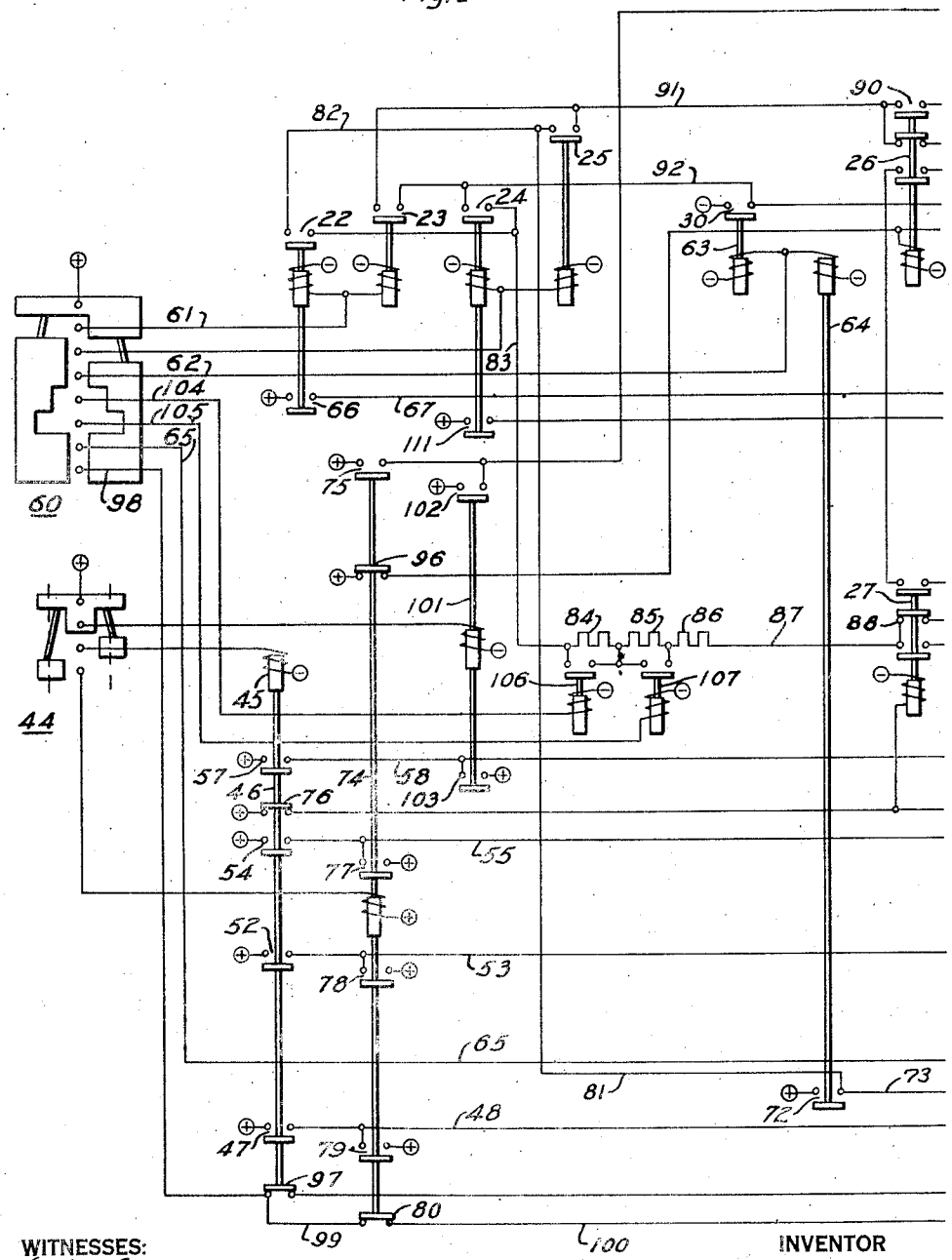
Jan. 7, 1941. J. E. BORLAND 2,228,072

HOIST CONTROL

Filed Sept. 9, 1939 3 Sheets-Sheet 1

Fig. 1



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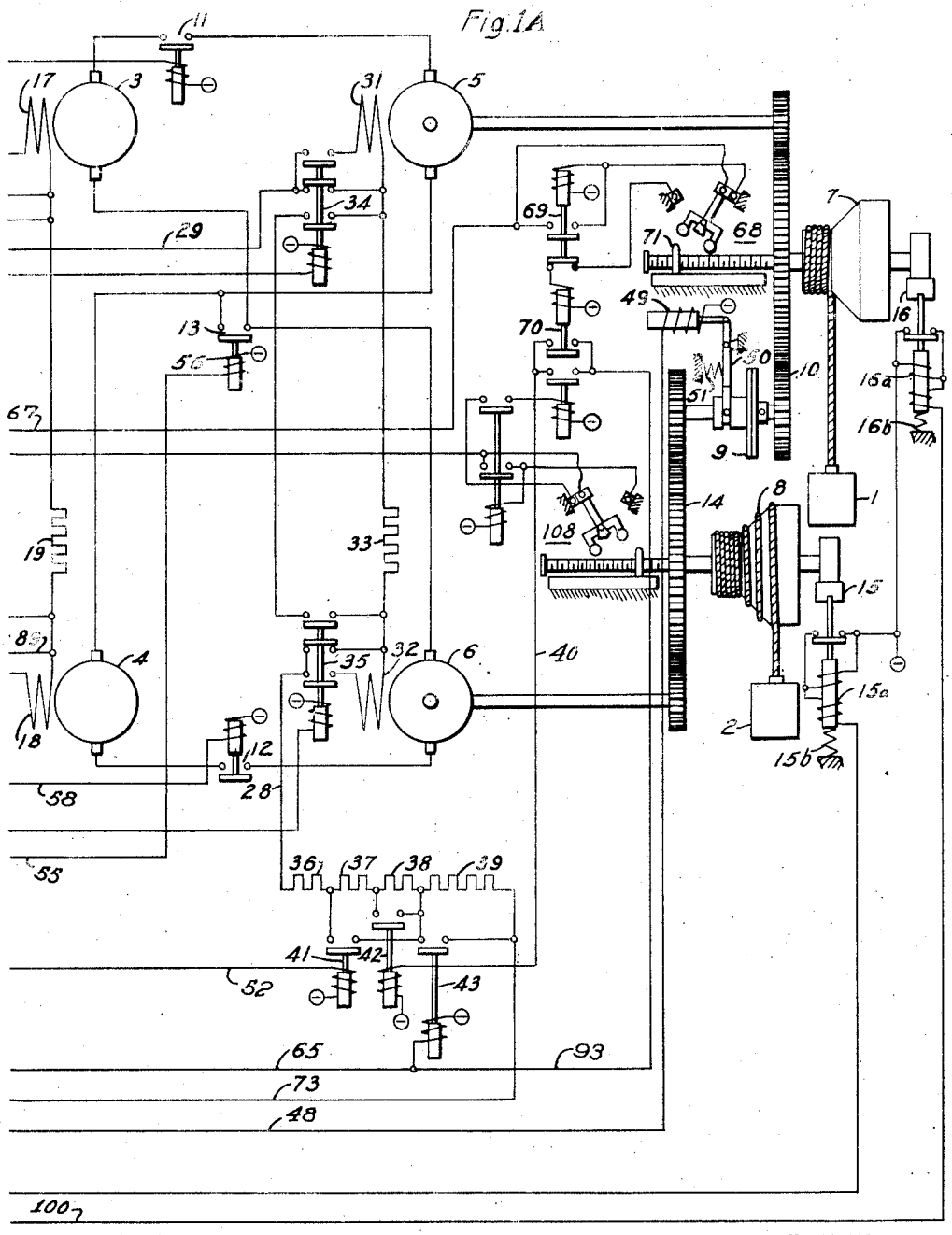
HOIST CONTROL

