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Cherry

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[54] **DRIVE AND CONTROL SYSTEM FOR DIAGNOSTIC AND THERAPEUTIC EXERCISE TREADMILL**

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[52] **U.S. Cl.**....................**338/200**, 272/69, 200/50 C

[51] **Int. Cl.**..**A63b 23/06**

[58] **Field of Search**......338/200, 201, 198, 172, 173; 272/69; 200/42 R, 172 R, 172 A, 50 C; 318/430

[56] **References Cited**

UNITED STATES PATENTS

3,659,845	5/1972	Quinton	272/69
2,942,221	6/1960	DiGirolamo	338/200
3,413,431	11/1968	Bang	338/200

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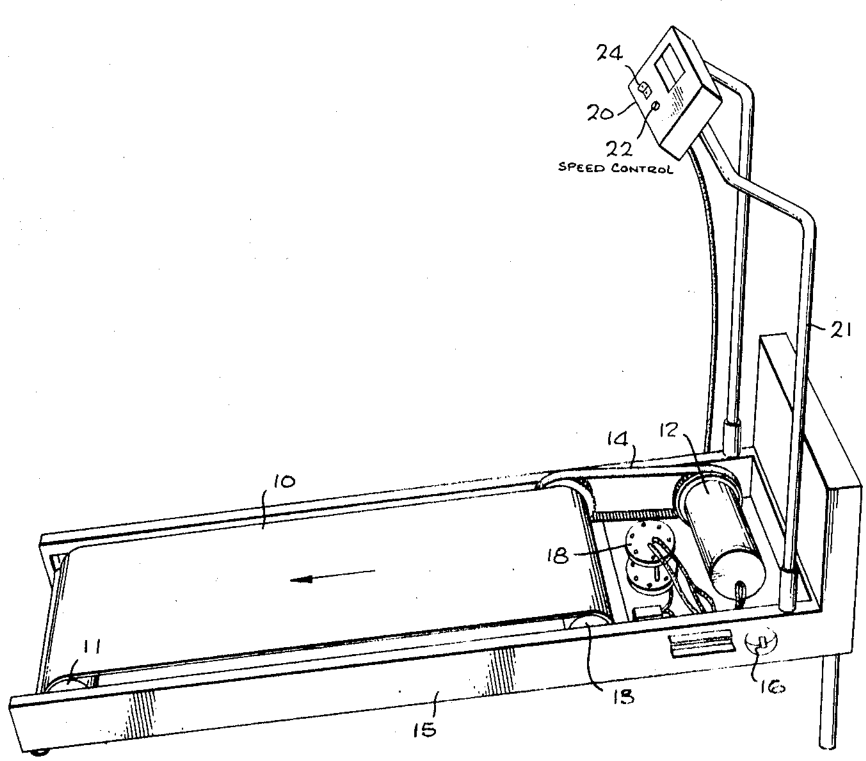
[57] **ABSTRACT**

An improved drive and control system for an exercise treadmill is provided which incorporates safety features for the prevention of a start-up at high belt speed after the treadmill has been turned off, or upon the resumption of power after a power failure, and to prevent rapid acceleration of the belt to a high speed condition in the case of certain control circuit failures. Circuitry, or other means, has been included in the drive system as an interlock whereby the manual on-off switch which activates the drive motor will not be effective until the motor speed control has been reset to the zero speed position. In addition, circuitry is included to provide for shutting down the drive motor in the event of a failure or malfunction in its control circuitry which could cause an unscheduled rapid increase in the treadmill belt speed to a high speed condition.

