

Jan. 29, 1952

W. H. ELLIOT

2,583,731

HOIST CONTROLLER

Filed June 21, 1945

2 SHEETS—SHEET 1

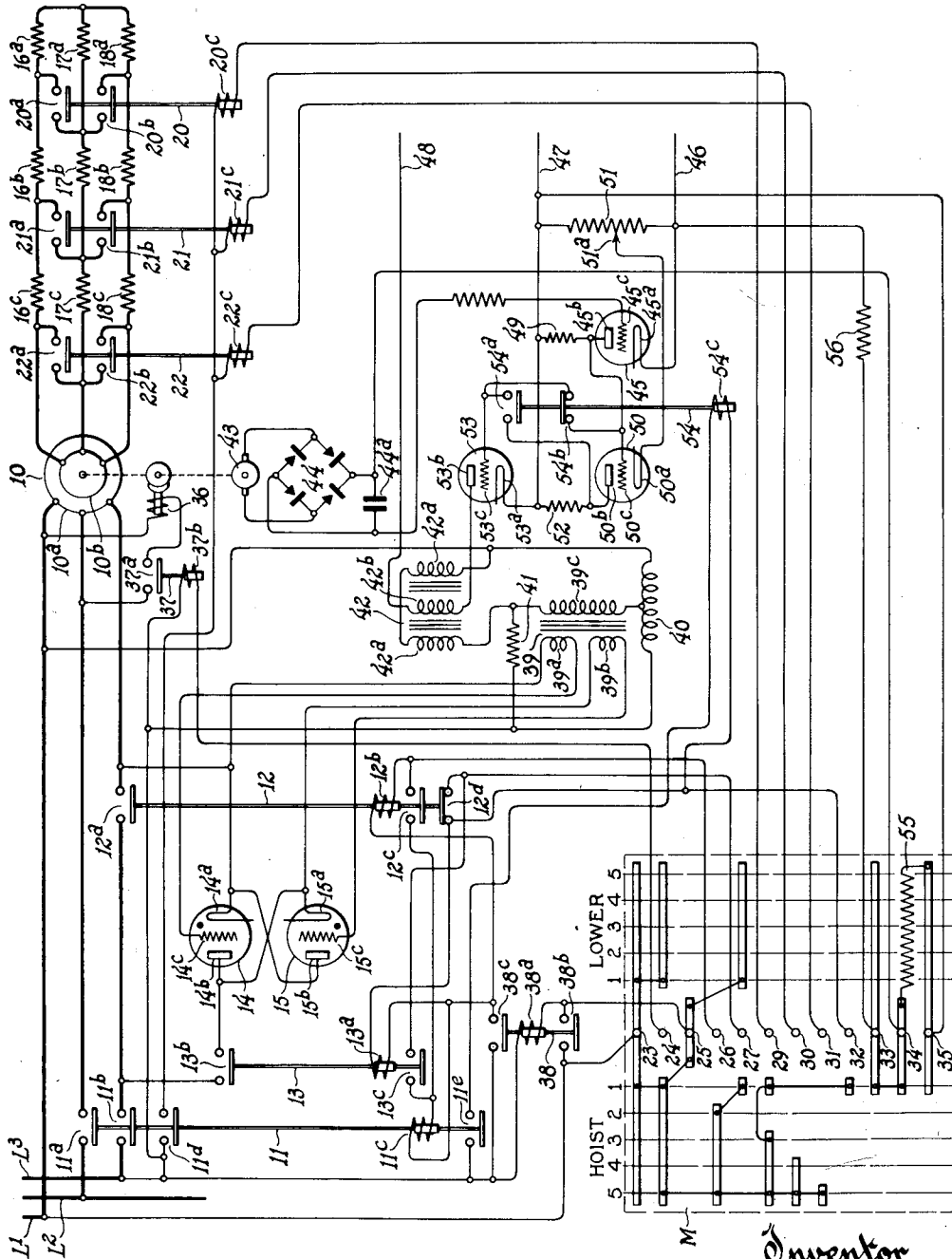


Fig. 1

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2 SHEETS—SHEET 2

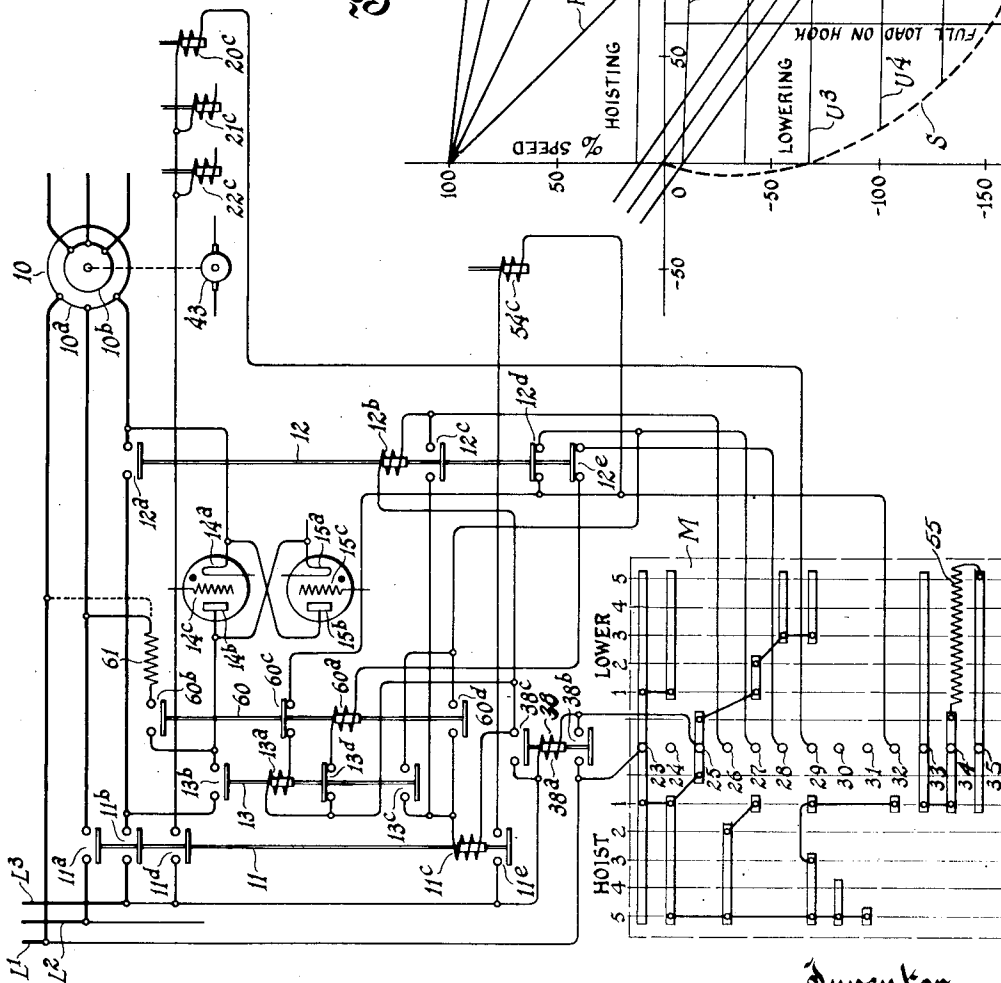
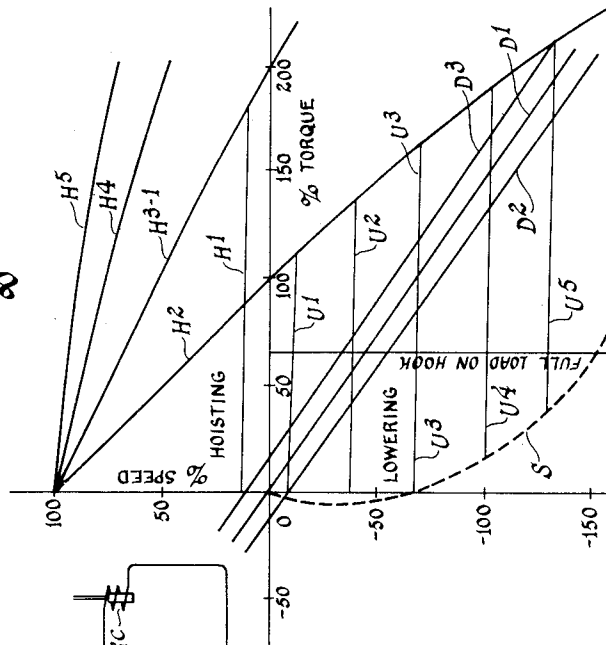


Fig. 3



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UNITED STATES PATENT OFFICE

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HOIST CONTROLLER

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The invention relates to the speed control of motors and while not limited thereto is particularly adapted to the control of induction motors operating hoists which are required to operate over a relatively wide range of loads and speeds and where it is desired to maintain certain speeds constant for widely varying positive and/or negative motor loads.

In carrying out the invention gaseous discharge devices are connected in various relations to the primary motor winding and their conductivity is controlled in response to the tendencies of the speed of the motor to vary while the operating speed may be manually adjusted.

An object of the invention is to provide an alternating current hoist controller affording a plurality of constant lowering and/or hoisting speeds.

