with respect to torque is substantially constant.

Most series motor crane control systems incorporate a shunting connection for the motor or the motor armature in one or more slow speed hoist positions of the master switch. Our invention incorporates a resistance connected to the source through contacts of a lowering contactor and in shunt with the motor armature to obtain stable speeds for light loads in these positions of the master switch.

To prevent the load from being raised too high due to defects in the controls or to carelessness of the crane operator, cranes in steel mill installations and the like which are required to lift

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such dangerous loads as ladles of molten metal are provided with overhoist limit switches to achieve the ultimate in safety.

Cranes having both the shunting circuit established through the contacts of the lowering contactor and having an overhoist limit switch are subject to "cycling" or "pumping" after the limit switch operates while the master switch is in one of its slow speed hoist positions. When the crane hook passes a predetermined position, the hoist contactor remains closed but its line is opened by contacts of the overhoist limit switch. Other contacts of the overhoist limit switch reverse connections of the series field from one terminal to the other of the motor armature while still other contacts of the overhoist limit switch connect a braking resistance in series with the armature and the series field of the motor to connect the motor as a series generator. When the overhoist limit switch operates, braking current flows between the motor and the braking resistance in a direction opposite to the hoist direction of flow, dynamically braking the motor to a stop.

When the motor stops, current flows through the lowering contactor which is still picked up causing the motor to reverse and drive down as a motor with the armature and field shunted by the braking resistance. With the hook load, the down speed is comparatively slow but with a heavy or overhauling load, the speed is fast. When the hook descends below the predetermined limit, the overhoist limit switch operates and the hoist again raises the load. This abrupt reversal of energization of the motor causes severe plugging action through the lowering and hoist contactors of the hoist and on heavy loads, the cables are jerked quite severely. Accordingly, a further object of our invention is to prevent this cycling by providing means for dropping out the lowering contactor when the overhoist limit switch operates.

In carrying our invention into effect, the circuit corresponding to the first lowering position of the master switch includes a series connection between the motor field and a resistance with the armature in shunt across the series connection. For successive lowering positions of the master switch, the value of this resistance is varied while the armature remains in shunt connection with this series connection in all of the lowering positions of the master switch to provide the desired characteristics of speed with respect to torque in the lower positions of the master switch.

The operating coil of an overhoist relay having normally closed releasing contacts is connected in series with the releasing contacts and across the series connection of the series field and normally closed contacts of the overhoist limit switch in the slow hoist positions of the

master switch. The relay is provided with normally closed contacts connected in the energizing circuit of the lowering contactor to drop out the lowering contactor when the overhoist limit switch operates. A holding resistance is connected between the coil of the overhoist relay and the power source to allow a value of current to pass through the coil that is greater than the dropout and lower than the pickup values of current of the relay.

For a better understanding of our invention, reference is made to the following specification and the accompanying drawing of one form of our invention as embodied in a control system for crane hoists and the like, the single figure of which is a simple diagrammatic sketch of the control system.

According to the drawing, the hook 1 of a crane hoist is connected to a cable 2 which is wound upon a drum 3 or unwound therefrom by a hoist motor 4. This hoist motor is illustrated as a series type direct current motor having a series field winding 5 and a commutating field winding 6. Motor 4 may be supplied from any suitable source such as supply lines 7 and 8 connected through energizing switch 9.

Motor 4 is controlled by a multi-position reversing type master switch 10 provided with pairs of conducting fingers and having five hoist positions, an off position and five lower positions. A conductor 11 connects one of each pair of fingers to supply line 7 through switch 9. In the various hoist and lower positions and the off position of switch 10, conducting segments connect selected pairs of conducting fingers.

Main line contactor 12 is energized in all hoist positions and lower positions 1, 2, 3 and 4 through fingers 14 and segments 15 and 16, respectively, closing normally open contacts 13 in its picked up position to connect the control to switch 9. The coil of contactor 12 is also connected to a pair of normally open contacts 60a and 74 to be explained later.

