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[54] ELECTRICAL HOIST CONTROL SYSTEM

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[63] Continuation-in-part of Ser. No. 766,270, Oct. 9, 1968, abandoned.

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[51] **Int. Cl.**.....**H02k 7/34**

[58] **Field of Search**.....318/151–154; 187/29

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[57] **ABSTRACT**

An electrical control system for raising and lowering a drum-and-cable supported load. A reversible shunt wound drive motor which is connected to the drum is operable under the control of a continuously driven shunt wound generator. By measuring the amount of current flowing in the armature coil of the drive motor and varying the flow of current in the field coil thereof in relation to such armature current, the speed of the drive motor will become a direct function of the load which is placed on the latter. By reversing the polarity of the voltage which is supplied to the field coil of the generator, the direction of rotation of the drive motor may be reversed without disturbing the relationship between the load and the motor speed. Thus, whether the load is rising or descending, the greater its magnitude, the slower its speed. An electromechanical brake arrangement becomes automatically effective to lock the cable drum in a fixed position when load speed drops substantially to zero.

9 Claims, 2 Drawing Figures

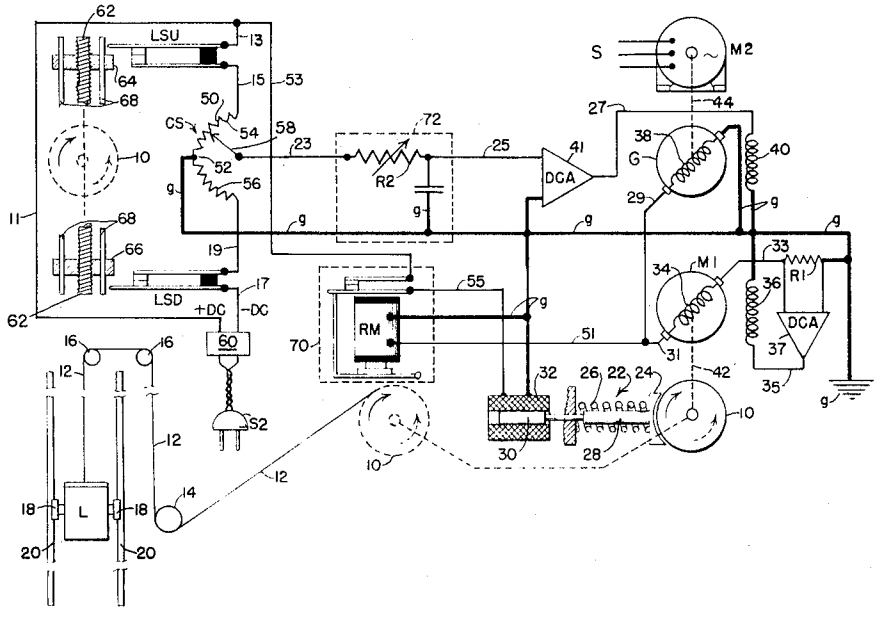


FIG. 1

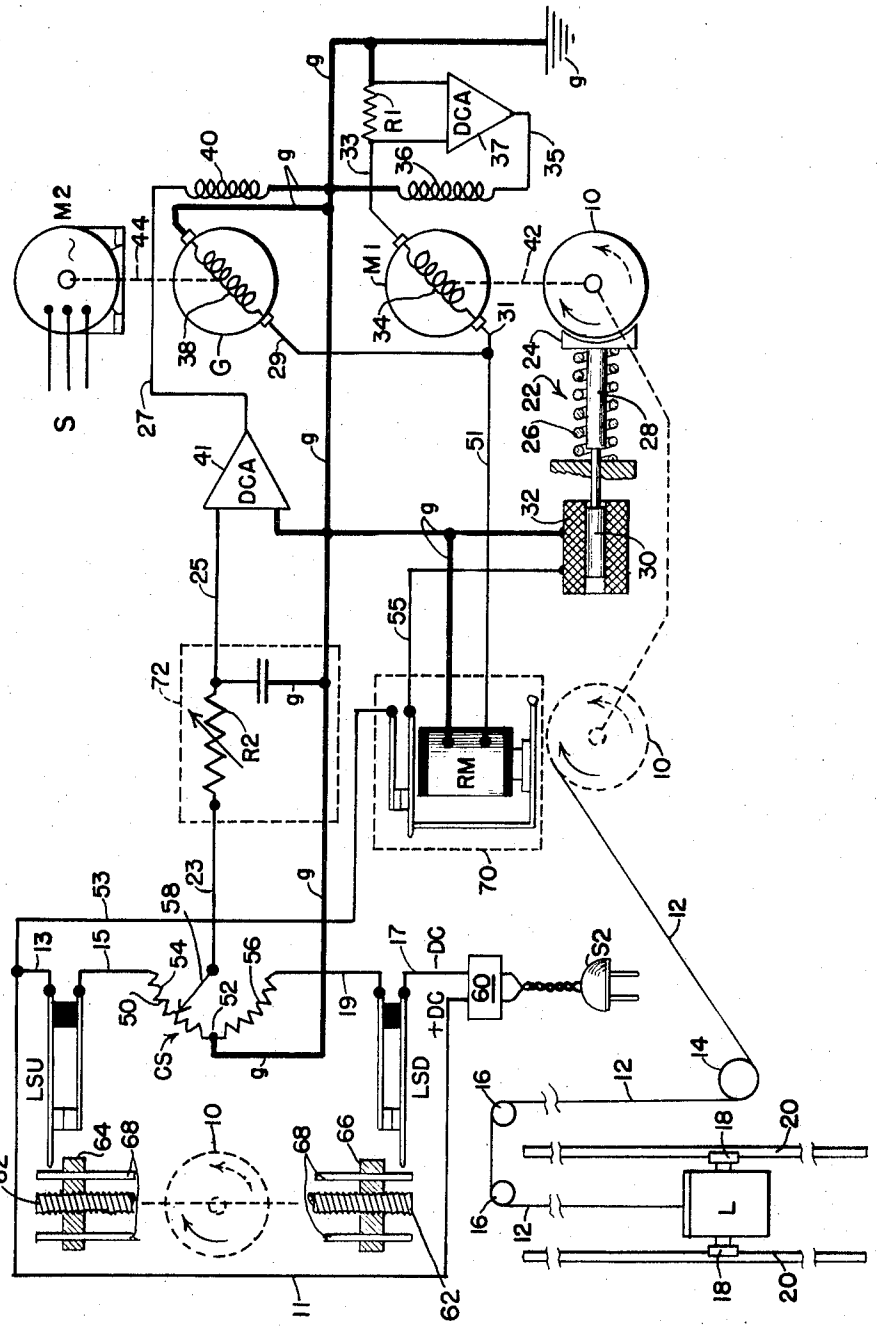
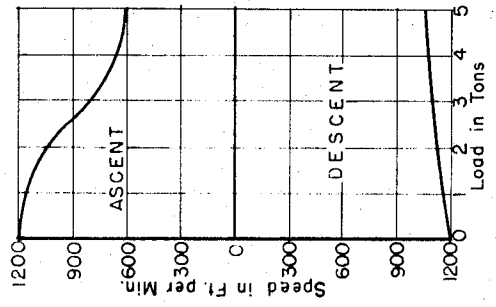


FIG. 2



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ELECTRICAL HOIST CONTROL SYSTEM

This is a continuation-in-part of our copending U.S. Pat. application Ser. No. 766,270, filed on Oct. 9, 1968 now abandoned and entitled "Hoist and Method of Operating Same."

The improved hoist control system comprising the present invention is designed for use primarily in connection with the erection of so-called high-rise buildings of multi-level construction wherein the load which is operated upon by the system is in the form of a conventional hoist car by means of which workmen and materials may be hoisted from ground level to various selected levels within the building undergoing erection, and also returned therefrom. The invention is, however, not limited to such use and a hoist system embodying the present invention may, if desired and with or without modification as required, be employed for raising and lowering other types of loads regardless of their nature or function. Irrespective of the particular use to which the invention may be put, the essential features thereof are at all times preserved.