7 Claims, 6 Drawing Figures



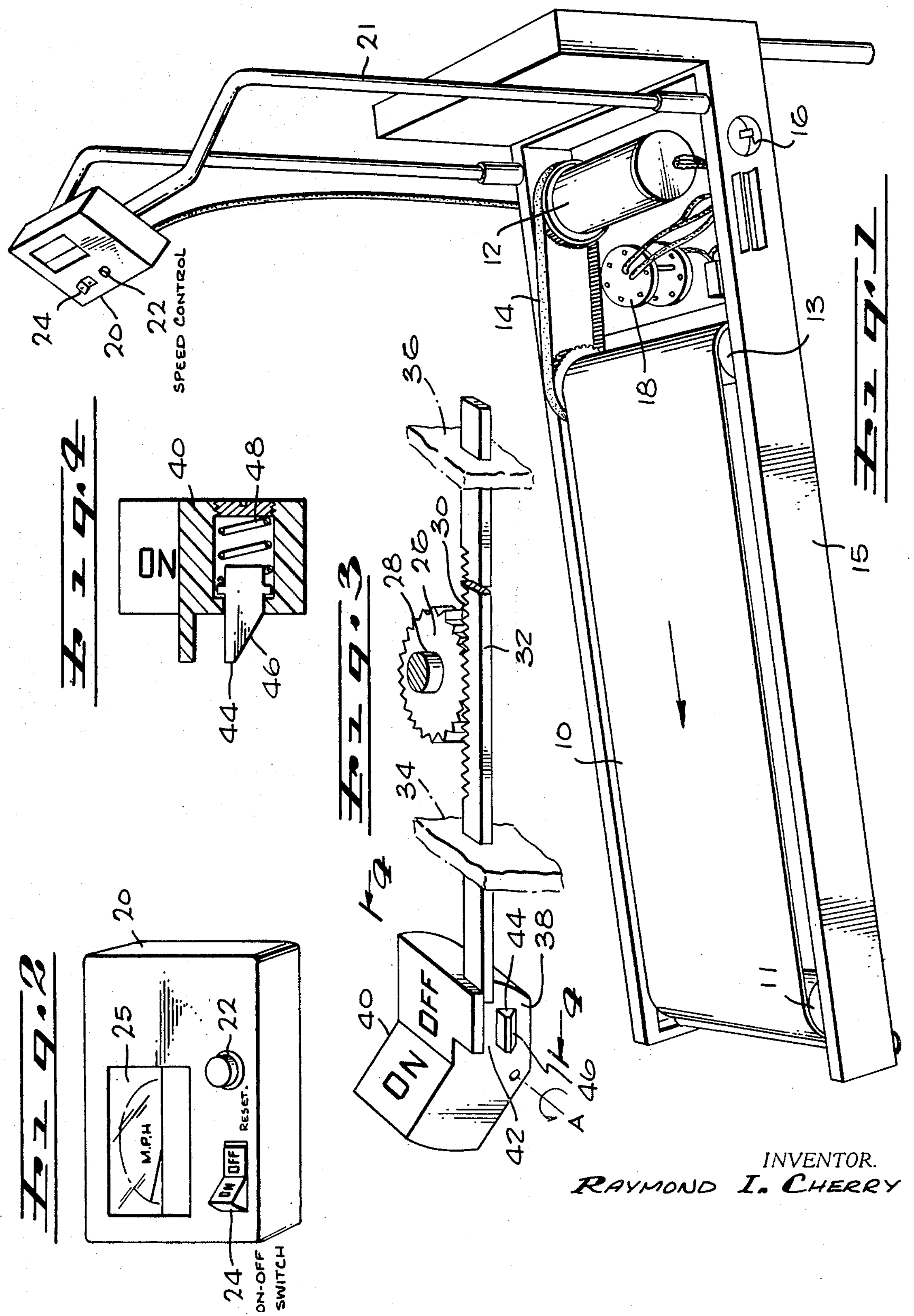


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