A hoist contactor 17 is energized in all the hoist positions through fingers 18 and segment 19, closing normally open contacts 20 in its picked up position to connect switch 9 through a trolley 21 and normally closed power contacts 22 of an overhoist limit switch 23 to the armature of motor 4. In hoist position 1, connection is made from line 7 through one pole of switch 9, contacts 20, trolley 21, contacts 22 of switch 23, the armature and commutating field winding 6 of motor 4, normally closed field contacts 24 of limit switch 23, series field winding 5 of motor 4, the operating coil 25 of a spring biased solenoid brake 26, a trolley 27, line resistances 28, 29 and 30, normally open contacts 13 (in the closed position thereof) and through the other pole of switch 9 to line 8. Normally closed contacts 17a in the line of contactor 17 will be described later.

A lowering contactor 31 is connected through fingers 32 and conductor 11 and through normally closed energizing contacts 31a to switch 9. Segment 33 connects fingers 32 in all the lower positions of switch 10 so that contactor 31 is picked up in those positions closing normally open contacts 34 to complete connections from supply conductor 7 to the motor armature for rotation of motor 4 in the lowering direction. Contactor 31 is also picked up through segment 35, closing contacts 34 in hoist positions 1 and 2. Contacts 34 close to connect line 7 through switch 9, a lowering resistance 36 and trolley

37 to the armature of motor 4. Contacts 34 are closed in hoist positions 1 and 2 to complete a connection from the armature through trolley 37, resistance 36, contacts 20, trolley 21 and contacts 22 to the armature to connect resistance 36 in shunt with the armature to obtain good speed regulation when a light load is applied to hook 1 in those hoist positions.

A dynamic braking contactor 38 is energized in all the lowering positions through fingers 39 and segment 40 to close normally open contacts 38a and to open normally closed contacts 17a in its picked up position. A resistance 38b in shunt connection with the coil of contactor 38 delays the coil from dropping out.

A second dynamic braking contactor 41 is connected through normally open contacts 42 of contactor 17 to fingers 43 to be energized in all the hoist positions through segment 44 and in lower positions 3, 4, and 5 through segment 45. The capacitor 41a in parallel connection with the coil of contactor 41 provides a discharge path for the heavy current from coil 41. Other connections of contactor 41 will be described later.

Accelerating contactor 46 is energized through fingers 47 and segment 48 to be picked up in hoist positions 2, 3, 4 and 5 and through segments 49 in lower positions 2, 3, 4 and 5 to close normally open contacts 50. Contactor 46 is also connected to conductor 11 through a pair of normally closed contacts 46a of contactor 56 to be described later.

Series field winding 5 is connected through a trolley 51, normally closed contacts 52 of contactor 41, a resistance 53, the coil of a plugging relay 54, normally open contacts 50 and switch 9 to line 8. Switch 9, contacts 50 and contacts 38a of contactor 38 are connected in series between line 8 and resistance 53 to provide dynamic braking in the lowering positions. With hoist contactor 17 dropped out in off positions and in lowering positions contacts 20 are open and motor 5 becomes a generator resisting the torque of an overhauling load.

The coil of the second dynamic braking contactor 41 is also connected through normally open contacts 55 of contactor 38 and through fingers 43 to be energized through segments 44 and 45 and also through a pair of normally open contacts 73 and 74, to be described later, and fingers 14 to be energized through segments 15 and 16.

Contacts 52 operated by the second dynamic braking contactor 41 remain closed in the off position of switch 10 to apply dynamic braking from any lower position to off position, and to close in lower positions 1 and 2 to assist contactor 38 by reducing the braking resistance to increase the braking torque for the slower lower positions. Normally closed contacts 52 also insure dynamic braking from any lower position upon failure of power from the supply lines.