The problems which present themselves in connection with high speed hoists of the character under consideration are not the same as those which are encountered in connection with passenger elevators which ordinarily are designed to travel either upwardly or downwardly at a fairly constant speed, regardless of the load, after an initial acceleration has brought the car to its rated speed. Where a hoist is concerned, it is not desirable that an extremely high no-load speed which may amount to as much as 1,200 feet per minute shall be preserved under a condition of a heavy load which, in the construction field, may amount to as much as 5 tons. The stopping of such a load within a given short range of movement would place a tremendous strain on the hoist cable, any gearing which may be employed between the drive motor and the cable drum, or even the reaction or foundation supporting structure which carries the constituent elements or assemblies which make up the hoist system. Brake failure under such conditions, whether mechanical or dynamic, also must be considered to be a major problem and, obviously, any brake failure which is encountered while transporting a heavy load at great heights presents a hazard.

The electrical hoist control system of the present invention is designed to obviate the problem of heavy load stopping and toward this end it contemplates the provision of a novel means whereby differences in the magnitude of the load result automatically in changes in the speed at which the load is being driven, regardless of whether the load be ascending or descending. Specifically and according to the present invention the speed of the load is maintained inversely proportional to the magnitude of the load and this ratio of load-to-speed is maintained during hoist operation for all speed settings of the control switch which is employed for regulating the mean speed of the load (hoist car and contents).

A further feature of the present invention resides in the provision of a novel means for releasing a spring-loaded mechanical brake which operates upon the hoist cable drum only at such time as the load very closely approaches a condition of rest after a period of dynamic braking has brought the load to such a condition. The brake, therefore, is employed solely as a static brake for holding the load stationary against downward creeping due to the pull of gravity upon the cable and has no dynamic mechanical friction function so that there is no wear upon the brake shoes that are associated therewith.

