United States Patent [19]

Stone et al.

[11] **3,772,579**

[45] **Nov. 13, 1973**

[54] **CONTROL MEANS FOR HIGH SPEED HOIST**

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[73] Assignee: **Harnischfeger Corporation,** W. Milwaukee, Wis.

[22] Filed: **Sept. 11, 1972**

[21] Appl. No.: **287,706**

[52] **U.S. Cl.** .... **318/203 R,** 318/204, 318/209
[51] **Int. Cl.** **H02p 1/40**
[58] **Field of Search** 318/201, 203, 204, 318/209

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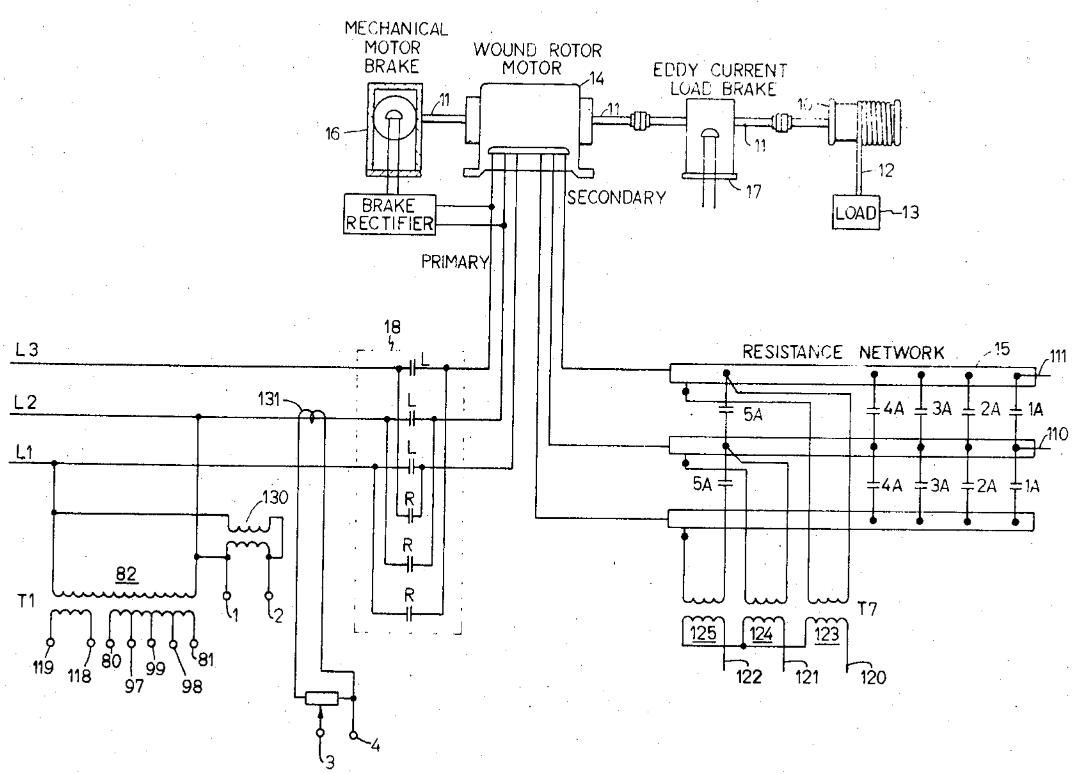
Primary Examiner—Gene Z. Rubinson
Attorney—James E. Nilles

[57] **ABSTRACT**

A control means for a high speed electric hoist or crane having an induction motor permits motor operation in the "raise" or "lower" direction at controlled speeds up to full load hoisting speed (i.e., the approximately synchronous speed of the motor). The control means also permits the motor to operate automatically in the "lower" direction so as to differentiate between a "light" and a "heavy" load and to allow a light load to free fall up to 275 percent of motor synchronous speed but forcing a heavy load to be lowered normally at a restrained speed of about 100 percent of motor synchronous speed.

8 Claims, 10 Drawing Figures



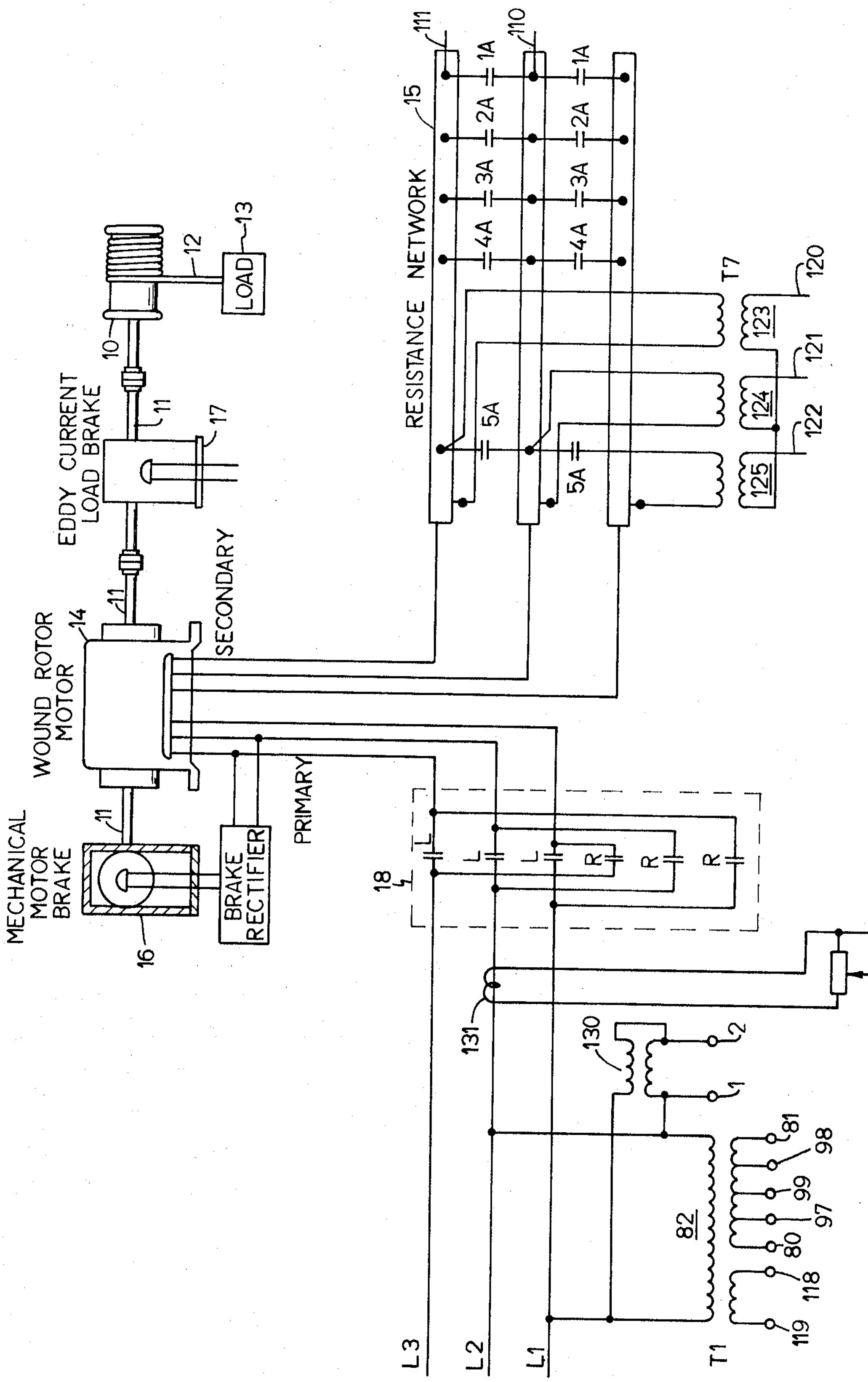

RESISTANCE NETWORK
15
111
110
1A
2A
3A
4A
5A
T7
120
121
122
123
124
125
LOAD
13
12
10
EDDY CURRENT LOAD BRAKE
11
17
WOUND ROTOR MOTOR
14
SECONDARY
PRIMARY
MECHANICAL MOTOR BRAKE
16
BRAKE RECTIFIER
18
L
R
4
3
131
130
2
1
81
98
99
97
80
82
118
119
L3
L2
L1
T1

FIG. 1 (SHEET 1)

