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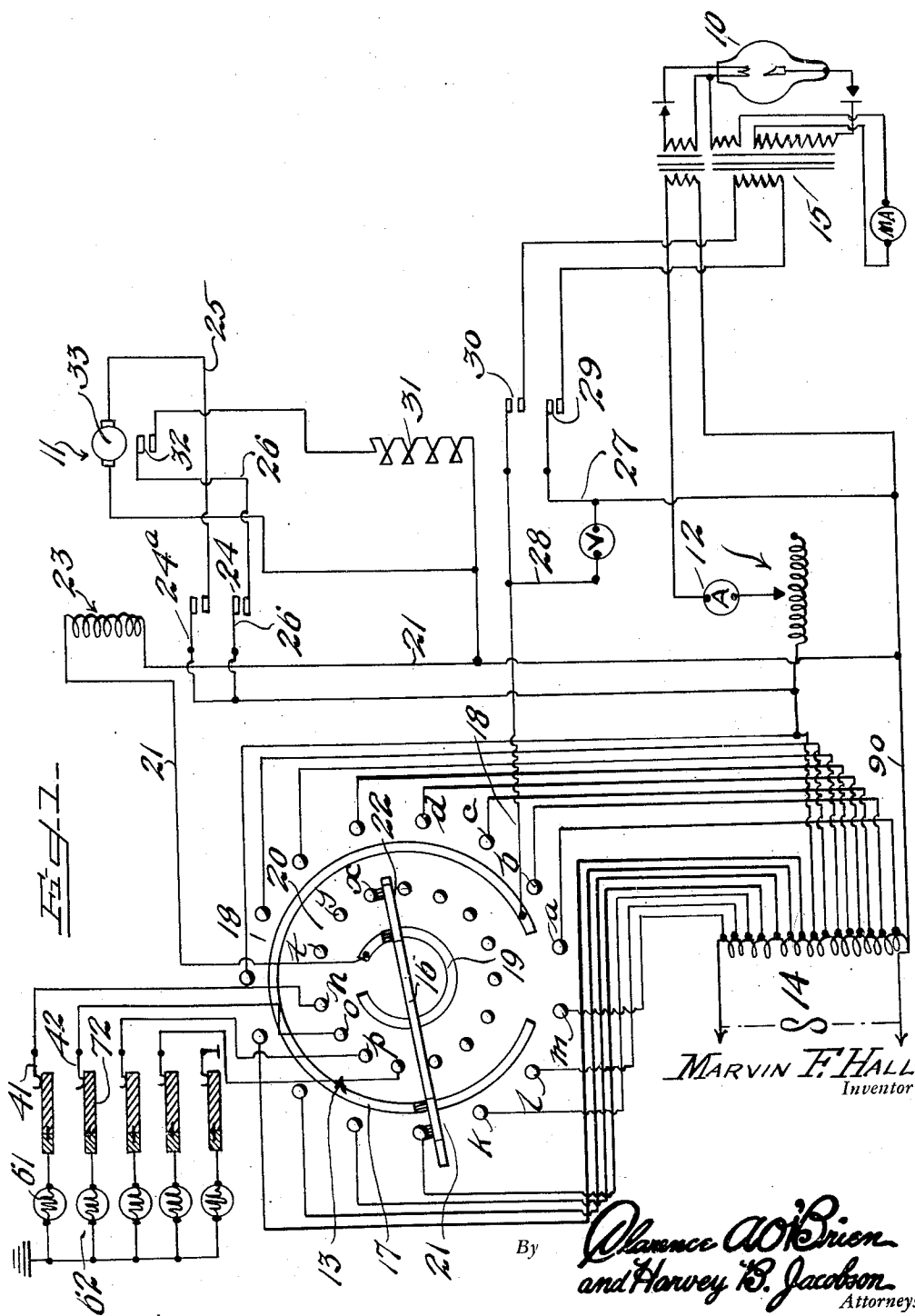
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SAFETY ARRANGEMENT FOR X-RAY APPARATUS

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SAFETY ARRANGEMENT FOR X-RAY
APPARATUS

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5 Claims. (Cl. 250-93)

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This invention relates to X-ray apparatus and it has particular reference to safety arrangements for preventing overdosage when handling equipment of this type for therapeutical purposes.