A field weakening contactor 56 is energized in off position, all the hoist positions and lower position 1 of switch 10 through fingers 57 and segment 58. The coil of contactor 56 is also connected to conductor 11 through normally open contacts 54b of plugging relay 54. Contactor 56 picks up to open normally closed contacts 46a to close normally open contacts 56a and to close normally open contacts 59 which are connected to a point between resistances 29 and 30 and in series connection with contacts 50 to switch 9. Since contacts 50 are closed in hoist positions 2, 3, 4 and 5, by contactor 46, resistance 30 is shorted from the circuit of motor 4 in these positions.

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In lower position 5, contacts 13 open to connect resistance 30a in the circuit of motor 4 to provide minimum field current for maximum speed lowering since contacts 59 are closed and contacts 58 are open in that position.

An accelerating time delay relay 60 is connected to be energized through fingers 61, segment 62 and normally open contacts 60a of contactor 56. In hoist positions 1 and 2, off position and lower position 1, segment 62 connects fingers 61 to complete an energizing circuit to pick up relay 60. Relay 60 is also connected to be energized through normally open contacts 60a to be described later, fingers 14 and segments 15 and 16.

The operating coil of an accelerating contactor 63 is connected through normally open contacts 64 of contactor 17, normally closed contacts 65 of relay 60 and fingers 66 to be energized through segments 67 in hoist positions 4 and 5 and through segment 68 in lower positions 3, 4 and 5. Contactor 63 is picked up in hoist positions 4 and 5 and lower positions 3, 4 and 5 opening normally closed contacts 77 and 83 to be described later and closing normally open contacts 69 to short circuit accelerating resistance 29 in those positions.

The operating coil of a decelerating time delay relay 70 is connected through normally closed contacts 71a of relay 54, normally open contacts 71 of contactor 31, normally closed contacts 65 of relay 60 and fingers 66 to be energized through segment 67 in hoist positions 4 and 5 and through segment 68 in lower positions 3, 4 and 5. Relay 70 operates as a time delay drop out when master switch 10 is suddenly thrown from lower speeds 3, 4, or 5 to off position. The coil of contactor 38 is also connected through normally open contacts 72 and normally open contacts 73 of relay 70 to fingers 43. The coil is also connected through contacts 72 and normally open contacts 74 of an accelerating contactor 75 through fingers 14 to be energized through segments 15 and 16.

Contacts 74 are operated by contactor 75, the operating coil of which is connected to be energized in lower positions 2 and 3 through fingers 76 and segment 77 and is connected to be energized in hoist position 5 and lower position 1 through normally closed contacts 79a of an accelerating relay 79, fingers 80 and segments 81 and 82, respectively.

Contactor 75 picks up in hoist position 5 closing normally open contacts 74 and normally open contacts 84 shunting resistances 28 and 29 from the circuit of motor 4 to provide full speed hoist. Contactor 75 also picks up in lower positions 1, 2 and 3 closing contact 84.

In all operating positions except lower position 5, contactor 12 is picked up, closing contacts 13. In the lower positions, lowering contactor 31 is energized closing contacts 34, contactor 41 is dropped out in lower positions 1 and 2 closing contacts 52 and contactor 56 is closed in lower position 1 closing contacts 59. To sum up the connections of motor 4 in the lower positions, the armature of motor 4 in lower position 1, therefore, is in shunt connection with field winding 5 and resistances 30 and 30A are connected in parallel between motor 4 and switch 9.

In lower positions 2, 3, 4 and 5, contactor 56 is dropped out. The circuit of lower position 2 is the same as for lower position 1 except that resistance 30 is connected between motor 4 and switch 9.

When switch 10 is thrown from any lower

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position to off position, contactor 12 drops out opening contacts 13 and contactor 41 drops out closing contacts 52 to apply dynamic braking in which current from motor 4 flows through contacts 24, field winding 5, trolley 51, contacts 52, resistance 33, a connection between resistance 33 and trolley 21, trolley 21 and contacts 22 to the armature of motor 4. An overhauling load drives the motor generating a current in the armature in the hoist direction of flow which brakes the hoist. Since contactor 41 is normally closed, dynamic braking is assured upon failure of supply power in any lowering position.