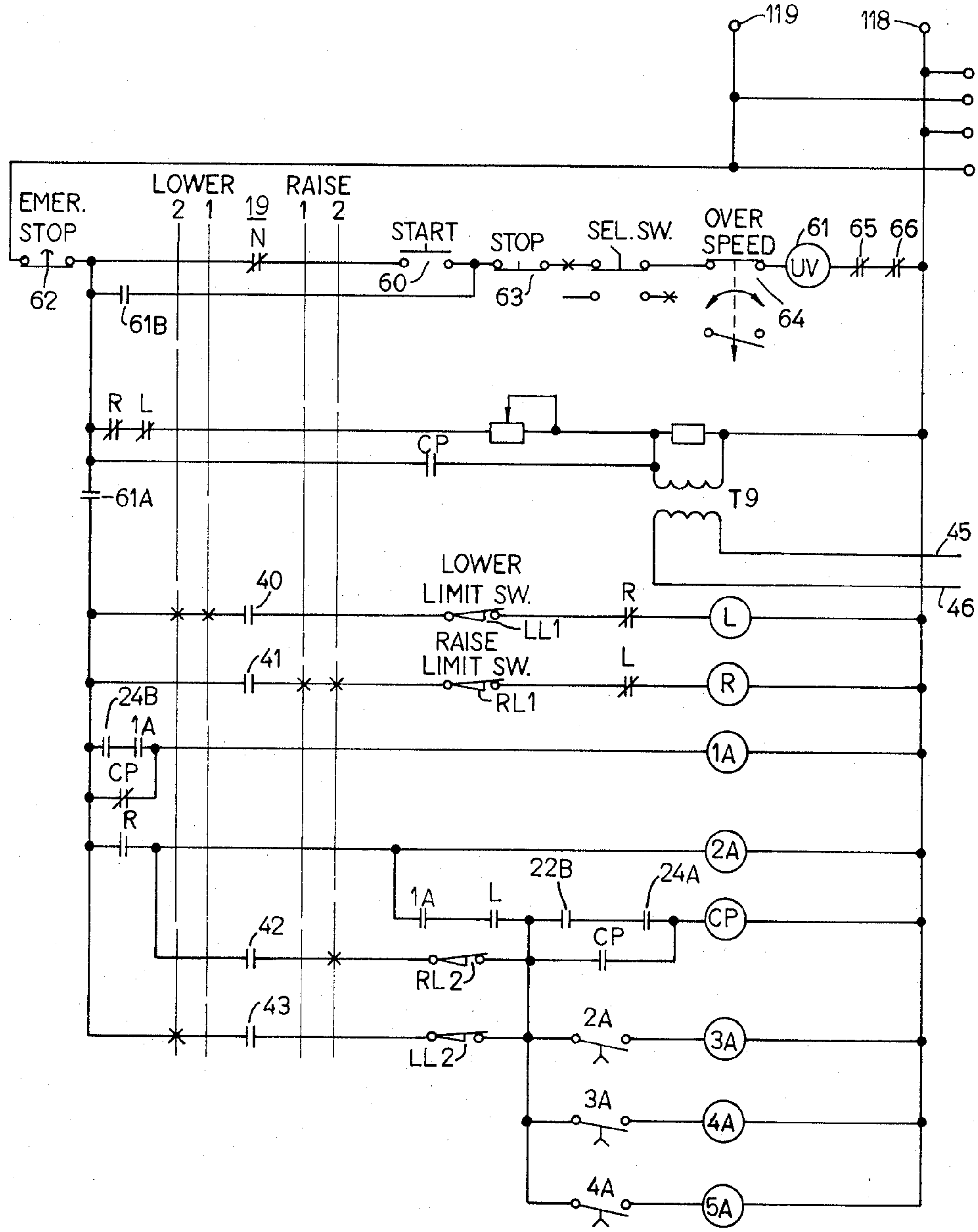

119
118
EMER. STOP
62
LOWER
2 1
19
N
RAISE
1 2
START
60
STOP
63
SEL. SW.
OVER SPEED
64
61
UV
65
66
61B
R L
CP
61A
T9
45
46
40
LOWER LIMIT SW.
LL1
R
L
41
RAISE LIMIT SW.
RL1
L
R
24B
1A
CP
1A
R
2A
22B
24A
1A
L
CP
42
RL2
CP
43
LL2
2A
3A
3A
4A
4A
5A

FIG. 1 (SHEET 2)

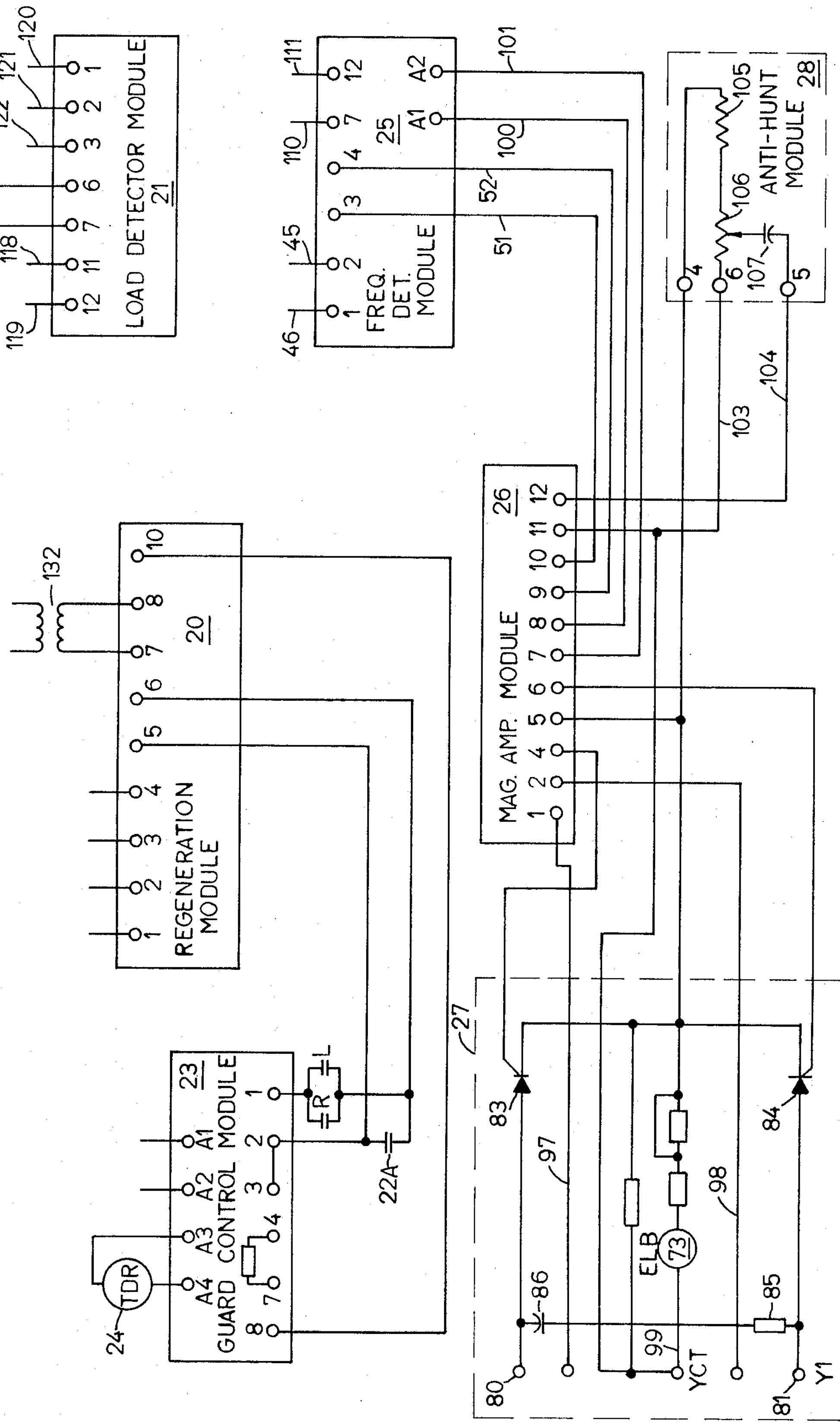

LOAD DETECTOR MODULE 21
FREQ. DET. MODULE
25
ANTI-HUNT MODULE 28
MAG. AMP. MODULE 26
REGENERATION MODULE
20
GUARD CONTROL MODULE 23
TDR
ELB
YCT
Y1

FIG. 1 (SHEET 3)