Means for finding and applying the correct dosage for the treatment of some tissue or of some part of the human body and means for controlling the emission of X-rays from the Roentgen tube in exact accordance with the calculated dosage as found have been developed to such a degree that errors in this respect have become unlikely, provided the various prescriptions as to the handling of the dosimeters and of the equipment are followed to the letter. It is however unavoidable that accidental errors occur now and then. By this term a type of error is designated which cannot be remedied by the above-mentioned control and safety appliances as it is an error due to the omission to operate, or to inadvertent or mistaken operation of one of the control levers, knobs or appliances while handling all the other controls properly in accordance with the desired dosage. The error is therefore due to incomplete or inconsistent handling of the apparatus while trying to follow the regular pattern of prescribed activities.

The number of such accidents will largely depend on the experience of the persons handling the apparatus, but accidents of this type can never be eliminated completely if a large number of treatments is administered by a number of persons, skilled as they may be. Experience shows that the number of such accidental overdosages is much larger than is usually supposed; for a large percentage of these accidents does not lead to harmful or to disastrous or to easily visible consequences. The real percentage of accidental incorrect treatment reveals itself merely if each treatment is carefully checked.

On account of the small number of cases with disastrous or manifest consequences little has been done at present to exclude such accidental false dosage and especially overdosage or to render it harmless.

The main object of this invention, therefore, consists in an arrangement which prevents such accidental errors and which especially prevents overdosages due to mistakes of commission or omission, thus cutting down the risk of causing damage to some tissue by accident.

A further and more specific object of the invention consists in providing circuits associated with the X-ray controlling means and especially with the means controlling the voltage applied to the X-ray tube which do not permit the application

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of such high voltage unless other means are properly set.

A further and specific object of the invention consists in providing circuits associated with the filters to be used during therapy treatment which prevent the use of a high tension voltage without filter or together with filters which are not suited to the voltage selected.

It is a further object of the invention to provide filter test and control circuits allotted to the filters and controlling the current supply to the high tension X-ray tube circuits which permit the application of high tension to the tube merely in connection with a properly selected filter.

It is a still further object of the invention to provide a filter arrangement with filters each of which has an individual characteristic shape or equipment adapted to operate one filter circuit, each of said circuits controlling the high tension current supply to the X-ray tube but each being only closed when a proper high tension voltage has been selected.

It is a still further object of the invention to provide an X-ray arrangement the high tension current supply of which is made adjustable in a series of steps by means of a selector and to further provide a number of filter test circuits each adapted to be closed by one filter only and moreover associated with the selector in such a way that the said circuit is only closed when a definite voltage has been selected on the selector, the circuit thus controlled by the nature of the filter selected and by the voltage selected controlling the high tension current supply to the X-ray tube.

It is a still further object of the invention to include the timing switch into the control exercised by the filter test circuits, so that said switch can be only operated when the filter circuits permit operation of the X-ray tube, this inclusion preventing errors as regards the actual application of a dosage of X-rays which might otherwise erroneously have been listed as applied while the filter test circuits prevented such application.

Other objects of the invention will be rendered apparent in the following detailed specification describing one embodiment of the invention which is also illustrated in the accompanying drawings.

It will be understood however that the present invention relates in first place to the system and that the details, components and parts may be

varied in many ways without departing from the essence or spirit of the invention.

Special mention in this connection may be made of the fact that the commercial types of X-ray equipment for therapy show a number of widely different circuit arrangements. Each can be adapted in the way shown, but each has to be adapted in a different way, using its individual way of regulating the high tension voltage and its other individual equipment.

The same X-ray equipment may be provided with exchangeable filters in several different ways, only two of these ways being illustrated. But every other way of using filters may be included in the presently described system. Moreover, filters have been illustrated closing the test circuits by virtue of special differences in their outline, but it is manifest that mere differences, as regards arrangement of insulating and conducting parts will work just as well and that all the various known methods of closing a switch indirectly may be used, the selection being obtained by configuration, thickness, localization and the like. All these adaptations of existing filter and equipment systems realizing the object of the invention will be obvious to or within reach of the skilled expert; but these adaptations like other changes and variations constitute merely another embodiment of the present invention which is clearly foreshadowed by the foregoing and following description.

In the accompanying drawings:

Figure 1 is a diagram of the circuits for one form of X-ray equipment, as commercially used and manufactured as a standard equipment which has been adapted for purposes of the present invention.

Figure 2 is a perspective view of one filter element as used in connection with equipment associated with the X-ray tube.