Another important feature of the present invention resides in the provision of a novel means for attaining uninterrupted and gentle acceleration and deceleration of the load in response to changes in setting of the speed control switch, this means being completely devoid of electrical relay devices which embody electrical switch-over contacts the opening and closing of which would ordinarily interrupt the smooth application of power during driving of the load with consequent or resultant jerky movement of the latter.

These and other features of the present invention are accomplished by the provision of a novel arrangement and association of electrical and mechanical components including a shunt wound drive motor for the cable drum, a constantly driven shunt wound generator which supplies motivating current to the drive motor, and an electrical interrelation between the armature and the field coils of this motor-generator combination whereby any change in the magnitude of the load is immediately measured and the output of the generator is altered accordingly. Insofar as the spring-loaded mechanical brake is concerned, a normally energized relay-actuated brake coil maintains the brake in a released condition. A relay magnet which receives its energizing current from the generator maintains the brake coil energized. At such time as the output of the generator drops below a value sufficient to supply motivating current to the drive motor, the relay magnet also becomes deenergized so that the relay drops out and effects deenergization of the brake coil, thereby applying the brake.

The provision of a hoist system such as has briefly been outlined above and possessing the stated advantages, constitutes the principal object of the present invention. Other objects and advantages of the invention, not at this time enumerated, will become readily apparent as the following description ensues.

The invention consists in the several novel features which are hereinafter described and are more particularly set forth by the claims at the conclusion hereof.

In the accompanying single sheet of drawings forming a part of this specification, one illustrative embodiment of the invention is shown.

In these drawings:

FIG. 1 is a schematic circuit diagram of the present electrical hoist control system, such system being operatively applied to a hoist drum; and

FIG. 2 is a graphic representation showing the relationship between the hoist load and the hoist speed in either direction (up or down) of hoist movement.

Referring now to the drawings in detail, the electrical hoist control system of the present invention is shown for exemplary purposes as being operatively applied to a reversible hoist drum **10** for the purpose of controlling the rotary movements thereof in accordance with the dictates of an operator who is stationed in the vicinity of a master control switch CS. The system is effective upon selective manipulation of the switch positively to drive the drum **10** in either a load-raising or a load-lowering direction at varying speeds, or to bring the load to a position of rest at any desired elevation, after which the system is automatically effective to apply a holding brake to the drum so as to maintain the

load in a stable condition at the point at which the operator has brought it to rest.

The schematic circuit diagram of FIG. 1 of the drawings embodies a disclosure of a typical hoist arrangement and no claim is made herein to any novelty which may be associated with the mechanical components of this illustrated arrangement. It will be understood that a wide variety of other hoist arrangements is capable of having the hoist control system of the present invention operatively applied thereto, the only requisite being that such arrangement shall have associated therewith a rotary hoist drum of the reversible type such as the illustrated hoist drum **10.** In the disclosed electric hoist system, the hoist drum **10,** when driven in a clockwise direction is indicated by the full line arrow, serves to draw in a hoist cable **12.** When driven in a counterclockwise direction as indicated by the dotted line arrow in FIG. **1,** the drum serves to pay out the cable. It will be understood, of course, that one end of the cable is fixedly secured to the drum as is conventional procedure with practically all hoist systems to prevent slippage of the cable on the drum. From the drum **10,** the cable passes over a pulley **14** which may be considered to be at or near ground level. From such pulley the cable passes upwardly and over a pair of overhead pulleys **16,** after which it extends downwardly and is attached to the load L which is to be hoisted. Since the present electrical hoist control system has been designed specifically for use in connection with the raising or lowering of a hoist car and its contents at the construction site of a very tall building, the load L assumes the form of such a car and will be discussed herein as such. Accordingly, it is shown as being providing with guide shoes **18** which are disposed on opposite sides thereof and are guided on vertical rails or tracks **20** which may exist within one of the elevator shafts of the building if the latter has been sufficiently erected to embody such a shaft, or otherwise the shaft may be provided in an outside tower in the vicinity of the building site. It will be understood, of course, that the hoist car which comprises the load L may be employed for transporting construction personnel and construction materials or tools to various building levels, or it may be employed for carrying discard materials or rubbish downwards from the various levels of the building.

The specific nature of the load L may vary widely and it is treated herein simply as a variable load. It will be understood, of course, that when this load assumes the form of a hoist car at the scene of a building installation, the load is likely to be changed frequently from a minimum which represents only the weight of the hoist car to a very heavy load which may be a batch of mixed concrete. As will become clear presently, such wide changes in the mass of the load are effectively sensed by certain electrical components of the present electrical hoist control system and the drive speed of the load, whether the load is moving upwardly or downwardly, is caused to increase or decrease in a positive manner, it being, of course, understood that the greater the load the slower the speed. As will also be described in detail presently, the control system of the present invention operates in a fully automatic manner to release an automatic, spring-loaded, electromechanical brake mechanism at such time as the hoist drum, when rotating in either direction, closely approaches a static condition, the braking effect being provided, not for the purpose of bringing the drum and, consequently, the load, to a position of rest, but for locking such drum in its stalled position at any desired load level so that when the electrical components which are associated with the control system are completely deenergized, there will be no downward creeping of the load L.