Filed Sept. 9, 1939 3 Sheets-Sheet 2

Fig. 1A



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HOIST CONTROL

Filed Sept. 9, 1939 3 Sheets-Sheet 3

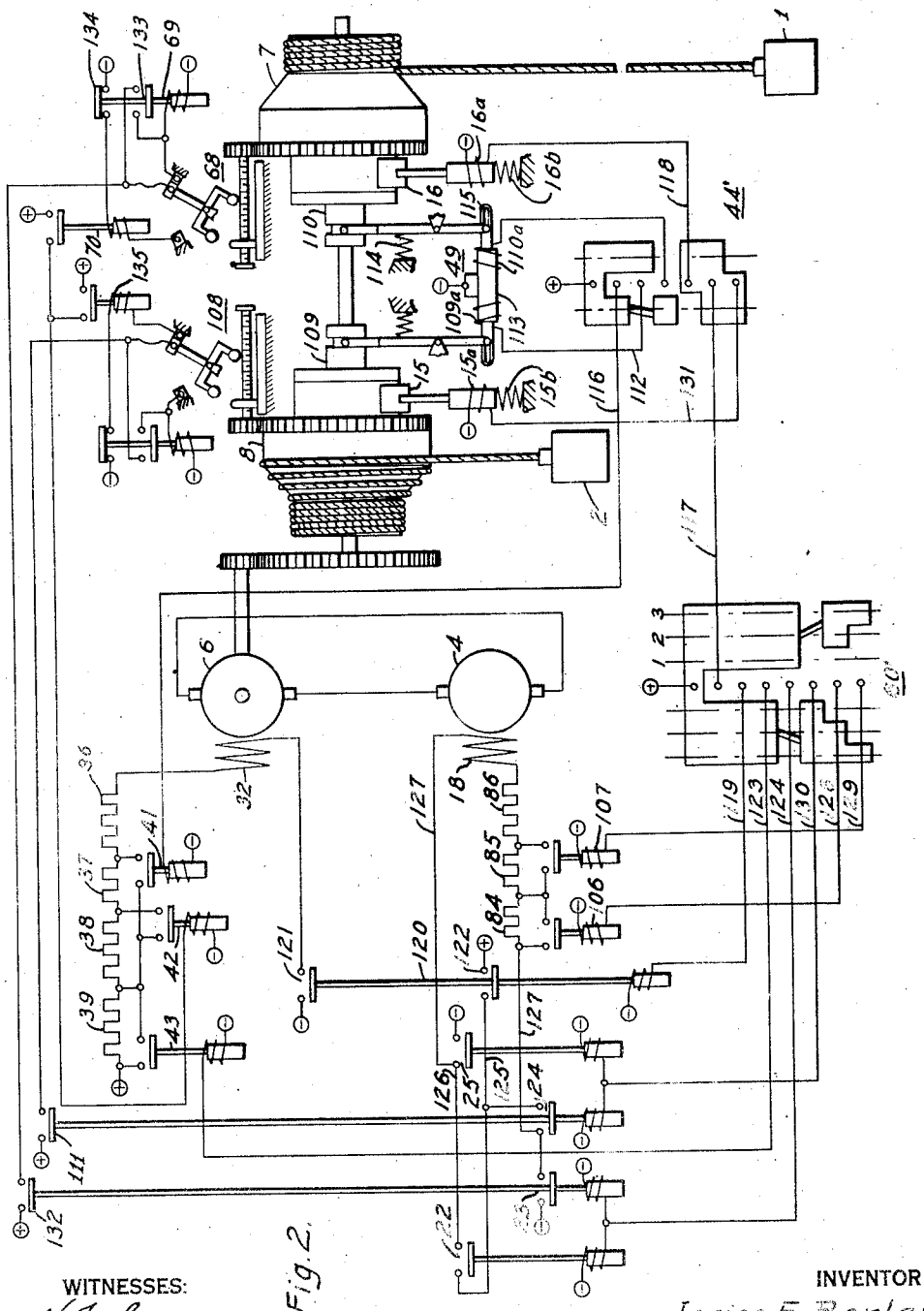

Fig. 2.

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Patented Jan. 7, 1941 2,228,072

UNITED STATES PATENT OFFICE

2,228,072

HOIST CONTROL

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Application September 9, 1939, Serial No. 294,099

19 Claims. (Cl. 187—29)

This invention relates to mine hoist control systems.

