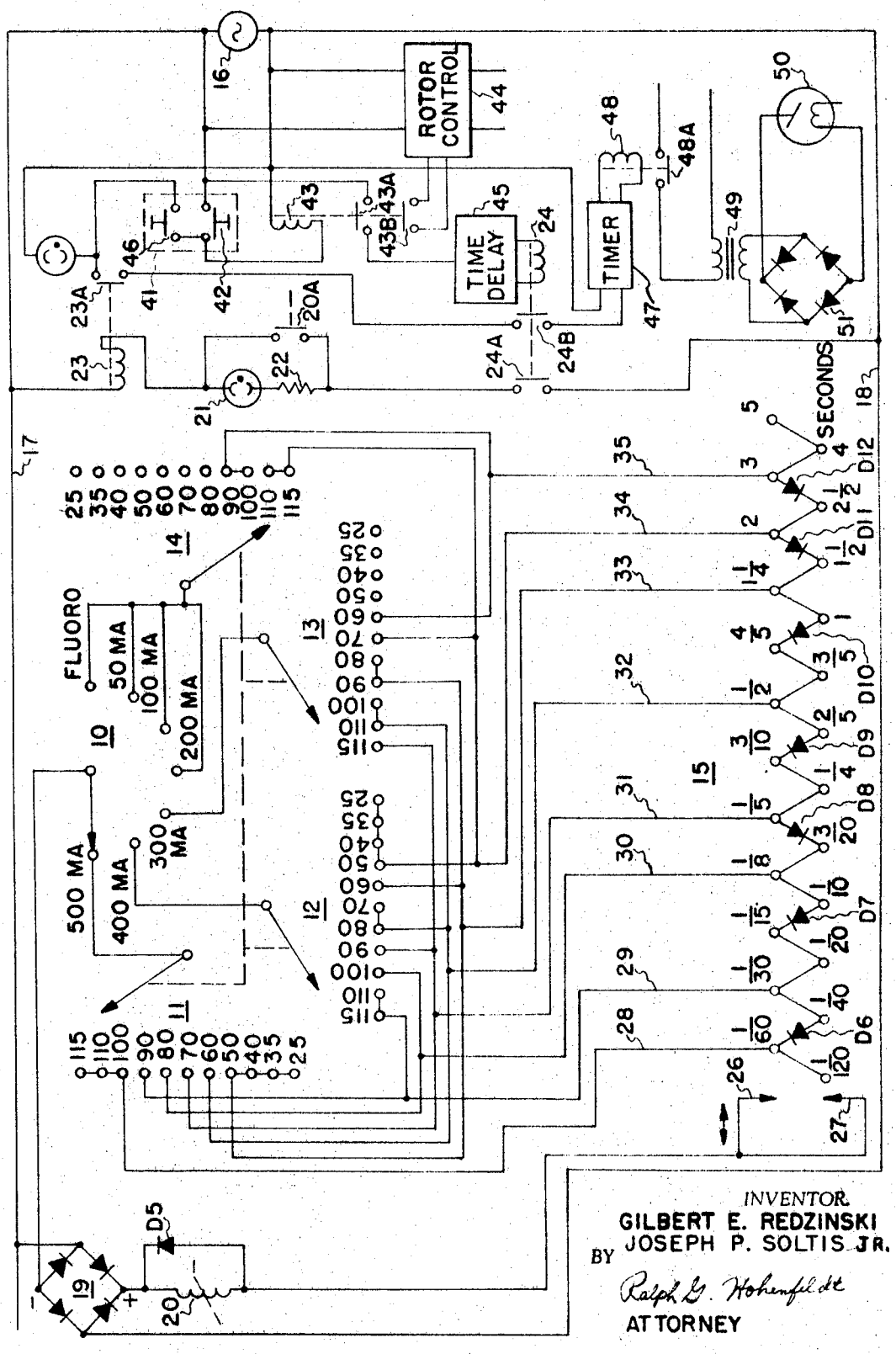
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INSTANTANEOUS OVERLOAD PROTECTOR FOR AN X-RAY TUBE RESPONSIVE TO A COMBINATION OF TUBE FACTOR SETTINGS

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INSTANTANEOUS OVERLOAD PROTECTOR FOR AN X-RAY TUBE RESPONSIVE TO A COMBINATION OF TUBE FACTOR SETTINGS

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ABSTRACT OF THE DISCLOSURE

In a system for prohibiting energization of an X-ray tube, if the combination of the tube factor settings would constitute an instantaneous overload on the tube, a time selector switch is provided having an open ended series of spaced apart stationary contacts with diodes connected between certain of the stationary contacts in a common direction and direct connections between the other contacts and a movable contact for supplying a D-C voltage selectively to the stationary contacts. The system includes tube factor selector switches which are connected in series with the time selector switch in certain positions of said movable contact. An overload responsive means is energized when a series circuit is completed through all of said switches.

