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PROTECTION SYSTEM

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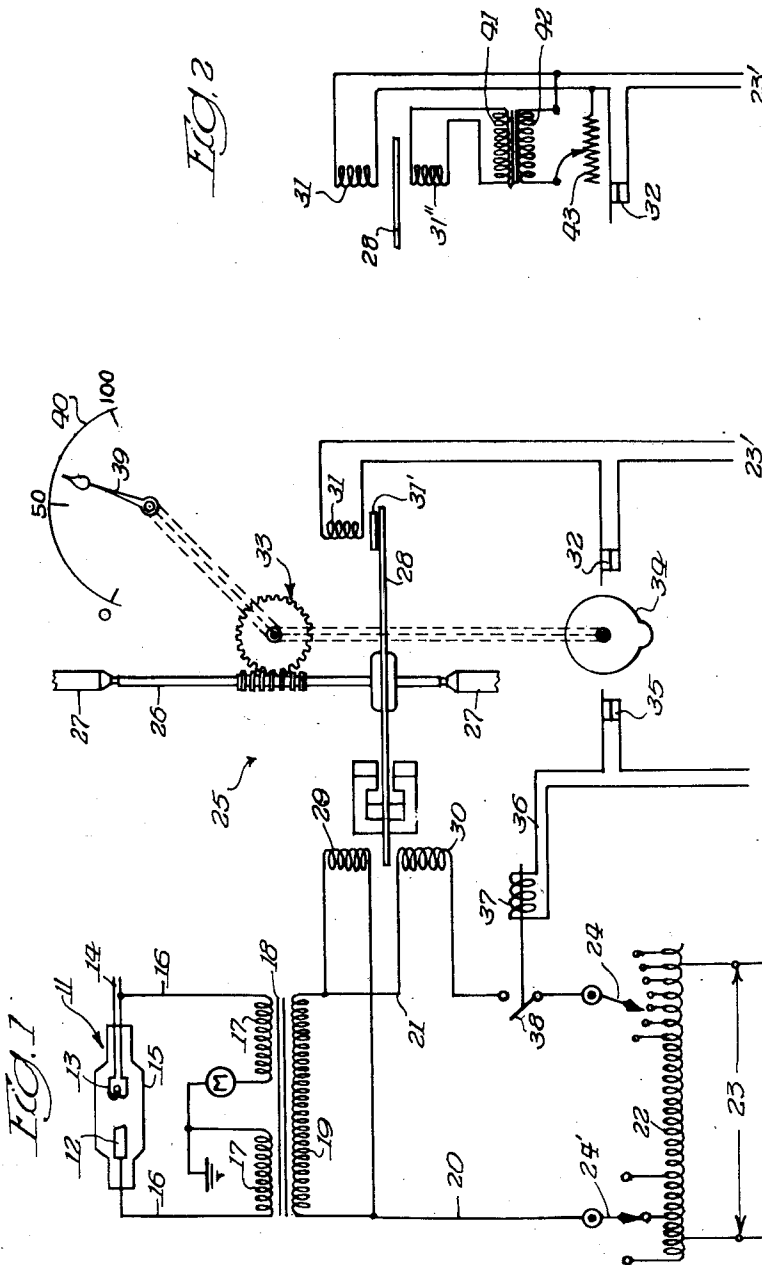
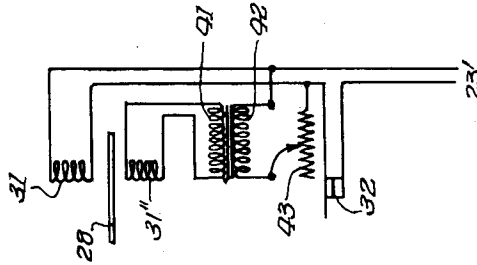


FIG. 2



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PROTECTION SYSTEM

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15 Claims. (Cl. 250—93)

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The present invention relates in general to electrical power supply systems and more particularly to systems for the supply of energizing power for the operation of X-ray generators, the invention specifically pertaining to novel control means for the supply system.

An X-ray generator commonly comprises a tube embodying an anode and a cooperating cathode enclosed in a sealed evacuated envelope, such a tube operating for the production of X-rays as a result of impingement on the anode of electrons emitted by the cathode. The cathode may and commonly does comprise a filament adapted to emit electrons when electrically energized as by the passage of electrical current through the filament. During the operation of the tube for X-ray production, electrons emitted by and at the filament are impelled toward and caused to impinge upon the anode under the influence of potential of proper polarity maintained between the anode and cathode.