Figure 3 is a top view of a series of filter elements showing the varying configuration which is used for closing individual circuits and further showing means for preventing improper insertion.

Figure 4 is a perspective view showing the co-operation of the filter elements with circuit closing elements.

Figure 5 is an elevational sectional view of a filter element, and

Figure 6 is a diagram of a filter arrangement of the turret type filter head, which may be mounted on the X-ray tube assembly for certain types of work.

The embodiment of the invention as illustrated in Figure 1 is based on an X-ray equipment for therapeutic purposes which is actually manufactured and is well known and it is therefore unnecessary to describe or illustrate in detail those parts, elements, components and connections which are not directly connected with the present invention.

These known parts which are to be found in various modifications in all X-ray arrangements are the X-ray tube 10, the timing device 11, the filament heating current regulator 12, the voltage regulator or selector 13, the low tension transformer or auto-transformer 14 and the high-tension transformer 15. The circuit also contains the customary ammeter and voltmeter.

The selector switch 13 is provided with a contactor arm 16, a contact segment 17 and a contact bank 18 of a voltage selector with a number of contacts *a, b, c, —k, l, m*, each connected with one of the tapped windings of the low tension or

auto-transformer 14. According to the invention this contactor switch is moreover provided with an additional contact segment 19 and an additional contact bank 20 of a filter selector, provided with contacts *n, o, p, —x, y, z*. The contactor is provided with conducting strips or bridge pieces 21, 22 for connecting the contact segments 17, 19 with the contacts of the respective contact banks 18, 20, while the contactor segment 17 is connected with the primary of the high tension transformer 15. The additional contact segment 19 is connected with a circuit 21, containing a relay 23, operating contacts 24*a, 24* located in the control circuits 25, 26 which in the example shown contains the timing device 11. The latter consists of a synchronous timing motor 33 inserted in circuit 25 and, when actuated, closing contact 32 of circuit 26 which contains the magnetic contactor or relay 31 controlling the primary circuit of the high tension transformer 15, by means of contacts 29, 30.

The segment 19, as has been mentioned, cooperates with the contacts *n, o, p, —x, y, z* of the contact bank 20 and these contacts which are provided for the purpose of matching the filters selected with the voltage of the high tension currents are hereinafter termed "matching contacts." They are connected with the filter contacts 41, 42 and with indicator lamps 61, 62 allotted to each filter contact.

The filter contacts 41, 42 are operated by the filters 71, 72 one of which is illustrated by way of example in Figure 2. Each filter is provided with a projection, lug or tongue 80, the exact location of which varies as clearly shown in Figure 3, representing a number of filters, of various filtering power such as used during therapy work. The filter may moreover be provided with a projecting portion or ledge 81 which in the example shown is shorter than the overall length of the filter. It therefore provides a corner 83 which has to fit into a recess 84 of the framework 85 receiving the filter. It is seen that the smaller end section of the filter can only be pushed into the right position when the filter is inserted correctly with the tongue pointing forward, for an insertion with the tongue pointing backward would not allow the filter to slide in and the operator would thus immediately be made aware of the fact that the filter is not in a correct position. This holds also good when the filter is inserted with the tongue pointing in the right direction but with the wrong side of the filter pointing upwardly. The ledge 81 thus prevents any incorrect insertion of the filter, which would affect the correct position of the lug or tongue 80 and secures positively the right position of the tongue. The lug or tongue cooperates with the row of filter springs 41, 42 and the filter is grounded or connected with the casing or with some other convenient point of the apparatus which is grounded and when the filter is inserted one of the springs 41, 42 which comes into contact with its tongue will be connected with ground and will complete the filter checking circuit connected with the matching contacts 20 and with segment 19. The energization of this circuit will put the timing device in readiness for action.

One of the filters 71 used may not be a filter but may simply be a frame provided with a window or opening or with a substance which is permeable for the X-rays and through which unfiltered X-rays may penetrate. The use of rays without filters is thus included into the safety

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system and the application of unfiltered rays is limited to voltages which cannot cause damage when the calculated time is not excessive.

From the above it is seen that the operation of the X-ray tube at a given voltage which is applied by timing the contactor arm 16 to a given contact for instance to contact c is merely possible with a filter which corresponds to this voltage. For the switching in of the exciter voltage corresponding to the desired kilo voltage also switches in a definite filter circuit connected with a filter matching this voltage and controlling the control circuits of the tube. Merely if and when the filter circuit is actually closed by the insertion of the right filter the control circuit of the X-ray tube is completed and permits operation of the X-ray tube and X-ray emission.