This invention relates to a system for preventing damaging localized melting at the focal spot on the target of an X-ray tube such as might occur during a single operation of the tube if operated at an improvidently chosen combination of current, voltage, and exposure time factors.

It is well-known that the electric energy dissipated at the focal spot of an X-ray tube target during an X-ray exposure depends on three selectable variables or tube factors: anode peak kilovoltage (kvp.), tube current in milliamperes (ma.), and exposure duration in seconds (s.). Whether or not the energy input to the tube is large enough to cause melting of the target at the focal spot depends on the product of these variables. Hence, some systems which have been in use allow the operator a free choice of two factors and automatically select the third factor in order to make the product a safe one for the tube rating. Some prior systems require the operator to adjust the third, or one of the other factors, until a safe product is found, in which case automatic operation of electric interlocks puts the system in condition for making an exposure.

For economic and other reasons, X-ray control systems are not designed so that the tube factors are infinitely variable within limits, but rather, so that only a predetermined number of ma., kvp. and s. settings are obtainable. Thus, although the X-ray tube characteristic curve, which is a graph of permissible kvp. vs. time for an available tube current setting, is a stepless or smooth curve, there are, nevertheless, exact products which are not obtainable because the factors must be adjusted in steps. Obviously, when there are a greater number of steps there will be a correspondingly better match with the characteristic curve and, hence, a finer control over exposure and radiographic film density. To achieve better control with prior art instantaneous tube protectors, however, it has been necessary to resort to numerous rotary switches and relays and to complicated wiring so that each protector scheme is individualized for a tube with a particular characteristic curve. This is uneconomical and emphasizes the need for a system that is essentially universally applicable or conveniently adaptable to protecting tubes of various ratings.

Accordingly, the several objects of this invention include providing an instantaneous overload protector: that uses inexpensive diodes in a manner that minimizes the number of switches and relays required; that has simplified construction and function; that is readily modified for adaptation to various X-ray tubes; that permits a closer match between the settable tube factors and the X-ray tube characteristics; and, that is reliable and fail-safe. How these and other more specific objects are achieved will appear from time-to-time throughout the course of the ensuing specification.

In general terms, an embodiment of the invention comprises a first relay which disables the X-ray tube starting circuit if tube factors resulting in an overload are set. The first relay is controlled by a second relay which is either energized or de-energized in accordance with whether or not the product of a selected tube factor exceeds the instantaneous thermal rating of the X-ray tube. The second relay is in series with lines to serially connected selector switches for setting current, kilovoltage and time. If the selector switch positions are such that the combination of tube factors amounts to an overload, the second relay is energized in the preferred embodiment to prevent starting of the X-ray tube. Upon this event, either the kvp., ma., or time selector switch may be readjusted until the overload setting is eliminated.

A unique feature of the present system is that diodes are interposed between certain of the terminals or steps in the time selector switch. These diodes isolate groups of permissible time steps for various combinations of kvp. and ma. steps. Thus, the diodes may be relocated or diodes may be added or removed to make certain of the time steps either permissible or impermissible as desired, whereby to secure a better match with the characteristic curve of the tube in one system or to adapt the protector system for use with an X-ray tube of different rating.

A more detailed description of an illustrative embodiment of the invention will now be given in reference to the drawing which shows a schematic diagram of that part of an X-ray tube control system which includes the invention and other components for facilitating explaining its construction and use.

Progressing from the top of the drawing, one may see that the instantaneous tube protector system comprises an ma. selector switch **10**, four switch decks for selecting kvp. **11**, **12**, **13**, and **14**, and an exposure time selector switch **15**. It will be realized that when any settings are made on these instantaneous tube protector switches, that corresponding settings will be made on other switches, not shown, which are driven by a common shaft and adapted to select taps which actually control the current, kilovoltage or time as the case may be.