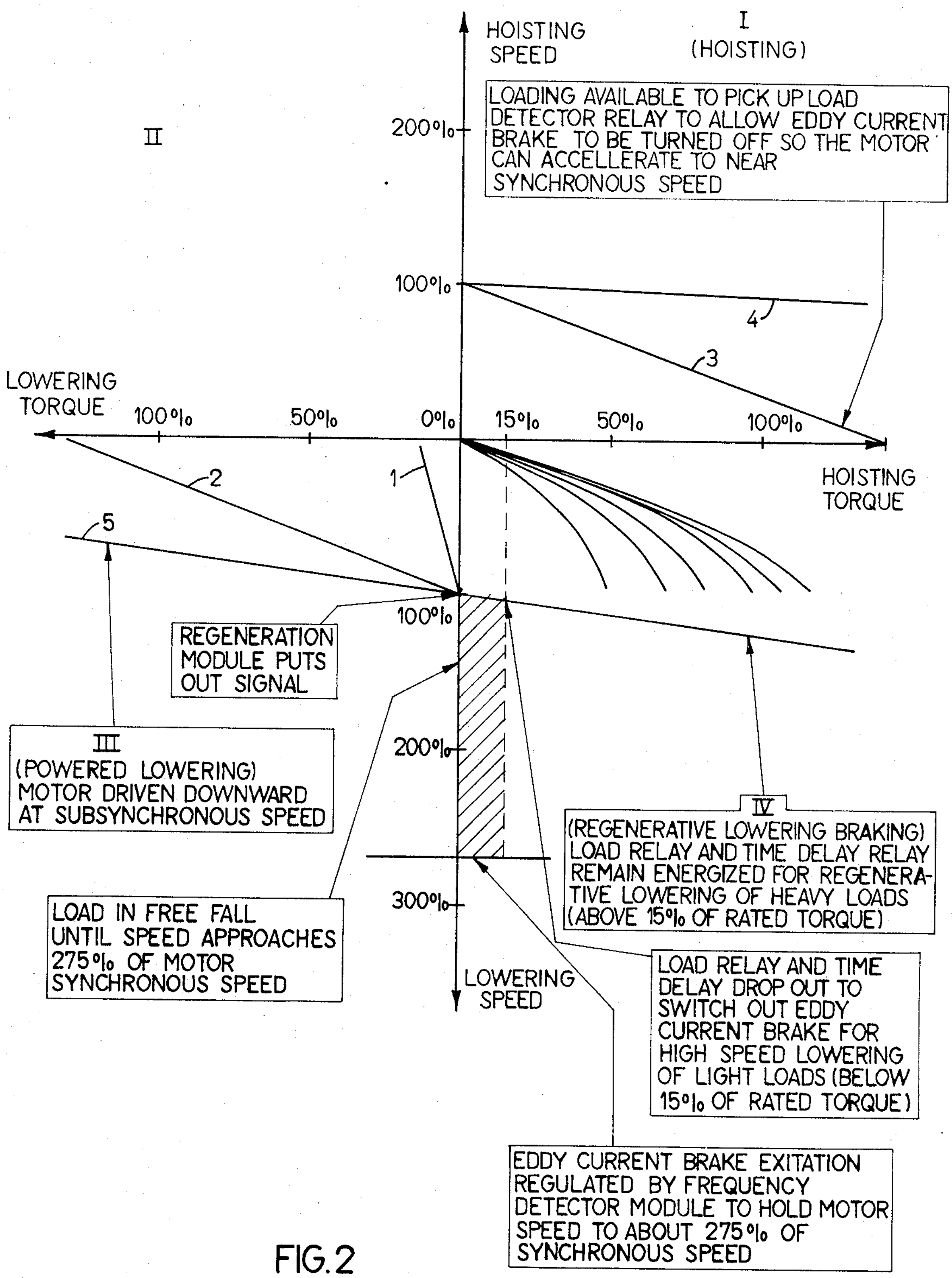
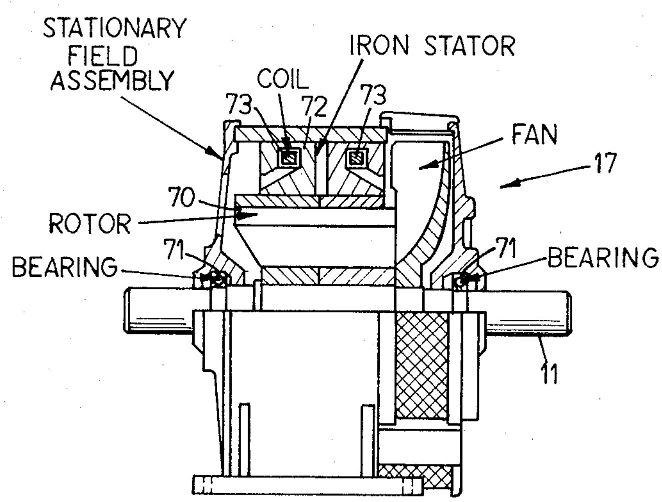
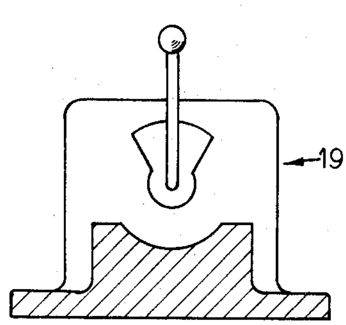

HOISTING SPEED
I
(HOISTING)
LOADING AVAILABLE TO PICK UP LOAD DETECTOR RELAY TO ALLOW EDDY CURRENT BRAKE TO BE TURNED OFF SO THE MOTOR CAN ACCELLERATE TO NEAR SYNCHRONOUS SPEED
II
200%
100%
4
3
LOWERING TORQUE
100%
50%
0%
15%
50%
100%
HOISTING TORQUE
2
1
5
REGENERATION MODULE PUTS OUT SIGNAL
100%
III
(POWERED LOWERING)
MOTOR DRIVEN DOWNWARD AT SUBSYNCHRONOUS SPEED
200%
IV
(REGENERATIVE LOWERING BRAKING)
LOAD RELAY AND TIME DELAY RELAY REMAIN ENERGIZED FOR REGENERATIVE LOWERING OF HEAVY LOADS (ABOVE 15% OF RATED TORQUE)
300%
LOAD IN FREE FALL UNTIL SPEED APPROACHES 275% OF MOTOR SYNCHRONOUS SPEED
LOWERING SPEED
LOAD RELAY AND TIME DELAY DROP OUT TO SWITCH OUT EDDY CURRENT BRAKE FOR HIGH SPEED LOWERING OF LIGHT LOADS (BELOW 15% OF RATED TORQUE)
EDDY CURRENT BRAKE EXITATION REGULATED BY FREQUENCY DETECTOR MODULE TO HOLD MOTOR SPEED TO ABOUT 275% OF SYNCHRONOUS SPEED

FIG. 2



EDDY CURRENT LOAD BRAKE

FIG. 5



MASTER CONTROL SWITCH (OFF POSITION)