To make this clear the operation of the device in the case of an example will be described. Let it be assumed for instance that a filter of $\frac{1}{2}$ mm. Cu.-1 mm. Al has been selected by the radiologist for the therapy in question and that this filter according to the dosage computation co-operates with a voltage of 140 kilovolt. When the filter has been correctly inserted in the example here adopted (it is the filter 72) it will be in contact with filter spring 42 and will be grounded. When the selector is turned to contact b, which is assumed to be the contact producing a kilovoltage of 140 kv., a circuit will be closed from lead 90 connected with one side of the auto-transformer 14 over conductor 21, relay 23, segment 19, matching contact o, filter checking circuit branch spring 42 and filter 72 to ground. Simultaneously, the lamp indicator 62 will clearly show that the circuit is completed and that the right filter matching the voltage selected has been inserted. The operator may set the time switch 11 and operate it as usual for by virtue of the completion of the circuit 21 relay 23 has been operated and has closed the circuit 25 leading to the synchronous motor 33 of the timing device 11 and the circuit 26 leading to the contact 32 operated by the time switch 11. When the latter is now operated, and its operation upon pressing of the starting button is audible, the contact 32 will be closed and the magnetic contactor 31 is energized which closes the two contactor arms 30, 29 of the circuit of the primary of the high tension transformer 15, thus operating the X-ray tube for the desired time period.

Assuming that a wrong filter has been placed in front of the window of the X-ray tube; then a spring, for instance the spring 41, is in contact with the filter; but as the selector arm 16 stands on contact n corresponding to the selected kilovoltage of 140 kv. the circuit of relay 23 is not closed and the timer remains disconnected.

It is, of course, possible and in some instances it may be preferable to arrange the contacts of relay 23 in the circuit 27, 28 of the primary of the high tension transformer. This eliminates however one of the controls exercised as in this case the timing switch, when operated, would seem to function while indeed the circuit of the X-ray tube has not been closed. The supervision in this case would have to be exercised solely by means of the indicator lamps, as no lamp signal is given when the proper filter corresponding to the voltage selected has not been inserted.

The constructions of the filters may be varied and may be adapted to the various purposes. It is, for instance, in many cases necessary to use filters with a variety of voltages which may be contained within wider limits than those set by

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the voltage steps between the voltage controller contacts. In this case the projection or tongue 80 is made wider than one spring so that it will be in contact with several springs 41, 42 simultaneously. If safety is to be maintained at the intended degree, the width has to be so arranged that no voltage likely to do damage is included.

It will be seen from the above description that the hazards of an incorrect or inconsistent manipulation of the various appliances or controls are minimized. The greatest possible error would be to overlook entirely the resetting of the machine when patients change and to treat one patient with the adjustment that has been made for another. Practically no really disastrous consequence can occur in this way however. The greatest difference in the dosage, which is possible, occurs when changing from a low voltage treatment without filter as prepared for superficial treatment to medium or deep therapy with filter to be applied to another patient. If the very gross error is made of preparing everything with the exception of voltage and filter, a double error which is most unlikely, to occur, the possible overdosage, assuming exposure for the same period, would be only $\frac{1}{2}$ or $\frac{1}{4}$ of the overdosage which is easily possible without safety device.

The device if constructed in the way described with a filterless window forming one of the contact making appliances which are part of the security scheme prevents therapy without filtration with a voltage higher than that regarded as safe when the device was originally set. Similarly, the device prevents operation when filtration and voltage are not matched.

Many X-ray machines use a turret type filter head or may be adapted for such use. The invention may be applied to this filter head without difficulty as illustrated in Figure 6. Turret type filter heads are used, as a rule, in connection with a tubular shielding and guide tube and are rotatably arranged, all the filters being arranged on the rotatable member, and are brought into correct operative position with respect to the beam by rotating said member.