The aforementioned automatic, spring-loaded, electromechanical brake mechanism for the drum **10** appears in the lower right hand corner region of FIG. **1** and is designated in its entirety by the reference numeral **22.** This brake mechanism is of conventional construction and includes a plurality of brake shoes **24,** only one of which is illustrated herein, the shoe being spring-loaded by a helical compression spring **26** which normally forces the brake shoe **24** against a circular braking surface on the drum **10.** The brake shoe **24** is connected by means of a plunger **28** to the movable core **30** of a solenoid winding **32,** the core being axially slidable in the winding and being effective when the winding is energized to overcome the compression of the spring **26** and move the shoe **24** out of contact with the braking surface on the drum **10.** At such time as the solenoid winding **32** (hereinafter referred to as the brake coil) becomes deenergized, the spring **26** causes the brake shoe **24** to be applied in the usual manner of operation of such spring-loaded solenoid-actuated brake assemblies.

The hoist drum **10** is adapted to be driven by a reversible drive motor **M1.** Such motor is a reversible shunt-wound direct current motor having an armature winding **34** and a field winding **36** which receives energizing current from a direct current amplifier **37.** This motor **M1** relies for its operation upon a generator G which also is of the shunt-wound direct current type and has an armature winding **38** and, in addition, a field winding **40** which receives current from a main direct current amplifier **41,** the motor **M1** and the generator G being electrically connected together in a manner that will be made clear presently. The generator G is, in turn, driven by a motor **M2** which may be in the form of a three phase, 60 cycle alternating current motor which may be supplied with current at 480 volts from a suitable source S. The driving connection from the motor **M1** to the hoist drum **10** is indicated by the dotted line **42** which may represent a suitable train of gearing. The driving connection between the motor **M2** and the generator G is similarly indicated by the dotted line **44** and may represent a suitable belt and pulley arrangement or a direct drive shaft.

Considering now the nature of the control switch CS and its associated adjuncts, this control switch constitutes the principal operating control instrumentality for the entire hoist control system. The switch is in the form of a resistance element **50** having a center tap **52** which is maintained at ground potential at all times. The center tap divides the resistance element **50** into an upper sector **54** and a lower sector **56.** A movable contact brush **58** is selectively operable throughout the upper and lower sectors **54** and **56.** The resistance element **50** is operatively connected to a direct current power supply unit **60** which may be in the form of a suitable rectifier having an alternating current input which is derived from a source **S2.** A pair of normally closed contacts which are associated with an upper limit switch LSU is interposed in the positive line which extends between the power supply unit **60** and the outer end of the upper sector **54** of the control switch

CS. In a similar manner, a pair of normally closed contacts which are associated with a lower limit switch LSD is interposed in the negative line extending between the power supply unit **60** and the outer end of the lower sector **56** of the control switch CS.

With the contacts of both limit switches LSU and LSD closed, a positive energizing circuit is established for the upper resistance sector **54** of the control switch CS, this circuit extending from the power supply unit **60**, through a pair of leads **11, 13**, the closed contacts of the upper limit switch LSU, a lead **15** and the upper resistance sector **54** to ground. A similar but negative energizing circuit extends from the power supply unit **60**, through a lead **17**, the closed contacts of the lower limit switch LSD, a lead **19** and the resistance sector **56** of the resistance **50** to ground.

The contacts of the upper limit switch LSU are adapted to become open when the load L attains a predetermined maximum height. Similarly the contacts of the lower limit switch LSD are adapted to become open when the load L reaches its lowermost level which may, for example, be ground floor level. Accordingly, the hoist drum **10**, as shown in dotted lines in the vicinity of these two limit switches LSU and LSD, may be connected in driving relationship to a worm **62** which carries a pair of travelling or movable nuts **64** and **66**, the nut **64** constituting an upper nut which is designed for engagement with the contacts of the upper limit switch LSU to open these contacts when the load reaches its uppermost limit, and the nut **66** constituting a lower nut which is designed for engagement with the contacts of the lower limit switch LSD to open these contacts when the load reaches ground floor level. The two nuts **64** and **66** travel on antitorque guide rods **58.**

From the above description it will be apparent that normally, with the contacts of both limit switches LSU and LSD closed, a positive potential will be placed upon the upper sector **54** of the resistance element **50** of the switch Cs, while a negative potential will be placed on the lower sector **56.** With the contact brush **58** at its center tap position, no current will be applied to this brush. With the brush in contact with either of the two sectors **54** or **56**, current of the appropriate polarity will be applied to the brush at a rate which is commensurate with he voltage drop which takes place as a result of the specific position of the brush.