Contactor 41 is picked up in lower positions 3, 4 and 5 to open contacts 52 and contactor 75 is picked up in lower positions 2 and 3 to close contacts 84. In lower position 3, therefore, the armature of motor 4 is in shunt connection with a series connection between field winding 5 and resistance 30.

Contactor 75 is dropped out in lower positions 4 and 5. In lower position 4, the armature of motor 4 is in shunt connection with a series connection between field winding 5 and resistances 28, 29 and 30.

As stated above, contactor 12 drops out in lower position 5 and as contactor 46 is energized in this position, the armature of motor 4 is in shunt connection with the connection of field winding 5 in series with line resistances 28, 29, 30 and 30a.

Relay 70 is provided with a time delay feature to remain energized after switch 10 is turned to off position to allow considerable dynamic braking to the hoist before solenoid brake 26 sets, thus preventing excessive wear on the linings of brake 26.

The operating coil of relay 70 is connected through normally closed contacts 83 of contactor 63 to fingers 43 to be energized through segments 44 and 45 and is also connected through normally open contacts 73 and 74 to fingers 14 to be energized through segments 15 and 16. Relay 70 is a time delay accelerating relay for contactor 75 in hoist position 5 and is a time delay decelerating relay when master switch 10 is suddenly thrown from high speed lower positions to lowering position 1.

Accelerating relay 60 is a time delay relay for contactor 63 in hoist positions and operates as an accelerating relay in lowering when master switch 10 is thrown from an off position to lowering positions 2, 3, 4 or 5, by allowing field weakening contactor 56 to remain picked up, thus affording series brake 26 time to release and motor 4 time to accelerate.

Plugging relay 54 performs a function in lower positions similar to that of relay 60 in hoist positions except for being closed in the higher hoisting speeds to be available for accelerating contactor 75 and for plugging in these points. Relay 54 also provides a longer timing period in plugging to insure release of brake 26.

In hoist positions 1 and 2, current is supplied to the armature through the shunt circuit including resistance 36 described above. When hook 1 passes its upper limit, the following means are provided to disconnect power from the armature of motor 4 and to disconnect the power supply from the shunt circuit.

As stated above, normally closed contacts 24 of limit switch 23 are connected between series field 5 and one terminal of the armature of motor 4. Contacts 24 and contacts 22 are closed in the hoist positions of master switch 10 to provide series motor operation of motor 4. Limit

switch 23 is provided with an arm 85 and hook 1 is provided with a projection 86. Normally open contacts 87 are connected between series field 5 and the other terminal of armature 4. As hook 1 passes a predetermined upper limit position, projection 86 engages arm 85. A movable contact 87a of switch 23 opens contacts 22 and closes contacts 87 and a second movable contact 88 of switch 23 opens contacts 24 and closes normally open contacts 88a to disconnect power from the armature of motor 4 and to connect a braking resistance 89 in series with the armature and field 5 of motor 4.

As hook 1 continues to move upward driving motor 4, braking current flows from motor 4 through contacts 87, series field 5, resistance 89, contacts 88a and back to motor 4 as motor 4 brakes to a stop as a series generator.

The coil of an overhoist limit relay 90, which operates normally closed contacts 31a and normally closed releasing contacts 91, is connected through normally open contacts 92 of relay 60, normally open contacts 93 of relay 17 and contacts 91 to one end of the armature of motor 4 and in shunt with series field 5 in hoist positions 1 and 2. Releasing contacts 91 will be described later.

In off position of master switch 10, relay 90 is deenergized since hoisting contactor 17 and line contactor 12 are deenergized. In hoist positions 1 and 2, relay 90 is energized only by the voltage drop across field 5 which under maximum conditions does not exceed 7% of line voltage. Operation of overhoist limit switch 23 opens contacts 24 and closes contacts 87 and 87a. Relay 90 is then connected across the armature and field 5 of motor 4 in series and is energized by the drop in voltage across the armature and field which is a minimum of 14.5% of line voltage. Relay 90 is designed to pick up at a value of voltage just below the value of voltage drop through the armature and field, such as at 14% line voltage.