Heat is developed within an X-ray generator, during the operation thereof, not only at the cathode, but also at the anode, as a result of electron impingement thereon, the major portion of such heat being generated at the anode which may operate at a temperature of the order of the melting point of the anode metal. The heat thus generated is commonly dissipated through the walls of the tube or by the circulation of a cooling fluid in heat exchange relation with the anode, or by other suitable heat dissipating means, heat dissipation taking place as rapidly as possible within the heat transferring limit of the dissipating means. Each individual generator, of course, has its characteristic relation between temperature and heat dissipation rate. When in operation, a generator of necessity will operate at a temperature which is a function of the differential of the heat equivalent of electrical energy put into the tube and the heat dissipated therefrom. The operating temperature of a tube is thus a complex function of the anode-cathode potential, the anode-cathode current at which the tube is operated, the time of current flow and the factors influencing heat dissipation.

An important object of the present invention is to provide means for preventing the delivery of energy to the tube at a rate to cause the device to operate at higher than a safe temperature; a further object being to ensure operation of the generator at temperatures at all times within a predetermined maximum limit to assure against tube injury through overloading.

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Another important object is to provide protective means for limiting the amount of electrical energy that may be delivered to an electrical load within a predetermined interval of time during the operation of the device; a further object being to provide means for limiting the rate at which operating energy may be applied to the device.

Another important object is to provide protective means, in association with a power supply system, comprising motor means adapted to be driven at a rate proportional to electrical voltage and current conditions prevailing in the system, and to utilize said motor means to control the system to protect the same against overload in the event that the average energy flow in the system exceeds a predetermined rate.

Another important object is to utilize an eddy current motor for electrical protective purposes by making the motor operable between limits wherein one limit is a zero or stand-by position and the other is the limit of the operating range, including means normally inactive when the motor is in stand-by position to drive the motor at a predetermined rate toward stand-by position when displaced therefrom toward operating range, means responsive to current and voltage conditions in the protected circuit for driving the motor toward operating range at a rate proportional to both current and voltage conditions in the protected circuit, and means operable by the motor when it reaches the limit of safe operating range to actuate safety or protective means to prevent overloading of the protected system.

Another important object is to provide means for protecting an X-ray generator against destructive overloading comprising an eddy current motor, means to drive the same from stand-by position in response to anode current and voltage applied to the generator, protection means for disabling the supply of electrical power to the generator when the motor reaches a predetermined position of displacement from its stand-by position, and means normally inactive, when the motor is in stand-by position, for driving the motor at a uniform rate toward stand-by position when displaced therefrom.

Another important object is to provide a watt-hour type eddy current motor in association with a pair of control switches, including a normally closed switch controlling a coil adapted to drive the motor in one direction toward a stand-by position in which the normally closed switch will be held open to disable the driving coil, the other of

said switches being normally in position allowing energy to flow in an energy transfer system and being operable by said motor upon predetermined displacement thereof from stand-by position to energize equipment for the protection of said system against electrical overload, including means for driving said motor from stand-by toward protection switch actuating position at a rate proportional to energy flow in the protected system.

The foregoing and numerous other important objects, advantages and inherent functions of the invention will become apparent as it is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses a preferred embodiment of the invention.

Referring to the drawings:

Fig. 1 is a diagrammatic representation of a protective system embodying the present invention; and

Fig. 2 is a diagrammatic representation showing a modified form of a portion of said system.

To illustrate the invention the drawings show an X-ray generator or tube 11 comprising an anode 12, a cooperating cathode 13 comprising an electron emitting filament adapted to be energized, from a suitable power source, through the filament conductors 14. The anode and cathode are conventionally enclosed in a sealed evacuated envelope 15, and actuating power is applied between the anode and cathode through suitable conductors 16 connected with the secondary winding 17 of a transformer 18. The primary winding 19 of the transformer 18 is suitably connected, as by means of conductors 20 and 21, through an autotransformer 22, with a suitable source of electrical power 23. If desired the center of the secondary winding 17 may be grounded as shown, and a meter M may be interconnected in said secondary winding for the purpose of showing anode current delivered to the tube for its operation. The autotransformer 22 also may be provided with adjustable taps 24 and 24' in order to adjust voltage delivered between the anode and cathode of the tube.

