315. ELECTRIC LAMP & DISCHARGE DEVICES, SYSTEMS.

360

Cross Reference Search Room

June 26, 1945. L. L. WEISGLASS 2,379,125

X-RAY TUBE PROTECTIVE SYSTEM

Filed July 4, 1942 2 Sheets-Sheet 1

Fig. 1.

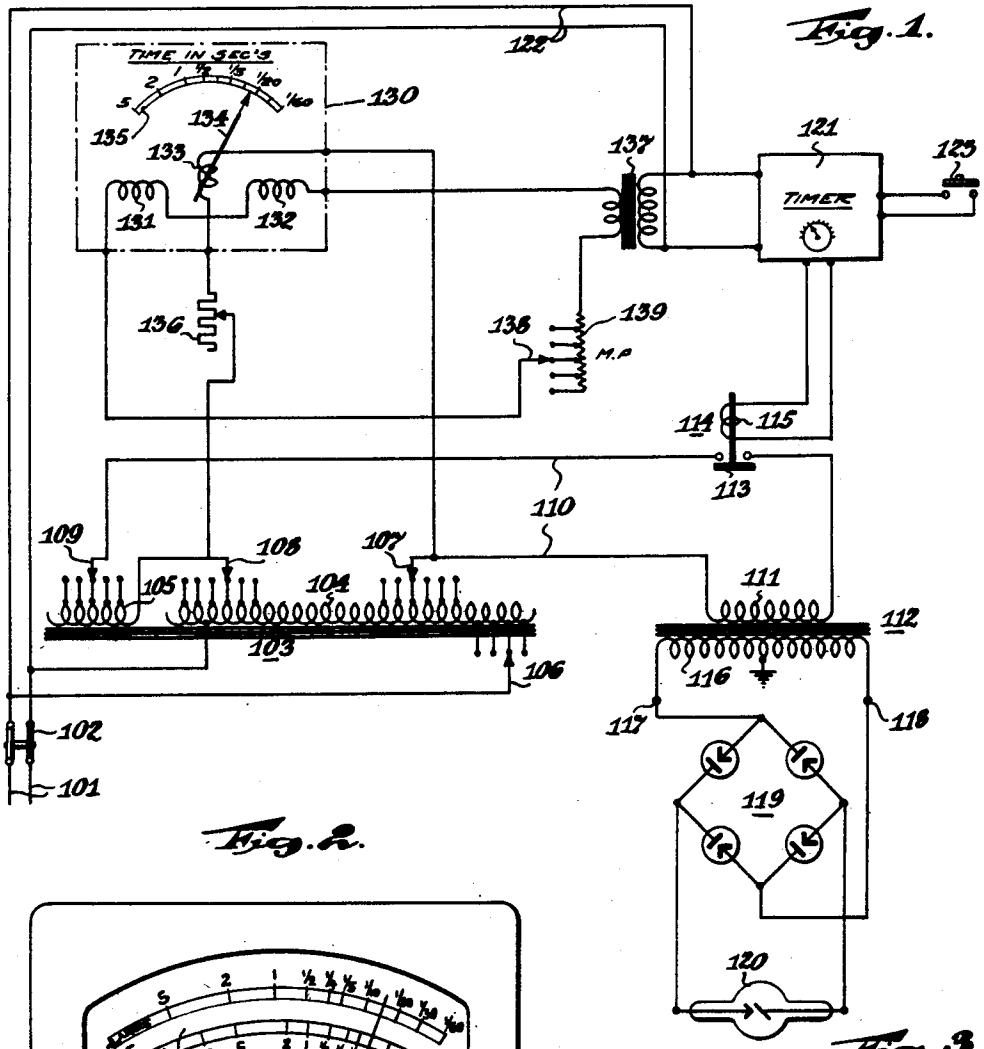


Fig. 2.