Another object is to provide a controller of the aforementioned type which affords lowering of an overhauling load, while limiting the speed of lowering.

Another object is to provide a controller affording a low constant speed for hoisting a light load, while alternatively affording hoisting of any load within the capacity of the hoist motor.

Another object is to provide a controller affording adjustment of the stalled torque of a motor.

Another object is to provide a controller affording continuous or stepless variation of the lowering speed.

Other objects and advantages will be hereinafter explained.

In the accompanying drawings,

Figure 1 is a diagram of a hoist controller embodying the invention.

Fig. 2 is a modification of the system illustrated in Fig. 1 and

Fig. 3 is a diagram illustrative of the speed-torque characteristics of the systems, Figs. 1 and 2.

Referring to Fig. 1, the same illustrates an induction motor 10, having a three phase primary winding 10^a and a three phase second winding 10^b. The primary winding may be supplied with electric energy from the lines L¹, L², L³ of a three phase supply source. One terminal of the primary winding is directly connected to the line L¹. A second terminal is connectible to the line L², through normally open main contacts 11^a of an electromagnetic main switch 11, while the third terminal of the primary winding 10^a is connectible to the line L³ through normally open main contacts 11^b of said electromagnetic switch 11, said contacts 11^b being in series with normally

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open main contacts 12^a of an electromagnetic switch 12. The electromagnetic switch 11 is further provided with an energizing winding 11^c and normally open auxiliary contacts 11^d and 11^e.

The electromagnetic switch 12 is further provided with an energizing winding 12^b, normally open auxiliary contacts 12^c and normally closed auxiliary contacts 12^d. The system also includes an electromagnetic switch 13 having an energizing winding 13^a, normally open main contacts 13^b and normally open auxiliary contacts 13^c. A pair of electron tubes 14 and 15 are connected in inverse-parallel with each other and in series with the contacts 13^b to parallel the contacts 12^a.

The electron tubes 14 and 15 are provided with cathodes 14^a and 15^a, respectively, anodes 14^b and 15^b, respectively, and control electrodes 14^c and 15^c, respectively. Connected to the terminals of the three phase secondary winding 10^b are secondary resistors 16, 17 and 18, respectively. These resistors are divided into three series connected sections 16^a, 16^b and 16^c; 17^a, 17^b and 17^c; 18^a, 18^b and 18^c, respectively. The end terminals of the resistors 16^a, 17^a and 18^a are joined to form a star connection. The resistors 16^a, 17^a and 18^a may be short circuited by normally open contacts 20^a and 20^b of an electromagnetic switch 20, which is provided with an energizing winding 20^c. Similarly the sections 16^b, 17^b and 18^b may be short circuited by the contacts 21^a and 21^b of an electromagnetic switch 21, having an energizing winding 21^c and the sections 16^c, 17^c and 18^c may be short circuited by normally open contacts 22^a, 22^b of an electromagnetic switch 22 which has an energizing winding 22^c. Upon closure of the contacts 22^a and 22^b the secondary winding 10^b is short circuited as is apparent from the diagram. One terminal each of the windings 20^c, 21^c and 22^c is connected through contacts 11^d to bus bar L³.

The system also includes a drum type master controller M of any suitable type of construction having stationary contacts 23 to 27, inclusive, and 29 to 35, inclusive, which are adapted to make contact with movable contact segments arranged on a rotating cylinder of the master controller, as will be explained hereinafter.

The motor is provided with an electromagnetic brake of any suitable type having an energizing winding 36, one terminal of which is connected to the line L¹ while the second terminal is connected through normally open contacts 37^a of an electromagnetic relay 37 and the contact 11^a to the bus L². The relay 37 is provided with an energizing winding 37^b, one terminal of which is

connected to bus L^3 while the second terminal is connected to the contact 24 of the master drum. A low voltage relay 38 has an energizing winding 38^a, one terminal of which is connected to the bus L^3 , while the second terminal is connected to the contact 25 of the master drum. The relay 38 is also provided with normally open contacts 38^b and 38^c. One terminal of the contacts 38^b is connected to the bus L^1 and also to the stationary contact 23, while the other terminal is connected to the contact 25. The normally open contacts 38^c have one terminal connected to the bus L^3 , while the other terminal is connected to one terminal each of the windings 11^c, 12^b and 13^a. The second terminal of the winding 13^a is connected to the contact 32 of the master drum and also through the contacts 12^d to drum contact 27. The second terminal of winding 12^b is connected to the drum contact 26. The second terminal of the winding 11^c is connected through contacts 13^c to drum contact 27 and alternatively through contacts 12^c to contact 26.