Means forming the subject matter of the present invention and shown generally at 25 is provided to limit the amount of energy that can be supplied through the transformer 18 for the operation of the tube 11, it being the intention to arrange the protective means 25 to allow electrical energy to be supplied to the tube at any rate that may be required or demanded, but to prevent the delivery of power to the tube in the event that the operating temperature of the tube exceeds safe limits. Accordingly, the protective equipment 25 is arranged to allow the delivery of power to the tube at all times and at any time except when the tube has received a quantity of energy within such time interval as to raise the temperature of the tube, in spite of its heat dissipating facilities, above a safe operating temperature.

To this end the protective apparatus 25 comprises an eddy current motor embodying a spindle 26, suitably journaled on supports 27 and carrying an eddy current disc 28. Electromagnetic means, including a potential coil 29 and a current coil 30, are mounted in position to drive the disc 28 in one direction when said coils are energized. The potential coil 29 is interconnected in the tube power supply system, as between the energizing conductors 20 and 21, so that the coil 29 is energized in proportion to the voltage pre-

vailing in the power supply system, that is to say, in proportion to the anode potential applied on the tube when the same is in operation. The current coil 30 also is interconnected in the power supply system, as in the conductor 21, so that it may be energized in proportion to current flow in the system, that is to say, in proportion to current flow in the tube when it is in operation. The disc 28 accordingly will be driven in one direction by the coils 29 and 30 at a rate in proportion to the operating power applied to the tube 11.

Associated with the eddy current disc 28 is a reverse driving potential coil 31 which is energized under the control of a switch 32 from any suitable preferably constant potential power source 23', said coil 31, when energized, serving to drive the eddy current disc in the direction opposite from the direction in which it is driven by action of the coils 29 and 30. The coil 31 thus serves to drive the disc 28 at a predetermined rate, which may be proportional to the normal cooling rate of the generator 11. To this end, the coil 31 may be provided with an adjustable shading pole 31' in order to adjust the driving action of the coil to the cooling rate of the generator, that is to say, to the rate at which power may safely be delivered in the supply system.

When the apparatus is in stand-by position, the disc 28 will occupy a predetermined starting or zero position in which the switch 32 will be held open. To this end the spindle 26 may be drivingly connected, as by geared means 33, with a switch actuating cam 34 adapted, when the mechanism is in stand-by position, to hold the switch 32 open and to allow the same to close whenever the disc 28 is displaced from stand-by position as by the action of the coils 29 and 30.

When the device is in operation the disc will be acted upon by the coils 29, 30 and 31. In the event that energy is delivered to the tube 11 more rapidly than it can be dissipated therefrom, as heat, the coils 29 and 30 will drive the disc 28, against the contrary urge of the driving coil 31, toward an actuating position displaced a predetermined distance of rotation from stand-by position. As the disc 28 is moved toward switch actuating position, the switch actuating cam 34 will also move to initially release the switch 32 for closure. Continued movement of the disc 28 will eventually shift the cam 34 into position to actuate a switch 35. This switch is controllingly connected in a relay circuit 36, including a relay 37. When the switch 35, which preferably is a normally closed switch, is actuated to open by the cam member 34, when the eddy current motor reaches its displaced actuating position, the relay 37 will be operated to actuate means, such as a switch 38, for protecting the device 11 against the effects of dangerous overload conditions. In the illustrated embodiment the relay 37 is connected to control the protection switch 38 interconnected in the power supply conductor 21, said switch being preferably of the type normally biased toward open position. When the relay 37 is energized, it will hold the switch 38 closed to maintain the power supply system in operation to energize the tube 11. When the relay 37 is de-energized, as by the opening of the switch 34, or otherwise as hereinafter explained, the switch 38 may open, under the influence of its bias. The power supply system will thus be disabled, by operation of the switch 35, to thereby protect the X-ray tube 11 against further operation after it has been

supplied with energy to an extent sufficient to raise the temperature to a dangerously high point.

If desired the driving means 33 may also be connected to actuate a visual indicator comprising a pointer 39 and a cooperating scale 40 which may serve to afford a visual indication of the extent, at any given moment, to which the protected device has been loaded. Such visual indicator will be of assistance to roentgenologists by affording instantaneously determinable indication of the condition of the X-ray tube, and whether or not it may be safely operated; to what extent in terms of energy input the device may be operated; and whether it should be allowed to cool off, before further operation.

