

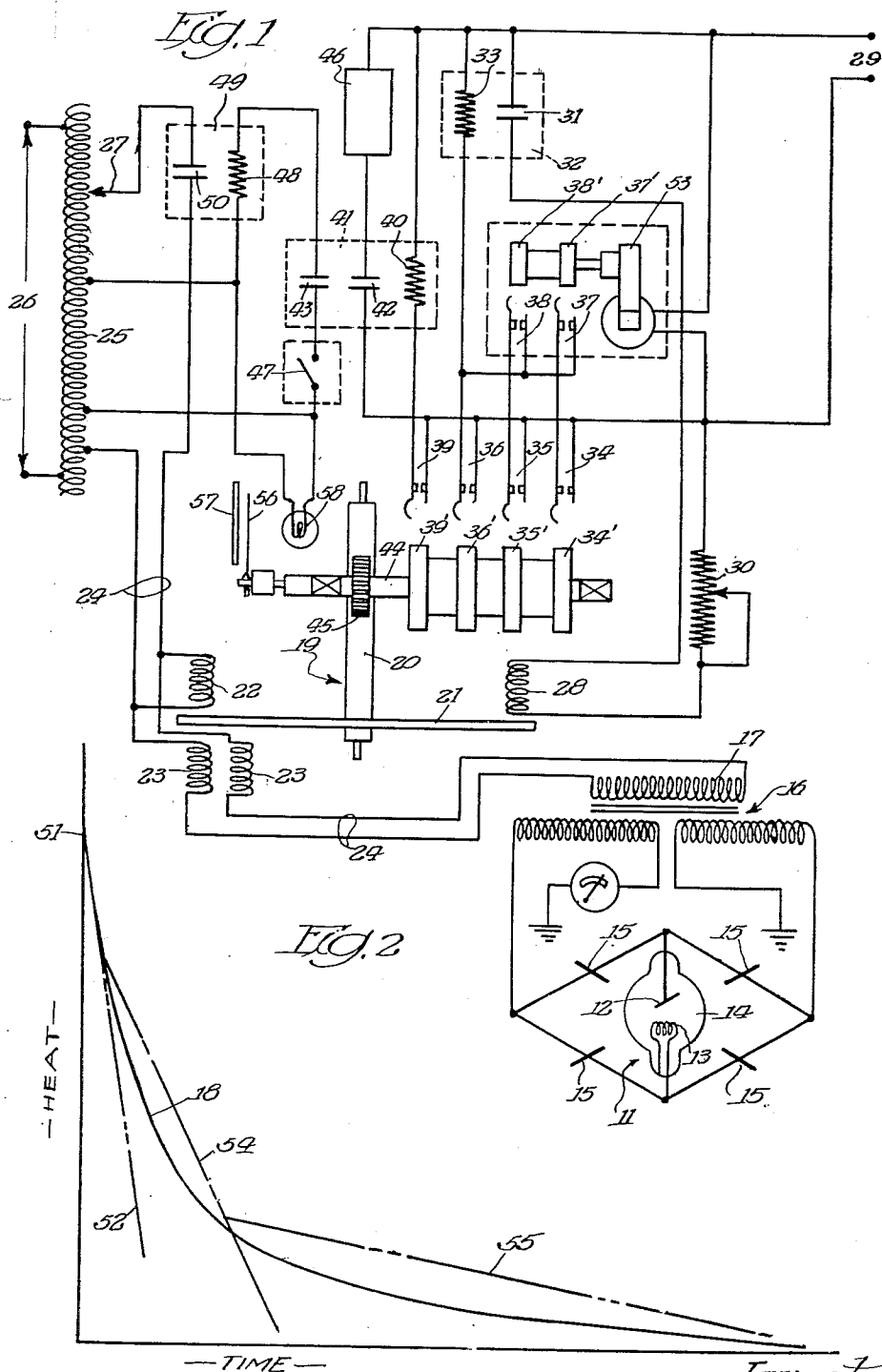
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ELECTRICAL PROTECTIVE SYSTEM

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ELECTRICAL PROTECTIVE SYSTEM

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The present invention relates in general to systems for supplying power to electrical load devices, and has more particular reference to the provision of novel means for preventing the supply of power in the event that the device becomes heated to a predetermined temperature, above which it is unsafe or undesirable to operate the device.