To control the grid potential of the tubes 14 and 15, respectively, secondary windings 39^a and 39^b of a transformer 39 having a primary winding 39^c are connected between the respective cathodes and control electrodes of said tubes 14 and 15. One terminal of winding 39^c is connected to the center tap of an inductance 40 connected across lines L_1 and L_2 . Connected between the other terminal of the winding 39^c and one end terminal of the inductance 40 is a resistor 41, while connected between the last mentioned terminal of winding 39^c and the other end terminal of the inductance 40 are the secondary windings 42^a of a saturable reactor 42 which is provided with a saturating winding 42^b. Thus, the inductance 40, the winding 39^c, the resistor 41 and the windings 42^a of the saturable reactor 42 form a phase shifting network for adjusting the phase of the potentials impressed upon the control electrodes 14^c and 15^c by the windings 39^a and 39^b.

The energization of the winding 42^b is controllable in accordance with the speed of the motor armature by the apparatus which will now be described. Coupled to the shaft of the armature 10^b is an alternating current tachometer generator 43, which supplies alternating current energy to a full wave rectifier 44 of any suitable type. One of the direct current terminals of said rectifier is connected to the contact 34 of the master controller. The other direct current terminal is connected to the control electrode 45^c of an electron tube 45, which is also provided with a cathode 45^a and an anode 45^b. A smoothing condenser 44^a may be connected across the direct current terminals of the rectifier. The cathode 45^a is connected to the zero potential bus bar 46 of a direct current power supply which is also provided with bus bars 47 and 48 having potentials positive with respect to the potential of the bus bar 46, the potential of the bus bar 48 being of the order of twice the potential of the bus bar 47. The anode of the tube 45 is connected through a resistor 49 to the bus bar 47, and is also connected to the control electrode 50^c of an electron tube 50, which is also provided with a cathode 50^a and an anode 50^b. The cathode 50^a is connected to the movable contact 51^a of a voltage divider 51 connected across the bus bars 46 and 47. The anode 50^b is connected to the bus bar 47, through a resistor 52. Also connected to the bus bar 47 is the cathode 53^a of an electron tube 53 which is also provided with an anode 53^b

and a control electrode 53^c. The anode 53^b is connected through the winding 42^b to the bus bar 48. Normally open contacts 54^a of an electromagnetic relay 54 are interposed between the anode 50^b and the control electrode 53^c and normally closed contacts 54^b of said relay 54, are interposed between the control electrode 53^c and the anode 45^b. The relay 54 is provided with an energizing winding 54^c, one terminal of which is connectable through the contacts 11^c to the line L^3 , while the second terminal is connected to the contact 32 of the master controller and also to one terminal of the winding 13^a and one terminal of contacts 12^d. The other terminal of contacts 12^d is connected to one terminal of contacts 13^c and to contact 27. The bus bar 47 is connected to drum contact 35. A variable resistor 55 is connected between the segments associated with drum contacts 34 and 35 in such a manner that upon rotation of the master controller the contact 34 makes circuit with different parts of said resistor. The bus bar 48 is connected through a resistor 56 to drum contact 33. The resistors 55 and 56 form a voltage divider across the bus bars 46 and 47 for controlling the potential impressed upon the control electrode 45^c as will be explained hereinafter.

All of the segments which cooperate with the stationary contacts 23 to 27, inclusive, and 29 to 32, inclusive, of the master controller are connected together, while the segments which cooperate with the stationary contacts 33, 34 and 35 are separately mounted and insulated from the former segments. Furthermore, the segment cooperating with the contact 33 is directly connected to the segment cooperating with the contact 34, while, as aforesaid, the segments cooperating with the contacts 34 and 35 are connected together through the resistor 55. The master controller may be provided with a conventional starwheel to locate the drum in the hoisting positions 1 to 5, inclusive, the center position and the first lowering position. For stepless control of lowering, the controller may, however, be arrested at any point between the first and the last lowering position so as to vary the potential derived from the resistor 55 in a substantially stepless manner.

The operation of the system thus far described is as follows: When the lines L^1 , L^2 and L^3 are energized, a circuit is established from line L^1 to drum contact 23, through the cooperating segments to contact 25, through winding 38^a to line L^3 . Thereupon the relay 38 is energized to close the contacts 38^b and 38^c. Closure of contact 38^b parallels the connection established between the contacts 23 and 25 of the master drum, so that now the drum may be moved from the off position to the first hoist position, thereby interrupting the circuit at contact 25, but the relay 38 remains energized over the parallel circuit heretofore traced.

When the master drum is in the first hoisting position a circuit is closed from line L^1 over contact 24, through the winding 37^b to line L^3 , and the relay 37 is energized thereby closing the contacts 37^a to energize the brake winding 36 and release the brake when the contact 11^c is closed as hereinafter set forth.

