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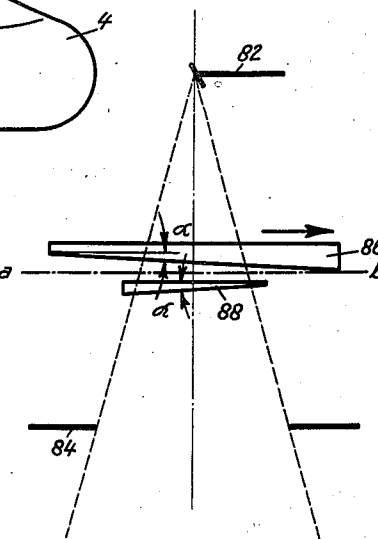


Fig. 3

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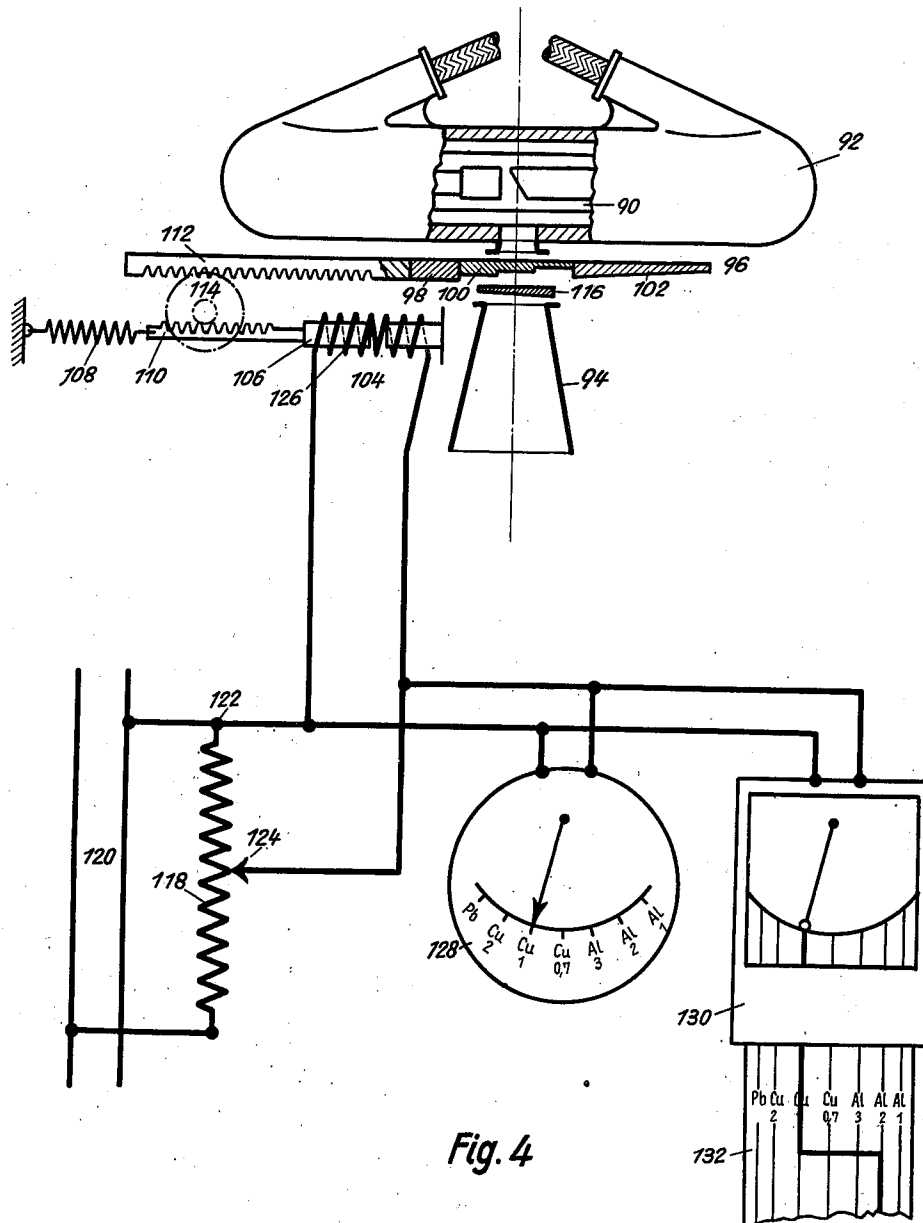
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METHOD OF AND APPARATUS FOR PROTECTING PATIENTS FROM INJURY BY X-RAYS

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2 Sheets-Sheet 2



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METHOD OF AND APPARATUS FOR PROTECTING PATIENTS FROM INJURY BY X-RAYS