While the teachings of the present invention may be applied in any electrical power supply system serving a load device which generates heat during the operation thereof, the same have particular application for the protection of X-ray generators, and like electrically energized devices, the operation of which at high energy levels, during short operating intervals, is desirable or necessary, but which, if operated continuously, or too frequently, at such high energy levels, may become irreparably damaged.

An X-ray generator commonly comprises a tube embodying an anode and a cooperating cathode enclosed in a sealed and evacuated envelope. Such a tube operates for the production of X-rays as a result of impingement, upon 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 electrical potential of suitable polarity, maintained between the anode and cathode.

During the operation of an X-ray generator, heat is developed therein at the anode, as a result of electron impingement thereon, and also at the cathode. The major portion of such generated heat is produced at the anode, which may operate at a temperature of the order of the melting point of the anode metal, the heat thus generated being commonly dissipated through the walls of the tube envelope, or by the circulation of a cooling fluid in heat exchange relation with the anode, or by other heat dissipating means. The X-ray generator tube is ordinarily designed to dissipate operating heat therefrom as rapidly as possible within the heat transferring limits of the dissipating means, and each individual generator, of course, has its own characteristic heat dissipation rate. When in operation, an X-ray generator will operate at a temperature which is a function of the differential of the heat equivalent of electrical energy applied to the tube and the heat dissipating rate of the tube.

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An X-ray generator is usually operated during relatively short intervals of time, at relatively high input energy levels. Such desirable operating energy levels are of an order such that, if continuously applied to the tube, the temperature thereof, because of the limited heat dissipating ability of the tube, would increase above the melting point of its constituent parts, thereby damaging or destroying the device. The possibility of destruction of the device through overheating is also present if it be operated, for short intervals of time, repeated at a frequency of operation such that heat is liberated in the device faster than it can be dissipated.

An important object of the present invention is to provide means for preventing the delivery of electrical energy to an electrically operated device at a rate such as to cause the device to operate, at any time, at a higher than safe temperature; a further object being to allow operation of the generator at all times and whenever its temperature is below a predetermined maximum safe temperature limit, to thereby assure against injury of the device through overloading.

Another important object is to provide protective means for limiting the amount of electrical energy that may be supplied to an electrical load device, to an energy delivering rate such that the device may never be operated at destructively high temperatures; a further object being to provide apparatus which will allow the device to be operated at any time at an operating energy level just short of the safe heat absorbing capacity of the device, regardless of what such capacity may be at such time of operation, it being understood that the available heat absorbing capacity of a device is proportionally reduced as its instantaneous temperature increases above a datum temperature, comprising the temperature to which the device will cool.

If the temperature of a heat liberating device is raised to a predetermined value, and additional heat thereafter is not put into the device, the temperature of the device, as the same cools off, will decline at a variable, initially rapid, and finally slow rate, terminating, in time, at the temperature of the atmosphere circumbient to the device, and it is a further object of the present invention to provide automatically self-adjusting protective means to allow the supply of energizing power to an electrical load device, at any time, in proportion to the safe heat absorbing capacity of the device, as determined by its temperature at the instant when such power is applied thereto, and regardless of what such

instantaneous temperature, variable in accordance with the normal cooling curve of the device, may be.