FIG. 3

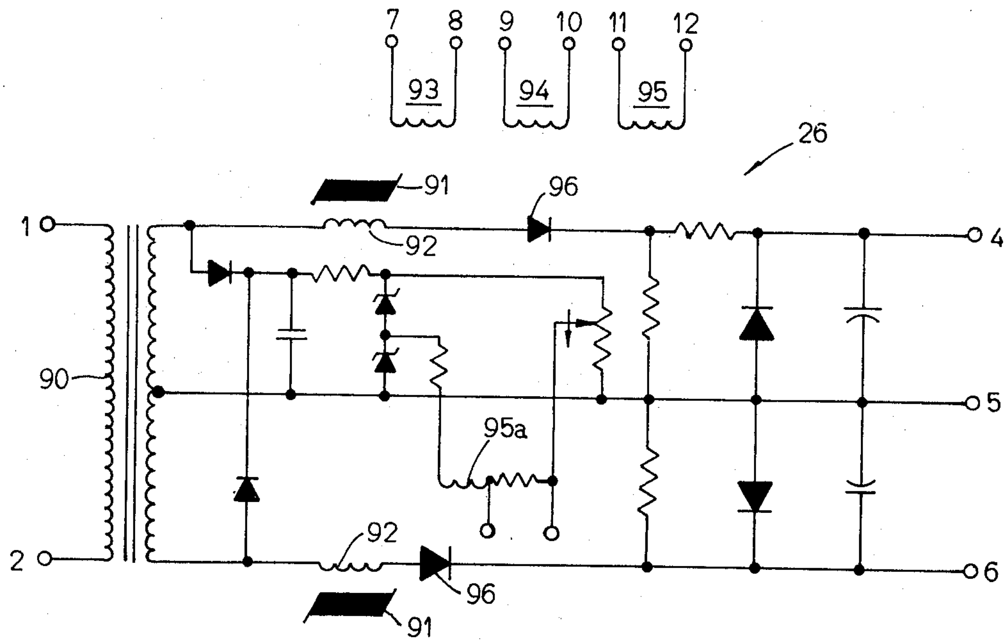

7
8
9
10
11
12
93
94
95
26
91
96
1
92
4
90
5
95a
2
92
96
6
91

FIG. 7

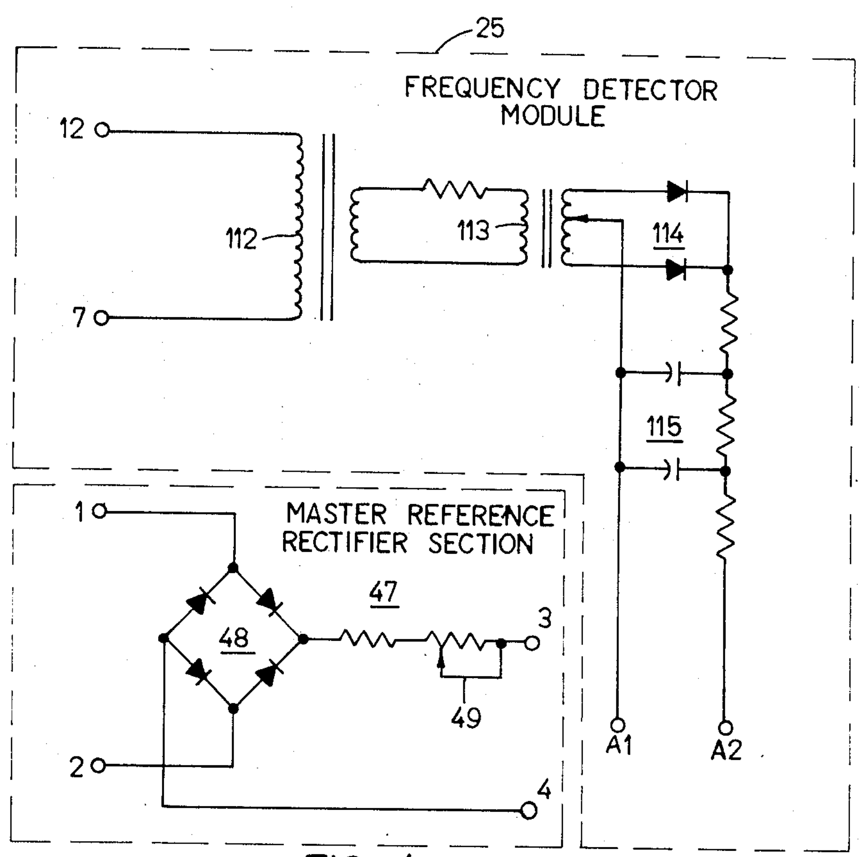

25
FREQUENCY DETECTOR MODULE
12
112
113
114
7
115
MASTER REFERENCE RECTIFIER SECTION
1
47
3
48
49
A1
A2
2
4

FIG. 4

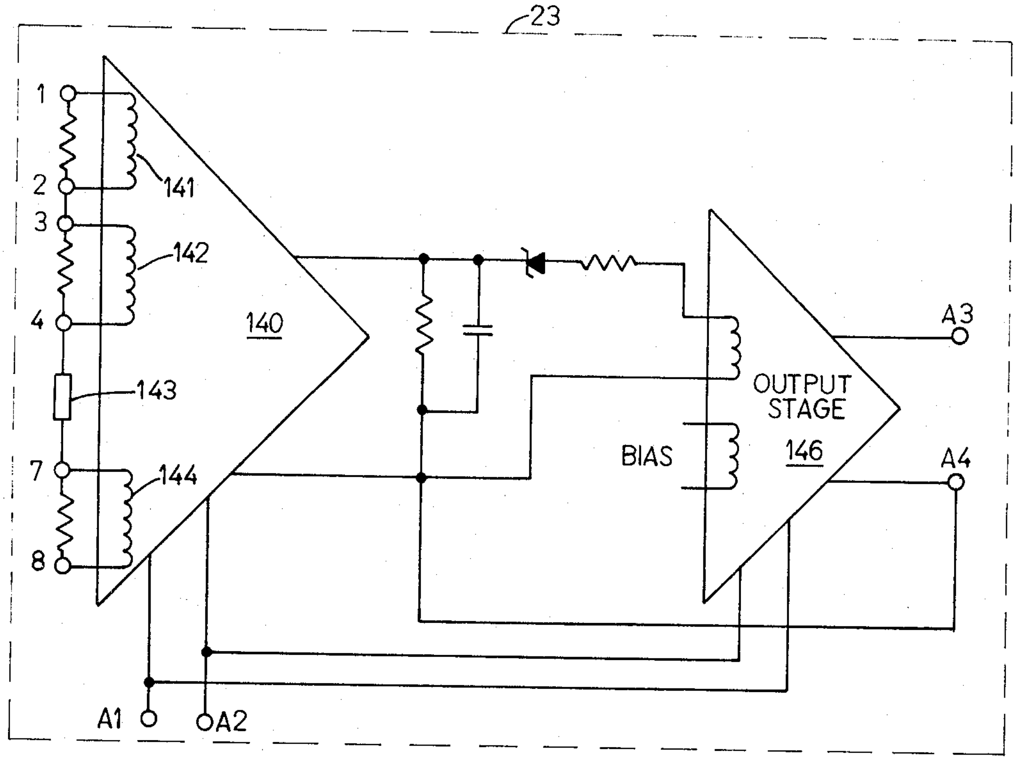
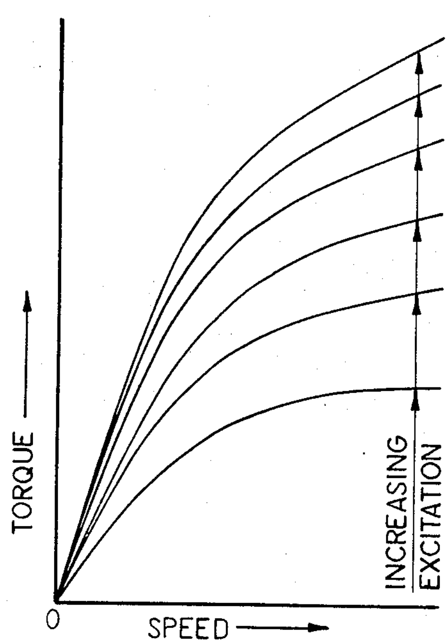