When relay 90 is picked up, contacts 31a open, dropping out lowering contactor 31 to open contacts 34 and to discontinue the flow of current through resistance 36 and the brake coil allowing brake 26 to set.

When motor 4 is stopped by dynamic braking action with master switch 10 in hoist positions 1 or 2, voltage across the armature and the field reduces to zero. Relay 90 is provided with contacts 91 in series with its solenoid to act in conjunction with a holding resistance 94 connected in series with contacts 93 and 92 between the coil of relay 90 and switch 9 to retain relay 90 in picked up position. Hence, lowering contactor 31 is retained in dropped out position and the "cycling" described above cannot occur.

Resistance 94 is provided with a value of resistance to allow a current to pass therethrough to the operating coil of relay 90 between the pickup and dropout values of relay 90. Relay 90 is designed to pick up after switch 23 trips and the operating coil is in shunt connection with the armature and series field winding 5 of motor 4 in series, which includes 14.5% of the total resistance of the circuit in hoist position. On a 260 volt line, the maximum drop across the coil of relay 90 is about 17.5 volts in normal operating including plugging acceleration or running at any speed or load. When the power limit switch trips in hoist position 1 or 2 the minimum voltage drop across the coil is 39 volts and may be considerably more such as with overhauling loads. With an overhaul voltage differential of 17.5 to 39 volts,

a reasonably safe pickup value of the coil of relay 90 is 35 volts.

To resume operation of the hoist after relay 90 has been energized, switch 10 is thrown to a lower position dropping out hoist contactor 17 to open contacts 93 in order to drop out relay 90, which allows contacts 31a to close. With contacts 31a closed, contactor 31 is picked up closing contacts 34 so that motor 4 can be operated in lower direction.

While a particular embodiment of this invention is illustrated and described, modifications thereof will occur to those skilled in the art. I desire it to be understood, therefore, that this invention is not to be limited to the particular arrangement disclosed and I intend in the appended claims to cover all such modifications which do not depart from the spirit and scope of this application.

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

1. In combination, an electric hoist motor having an armature and a series field winding, a multi-position reversing type master switch for controlling the operation of said motor and for completing connections between said motor and a source of supply, hoisting and lowering contactors controlled by said master switch, a shunt resistance connected in series connection with said lowering contactor to provide a circuit in shunt with said armature for stable operation of said motor in slow hoist positions of said master switch, a brake for said motor having an operating coil in series with said motor, a dynamic brake resistance, an overhoist limit switch having contacts connecting said armature and said source and connecting said series field to one terminal of said armature to operate said motor as a series motor in hoist positions of said master switch, said limit switch being responsive to operation of said motor beyond a predetermined limit to disconnect said armature from said source and to connect said brake resistance, said armature and said field winding in series and with said field winding connected to the opposite terminal of said armature to effect operation of said motor as a series generator, a limit relay having normally closed releasing contacts and normally closed contacts connected in the energizing circuit of said lowering contactor, said relay having a solenoid connected through said releasing contacts to one end of said armature and connected in shunt connection with said field winding in said slow hoist positions to be energized by current through said field, said relay being picked up responsive to drop in voltage across said armature and said field upon operation of said limit switch to interrupt said shunting connection thereby to effect the setting of said solenoid brake and a source for limiting the current in said solenoid to a value between the pickup and dropout current values of said relay to retain said relay in picked up position in said slow speed hoist positions.