Considering again the electromechanical brake mechanism **22**, this mechanism is operable under the control of a voltage sensitive relay mechanism **70** which includes a relay magnet RM and a pair of associated normally closed contacts. Normally, and as will be described presently, during actual movement of the load L in either direction, under the control of the motor M**1**, the relay magnet RM will remain energized so that the contacts thereof will be closed and current will be supplied to the solenoid winding **32** of the brake mechanism **22**, thereby maintaining the brake shoe **24** out of contact with the braking surface of the drum **10.** However, when the load L is at rest due to stopping of the motor M**1** and the drum **10**, little or no current will be applied to the relay magnet RM and the relay mechanism will drop out, thereby opening the contacts of the magnet RM and deenergizing the solenoid winding **32** so that the spring-loaded brake shoe **24** will be applied to the drum **10.**

Before considering the operation of the present hoist control system, it is well to bear in mind the fact that the speed of the hoist drum **10** is a function of the voltages which are applied to the armature winding **34** of the drive motor M**1** and the field winding **36** thereof. The direction of rotation of the drum **10** is determined by the polarity of the voltage which is applied to the armature winding **34.**

It is also important to bear in mind the fact that in the schematic circuit diagram of FIG. **1**, the system is illustrated as being conditioned for "up" operation wherein the load L is driven upwardly by the pulling action of the cable **12** which winds on the drum when the latter is rotating in a clockwise direction as indicated by the full line arrow.

The wiper or contact brush **58** is shown as being positioned for operation in the upper sector **54** of the resistance element **50** of the contact switch CS.

The nature and function of the various electrical components which have thus far been mentioned, as well as of certain components which have not yet been referred to, can best be described by setting forth the manner in which the control system as a whole operates, first in driving the load L upwardly and, secondly, in causing the load to move downwardly. As this description ensues, these heretofore unmentioned components will be introduced in their immediate electrical environment and their function will become clear by reason of the described relationship which they bear to other electrical components. For convenience in understanding the schematic circuit diagram of FIG. **1**, and in order to avoid detailed circuit tracing a common ground connection is illustrated by heavy lines, the remaining circuit leads being illustrated in light lines, the ground connection being indicated variously at *g*.

In operating the control system to move the load L, it must be assumed that a positive input to the amplifier **41** is effective to drive the load L either upwardly or downwardly. For purposes of discussion it will be assumed that such positive input to the amplifier **41** will effect upward movement of the load. Accordingly, with the contact brush **58** of the control switch CS engaging the upper sector **54** of the resistance element **50** as shown, a positive voltage will be applied to the input of the amplifier **41** from the direct current power supply unit **60**, this input circuit extending from the switch arm **58**, through a lead **23**, a linear time delay network **72** consisting of the usual variable resistor-condenser combination, and a lead **25** to the amplifier **41.** Again, it must be assumed that for a positive input, the amplifier will deliver a positive output. This positive voltage, acting through a lead **27** causes current to flow through the field winding **40** of the generator G and places a bias on such winding, it being understood, of course, that the generator G is continuously driven by the alternating current motor M**2.**

As soon as current flows in the field coil **40**, it causes the generator armature coil **38** to generate a voltage which is in proportion to the amount of current flowing through said field coil. Thus, as the control switch CS is manipulated by swinging the contact arm **58** across the upper sector **54** of the resistance element **50**, the voltage which is applied to the amplifier **41** will be varied accordingly, and the output current from the amplifier flowing through the generator field coil **40** will vary, so that the output voltage of the generator G will be varied.

Once again it must be assumed in the interest of clarity that the output from the generator armature wind-

ing 38 is positive. Since the upper side of this winding is connected directly to the ground *g*, any discussion of relative polarity is simplified. There is no negative output, the voltage at this point being simply zero. Now, with a positive voltage output from the generator armature winding 38, such voltage drives the drive motor M1, the lower terminal of the motor armature winding 34 receiving such voltage from the winding 38 through a pair of leads 29 and 31 and the upper terminal discharging to ground through a lead 33 and a resistor R1.

For the moment, it may be assumed that the resistor R1 represents substantially a short circuit from the armature winding 34. The resistor R1 has an extremely low resistance which may be on the order of less than one ohm and does not rob the armature winding 34 of any appreciable amount of power since the resistor does not develop a sufficient voltage drop to do so. The function of the resistor R1 is to measure the amount of current flowing through the armature winding 34 of the motor M1 and thus, for purposes of discussion it may be assumed that the armature winding will have a voltage across it which is roughly equal to that which is applied by the armature winding 38 of the generator G. With such a positive voltage applied to the armature winding 34 of the motor M1, the motor will rotate the drum in a direction that will pull the hoist load L upwardly, i.e., the clockwise direction which is indicated by the full line arrow in FIG. 1.

Considering now the field winding 36 of the motor M1 which, as previously stated, determines the speed of the motor, and consequently that of the hoist drum 10, the more field current present, the slower the motor will run. This is true because the field winding 36 causes the armature winding 34 to develop a back e.m.f. The more field current there is, the more easily this back e.m.f. is generated and the sooner it will equal the applied voltage and the slower the motor M1 will run.