A power source **16**, of any suitable voltage and frequency such as 117 volt, 60 cycle, at the upper right corner of the drawing, supplies a pair of line conductors **17** and **18** at the top and bottom, respectively, which in turn provide A-C to a rectifier bridge **19** at the far left of the drawing. The positive terminal of bridge **19** supplies an overload responsive means which, in this case, is a D-C relay coil **20** which is in a series circuit including contacts of time switch **15**, one of the kvp. selector switches **11**, **12**, **13** or **14**, the ma. switch **10** and back to the negative terminal of bridge **19**. If the switch settings amount to an X-ray tube overload, D-C relay coil **20** will be energized and indirectly prohibit making of an X-ray exposure by causing contact **20A** to open until the overload setting is removed. As long as there is no overload setting, relay **20** will remain de-energized and contact **20A** will remain closed in which case an X-ray exposure on command is permissible. Diode D5 across relay coil **20**

is merely a suppressor for the high inductive voltage that follows de-energization of D-C relay **20**.

The normally closed contact operated by relay **20** is designated **20A** and is shunted by an overload indicating lamp **21** in series with a relatively high value resistor **22**. When an overload setting has been made, contact **20A** opens and the indicating lamp **21** goes on. When there is no overload setting, contact **20A** remains closed in which case the full voltage between lines **17** and **18** may be applied to an X-ray start relay coil **23** which closes its normally open contact **23A** to permit an X-ray exposure in a manner that will be described later. Also in series with relay **23** is a normally open contact **24A** which is operable by a time delay relay **24**. It is evident that contact **24A** must also be closed to enable energization of relay **23** for making an X-ray exposure. Operation of relay **24** will be described later.

How the tube protector circuit makes certain combinations of tube current, kilovoltage and exposure time permissible while making others prohibitive will now be discussed. Assume, for example, that tube current selector switch **10** is positioned for 500 ma. tube current, as shown in the drawing, and that kvp. switch deck **11**, and the other decks, are set for 110 kilovolts as shown. Observe also that the movable wiper of time switch **15** includes a movable contact which for convenience of illustration is shown as comprising two contacts **26** and **27**. If contact **27** is moved until it connects with the time terminal corresponding with 1/120 of a second exposure, it will be seen that a complete circuit is formed between the positive terminal of rectifier bridge **19** and its negative terminal. This would energize relay coil **20** which would open its contact **20A** and turn on overload indicator lamp **21**. Because of the high resistance of the overload lamp and resistor **22** in series with it, the X-ray start relay **23** would have insufficient power to be operated so that no X-ray exposure could be made even though one were being commanded and even though relay contact **24A** were closed. If time switch **15** is adjusted until its contact **26** engages the 1/60 second terminal, at which time contact **27** is open, a circuit will again be completed through the kvp. switch **11** and ma. switch **10** in which case relay coil **20** will be energized to indicate an overload and prevent an exposure. It may be seen also that when current switch **10** is adjusted to its 500 ma. position and kvp. switch **11** is in either its 115, 110, or 100 kv. positions, that an overload will exist if the time switch **15** is set for either 1/120 or 1/60 of a second. This means that any of these combinations of ma., kvp. or time are prohibited because they constitute overloads.

One may see that for the ma. and kvp. switch settings discussed above, any setting of the time switch **15** will result in an overload. For instance, if its contact **27** is connected to the 1/40 second terminal in the time switch, the diode **D6** will be forward-biased and relay coil **20** will conduct. If time switch **15** were adjusted for its maximum time with contact **26** engaging the 5 second time terminal, then there would still be a series conductive path through all of the forward-biased diodes **D6** to **D12** in which case relay coil **20** would be energized and an exposure prohibited.

Since an overload prevailed with the current switch set at 500 ma. and the kvp. switch set at as low as 100 kvp. at exposure time intervals of either 1/20 or 1/60 of a second, the operator is required to reduce the current, increase the time in order to get the same energy for film exposure and select a voltage at which the new combination of time and current permits an exposure. On the other hand, it may be that the kvp. setting was unnecessarily high in which case only a voltage adjustment needs to be made. For instance, if kvp. switch **11** were adjusted to its 90 kvp. terminal and the time switch **15** were adjusted so its contact **26** would engage the 1/60 second terminal, then the series circuit through relay coil **20** would be open in kvp. switch **11** even though the path were otherwise completed from contact **26** to the 1/60 second terminal and line **28**, the 500 ma. terminal and back to the negative side of rectifier **19**. With contact **26** on the 1/60 second terminal, diode **D6** is reversed-biased which means that there is no conductive path from the 1/60 second terminal to the 1/30 second terminal and through line **29** to the 90 kvp. terminal in switch **11**. One may see that kvp. switch **11** may be set at any value below 90 kvp. without causing an overload setting for either 1/60 or 1/120 second exposures, because diode **D6** will remain in its reversed-biased state for these low time values.