2. A control system for hoists and the like having an electric hoist motor provided with an armature and a series field winding and a reversing type master switch for the control of said motor having high and slow speed hoist and lower positions and for completing connections between said motor and a source of supply, comprising in combination a solenoid brake having the solenoid thereof connected in series with said motor, means operable in the slowest of said lower positions for connecting a field resistance in series connection with said field winding and said ar-

mature in shunt connection with said series connection and for connecting a line resistance in series with said motor, said means being operable in the next faster of said lowering positions for disconnecting said line resistance and for increasing said field resistance and operable in the succeeding faster lowering positions for successively increasing said field resistance whereby said armature is maintained in shunt connection with the series connection between said field winding and said field resistance in all said lower positions, hoisting and lowering contactors controlled by said master switch, a shunt resistance connected in series connection with said lowering contactor between said armature and said source, said contactors and said shunt resistance being connected to provide a shunting connection with said armature in slow hoist positions of said master switch for stable operation of said hoist at light loads, a dynamic braking resistance, an overhoist limit switch having power contacts for connecting and disconnecting said armature and said source and normally closed field contacts for connecting said field to one terminal of said armature in said hoist positions to cause said motor to operate as a series motor, said limit switch being provided with normally open field contacts for connecting said series field winding to the opposite terminal of said armature and normally open braking contacts for connecting said braking resistance in series with said armature and said field winding to cause said motor to act as a generator to brake said hoist responsive to operation of said hoist beyond a predetermined limit, an overhoist relay having normally closed releasing contacts and normally closed energizing contacts connected in the energizing circuit of said lowering contactor, said relay being provided with a solenoid connected through said releasing contacts to said one terminal and in shunt connection with said series field winding in said low speed hoist positions, whereby when said master switch operates said solenoid is shunt connected across said armature and said series field to pick up said overhoist relay responsive to voltage drop across said armature and said field winding, thereby to drop out said lowering contactor to allow said solenoid brake to set and a holding resistance connected between said solenoid and said source for limiting the current in said solenoid to a value between the pickup and dropout current values of said relay to retain said relay in picked up position when said limit switch operates in said slow speed hoist positions.

3. A control system for hoists and the like having an electric hoist motor provided with an armature and a series field and a reversing type master switch for the control of said motor having high and slow speed hoist and lower positions, comprising in combination a solenoid brake having the solenoid thereof connected in series connection with said motor, means operable in the slowest of said lower positions for connecting a field resistance in series connection with said field winding and the armature of said motor in shunt with said series connection and for connecting a line resistance in series with said

motor, said means being operable in the next faster of said lowering positions for disconnecting said line resistance and increasing said field resistance and operable in the succeeding faster lowering positions of said master switch for successively increasing said field resistance, whereby said armature is maintained in shunt connection with the series connection of said field winding and said field resistance in said lower positions to maintain a substantially constant rate of change of speed with respect to load torque in said lower positions, hoisting and lowering contactors controlled by said master switch, a shunt resistance connected in series connection with said lowering contactor between said armature and said source, said contactors and said shunt resistance being connected to provide a shunting connection with said armature in slow hoist positions of said master switch for stable operation of said hoist at light loads, a dynamic braking resistance, an overhoist limit switch having normally closed power contacts connected between said armature and said source and normally closed contacts connected between one terminal of said armature and said field winding whereby said motor operates as a series motor in said hoist positions, said limit switch having normally open field contacts connected between said field winding and the opposite terminal of said armature and normally open braking contacts in series connection with said dynamic braking resistance, said braking series connection being connected to said one terminal and being shunt connected around said field winding whereby when said switch operates said contactors responsive to operation of said hoist beyond a predetermined position, said power supply is disconnected from said armature and said dynamic braking resistance is connected in series connection with said armature and said field to cause said motor to operate as a generator to brake said hoist, an overhoist relay having normally closed releasing contacts and normally closed energizing contacts connected in the energizing circuit of said lowering contactor, said relay being provided with a solenoid connected through said releasing contacts to said one terminal and in shunt connection with said field winding in said slow speed positions to be energized by current through said field, said solenoid being connected across said armature and said field winding when said limit switch operates to be picked up responsive to flow of current through said field and said armature to drop out said lowering contactor and allow said brake to set and a holding resistance connected between said solenoid and said source for limiting the current in said solenoid to a value between the pickup and dropout current values of said overhoist relay, thereby to retain said relay in picked up position when said master switch is in said slow speed hoist positions.

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No references cited.