One object of my invention is to provide a system in which the motor circuit and the circuits for the control equipment are compensated for various conditions of operation of a skip or cage from different levels in a shaft compartment.

Where cylindro-conical drums or bi-cylindro-conical drums or reels are employed for the purpose of reducing power requirements during the accelerating period and for the operation from the lower levels of the mine shaft, greater counterbalancing effects are obtained with the empty skip or cable suspended from a large diameter, corresponding to the skip or cage position in the upper parts of the shaft and the other skip or cage suspended from a small diameter or drum and is positioned at the lower level of the shaft. The benefit of this type of hoist drum may be lost in a more or less degree when the drums are set to operate the cages from upper levels. Under this condition the loaded skip or cage may be suspended from a part of the drum on which the diameter approaches the maximum, so that conditions of operation on both drums approach the condition of operation on a cylindrical drum.

At the same time, when hoisting from the upper levels, the average hoisting speed is greater than when hoisting from the lower levels, because of the greater average drum diameter on which the rope is wound at the time that the skip or cage is at the upper level.

Such operation at high hoisting speed, and in balance, from the upper levels, because of the extra power requirements during the accelerating period, tends to result in increased heating in the direct current motor, and in the direct current generator which supplies the motor on a variable voltage system. However, since for the same production a lower rope speed is permissible from the upper levels, a saving in the size and capacity of the direct current driving motor and in the motor generator set supplying it can be made by providing for an automatic reduction in the maximum motor speed by increasing its field strength when the drums are set for balanced operation above a predetermined level.

Another object of my invention, therefore, is to provide a control system for normally balanced mine hoist operation in which provision is made for automatically reducing the maximum motor speed that may be attainable when the drums are set for balanced operation above a predetermined level in the shaft compartments. A specific provision of this general object is to reduce the maximum motor speed attainable, by increasing the excitation or field strength of the motor by over-energizing the field winding considerably beyond its normal operating requirements for operation from the lower levels of the mine.

Another object of my invention is to provide a system whereby the location of the starting position of the cage during a hoisting operation may be mechanically detected and utilized to establish a control function in the operation of the system to permit the motor to operate at high speed when a cage is hoisted from a lower level, and to automatically control the motor to reduce the permitted maximum motor speed when the hoisting operation of a cage is started from an upper level.

In order to change the hoist system from balanced operation at a lower level to balanced operation at an upper level, the relative position of the drums to each other must be modified. During balanced operation the two drums may be connected through a single clutch to permit both drums to be connected to the driving mechanism or drive shaft, and thence to two driving motors. In one position of this clutch, both drums would be connected to the drive shaft and thence to both driving motors for balanced operation. In another position of the clutch, either drum might be driven by its corresponding motor with the other drum remaining at rest and held against rotation by a gravity brake. The latter arrangement would provide for unbalanced operation of the system from either drum as desired.

A further object of my invention, therefore, is to provide a control function in the system to establish an increase in the motor field strength automatically when the clutch is set for unbalanced operation from either system.

In the usual arrangement at present generally employed, two motor generator sets are used, and the shunt field windings of the motor are connected in series in one circuit, and the shunt field windings of the generator are connected in series in a second circuit, in such manner as to provide for and to permit the simultaneous energization of both sets of windings. When one motor generator set, as a unit, is not to be employed and one drum is to be held stationary for unbalanced operation with the other drum, the unused generator is arranged to be electrically isolated by a short circuiting connection which

then energizes the operating motor alone from its generator. Under such condition of unbalanced operation, it is desirable to deenergize the field windings of the motor and of the generator of the unused set.

A further object of my invention, therefore, is to provide a system whereby the field windings of the unused motor and generator units are effectively isolated by a short circuit around the field winding. A dummy resistor, whose resistance is made equal to the resistance of each of the field windings, is thus included in the circuit of the operating field winding so that when the dummy resistor is substituted for either field winding the proper previously determined field excitation is retained for the operating winding.

Other objects and advantages will become more apparent from a study of the following specification when considered in conjunction with the accompanying drawings, in which:

Figures 1 and 1*a* together form a schematic showing of a control system embodying the principles of my invention.

Fig. 2 is a schematic showing of a control system embodying a modification of my invention.

Referring to Figure 1, a mine hoist system for operating two skips or cages 1 and 2 is provided briefly with two main variable voltage direct current generators 3 and 4, and two direct current motors 5 and 6 to control the raising and lowering of the cages 1 and 2 through two drums 7 and 8 that may be disconnected for independent operation, or connected for joint operation, through a clutch 9.

The two generators 3 and 4 may be operated by any suitable motive power such as engines or other motors, the usual arrangement being preferably to use alternating current motors with which the generators will constitute motor-generator units. The nature of the motive power for the generators is immaterial for the present invention, and for the sake of simplicity is not shown. The armature of the motors and of the generators are connected in series in a closed circuit through two circuit breakers 11 and 12. A third circuit breaker 13 is provided to short circuit the combined armatures of one generator motor unit in order to provide a closed circuit for the other generator motor unit when the first unit is not to be employed.

The two motors 5 and 6 are illustrated, for simplicity, as being mechanically connected through suitable gearing 10 and 14 which, in turn, are interconnected through a clutch 9. The drum 8 is shown coupled to gearing 14 (which drum 8 may be held against rotation by a brake 15). The drum 7 is arranged to be driven by the drum 8 through the gearing 14, clutch 9 and gearing 10. When the clutch 9 is disengaged, however, the drum 7 is held against rotation by its brake 16.

The generators 3 and 4 are provided with field windings 17 and 18, respectively, and those windings are arranged to be connected individually in series circuit relation with a dummy resistor 19 to compensate for the resistance lost by the omission of the other field winding. The field winding circuit, including the two field windings 17 and 18 and the dummy resistor 19, is arranged to be connected to a suitable source of energizing current such as a direct current exciter whose terminals are indicated by the positive and negative signs, respectively, through a bridge arrangement of reversing switches 22 and 23 or 24 and 25, to provide selective energization of the generator field windings of the proper polarity to establish the rotation of the motors in either direction, as desired.