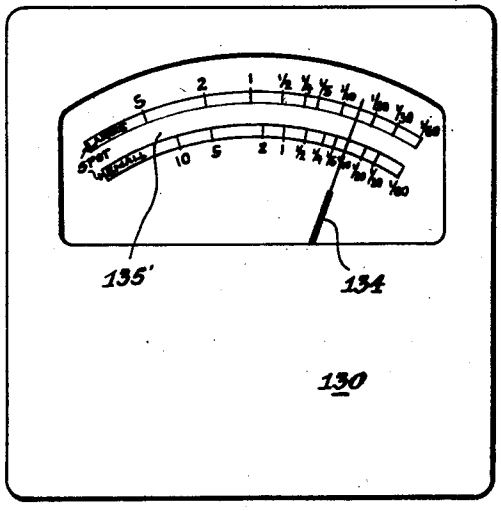
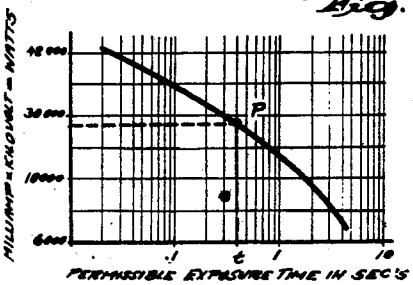


Fig. 3.



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Fig. 4.

