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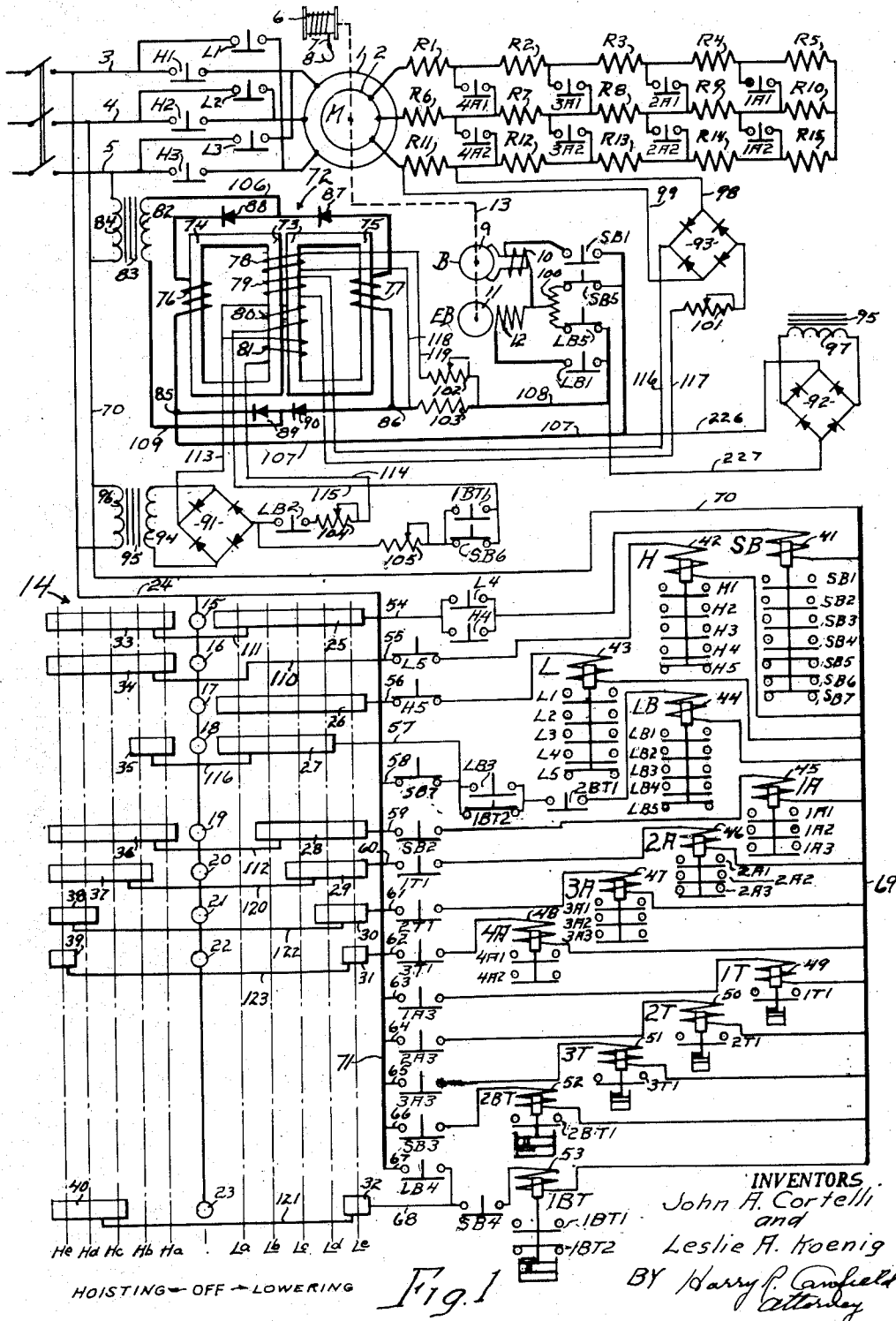
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ELECTRIC HOIST CONTROL

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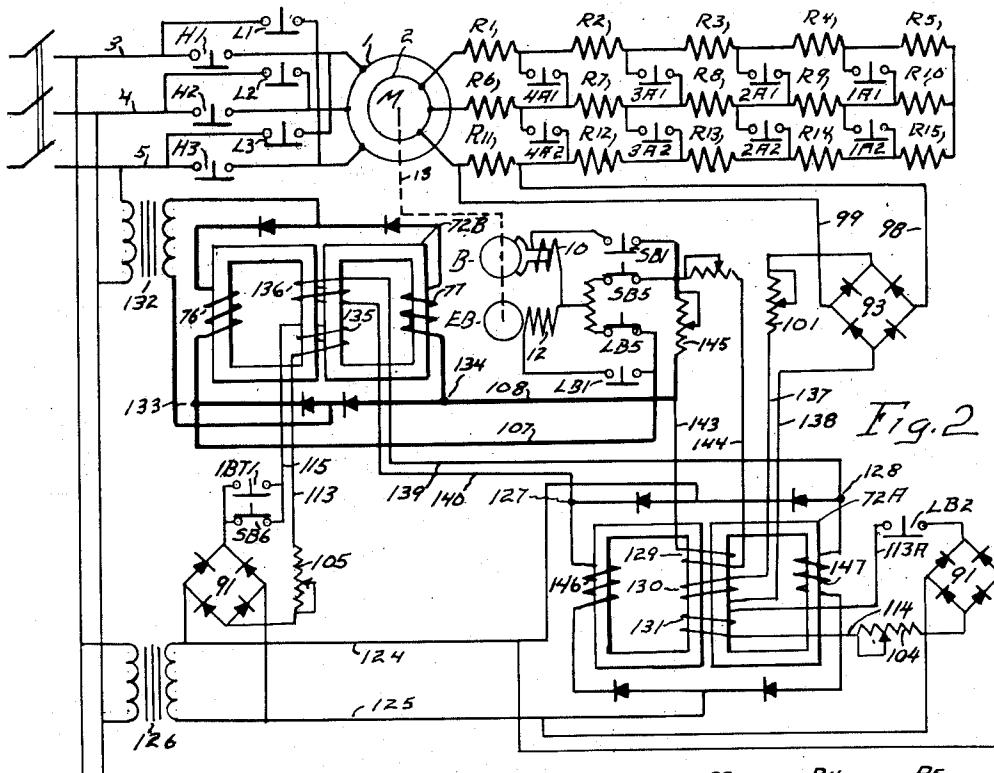