In order to render the dummy resistor 19 effective or non-effective in the energizing circuit of the generator field windings, two by-pass relays 26 and 27 are provided to cooperate to establish a short circuiting connection around the dummy resistor 19 when both relays are energized, but to open the short circuit by-pass connection when either relay 26 or 27 is deenergized and open. Either relay 26 or 27 in its energized position connects its associated generator field winding in the energizing circuit; and in its deenergized position disconnects the associated field winding from the energizing circuit.

The two motors 5 and 6 are similarly provided with shunt field windings 31 and 32 connected in series relation through a dummy resistor 33. By passing relays 34 and 35 in their energized condition are both arranged to establish the by-passing short-circuit connection around the dummy resistor 33, and at that time also connect the two windings 31 and 32 directly to the energizing exciter circuit. When either of the by-passing relays 34 and 35 is deenergized, it disconnects its associated field winding from the energizing circuit and at the same time breaks the by-pass short-circuiting connection around the dummy resistor 33 to substitute that resistor for the disconnected field winding.

The field winding circuit for the motor windings 31 and 32 also includes a group of series connected resistors 36, 37, 38 and 39 which are arranged to be suitably controlled by the contact members of relays 41, 42 and 43 to modify the degree of energization of the field winding circuit to establish a desired type of operation of the motors, in a manner that will be explained.

As previously mentioned, the system may be operated normally in balance for operation of the skips or cages at the lower level. The weight of the rope or cable of the lower skip or cage becomes an appreciable item in the total weight of the cage in the lowered position at the lower level. Under such conditions the conical shape of the drum is effective to provide a greater leverage to the skip or cage at the top of the shaft compartment. Therefore, when the lower cage is to be raised from the lowermost level, the maximum balancing effect of the upper cage will be available and the power necessary to accelerate the skip or cage from the lowermost level will be a minimum. The system may, therefore, be operated at its maximum speed since the power demand to start or accelerate the hoist system may be well within the capacity of the motor units. Under such conditions the system may, therefore, be set to operate to raise the cage from its lowermost position at maximum speed.

When the system is to be operated, however, between the top of the shaft and the intermediate level, the suspending cable for the lower cage at the intermediate level will at that time be wound upon a relatively large diameter of its drum and the counterbalancing benefit of the other cage will therefore be lessened, since there will be a smaller beneficial ratio between the relative diameters at which the two cables are wound upon their respective drums. Consequently, a greater starting load will be impressed upon the motors when the system is operating at balance for operation from an upper level. To operate the system from such upper level, at the high speed possible and desirable from the lowermost level, would impress a load on the motors and the gen-

erators that would cause overheating under continuous operation unless such motors were made oversize. Since relatively the same production is available from the upper level even at a reduced speed of the hoist motor, there is no objection to operating the system at a reduced speed above the intermediate level. In order to limit the maximum motor speed that may be attained, however, while at the same time providing additional power to the motors when operating from the intermediate level, provision is made to short circuit and effectively eliminate the resistors **37**, **38** and **39**, under various conditions, to establish the correspondingly appropriate energization of the motor field windings.

In the drawings, all the terminals marked (+) and (—) may be assumed to be energized from the same direct current source or exciter.

Selector switch **44** is for the purpose of selecting either of the skips **1** and **2** for individual (or unbalanced) operation or both for simultaneous (or balanced) operation. Generally speaking, when the right hand contact members of selector switch **44** are closed the right skip **1** is selected and isolated for unbalanced operation whereas if the left hand contact members of selector switch **44** are closed the left skip **2** is selected and isolated for unbalanced operation. On the other hand, if the central contact members of selector switch **44** are closed (as shown in the drawings) both skips **1** and **2** are selected for simultaneous or balanced operation. After the selector switch **44** is set for the desired operation of the skip or skips, the drum controller **60** is moved either in one direction or another depending upon the direction of movement desired of the skip or skips.

Assume that the right hand skip **1** is desired for unbalanced (sole) operation in an upward direction, hence that the right hand contact members of selector switch **44** have been closed then a circuit is completed from the selector switch (+) terminal through the actuating coil **45** of the relay **46**. Upon operation of relay **46** the contact members thereof will be in such position as to select a control circuit which will allow operation of the right drum **7** only. More specifically, when relay **46** is energized a circuit is completed from the (+) terminal through the contact members **47**, conductor **48**, the clutch disengaging coil **49** to the (—) terminal. Energization of coil **49** will rock lever **50** and overcome the biasing action of spring **51** thus disengaging clutch **9**. Another circuit will be completed from the (+) terminal, through contact members **52**, conductor **53**, the actuating coil of relay **41** to the (—) terminal. Energization of relay **41** effects shunting of resistors **37** and **38**. Still another circuit is completed from the (+) terminal through contact members **54**, conductor **55**, the actuating coil of relay **56** to the (—) terminal. Actuation of relay **56** closes circuit breaker **13**. Still another circuit is completed from the (+) terminal, through contact members **57**, conductor **58**, the actuating coil of circuit breaker **12** to the (—) terminal. Energization of relay **46** also effects opening of contact members **76** which effects deenergization of the coil of relay **35**. Energization of relay **46** also effects opening of contact members **97** which effects deenergization of brake solenoid **15***a* of brake **15** so as to allow the spring **15***b* thereof to hold drum **8** stationary.

Still assuming that the right hand contact members of selector switch **44** are closed let us now assume that the drum controller **60** is moved to the first step of the right hand contact members. A circuit will thus be completed from the (+) terminal of the drum controller **60** through the first step of the right hand contact members, conductor **61**, both of the actuating coils of reversing switches **22** and **23** to the (—) terminal. Another energizing circuit similarly will be completed through conductor **62** and the actuating coils of relays **63** and **64**. Still another energizing circuit will be completed through conductor **65** and the coil of relay **43** to effect short circuiting of economy resistor **39**, (which resistor is merely used to conserve power while the motor is idle). Still another circuit will be completed from the (+) terminal of the drum controller through conductors **98** and **99**, contact members **80**, conductor **100**, brake solenoid **16***a* to the (—) terminal to disengage brake **16**. The completion of the above described control circuits will effect completion of a motor field excitation circuit from the (+) terminal through contact members **72**, conductor **73**, resistor **39**, the bridged contact member of relay **41**, resistor **36**, conductor **26**, the bridged central contact members of by-pass relay **35**, dummy resistor **33**, field winding **31**, the bridged middle contact members of by-pass relay **34**, conductor **29**, contact members **30** to the (—) terminal.