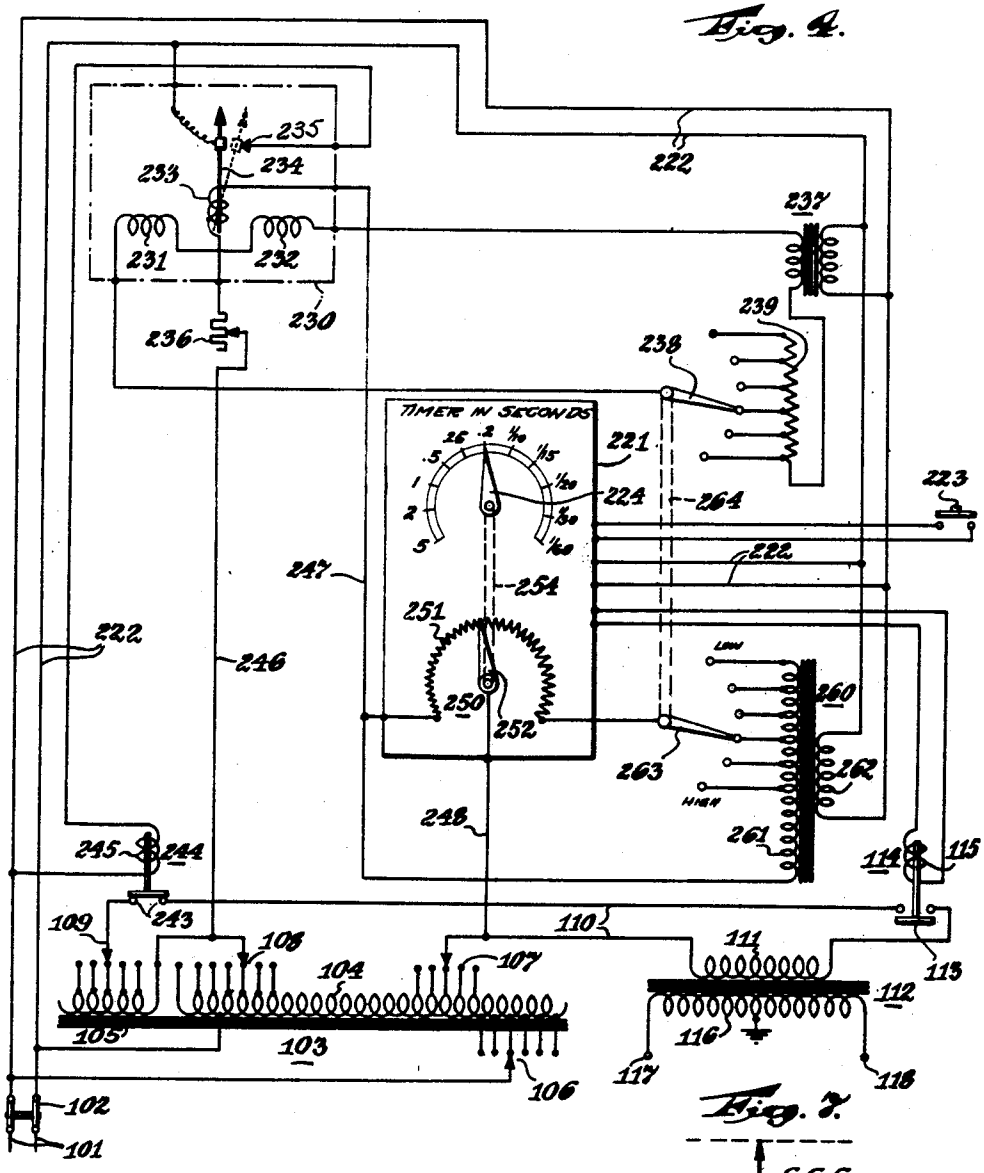


Fig. 5.

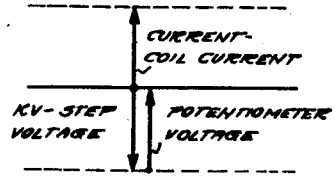


Fig. 6.

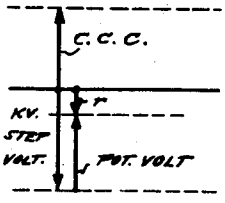
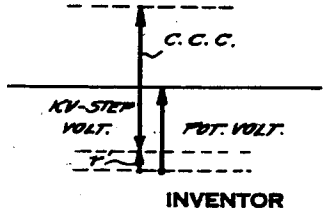


Fig. 7.



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UNITED STATES PATENT OFFICE

2,379,125

X-RAY TUBE PROTECTIVE SYSTEM

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Application July 4, 1942, Serial No. 449,814

6 Claims. (Cl. 250—95)

The invention relates to X-ray apparatus and concerns electric measuring systems, in connection with such apparatus, for indicating or preventing X-ray exposures under overload conditions.

The permissible duration of an exposure to be carried out with an X-ray tube without damage to the latter depends on the magnitude of the anode current, the magnitude and kind of the high-tension anode voltage, and on the spot size of the concentrated electron beam impinging upon the target electrode. This exposure time, varying as a rule between 1/60 of a second up to several seconds, is limited by the maximum temperature which the target can withstand without damage to its metal (tungsten) body or to other parts of the tube structure. At higher temperatures, the target metal may crack or melt, or gas may be liberated therefrom.

For a given high-tension generator (full-wave, half-wave, self-rectified or three-phase current) and a selected focal spot size (projected area of the target), there is a definite relationship between anode current (ma.), anode voltage (kv. peak value), and permissible maximum exposure time. The tube rating charts, available to the operator, contain these relationships expressed by families of parameter curves. By properly reading these charts, and based upon a selected current, voltage, and focal spot, the X-ray technician can determine the permissible maximum exposure time. This method requires relatively great skill and attention and hence may easily incur errors to the detriment of the X-ray tube.

It has been suggested to simplify the operation of X-ray apparatus and to protect them from overload adjustments by interconnecting the voltage and current controlling rheostats and the timing device of the apparatus so as to indicate injurious adjustment combinations or prevent an exposure with such combinations. These known devices contain mechanical blocking devices or cam gears of complicated design and are of rather limited accuracy.

It is an object of the invention to provide X-ray apparatus with means for accurately determining the safe maximum exposure load of the X-ray tube under a great variety and within a large range of selective operating conditions. It is also an object to achieve this result with the aid of electric devices of high reliability, and more particularly, by means of an electrical measuring circuit whose function is based on a measurement of electrical magnitudes rather than on the operation of mechanical interlocking devices and cam gears.

Another object, in conjunction with the foregoing, is to provide a measuring instrument for directly indicating the permissible maximum exposure time for any chosen X-ray technique (focal spot, milliamps, kilovolts).

An object of the invention is also to provide X-ray apparatus with a protective relay which automatically prevents energizing the X-ray tube under conditions which would incur overloading the tube.

Other objects of the invention will be apparent from the following, in particular from the detailed description of embodiments presented in a later place.