Fig. 2

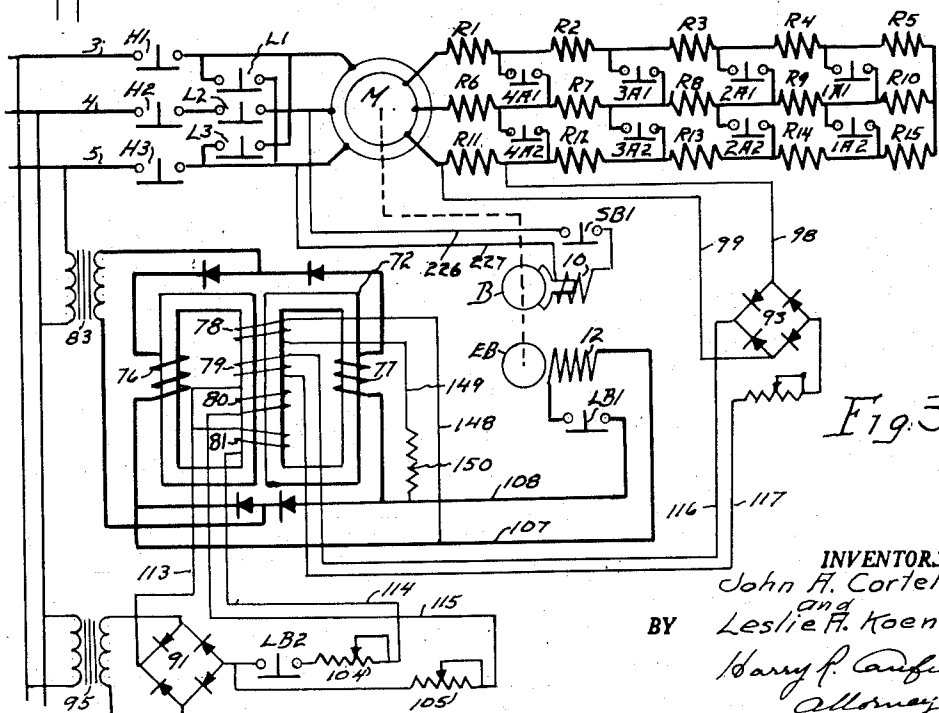


Fig. 3

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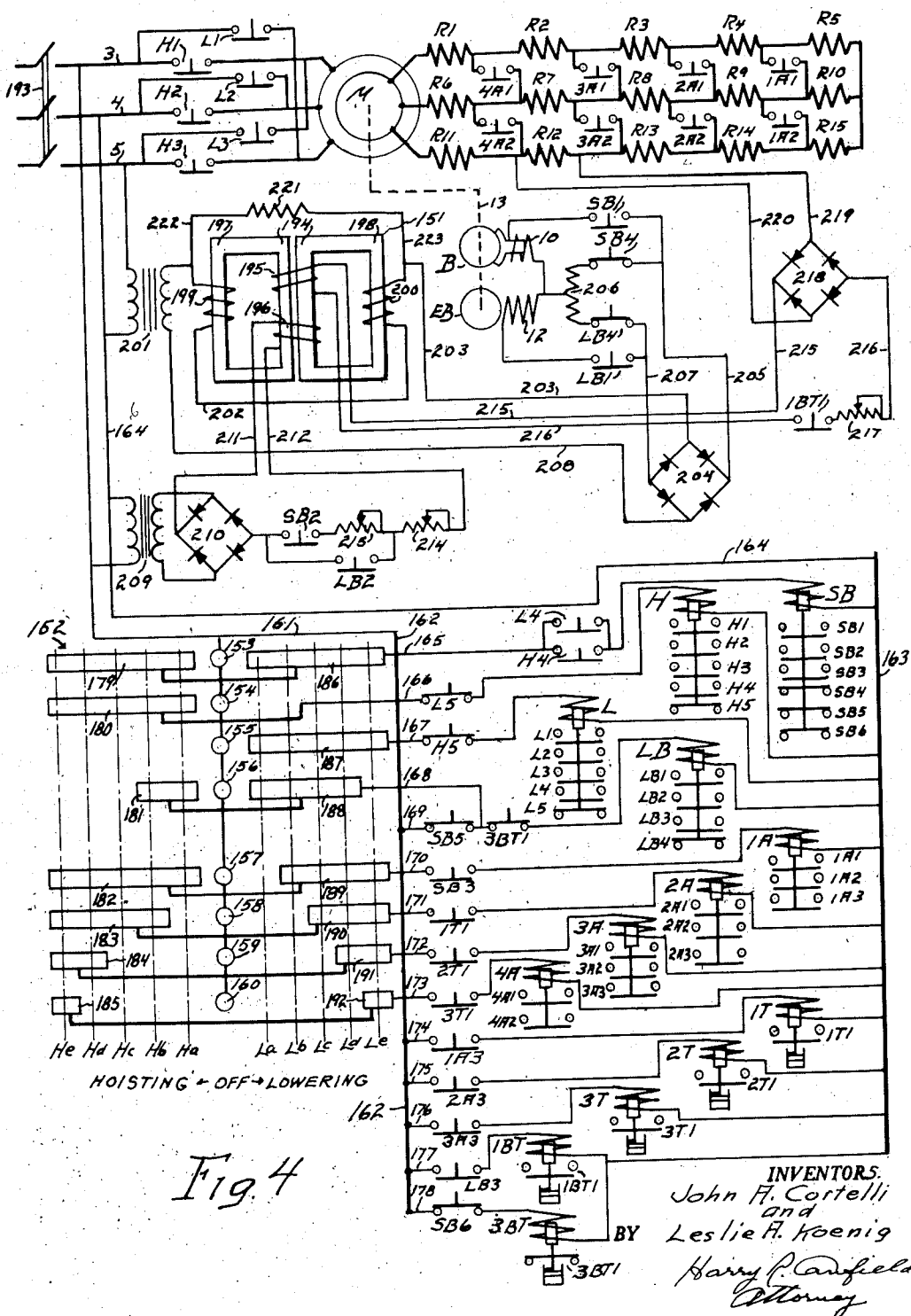
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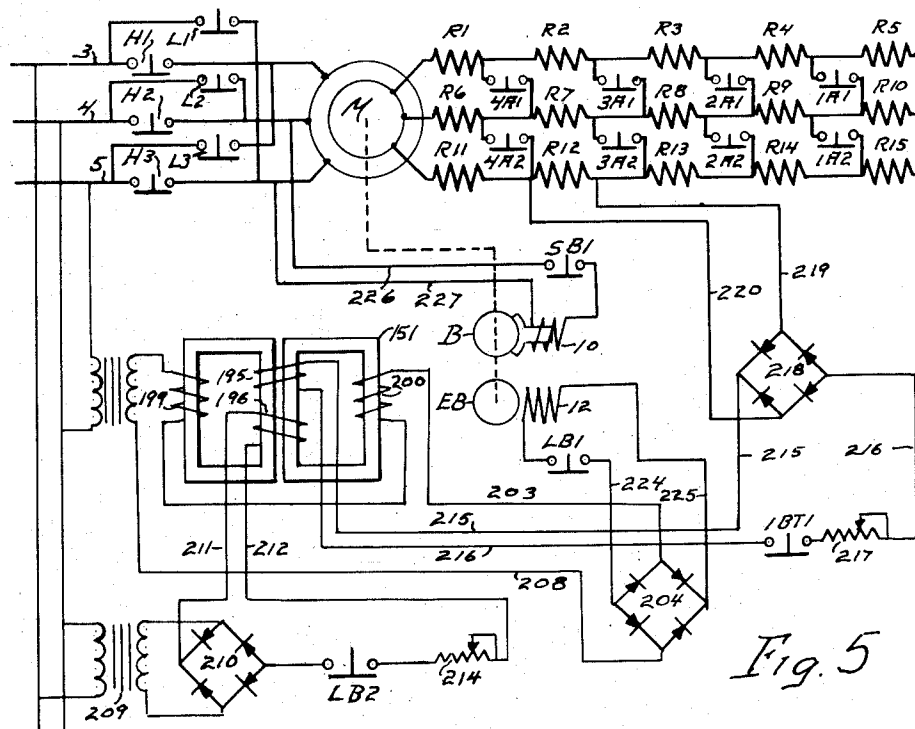
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2,963,634

ELECTRIC HOIST CONTROL

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7 Claims. (Cl. 318—209)

This invention relates to electric hoists of the class in which a hoist cable winding drum for hoisting and lowering loads is connected to an alternating current motor; and relates particularly to control systems for controlling the speed of hoisting and lowering various loads, by controlling the speed of the motor.

In a known general class of hoist controls a polyphase alternating current motor is utilized of the type having a wound rotor or secondary, and external resistance in the rotor circuit; and a manually operable drum controller is provided, having a number of load hoisting "points" and load lowering "points," at which sections of the resistance are cut into and out of the rotor circuit, to control the speed of hoisting loads, which may vary from a heavy load to an empty cable hook, and the speed of lowering loads which may vary from an empty hook to a load heavy enough to overhaul and drive the motor rotor.

Such controls are not satisfactory. Among the reasons are that the selection of points on the drum controller is optional with the operator, and due to the wide variations of load, there is no correspondence between the hoisting and lowering points at which he sets the drum controller, and the speed at which the load hoists or lowers.