For some radiographic techniques, current selector switch **10** may be adjusted to one of its available lower current settings. For instance, its swinger may be positioned on the 300 ma. terminal in which case kvp. switch **13** participates in the protective function. Assume that an exposure is desired at 300 ma. with a kvp. setting on switch deck **13** and the others of 115 kvp. and at a time setting of $\frac{1}{5}$ second. This adjustment would place contact **26** on the $\frac{1}{5}$ second terminal in time switch **15** to complete a path from the positive terminal of rectifier **19** through relay **20**, contact **26**, the $\frac{1}{5}$ second terminal, line **31**, the 115 kvp. contact in switch **13** and then through the 300 ma. terminal back to the negative side of rectifier **19**. In other words, setting the X-ray tube factors at 300 ma., 115 kvp. and $\frac{1}{5}$ second constitutes a prohibited overload under which conditions an X-ray exposure could not be made. However, if the time switch were adjusted so that its movable contact **27** engaged the shorter period $\frac{3}{20}$ second terminal, then diode **D8** would be reversed-biased, thereby opening the path through line **31**, the 115 kvp. terminal and the 300 ma. terminal. This means that any exposure at these currents and voltages at less than $\frac{1}{5}$ second is permissible.

Those skilled in the art will readily be able to trace out other permissible and prohibited tube factor combinations by adjusting the time switch **15**, the ganged kvp. switch decks **11–14**, and the current switch **10** to their various positions to determine whether or not relay coil **20** will be energized or de-energized as an indication of either an overload or permissible condition. In general, it will be noted, that removal of an overload condition by adjustment of the time switch **15** involves tarnsferring its contacts in the anode to the cathode direction of one or more of the diodes **D6–D12**. Thus, it can be seen that elimination of diodes makes fewer time settings permissible and addition of diodes between adjacent time steps makes additional settings permissible. Hence, it may be seen that the diodes may be located at such places as to bring about the nearest approximation of the available kvp. and time settings at a given current value for the characteristic curve of a particular X-ray tube.

A feature of this invention is that if a diode fails in its most common mode, which is to become conductive in both directions, the system will fail-safe or, in other words, exposures which would normally be permissable would merely be prevented. As an example, consider a case where the current switch **10** is set at 500 ma. and the voltage selector switch decks **11–14** are set on 90 kvp. If diode **D6** has not failed, exposures of $\frac{1}{120}$ and $\frac{1}{60}$ second are permited since there is an open path through the higher voltage contacts of switch deck **11**. If diode **D6** has failed by becoming reversely conductive, however, then a path would be completed from the $\frac{1}{60}$ second contact, through the diode and eventually through the 90 kvp. in switch **11** thus producing the effect of an overload through none exists. By this example and by choosing other combinations of current and voltage settings along with an assumed diode failure, one may see that those exposure times which are shorter than the one selected may cause an overload indication and that in any case the selected time and any longer times will also cause an overload indication if a diode fails.

At this juncture it may be appropriate to observe that

to a large extent the circuitry described above can be conversely arranged. That is, the terminal polarity on rectifier 19 may be reversed and the contact 20A operated by relay 20 may be made normally open instead of closed. Likewise, the diodes D6–D12 may be reversed and paths through kvp. decks 11–14 which are now connected may be disconnected. In any case, however, it is desirable that the diodes in the time switch 15 be arranged to prevent increasingly higher unsafe conditions if any diode breaks down.

In the interest of outlining a completely opeartive X-ray control system, an illustration of how X-ray exposures are started and stopped in conjunction with the instantaneous tube protector will now be descirbed. A hand switch defined by the broken line box 41 is shown. This switch has one pushbutton 42 for starting the X-ray tube rotor, not shown, and getting it up to speed when an X-ray exposure is contemplated. One may see that closure of switch 42 applies A-C voltage from a source 16 to energize a relay coil 43 which closes its contacts 43A and 43B. Closure of contact 43B energizes the X-ray tube rotor control 44. Closure of contact 43A starts a time delay period for time delay device 45 during which period the rotor reaches its full speed. At the end of the rotor acceleration interval, relay 24 is energized and its contacts 24B and 24A are closed. 24A must, of course, be closed in order for X-ray exposure start relay 23 to be energized if there is no overload setting, in which case contact 20A would be closed.