The completion of the above described control circuits will also effect completion of a generator field excitation circuit from the (+) terminal through contact members **72**, conductors **81** and **82**, the bridged contact members of reversing switch **22**, conductor **83**, resistors **84**, **85**, **86**, conductor **87**, bridged contact members **88** by by-pass relay **27**, conductors **89**, dummy resistor **19**, generator field winding **17**, contact members **90**, conductor **91**, reversing switch **23**, conductor **92**, contact members **30** to the (—) terminal.

If it were desired to move skip **1** in the opposite direction, that is, to lower it instead of raising it, the left contact members of the drum would be closed (instead of the right) thus completing a circuit through the actuating coils of reversing switches **24** and **25** (instead of **22** and **23**) hence reversing the direction of energizing current through field winding **31**.

Assuming that if it were desired to operate only the left skip **1**, then selector switch **44** would be moved to the left position thus completing an energizing circuit through the actuating coil of relay **74** which in turn completes a series of control circuits similar to the previously described operation of the right hand skip **1**, more specifically, closing of contact member **75** effects energization of circuit breaker **11**; opening of contact members **96** effects deenergization of by-pass relay **34** thus shunting out motor field winding **31** and inserting resistor **33** in series with motor field winding **32**; closing of contact members **77** effects energization of the actuating coil of circuit breaker **13**; closing of contact members **78** effects energization of relay **41** and shunting of resistors **37** and **38** to increase the motor field current and reduce the maximum speed; closing of contact members **79** effects energization of coil **49** and disengagement of clutch **9**; and opening of contact members **80** effects deenergization of brake solenoid **16***a* thus allowing the spring **16***b* to apply brake **16**.

Assuming that if it were desired to operate both skips **1** and **2** simultaneously, that is, in balance, then the selector switch **44** will be placed in the mid-position (as shown in the drawings), hence a circuit will be completed through the coil

of relay 101 thus effecting closing of contact members 102 and 103 which, in turn, complete separate energizing circuits through circuit breakers 11 and 12. Since both relays 46 and 74 remain deenergized contact members 97 and 80 thereof, respectively, remain closed thus completing an energizing circuit through both brake solenoids 15a and 16a to release the brakes. Clutch 9 is engaged by spring 51. Furthermore, since contact members 76 and 96 of relays 46 and 74, respectively, are closed both of the by-passing relays 34 and 35 will be energized thus completing a circuit through both motor field windings 31 and 32. Also both of the by-pass relays 26 and 27 will be closed, hence another circuit will be completed through both generator field windings 17 and 18.

In the second and third position of controller 60 (in either direction) a circuit will be completed through conductors 104 and 105, respectively, to effect energization of relays 106 and 107, respectively, so as to successively shunt out resistors 84 and 85 in the generator field circuit to afford speed control. While only two steps of speed control have been shown, for simplicity, it is apparent that any number of steps may be used instead.

When drum controller 60 is moved to the first step (in the right or hoisting direction) a circuit will be completed from the (+) terminal through contact members 66 of reversing switch 22, conductor 67, the right hand contact members of limit switch 68 (assuming skips 1 and 2 are operating in balance and that skip 1 is below a predetermined intermediate level), the actuating coil of relay 69 to the (—) terminal. The upper contact members of relay 69 will effect an interlock, permitting relay 69 to seal itself in an energized condition while the opening of the lower contact members of relay 69 maintains relay 70 deenergized thereby interrupting the circuit through relay 42 even after skip 1 has been moved above the predetermined intermediate level after the movable element of limit switch 68 has moved to the left stationary contact member thereby keeping resistor 38 in the motor field and allowing maximum speed of the motor in driving skip 1 in the entire upward direction. If it had been assumed that skip 1 was already above a predetermined level at the time it was to be hoisted then the left hand contact members of limit switch 68 would have closed effecting energization of relay 70 and closing of the contact members of relay 70 and would have completed a circuit through relay 42 to short circuit resistor 38.

If it had been assumed, instead, that skips 1 and 2 were operating in balance but that their suspending cables were both wrapped around their respective drums so that they would be operating above a predetermined intermediate level then the screw propelled nut 71 of switch 68 would have thrown the movable contact element thereof to the left hand stationary contact member thus completing an energizing circuit through relay 70 hence completing a circuit from the (+) terminal of drum 60 through conductors 65 and 93, the bridged contact members of relay 70, conductor 40, the actuating coil of relay 42 to the (—) terminal. Energization of relay 42 would short circuit resistor 33 thus increasing the motor field strength and decreasing the maximum possible speed of the motors. A similar limit switch 108 is provided in connection with contact members 111 of reversing switch 24 and drum 8 which would operate the same way as limit switch 68 together with its associated reversing switch 22.

In Fig. 2 a modification of my invention is shown in which two clutches 109 and 110 are used instead of the single clutch 9 of Fig. 1 and in which corresponding clutch solenoids 109a and 110a are used. The clutch operating levers each include a slot so as to permit operation of one clutch without interfering with the other. Also in Fig. 2 a single motor 6 and generator 4 are used which generator motor set can selectively drive either of the skips 1 and 2 or both depending upon the setting of selector switch 44'. The controller 60' is essentially the same as controller 60 of Fig. 1, since it selects the direction of drive of the skip. The remaining parts are identical to those described in Fig. 1 and are identified by the same reference numerals and the operation thereof is the same, hence it is deemed that further description is unnecessary. For this type of hoist it will be apparent that an increase in motor field strength (by short circuiting resistor 38) is automatically obtained when the clutch is set for unbalanced operation from either drum so as to reduce the maximum speed inasmuch as the torque required to operate a single unbalanced drum would be high. In this manner the developed horsepower is restricted in value.