To apply the invention the filter carrier 101 (Figure 6) arranged within the turret head 102 is provided with the requisite number of filters, 103, 104, 105, 106, four being shown in the drawing, and may rotate around a shaft 107. The turret head is arranged eccentrically with respect to the beam guiding and shielding tube 108. Each filter is again provided with a lug or tongue 123, 124, 125, 126 located on its periphery arranged at different places along the arc forming said periphery as clearly shown in the figure and cooperates with a spring 110 which forms part of a series 110, 111, 112, 113. Contact is established by the lugs or tongues 123, 124, 125, 126 with one individual spring of said series only when the filter is moved to the operative position covering the beam tube 108. In this case the lug or tongue comes into contact with one of the springs and completes the circuit which is otherwise identical with that shown in Figure 1. If removable combination filters are used the filters should be fixed to each other by riveting or otherwise to prevent mistakes. In turret filter heads where filters forming a combination are used which are sometimes arranged on superposed filter carriers each of which is separately movable, the carriers may all be provided with tongues, as described, and may cooperate with springs, as illustrated, pairs of springs being preferably used with the control and matching circuit wired over the

springs of the combination or combinations matching the high tension voltage.

Finally, it may be mentioned that it is possible, although hardly advisable, to arrange a master contactor switch permitting the radiologist to administer larger doses within a short time; switches of this type are now used to treat without filter at low kilovoltages. Such a switch or contactor even if provided with security means introduces however a definite hazard; its arrangement should therefore be confined to those cases in which the taking of risks is necessary to accomplish results which are otherwise unobtainable.

I claim:

1. A safety system for excluding dosages in X-ray apparatus, comprising an X-ray tube, means to supply said tube with high tension currents of different voltages, means for producing a step by step regulation of said voltage, said means including a voltage selector having a set of fixed voltage selector contacts, each corresponding to an operational voltage supplied to the X-ray tube and further having a movable contact member for selecting a fixed contact, corresponding to a definite voltage, a number of filters of different filtering power adapted to be inserted into the path of the X-ray beams, filter checking contact closing means on each filter occupying different positions on filters of different filtering power, a filter selector, including fixed filter selector contacts, a filter checking circuit branch connected with each filter selector contact, a fixed filter checking contact in said filter checking circuit branch adapted to cooperate with the filter checking contact closing means of a filter of definite filtering power occupying a definite position on said filter, said filter selector moreover including a movable contact member cooperating with the fixed filter selector contacts, a common circuit branch for all the filter checking circuits, a control device for the means for supplying the X-ray tube with high tension current and a positive permanent mechanical connection between the movable contact members of the voltage selector and the movable contact member of the filter selector, coordinating automatically the filter selection and the voltage selection of the X-ray tube, the operation of the X-ray tube being dependent on the selection of a safe voltage filter combination.

2. A safety system for excluding dosage errors in X-ray apparatus, comprising an X-ray tube, a surrounding box provided with an outlet for the X-rays, means for supplying the said X-ray tube with high tension currents of different voltages, a voltage selector, including a set of fixed voltage selector contacts and an adjustable movable contact member, cooperating with the set of fixed contacts, voltage selecting circuits connected with the means to supply X-ray tube with high tension currents, a number of exchangeable filters adapted to be inserted into the box for filtering the X-rays emanating from the outlet of the box, each filter being provided with contact closing filter checking means arranged in a definite position on the filter, said positions being different for filters of different filtering power, a fixed filter checking contact in said box for each of said filters, a filter checking circuit branch connected with each of said fixed contacts in the box, a filter selector, including a set of fixed selector contacts, a common segment and a movable contact member for con-

necting one of said fixed filter selector contacts with the common segment, each fixed filter selector contact of the set being connected with one of the filter checking circuit branches, a common circuit branch connected with said common segment, a control relay means in said common branch for controlling the means to supply the X-ray tube with high tension currents, a movable contact arm carrying the movable contact members of both the voltage selector and of the filter selector, said arm being arranged for bringing its movable contact members simultaneously into contact with one of the fixed contacts of the two selectors in order to select simultaneously a voltage selecting circuit and a filter checking circuit branch, the latter when closed by a filter and connected with the common branch operating the control relay means for supplying current to the X-ray tube.