According to the invention, a wattmetric instrument has its voltage-responsive coil connected with the energizing network of the X-ray apparatus to be operated, while the current coil of the instrument is energized in proportion to the anode current of the apparatus. In one of the aspects of this invention, the wattmetric instrument is designed as an indicating or recording device having its wattage-responsive armature movable in relation to a time scale calibrated in permissible maximum exposure periods. In another aspect the wattmetric instrument forms a relay which causes an interruption of the energizing network when the selected combination of current, voltage and time adjustments would result in an exposure energy whose wattage exceeds a given limit value.

The invention is based on the following consideration: Between the various curves of the above-mentioned rating charts of an X-ray tube exists a definite relationship, namely, that in all possible cases of exposures the permissible maximum of the exposure time (t) is a definite function of the wattage (kv. · ma.) applied to the target spot:

$$t = f(\text{wattage})$$

Consequently, the maximum exposure time (t) is a definite function of the product of the tube current and the primary voltage impressed on the high-tension transformer feeding the tube. Hence, if this wattage is measured, according to the invention, the measuring result is indicative of the permissible maximum time.

Instead of measuring the tube current directly, another current can be supplied to the wattmetric instrument and if kept sufficiently proportional to the tube current will also result in a wattage

measurement proportional to the permissible time maximum.

Other and more specific features of the invention relate, among other things, to the provision of correcting, calibrating and compensating means within or in connection with the circuits of the voltage and current coils of the wattmetric instrument and will be understood from the following description of the embodiments shown in the drawings.

Fig. 1 of the drawings is a circuit diagram of an X-ray apparatus embodying a wattmetric measuring system in accordance with the invention.

Fig. 2 is an exterior front view of the wattmetric instrument used in the system of Fig. 1 and shows details of the scale calibration of the instrument.

Fig. 3 is explanatory and exemplifies a rating chart of an X-ray tube applicable in connection with the invention.

Fig. 4 illustrates diagrammatically another embodiment containing a wattmetric control relay for automatic overload protection of an X-ray apparatus.

Figs. 5, 6 and 7 are explanatory, referring to the embodiment of Fig. 4, and serve to elucidate some voltage relations occurring in the wattmetric relay circuit.

Referring to the embodiment shown in Fig. 1, 101 is the feeding A. C. line and 102 the main switch connecting the line with a regulating transformer 103 which, in the example, consists of an autotransformer with two series connected windings 104 and 105. A line voltage regulator 106 in the primary transformer connection permits adjusting the proper number of transformer turns (line voltage selector). Two selector switches 107 and 108 have their contact rows connected with transformer taps and serve for the coarse (in terms of tens) and fine (in terms of units) regulation respectively of the secondary voltage in order to adjust the kilovoltage (kv.) of the X-ray tube. The winding 105, in conjunction with an additional selector switch 109, permits compensation of load losses occurring within the elements of the network as to their effect on the high-tension voltage actually supplied to the X-ray tube.

The secondary circuit 110 of the autotransformer 103 leads to the primary 111 of a high-tension transformer 112 over the control contacts 113 of a timer relay 114 actuated by a relay coil 115. The secondary 116 of the high-tension transformer 112 has its midpoint grounded and its terminals 117 and 118 connected with a rectifier bridge 119 whose D. C. output diagonal includes the anode circuit of the X-ray tube 120.

The above-described portion of the apparatus forms the energizing network of the apparatus. When the main switch 102 and the relay contacts 113 are closed, the X-ray tube 120 is energized by a high-voltage current whose kilovoltage depends on the adjustment of the selector switches of the regulating transformer 103. The relay coil 115 is controlled by a timing device 121. The operating circuit 122 of this device is connected with the main switch 102 over a starting switch 123, for instance, of the push button type. When actuating the starting switch, the relay coil 115 is energized and starts the X-ray exposure by closing the circuit 110. At the same time the timing mechanism (not shown) of the device 121 is set in motion and after a preadjusted period interrupts the coil circuit of 115 thereby opening the tube circuit 110 and terminating the exposure.

Combined with the above-mentioned excitation and timing means of the apparatus is a metering system to be described presently.