Fig. 5

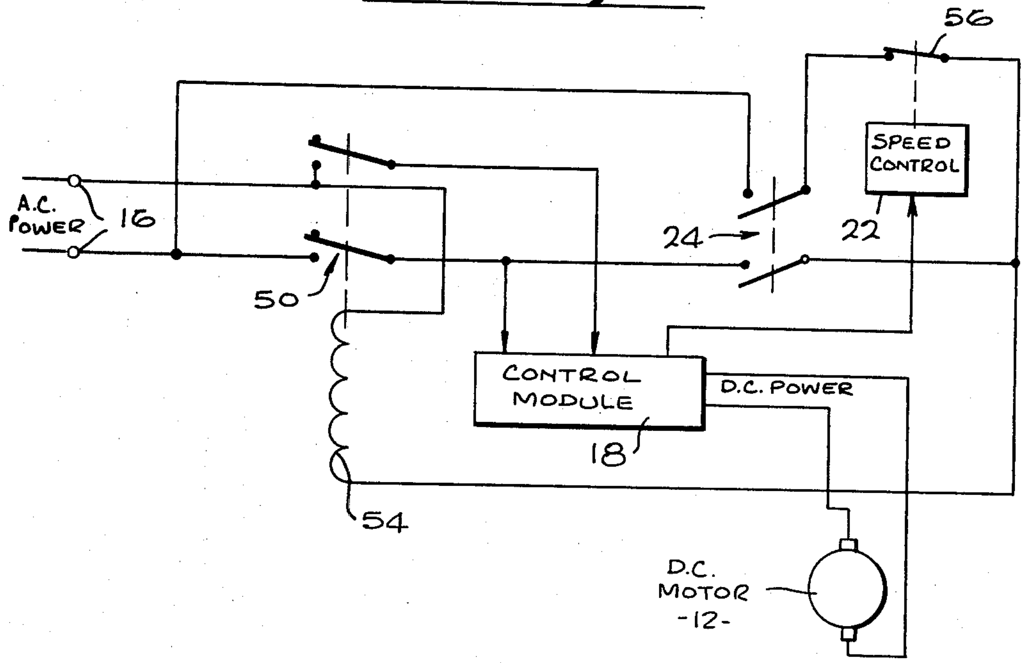
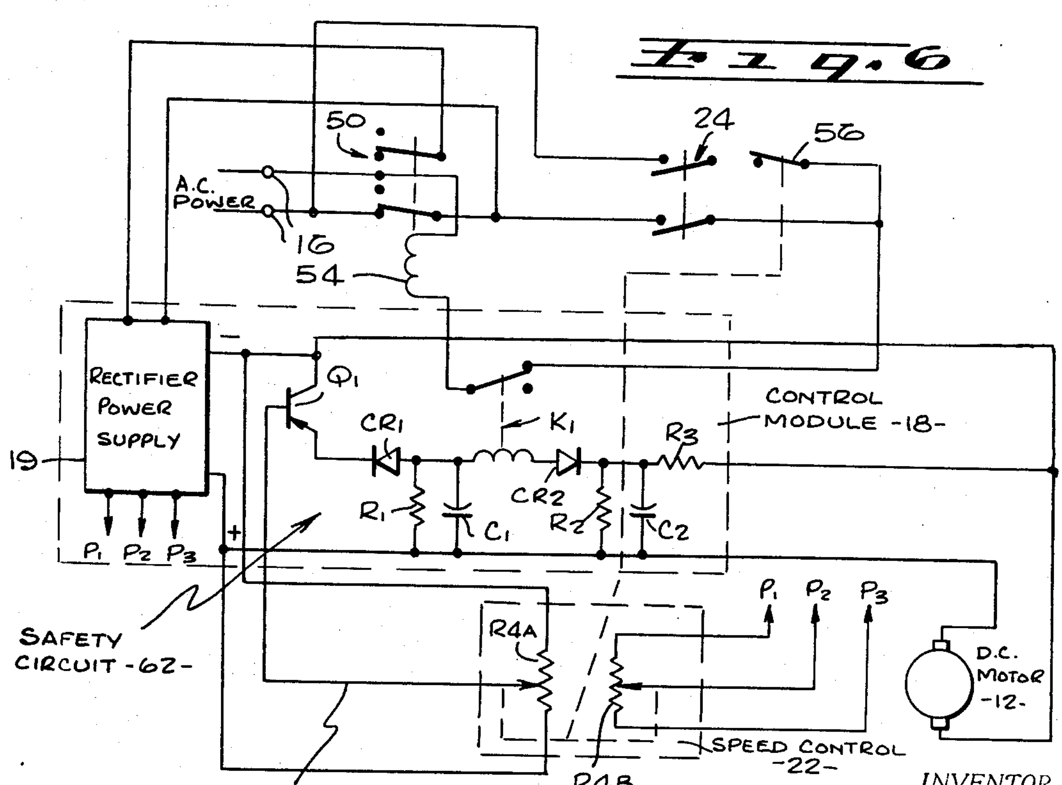