FIG. 10



LOAD BRAKE SPEED-
TORQUE CHARACTERISTICS

FIG. 6

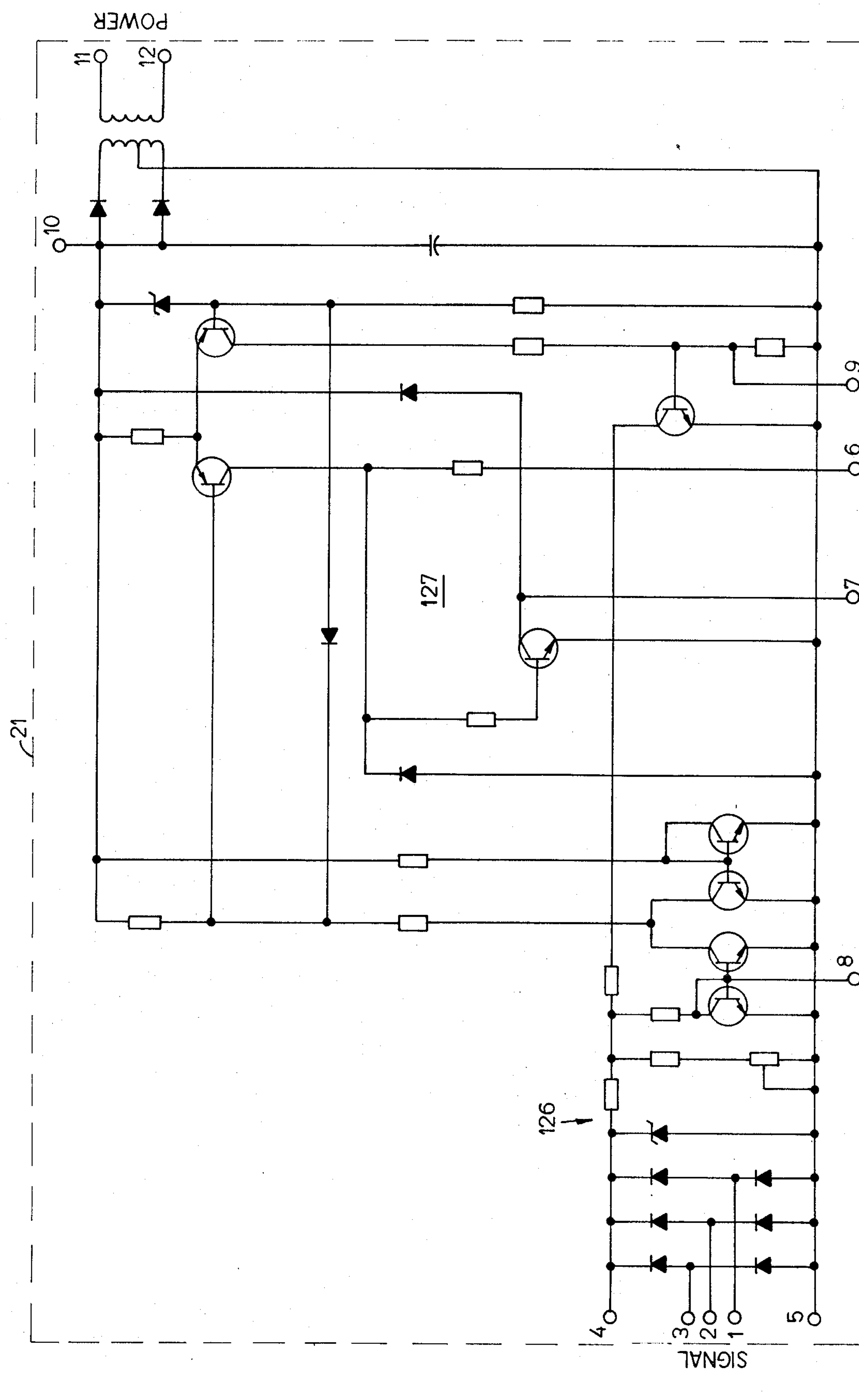


FIG. 8

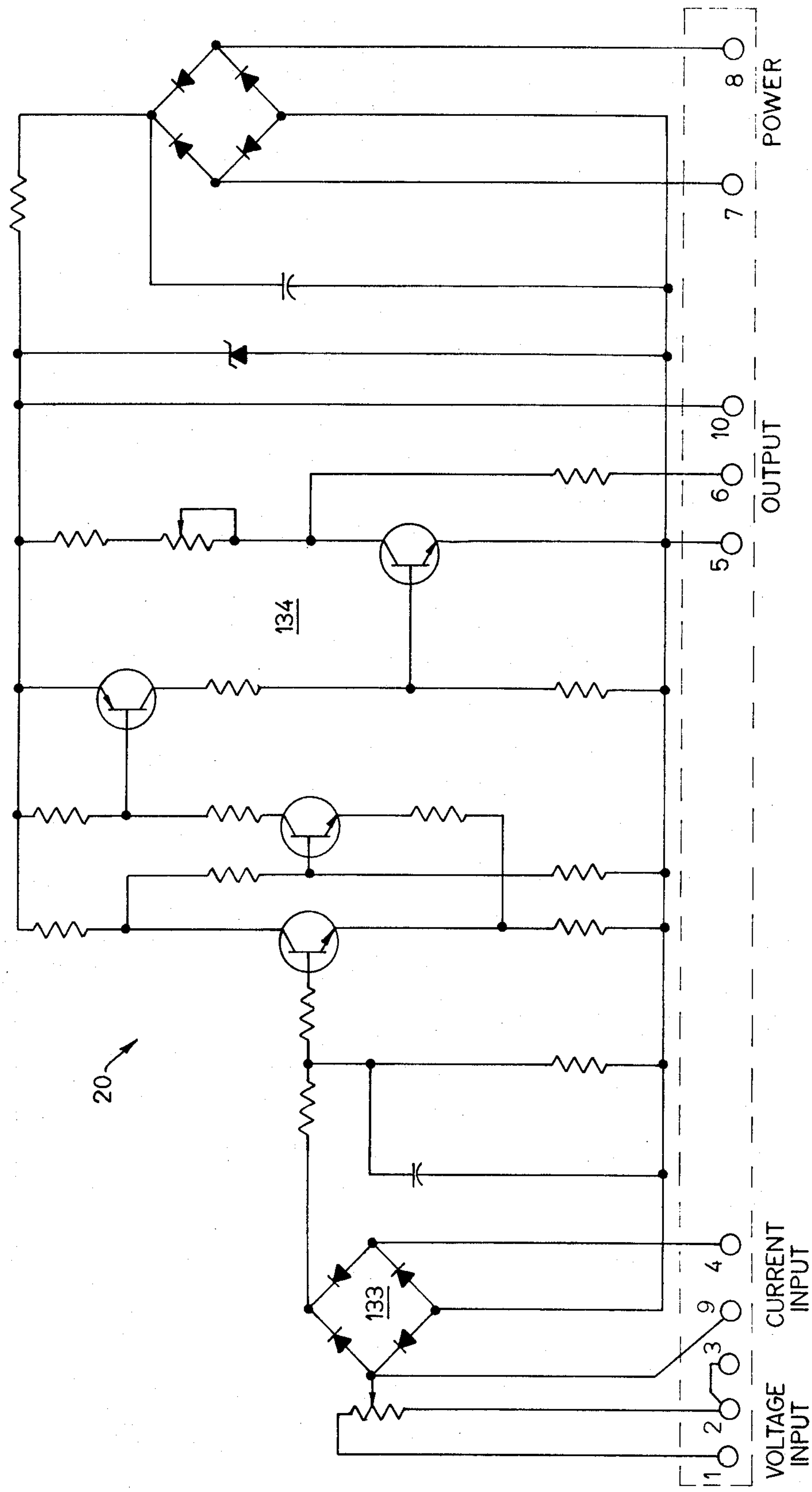

POWER
8
7
OUTPUT
10
6
5
134
133
20
CURRENT INPUT
4
9
3
VOLTAGE INPUT
2
1

FIG. 9

CONTROL MEANS FOR HIGH SPEED HOIST

BACKGROUND OF THE INVENTION

1. Field of Use

This invention relates to control means for hoists or cranes which effect controlled "raise" and "lower" operations and also effect automatic high speed "lower" operation at two different speeds under light and heavy loads.

2. Description of the Prior Art

High speed AC electric hoists used, for example to transport concrete buckets to pouring levels on high rise buildings must operate at the highest rate of speed possible consistent with safety requirements. Heretofore, such hoists had control means to effect controlled "raise" and "lower" operations up to a certain speed (full load hoisting speed) and automatic high speed "lower" operation at some single speed well in excess of that speed. Such control means, when operating in automatic high speed "lower", did not distinguish speedwise between light or heavy loads. Thus, the braking means brought into play to maintain constant high speed lowering tended to be potentially less effective when heavy loads were involved and increased the danger of a runaway load.

SUMMARY OF THE PRESENT INVENTION

The present invention contemplates a high speed hoist comprising a hoist drum on a shaft driven by an AC electric motor. The hoist control means include an electrically operable mechanical brake for the hoist drum (i.e., motor shaft), a magnetic or eddy current brake coupled to the shaft, and an electric controller for operating the motor, the mechanical brake and the magnetic brake.

The hoist control means permits motor operation in the "raise" or "lower" direction at controlled speeds up to full load hoisting speed (i.e., the approximately synchronous speed of the motor). The control means also permits the motor to operate automatically in the "lower" direction so as to allow an empty bucket to free fall up to 275 percent of full load hoisting speed. However, any heavier load that cannot be safely handled at this high speed will be restrained to about 100 percent of full hoisting speed.

The electric controller of the control means comprises certain components or modules which come into play during "raise" and "lower" operation of the motor and during lightly-loaded or heavily loaded "lower" conditions, namely, a load detector module including a load detector relay, a regeneration module, a magnetic brake guard control module including a time delayed relay, a frequency detection module, a magnetic amplifier module, a controlled rectifier module, and an antihunt module. The time delayed relay and guard control module together, in effect, constitute a time delay relay.

The hoist control means operates as follows. Before electric power is applied, the motor shaft is held stationary by the mechanical brake. After electric power is applied, the magnetic brake is energized to an "off position" level to exert a nominal retarding torque to the motor shaft if it should move to prevent its runaway should the mechanical brake fail in operation. When electric power is applied to operate the motor in low-speed "raise" or "lower" directions, the mechanical brake releases and excitation of the magnetic brake means increases from the "off position" level to a "maximum" level. The stall motor torque is normally 10 percent for lowering and 140 percent for hoisting. When the motor is operated at full-speed "raise" or "lower", permissive interlocking functions are carried out by the controller as follows. The load detector module senses when the motor delivers **15** percent or more of full load torque and the load detector relay picks up (this relay also drops out at slightly lesser torque, i.e., 12 to 13 percent). The regeneration module senses when the motor exceeds synchronous speed and provides a control signal. The magnetic brake guard control module causes its time delayed relay (normally picked up) to drop outafter a short time delay in response to receiving both the control signal from the regeneration module and drop out of the load detector relay.

The net functional result of the operation of these modules is as follows. In the slow "raise" or slow "lower" conditions, the motor accelerates, stabilizes at a slow speed and continues running until stopped by the operator or by limit switches. In the full speed "lower" condition, stabilization of motor speed will occur at a running point which will be in one of three general conditions, namely: sub-synchronous (driving a light load down); restrained fall at 100 percent of hoisting speed with a heavy load causing the motor to regenerate more than 15 percent of full load torque; or free fall to 275 percent of full load hoisting speed and then controlled with a light load causing the motor to regenerate less than 15 percent of full load torque. If full speed "raise" is selected, the motor will be accelerated only if the time delay relay and load detector relay are picked up. The motor will continue until there is operator or limit switch intervention.

All three of these lowering conditions are stable and will continue until the motor is slowed or stopped by the operator or by limit switches which effect progressive slow down and stopping of the motor and simulate the effect of the operator's return of a master control switch toward neutral position.

In condition (1), the load detector relay may drop out, but nothing else.