Obviously a heavy load will tend to hoist slowly and lower rapidly, and a light load or empty cable hook will tend to hoist rapidly, and lower slowly. It is desirable to hoist and lower all loads at the best speeds dictated by the circumstances and by the height of the load at the time; and to do so in the minimum of time; and without the danger, present in the case, for example, of lowering a heavy load, that it may lower so fast as to get out of control and cause damage or injury.

The usual prior controls call for operation of the drum controller by the operator with great care and skill.

In the development of the art, a particular type of hoist control has been proposed in which an artificial load in the form of an eddy current brake is at all times connected to the motor rotor, and exerts a braking action thereon proportional to the degree of energization of an eddy current brake winding; and the winding energization is changed concurrently with changes of the resistance of the motor secondary, by the operator's drum controller.

The speed of the motor is controlled partly by its secondary resistance and partly by the braking action of the eddy current brake; and some of the defects of prior controls are thereby eliminated.

The present invention is an improvement over prior controls of this particular type utilizing an eddy current brake.

The invention is based upon the concept, which is believed to be new, that when a hoist control is operated by a drum controller having a number of hoisting and lowering speed points, the motor should have definite predetermined speeds, corresponding to the respective speed points, and each of a predetermined value, regardless of the amount of load on the hoist cable, and should come to these speeds automatically upon setting the controller at the said points.

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In the embodiment of the invention hereinafter described, it comprises in general the following features and mode of operation; the actual invention being that set forth in the appended claims.

5 An eddy current brake has its rotor permanently connected to the rotor of an alternating current motor, and has an energizing field winding, variably energizable, to cause it to exert variable braking action on the motor rotor.

10 An electromagnetic device of either the saturable reactor or magnetic amplifier class has main windings supplied with A.C. from A.C. mains, and has a pair of control windings controlling its output; and its output energizes the winding of the eddy current brake.

15 One control winding is energized at constant value and may be referred to as a reference winding; and is polarized to increase the output of the magnetic device.

The other control winding is energized by current that may be referred to as signal current and the winding may be referred to as a signal winding, and its polarity is opposite to that of that of the reference winding; and in general is predominated over by the reference winding.

The output of the magnetic device, and its energization of the eddy current brake winding, is thus caused to 25 vary inversely with the signal current.

The signal current is provided as described later.

The motor rotor has resistance in sections in an external circuit or rotor circuit, which may be cut in or out in steps by moving a manual drum controller to speed points thereon; and the current in the rotor circuit may thereby be increased or decreased, by the points on the manual controller.

30 When the current in the rotor circuit is decreased or increased, by the drum controller, the rotor tends to go faster or slower, respectively, as is well known; that is, the speed varies inversely with the current.

The said signal winding of the magnetic device is connected in a control system such that the signal current energizing it varies directly with the current in the rotor circuit, and therefore varies inversely with the rotor speed.

In consequence, the output of the magnetic device and its energization of the eddy current brake winding, varies inversely with the current in the rotor circuit, and directly with the speed of the rotor.

40 Accordingly, if, as an example, the drum controller is moved to a higher speed point, the rotor speed will begin to increase toward a higher value, but at the same time the signal current will decrease and the output of the magnetic device will increase and increase energization of the eddy current brake, and the brake will increasingly oppose rotation of the rotor; so that the motor rotor will come up to only a certain speed and cannot increase beyond that speed; this being the speed predetermined for the said higher speed point of the controller.

55 In this manner at each speed point on the manual controller, whether for hoisting or lowering, the motor rotor will come to a definite predetermined respective speed at which it will be maintained at substantially constant value, regardless of the amount of load on the hoist cable.

60 The embodiment of the invention as described hereinafter also comprises a mechanically set friction brake for the motor, releasable by an electric winding; and in one arrangement, the winding is in series with the winding of the eddy current brake, whereby an element of safety is introduced; that is, the friction brake will set and stop the motor if the magnetic device energizing the eddy current brake winding, or the winding itself of the eddy current brake, should fail.

The invention also comprises a compensating control 70 winding on the magnetic device energized commensurably with the current energizing the eddy current brake winding, which, in the event of a tendency of energization of

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the eddy current brake winding to decrease due to any cause, for example, due to a reduction of the output of the device because of a fall of line potential, or due to an increase of resistance in the electric lines carrying the output to the brake winding, the control winding will perform a compensating action and elevate the output of the device and prevent the energization of the brake winding from decreasing; and similarly conversely if it should tend to increase.

The invention also comprises means by which, with the eddy current brake winding and the friction brake winding in series, it is insured that the friction brake winding will be energized sufficiently to keep the brake released, at very low values of energization of the eddy current brake winding.

The invention also comprises alternative arrangements in which the friction brake winding is energized independently of the eddy current brake winding.

The objects of the invention are to provide a hoist control having, among others, the features and modes of operation above described generally, singly or in combination.

An embodiment of the invention in several forms is fully described in detail in the following description, taken in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic view illustrating an embodiment of the invention, utilizing a one stage magnetic amplifier;

Fig. 2 is a view similar to Fig. 1, utilizing a two stage magnetic amplifier;

Fig. 3 is a view similar to Fig. 1 illustrating a modification;

Fig. 4 is a view similar to Fig. 1 utilizing a saturable reactor;

Fig. 5 is a view similar to Fig. 4 illustrating a modification;

Referring to the embodiment of the invention in Fig. 1 of the drawing there is shown at M an alternating current motor having a three phase stator 1 and a wound rotor 2 with a three phase external circuit having, in the respective phases, resistance sections R1 to R5; R6 to R10; and R11 to R15.

The stator 1, is connected to alternating current supply lines 3—4—5, in which respectively are normally open contacts H1, H2, H3 of magnetic contactors to be referred to, which when operated close the contacts and energize the stator 1 to drive the rotor 2 in the hoisting direction; and like normally open contacts L-1, L-2, L-3, which when closed energize the stator to drive the rotor in the lowering direction. The rotor 2 is connected to a hoist drum 6, and a cable 7 is wound thereon having a load hook 8.

The rotor 2 is also connected to the drum 9 of a normally set friction brake B, of known construction, having an electromagnetic winding 10 for releasing the brake when energized.

The rotor 2 is also connected to the rotor 11 of an eddy current brake EB having an energizing field winding 12; and which exerts braking action on the rotor 2 commensurably with the degree of energization.

These connections to the rotor 2 are diagrammatically represented by the dotted line 13.

At 14 generally is a drum type controller which in the diagrammatic illustration thereof comprises movable contacts 15 to 23, all connected together as shown; and connected by a wire 24 to the current supply line 3.

These contacts, as will be understood by those skilled in the art, are all movable in unison from the "off" position illustrated toward the right to five successive "lowering" points La to Le, or toward the left to five successive "hoisting" points Ha to He, indicated by the vertical lines above the legends "lowering" and "hoisting."

On the several lowering points the movable contacts

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15 and 17 to 23 are engageable with stationary bar contacts 25 to 32 and on the several hoisting points, the movable contacts 15, 16 and 18 to 23 are engageable with bar contacts 33 to 40.

The drum controller 14 on various lowering and hoisting points, operates or restores electromagnetic contactors as follows.

A contactor SB having a winding 41 and normally open contacts SB1 to SB4 and normally closed contacts SB5 to SB7.

A contactor H having a winding 42 and normally open contacts H1 to H4 and normally closed contacts H5.

A contactor L having a winding 43 and normally open contacts L1 to L4 and normally closed contacts L5.

A contactor LB having a winding 44 and normally open contacts LB1 to LB4 and normally closed contacts LB5.

Contactors 1A, 2A, 3A, and 4A having respective windings 45 to 48 and having respectively normally open contacts 1A1 to 1A3; 2A1 to 2A3; 3A1 to 3A3; and 4A1 to 4A2.