As the contact 38^c is closed a circuit is also established from line L^3 , through contacts 38^c, winding 13^a, contacts 12^d to contact 27, back to line L^1 . This effects energization of switch 13 to close the contacts 13^b and also the contacts 13^c.

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Thereupon a further circuit is established from line L², through contacts 38^c, winding 11^c, contacts 13^c, drum contact 27, and back to line L¹. Energization of winding 11^c causes closure of contacts 11^a and 11^b, thereby connecting the primary winding 10^a to the bus bar L². Closure of contact 11^b completes a circuit from bus bar L², through contacts 11^b and 13^b, through the tubes 14 and 15 to the third terminal of winding 10^a. The motor is thus energized to receive an unbalanced polyphase current in accordance with the conduction of tubes 14 and 15. At the same time the brake solenoid winding 36 is energized through closure of contact 11^a and the brake is lifted and the motor starts if the load is not too heavy.

A circuit is also established from line L¹, through drum contacts 29, the energizing winding 20^c, over contact 11^d to line L³, so that the resistors 16^a, 17^a and 18^a are short circuited and the motor starts with the remainder of the balanced secondary resistance star connected across the secondary winding. A further circuit is established from line L², through contacts 11^c, winding 54^c, to drum contacts 32, and through the drum to line L¹. This energizes the relay 54 thereby opening contacts 54^b and closing contacts 54^a.

The phase shifting network, comprising the transformer 39, inductance 40, resistor 41 and reactor coil 42^a, is normally so adjusted that with no current flowing in the saturating winding 42^b, the voltage impressed on the control electrodes 14^c and 15^c, respectively, has a maximum phase displacement with respect to the cathode voltages so that little current flows through the tubes to the primary motor winding. However, the potential of grid 45^c is positive, so that a current flows through resistor 49, which makes the grid 50^c negative and tube 50 accordingly carries little or no current. The voltage drop through resistor 52 is therefore practically zero and the grid 53^c has practically zero potential, rendering the tube 53 fully conducting and thereby saturating the reactor 42, which in turn shifts the voltage of grids 14^c and 15^c to render the tubes 14 and 15 fully conducting. The motor therefore starts and the tachometer generator 43 generates a voltage which is rectified and the rectified voltage, which is opposed to the voltage drop through resistor 56 reduces the potential of the control electrode 45^c. The total potential impressed upon the control electrode 45^c with respect to the cathode 45^a is composed of the voltage drop through the resistor 56 and the rectified voltage of the tachometer 43. This potential renders the tube 45 conducting and the higher its conduction the lower will be the potential of its anode and therefore the potential impressed upon the control electrode 50^c. The potential of the control electrode 50^c with respect to the cathode 50^a is the voltage drop through the tube 45 minus the voltage drop between the bus bar 46 and the movable contact 51^a. This potential may be varied by adjustment of contact 51^a. The potential of the anode 50^b is higher than the potential of the cathode by the voltage drop through the tube 50. The potential of the anode 50^b is impressed through the contact 54^a upon the grid 53^c, thereby regulating the current flowing from the bus bar 47, through the tube 53, the saturating winding 42^b, back to bus bar 48. It will be observed that the potential impressed upon the grid 53^c becomes more negative, the higher the current flow is through the tube 50 by virtue of the voltage drop through

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the resistor 52. Hence as the speed of the motor increases and the voltage of the tachometer 43 increases, the conduction of tube 45 decreases, which in turn increases the conduction of the tube 50 and this decreases the conduction of the tube 53, thereby decreasing the saturating current of the winding 42^b. The phase relation of the potentials of the grids 14 and 15 with respect to the cathodes is such that a decrease of the current of the saturating winding 42^b decreases the conduction of the tubes 14 and 15. Therefore as the tachometer 43 speeds up the decrease through the tube 53 decreases the saturating current, thereby tending to reduce the current flow through the tubes 14 and 15 to maintain it at a value which will maintain the desired speed of the motor. This speed is determined by the magnitude of the voltage drop across resistor 56.

Thus the present system provides by control of the unbalance of primary current, a low, constant hoisting speed at all loads between zero load and a maximum load determined by the resistance in the secondary circuit of the motor.

If it is desired to increase the hoisting speed, the master controller is moved to the second position. This deenergizes the electromagnetic switch 13 and energizes the electromagnetic switch 12, by a circuit from line L₁, through drum contacts 23 and 26, winding 12^b, contacts 38^c, to line L². Closure of contacts 12^a short circuits the tubes 14 and 15 and opening of contacts 13^b disconnects the tubes from the line L². The motor now operates with balanced primary current in the usual manner. At the same time relay 20 is deenergized thereby connecting all of the secondary resistors across the motor secondary. The relay 54 is also deenergized and the electronic speed regulating circuit has no more control over the motor.