In condition (2), the load detector relay drops out. The regeneration module provides a control signal at synchronous speed, but before the time delayed relay drops out, the load detector relay picks up again. Therefore, the time delayed relay remains picked up.

In condition (3), the load detector relay drops out. The regeneration module turns on at synchronous speed and, since the load detector relay does not pick up again, the time delayed relay eventually drops out. This causes all motor accelerator contacts to open and, with the secondary winding of the motor open, the motor exerts no torque and the secondary voltage and frequency is applied to the frequency detector module. The light load is then in free fall, restrained only by friction, windage and mass. When it accelerates to approximately 270 percent of full load hoist speed, the frequency detector module provides an output signal which starts to increase the magnetic brake excitation and the motor speed stabilizes at about 275 percent of full load hoisting speed.

DRAWINGS

FIG. 1 (sheets 1, 2 and 3) is a schematic diagram of a hoist and control means therefor in accordance with the invention;

FIG. 2 is a graph wherein motor speed is plotted against motor torque under various operating conditions, as described in legends on the graph;

FIG. 3 is a side view of the master control switch shown schematically in FIG. 1;

FIG. 4 is a diagrammatic view of the frequency detector module shown in FIG. 1 and includes details of a master reference rectifier;

FIG. 5 is a cross-section view of the magnetic or eddy current load brake shown in FIG. 1;

FIG. 6 is a graph showing the speed-torque characteristics of the magnetic load brake shown in FIGS. 1 and 3;

FIG. 7 is a diagrammatic view of the magnetic amplifier module shown in FIG. 1;

FIG. 8 is a diagrammatic view of the load detector module shown in FIG. 1;

FIG. 9 is a diagrammatic view of the regeneration module shown in FIG. 1; and

FIG. 10 is a diagrammatic view of the guard control module shown in FIG. 1;

DESCRIPTION OF A PREFERRED EMBODIMENT

General Arrangement and Operation

FIG. 1 (sheet 1) shows a hoist comprising a hoist drum 10 on a shaft 11 with a cable 12 to which a load 13 is attached. Shaft 11 is driven by a wound rotor induction motor 14 having primary and secondary windings. A variable resistance network 15 including accelerator contacts is connected to the motor secondary windings. A spring applied electrically releasable mechanical holding brake 16 is provided for shaft 11. An eddy current or magnetic load brake 17 is also provided for motor shaft 11. The primary of motor 14 is connectible for hoist and lower operation to an electrical power source comprising ac power lines L1, L2 and L3 by reversing contractor 18.

FIG. 1 (sheets 2 and 3) also shows a controlller for operating contactor 18 and motor 14, mechanical brake 16, eddy current brake 17, and resistance network 15. As FIG. 1 (sheet 2) shows, the controller comprises a control switch 19 having first and second point positions in both "lower" and "raise" (a total of five contact circuits) and push-button switches, relays and limit switches hereinafter described. As FIG. 1 (sheet 3) shows, the controller further comprises a regeneration module 20, a load detector module 21, and its load dector relay 22, a guard control module 23 and its time delayed relay 24, a frequency detector module 25, a magnetic amplifier module 26, a controlled rectifier module 27 and an anti-hunt module 28. All modules are hereinafter described in detail.

Before power is applied, shaft 11 is held stationary by mechanical brake 16. After power is applied, eddy current brake 17 is energized to an "off position" level to exert a nominal retarding torque on shaft 11 to prevent runaway if mechanical brake 16 fails. When master control switch 19 is moved to a first position to operate motor 14 for operation in either the raise or lower direction, mechanical brake 16 releases and eddy current brake 17 energization is increased from "off position" level to a "maximum" level. Stall motor torque exerted on shaft 11 is 10 percent for lowering ad 140 percent for hoisting. When master control switch 19 is moved beyond first point to second point position to operate motor 14 at full raise or lower speed, permissive interlocking functions are carried out by the controller as follows, with stall motor torque first going to 140 percent as during hoisting.

Load detector module 221 senses when motor 14 delivers 15 percent or more of full load torque and causes detector relay 22 to pick up (close) its contacts 22A and 22B. Module 21 also causes relay 22 to drop out (open) its contacts at a slightly lesser torque of about 12 or 13 percent. Regeneration module 20 senses when motor 14 reaches or exceeds synchronous speed and provides a control signal to guard control module 23. The guard control module 23 causes its time delayed relay 24 to drop out (open) its contacts 24A and 24B after an appropriate time interval if regeneration control module 20 is providing a signal and load detector module relay 22 is energized.

The result of the relays 22 and 24 both being energized when motor 14 is being operated in the raise direction is to bias the guard module 23 off at the same time as 3A, 4A and 5A in the controller sequentially operate their contacts in resistance network 15 to remove resistance and accelerate motor 14. Motor 14 stabilizes at a speed determined by the load and the permanent slip resistor and continues running until decreased or stopped by the hoist operator or slowed and stopped by the appropriate limit switches RL1 and RL2.

When the motor 14 operates in the lower direction the accelleration is accomplished in the same way as in second point raise. Since the final permanent resistance is the same, the reflected load will cause the motor to stabilize. The speed will be either barely subsynchronous (for effectively no load); just over motor synchronous speed with a load sufficiently heavy to cause the motor to regenerate more than 15 percent of full load torque; or just over motor synchronous speed with a load causing the motor to regenerate less than 15 percent of full load torque. If it is the latter case, the controller will allow the load to accelerate the motor shaft to 275 percent of motor synchronous speed, at which point the eddy current brake will then regulate motor speed. Motor speed is stable at each of the three conditions and continues until slowed or stopped by the hoist operator or by limit switches LL1 and LL2.

It is to be understood that guard module 23 is always biased on and time delayed relay 24 is picked up (energized) at all times except when the interlock contacts L or R of lower relay L or raise relay R are closed and contact 22A of relay 22 is open and regeneration module 20 has an output at its terminals 5 and 6 and sufficient time has passed. The time delay is brought about by integration of the difference between the internal bias in guard module 23 and the current at terminals 1 and 2 of guard module 23 from regeneration module 20.

As movement of master control switch 19 continues, contactor 2A is energized and this causes rapid subsequent successive energization of the other contactors 3A, 4A and 5A. Contactor 2A is energized at first point raise and immediately in full (second point) lower. When contactor 2A is energized, relay 22 picks up and closes its contacts 22A and 22B. Therefore, at full raise or lower, relay 22 and time delay relay 24 are picked up. THis, in turn picks up relay CP, which in turn removes the excitation of eddy current brake **17**.

This system uses a wound-rotor induction motor whose second point raise and lower speeds depend only upon the motor constant, the line voltage and fixed permanent secondary resistors and the reflected shaft load.

In order to drop out or unexcite the eddy current brake **17** when going from first point raise or lower to second point, both the time delayed relay **24** and the current (or load) sensing relay **22** must be energized and one of their N.O. contacts on each relay closed. This is for safety and required to prove the circuits are working.

In order to go to high speed, lower both time delayed relay **24** and the current sensing relay **22** must be deenergized and another of their N.O. contacts on each relay must be open.

The first point speeds depend upon the motor constants, secondary resistors, line voltage, eddy current brake **17** excitation and reflected shaft load. Full load first point raise is approximately 3 percent synchronous speed and empty bucket, first point lower is approximately 1 percent synchronous speed.

Assuming that the above described sequences are carried out to effect a lowering operation of the hoist, one of the three conditions specified hereinbefore occurs, namely:

1. The load, if any, is driven down undercontrol at some desired subsynchronous speed, or
2. The load descends at a restrained speed (slowly, over 102 percent of synchronous speed) with a heavy load causing motor **10** to regenerate more than 15 percent of full load torque, or
3. Free fall at 275 percent of synchronous speed with a light load **16** caused by motor **10** regenerating less than 15 percent of full load torque.

As previously noted, all three of these lowering conditions are stable and will continue until slowed or stopped by the operator or by the limit switches **LL1**, **LL2**, **RL1** or **RL2** in the control circuit. The limit switches are arranged to effect progressive slow down and stopping of the motor and simulate the effect of the operator's return of the master control switch toward neutral position.

In condition (1), the load detector relay **22** may drop out, but nothing else.

In condition (2), the load detector relay **22** drops out and the regeneration module **26** provides a control signal at synchronous speed. But before the time delayed relay **24** drops out, the load detector relay **222** picks up again. Therefore, time delayed relay **24** remains picked up.

In condition (3), load detector relay **22** drops and regeneration module **20** turns on at synchronous speed. Since load detect or relay **22** does not pick up again, time delayed relay **24** eventually drops out. This drops relay **1A**, which drops **2A**, causes all contacts of resistance network **15** to open and, with the secondary winding of motor **14** open, the motor exerts no torque and the secondary voltage and frequency is applied to frequency detector module **25**. The light load **13** is then in free fall, restrained only by friction, windage and mass. When it accelerates to approximately 270 percent of full load hoist speed, frequency detector module **25** provides an output signal which starts to increase the excitation of eddy current brake **17** and motor speed stabilizes at about 275 percent of full load hoisting speed.