Fig. 6



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DRIVE AND CONTROL SYSTEM FOR DIAGNOSTIC AND THERAPEUTIC EXERCISE TREADMILL

BACKGROUND OF THE INVENTION

The drive and control system of the present invention may be used, for example, in conjunction with the diagnostic and therapeutic exercise treadmill described and claimed in copending application, Ser. No. 103,155, which was filed Dec. 31, 1970, in the name of Joseph A. Hesen, and which is assigned to the present assignee. However, it will become evident as the present description proceeds, that the drive and control system of the invention has general utility in conjunction with a wide variety of exercise treadmills, and the like.

As described in the aforesaid copending application, it is the usual prior art practice for electrocardiograms to be taken of patients in a resting position on a table or bed. However, it has been found that a resting patient may often produce a normal electrocardiogram, even though there is clinical or other evidence of abnormalities. It has been found, for example, that more conclusive electrocardiograms may be obtained if the patient is subjected to a continuous exercise representing a constant work load which may be graded at various time intervals. The treadmill has proven to be a suitable instrument for that, and other purposes, and clinical treadmill stress testing has become widespread as a basis for the study and diagnosis of the physical condition of patients.

An important objective of the present invention is to provide an appropriate drive and control system which renders the electric motor power driven treadmill absolutely safe, and easy to operate. For example, it is known to the art to provide a manual speed control in conjunction with the power driven treadmill, whereby the attending physician, or the patient himself, may control the treadmill belt speed from a low to a relatively high value.

It is usual in the prior art power driven treadmills to drive the treadmill belt with an alternating current electric motor, and to vary the speed of the motor over a limited range by varying the applied voltage. Some treadmills have been provided in the art with mechanical variable speed control mechanisms, and some with hydraulic drives. However, with such equipment, it is difficult to obtain a smooth control to zero speed while operating under load. An improved drive for the treadmill belt which permits a smooth speed control to zero speed is obtained by using a high-permeability permanent magnet direct-current motor, and by varying the direct-current voltage applied to the motor by an appropriate speed controller. Such a motor provides the necessary high torque at low speeds, and is capable of providing, for example, smoothly variable belt speeds in a range from 0–10 miles an hour.

A suitable speed controller for use in conjunction with such a direct-current motor incorporates, for example, a bridge rectifier including silicon controlled rectifiers, or the like, which are controlled so that a varying amplitude direct-current voltage may be applied to the direct-current motor for speed control. However, there is a possibility for the silicon controlled rectifiers, or other elements in such a controller to burn out or malfunction, and this can result in the controller introducing maximum direct-current voltage to the motor which, in turn, results in an unanticipated abrupt rise in the motor speed from the controlled level to a maximum level.

Such an unscheduled increase in the motor speed can be hazardous, and gives rise to the possibility of injury to the patient using the treadmill. The control system to be described incorporates appropriate circuitry which responds to an unanticipated rise in the direct-current voltage applied to the motor which could result, for example, from the aforesaid malfunction in the control circuit, and which serves to de-energize the motor and shut down the system in the presence of such a condition.

The control system to be described also includes interlocking means which may be of a mechanical or electrical nature, and which prevents the drive motor from being activated until the speed control has been set to a zero or reset position. Such an interlocking means prevents the activation of the drive motor by the main switch when the speed control is in any position other than zero. Without this feature, it would be possible for a patient to be standing on the belt, with the speed control setting at some value other than zero, and with the resulting unanticipated and rapid acceleration of the belt up to the set speed, with possible injury to the patient, when the switch is turned on.