Now, the field winding 36 derives its current from the direct current amplifier 37 through a lead 35 and, since the amplifier responds to the direct current drop across the resistor R1, as that voltage drop increases additional current is added to the current which is sent to the field winding 36 of the motor M1 through the lead 35. For a small amount of current flowing through the resistor R1, a small added voltage is applied to the field winding 36. For a large amount of current flowing through the resistor, with a consequent large voltage drop, a large additional current is applied to the field winding. Furthermore, since the current flowing through the resistor R1 is derived from the armature current of the motor M1 as previously noted, this armature current being proportional to the mass of the load as is the case with motors of this type, it can now be appreciated that for a heavy load there will be a heavy current in the resistor R1 with a consequent large voltage drop therethrough, resulting in the addition of a large component of current to the field winding 36. For a light load, there will be a small current flowing through the resistor R1 and this will add a small component of current to the field winding 36. The net result of this is that for a heavy load, there actually will be a stronger field current and, as previously pointed out, a stronger field current causes the motor M1 to run slower, thus slowing down the speed of the load L.

It is to be noted at this point that insofar as upward load movement is concerned this slowing down of the load L is not the expected result which takes place when a heavy load is placed upon any given shunt wound motor due to the back reaction force of the mass of the load and the inability of the motor to maintain its normal driving speed. It is a more positive electrically initiated slowing down of the load resulting from measuring the voltage drop across the resistor R1 and feeding this voltage differential through the amplifier 37 thereby to add a component of current flow through the field winding 36 of the motor M1. This unexpected result constitutes one of the principal features of the present invention. As will be pointed out presently, the same slowing down condition of the load L takes place regardless of whether this load is travelling upwardly or downwardly. During its down travel, the current flow conditions in the armature winding 34 and the field winding 36 become such that the gravitational pull of the load on the driving connection 42 (gear train) and the drum is exceeded by development of a back e.m.f. condition which actually retards the downward movement of an extremely heavy load. The heavier the load, the greater will be this retarding effect.

When it is desired to move the load L downwardly, the contact brush 58 will be moved into the lower sector 56 of the resistance element 50 of the control switch and, as long as the contacts of the two limit switches LSU and LSD are closed, negative and positive voltages will be applied to said resistance element 50. Upon such movement of the contact brush 58 of the control switch CS, a voltage which is proportional to the position of this brush is delivered to the direct current amplifier 41 but, since this voltage is a negative voltage, it is amplified as such, the amplified negative voltage being conducted to the field winding 40 of the generator G, the conditions being substantially the same except for the reversal in polarity and the current path being the same as that which was described when a positive voltage was applied to the amplifier 41 and to the field winding 40.

Under these conditions, the armature winding 38 of the generator G will now deliver a negative voltage which is then applied to the armature winding 34 of the drive motor M1 through the leads 29 and 31 so that this motor will drive the hoist drum 10 in the "down" direction of the load L. Again, the drive motor armature winding 34 returns to ground through the resistor R1 which may be neglected as far as any effective loss of power in the armature winding 34 is concerned.

At this point it is deemed pertinent to investigate what takes place with respect to the field winding 36 of the drive motor M1 and the load L. This field winding can be assumed to always conduct a small amount of current as before because the direct current amplifier 37 is so biased that the field winding 36 will always receive current whether or not there is any voltage drop across the resistor R1. At first glance it would be reasonable to assume that because the voltage which is applied to the armature 34 is negative, the resistor R1 would develop a negative voltage drop from right to left. However, it must be realized that the motor M1 is not necessarily operating under a load. In fact, since the load L is descending, it may be assumed that the load is working with the motor and is, in fact, actually pulling the motor ahead of itself or, in other words, overdriving. When a motor is overdriven a curious condition results, namely, that a reverse current flow is in-

duced in the armature thereof. In the present situation, current will actually continue to flow in the armature winding **34** in the same direction that it flowed when the load L was being pulled upwardly and the result of this is that there still is a voltage drop or bias in the same direction across the resistor **R1** so that current will be added to the field current of the motor **M1.** Thus for a heavier load there is more current in the field winding **36** and, otherwise, everything remains exactly the same as if the load L were being pulled upwardly, the only difference being that the polarity has been reversed but the current has not. Thus for a heavier load L there will be a greater field current and the motor **M1** will slow down regardless of the direction of the load.

Considering now a situation where it is desired to stop the load L at a predetermined level, the contact arm **58** of the control switch CS is moved to its center position, i.e., in register with the center tap **52** so that no voltage is applied to the amplifier **41** from the direct current power supply unit **60.** For a short period of time on the order of from 6 to 8 seconds as determined by the time delay network **72,** the amplifier **41** will continue to receive an input voltage because the load has not yet fully stopped at the moment that the contact brush **58** touches the center tap **52.** After the expiration of such time delay period, the input voltage to the amplifier **41** will settle down to zero, thus affecting the output voltage, as well as the flow of current through the field winding **40** of the generator G. As soon as the field current of the generator approximates zero, the armature output voltage will also approach zero. Prior to this time, the relay magnet RM is maintained energized by the current issuing from the armature winding **38** and conducted to the relay magnet through the lead **29** and a lead **51.** The relay magnet RM and its associated contacts constitute a voltage-sensitive relay device which drops out when the voltage which is applied to the magnet is extremely low and thus, when the generator G is no longer able to deliver sufficient voltage to the relay magnet RM, the now closed but normally open contacts which are associated therewith are released by the magnet so that they open and disable the brake coil **32** circuit which otherwise remains effective at all times when the armature winding **38** of the generator G is delivering current of either a positive or a negative polarity for load moving purposes. This brake coil circuit extends from the direct current power supply unit **60,** through the lead **11,** a lead **53,** the contacts of the relay magnet RM, a lead **55** and the brake coil **32** to ground. As soon as the brake coil **32** becomes deenergized, the compression in the spring **26** is released and the brake shoe **24** moves into contact with the braking surface on the drum **10** and locks the latter in its position of rest.