Where the protective system 25 is incorporated in X-ray apparatus, the circuit 36 may be interconnected with a conventional timer control mechanism comprising a normally open switch adapted to be closed and to remain closed during a preselected time interval during which it is desired to operate the device 11, and to open at the conclusion of the selected time interval. So long as the switch 35 remains closed, the relay 37 and its switch 38 may be operated by the timer mechanism to actuate the tube 11 as required by the timing mechanism. The tube 11 may thus be operated in conventional fashion, until and unless the protective mechanism 25 causes the switch 35 to open, as heretofore described, after which the mechanism will remain inoperable until the tube has cooled off. While the tube is cooling off, the eddy current motor under the influence of its reverse driving coil 31 will return toward stand-by position and will allow the switch 35 to close by retroaction of the actuating cam 34.

As shown in Fig. 2, the reverse driving action of the eddy current motor may be accomplished by means of a current coil 31', in addition to the potential coil 31. In such case the adjustable shading pole 31' may be eliminated and adjustment of reverse driving rate accomplished by energizing the current coil from the power source 23', through a voltage step down transformer having a secondary winding 41 connected with the current coil 31' and a primary winding 42 connected with the power source through the switch 32 and an adjustable current limiting resistor 43 whereby the rate of reverse rotation of the eddy current motor may be regulated and adjusted to the safe power consumption rate of the protected device 11.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the form herein disclosed being a preferred embodiment for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. A protection system for an X-ray tube comprising the combination, with circuit means for energy delivery to said tube, of a watt hour meter type electrical motor having current and potential coils respectively energized in accordance with operating current and potential delivered to said tube whereby to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery to said tube, reverse

driving means comprising a coil to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the cooling rate of said tube corresponding with the safe average rate of energy delivery in said translation system, a normally closed reverse drive control switch for energizing said reverse driving coils from a suitable power source, a normally open power control switch for controlling the delivery of energy through said circuit means to said tube, relay means operable to actuate said normally open power control switch to close the same for energy delivery to said tube, a normally closed relay operating switch forming overload protection means, and switch operating cam means, driven by said motor for opening said normally closed relay operating switch, when the motor reaches its actuating position, to disable said relay and allow said power control switch to open, and motor driven cam means for actuating said reverse drive control switch to open the same and disable said reverse drive means when said motor reaches and remains in stand-by position.

2. A protection system for electrical power operated apparatus comprising the combination, with an electrical translation system for energy delivery to said apparatus, of an eddy current motor having current and potential coils respectively energized in accordance with current and potential delivered to said apparatus whereby to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of energy delivery to said apparatus, reverse driving means to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery to said apparatus, reverse drive energizing means for actuating said reverse driving means from a suitable power source, power control means to control the delivery of energy in said translation system to said apparatus, overload protection means for operating said power control means and means driven by said motor for actuating said overload protection means when the motor reaches its actuating position, and for actuating said reverse drive energizing means to disable the same when said motor reaches and remains in stand-by position.

3. A protection system for an electrical translation system comprising an eddy current motor, current and potential coils, respectively adapted to be energized in accordance with current and potential conditions prevailing in said translation system, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said translation system, reverse driving means normally operable to drive the motor, in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said translation system, means to control the delivery of energy in said translation system and means, driven by said motor, for actuating said control means to prevent energy delivery in said translation system, when the motor reaches its actuating position, and for disabling said reverse driving means when said motor reaches and remains in stand-by position.

4. A protection system comprising the combination, with a circuit for electrical power delivery, of an eddy current motor having current and potential coils, respectively energized in ac-

cordance with current and potential conditions prevailing in said circuit, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, reverse driving means to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said translation system, and means, driven by said motor, for disabling said circuit for energy delivery when the motor reaches and remains in its actuating position, and for disabling said reverse driving means when said motor reaches and remains in stand-by position.

5. A protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, reverse driving means to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said circuit, and means driven by said motor for preventing energy delivery in said circuit when the motor reaches its actuating position.

6. A protection system comprising an eddy current motor having current and potential coils respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction, from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, coil means associated with said eddy current motor and adapted to be energized to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said circuit, adjustable means to adjust the motor driving effect of said coil means whereby to regulate the rate of reverse drive, and means actuated by said motor when in actuating position for preventing energy delivery in said circuit.