Timing contactors 1T, 2T, 3T having respective windings 49 to 51 and having, respectively, normally open contacts 1T1, 2T1, and 3T1; and a timing contactor 1BT having a winding 53 and normally open contacts 1BT1 and normally closed contacts 1BT2; these timing contactors being of a known type that have means delaying their operation until a time interval has elapsed after energization of their windings, said means being indicated diagrammatically as dash-pots under the contacts.

A timing contactor 2BT having a winding 52 and normally open contacts 2BT1; this contactor being of a type that closes its contacts at once upon energization of its winding, but delays opening them when de-energized.

The contactors are all illustrated in normally de-energized or restored condition; and the said contacts of these contactors are shown without connections thereto, but are reproduced elsewhere in Fig. 1, with their connections, to thereby avoid complexity in the drawing.

The said windings of the contactors are in an across-the-line type of diagram, comprising horizontal cross lines 54 to 68, with their right ends connected to a common wire 69 going by wire 70 to supply line 4; and the cross lines 58 and 63 to 67 are connected at their left ends to a common wire 71 going by wire 24 to another supply line 3, and the remaining cross lines, at their left ends are connected to the wire 24 and supply line 3 through the contacts of the drum controller 14.

At 72 generally is a magnetic amplifier comprising a core having central legs 73—73 and opposite side legs 74 and 75; main windings 76 and 77 on the respective legs; and control windings 78 to 81 on the central legs 73.

The main windings 76—77 receive input current from the secondary 82 of a transformer 83 whose primary 84 is connected across the supply lines 4—5, and supply output from point 85—86, rectified to be unidirectional by rectifiers 87 to 90.

The control winding 78 functions as a compensating winding; the winding 79 as a signal winding; the winding 80 as a biasing winding; and the winding 81 as a reference winding.

The reference, winding 81 is is poled to increase the output of the amplifier at points 85—86, and the windings 80, 78 and 79 are poled to oppose the winding 81; as will be more fully described.

At 91, 92, 93 are loop rectifiers.

The rectifier 91 has input from one secondary 94 of a transformer 95, whose primary 96 is connected across the supply lines 3—4; and the rectifier 92 has input from another secondary 97 of the same transformer 95.

The rectifier 93 has input by wires 98 and 99 connected across the resistance section R11 of the rotor external circuit, and subjected to potential drop in the resistor, to be discussed.

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At 100 to 105 are resistors, some of which are adjustable as indicated.

Other parts of Fig. 1, and electrical connections, not thus far described, are described in the following description of the operation as a whole.

In the illustrated off position of the controller 14, the magnetic amplifier 72 is energized by transformer 83, and current waves, say from the top of the secondary 82, flow by wire 106, rectifier 88, and main winding 76, to output point 85, and by a wire 107, closed contacts SB5, resistor 100, closed contacts LB5, a wire 108, through resistor 103 to output point 86, and thence through rectifier 90, and by a wire 109 to the lower side of the secondary 82.

Waves in the opposite direction flow from the lower side of the secondary 82, by wire 109, rectifier 89 to output point 85, and again by wires 107 and 108 to output point 86, through main winding 77 and by rectifier 87 and wire 106 to the top of the secondary 82.

The bias winding 80 is energized at this time from the rectifier 91 by a circuit 113—115, through closed contacts SB6.

The reference winding 81 has a circuit 113—114 for energizing it from rectifier 91 which at this time is open at the contacts LB2.

The amplifier 72 has output in the wires 107—108 due to the bias winding 80 alone, but the windings 10 and 12 of the friction brake B and eddy current brake EB, are both de-energized, the output current in wires 107 and 108 being shunted around them through the resistor 100, and closed contacts SB5 and LB5.

On the first point H_a of hoisting, contactor H is operated by current through controller contact 16, bar contact 34, connecting wire 110, cross line 55, contacts L5, and winding 42; and closes line contacts H1, H2, H3, to give current to the motor M; but only if contactor L is restored to close said contacts L5.

Contactor SB then operates by current through controller contact 15, bar contact 33, connecting wire 111, bar contact 25, cross line 54, closed contacts H4, and winding 41.

Contacts SB3 in cross line 66 close, energizing winding 52 of timing contactor 2BT and it operates without delay closing contacts 2BT1, which are reproduced in cross line 57. Current then goes through controller contact 18, bar 35, connecting wire 116, bar contact 27, cross line 57, contacts 1BT2 and 2BT1 and energizes winding 44 of contactor LB and it operates. Contacts SB1 and SB5 are respectively closed and opened by contactor SB; and contacts LB1 and LB5 are respectively closed and opened by contactor LB; and amplifier output current in lines 107—108 goes through the windings 10 and 12 of the friction brake B and eddy current brake EB in series, so that the brake B is released and the motor M starts.

At this time, the circuit 113—115 of the bias winding 80 is open at contacts 1BT1 and became open at contacts SB6 when SB operated. Contactor 1BT had its winding 53 energized in cross line 67, through contacts LB4 and SB4 when contactors LB and SB operated, and began to run its delay interval, but has not yet closed its said contacts 1BT1.

The circuit 113—114 of the reference winding 81 became energized when contacts LB2 closed upon operation of contactor LB.

The reference winding 81 alone is therefore energized and causes a high output from the amplifier in its lines 107—108 so that the energization of the winding 10 of the friction brake B is high and it releases quickly and with certainty.

At the end of the delay of contactor 1BT, it closes the circuit of 113—115 of bias winding 80 at contacts 1BT1, which energizes the bias winding 80 in opposition to the reference winding 81.

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This reduces the amplifier output to a value for normal operation to be presently described.

At this point it is interjected that upon going back to the off position of the controller 14 at any time during operation, contactor SB will immediately restore; but restoring of contactor LB will be delayed, because it is maintained energized through cross line 58, contacts SB7 and contacts 1BT2 and 2BT1, and contacts 1BT2 being immediately closed by restoring of contactor 1BT upon opening of contacts SB4; and the opening of contacts 2BT1 being delayed by the delayed restoring of contactor 2BT upon opening of contacts SB3.

After the interval of delay of contactor 2BT, contactor LB is restored by opening of contacts 2BT1. During this interval, the bias winding 80 is energized through contacts SB6 and the reference winding 81 is energized through contacts LB2, and the amplifier has normal output.

When contactor SB restores it cuts off energization of winding 10 of the brake B at contacts SB1, and brake B immediately sets to stop the motor M; but energization of the winding 12 of the eddy current brake EB is maintained through contacts SB5, the upper part of resistor 100, and contacts LB1; so that during the delay of restoring of contactor LB and opening of contacts LB1, the output of the amplifier, under control of the bias and reference windings 80 and 81, causes the eddy current brake EB to exert braking action assisting the brake B in stopping the motor.

Further, upon going to the first point hoisting, contactor 1A operates by current through contact 19, bar contact 36, connecting wire 112, bar contacts 28, contacts SB2 and winding 45, cutting out motor rotor resistance sections R5, R10, R15, without interposed delay after operation of contactors H and SB.

The motor M being energized and running as referred to, current flows in the external rotor resistance sections, and a drop of potential appears across the section R11, which gives input to the rectifier 93 by wires 98—99 and its output energizes the signal winding 79 by a signal circuit 116—117.

The effects of the above described conditions on the first point of hoisting, will be the same whether the motor rotor was running or whether it starts from rest, and the later condition is chosen for description as being more readily understood and is as follows.

The motor stator 1 is given line current and the friction brake B is released and the eddy current brake EB is energized, with normal amplifier output due to both the reference winding 81 and bias winding 80 as described, and the motor M starts to run.

Due to the high resistance of the rotor external circuit at the time, the rotor tends to accelerate up to a certain speed and with small decreasing current in the circuit.

It is highly desirable in hoists of this class to have a very low speed on the first hoisting point to facilitate manipulation of the empty cable book into hoisting engagement with the load; and this very low speed is preselected.

While the rotor 2 is accelerating, the eddy current brake EB will exert braking action on the rotor and the braking action will increase directly as the rotor speed increases; and the speed of the rotor while tending to go beyond the preselected speed, will come up only to the preselected speed; as follows.