From the above description it will be appreciated that at no time is the brake mechanism **22** relied upon to exert a frictional braking effect on the brake drum for the purpose of bringing the same to a position of rest over a wide range of speeds. This mechanism is effective only at such time as the load L, whether ascending or descending, is merely creeping at a very slow speed. Even a sudden shifting of the contact brush **58** of the control switch CS from a remote position to a position of contact with the center tap **52** will not cause the brake mechanism **22** to be applied until the load has very nearly come to rest under the influence of the time delay network **72.** This network slowly dissipates the voltage input of the amplifier **41** and thereby reduces the current feed to the generator field winding **40.** As the current flowing in the generator field winding drops off, the induced voltage in the generator armature winding **38** decreases so that it is unable to feed the armature winding **34** of the motor **M1** with the current which is necessary to maintain high motor speed. This phenomenon is advantageous in assisting the operator in bringing the load L to rest at a predetermined or desired level. For this purpose, the operator will observe the load as it travels at high speed in either direction and then, a short time before he wants the load to stop, amounting to only a few seconds, he will place the contact brush **58** of the control switch CS near the center tap **52** and observe the load while it slows down and closely approaches the desired level. Then, with the load merely creeping toward this level at a very slow speed, the operator can easily predict the last short span of the stall period and immediately before the load reaches the desired level he will place the contact brush **58** on the center tap. By this time the time delay network **72** has practically run out and no appreciable time delay is involved in bringing the load to substantial register with such desired level. Under some circumstances, the operator may even place the contact brush **58** into the sector of reverse polarity so as to discharge the time delay network more rapidly.

Considering now the function and operation of the two limit switches LSU and LSD, if the load L is rising and it closely approaches the uppermost limit of its travel, the nut **64** will engage the contacts of the upper limit switch LSU and open the same. The contact brush **58** will, of course, be in the upper sector **54** of the control switch CS. At this time all current flow in the resistance element **50** of said control switch is terminated and, therefore, the potential on this resistance is reduced to ground potential or, in other words, zero. This is exactly what happens when the contact brush **58** is placed on the center tap **52.** Any further discussion would be a repetition of that already made and the load comes to a stop exactly as if the center tap connection had been made by the operator. The time delay network **72,** the amplifiers **37** and **41,** and the various generator and motor field and armature windings respond as heretofore described to bring the load to a gradual stop and effect brake application to the drum **10.** A similar situation exists when the load is descending and approaches ground floor level, the opening of the contacts of the limit switch LSD having the same effect as opening of the contacts of the limit switch LSU since the contacts of both limit switches are disposed in series relationship in the control switch CS circuit.

The graphic representation of FIG. **2** is exemplary of the manner in which the speed of the drive motor **M1** varies in accordance with the load L, the upper section of the graph relating to the up-movement of the load and the lower section relating to the down-movement thereof. The axis of abscissas is legended on the basis of a maximum load of 5 tons, while the axis of ordinates is legended on the bases of 1,200 feet per minute so that for an upward movement of the load, for example, under a condition of no load, a hoist speed of 1,200 feet per minute will at attained whereas, for a full load condition, the hoist speed will be approximately 600 feet per minute. These figures are merely exemplary and, in actual practice, will depend on many factors such as

the ratings of the various motor-generator components, the drag of the gearing, the character of the time delay network **72**, etc.

At the risk of repetition, it is pointed out that the illustrated sharp decrease in load speed with relation to the magnitude of the load when the latter is ascending is a result of a sensing of the resistor **R1** by the amplifier **37**, it being understood that as heretofore described the placing of a load on the motor **M1** will naturally cause a rise in armature current. This increased armature current develops a large voltage drop across the resistor **R1** and this voltage drop causes the amplifier **37** to yield more field current to the field winding **36**, thereby decreasing the speed of the load to a greater extent than ordinarily would be the case if load drag on the motor **M1** alone were relied upon. The less sharp decrease in load speed with relation to the magnitude of the load when the load is descending is attributable to the fact that despite the overdriving of the load, current in the armature **34** of the motor **M1** continues to flow in the same direction as it did before any overriding tendency was encountered. The downcoming load is now classifiable as a "light" load regardless of its true magnitude in that it does not increase the current flowing in the armature **34** and, therefore, only a small voltage drop occurs across the resistor **R1** and the added current which is supplied by the amplifier **37** to the field winding **36** is small, but nevertheless its presence is felt as the magnitude of the load increases. This decrease in load speed in proportion to the magnitude of the load obviously represents a safety factor since it positively prevents "running away" of the load under the influence of gravity. By the same token, since there is always a unidirectional current flow in the armature winding **34**, and since overrunning of the motor **M1** will cause an increase in the current flowing through the field winding **36**, any tendency for the load to cause overrunning of the motor **M1** prior to brake application will be eliminated and the brake mechanism **22** will come into operation only at such time as the load is nearly at a stall.