All of the operating conditions hereinbefore described are depicted in the graph in FIG. **2** wherein motor speed is polotted against motor torque for motor operation in the raise and lower directions.

A more detailed description of the construction and operation of controller components is as follows.

Master Control Switch

Master control switch **19**, shown schematically in FIG. **1** (sheet **2**) and in FIG. **3** operates contacts N, **40**, **41**, **42** and **43** to operate reversing contactor **18** and resistance network **15** to establish motor direction of speed. Section **47** of frequency detector module **25** (FIG. **4**) comprises a full wave rectifier **48** to convert the ac signal to dc and a signal adjustment rhostat or potentiometer **49**. As FIG. **1** (sheet **3**) shows, the output terminals **3** and **4** of section **47** of module **25** are connected by conductors **51** and **52** to provide a variable dc speed reference signal to terminals **9** and **10** of magnetic amplifier module **26**.

Master control switch **19** will not function until "start" button **60** is depressed with the induction master control switch in neutral with contact N closed. When "start" button **60** is depressed, UV relay coil **61** is energized and UV relay coil **61** is de-energized by emergency stop pushbutton **62**, stop pushbutton **63**, manual reset overspeed switch **64**, or motor overload contacts **65** and **66**.

The desired side of reversing contactor **18** will come in to energize motor **14** when master control switch **19** is moved to first point raise or lower position, provided the corresponding travel limit switches LL1 and RL1 are not open. With motor **14** energized for rotation in the desired direction, mechanical brake **16** releases and excitation of eddy current brake **17** increases from the "off position" level to the "maximum"level. Stall motor torque is 10 percent for lower and 140 percent for raise.

Eddy Current Brake

As FIG. **5** shows, eddy current brake **17** comprises an iron rotor **70** mounted on bearings **71** on shaft **11** inside a stationary field assembly having an iron stator **72** and coils **73**. When direct current flows through coils **73**, alternate magnetic poles are produced in stator **72** (i.e., north next to south, etc.) which induce alternate field in rotor **70** when the latter moves. This interaction induced by eddy currents in rotor **70** produces retarding torque at various speeds, as shown in the speed-torque graph in FIG. **6**.

Excitation of the elctric brake coils **73** in eddy current brake **17** is provided by controlled rectifier module **27** which, in turn, is operated by magnetic amplifier module **26**. Magnetic amplifier module **26**, in turn is responsive to its own internal (off) bias and to the off biases from transformer **T9** (rectified in rectifier section **47** of frequency detector module **25**; the speed feedback signal from the secondary windings of motor **14** (as sensed and provided by frequency detector module **25**); and an anti-signal from anti-hunt module **28**.

Controlled Rectifier Module

As FIG. **1** (sheets **1** and **3**) shows, controlled rectifier module **27** has power input terminals **80** and **81** which are supplied with power from correspondingly numbered terminals of an anode transformer **82** connected to lines L1 and L2 of the main power supply. Module **27** comprises two SCR's **83** and **84** (silicon controller rectifiers) which, when gated, supply ac current to the electric brake coils **73** of eddy current brake **17**. The SCR's **83** and **84** block current in the forward direction until a positive gate signal is applied by magnetic amplifier module **26** to cause them to fire. The SCR's continue to conduct even if the gate signal is removed until anode current from transformer **82** falls to zero and reverses. Module **27** includes a surge suppression resistor **85** and capacitor **86** across the secondary of anode transformer **82** to dissipate harsh transients.

Magnetic Amplifier Module

As FIG. **7** shows, magnetic amplifier module **26** comprises a power supply transformer **90**, a self-saturating magnetic amplifier havingiron cores **91** on which ac windings **92** are provided, three control windings **93**, **94** and **95**, and a bias winding **95***a* and small rectifiers **96** in series with each ac winding **92**. As FIG. **1** (sheets **1** and **3**) shows, the input terminals **1** and **2** of power supply transformer **90** of magnetic amplifier module **26** are connected by conductors **97** and **98** to correspondingly numbered terminals of anode transformer **82**. The output terminals **4**, **5** and **6** of magnetic amplifier module **27** are connected, respectively, to the gate of SCR **83**, to one side of eddy current brake coils **73** and the SCR's **83** and **84**, and to the gate of SCR **84**. The other side of coil **73** is connected to terminal **99** of anode transformer **82** by a similarly numbered conductor. The terminals **7** and **8** of control winding **93** (speed feedback signal) are connected by conductors **100** and **101** to terminals A1 and A2 of frequency detector module **225**. The terminals **9** and **10** of control winding **94** (speed reference signal) are connected by conductors **52** and **51** to terminals **4** and **3** of frequency detector module **25**. The terminals **11** and **12** of control winding **95** (anti-hunt signal) are connected by conductors **103** and **104** to terminals **6** and **5** of anti-hunt module **28**. The anti-hunt module **28** provides transient signals which compensate for system response delays which could result in hunting and comprises a resistor **105**, an adjustable potentiometer **106**, and a capacitor **107**.

The magnetic amplifier in module **26** is self-saturating and, if not excited by the control windings **93**, **94** and **95** or bias winding **95***a*, tends to turn the SCR's **83** and **84** full on to fully energize eddy current brake coil **73**. Control current in one or more of the control windings **93**, **94** and **95** or bias current in bias winding **95***a* resets the amplifier and it can be made to saturate over the entire ac half cycle, partial cycle or not at all. When the magnetic amplifier functions as an error detector, it continuously compares the off and bias signals with the speed feedback signal (and the anti-hunt signal) and providing SCR control output signals at terminals **4**, **5** and **6** of module **26** which are the resultant thereof.

When the odd numbered terminal of a control winding is positive with respect to its even numbered terminal, the current in the control winding tends to turn the output pulse on. The reverse is true when the odd numbered terminal is negative with respect to its even numbered terminal. All of the control signals are of constant polarity except the anti-hunt signal. The values may vary from zero to a minimum, but never reverse in polarity. The anti-hunt signal is not constant, but allows current to flow in its control winding only under transient conditions.

Frequency Detector Module

When master control switch **19** is in first point LOWER position, motor **14** is energized but the rotor is restrained because magnetic amplifier module **26** is at maximum "on" and load brake **17** is excited. If motor **14** starts to turn, all signals remain constant. The frequency detector module **25** input is shorted by contacts **1**A.

The frequency detector module **25** shown in FIGS. **1** and **4** has its input terminals **7** and **12** connected across the secondary winding of motor **14** by conductors **110** and **111**, respectively, and provides, at its output terminals A1 and A2, a dc speed feedback signal which is proportional to the rotor frequency of motor **14**, which in turn is proportional to motor slip and below motor synchronous speed. It may be assumed that motor **14** at rest produces a frequency of 60 Hertz and at synchronous speed produces a zero frequency. There is no input from the motor secondary into frequency detector module **25** whenever contactor **1A** is energized. If motor **14** is driven faster than synchronous speed by an overhauling load, rotor frequency again increases. The magnitude of voltage induced in the rotor (secondary) windings varies directly with frequency. As FIG. **4** shows, frequency detector module **25** comprises an input transformer **112** and a saturating transformer **113** saturated by rotor voltage and having a square hysterisis loop core which tends to produce constant energy pulses for each half cycle fo input frequency. These pulses, when rectified and filtered by the rectifiers **114** and capacitors **115**, produce a dc voltage signal (speed feedback signal) directly proportional to motor frequency at terminals A1 and A2.

Load Detector Module

Referring to FIGS. **1** (sheet **3**) and **8**, the load detector module **21** has power supply terminals **11** and **12** which are connected by conductors **118** and **119** to anode transformer **82**. Module **12** also has signal input terminals **1**, **2** and **3** which are connected by conductors **120**, **121** and **122**, respectively, to transformers **123**, **124** and **125**, respectively, which are connected to a portion of the permanent resistors for motor **14** to sense current conditions therein. Load detector module **21** which includes a signal detection section **126** and an amplifier section **127** senses when motor **14** is delivering over a maximum of 15 percent of full load torque and provides an output signal at its signal output terminals **6** and **7** to energize relay coil **22** connected thereto. Relay coil **22** operates relay contacts **22A** and **22B**. Load detector module **21** is designed to effect deenergization of relay coil **22** if motor torque drops to between about **12** and **13** percent of full load torque. The load detector module **21** has an "On" bias in it that varies with line voltage so that in the first approximation, the circuit trips on power and not current, i.e., shaft torque.