The reference winding 81 on the amplifier is energized at constant value. It produces flux in the core of the amplifier in the direction to give high amplifier output to the eddy current brake winding. The reference winding 81 is opposed by the signal winding 79; but predominates over it; and the signal winding is energized proportional to the motor current; the resultant flux in the amplifier is therefore caused by the differential effect of the signal winding and the predominating reference winding.

The energization of the reference winding 81, is adjust-

able at the resistor 104; and the bias winding 80 is adjustable at the resistor 105. By these adjustments the flux in the core is preset to a point on the saturation curve at which small changes in flux, as would be caused by small changes of the signal current in the signal winding 79, will cause great changes of amplifier output going to the eddy current brake winding.

It follows that as the motor accelerates, and its rotor current and the consequent signal current fall by small decrements, the amplifier output due to amplification, rises by very great increments and increases the braking action of the eddy current brake accordingly, until the motor speed can not increase further; that is, comes to a definite predetermined speed; which as in the premises is an important part of the invention.

This predetermined speed on the first hoist point will be always substantially the same regardless of the amount of load on the cable. With a heavy load, the rotor will tend to rotate more slowly and with greater rotor current, and thereby produce correspondingly greater signal current, which will produce less eddy current braking action; and vice versa with small loads.

The eddy current braking action is at all loads directly proportional to the rotor speed. Any tendency of the speed to decrease or increase is counteracted by a preponderating decrease or increase of eddy current brake action, and so that the speed is held substantially constant.

The speed may deviate from absolutely constant speed since some change of motor speed and consequent change of motor current is required to effect the said regulation; but because of the sensitivity of response of the amplifier to changes of signal current and the magnification of changes of output by amplification, the deviation from absolute constancy of speed is maintained within a small range.

The output of the amplifier in the circuit 107—108 is not affected by the cutting in or out of the windings 10 and 12 of the brake B and brake EB. The whole resistance 100 is made equal to the combined resistance of the two windings in series; and that of the upper and lower parts of the resistor are made equal respectively to that of the windings 10 and 12; and the contacts associated therewith are, as described, arranged so that when either winding is cut out of the circuit, a corresponding part of the resistance is cut into the circuit.

It is desirable to keep the current energizing the eddy current brake winding 12, from changing due to extraneous influences; for example, a drop in line potential; or an increase in the resistance of the lines 107—108 between the amplifier and the brake, which lines may in some installations be of considerable length.

To this end the resistor 103 is placed in the line 108, and the brake energizing current in it produces a drop of potential therein which is utilized in wires 118—119 to energize the compensating winding 78.

This winding 78 opposes the winding 81 by an amount adjustable by a resistor 102, and at normal values of current in the wire 108 its opposition is neutralized by the adjustment of the energization of the windings 80—81 so that under normal conditions it is of no effect.

If however the current in the circuit 107—108 should tend to decrease due to said extraneous cause, said opposition by the compensating winding would be decreased causing the reference winding to be more effective and prevent the decrease of current.

On going to the second point of hoisting, Hb, Fig. 1, the operating conditions described for the first hoisting point remain the same; but, additionally, contactor 2A operates, cutting out sections of rotor resistance R4, R9, and R14 as follows.

The operation of contactor 1A as described closed contacts 1A3 in cross line 63, and the winding 49 of contactor 1T was thereby energized and it ran a time interval and then operated closing contacts 1T1 in cross line 60.

Current then goes through controller contact 20, bar

contact 37, connecting wire 120, bar contact 29, to cross line 60, contacts 1T1 winding 46 of contactor 2A and operates it.

The rotor 2 then speeds up toward a higher speed; but as explained above, the eddy current brake action increases preponderatingly with increase of motor speed so that again a balance is reached at which the rise of rotor speed is stopped by rising eddy current braking action and the rotor comes again to a definite predetermined speed, on the second hoist point, but this time the predetermined speed is higher.

The aforesaid action producing definite speeds of the rotor 2 on controller hoist points, is provided for on only the first and second hoist points Ha and Hb; it having been found that is all that is necessary to meet practical hoisting requirements;

So that in going to the third hoist point, Hc, Fig. 1 the controller contact 18 leaves the bar contact 35, through which operation of contactor LB and energization of the eddy current brake winding 12 is effected, as described.

Accordingly, contactor LB restores, and, at the brakes B and EB, contacts LB1 open and contacts LB5 close opening the circuit to the eddy current brake winding 12 at LB1.

The output of the amplifier in lines 107—108 then goes through the winding 10 of brake B alone by way of contacts SB1 and LB5 and the lower part of the resistor 100, keeping the winding 10 energized and the friction brake B released.

Restoring of contactor LB opens contacts LB2, opening the circuit 113—114 and cutting off the reference winding 81.

Restoring of contactor LB also opens contacts LB4 in cross line 67, and in the absence of other provisions would de-energize winding 53 and cause contactor 1BT to restore and open the bias winding circuit 113—115, at contacts 1BT1; but on this third hoist point, current goes through controller contact 23, bar contact 40, connecting wire 121, bar contact 32, cross line 63, closed contacts SB4, and maintains contactor 1BT operated and maintains the bias winding 80 energized.

On going to the fourth hoist point, Hd, Fig. 1 contactor 3A is operated with delay as follows.

When contactor 2A operated it closed contacts 2A3 in cross line 64 in which winding 50 of contactor 2T is energized, and this operated contactor 2T closing contacts 2T1 after delay. These contacts are in cross line 61. On fourth point hoisting, current goes through controller contact 21, bar contact 38, connecting wire 122, bar contact 36, closed contacts 2T1 and winding 47 of contactor 3A operating it, cutting out resistance sections, R3, R8 and R13 at 3A1, 3A2.

On the fifth hoist point, He, Fig. 1, contactor 4A is operated with delay as follows.

Operation of contactor 3A, closed contacts 3A3 in cross line 65 and this caused contactor 3T to operate and, after delay, to close contacts 3T1, which are in cross line 62. On the fifth point hoisting, controller contact 22 is on bar 39, and current goes therefrom through connecting wire 123, and bar 31 to cross line 62 and contacts 3T1 and operates contactor 4A, closing its contacts to cut out resistance sections R2, R7, R12.

Contactors 2A, 3A and 4A therefore are constrained to operate successively on successive hoisting points, each with its own timed interval.

On the third, and fourth and fifth points hoisting, Hc, Hd, and He, contactor 1BT is maintained operated through the contact bar 40 as referred to.

On hoist points three and four and five, the control of the motor speed is left to the judgement of the controller operator.

On going to the first point of lowering, La, Fig. 1, contactor L operates by current in its winding 43 through controller contact 17, bar contact 26, cross line 56 and

contacts H5; to give current to the motor in the reverse or lowering direction through contacts L1 to L3.

Thereupon, controller contacts 15 to 18 being on contact bars 25 to 27, operation of contactors SB and LB occurs as described for hoisting.

The conditions and operation are then the same as on hoisting and the motor starts and comes up to the predetermined speed for first lowering point La.

It will be noted that on lowering the contactor 1A is not operated on the first point as it was for hoisting, and that therefore the predetermined speed on first point lowering will be a lower predetermined speed.

On the second point lowering Lb, contact 19 engages bar contact 23 and contactor 1A operates by current in cross line 59, decreasing the resistance in the rotor circuit, causing the motor to speed up, and causing the braking effect of the eddy current brake EB to increase; and the motor comes up to another and higher predetermined speed, as described for hoisting.

On the third and fourth lowering points Lc and Ld, contacts 20 and 21 engage contact bars 29 and 30 successively and contactors 2A and 3A operate, subject to the delays respectively of the timing contactors 1T and 2T as described, and the motor comes up to successively higher predetermined speeds on these points, respectively.

On to the fifth point of lowering, Le, contact 18 leaves contact bar 27, and contactor LB restores. Energization of the eddy current brake is cut off at contacts LB1, but leaving the friction brake B energized as described for hoisting.