Assume that it is desired to operate only the right hand skip 1 and to maintain the left hand skip 2 stationary. Selector switch 44' is moved to the "right" position, thereby completing a circuit from the (+) terminal through conductor 112, clutch coil 109a to the (—) terminal, thereby causing movement of armature 113 to the left, effecting disengagement of clutch 109 and retaining engagement of clutch 110 (by the force of spring 114) due to the pin and slot connection 115. Another circuit will be completed from the (+) terminal of selector switch 44', through conductor 116, relay 41 to the (—) terminal, thereby causing short circuiting of resistors 37 and 38. Assume further that it is desired to hoist the skip 1. Drum controller 60' is thus moved to the "hoist" position thereby connecting the (+) terminal of the drum controller through a plurality of circuits to a (—) terminal which circuits are (in order, from top to bottom) as follows: a circuit through conductor 117, a segment of selector switch 44', conductor 118 through brake coil 16a, thereby releasing brake 16; a circuit through conductor 119 and the operating coil of line contactor relay 120, thereby closing contact members 121 to complete an energizing circuit through motor field winding 32, also closing contact members 122 to complete a circuit through generator field winding 18, a circuit through conductor 123 and the coil of relay 43 to effect short circuiting of economy resistor 39; a circuit through conductor 124 to the coils of reversing switches 22 and 23, thereby selecting the direction of current application through the generator field winding 18, which in this instance may be traced from the (+) terminal adjacent one of contact members 122, thence through contact members 122, conductor 125, contact members 22, conductor 126, generator field winding 18, resistors 86, 85 and 84, conductor 127, contact members 23 to the (—) terminal, thereby generating current in the generator field winding in such direction as to cause motor 6 to drive drum 7 so as to wind the cable and raise skip 1.

Upon moving drum controller 60' to the sec-

ond "hoist" position a circuit will be completed through conductor 128 and relay 106 to effect short circuiting of resistor 84—and upon removing the drum controller to the third "hoist" position a circuit will be completed through both conductors 128 and 129 to both relays 106 and 107, respectively, to effect short circuiting of resistors 84 and 85 to further increase the strength of generator field winding 18 for effecting increase in hoisting speed.

If it were desired to lower the right skip 1 instead of raising it, drum controller 60' would be moved to the "lower" position and the same circuits as outlined above will be completed with the exception that instead of a circuit through conductor 124 and the coils of reversing switches 22 and 23, there would be completed a circuit through conductor 130 and the coils of reversing switches 24 and 25 to effect reversal of the direction of current flow through generator field winding 18, hence causing downward drive of skip 1.

If it were desired to operate both skips 1 and 2 simultaneously for balanced operation, selector switch 44' would be placed in the mid position, as shown in the drawings (indicated as "both"). In such position no circuit will be completed through conductor 116 and relay 41, therefore resistors 37 and 38 remain in the motor field circuit, thereby permitting maximum motor speed. In such position, also, neither of the clutch coils 109a or 110a is energized, hence both clutches 109 and 110 remain engaged. Also both of the brake coils 15a and 16a are energized through conductors 131 and 118, respectively, thereby overcoming the action of springs 15b and 16b and releasing brakes 15 and 16, respectively.

During balanced operation with both skips it will also be noted that the circuit through conductor 116 and relay 41 is interrupted, hence this relay will not effect shunting of resistors 37 and 38. As reversing switch 23 closes, contact members 132 simultaneously close and complete a circuit through the right hand contact members of limit switch 68 (assuming that skip 1 is initially below an intermediate level) and the coil of relay 69 is energized, thus closing interlocking contact members 133 which will bridge the right hand contact members of limit switch 68 and maintain relay 69 energized as long as reversing switches 22 and 23 remain closed. Thus as skip 1 passes the intermediate level at which the movable contact member of the limit switch 68 moves to the left, the circuit through the coil of relay 69 is broken by the presently open contact members 134 of relay 69. Thus for hoisting from positions below an intermediate level, the hoist speed is not reduced as skip 1 passes the level except that if skip 1 should be stopped above this level and restarted to hoist skip 1 again, then the remainder of the hoisting cycle will be made at reduced speed, for this would mean that upon such restarting, a circuit will be completed through the left hand contact members of limit switch 68, the coil of relay 70 and contact members 134, thereby effecting completion of another circuit through relay 42 to effect shunting of resistor 38. Similarly if the left skip 2 is raised from a position above a predetermined intermediate level (as shown in the drawings) a circuit will be completed through the right hand contact members of limit switch 108 through the coil of relay 135, hence completing another circuit through relay 42 to shunt resistors 37 and 38 for reduced maximum speed operation. Had skip 2 been raised from a position lower than the intermediate level, the left hand contact members of limit switch 108 would have been closed and the circuit through relay 135 would have been interrupted. The remainder of the operation is exactly the same as described above in connection with a single skip operation except, of course, that the motor 6 drives both of the skips 1 and 2 (since they are coupled) instead of a single skip.

While a single clutch hoist (Fig. 1) and double clutch hoist (Fig. 2) have been described, other types of hoists could be adapted so as to use the feature of an adjustable speed motor with a control scheme to give increased field strength automatically when the clutch or clutches are set for unbalanced operation.

Furthermore, while Fig. 1 shows two driving motors and two driving generators, the invention could be equally applied to a scheme, for example, employing a single motor supplied by one or more generators, as shown in Fig. 2.

I am, of course, aware that others, particularly after having had the benefit of the teachings of my invention, may devise other devices embodying my invention, and I, therefore, do not wish to be limited to the specific showings made in the drawings and the descriptive disclosure hereinbefore made, but wish to be limited only by the scope of the appended claims and such prior art that may be pertinent.

I claim as my invention:

1. In a mine hoist control system, the combination with a generator-motor set, having a field winding for the generator and a field winding for the motor, a cage, a cable for supporting the cage, and a drum driven by the motor to wind the cable in or out, of means for controlling the excitation of the field winding of the motor, and means responsive to the starting terminal position of the cage for controlling the excitation means to determine the degree of excitation according to the location of the starting terminal position.