A wattmetric measuring instrument 130 is shown which is provided with stationary current coils 131 and 132 and a movable voltage coil 133 for actuating a pointer 134 over a scale 135 of the instrument. The voltage coil 133 is excited in accordance with the kilovoltage of the X-ray tube and, to this end, is connected with the selector switches 107 and 108 over a series resistor 136. By virtue of the correction effected by coil 105 and switch 109, the voltage acting on the instrument coil 133 is in fact equal to the primary voltage of the high-tension transformer 112. The current coils 131 and 132 of the wattmetric instrument are connected with a transformer 137 energized with line current of constant voltage. A tap switch 138 controlling the effective resistance of a resistor set 139 is disposed in the current coil circuit and serves for adjusting the coil current in proportion to the milliamperage of the X-ray tube current since the scale of resistor set 139 is calibrated in milliamperes and is initially set prior to each exposure to correspond to the milliamperage desired for the X-ray tube as set by the cathode heating control (not shown). Current and voltage effective in the wattmetric instrument are supposed to be in phase with each other.

The scale 135 of the wattmetric instrument is calibrated in seconds ranging, for instance, from 1/60 of a second up to several seconds. When in operation, the pointer of the instrument indicates the maximum exposure time for which the timer 121 can be set under the chosen energy conditions without overloading the X-ray tube. That is, when the X-ray apparatus is adjusted for a given technique, i. e., a selected focal spot size of the target, a selected kilo-voltage and milliamperage, the pointer shows a corresponding time value in seconds; and the timer should not be set to an exposure period exceeding the limit thus indicated, to prevent overheating the target.

The scale of the wattmetric instrument 130 may be provided with two or more scales for different focal spot sizes. An example of a double scale instrument is apparent from Fig. 2. The scale 135' contains two rows of indicia for a large and a small focal spot. The division of each row corresponds to the actual exposure and circuit conditions. The 1/60 second divisions of the two rows coincide. This is obtained by changing the calibration of the meter when changing from one to the other focal spot. The change in calibration is effected by varying the resistance value of resistor 136 in Fig. 1 in accordance with the selected setting of the focal spot control (not shown). Hence, if the operator varies any of the voltage, current, or spot determining settings and adjusts the resistors 138 and 136 in accordance with the selected current and spot data, the permissible exposure time is indicated by the pointer 134 of the instrument 130.

The operation of the wattmetric system in dependence upon the determinants of a chosen technique will be more full understood from the following. As mentioned, the permissible exposure time of an X-ray tube is a function of the target spot wattage of the tube. This wattage is determined by the product of the primary voltage of the high-tension transformer and the tube current. The deflection of the wattmetric instrument 130 is proportional to the product of the primary voltage of the high-tension transformer and a current which, by means of the variable resistance set 139, is kept sufficiently proportional to the load

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current of the tube network. Hence, the indication of the instrument is in fact proportional to the wattage supplied to the target spot and can be taken as a measure of the maximum exposure time permissible with any given energizing conditions of the tube. For instance, the permissible maximum exposure time as a function of the wattage for a chosen focal spot is represented by the rating chart shown in Fig. 3. Point P, representing a chosen wattage of somewhat less than 30,000 (milliamps times kilovolts), corresponds to a permissible maximum time *t*. Since the deflection of the meter is proportional to the wattage, its scale can be correctly calibrated in exposure seconds in accordance with the rating chart of the tube.

While the wattmetric instrument in the embodiment of Fig. 1 serves merely as an indicator in order to obviate the study of rating charts or tables by the operator, a similar wattmetric principle can also be applied for controlling a protective relay so as to prevent overload exposures. An example of such a protective system is illustrated in Fig. 4.

The energizing circuit proper of the system according to Fig. 4 is largely similar to that of Fig. 1, the similarity being made apparent by the use of the same reference numeral for parts identical in both figures. The energizing current from line 101 passes through the main switch 102 to the regulating autotransformer 103 having two windings 104 and 105 provided with taps and connected with selector or dial switches 106, 107, 108 and 109 whence the secondary circuit 110 of the autotransformer leads to the primary 111 of a high-tension transformer 112 through contacts 113 of a timer relay 114 whose control coil is denoted by 115. The secondary 116 of the high-tension transformer is grounded at its midpoint and has its terminals 117 and 118 connected with a rectifier and tube circuit (not shown in Fig. 4) similar to the circuit denoted by 119 and 120 in Fig. 1.