On the fifth point lowering, also, the contact 23 engages contact bar 32 and maintains contactor 1BT operated, for the same purposes as in hoisting upon engagement of the contact bar 40 by the contact 23.

On the fifth lowering point, Le, of Fig. 1, the contact 18 leaves the bar 27, and predetermined speeds by energization of the eddy current brake EB is discontinued; the same as discontinuing predetermined speeds on hoisting when the contact 18 left the bar 35 on the third speed, as described.

Predetermined speeds are thus provided for on the first four lowering points only.

On the fifth lowering point Le, Fig. 1, contact 22 engages bar contact 31 and contactor 4A operates subject to delay of contactor 3T as described for hoisting.

The load on lowering may be a heavy load, and overhaul and drive the motor rotor; but the current in its secondary is still proportional to its speed; the signal current is inversely proportioned to its speed; and the eddy current brake action is directly proportional to its speed; and on the first four points of lowering hold the motor at the speeds predetermined for these respective points.

If the signal current were adjusted to be excessively high, to attain an excessively high predetermined speed, the current in the wires 107—108 would be very low, and in the winding 10 of the friction brake B it might not be enough to keep the brake B released.

Accordingly, in Fig. 1, means is provided to prevent the current going to the brakes, in wires 107—108, from ever being less than enough to keep the friction brake B released.

This means comprises a rectifier 92 having input from another secondary 97 of the transformer 95 and on output in wires 226 and 227 connected to the wires 107—108 respectively.

The output potential of the rectifier 92 is superimposed upon the wires 107—108 so that the current therein will always be maintained by the rectifier potential at a value sufficient to keep the brake B released no matter how high the signal current may be raised by adjustment.

From the foregoing it will be apparent that the predetermined speeds on the respective controller points, may be adjustably predetermined, to be higher or lower, by adjustably raising or lowering the signal current; and that at the maximum adjusted predetermined speed, the

current going to the winding 12 of the eddy current brake EB in wires 107—108 will be at the minimum to give minimum braking thereby.

Fig. 2 may be considered as illustrating a modification or further development of the embodiment of the invention of Fig. 1.

In view of the detailed description of Fig. 1, a briefer description will suffice and some of the parts being the same as in Fig. 1 have been given the same reference numerals as in Fig. 1 to identify them.

This form will have a drum controller not shown, and it will be the same as in Fig. 1.

A magnetic amplifier in two stages 72A and 72B is provided instead of the single stage amplifier 72 of Fig. 1.

The first amplifier stage 72A has input by wires 124 and 125 from a transformer 126 to main windings 146—147 and operates to deliver unidirectional output from output points 127—128 in response to energization of a compensating winding 129, a signal winding 130 and a reference winding 131; and the second stage amplifier 72B has input from a transformer 132 to main windings 76—77 and operates to deliver unidirectional output at output points 133—134 in response to energization of a bias winding 135 and a control winding 136; both amplifier stages operating generally in the same manner as the fully described amplifier 72 of Fig. 1.

At the first stage amplifier 72A, its signal winding 130 is continuously energized by current in wires 137—138 from the rectifier 93 which receives input in wires 98 and 99, derived from the current in rotor resistor R11; and the reference winding 131 is energized at constant value by current in wires 113A and 114 from the rectifier 91 through contacts LB2 and adjustable resistor 104, the rectifier 91 having input from the transformer 126, by wires 124—125; the reference winding 131 being poled in the same flux direction as the main windings 146—147; and the signal winding 130 being poled oppositely thereto, the reference winding always predominating.

The output of the first stage 72A goes from output points 127 and 128 by wires 139 and 140 to energize the control winding 136 of the second stage 72B; and the bias winding 135 of the second stage is continuously energized at constant value by current in wires 113 and 115 from rectifier 91, through contacts SB6 or 1BT1 and an adjustable resistor 105; the rectifier 91 having input from the transformer 126; the control winding 136 polarized in the same direction as the main windings 76—77, and the bias winding 135 poled in opposition thereto, the control winding 136 always predominating.

The output of the second stage 72B goes from output points 133 and 134 by wires 107—108 to energize the windings 10 and 12 of the friction brake B and eddy current brake EB through contacts SB1, SB5, LB5 and LB1, as described for Fig. 1.

All of the above mentioned contacts as well as the main line hoisting and lowering contacts H1, H2, H3; L1, L2, L3; and resistor contacts 1A1 to 4A2, are operated on hoisting and lowering as described for Fig. 1; and effect respective substantially constant predetermined speeds at all loads, on the first two hoisting points Ha, Hb and the first four lowering points La, to Ld, in the same manner, as in Fig. 1 but with the following particular features due to utilizing a two stage amplifier.

A tendency for the rotor 2 to increase in speed, reduces the signal current in the winding 130 of the first stage 72A and increases its output in wires 139—140 going to the control winding 136 of the second stage 72B; and this increases the output of the second stage 72B in wires 107—108 going to the winding 12 of the eddy current brake EB until increase of rotor speed is stopped at the predetermined speed.

The output of the first stage 72A is adjusted by adjusting the energization of the reference winding 131 by

the resistor 104, so that for the maximum of signal current, adjusted at the resistor 101 (as referred to for Fig. 1) the first stage output, going to control winding 136 of the second stage 72B, will always be great enough to give an output from the second stage great enough to keep the friction brake B released. Thus there is automatically a bottom limit to the output of stage 72B, determining a minimum braking action by the eddy current brake EB, and a maximum predetermined speed, and insurance that the friction brake B will be maintained released.

Furthermore, the two stages 72A and 72B provide in effect a double amplification of the signal current, to which the eddy current brake EB responds to maintain constant speed; rendering the response more sensitive to changes of motor speed, and maintaining the constant speed more nearly absolutely constant.

In Fig. 2, also the compensating winding 129 on the amplifier first stage 72A is energized in the same manner and for the same purposes as the compensating winding 78 of Fig. 1 by being connected by wires 143—144 across a resistor 145 in the path of the current in wires 107—108 going to the eddy current brake winding 12.

Fig. 3 may be considered as illustrating a modification of the embodiment of Fig. 1.

A brief description will suffice in view of the description of Fig. 1, and some of the parts being the same as in Fig. 1, have been given the same reference numerals as in Fig. 1 to identify them therewith.

This form will have a drum controller, not shown, and it will be the same as the controller 14 of Fig. 1, except that contacts SB5, LB5, SB6 and 1BT1 will not be used.

In this form the winding 10 of friction brake B is energized directly from main lines 4 and 5 by wires 226—227, through contacts SB1; and the winding 12 of the eddy current brake EB is energized directly from the amplifier output wires 107—108 through contacts LB1.

At the amplifier 72, the signal winding 79 and reference winding 81 are energized in the same manner and through the same contacts as in Fig. 1; but the bias winding 80 is permanently energized through resistor 105.

The compensating winding 78 is connected across the output wires 107—108 by wires 148—149 through a resistor 150; and is therefore energized proportionally to energization of the eddy current brake winding, with the same result as that of the compensating winding 78 described for Fig. 1.

The operation of the eddy current brake EB to maintain constant respective speeds of the motor rotor on the first two points of hoisting and the first four points of lowering is the same as that described for Fig. 1.

In this embodiment, Fig. 3, since the winding 10 of the friction brake B is energized across the lines 4—5, independently of the eddy current brake winding 12, adjustment to very high predetermined speeds, and corresponding reduction of energization of the winding 12 of the eddy current brake EB to low values cannot cause the friction brake to set as was referred to in the description of Fig. 1.

In Fig. 4 is illustrated an embodiment of the invention utilizing at 151 a non-rectifying magnetic amplifier of the type sometimes known as a saturable reactor, instead of the rectifying amplifiers of Figs. 1 to 3.

A drum controller 152 similar to that of Fig. 1, is provided. Some of the contacts in the part of the diagram above the controller, are the same and perform the same control functions as in Fig. 1 and have been given the same reference characters to identify them, whereby description will be simplified.