Another important object is to provide protective means, in association with a power supply system, comprising motor means adapted to be driven, in one direction, at a rate proportional to power delivered through said system to a load device, during intervals of power supply, including means for driving such motor means in the reverse direction, at a rate at all times substantially proportional to the varying cooling rate of the load device, whereby the displacement of said motor means from a stand-by position, representing the fully cooled condition of the load device, may represent, at all times, substantially exactly, the heated condition of such load device; a further object being to provide switching means for preventing the supply of energizing power to the load device whenever and so long as said motor means is thus displaced beyond a predetermined distance from its normal or stand-by position; a further object being to provide indicator means driven by said motor means for indicating at all times motor displacement from stand-by position, and the equivalent remaining heat absorbing capacity of the load device with which the apparatus may be associated.

Another important object is to provide protective apparatus of the character mentioned, comprising motor means adapted to be driven in one direction, in accordance with the heating of a load device when electrically energized for operation, there being means for driving the motor means in the reverse direction in accordance with the heat dissipating ability of the load device, said reverse driving means being adapted for continuous, as well as intermittent operation, whereby to regulate the reverse driving effect in accordance with the variable cooling rate of the load device at the successive cooling temperatures thereof.

Another important object is to provide for operating the reverse driving means continuously when the load device is at relatively high temperature, and to operate the reverse driving means intermittently at progressively decreasing frequency, as the temperature of the load device falls.

Another important object is to utilize an eddy current motor for the electrical protective purposes contemplated by the present invention, by making the motor operable between limits, wherein one limit is a zero or stand-by position representing the fully cooled condition of an electrical load device, and the other limit represents the maximum safe operating temperature of the load device, including means for driving the motor in one direction from its stand-by position toward its limiting position, at a rate proportional to the delivery of energizing power to the load device, and reverse driving means for returning the motor toward stand-by position, whenever the same is displaced therefrom, at varying rates corresponding with the normal cooling rate of the load device, such rates varying in accordance with the temperature of the load device above its normal temperature in fully cooled condition.

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

Referring to the drawing:

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

Fig. 2 is a graphical illustration of the manner in which the system shown in Fig. 1 may operate.

To illustrate the invention, the drawing shows a load device comprising, in the present instance, an X-ray generator tube 11, including an anode 12 and an electron emitting filament 13 adapted to be suitably energized for operation as a cathode. The anode and cathode are conventionally enclosed in a sealed, evacuated envelope 14, and electrically connected with a suitable source of energizing power. An X-ray generator tube may be operated either as a self-rectifying device, by connecting the anode and cathode directly with a suitable source of alternating current power, or the anode and cathode may be operated by application of direct current power between anode and cathode. As shown, the device 11 is interconnected with the direct current output of a suitable full wave rectifying system, comprising the rectifiers 15 energized by alternating current power through a suitable transformer 16, the secondary or high voltage windings of which are suitably connected with the input side of the full wave rectifying system, the primary winding 17 being suitably connected with a source of relatively low voltage alternating current power, as hereinafter more particularly described.

The tube 11 may be operated as an X-ray generator by energizing the cathode 13 for the emission of electrons, and by simultaneously applying relatively high electrical potential between anode and cathode to impel cathode emitted electrons at high velocity upon the anode.

While a certain amount of heat is generated in the tube as a result of the release therein of energy supplied for energizing the cathode, such heat is relatively insignificant when compared with the enormously larger quantities of heat developed as the result of X-ray producing electron impingement on the anode. For practical purposes in determining the heat loading of the tube, in operation, cathode energizing heat may be disregarded. Thus it is that the heating effect due to tube operation may be measured with sufficient exactness for practical purposes, in terms of electrical power (volts×amps×time) released at the anode for electron driving purposes.

Usually, when an X-ray generator tube is operated as such, heating power is liberated therein at a rate many times greater than the heat dissipating capacity of the tube. Accordingly, it is necessary to allow the tube to cool off from time to time to prevent the same from reaching destructively high temperatures as the result of operation at too frequent intervals, or of operation over a dangerously extended time interval.

With respect to cooling, each individual tube, of course, has its own cooling characteristics, although every tube, in cooling from an elevated temperature, will lose its heat at a rate which becomes progressively slower as the temperature difference between the tube and its circumambient atmosphere diminishes, the characteristic cooling curve 18 of X-ray generators being illustrated in Fig. 2.