After the rotor is up to speed, and if no overload condition has been set, an exposure may be made by pressing pushbutton 46 in hand switch 41. This applies power from A-C source 16 through rotor switch 42, which is also held closed, and then through X-ray start contact 23A in the absence of an overload, and then through contact 24B to the X-ray exposure interval timer 47. The time constant of timer 47 is adjusted in the conventional manner by selecting resistors through the agency of one of the decks, not shown, of a switch that includes the time switch deck 15 which was previously discussed. In any event, when the timer 47 is energized at the start of an exposure, a reley coil 48 is also energized so as to close its contact 48A to apply the selected voltage to an X-ray transformer 49 which supplies an X-ray tube 50 through a full wave rectifier bridge 51. At the expiration of the time interval, timer 47 de-energizes relay 48, thereby terminating the X-ray exposure.

To summarize, the X-ray tube protector requires adjustment of ma. switch 10, kvp. swtch decks 11–14, and time switch 15, to a combination of values that lie on the permissible side of the X-ray tube characteristic or rating curve. A permissible exposure allows relay 20 to remain in one state wherein its contact 20A remains closed, thus enabling energization of X-ray start relay 23. If an overload condition has been set, relay contact 20A opens so that an indicator lamp 21 and resistor 22 are inserted in the line to the relay 23, thus prohibiting it from receiving enough power to operate and enable an X-ray exposure. It should be appreciated that although diodes D6–D12 in time setting switch 15 are shown as being poled in one direction, they could well be poled in the opposite direction if the polarity of rectifier 19 were reversed. In addition, relay 20 could, with circuit modifications within the purview of a skilled designer, be made as a normally open relay or a solid state electronic relay could be substituted for the relay without departing from the principles of the invention.

Those versed in the art will readily comprehend that additional exposure time settings may also be included in time switch 15 and that additional kvp. decks and current decks, respectively, may be added to current selector switch 10 and kvp. selector decks 11–14.

Although one embodiment of the invention has been described in considerable detail, such description is intended to be illustrative rather than limiting for the invention may be variously embodied and is to be limited in scope only by interpretation of the claims which follow.

It is claimed:

1. A system for prohibiting energization of an X-ray tube if the combination of the tube factor settings would constitute an instantaneous overload on the tube comprising:

(a) a first tube factor selector switch having a movable contact and several cooperating stationary contacts each of which represent at least one value of the first tube factor,

(b) a second tube factor selector switch having a movable contact connected with a stationary contact of the first switch and several cooperating stationary contacts each of which represents at least one value of the second tube factor,

(c) a third tube factor selector switch for selecting exposure time intervals having an open ended series of spaced apart stationary contacts which each represent a different time setting and certain ones of which are interconnected with certain of the stationary contacts of the second selector switch,

(d) diodes connected in said third selector switch between certain of the stationary contacts and the next consecutive stationary contact in said series and a direct connection between stationary contacts and next consecutive stationary contacts which do not have a diode connected between them, all of said diodes being connected in a series circuit with said stationary contacts and said direct connections to block current in one direction through the series and to conduct current in the other direction through the series,

(e) a D-C power supply having terminals of opposite polarity,

(f) a movable contact in the third selector switch which contact is supplied with voltage of one polarity and is adjustable to select and engage any time setting stationary contact in the series so that any diode following the engaged stationary contact in the series is reverse biased and any diode preceding the engaged contact in the series is forward biased to permit current flow in any otherwise closed path that extends from a stationary contact of the third selector switch through one of the aforesaid interconnections to a stationary contact of the second selector switch, whereby to render a series circuit through the first and second tube factor selector switches either conductive or nonconductive depending on whether they are set at values which would constitute an overload in combination with the selected time setting, and

(g) an overload responsive means for controlling energization of the X-ray tube, said overload responsive means being energized or de-energized by the D-C power supply depending on whether a series circuit is completed through all of the selector switches.

2. The invention set forth in claim 1 wherein:

(a) said second tube factor selector switch comprises more than one deck of contacts in which each stationary contact of a deck has the same assigned voltage value as a corresponding contact in the other decks,

(b) said second switch also having in each deck a movable contact which is individually connected to a different stationary contact representing a current value in the first tube factor selector switch,

(c) certain of the stationary contacts in the first of the decks which represent voltages in the second switch being interconnected to stationary contacts representing higher voltage values in succeeding decks, the movable contacts of the succeeding decks being connected to stationary contacts in the first switch which represent successively higher current values,

(d) the interconnections between the contacts in the decks being variously connected to stationary con-

tacts between diodes in the third switch for selecting time intervals.