The controller 152 has movable contacts 153 to 160 all connected to line wire 3 by a wire 161; and a vertical common wire 162 is provided connected to the wire 161. Another vertical common wire 163 is connected to the line wire 4 by a wire 164; providing an across-the-line type of diagram comprising cross lines 165 to 178.

The controller contacts 153 to 160 are movable to five hoisting positions Ha to He to variously engage stationary bar contacts 179 to 185; and to five lowering positions La to Le to variously engage stationary bar contacts 186 to 192.

Magnetic contactors H, L, SB, LB, 1A to 4A, and timing contactors 1T to 3T are provided operating and functioning generally as in Fig. 1; and timing contactors 1BT and 3BT are provided, all delaying operation of their contacts when their windings are first energized.

The cross lines 165 to 178 are energized from the main lines 3 and 4, cross lines 169 and 174 to 178 being connected directly between the common wires 162 and 163; and the other cross lines by being connected to common wire 163 and to main line 3 through the controller contacts.

It is believed that the operation and restoring of the contactors by the controller will be understood from a brief description in view of the more complete description of the similar controller of Fig. 1.

With the controller in the illustrated off position, and when current is first supplied to main lines 3, 4, 5 by closing a line switch 193 in the usual manner, all of the cross lines 165 to 178 are de-energized except 169 and 178.

Current flows in cross line 169 through contacts 3BT1 and SB5 and operates contactor LB; and current flows in cross line 178 through contacts SB6 and operates contactor 3BT; and as soon as contactor 3BT runs its delay interval, it opens contacts 3BT1, which restores contactor LB, to normal off position condition.

Thus with the controller in the off position, all cross lines except 178 are de-energized and all contactors restored as illustrated except 3BT.

The saturable reactor 151 has a core with central legs 194 and a reference winding 196 opposed by a signal winding 195 thereon; and side legs 197—198 with main windings 199 and 200 thereon respectively.

The main windings 199—200 are supplied with alternating input current from a transformer 201, the current flowing through winding 199, a wire 202 and winding 200 and by wire 203 to a loop rectifier 204, thence, through a wire 205, contacts SB4, a two part resistor 206, contacts LB4 and by wire 207 to the rectifier 204 and thence through wire 208 back to the transformer 201; the current in wires 205 and 207 being unidirectional. The wires 205 and 207 may be referred to as a brake winding circuit.

The reference winding 196 is connected in a circuit 211—212 to be energized at constant value with unidirectional current from a transformer 209 through a loop rectifier 210, and through contacts SB2 and LB2 and adjustable resistors 213—214; but in the off position here considered is unenergized, contacts SB2 and LB2 being open.

The signal winding 195 is connected in a circuit 215—216, to be energized with unidirectional current through a loop rectifier 218, receiving input from the potential drop across motor resistor R12, and through contacts 1BT1 and an adjustable resistor 217; but in the off position here considered is unenergized, contacts 1BT1 being open.

As in the embodiment of Fig. 1 there are two hoist points Ha and Hb and four lowering points La to Ld on the controller 152 on which the motor runs at predetermined respective speeds, as follows.

On going to first hoist point Ha, cross line 166 is energized through contact 154, bar 180, and contacts L5; and contactor H is operated, giving main line current to the motor at contacts H1 to H3.

Cross line 165 is energized through contact 153, bar contact 179 and bar contact 186, and contacts H4 and operates contactor SB.

Cross line 178 is then de-energized at contacts SB6 and contactor 3BT restores closing contacts 3BT1, which are in cross line 168—169, and contactor LB operates,

by current through contact 156, bar contacts 181 and 188, and contacts 3BT1.

In the upper part of the diagram, contacts LB2 close, and reference winding 196 is energized through resistor 214 alone, to a high value, resistor 213 being bridged by contacts LB2.

Energization of the reference winding 196 causes the reactor 151 to give high output in the brake circuit 205—207; and contacts SB1 and LB1 both being closed, both brake windings 10—12 are energized in series, and the friction brake B is quickly and positively released for the motor to start.

The reference winding 196 continues to be energized through resistance 214 alone, contacts LB2 remaining closed.

Also at the controller, cross line 177 is energized through contacts LB3 and operates contactor 1BT, and after its interval it closes contacts 1BT1.

In the upper part of the diagram when contacts 1BT1 close, the signal control winding 195 is energized by wires 215—216, connected to the output of rectifier 218 as referred to, through adjustable resistor 217.

The signal winding 196 then opposes the reference winding 195 and the output to the brake circuit decreases to an operating value, but enough to keep the brake B released.

The rotor starts and rotates at increasing speed; the signal current decreases, and in signal winding 195 decreasingly opposes the reference winding 196 and the current in wires 203—208 and in the brake winding circuit 205—207 increases and increases the braking action of the eddy current brake EB.

The rotor then comes up to a predetermined speed and no higher, for this point of the controller.

Also on the first hoist point Ha, cross line 170 was energized through contact 157, bar contact 182, bar contact 189 and contacts SB3, and contactor 1A operated without delay, cutting out rotor resistance sections R5, R10, R15 and closing contact 1A3 in cross line 174, and thereby operating contactor 1T and closing contact 1T1 after delay.

At this point herein it is interjected that upon going back to off position at any time during operation, contactor SB will restore; as will be understood. In cross line 169, SB5 and 3BT1 are closed and maintain contactor LB operated; and in the braking circuit 205—207 contacts SB1 are open and SB4 closed, LB4 open and LB1 closed. The brake B is cut off and sets; and the eddy current brake EB is energized through the upper part of resistor 206.

The signal current in winding 195 dies out when contactor H or L is restored and winding 196 is energized strongly through contacts LB2 and resistor 214; so that high output to the eddy current brake is maintained.

In cross line 178, contactor 3BT is energized and starts to run its interval.

At the end of the interval it opens contacts 3BT1, which restores contactor LB, and the parts all go to normal off condition, but during this interval the eddy current brake EB is acting jointly with the friction brake B to quickly bring the motor to rest.

Upon going to the second hoist point Hb, cross line 171 is energized through contact 158, bar contact 183, bar contact 190 and contacts 1T1, operating contactor 2A, cutting out rotor resistance sections R4, R9, and 14 increasing the motor speed.

The circuit conditions in the upper part of the diagram remain the same as on first hoist point Ha, but now the signal current in the signal winding 195 falls to a lower value and the current in the brake winding circuit 205—207 increases, increasing the braking action of the eddy current brake EB and the motor comes up to a higher predetermined speed for this controller point.

On going to the third hoist point, contact 156 leaves bar contact 181 and contactor LB restores by de-energiza-

tion of cross line 168, and by contacts SB5 being open in cross line 169; and this interrupts the braking action of the eddy current brake, energization of its winding being opened at contacts LB1.

Current in the braking circuit 205—207 then goes through contacts SB1 and the winding 10 of brake B, and through the lower part of resistor 206, and through LB4 keeping the brake B released.

In cross line 177, contactor 1BT is restored by opening of contacts LB3, and contacts 1BT1 open, and the signal circuit 215—216 to the signal winding 195 is opened at contacts 1BT1.

This leaves the reference winding 196 energized alone and its energizing current in circuit 211—212 is cut down by the opening of contacts LB2, contacts SB2 remaining closed, and by thereby introducing both resistor 213 and 214 into the circuit; thereby energizing the winding 10 of brake B with reduced amplifier output, and avoiding excess current to the winding.

On going to any of the first four lowering points of Fig. 4, contact 156 will be on bar contact 188 and the operation will be the same as on the first two hoisting points above described, with contact 156 on bar contact 181; that is, the motor will come to predetermined respective constant speeds on these four points of lowering, by action of the eddy current brake EB.

On lowering however these constant predetermined speeds are in general made lower speeds than those on hoisting, as follows.