The invention is not to be limited to the exact arrangement of parts or elements shown in the accompanying drawings or described in this specification since various changes in the details of the mechanical and electrical components of the hoist control system may be resorted to without departing from the spirit or scope of the invention. For example, the figures mentioned herein relating to load speed and magnitude, the specific duration of the discharge characteristics of the time delay network **72**, and the values of various electrical components, are merely exemplary figures and may be varied within the limits of operability. The specific circuit wiring which is illustrated and described herein obviously would be modified in an actual hoist control installation. Therefore, only insofar as the invention is particularly pointed out in the accompanying claims is the same to be limited.

Having thus described our invention what we claim and desire to obtain by Letters Patent is:

1. In an electrical hoist control system for effecting raising and lowering of a cable-attached load and wherein the cable is wound upon a drum, the combination of: a reversible shunt wound direct current drive motor operatively connected to the drum in driving relationship, said motor having an armature winding and a field winding and being effective when driven in one direction to cause raising of the load and when driven in the opposite direction to cause lowering of the load, and control means automatically effective during driving of the motor in either direction to vary the speed of the motor,and consequently the speed of the load, in inverse proportion to the magnitude of the load , said control means embodying a main direct current amplifier effective selectively and continuously to apply varying voltage of opposite polarity to said armature winding to drive the motor in opposite directions, an additional direct current amplifier effective to supply current unidirectionally and continuously to said field winding to regulate the speed of said motor, and current sensing means responsive to an increase of current flow in said armature winding incident to an increase in the magnitude of the load for increasing the amount of current supplied to said field winding by said additional direct current amplifier in order thus to reduce the speed of the motor.

2. A hoist control system as set forth in claim **1** and including, additionally, a holding brake for said drum and movable between a position of drum engagement and a position of drum release, spring means yieldingly maintaining said brake in its engaged position, and holding means automatically effective during driving of said motor in either direction for overcoming said spring means and maintaining the brake in its released position except when said motor closely approaches a static condition.

3. A hoist control system as set forth in claim **2** and wherein said holding brake is solenoid-actuated and includes a brake coil, a normally closed relay switch in series with said brake coil and a source of current, and a relay magnet coil in series with said armature winding, said relay switch opening when current in said armature winding approaches zero, whereby said brake coil is deenergized and said spring means applies said holding brake.

4. An electrical hoist control system as set forth in claim **1** and wherein said control means further embodies a generator having a single armature winding and a single field winding, and motor means for driving said generator, the generator field winding being electrically connected to the main direct current amplifier and the armature winding of the generator being electrically connected to the armature winding of the shunt wound direct current drive motor.

5. In a direct current electrical hoist control system for effecting raising and lowering of a cable-attached load and wherein the cable is attached to a rotary drum, the combination of a power supply unit establishing a source of current at a positive voltage and a source of current at a negative voltage, means establishing a common ground for said current sources, a reversible shunt wound drive motor including an armature winding and a field winding having one end grounded, a shunt wound generator including an armature winding having one end grounded and its other end connected to one end of the motor armature winding, and a field winding having one end grounded, a current measuring resistor connecting the other end of the motor armature winding to ground, a first amplifier responsive to the voltage drop across said resistor and having its output connected to the other end of said motor field winding, said resistor having an ohmic value sufficiently low as not appreciably to affect the flow of current through said motor armature winding,

a second amplifier having its output connected to the other end of said generator field winding, a control switch connected to said power supply unit and effective selectively to supply current of opposite polarity to the input of said second amplifier, and motor means for driving said generator.

6. A direct current electrical hoist control system as set forth in claim **5** and wherein said control switch is in the form of a resistance having a grounded center tap which divides the resistance into a positive sector and a negative sector, the ends of said sectors being connected respectively to the sources of current established by said power supply, and a movable contact brush positionable along said resistance and connected to the input of said second amplifier.

7. A direct current electrical hoist control system as set forth in claim **6** and including, additionally, a solenoid-actuated normally engaged spring-loaded brake for said drum, a brake coil effective upon energization thereof to release said brake, a relay magnet effective upon energization thereof to energize said brake coil, said relay magnet being responsive to current flowing through the armature winding of said drive motor.

8. A direct current electrical hoist control system as set forth in claim **7** and wherein said relay magnet has one end grounded and its other end connected to said one end of the motor armature winding.

9. A direct current electrical hoist control system as set forth in claim **6** and including, additionally, time delay means interposed between said movable contact brush and the input of said second amplifier whereby changes in the flow of current from said contact brush are delayed in their transmission to the input of the second amplifier.

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