The present invention proposes mechanism for automatically differentiating, with respect to

time, and at all times, the heated condition of the load device in terms of the heat equivalent of electrical energy delivered to the device, less the heat dissipated therefrom in accordance with the heat dissipating characteristic of the load device. This is accomplished, in accordance with the teachings of the present invention, by providing a protective system embodying an eddy current motor 19. This motor comprises a spindle 20, suitably journaled in a supporting frame and carrying an eddy current disk 21. Electromagnetic means, including a potential coil 22 and a current coil or coils 23, are mounted on the frame in position to drive the disk 21 in one direction when such coils are energized.

As shown, the primary winding 17 of the tube power supply system is suitably connected, as by means of conductors 24, through an auto-transformer 25, with a suitable source of electrical power 26. The auto-transformer may be provided with adjustable means 27 in order to adjust the voltage delivered through the power supply system to the X-ray generator tube. The motor driving potential and current coils 22, 23, are interconnected in the supply conductors 24, so that the same are energized respectively in accordance with the tube energizing voltage and current supplied through said conductors. Accordingly, when the device is in operation, the motor 19 will be driven in one direction at a rate proportional to the delivery of operating power to the tube, in accordance with well known watt hour meter principles, and the apparatus may be adjusted so that the rotary displacement of the disk 21 in said direction is substantially proportional to the heat generated in the tube as the result of its operation.

Associated with the eddy current disk 21 is a reverse driving coil 28, which is adapted to be energized from any suitable, preferably constant potential power source 29, under the control of switching means through which the reverse driving effect of the coil 28, on the disk 21, varies substantially in accordance with the cooling characteristics of the controlled load device. Any suitable means may, of course, be employed for so controlling the reverse driving effect of the coil 28. As illustrated herein, however, the coil 28 is connected in a circuit including the power source 29, an adjustable rheostat 30, and the normally open switch 31 of a relay 32, comprising an actuating coil 33 to close the switch 31 when electrically energized. The coil 33, in turn, is connected in a circuit including the power source 29, and selectively operable control switches 34, 35, 36, 37, and 38, such switches being interconnected in fashion such that the coil 33 will be energized to close the switch 31 and thus energize the coil 28, subject to regulation of the rheostat 30, whenever the switch 36 is closed, when both of the switches 35 and 38 are closed, and when both of the switches 34 and 37 are closed.

The system also includes a control switch 39 interconnected in circuit with the power source and with the operating coil 40 of a relay 41, comprising a normally open switch 42 and a normally closed switch 43 adapted, respectively, to be closed and opened when the actuating coil 40 is energized. The switches 34, 35, 36, and 39 are normally open switches adapted to be closed by corresponding actuating cams 34', 35', 36', and 39', mounted on a shaft 44 suitably journaled on the support frame and drivingly connected, as by suitable reduction gearing 45, with the stem

20 of the eddy current motor, whereby the cams 34', 35', 36', and 39' are turned in response to operation of the motor 19, the cams being so arranged and driven that the switch 39 will be closed when the motor 19 reaches a maximum displacement from its zero or stand-by position, representing maximum allowable heated condition in the load device. Closure of the switch 39, which results in energizing the coil 40, causes closure of the switch 42, which is connected in circuit with the power source 29 and a counting device 46, to operate the device 46 as a register to indicate the number of closures of the switch 39, and thus obtain, over an extended period of operation, an indication of the number of times the load device has reached dangerously high temperatures. Closure of the switch 39 also opens the switch 43, which is connected in a circuit including the auto-transformer 25, a manual control switch 47, and the operating coil 48 of a relay 49, comprising a normally open switch 50 interconnected in at least one of the supply conductors 24, whereby to control the supply of operating energy to the load device and to the driving coils 22 and 23 of the motor 19.