On hoisting as described, contactors 1A and 2A, operated on the first and second hoist points to cut out rotor resistance and speed up the motor; by controller contacts 157 and 158 coming on to bar contacts 182 and 183.

On lowering, contactors, 1A and 2A are not operated on the first and second points, but on the second and third points by contacts 157 and 158 coming on bar contacts 189 and 190; and contactor 3A is operated on the fourth lowering point.

After the contact 156 leaves the bar contact 188 to go to the fifth point lowering, the constant speed control is interrupted in the same way that it was interrupted on hoisting when the contact 156 left the bar contact 181 to go to third point hoisting; with the same operative results.

In Fig. 4, the value of the signal current in winding 195 can be adjusted at the resistor 217 to adjust its opposition to the winding 196 and thereby adjust the constant predetermined speed on the controller points.

On the succeeding hoist points; the contactors 3A and 4A operate and cut out corresponding resistance sections under control of the timing contactors 2T and 3T under the judgement of the operator, as explained for Fig. 1.

In this embodiment, Fig. 4, a resistor 221 is connected by wires 222—223, across the main windings 199 and 200 of the amplifier and provides a current path in parallel with the path of the output current from the amplifier in wires 203 and 208, which supply rectified current through the rectifier 204 to the brake windings 10 and 11 in series.

A fixed value of supplemental current through the resistor 221 will therefore flow through the brake windings in series and be maintained at constant value, independently of variations of the brake winding current from the amplifier.

A value is chosen for the resistor 221 such that this supplemental current will always be sufficient in the winding 10 of the friction brake, to keep it released, no matter how low the output of the amplifier is adjusted by adjusting the signal current for higher predetermined speeds.

In Fig. 5 is shown a modification of Fig. 4. There will be a controller, not shown, but it will be the same as the controller 152 of Fig. 4 except that contacts SB4, LB4; SB2 will not be used.

In this embodiment, similarly to that of Fig. 3, the

winding 10 of the friction brake B is energized directly from the main lines 4—5, by wires 226—227 through contacts SB1.

The winding 12 of the eddy current brake EB is energized from the amplifier output wires 203—208 through rectifier 204, and by wires 224—225 through contacts LBI.

The operation of Fig. 5 will be the same as that of Fig. 4 except that, upon adjustment to very high predetermined speeds, thereby reducing energization of the winding 12 of the eddy current brake EB to low values, the friction brake B is prevented from setting as was first referred to herein in connection with Fig. 1 by being energized independently of the eddy current brake winding 12 instead of in series with it as in Fig. 4, and the supplemental current to energize the friction brake through a resistor such as 221 in Fig. 4 is not needed.

We claim:

1. In a hoist control system, a hoist motor comprising a rotor; an eddy current brake connected with the rotor and having a winding and exerting braking action on the rotor commensurable with the degree of energization of the brake winding; a normally set friction brake connected with the rotor and having a winding to release it when energized and connected in series with the eddy current brake winding; a magnetic amplifier having main winding means supplied with current from a source and delivering output current therethrough to output mains energizing the two brake windings; a control winding on the amplifier; a control actuated in response to changes of rotor speed and changing the energization of the control winding to correspondingly change the output; means for adjusting energization of the control winding to adjustably reduce the output in the output mains to a low value insufficient to maintain the friction brake released; and a bypass across the main winding means containing a resistor and shunting current from the source directly to the output mains of sufficient value to maintain the friction brake released.

2. In a hoist system, a hoist motor having a rotor, an eddy current brake connected with the rotor and having a winding and exerting braking action on the rotor commensurable with the degree of energization of the winding; a normally set friction brake connected with the rotor and having a winding to release it when energized; the two brake windings connected in series, in a brake circuit; a magnetic amplifier having main windings supplied with current from a source and connected to deliver output current therethrough to the brake circuit; the amplifier having a reference control winding polarized to increase the amplifier output; and having a signal control winding polarized to oppose the reference winding; operable contacts and circuits controlled thereby, to supply source current to the motor and to energize the reference winding alone to cause the amplifier to deliver high output to the brake circuit to positively and quickly release the friction brake to let the motor start; connections automatically energizing the signal winding circuit, after a time interval following energization of the reference winding, inversely commensurably with the speed of the motor to cause the output to vary and to energize the brake circuit directly commensurably with speed of the motor; operable contacts and circuits controlled thereby to interrupt energization of the eddy current brake winding while leaving the friction brake winding energized; and to interrupt energization of the signal winding, and connections then automatically reducing energization of the reference winding.

3. In a hoist system, a hoist motor having a rotor, an eddy current brake connected with the rotor and having a winding and exerting braking action on the rotor commensurable with the degree of energization of the winding; a normally set friction brake connected with the rotor and having a winding to release it when energized; the two brake windings connected in series, in a brake

circuit; a magnetic amplifier having main windings supplied with current from a source and connected to deliver output current therethrough to the brake circuit; the amplifier having a reference control winding polarized to increase the amplifier output; and having a signal control winding polarized to oppose the reference winding; operable contacts and circuits controlled thereby, to supply source current to the motor and to energize the reference winding alone to cause the amplifier to deliver high output to the brake circuit to positively and quickly release the friction brake to let the motor start; connections automatically energizing the signal winding circuit, after a time interval following energization of the reference winding, inversely commensurably with the speed of the motor to cause the output to vary and to energize the brake circuit directly commensurably with speed of the motor; operable means to adjustably increase the energization of the signal winding to correspondingly decrease the output to the brake circuit; and a circuit containing resistance bridging the main windings of the amplifier and supplying a constant predetermined value of current to the brake circuit to prevent energization of the brake circuit to a value low enough to allow the friction brake to set.

4. In a hoist control system comprising a hoist motor having primary and secondary circuits, said secondary circuit including an adjustable resistor; an eddy current brake connected with the motor and having a winding and exerting braking action on the motor commensurable with the degree of energization of the winding; a normally set friction brake connected with the motor and having a winding to release it when energized; the two brake windings connected in series in a brake circuit; a magnetic amplifier having main windings supplied with current from a source and connected to deliver output current therethrough to the brake circuit, the amplifier having a predominating reference control winding, and a signal control winding to oppose the reference control winding; operable contacts and circuits controlled thereby, to supply source current to the motor and to energize the reference control winding alone to cause the amplifier to deliver high output to the brake circuit to release the friction brake; connections automatically energizing the signal control winding directly commensurable with the current in the secondary circuit resistor after a time interval following energization of the reference control winding and to cause the amplifier output to vary and to energize the brake circuit directly commensurably with the speed of the motor.

5. A hoist control system as in claim 4, and having a circuit containing resistance bridging the main windings of the amplifier to supply a constant pre-determined value of current to the brake circuit to prevent energization of the brake circuit to a value low enough to allow the friction brake to set.

6. A hoist control system as in claim 4, and having means to maintain the eddy current brake winding energized for a predetermined time interval, after the operable contacts are restored and remove current from the motor and allow the friction brake to set, whereby both brakes brake the motor during the said interval.

7. In an electric hoist system, a hoist motor connected to supply mains and comprising a rotor having an external circuit comprising resistors, in which current decreases and increases upon increase and decrease of the rotor speed; an eddy current brake having a brake rotor connected with the motor rotor to be driven thereby and having an energizing winding and exerting braking action on the motor rotor in accordance with energization of the winding; a normally set friction brake connected with the motor rotor and having a winding to release it when energized; the two brake windings connected in series; control means comprising a magnetic amplifier energized from supply mains and having an output energizing the brake windings, the amplifier having a reference wind-

ing and an opposing signal winding, the reference winding being energized at a constant value and poled to increase the amplifier output, the signal winding connected to be variably energized by a variable drop of potential in the resistors upon decrease and increase of current in the external rotor circuit to correspondingly increase and decrease the amplifier output and means of impressing on the brake windings at all times a constant supplemental potential to maintain the friction brake released when the amplifier output decreases to a value insufficient to maintain it released.

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