The control coil 115 of the relay 114 (Fig. 4) is connected with a timing device 221 fed through leads 222 from the main switch 102 and provided with a push button starter switch 223. Similar to the timing means in the system of Fig. 1, the exposure is started by pushing the button 223 thereby energizing the relay coil 115 to close the circuit 110. At the same time the timer mechanism is released so as to interrupt the circuit of coil 115 when reaching the time limit set by means of a manually adjustable pointer 224.

The operation of the above-mentioned elements is substantially similar to that of the corresponding portion of the system described in connection with Fig. 1. However, a protective relay 244 is added having its contacts 243 disposed in the energizing circuit 110. The contacts are normally closed and hence do not interfere with the regular operation of the circuit. The purpose of the protective relay is to prevent an exposure when the combination of settings chosen by the operator represents a target spot load injurious to the tube. The means for controlling the relay 244 in dependence upon this load are of wattmetric nature and will be described presently.

A wattmetric relay 230 with an armature 234 consisting of a light-weight contact arm has its movable and stationary contacts 234 and 235, respectively, connected with the control coil 245 of the protective relay 244 and with the feed line 222 so as to excite the relay coil 245 when the contacts are closed, thereby causing the relay 244 to open the X-ray apparatus circuit 110.

The relay armature is controlled by a wattmetric coil assembly comprising a set of current coils 231 and 232 and a voltage coil 233. The current coils are excited from a transformer 237 through the resistance coils 239 and the movable selector contact 238 of a variable resistance device. The primary of transformer 237 receives constant voltage through leads 222 from the main switch 102.

The voltage coil 233 of the wattmetric relay is connected with the regulating selector switches 107 and 108 over a variable resistor 236 and a potentiometer 250. The circuit of voltage coil 233 extends from switch 108 over lead 246 to resistor 236, thence through the coil 233 and lead 247 to a terminal of the potentiometer resistor 251, and from the movable contact 252 of the potentiometer through lead 248 to switch 107. The potentiometer resistor 251 is connected to the tapped secondary 261 of a transformer 260 whose primary 262 is excited by a constant voltage over leads 222 from the main switch 102. A voltage-controlling selective switch 263 is inserted between the transformer secondary 261 and the potentiometer. Consequently, the wattmetric voltage coil 233 is subjected to the resultant effect of two voltage components, one being supplied from the autotransformer 103 and proportional to the kilovoltage of the X-ray tube, the other being supplied from transformer 261 and potentiometer 250. The voltage component controlled by the potentiometer 250 is 180° out of phase (bucking voltage) with respect to the component supplied from the kilovoltage selectors and serves to compensate the latter down to zero. At zero compensation the armature 234 of the wattmetric zero receives no torque and assumes the contact position shown in broken lines. In this position the relay contacts 234 and 235 are closed and cause the coil 245 to open the contacts 243 of the protective relay 244 in order to prevent the exposure.

The just-mentioned voltage compensation and interruption of the exposure network is to occur when the target spot wattage exceeds the safe limit. To ensure this dependency the bucking voltage supplied by the potentiometer 250 must be indirectly proportional to the wattage. This condition is satisfied if the output voltage of this transformer 260, adjusted by switch 263, is indirectly proportional to the milliamperage. In order to secure this relationship, the movable member of switch 263 is mechanically coupled, for instance placed on the same shaft 264, with the movable contact of switch 238, and the taps of the transformer secondary 261 are so rated that each current adjustment of switch 238 corresponds to a proper magnitude of the output voltage of transformer 260 feeding the potentiometer 250. Similarly, the movable contact 252 of the potentiometer 250 is mechanically connected with the setting mechanism or pointer 252 of the timing device 221, as is indicated at 254, and the resistance steps of the potentiometer resistor 251 are graduated in accordance with the gradation of the timer scale so as to satisfy the relationship $t=f$ (wattage) corresponding to the time divisions of the timer dial.