To further increase the speed of the motor in the hoisting direction, the master controller is moved successively to the third, fourth, and fifth position in which the relays 20, 21, and 22, respectively, are energized, thus gradually cutting out sections of the secondary resistor and ultimately short circuiting the secondary winding of the motor whereupon the motor operates at its maximum speed in the hoisting direction.

The speed characteristic of the motor for the different positions of the master drum in the hoisting position is illustrated in the diagram, Fig. 3. As has been explained, in the first hoisting position one section of secondary resistance in all three phases is short circuited by the switch 20 and the balance of the secondary resistance is such that with the tubes 14 and 15 fully conductive, the stalled torque of the motor is of the order of 200 per cent and the speed-torque of the motor is therefore represented by the curve H³⁻¹. However, due to the action of the tachometer 43, the conductivity of the tubes is regulated in such a manner that the speed of the motor is maintained at a constant value indicated by the horizontal line H¹, except when the torque required of the motor exceeds a given value, whereupon the speed torque curve H¹ merges into the line H³⁻¹.

On the second hoisting point, the tubes 14 and 15 are cut out of circuit and all of the secondary resistors are inserted. The total secondary resistance in the present instance is chosen so that the corresponding stalled torque of the motor is 100 per cent. The speed of the motor therefore varies with the load in accordance with curve H². On the third speed point,

the value of the secondary resistance is the same as it was on the first speed point. Therefore, the speed of the motor varies in accordance with the curve H^{3-1} . The curve H^4 represents the speed-torque curve on the fourth point of the controller, while the curve H^5 represents the maximum speed-torque curve obtaining when the secondary motor winding 10^b is short circuited.

If it is desired to lower a load, the motor controller is moved to the position 1 in the lowering direction. As will be apparent in this and in all other lowering positions, the electromagnetic switches 11 and 13 are energized while the electromagnetic switch 12 is deenergized. The switch 20 being deenergized, the basic speed-torque curve of the motor for all lowering positions of the master drum is therefore represented by the curve H^2 . However, due to the action of the tachometer 43 upon the control electrodes of the tubes 14 and 15 in the manner described, the tubes are not fully conducting during the respective half-cycles and therefore the primary winding 10^a is supplied with an unbalanced voltage and the current passing through the tubes to the motor is regulated to a value to afford a speed torque curve represented by the horizontal line U^1 in Fig. 3. In other words, the speed is maintained constant for all torques up to that value at which the line U^1 intersects the speed torque curve H^2 .

It is now desired to increase the lowering speed of the motor, the master controller is moved in the lowering direction so as to gradually move the contact 34 with respect to resistor 55. The effect of this is to render the control electrode 45^c progressively more positive with respect to its cathode and thus increase the current passing through the tube 45.

In the lowering direction, the relay 54 is not energized. Therefore, the contacts 54^b are closed and the contacts 54^a are opened with the result that the voltage of the anode 45^b is impressed on the grid 53^c . Hence an increase in the potential impressed upon the grid 45^c , due to the movement of resistor 55 with respect to contact 34, resulting from rotation of the master controller, causes a decrease of the conduction of the tube 53 and therefore a decrease in the conduction of the tubes 14 and 15 and an increase in the speed of the motor. Furthermore, an increase in the speed of the tachometer 43 results in a decrease of the positive potential of the grid 45^c , which causes an increase of the conduction of the tube 53 and an increase of the conduction of the tubes 14 and 15, which will lower the lowering speed of the motor.

By progressively increasing the potential of contact 34 by rotation of the master controller in the lowering direction, speed torque curves similar to those marked U^2 , U^3 , U^4 , and U^5 in Fig. 3 may be obtained. The maximum torque in each case is determined by the intersection of the horizontal lines with speed-torque curve H^2 .

It is well known that the torque of a three phase motor supplied with unbalanced primary current is very low when the unbalancing is great and the speed of the motor is low and that the motor has to be brought up to a certain minimum speed before any substantial torque can be developed thereby. This is indicated by the curve S in Fig. 3. The minimum speed at which the motor operating single phase, that is, with zero conduction of the tubes 14 and 15, can develop any torque is shown to be approximately 75 per cent of synchronous speed. If this speed, which in the pres-

ent case is the lowering speed of the motor, increases, the minimum torque increases as shown by curve S.