2. In a mine hoist control system, the combination with a generator-motor set, having a field winding for the generator and a field winding for the motor, a cage, a cable for supporting the cage, and a drum driven by the motor to wind the cable in or out, of means for controlling the excitation of the field winding of the motor, and means responsive to the starting terminal position of the cage for controlling the excitation means to determine the degree of excitation according to the location of the starting terminal position, of a source of excitation for the field winding of the motor, a resistor in the circuit of the field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch movable to either of two positions according to the position of the cage, and means controlled by the limit switch for controlling the short-circuiting switch to short-circuit the resistor.

3. In a mine hoist control system, the combination with a generator-motor set, having at field winding for the generator and a field winding for the motor, a cage, a cable for supporting the cage, and a drum driven by the motor to wind the cable in or out, of means for controlling the excitation of the field winding of the motor, and means responsive to the starting terminal position of the cage for controlling the excitation means to determine the degree of ex-

citation according to the location of the starting terminal position, of a source of excitation for the field winding of the motor, a resistor in the circuit of the field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch movable to either of two positions according to the position of the cage above or below an intermediate level, and means controlled by the limit switch according to its position at the starting terminal position of the cage for controlling whether the short-circuiting switch for the resistor shall be operated or not.

4. In a mine hoist control system, the combination with a generator-motor set, having a field winding for the generator and a field winding for the motor, a cage, a cable for supporting the cage, and a drum driven by the motor to wind the cable in or out, of means for controlling the excitation of the field winding of the motor, and means responsive to the starting terminal position of the cage for controlling the excitation means to determine the degree of excitation according to the location of the starting terminal position, of a source of excitation for the field winding of the motor, a resistor in the circuit of the field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch movable to either of two positions according to the position of the cage above or below an intermediate level, a relay controlled by the limit switch, when the limit switch is in lower position, to prevent operation of the short-circuiting switch while the cage is being raised from its lowest position.

5. In a mine hoist control system, the combination with a generator-motor set, having a field winding for the generator and a field winding for the motor, a cage, a cable for supporting the cage, and a drum driven by the motor to wind the cable in or out, of means for controlling the excitation of the field winding of the motor, and means responsive to the starting terminal position of the cage for controlling the excitation means to determine the degree of excitation according to the location of the starting terminal position, of a source of excitation for the field winding of the motor, a resistor in the circuit of the field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch movable to either of two positions according to the position of the cage above or below an intermediate level, a relay controlled by the limit switch, when the limit switch is in the upper position, to operate the short-circuiting switch when the cage is being raised from an intermediate starting position.

6. In a mine hoist system, provided with two cages arranged for operation in balance, a cable to suspend each cage, a drum for each cable, and a motor for the drums, with a shunt field winding for the motor, and a source of energy for the field winding of the motor, the combination of a resistor in the circuit of the motor field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, and means for controlling the operation of the short-circuiting switch according to the location of the starting position of either cage in an upward direction.

7. In a mine hoist system, provided with two cages arranged for operation in balance, a cable to suspend each cage, a drum for each cable, and a motor for the drums, with a shunt field winding for the motor, and a source of energy for the field winding of the motor, the combination of a resistor in the circuit of the motor field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch for each cage and movable to either of two positions according to the position of the cage above or below an intermediate level when hoisting of the respective cage is started, and means selectively controlled by each limit switch according to whether the starting position of either cage in an upward movement is below or above the intermediate level, said means operating selectively to operate or to prevent operation of the short-circuiting switch, thereby to control the degree of excitation of the motor field winding.

8. In a mine hoist system, provided with two cages arranged for operation in balance, a cable to suspend each cage, a drum for each cable, and a motor for the drums, with a shunt field winding for the motor, and a source of energy for the field winding of the motor, the combination of a resistor in the circuit of the motor field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch for each cage and movable to either of two positions according to the position of the cage above or below an intermediate level when hoisting of the respective cage is started, a source of energy for the motor, a control switch to control the supply of energy to the motor, and means responsive to a control operation of the control switch and operative in accordance with the then position of the limit switch to selectively control the operation of the short-circuiting switch, by closing it or by preventing its closure, thereby to control the degree excitation of the motor field winding for the duration of that operation of the motor in response to the control movement of the control switch.

9. In a mine hoist system, provided with two cages arranged for operation in balance, a cable to suspend each cage, a drum for each cable, and a motor for the drums, with a shunt field winding for the motor, and a source of energy for the field winding of the motor, the combination of a resistor in the circuit of the motor field winding, a switch operative to short-circuit the resistor when the switch is moved to closed position, a limit switch for each cage and movable to either of two positions according to the position of the cage above or below an intermediate level when hoisting of the respective cage is started, a source of energy for the motor, a control switch to control the supply of energy to the motor in a selected direction, thereby to control the direction of rotation of the motor for raising or lowering the cage, and relay means selectively controlled by each limit switch at the beginning of a raising movement of the cage, to close or to prevent closure of the short-circuiting switch according to whether the starting position of the cage is above or below the intermediate position, thereby to control the degree of excitation of the motor field winding.

10. In a mine hoist system, provided with two cages, to be operated simultaneously in balance or singly unbalanced from a level either below or above a predetermined intermediate level, with cylindro-conical drums for the suspending ropes or cables for the cages, of two motors for driving the drums, a field winding for each motor, the combination of means connecting the motor field windings in series in a circuit including a cur-

rent-limiting resistor and a dummy resistor, means for separately energizing and operating the motors to operate either cage independently or both cages simultaneously, and means operative, when only one motor is to be operated, for short-circuiting the field winding of the other motor and inserting the dummy resistor in the circuit.

11. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable and each drum having a frusto-conical portion on its surface, a reversible driving motor, a pair of clutches each being interposed between said driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches thereby making possible single unbalanced operation of either skip or balanced operation of both skips, speed reducing means for reducing the maximum attainable speed of said driving motor, means including a limit switch for making said speed reducing means operative when either skip is operated singly for unbalanced operation, or when both skips are operated in balance with one of the skips being hoisted from a position above a predetermined intermediate level.

12. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable and each drum having a frusto-conical portion on its surface, a reversible driving motor, a pair of clutches each being interposed between said driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches, thereby making possible single unbalanced operation of either skip or balanced operation of both skips, said driving motor having a shunt field winding and a resistor in series with said winding, limit switch means responsive to the respective positions of the skips which is effective to short circuit a portion of said resistor whenever both skips are operating simultaneously in balance above an intermediate level, or when one of said skips is being hoisted from a position above an intermediate level during balanced operation or when either skip is operated singly for unbalanced operation irrespective of the initial starting position of such singly operated skip.

13. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable, and each drum having a frusto-conical portion on its surface, a motor-generator set for driving said drums, a pair of clutches, each being interposed between the driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches, thereby affording single unbalanced operation of either skip or balanced operation of both skips, speed reducing means for reducing the maximum attainable speed of said driving motor, means including limit switches for making said speed reducing means operative when either skip is operated singly for unbalanced operation, or when both skips are operated in balance with one of the skips being hoisted from a position above a predetermined intermediate level, said generator having a field winding and a resistor in series therewith, control means for controlling the direction of flow of energizing current through said generator field winding and for selectively shunting portions of said last mentioned resistor, thereby obtaining variable speed drive in either the hoisting or lowering direction of the skip or skips.

14. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable, and each drum having a frusto-conical portion on its surface, a motor-generator set for driving said drums, a pair of clutches, each being interposed between the driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches, thereby affording single unbalanced operation of either skip or balanced operation of both skips, said driving motor having a shunt field winding and a resistor in series with said winding, a double throw limit switch associated with each of said drums and which is responsive to the position of the respective skip as being above or below a predetermined intermediate level, means including said limit switches, which is effective to short circuit a portion of said resistor wherever both skips are operating simultaneously in balance above an intermediate level, or when one of said skips is being hoisted from a position above an intermediate level during balanced operation or when either skip is operated singly for unbalanced operation irrespective of the initial starting position of such singly operated skip, said generator having a field winding and a resistor in series therewith, control means for controlling the direction of flow of energizing current through said generator field winding and for selectively shunting portions of said last mentioned resistor, thereby obtaining variable speed drive in either the hoisting or lowering direction of the skip or skips.

15. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable, and each drum having a frusto-conical portion on its surface, a reversible driving motor, a pair of clutches each being interposed between said driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches thereby making possible single unbalanced operation of either skip or balanced operation of both skips, speed reducing means for reducing the maximum attainable speed of said driving motor, means including limit switches for making said speed reducing means operative when either skip is operated singly for unbalanced operation, or when both skips are operated in balance with one of the skips being hoisted from a position above a predetermined intermediate level, limit switch means which is responsive to the initial starting position of the respective cages and responsive to the condition of whether the cages are operated singly or simultaneously to effect shunting of a portion of said motor field current limiting resistor thereby limiting the maximum obtainable motor speed whenever both cages are operated in balance above a predetermined intermediate level or whenever either cage is being operated singly or unbalanced.

16. In a mine hoist system provided with two cages, to be operated simultaneously in balance or singly unbalanced from a level either below or above or predetermined intermediate level, with cylindro-conical drums for the suspending ropes or cables for the cages, of two motor-generator sets comprising a field winding for each generator, means connecting said generator field winding in series circuit including a variable speed control resistor and a dummy resistor, and comprising a field winding for each motor and means connecting the motor field windings in series in a circuit including a current-limiting resistor and a dummy resistor, means for selectively energizing and operating either of said

motor-generator sets singly for unbalanced operation of the cage or simultaneously for balanced operation of the cages, and means operative when only one motor generator is to be operated for short circuiting the field windings of the other motor and generator and substituting therefor the respective dummy resistors.

17. In a mine hoist system, provided with two cages, to be operated simultaneously in balance or singly unbalanced from a level either below or above a predetermined intermediate level, the combination with cylindro-conical drums for the suspending ropes or cables for the cages, of two motor-generator sets comprising a field winding for each generator, means connecting said generator field winding in series circuit including a variable speed control resistor and a dummy resistor, and comprising a field winding for each motor and means connecting the motor field windings in series in a circuit including a current-limiting resistor and a dummy resistor, means for selectively energizing and operating either of said motor-generator sets singly for unbalanced operation of the cage or simultaneously for balanced operation of the cages, and means operative when only one generator is to be operated for short circuiting the field windings of the other motor and generator and substituting therefor the respective dummy resistors, speed reducing means for reducing the maximum obtainable speed of said driving motor or motors, means including limit switches for making said speed reducing means operative only when either cage is operated singly for unbalanced operation or when both cages are operated in balance above a predetermined level.

18. In a mine hoist system, provided with two cages, to be operated simultaneously in balance or singly unbalanced from a level either below or above a predetermined intermediate level, the combination with cylindro-conical drums for the suspending ropes or cables for the cages, of two motor-generator sets comprising a field winding for each generator, means connecting said generator field winding in series circuit including a variable speed control resistor and a dummy resistor, and comprising a field winding for each motor and means connecting the motor field windings in series in a circuit including a current-limiting resistor and a dummy resistor, means for selectively energizing and operating either of said motor-generator sets singly for unbalanced operation of the cage or simultaneously for balanced operation of the cages, and means operative when only one motor generator is to be operated for short circuiting the field windings of the other motor and generator and substituting therefor the respective dummy resistors, speed reducing means for reducing the maximum obtainable speed of said driving motor or motors, means including limit switches for making said speed reducing means operative only when either cage is operated singly for unbalanced operation or when both cages are operated in balance above a predetermined level, or when both cakes are operated in balance, one above and one below the predetermined intermediate level and the cage at the lower level is to be hoisted.

19. In a hoist system, in combination, a pair of drums each having a cable wound thereon and a skip suspended from each cable and each drum having a frusto-conical portion on its surface, a reversible driving motor, a pair of clutches each being interposed between said driving motor and one of said drums, selective means for effecting engagement of either or both of said clutches thereby making possible single unbalanced operation of either skip or balanced operation of both skips, speed reducing means for reducing the maximum attainable speed of said driving motor, means including limit switches for making said speed reducing means operative when either skip is operated singly for unbalanced operation, or when both skips are operated in balance above a predetermined intermediate level or when both skips are operated in balance, one above and one below said intermediate level and the lower skip is to be hoisted.

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