When, according to the diagram of Fig. 5, the current coil 232 of the wattmetric relay is energized by a coil current corresponding to the adjustment of the current selector switch 238, while the voltage coils 231 and 232 are not energized, since with the chosen combination of milliamperage, kilovoltage and exposure time the voltage

supplied from the kv.-step switches 107 and 108 is fully compensated by the bucking voltage superimposed by the potentiometer, no torque is exerted on the relay armature so that the above-mentioned protective operation takes place. When, according to the diagram of Fig. 6, the chosen combination of adjustments corresponds to a bucking voltage from the potentiometer smaller than the kv.-step voltage, a resultant voltage r remains effective on the voltage coil 233 of the wattmetric relay so that a deflecting torque is produced and the relay contact opened. Hence, the protective relay 244 remains closed and the X-ray apparatus is now ready for operation. When selecting the determinants of an exposure so that, for instance, a considerable overload would occur, the potentiometer voltage, according to Fig. 7, is correspondingly larger than that supplied from the kv.-step switches. As a result, the resultant voltage r' impressed on the voltage coil 233 has a direction opposite to that of the voltage r in Fig. 6. The relay armature is now under a torque of unsuitable direction so that its contacts remain closed and the protective relay 244 energized. Consequently, when using the X-ray apparatus, the operator has merely to set his dial switches in accordance with the kilovoltage, milliamperage and time of the contemplated exposure. If the load corresponding to the selected combination involves a target spot wattage beyond the safe limit, the exposure is automatically prevented by the wattmetric relay system.

It will be apparent to one skilled in the art, that many modifications of the above-described systems are applicable within the scope of this invention. For instance, the transformers 237 and 260 shown in Fig. 4 may consist of a single unit having a common core and primary; the resistance potentiometer 250 may be replaced by another regulatable voltage source, the current selector 238 can be mechanically connected with the milliamperage adjusting means of the regulating transformer of the energizing tube network, or the wattmetric current-coil current can otherwise be made dependent on the anode current of the X-ray tube, for instance by coupling it electrically with one of the circuits of the tube network. Such modifications do not affect the basic operation of wattmetric measuring systems according to the invention.

I claim:

1. An X-ray apparatus, comprising an energizing network having regulating circuit means for adjusting the exposure energy of the apparatus, a selective timing device connected with said network for limiting the flow period of said energy, a wattmetric relay having a movable member and voltage and current coils respectively for controlling said member, circuit means connected between said network and said voltage coil for supplying to the latter a voltage dependent on that of the exposure energy, current supply means of variable output voltage connected with said current coil for energizing the latter in accordance with the current magnitude of said energy, whereby said movable relay member is controlled in accordance with the wattage of said energy, and a protective relay disposed in said network and connected with said relay member for controlling said network so as to prevent an exposure to be started when said wattage exceeds a given limit value.

2. In combination, an X-ray tube, a regulating network connected with said tube for supplying exposure energy thereto, a selective timing device also connected with said network for limiting the flow period of said energy, an indicating instrument having a multiple time scale for different focal spot sizes and a wattmetric system for effecting an indication on said scale, said scale being calibrated in permissible maximum exposure times, said system containing a current coil and a voltage coil, said voltage coil being connected with said network and excitable by a voltage dependent on that of said exposure energy, a variable resistor inserted between said voltage coil and said network for changing the calibration of said instrument in accordance with the selected focal spot size, and variable current supply means connected with said current coil for energizing the latter in accordance with the current magnitude of said energy, whereby said instrument is caused to indicate the permissible maximum exposure time as a function of the wattage of said energy.

3. An X-ray apparatus comprising in combination, an X-ray tube, a regulating transformer having a tapped main winding and a tapped auxiliary winding arranged in series for supplying exposure energy to said tube, main selective switch means interposed between the taps of said main winding and said tube for adjusting the voltage of said energy, and auxiliary selective switch means interposed between the taps of said auxiliary winding and said tube for providing a corrective additional voltage for compensating losses within said network, a wattmetric instrument having an operating movable member and voltage and current coils respectively for controlling said member, said voltage coil being connected with said network and subjected to a voltage dependent upon the voltage of said energy adjusted by said main switch means and effective in said tube, and variable current supply means connected with said current coil for energizing the latter in proportion to the current magnitude of said energy, whereby said movable member is controlled in accordance with the wattage of said energy and its operation is indicative of the permissible maximum exposure time.