A further feature of the electrical interlocking circuit to be described is that in the event of a power failure, or should the power cable for the treadmill be unplugged from the power main receptacle, while the treadmill is operating; the drive motor will not be energized when power is restored, unless the speed control is first reset to zero. This latter control prevents possible injury to a patient who is standing on the belt when power is restored, since it prevents the belt from rapidly accelerating to the preset speed, and requires a resetting of the system before it again becomes operational.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective representation of treadmill apparatus which may be constructed to incorporate the improved drive and control system of the invention;

FIG. **2** is a front view of a control unit for the treadmill of FIG. **1**, illustrating certain indicators and controls for the treadmill;

FIG. **3** is an enlarged fragmentary perspective view of a mechanical interlock between a power switch and speed control which are included in the unit of FIG. **2**;

FIG. **4** is a sectional view of a latch component of the interlock of FIG. **3**, taken essentially along the line **4—4** of FIG. **3**;

FIG. **5** is a circuit diagram of an equivalent electrical interlock between the power switch and speed control of the unit of FIG. **2**; and

FIG. **6** is a circuit diagram of an overspeed protection circuit for the drive motor of the treadmill of FIG. **1**.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

The treadmill shown in FIG. **1** includes an endless belt **10** riding on rollers **11** and **13** which, in turn, are mounted on appropriate bearings attached to a frame **15**. The belt **10** is driven, for example, by means of a motor **12** through an appropriate drive such as a toothed belt **14**. Power in the form of 110-volt AC current from the usual mains is supplied through a connector **16** to an electric control module **18** which, in turn, is controlled by a speed control rheostat **22** in a control unit **20**, to control the speed of the motor **12**. The control unit **20**, as described in the aforesaid copending application, may be mounted on a handle section **21** of the treadmill, for appropriate control by the patient himself, or it may be removed for remote control by the attending physician, or other attendant. When activated, the motor **12** drives the belt **10** in the direction of the arrow, and at a speed set by the setting of the speed control **22**.

As shown in FIG. **2**, the speed control rheostat **22** in the control unit **20** includes a knob which is turned, for example, in a clockwise direction to increase the motor speed, and which is turned in a counterclockwise direction to reduce motor speed. The speed control **22** may be turned in the counterclockwise direction to a zero "reset" position, at which the motor speed is zero. A snap-acting toggle-type manual on-off master power switch **24** is positioned on the control unit **20** adjacent to the speed control **22**, as shown in FIG. **2**. A speed control indicator **25** is also mounted on the control unit, and it may be directly calibrated in miles per hour (mph).

As stated above, an important objective of the present invention is to prevent any activation of the drive motor **12** when the on-off switch **24** is turned on, unless the speed control **22** has been turned back to its zero "reset" position, at which the speed of the belt **10** is reduced to zero. As will be described, this objective may be achieved in accordance with the invention, either mechanically, as shown in FIGS. **3** and **4**, or electrically as shown in FIG. **5**.

The mechanical assembly of FIG. **3** comprises a pinion **26** which engages a rack **30** on a slide **32**, the slide being held in position by bearing surfaces in bulkheads **34** and **36**, such that its left-hand end will enter the area **42** in the switch button **40** of the power switch **24** when the slide is moved to the left in FIG. **3**. The pinion is attached to the shaft **28** of the speed control **22**, so that rotation of the speed control **22** results in corresponding rotation of the pinion. In order to cause the left-hand end of the slide **32** to be removed completely from the area **42** of the switch button **40**, so as to permit full freedom in the movement of the master switch **24** from one position to the other, the speed control **22** must be turned in the counterclockwise direction to its zero or "reset" position, at which position the shaft **28** turns the pinion **26** to an angular position so as to displace the slide **32** to the right in FIG. **3**, thereby removing the left-hand end of the slide from the aforesaid area **42**.