In the control shown by Fig. 1, provision was made for maintaining only a single hoisting speed constant, which speed is represented by the curve H^1 . It would, of course, be possible to provide for a plurality of constant hoisting speeds in a manner similar to that for obtaining a plurality of constant lowering speeds. This could be accomplished by providing a separate resistor in place of the resistor 55 for hoisting, or by providing the master controller M with means for commutating the resistor 55 for hoisting in a manner similar to the manner in which it is commutated for lowering.

The controller shown and described does not afford any positive lowering torque, which is sometimes required to lower a crane hook against the friction of the mechanical system and/or an overbalancing counterweight. This, however, can be provided for by the addition of a conventional reversing switch for reversing two of the primary phases of the motor thus reversing the torque of the motor with the master controller in an added position preceding the first lowering position in the drawing.

The system disclosed in Fig. 2 is a modification of the system shown in Fig. 1 and provides for energizing the primary winding 10^a of the motor under certain lowering conditions with single phase current. The system, Fig. 2, is the same as that of Fig. 1, except for the following changes: The segment of the master controller which engages the stationary contact 27 in the lowering direction is of such length that it engages the stationary contact 27 only in the first and second lowering position of the master drum. A stationary contact 28 and a cooperating segment have been added to the master controller, the segment engaging the contact 28 in the third to the fifth lowering position. An additional segment has been added which engages the stationary contact finger 29 in the third to the fifth lowering position. The electromagnetic switches 12 and 13 are provided with additional normally closed auxiliary contacts 12^c and 13^d , respectively. There is also added an electromagnetic switch 60, having an energizing winding 60^a , normally open main contacts 60^b and 60^d and normally closed auxiliary contacts 60^c . The auxiliary contacts 60^c are interposed between one terminal of the winding 13^a and the drum contact 32, while the contacts 60^d parallel the contacts 13^c . The auxiliary contacts 12^c are adapted to connect the drum contact 28 with one terminal of the energizing winding 60^a . The second terminal of the winding 60^a is connected through normally closed contact 13^d and the normally open contacts 38^c to the bus bar L^2 . A resistor 61 is connectible between that terminal of the winding 10^a which is energized from the line L^2 when the switch 11^a is closed, and the anode 14^b through the contacts 60^b . If desired, under certain conditions the resistor may alternatively be connected to that terminal of the motor winding 10^a which is connected to the line L^1 , as shown in dotted lines.

The operation of the system shown in Fig. 2 for hoisting, is the same as that of the system shown in Fig. 1 and described in connection therewith. If it is desired to lower a load with the controller, Fig. 2, the master controller is moved to the first lowering position. In this position the electromagnetic switches 12 and 60

are deenergized and the electromagnetic switches 11 and 13 are energized. The motor primary is thus supplied with polyphase current through the tubes 14 and 15 and the operation is the same as in the system, Fig. 1, in the first lowering position. By moving the master controller gradually toward the second lowering position, the resistance 55 is commutated by contact 34 resulting in an action similar to that described in connection with Fig. 1.

Now, by moving the drum from the second toward the third position, the switch 13 is deenergized by interrupting its energizing circuit at the contact 27, while the electromagnetic switches 60 and 20 are energized by closing the circuit in the master controller at the contacts 28 and 29, respectively. Thus the motor primary winding 10^a is energized single phase. The basic speed torque curve for the three phase primary motor connection is represented by the curve H² in Fig. 3. If instead of supplying polyphase current to the primary winding, two of the terminals are joined together and the winding is supplied with single phase current, a speed torque curve substantially parallel to curve H², the slope of which depends upon the resistance in the secondary circuit, results. By inserting resistance between the two phase windings which are connected together, this curve, D¹, is in turn shifted to the left as represented by the curve D² or to the right as represented by the curve D³ in Fig. 3, the direction of shift being dependent upon the phase rotation and sequence of the three-phase supply. The shift can be changed for a given installation by changing the connection of the resistor 61 to that shown in dotted lines, thus making it possible to influence the speed torque curve for lowering. The amount of shift in either direction may be varied by varying the value of the resistor 61. The higher that resistor up to a certain value the greater will be the shift of the curves D² or D³ from the curve D¹. However, due to the action of the tachometer 43 on the conductivity of the tubes 14 and 15, the speed-torque curves are modified so as to maintain the speed of the motor substantially constant as represented by the horizontal lines U³, U⁴, U⁵ between the limiting speed-torque curves S and D¹, D², or D³, corresponding to the positions of the master controller indicated in the diagram. The minimum torque which the motor may exert at any speed is again represented by the curve S in Fig. 3. It will be observed that speed-torque curve D² provides a certain amount of power lowering torque for an empty hook, whereas D³ provides a certain amount of positive torque for taking up slack in the hoisting cable, without providing sufficient torque to hoist the load and provided the tubes are rendered conducting while the motor is at rest.