So long as the switch 39 remains open, which condition prevails as long as the load device is below a predetermined dangerous heat condition, power may be supplied to energize the load device and the forward driving windings of the motor 19 whenever the manual switch 47 is closed, since closure of such manual switch, the switch 43 being closed, will energize the coil 47 to close the normally open switch 50. As soon as the switch 39, however, is opened by action of the motor driven cam 39', the switch 43 will be opened by operation of the coil 40, even though the manual switch 47 remains in closed position. Accordingly, the energizing circuit of the coil 48 will be broken at the switch 43, to thereby instantly allow the switch 50 to open and disable the power supply circuit to the motor 19 and the load device, thus insuring against the supply of actuating power to the load device when the same is in a dangerously high heat condition, indicated as at 51 on the curve 18 in Fig. 2.

From the overheated condition 51 the load device, if additional heat is not supplied thereto, will initially cool off rapidly, as indicated by the relatively steep portions of the curve 18, and the present invention provides for reversely driving the disk 21 by means of the coil 28 at a speed substantially corresponding with the cooling rate represented by the steep portion of the curve 18. To this end, the cam 36' is so arranged as to maintain closed the switch 36 during the period in which the load device loses its heat most rapidly. Closure of the switch 36 energizes the coil 33 continuously and holds closed the switch 31, thereby continuously energizing the coil 28, so long as the switch 36 remains closed, to drive the disk 21 toward its zero or stand-by position, at a rate indicated in Fig. 2 by the line 52, which rate, by adjustment of the rheostat 30, may be regulated to substantially coincide with the steepest portions of the curve 18.

At a predetermined displacement of the disk 21 from its zero or stand-by position, the switch closing cam 36' may be formed to release its corresponding switch 36 for opening movement. In such disk position the cam 35' may be formed to close its corresponding switch 35, to thus place the coil 33 under the control of the switch 38. The switches 37 and 38 are closed periodically by corresponding cams 37' and 38' driven, prefera-

bly at constant speed, by means of a motor 53 energized for continuous operation from the power source 29. The actuating cam 38' is formed to close the switch 38 at frequent intervals, while the cam 37' is formed to close the switch 37 at substantially less frequent intervals. So long as the switch 35 remains closed by its corresponding cam 35', the switch 38, being closed at frequent intervals by the operation of the cam 38', will correspondingly energize the coil 33 to close the switch 31 and energize the reverse driving coil at frequent intervals, in order to accomplish the reverse driving of the disk 21 at an average rate represented by the line 54 in Fig. 2, such rate being somewhat slower than the rate represented by the line 52, in order to correspond with the slower cooling rate of the load device during intermediate cooling stages after the first cooling switch 35 shall have been opened.

When the motor 19, in returning to its stand-by position, reaches a predetermined position, the cam 35' may be formed to release the switch 35 to discontinue operation of the coil 33 under the control of the cam 38'. When the motor reaches such position, the cam 34' may be formed to close the switch 34 and thereby place the coil 33 under the control of the switch 37. Thereafter, the switch 37 will be closed by its cam 37' at intervals, to energize the coil 33 and thereby energize the coil 38 at intervals such as to drive the disk 21 toward its zero or stand-by position at a slow rate represented by the line 55 in Fig. 2, approximating the relatively slow cooling rate of the load device as it approaches the temperature of its circumambient atmosphere.

It will be appreciated, of course, that additional switches, like switches 37 and 38, in combination with corresponding switches, like 34 and 35, may be employed for operation in order to drive the disk 21 in exact conformity, if desired, with the cooling characteristic of the load device. As a practical matter, however, it is satisfactory to closely approximate the cooling characteristics of the load device with the minimum number of coil actuating switches required to reversely drive the motor 19 at fast, intermediate, and slow rates, represented by the lines 52, 54, and 55 in Fig. 2, since such rates may be employed to operate the motor 19 in sufficiently close conformity with the cooling characteristics of the load device as to afford satisfactory and reliable protection against heat overloading.