With the master switch **24** in the "off" position, illustrated in FIG. **3**, rotation of the speed control **22** and pinion **26** in the clockwise direction from the "reset" position to increase the speed of the belt **10**, drives the left-hand end of the slide into the area **42** and over a spring-loaded latching cam **44**. The latching cam **44** is a part of the latch assembly shown in FIG. **4**. As illustrated in FIG. **4**, the latching cam **44** is contained in the body of the switch button **40**, and in its normal position is caused to protrude by the force of a spring **48**. The master switch is now prevented from being switched to its "on" position by the presence of the latch cam **44**, so long as the left-hand end of the slide **32** is in the area **42**. However, when the speed control is returned to the zero "reset" position, the left-hand end of the slide **32** is removed from the area **42**, and the switch **24** may then be turned on by depressing the switch button **40** so as to pivot the button in a counterclockwise direction about the axis A in FIG. 3.

Should the speed control be turned while the switch **24** is in its "on" position, the end of the slide **32** enters the area **38** under the latching cam **44**. Now, when the switch button **40** is pivoted in a clockwise direction about the axis A to its "off" position, the end of the slide **32** moves up the inclined surface **46** of the latching cam **44**, and forces the cam into the cavity in the switch button **40** against the force of the spring **48**. The left-hand end of the slide **32** then moves into the area **42**, and the latching cam **44** snaps out to its outer position, thereby trapping the slide **32**, and preventing the switch **24** to be returned to its "on" state, until the speed control **22** has been returned to zero, thereby removing the left-hand end of the slide **32** from the area **42**.

The interlock between the power switch **24** and the speed control **22** can be achieved electrically, as shown by the circuit of FIG. **5**. The circuit of FIG. **5** includes a normally open solenoid-operated relay switch **50** which includes a relay coil **54** connected in series with the incoming alternating-current power line. The relay switch **50** is connected, for example, to the control module **18** which supplies the direct-current power to the motor **12**. In its normal state, the relay switch **50** prevents the flow of alternating current to the control module **18**, so that the drive motor **12** which, in turn, drives the treadmill belt **10**, is deenergized. The coil **54** of the relay switch **50**, which when energized closes the relay switch, is included in the circuit in series with a switch **56**. The switch **56** is an integral part of the speed control **22**, and is closed only when the speed control is returned to its "reset" position.

As shown in FIG. **5**, the master switch **24** is a two-pole switch. One of the poles of the switch **24** completes the circuit to the relay coil **54**, only when the switch **56** is closed, so that the relay **54** can be energized only when the speed control **22** is in its "reset" position. The other pole of the switch **24** serves as a holding circuit to maintain the relay coil **54** energized after the speed control is subsequently turned from its "reset" position and the switch **56** is open. However, when the power switch **24** is actuated to its "off" position, the circuit cannot be energized until the speed control **22** has again been turned to the "reset" position to close the switch **56**. Also, if power is lost for any reason, such as a power failure, or the power cable becoming unplugged, the speed control **22** must be turned back to "reset" before the motor **12** can again be activated.

It is clear, therefore, that the speed control **22** must be returned to its "reset" position before any belt speed can be resumed. In this way, the belt **10** of the treadmill can be started only after the speed control **22** has been turned back to the zero speed condition of the belt.

As mentioned above, the circuit of FIG. **6** shows the drive system for the motor **12**, and it includes a safety circuit for preventing overspeed of the belt **10** of the treadmill due to a failure in the control circuit of the motor **12**.