I claim:

1. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting it to said source, space discharge means having a control element for varying the effective impedance thereof interposed between said source and one of said terminals, means to impress upon said control element a biasing potential variable relative to the voltage of said source in response to speed variations of said motor, and means to reverse the sense of said response to thereby control the current passing through said first named means to afford, through potential regulation of

a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip.

2. In a hoist control system or the like having a motor subject to an overhauling load, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting it to said source, an impedance, space discharge means connected to one of said motor terminals and having a control element for varying the effective impedance thereof, means for interposing said space discharge means between said source and said one terminal and alternatively disconnecting said space discharge means from said source and connecting it in series with said impedance between said one and another of said terminals, and means to impress upon said control element a biasing potential variable relative to the voltage of said source in response to speed variations of said motor, to thereby control the current passing through said first named means to afford motor speed control through potential regulation of the terminals of said primary winding.

3. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting it to said source, a space discharge device interposed between said source and one of said terminals and having a control element for varying its effective impedance in response to variations of a potential impressed thereon, means for impressing upon said control element an alternating potential of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, means to reverse the sense of said response, and means to derive a modified voltage from said speed responsive potential and impress it upon said first mentioned means, to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip.

4. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting it to said source, a pair of space discharge devices connected inversely parallel to each other and interposed between said source and one of said terminals, each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means to reverse the sense of said potential variations relative to the variation of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip.

5. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase winding including a plurality of terminals for connecting it to said source, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current,

means affording a potential which varies in response to the speed of said motor, manual means for effecting connection of said terminals to said source and interposing said space discharge device between said source and one of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and further including selective means affording reversal of said potential variations relative to the variations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip.

6. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase winding including a plurality of terminals for connecting it to said source, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means operative to effect connection of said terminals to said source and interposing said space discharge devices between said source and one of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and including means to reverse the relation of said potential variations and the variations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means, to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip, said manual means being alternatively operative to effect connection of said terminals to said source exclusive of said space discharge devices to afford operation of said motor through a range between approximately 100% and substantially zero slip.

7. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase winding including a plurality of terminals for connecting it to said source, an impedance, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means for effecting connection of said terminals to said source and interposing said space discharge device between said source and one of said terminals and alternatively effecting disconnection of said one terminal from said source and connection thereof in series with said space discharge devices to another of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and means to reverse the response of said potential variations relative to the variations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding,

motor speed control through a range extending between approximately 90% and 250% slip.

8. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase winding including a plurality of terminals for connecting it to said source, an impedance, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means operative to effect connection of said terminals to said source and interposing said space discharge devices between said source and one of said terminals and alternatively effecting disconnection of said one terminal from said source and connection thereof in series with said space discharge devices to another of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and including means to reverse the response of said potential variations relative to the variations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip, said manual means being alternatively operative to effect connection of said terminals to said source exclusive of said space discharge devices to afford operation of said motor through a range between approximately 100% and substantially zero slip.

9. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting it to said source and a secondary winding, a variable impedance connected to said secondary winding, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means operative selectively to effect connection of said terminals to said source with and without said space discharge devices between said source and one of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and including means to reverse the relation of said potential variations and the variations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip, said manual means being alternatively operative to effect connection of said terminals to said source exclusive of said space discharge devices and to vary said variable impedance to afford operation of said motor through a range between approximately 100% and substantially zero slip.

10. In a hoist control system or the like, in combination, a source of polyphase current, a motor having a polyphase primary winding including a plurality of terminals for connecting

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it to said source and a secondary winding, a variable impedance connected to said secondary winding, a second impedance, a pair of space discharge devices connected inversely parallel to each other and each having a control electrode, means for impressing upon said control electrodes alternating potentials of the same frequency as that of said polyphase current, means affording a potential which varies in response to the speed of said motor, manual means operative selectively for effecting connection of said terminals to said source with and without said space discharge devices between said source and one of said terminals and alternatively effecting disconnection of said one terminal from said source and connection thereof in series with said space discharge devices and said second impedance to another of said terminals, said manual means including means affording adjustment of said speed responsive potential with respect to said speed and means to reverse the relation of said potential variations and the vari-

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ations of said speed, and means to impress a voltage derived from said speed responsive potential upon said first mentioned means to afford, through potential regulation of a single terminal of said primary winding, motor speed control through a range extending between approximately 90% and 250% slip, said manual means being alternatively operative to effect connection of said terminals to said source exclusive of said space discharge devices and to vary said variable impedance to afford operation of said motor through a range between approximately 100% and substantially zero slip.

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The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
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