3. A system for prohibiting energization of an X-ray tube if the selected combination of tube factors such as current, voltage and exposure time would constitute an instantaneous overload on the tube, comprising:

(a) a first selector switch having multiple paths which each represent a selectable current value,

(b) a second selector switch having multiple paths which each represent a selectable voltage value and which are interconnected with the first switch in such manner as to permit forming open or closed series circuits that represent selected combinations of current and voltage, with closed circuit paths representing conditions for prohibiting energization of the X-ray tube if a chosen time value is of excessive duration,

(c) a third selector switch having an open ended series of spaced apart stationary contacts with each stationary contact after the first one being assigned a progressively higher time value than the contact preceding it, said third switch also having a movable contact,

(d) diodes connected in said third selector switch between certain of the stationary contacts and the next consecutive stationary contact in said series and a direct connection between stationary contacts and next consecutive stationary contacts which do not have a diode connected between them, all of said diodes being connected in a series circuit with said stationary contacts and said direct connections to block current in one direction through the series and to conduct current in the other direction through the series,

(e) a D-C power supply having an output terminal of one polarity connected to the movable contact means of the third selector switch which movable contact means may be selectively connected with the stationary contact representing the desired time,

(f) a plurality of respective interconnections between different stationary contacts of the third selector switch and different possible paths through the first and second selector switches,

(g) any diode in said series arrangement being so poled and located as to block voltage applied by the movable contact in the third switch to a stationary contact corresponding with a selected time from being applied to the next and succeeding stationary contacts in the series and to permit voltage to be applied to preceding stationary contacts in the series to thereby permit current flow from one of said stationary contacts through one of said interconnections to the second and first selector switches if paths through both of the latter are closed, and

(h) means that are electrically energized and de-energized as indicative of an overload condition depending on whether a series path is completed through the first, second, and third switches and the D-C power supply.

4. An X-ray tube control system, comprising:

(a) an exposure time selector switch including an open ended series of stationary contacts which correspond with increasingly longer exposure time intervals,

(b) diodes connected between certain consecutive stationary contacts in the series and direct connections between other stationary contacts which are not connected by diodes whereby to form a first open ended series circuit constituting the stationary contacts, diodes, and direct connections with all the diodes being poled to conduct in one direction from one end of said series circuit toward the other,

(c) an overload responsive circuit including a D-C power supply and an overload responsive device in series with the supply,

(d) a movable contact element in the time selector switch which element is also in series with the supply and adapted to selectively engage the stationary contacts in the time selector switch in seriatim whereupon the diode following any selected contact in the series will be reverse biased to thereby block conduction to successive contacts in the series corresponding with higher time values,

(e) a plurality of conduction paths which are selectively opened or closed depending on the combination of current and voltage that are selected to be applied to the X-ray tube,

(f) said paths being connected to different stationary contacts in the time selector switch in series circuit with the power supply so that the movable contact element may be engaged with a stationary contact in an open path which is isolated from the other paths by a diode.

5. In an X-ray tube control system:

(a) an exposure time interval selector switch comprising an open ended series of stationary contacts which represent progressively higher time intervals and some of which contacts are directly connected with others,

(b) diodes interposed between stationary contacts that are not directly connected whereby to form an open ended series circuit including the contacts, diodes and direct connections with all diodes being forward biased in the same one direction from one end of said series circuit to the other and reversed biased in the other direction so that a voltage applied to a stationary contact will encounter a reverse biased diode in one direction through the series circuit and a forward biased diode in the other direction,

(c) a movable contact adapted to establish a circuit with a selected stationary contact,

(d) multiple path series connected switches which have multiple input paths that are connected to certain of the stationary contacts and a single output path, the said switches forming closed or opened conductive paths depending on the combination of their settings,

(e) a D-C power supply and an overload responsive device in series with it, the output path and the movable contact,

(f) the said movable contact being movable from the beginning of the open ended series circuit toward the other end to establish contact with a selected stationary contact which has a reversed biased diode connected to it next in the series circuit and a forward biased diode connected to it and preceding it in the series circuit so that the forward biased diode will conduct if both of the foresaid multiple path series are set with closed conductive paths.

References Cited

UNITED STATES PATENTS

2,365,554	12/1944	Jeans	250—95
2,572,258	10/1951	Goldfield et al.	250—95

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