3. A safety system for protection against dosage errors in X-ray apparatus, comprising an X-ray tube, means for supplying the same with high tension currents of different voltages, a voltage selector having a set of fixed voltage selector contacts and a movable voltage selector contact member for selecting a predetermined operational voltage for the X-ray tube, a control means for the high tension supply means of the X-ray tube, exchangeable filters provided with circuit closing means located on the filter at a point characteristic for the filter power of the filter, a separate circuit for each predetermined operational voltage of the X-ray tube, each circuit being connected with one contact of said voltage selector, a filter holder, a filter selector, including a set of fixed contacts and a movable contact member cooperating with the said fixed contacts, means for mechanically coupling the movable contact member of the voltage selector and of the filter selector, filter checking circuit branches associated with each of said fixed filter selector contacts, each circuit branch being provided with circuit closing means closed by the circuit closing means of a filter upon insertion of the same, the insertion of a filter of definite filter power into the filter holder, closing one of said circuit branches, an operational circuit for the high tension supply control means of the X-ray tube, closable by the movement of the movable contact member of the filter selector to a contact, connected with a filter checking circuit branch closed by a filter, the operation of the X-ray tube being thus dependent on the use of a safe filter voltage combination.

4. A safety system for protection against dosage errors in X-ray apparatus, comprising an X-ray tube, means for supplying the same with high tension currents; a voltage selector with fixed contacts and a movable contact member for selecting a predetermined operational voltage for the X-ray tube, a control means for the high tension supply means of the X-ray tube, a box surrounding said X-ray tube and provided with an outlet for the X-rays, a filter holder in said outlet, filters with individual circuit closing contact means, each contact means being located on said filter in a position characteristic for the filtering power of said filter, a fixed contact on said filter holder adapted to cooperate with the contact closing means on one of the filters usable in the holder, a filter checking circuit branch for each filter, said branch being connected with the aforesaid fixed contact of the holder and closed by the cooperation of the contact with the contact closing means of a filter,

a filter selector including a set of fixed contacts and a movable contact member, each of said filter selector contacts being connected with one of the filter checking circuit branches, a mechanical coupling means between the movable contact members of the voltage selector and filter selector, a separate circuit for each predetermined operational voltage of the X-ray tube, closable by the contact of the movable member with the fixed contact of the voltage selector, an operational circuit for the high tension supply control means, a timing device controlling said operational circuit, means for supplying current to said timing device, control means for the last mentioned supply means, an operational circuit for the said control means, said circuit being controlled by the adjustment of the voltage selector and by the insertion of a filter into the filter holder, corresponding to the voltage selected, said correspondence being produced by the closing of one of the filter checking circuit branches connected with one of the filter selector contacts and by the selection of a corresponding position of the coupled movable contact members of the two selectors.

5. A safety system for protection against dosage errors in X-ray apparatus comprising an X-ray tube, a box with an outlet for the X-rays, a filter holder on said outlet, filters adapted for insertion into said holder, each filter being provided with a contact means located at a point characteristic for the filter power of the filter, means for supplying the X-ray tube with high tension current of different voltages, a relay controlling the supply of the X-ray tube with high tension currents, an operative circuit for said relay, a timing device with timing contacts, the latter controlling said relay, means for supplying said timing device and said timing contacts with low tension currents, a further control relay controlling the low tension current supply to the timing device and timing contacts, an operational circuit for the last named control relay, a voltage selector having a set of fixed contacts arranged in a circle and a movable contact member rotatable around the center of said circle, a filter selector having a set of fixed contacts arranged in a circle concentric to the aforesaid circle, circular seg-

ments concentric with each of the sets of fixed contacts, a single rotatable arm carrying both movable contact members, insulated from each other, individual contacts of the two sets of said contacts being overrun simultaneously by the movable contact members on said arm, a common circuit branch connected with the common segment of the filter selector forming part of the operational circuit of the control relay for controlling the low tension current supply to the timing device and contacts, a fixed filter checking circuit branch connected with each fixed contact of the filter selector, filter checking contacts in each of said filter checking circuit branch, each adapted to cooperate with the filter contact located at a definite point characteristic of the filter power of said filter, to close the filter checking circuit branch connected with one of said fixed filter selector contacts upon insertion of the filter, said closed filter branch being adapted to complete the operational circuit of the control relay for controlling the low tension current supply to the timing device, when connected, by way of the movable contact of the selector with the common circuit branch, the selection of an operational voltage of the X-ray tube thus entailing a selection of a definite filter selector contact and of a definite filter checking circuit closable only upon insertion of a filter of definite filter power.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,449,357	Waite	Mar. 20, 1923
2,094,103	Horsley	Sept. 28, 1937
2,225,940	Grossmann	Dec. 24, 1940

FOREIGN PATENTS

Number	Country	Date
366,925	Germany	Jan. 13, 1923
487,665	Germany	Dec. 14, 1929
506,758	Germany	Sept. 8, 1930