In the circuit of FIG. **6**, the control module **18** includes a rectifier power supply **19** which is energized from the alternating-current power source when the relay switch **50** is closed. The rectifier **19** develops the direct-current voltage for the motor **12**, and the amplitude of this voltage is controlled so as to control the speed of the motor. For example, the rectifier power supply **19** may include a usual bridge rectifier which incorporates silicon controlled rectifiers in two of its arms. The direct-current voltage supplied to the motor **12** from the rectifier power supply **19** may be in the form of unfiltered, partial half-waves which, in turn, are controlled by the setting of the speed control **22** which, in turn, controls the silicon controlled rectifiers in the bridge network. Such variable controlled rectifier power supplies are known. However, should a silicon controlled rectifier, or other element in the power supply malfunction, an unscheduled and abrupt rise to maximum direct-current output could result, and this could result in an unexpected rapid acceleration of the motor **12** from its set speed to a maximum speed, with possible injury to the person using the treadmill. For that reason, a safety circuit designated **62** is incorporated into the control module, which will now be described.

The direct-current output from the rectifier **19** is connected to a potentiometer **R4A** which is included in the speed control **22**, and which has a movable element connected to the base of a PNP transistor **Q1**. The collector of the transistor **Q1** is connected to the negative output terminal of the power supply **19**, and the emitter is connected to the cathode of a diode **CR1**. The anode of the diode **CR1** is connected through the coil of a relay **K1**, through a further diode **CR2**, and through a resistor **R3** to one terminal of the motor **12**. The positive terminal of the power supply **19** is directly connected to the other terminal of the motor **12**. The speed control **22** includes a further potentiometer **R4B** which moves in unison with the potentiometer **R4A**, and which is connected by way of terminals **P1**, **P2** and **P3** to the rectifier power supply **19**. The potentiometer **R4A** serves to control the timing of the firing of the aforesaid silicon controlled rectifiers, and thereby controls the effective amplitude of the direct-current voltage applied to the motor **12**, in a manner known to the art.

A resistor **R1** and capacitor **C1** are connected from the junction of the diode **CR1** and relay coil **K1** to the positive terminal of the power supply **19**, and a resistor **R2** and capacitor **C2** are connected from the junction of the diode **CR2** and resistor **R3** to the aforesaid positive terminal. The relay **K1** has a normally closed contact in circuit with the energizing coil **54** of the power switch **50**.

The setting of the potentiometer **R4A** provides a reference voltage at the base of a PNP transistor **Q1**. The transistor **Q1** is connected as an emitter follower, the emitter of which being connected through a diode **CR1** to a resistor **R1**. The collector of the transistor **Q1** is connected to the negative terminal of the power supply **64**, whereas the resistor **R1** is connected to the positive terminal. The resistor **R1** is shunted by a capacitor **C1**. The diode **CR1**, resistor **R1** and capacitor **C1** are all connected to the other side of the energizing coil of the relay **K1**.

The setting of the potentiometer **R4A** provides a reference voltage at the base of the emitter follower transistor **Q1**, and this results in a negative reference voltage across the resistor **R1** in the emitter circuit of the transistor. This voltage is stored in the capacitor **C1** for a period of time sufficient to permit the voltage lag of the motor **12** to equalize any change in the field current, when the potentiometer **R4B** section of the speed control is changed rapidly for a reduced belt speed. This storage across the capacitor **C1** is necessary to prevent operation of the relay **K1**, with a resulting full shutdown of the system, when the speed control **22** is rapidly turned in the reduce speed direction. The voltage stored by the capacitor **C1** provides a reference voltage for the relay **K1**.

The relay **K1** is a conventional 12-volt relay, for example, which typically operates when 6 volts is placed across the coil or across its energizing coil, or when the current in its energizing coil in either direction exceeds a minimum value. The relay **K1**, therefore, acts as a differential switch, and opens the circuit of the energizing coil **54** of the relay switch **50** to shut down the system whenever the voltage differential across the capacitor **C1** and resistor **R2** exceeds a predetermined level. When the relay coil **54** is energized, the motor **12** cannot again be energized until the speed control **22** is returned to the "reset" position to close the switch **56**.