4. The combination with an X-ray apparatus having regulating means for providing exposure energy of adjustable current and voltage magnitudes and a selective timing device for limiting the flow periods of said energy, of a measuring system comprising a wattmetric instrument having a movable member and voltage and current coils respectively for controlling said member, variable current supply means connected with said current coil for energizing it in accordance with the selected current magnitude of said exposure energy, circuit means connecting said voltage coil with said regulating means to provide a voltage component dependent upon that of said exposure energy, a voltage source connected with said circuit means for providing a bucking voltage component in opposition to said first component so that said voltage coil is energized by the resultant of said two voltage components, adjusting means associated with said voltage source for varying the magnitude of said bucking component in accordance with said selected current magnitude, and adjusting means also associated with said voltage source for superposing a variation of said bucking voltage component in accordance with the selected time adjustment of said timing device so that the effective total magnitude of said bucking voltage component is in accordance with a given time function of the wattage of said

energy, to cause said movable member to effect a control operation indicative of the maximum permissible exposure time when said bucking voltage component reaches a total magnitude equal to that of said first voltage component.

5. The combination with an X-ray apparatus having regulating means for providing exposure energy of adjustable current and voltage magnitudes and a selective timing device for limiting the flow periods of said energy, of a wattmetric relay having a movable contact member, a stationary current coil and a movable voltage coil for controlling said member, a protective relay controlled by said contact member and connected with said regulating means for preventing the flow of said exposure energy when the selected adjustments of said regulating means and said timer involve overload conditions, variable current supply means connected with said current coil for energizing it in accordance with the selected current magnitude of said exposure energy, circuit means connecting said voltage coil with said regulating means to provide a voltage component dependent upon that of said exposure energy, a voltage source connected with said circuit means for providing a bucking voltage component in opposition to said first component to cause said voltage coil to be energized by the resultant of said two voltage components, adjusting means associated with said voltage source for varying the magnitude of said bucking component in accordance with said selected current magnitude, and adjusting means also associated with said voltage source for superposing a variation of said bucking voltage component in accordance with the selected time adjustment of said timing device so that the effective total magnitude of said bucking voltage component is in accordance with a given time function of the wattage of said energy, whereby said movable member is caused to effect a preventive operation of said protective relay when the total magnitude of said bucking voltage component exceeds that of said first voltage component.

6. The combination with an X-ray apparatus having regulating means for providing exposure energy of adjustable current and voltage magnitudes and a selective timing device for limiting the flow periods of said energy, of a wattmetric relay having a movable contact member, a stationary current coil and a movable voltage coil for controlling said member, a protective relay controlled by said contact member and connected with said regulating means for preventing the flow of said exposure energy when the selected adjustments of said regulating means and said timer involve overload conditions, variable current supply means connected with said current coil for energizing it in accordance with the selected current magnitude of said exposure energy, circuit means connecting said voltage coil with said regulating means to provide a voltage component dependent upon that of said exposure energy, a potentiometric arrangement containing a voltage source and being connected with said circuit means for providing a bucking voltage component in opposition to said first component to cause said voltage coil to be energized by a resultant voltage determined by said two voltage components, said potentiometric arrangement comprising voltage regulating means connected with said variable current supply means for varying said bucking component in dependence upon said selected current magnitude, further voltage regulating means associated with said arrangement and connected with said timing device for varying said bucking component in dependence upon the selected exposure time adjusted by said timing device in order to obtain a total magnitude of said bucking component in accordance with the wattage of said exposure energy as a given function of the exposure time, whereby said movable member is caused to control said protective relay for preventing an exposure when the wattage of said energy obtained with the selected adjustments of said regulating means and said timing device would exceed a safe maximum value.

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