7. A protection system comprising an eddy current motor having current and potential coils respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction, from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, coil means associated with said eddy current motor and adapted to be energized to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate or energy delivery in said circuit, an adjustable shading pole associated with said coil means to adjust its reverse driving effect, and means actuated by said motor, in its actuating position, for preventing energy delivery in said circuit.

8. A protection system comprising an eddy current motor having current and potential coils respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction, from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, reverse driving means to drive the motor in the opposite direction toward stand-by position, at a rate pro-

portional to the safe average rate of energy delivery in said circuit, means actuated by said motor, in its actuating position, for preventing energy delivery in said circuit, and means actuated by said motor, in its stand-by position, for disabling said reverse driving means.

9. A protection system comprising an eddy current motor having current and potential coils respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction, from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, coil means associated with said eddy current motor and adapted to be energized to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said circuit, said coil means comprising a potential coil and a current coil energized from a constant potential source of electrical power, an adjustable resistor connected with one of said coils for adjusting the energizing power delivered thereto in order to regulate the rate of reverse drive, and means actuated by said motor, in its actuating position, for preventing energy delivery in said power delivery circuit.

10. A protection system comprising an eddy current motor having current and potential coils respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction, from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, coil means associated with said eddy current motor and adapted to be energized to drive the motor in the opposite direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said circuit, said coil means comprising a potential coil and a current coil energized from a constant potential source of electrical power, said current coil being energized through a transformer connected with said source, and an adjustable resistor for adjusting the energizing current supplied to said current coil whereby to regulate the reverse driving rate of said reverse driving means, and means actuated by said motor, in its actuating position, for preventing energy delivery in said power delivery circuit.

11. A protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in a power delivery circuit to drive the motor in one direction for a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit, means to deliver electrical energy in said circuit from a suitable power source, including a control switch normally biased to prevent power delivery from said source to said circuit, a relay operable to actuate said switch against its bias to allow energy delivery in the circuit, switch means operable by said motor, in its actuating position, to disable said relay, reverse driving means to drive the motor in the reverse direction toward stand-by position, at a rate proportional to the safe average rate of energy delivery in said circuit, and means actuated by said motor, in its stand-by position, to disable said reverse driving means.

12. A protection system for an X-ray tube having a power delivery circuit for supplying electrical energy for the operation of the tube, said

protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in said power delivery circuit, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit to said tube, reverse driving means to drive the motor in the reverse direction toward stand-by position, at a rate proportional to the normal cooling rate of the tube, and means actuated by said motor, in its actuating position, for preventing energy delivery in said delivery circuit.

13. A protection system for an X-ray tube having a power delivery circuit for supplying electrical energy for the operation of the tube, said protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in said power delivery circuit, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit to said tube, reverse driving means to drive the motor in the reverse direction toward stand-by position, at a rate proportional to the normal cooling rate of the tube, means actuated by said motor, in its actuating position, for preventing energy delivery in said delivery circuit, and means actuated by said motor, in its stand-by position, to disable said reverse driving means.

14. A protection system for an X-ray tube having a power delivery circuit for supplying electrical energy for the operation of the tube, said protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in said power delivery circuit, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit to said tube, reverse driving means to drive the motor in the reverse direction toward stand-by position, at a rate proportional to the normal cooling rate of the tube, means actuated by said motor, in its actuating position, for preventing energy delivery in said delivery circuit, said reverse driving means comprising coil means associated with said eddy cur-

rent motor and energized from a suitable source of constant level power, and means to adjust the delivery of energizing power to said coil means whereby to obtain the desired reverse driving rate.

15. A protection system for an X-ray tube having a power delivery circuit for supplying electrical energy for the operation of the tube, said protection system comprising an eddy current motor having current and potential coils, respectively energized in accordance with current and potential conditions prevailing in said power delivery circuit, to drive the motor in one direction from a stand-by position toward an actuating position, at a driving rate proportional to the rate of power delivery in said circuit to said tube, reverse driving means to drive the motor in the reverse direction toward stand-by position, at a rate proportional to the normal cooling rate of the tube, means actuated by said motor, in its actuating position, for preventing energy delivery in said delivery circuit, means actuated by said motor, in its stand-by position, to disable said reverse driving means, said reverse driving means comprising a potential coil and a current coil associated with said eddy current motor and energized from a constant potential source of electrical power, said current coil being energized through a transformer, and an adjustable resistor for controlling the energizing current supplied to said current coil to obtain the desired reverse driving rate.

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