Therefore, if, for any reason, the voltage introduced to the motor **12** by the control module **18**, and which appears across the terminals **B1** and **B2**, exceeds by a predetermined amount the reference voltage established by the setting of the speed control **22**, the relay **K1** is activated to shut down the system, thereby preventing an unexpected acceleration of the motor **12**. Since the shut down operation is desired only where the motor voltage materially exceeds the reference voltage, the diode **CR2** is included in the circuit to prohibit any excitation of the relay **K1** except when the motor voltage exceeds the reference voltage, and not vice versa. In this way, inadvertent shut down of the system is obviated, for any condition except when the motor voltage **12** rises above the reference voltage so as to indicate the existence of a runaway condition.

The drive circuit of FIG. **6** causes the treadmill to continue to operate satisfactorily so long as the motor and reference voltages are in balance. However, the safety circuit **62** in the drive circuit constantly compares the reference voltage and the motor voltage, so that any failure, for example, in the control module **18**, whereby the direct current output voltage to the motor **12** increases beyond a predetermined amount, causes a flow of current in the differential relay **K1**. This, in turn, causes the relay **K1** to be activated to open the circuit of the energizing coil **54** of the relay switch **50**. As mentioned above, with the coil **54** deenergized, the relay switch **50** reverts to its normally open position thereby interrupting the flow of alternating current to the control unit **18**, and effectively arresting the motion of the treadmill belt **10**. The response to such an unbalance beyond a predetermined amount between the reference voltage and the motor voltage is almost instantaneous and the shut down of the treadmill is accomplished without the patient sensing any particular increase in belt speed.

The invention provides, therefore, an improved drive and control system for an exercise treadmill, and one which incorporates safety features, so that the use of the treadmill, and especially for therapeutic purposes, is safe and foolproof.

While particular embodiments of the invention have been shown and described, modifications may be made. It is intended in the following claims to cover all modifications which fall within the spirit and scope of the invention.

What is claimed is:

1. In an exercise treadmill having an endless belt and an electric drive motor for the belt, a drive and control system for said motor including: an input circuit adapted to be connected to a source of electrical energy; a control circuit connected to said input circuit and responsive to electrical energy from said source for introducing control energy to said drive motor; a manually adjustable speed control for contrôlling the speed of said motor; an electric switch for controlling the activation of said motor; and interlocking means intercoupling said speed control and said electric switch to prevent said motor from being activated until said speed control is adjusted to a particular position.

2. The combination defined in claim 1, in which said speed control comprises potentiometer means included in said control circuit, and said electric switch is interconnected between said input circuit and said control circuit, said interlocking means preventing said control circuit from being energized until said potentiometer means is adjusted to a particular position corresponding to zero speed of the motor.

3. The combination defined in claim 2, in which said electric switch includes a manually movable button member having a slot therein, and which includes a slide member mechanically coupled to said potentiometer means and movable into said slot to prevent actuation of said switch when said potentiometer means is turned away from a position corresponding to zero speed of said motor.

4. The combination defined in claim 3, and which includes a spring-loaded latch mounted on said button member to cause said button member to latch with said slide member when said switch is actuated to its "off" position during a time when said potentiometer means is turned away from its aforesaid zero speed position.

5. The combination defined in claim 2, and which includes a relay switch in circuit with said input circuit to disconnect said input circuit from said source of electrical energy; and a second switch in circuit with said relay switch and mechanically coupled to said potentiometer means to cause said relay switch to disconnect said input circuit from said source of electrical energy whenever said potentiometer means is moved from a position representing zero speed of said motor.

6. The combination defined in claim 1, and which includes circuitry connected to said control circuit for disconnecting said input circuit from said source of electrical energy whenever the electrical control energy introduced to said drive motor by said control circuit exceeds a particular reference level.

7. The combination defined in claim 6, in which said circuitry includes variable potentiometer means included in said speed control, a source of reference potential connected to said variable potentiometer means to establish different reference potential levels for different settings of said potentiometer means, a differential relay circuit connected to said source of reference potential, and a second circuit for introducing a second potential to said differential relay representing the potential introduced to said motor for any particular setting of said potentiometer means, said relay responding to a predetermined differential between said reference potential and said second potential to disconnect said input circuit from said source of electrical energy.

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