Regeneration Control Module

Referring to FIGS. **1** (sheet **3**) and **9**, the function of regeneration control module **20** is to provide an output signal at its terminals **5** and **6** for guard module **23** when motor **14** reaches and exceeds synchronous speed. Module **20** receives a voltage input signal at its terminals 1 and 2 from a voltage transformer **130** coupled to the main supply lines L1 and L2. Module **20** also receives a current input signal at its terminals **3** and **4** from a current transformer **131** coupled to main supply line L2. Power for module **20** is provided at its power supply terminals **7** and **8** from a transformer **132** understood to be connected to lines L1 and L2. The regeneration module **20** comprises a rectifier section **133** to combine and rectify the voltage and current signals and a level detector-switching section **134** to detect when the combined and rectified signal falls below a level and switches on a power level for delivery to signal output terminals **5** and **6.**

Guard Control Module

Referring to FIGS. **1** (sheet **3**) and **10,** the guard control module **23** is designed to maintain relay **24** energized at all times, except under specified conditions. Module **23** comprises an input amplifier **140** having input terminals **1** and **2** for a first control winding **141.** Terminal **2** is connected to terminal **5** of the regeneration module **20** and to terminal **3** of a second control winding **142,** and the latter's terminal **4** is connected through a resistor **143** to the terminal **7** of a third control winding **144.** The latter's terminal **8** is connected by a conductor **145** to terminal **10** of regeneration module **20.** When the signal is present in the control winding **141** of guard control module **23** from terminals **1** and **2,** the input amplifier **140** tends to turn off a second stage amplifier **146** of guard module **23** after a time delay. However, the presence of an input signal at input terminals **2** and **8** to control windings **142** and **144** of guard module **23** (from terminals **5** and **10** of the regeneration module **20**) tends to turn on module **23.** During subsynchronous operation only, the ON signal exists and the output terminals A3 and A4 are energized to energize, pick up or close time delay relay **24.**

With a signal at terminals **1** and **2,** the OFF signal cancels the ON signal and after a predetermined time delay output terminals A3 and A4 are deenergized, dropping out relay **24.** Power to the module is supplied through terminals A1 and A2 from terminals **118** and **119** of anode transformer **82.**

We claim:

1. A hoist comprising an induction type electric motor and control means for operating said motor in raise and lower directions, said control means comprising, a controller, electrically operable brake means for said motor, brake control means for controlling said brake means, first means responsive to regenerative conditions in said motor to effect operation of said brake control means, and second means responsive to torque conditions in said motor to effect operation of said brake control means, said first and second means, when said controller is operating said motor in the lower direction, being responsive to the regenerative and torque characteristics exhibited by said motor when subjected to various loads in the lower direction to operate said brake control means to effect motor operation at a first speed which is approximately the synchronous speed of the motor when a load is sufficiently light to be non-regenerative; to effect motor operation at a second speed which is approximately the synchronous speed of the motor when a load is sufficiently heavy to be regenerative and is producing more than a predetermined amount of torque; and to effect motor operation at a third speed which is in excess of the synchronous speed of the motor when a load is sufficiently heavy to be regenerative and is producing less than a predetermined amount of torque.

2. A hoist according to claim **1** wherein said first speed is slightly below a synchronous speed, wherein said second speed is slightly above motor synchronous speed, and wherein said third speed is substantially greater than motor synchronous speed.

3. A hoist comprising a wound rotor induction type electric motor and control means for operating said motor in raise and lower directions, said control means comprising:

a controller for selectively operating said motor in at least one speed range in the raise direction and in at least a slower and faster speed range in the lower direction; an eddy current type load brake for said motor; magnetic amplifier means for operating said load brake; first means including a regeneration circuit and a frequency detector circuit for sensing whether or not said motor is regenerating at least when operating in the lower direction and for providing a related control signal for effecting operation of said magnetic amplifier means; and second means including a load detector circuit for sensing the torque of said motor at least when operating in the lower direction and for providing a related control signal for effecting operation of said magnetic amplifier means, said magnetic amplifier means being operative in response to said first and second means at least when said controller is operating said motor in the lower direction to operate said load brake to enable said motor: to drive a load sufficiently light to be non-regenerative at a rate of speed corresponsing to approximately the synchronous speed of said motor when said first means sense such non-regenerative condition; to lower a load sufficiently heavy to be regenerative and producing more than a predetermined amount of torque at a rate of speed corresponding to approximately the synchronous speed of said motor when said first and second means sense such regenerative and torque conditions; and to lower a load sufficiently heavy to be regenerative and producing less than said predetermined amount of torque at a rate of speed corresponding to a speed greater than the synchronous speed of said motor when said first and second means sense such regenerative and torque conditions.

4. A hoist according to claim **3** wherein said first means sense a non-regenerative load and operates said magnetic amplifier means to effect motor operation at a rate of speed slightly below synchronous speed; wherein said first and second means sense a regenerative load producing more than said predetermined amount of torque and operate said magnetic amplifier means to effect motor operation at a rate of speed slightly above synchronous speed; and wherein said first and second means sense a regenerative load producing less than said predetermined amount of torque and operate said magnetic amplifier means to effect motor operation at a rate of speed in excess of twice synchronous speed.

5. A hoist according to claim **4** wherein said predetermined amount of torque is approximately 15 percent of full load torque.

6. A hoist according to claim 5 wherein said rate of speed in excess of twice synchronous speed is approximately 270 percent of synchronous speed.

7. A hoist comprising a wound rotor induction type electric motor and an eddy current type load brake for said motor and control means for said brake and said motor comprising:

a. a controller for selectively operating said motor in at least one speed range in the raise direction and in at least a slower speed range and a faster speed range in the lower direction,

said controller comprising a first relay;

b. a magnetic amplifier for controlling energization of said brake to control motor speed;

c. a regeneration circuit responsive to motor speed in said faster speed range to provide an output signal when motor speed exceeds synchronous speed;

d. a frequency detector circuit responsive to motor speed in said faster speed range to provide an output signal when motor speed exceeds synchronous speed, provided said controller effects connection of said frequency detector circuit to said motor,

e. a load detector circuit responsive to motor torque when said motor is operating in the lower direction to operate a second relay when motor torque exceeds a predetermined value and to de-energize said second relay when motor torque is slightly below said value;

f. a guard circuit having a third relay, said guard circuit effecting operation of said third relay after a predetermined interval of time in response to an output signal from said regeneration circuit, provided said second relay is in a predetermined condition;

g. and a magnetic amplifier firing circuit for controlling said brake and responsive:

i. to operation of said controller in at least said slower speed range to effect maximum energization of said brake;

ii. to operation of said controller in said faster speed range, when said second relay and said third relay have been at least momentarily operated simultaneously and said first relay is operated as a result thereof, to effect total deenergization of said brake to permit said motor to operate at approximately synchronous speed, and

iii. to operation of said controller in said faster speed range when said second relay is operated to effect operation of said third relay, thereby effecting an output signal from said frequency detector circuit, and said first relay is operated and is responsive to said output signal from said frequency detector circuit to effect increased energization of said brake to limit motor speed to a speed substantially in excess of synchronous speed.

8. A hoist comprising a wound rotor induction type electric motor and an eddy current type load brake for said motor and control means for said brake and said motor comprising:

a. a controller for selectively operating said motor in at least one speed range in the raise direction and in at least a slower speed range and a faster speed range in the lower direction,

said controller comprising a first relay;

b. a magnetic amplifier for controlling energization of said brake to control motor speed;

c. a regeneration circuit responsive to motor speed in said faster speed range to provide an output signal when motor speed exceeds synchronous speed;

d. a frequency detector circuit responsive to motor speed in said faster speed range to provide an output signal when motor speed exceeds synchronous speed, provided said controller effects connection of said frequency detector circuit to said motor,

e. a load detector circuit responsive to motor torque when said motor is operating in the lower direction to energize a second relay and close its contacts when motor torque exceeds a predetermined value and to de-energize said second relay and open its contacts when motor torque is slightly below said value;

f. a guard circuit having a normally energized third relay with contacts which are closed when said third relay is energized, said guard circuit effecting de-energization of said third relay after a predetermined interval of time in response to an output signal from said regeneration circuit, provided said second relay is de-energized;

g. and a magnetic amplifier firing circuit for controlling said brake and responsive:

i. to operation of said controller in at least said slower speed range to effect maximum energization of said brake;

ii. to operation of said controller in said faster speed range, when said second relay and said third relay have been at least momentarily energized simultaneously and said first relay is energized and remains energized as a result thereof, to effect total de-energization of said brake to permit said motor to operate at approximately synchronous speed; and

iii. to operation of said controller in said faster speed range when said second relay is de-energized to effect de-energization of said third relay, said de-energization of said third relay occurring when said second relay is de-energized thereby removing torque from said motor and effecting an output signal from said frequency detector circuit, and said first relay is energized and is responsive to said output signal from said frequency detector circuit to effect increased energization of said brake to limit motor speed to a speed substantially in excess of synchronous speed.

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