In practical embodiments of the apparatus herein described, it is preferable that the operation of the cams 34', 35', 36', and 39' be held within operating limits of the order of 110 angular degrees between stand-by position and the position of maximum displacement at which the switch 39 is closed. It is preferable, also, that the cam 34' be formed to hold its switch closed during, say, 25% of cam movement; that the cam 35' be formed to hold its switch closed during, say, the medial 50% of cam movement; and that the cam 36' be formed to hold its switch closed during, say 25% of cam movement. It is desirable, also, that the cams 34', 35', 36', and 39' slightly overlap each other, so that at least one of the switches controlled by said cams is closed at all times except when the apparatus is in zero or stand-by position, when all of said switches will be open.

If desired, means may be provided to give visual indication of the heated condition of the load device, at all times. To this end, the shaft 44 may be provided with a point 56 to turn with the con-

trol cams on said shaft. A suitably graduated dial 57 may be provided, in conjunction with the pointer 56, in order to show, at all times, the heated condition of the load device in terms of displacement of the shaft 44 for the zero, stand-by, or fully cooled position. If desired, the dial 57 may comprise translucent material, and the shaft 56 may be hidden behind the dial and made visible therethrough by means of a suitably positioned lamp 58, which may be interconnected with the auto-transformer 25 for operation. The indicator 56 and 57 may be employed as a guide by the operator of X-ray equipment with which the present protection system may be controllably connected. Such operator, by glancing at the dial, and, if necessary, by reference to an operating manual, may instantly determine the amount of operating energy that may be applied to the load device, at any time, without dangerously raising the same above a safe operating temperature. Even if the operator should attempt to energize the device beyond its safe capacity, the protection system of the present invention will, by closure of the switch 39, automatically disable the power supply system as soon as a safe heat condition has been exceeded.

Devices embodying the present invention have the further advantage in that they operate substantially exactly in accordance with the cooling characteristics of the protected device, and consequently afford a substantially true index of heat conditions prevailing in the load device, at all times.

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 a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of a motor and electrical connections with said power supply means for driving the motor in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, a plurality of reverse driving circuits for controlling the operation of the motor in the opposite direction, toward said datum position, including a rapid drive circuit and a relatively slower driving circuit, means for placing said rapid drive and relatively slower driving circuits in controlling relationship with respect to the motor, respectively, when the motor is displaced from datum position beyond and within a selected circuit control position of displacement, and means controlled by said motor in a predetermined displaced position for disabling said power supply means.

2. A protection system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of an eddy current motor having a rotor and current and potential coils connected to drive the rotor, in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, and a reverse driving coil, means operable under the control of said rotor to en-

energize said reverse driving coil at periodic intervals, including means to alter the frequency of such intervals, as the rotor is displaced from its datum position, to drive the rotor, in the opposite direction toward said datum position whenever displaced therefrom, at reverse driving rates which change as the rotor is displaced from its datum position, and means, controlled by said motor in a predetermined position of displacement from said datum position, for preventing the supply of heat generating power to said device.

3. A protective system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of a motor operable, in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, means for driving the motor, in the opposite direction toward said datum position, when displaced therefrom, comprising a plurality of reverse driving circuits, control switches for said circuits selectively actuated by said motor when displaced from datum position, each of said circuits, when energized, serving to control said reverse driving means to reversely drive the motor at a corresponding rate, and means controlled by said motor in a predetermined displaced position for disabling said power supply means, to thus prevent the supply of heat generating power to said device beyond limits determined by motor displacement from said datum position.

4. A protective system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of a motor operable, in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, means for driving the motor, in the opposite direction toward said datum position, when displaced therefrom, comprising a plurality of reversed driving circuits, control switches for said circuits selectively operated by said motor, when displaced from said datum position at least one of said reverse driving circuits, when energized, serving to operate said reverse driving means continuously, and another of said circuits, when energized, serving to operate said reverse driving means intermittently, whereby to reversely drive the motor at unlike rates of speed, and means controlled by said motor, when the same is in a predetermined position of displacement from datum position, to disable said power supply means.

5. A protective system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of a motor operable, in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, means for driving the motor, in the opposite direction toward said datum position, when displaced therefrom, comprising a plurality of reversed driving circuits, control switches for said circuits selectively operated by said motor, when displaced from said datum position at least one of said reverse driving circuits, when energized, serving to operate said reverse driving means intermittently at a selected frequency to reversely drive the motor at a rate corresponding with such frequency, and another of said circuits, when energized, serving to operate said reverse driving means intermittently at a different selected frequency,

whereby to reversely drive the motor at a different rate of speed, and means controlled by said motor, when the same is in a predetermined position of displacement from datum position, to disable said power supply means.

6. A protective system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of an eddy current motor having a rotor and coils for driving the rotor in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, and a reverse driving coil, means to energize the reverse driving coil to drive the motor toward said datum position, when displaced therefrom, comprising a pair of reverse driving circuits including breaker switches operable at unlike frequency and selectively connectible in said coil energizing circuit to operate the same at corresponding unlike frequencies, and means, controlled by said motor in predetermined position of displacement from said datum position, for preventing the supply of heat generating power to said device.

7. A protective system for a power operated heat generating device comprising the combination, with power supply means for delivering heat generating power to the device, of an eddy current motor having a rotor and coils for driving the rotor in one direction from a zero or datum position, in proportion to the delivery of heat generating power to the device, and a reverse driving coil, means to energize the reverse driving coil to drive the motor toward said datum position, when displaced therefrom, comprising a pair of reverse driving circuits including breaker switches operable at unlike frequency and selectively connectible in said coil energizing circuit to operate the same at corresponding unlike frequencies, and constant speed, motor driven cam means for actuating said breaker switches, and means, controlled by said motor in predetermined position of displacement from said datum position, for preventing the supply of heat generating power to said device.

8. A protection system for an X-ray tube comprising the combination, with translation means for supply power for the operation of the tube, of a motor operable, in one direction, in proportion to the rate of power delivery to the tube, reverse driving means for driving the motor, in the opposite direction, at rates varying substantially in accordance with the heat dissipating characteristics of the tube, in cooling from an elevated temperature to the temperature of the surrounding atmosphere, said reverse driving means comprises pulsating power delivery means, and means controlled by the movement of said motor for varying the power pulse frequency rate of said power delivery means in accordance with the temperature of said tube, and means controlled by said motor for controlling the supply of energizing power to the tube.

9. A protection system for an X-ray tube comprising the combination, with translation means for supply power for the operation of the tube, of a motor operable, in one direction, in proportion to the rate of power delivery to the tube, reverse driving means for driving the motor, in the opposite direction, at rates varying substantially in accordance with the heat dissipating characteristics of the tube, in cooling from an elevated temperature to the temperature of the surrounding atmosphere, said reverse driving means comprises a plurality of reverse driving

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circuits, each of said circuits, when energized, serving to control said reverse driving means to drive the motor at a corresponding rate of speed, means to apply power pulsations at unlike frequencies in a plurality of said circuits, and control switches for said circuits selectively actuated by said motor, and means controlled by said motor for controlling the supply of energizing power to the tube.

10. A protective system for an X-ray tube comprising the combination, with translation means for supply power for the operation of the tube, of a motor operable, in one direction, in proportion to the rate of power delivery to the tube, reverse driving means for driving the motor, in the opposite direction, at rates varying substantially in accordance with the heat dissipating characteristics of the tube, in cooling from an elevated temperature to the temperature of the surrounding atmosphere, said reverse driving means comprises a plurality of reverse driving

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circuits, each of said circuits, when energized, serving to control said reverse driving means to drive the motor at a corresponding rate of speed, means to apply energy continuously in one of said circuits and pulsatingly in another, and control switches for said circuits selectively actuated by said motor, and means controlled by said motor for controlling the supply of energizing power to the tube.

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