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9 Claims. (Cl. 250—108)

This invention relates to method of and apparatus for protecting patients from injury by X-rays. One of the objects of the invention is to provide apparatus by which the weakening power (thickness, aluminum equivalent, copper equivalent) of a protective filter can be varied in dependence on one or more physical magnitudes (tube voltage, tube current, X-ray dose per second, or an adjustable auxiliary voltage) in accordance with a fixed law. The invention aims more particularly to provide a movable (slidable or rotatable) filter of which the weakening power (thickness, aluminum equivalent, copper equivalent) is variable lengthwise of the direction of the movement of the filter, and also electrical (electromagnetic or electrodynamic) actuating means by which said filter is adjusted in dependence of the physical magnitudes acting thereon.

The invention serves both for X-ray diagnosis and for X-ray therapy, its use in these two fields being carried out in two different ways. The invention represents a material technical advance in both fields as regards the protection of patients from injury by X-rays.

In its application to X-ray diagnosis the invention is based upon the following.

The measures heretofore used to protect patients from injury by X-rays in radiology or radiography have consisted in not allowing the focal distance of the skin of the patient, that is to say, the distance separating the patient's skin from the point of emission of the X-ray, to be less than a certain minimum, and in providing a fixed protective filter. In the case of radiology with higher voltages, where it was desired or necessary to prolong the duration of the observation (in the case of the stomach for example), and in the case of the radiography of thick body portions, a supplementary aluminum filter inserted by hand has also been used.

These measures, however, do not provide sufficient protection for the patient, more particularly as the insertion of the filter may be easily overlooked.

In applying his invention to diagnosis, the inventor goes upon the principle of providing positively for each value of the variable tube voltage in operation, a movable filter of such weakening power that the incident dose predetermined for a given focal distance per milliamper-minute (mAmin) shall remain constant or shall vary according to a given law with the tube voltage.

Let it be assumed that the law according to which the thickness of the movable aluminum protective filter varies positively with the tube

voltage is such that with a distance of 35 cm. of the focus from the skin the incident dose per mAmin shall be equal to $2r$ for each value of the tube voltage. In such case if in practice a radioscope examination be made of a patient using a 35 cm. distance of the focus from the skin and any tube voltage and care be taken only that the strength of the tube current shall never exceed 5 mA and that the time of exposure shall not exceed 10 minutes, then the total incident dose received at most by the patient will not exceed $2r/\text{mAmin} \times 5 \text{ mA} \times 10 \text{ min} = 100r$ no matter how high the tube voltage may have been. As a total incident dose of $100r$ is permissible in radiology, it follows that by using a filter the thickness of which varies positively with the tube voltage any injury to the patient by the ray will be excluded.

The relation of the aluminum equivalent of the filter to the X-ray tube voltage may be such in accordance with my invention, that the incident dose per minute and per mA tube current, based upon a predetermined focal distance from the patient's skin, shall vary continuously according to a fixed law or rule with an increase in the X-ray tube voltage, for example diminish within a voltage range of 50 to 110 kv. in the ratio of 2 to 1, for instance from $4r$ to $2r$. If care be taken that the limit which the intensity of the X-ray tube current must not exceed with a given X-ray tube voltage shall decrease as said voltage increases, for example in the ratio of 2 to 1 (for instance from 5 to 2.5 mA) then the duration of the examination may be the more prolonged the higher the X-ray tube voltage is without the total incident dose exceeding the predetermined limit ($100r$ for example). In the example given the duration of the examination could be increased from

$$\frac{100r}{4r/\text{mAmin} \cdot 5\text{mA}} = 5 \text{ minutes at } 50 \text{ kv.}$$

to

$$\frac{100r}{2r/\text{mAmin} \cdot 2.5\text{mA}} = 20 \text{ minutes at } 110 \text{ kv.}$$

In carrying out my invention, in order to vary the weakening or absorption power of the filter with the X-ray tube voltage in accordance with any of said laws, an auxiliary voltage may be caused to act upon the means for adjusting the filter and varying the aluminum equivalent of the filter, said auxiliary voltage being chosen according to the X-ray tube voltage. Preferably, however, a voltage which is proportional to the X-ray tube voltage, for example the primary voltage of

the X-ray transformer, will be caused thus to act upon said filter adjusting means. The arrangement will then operate automatically. This arrangement has the advantage that for each X-ray tube voltage the selection of a filter is assured which shall permit the one making the examination to extend the duration of the examination to the predetermined limit. Were it necessary to change the filter by hand, this might easily be overlooked in changing patients or in the case of a variation in the X-ray tube voltage during the examination.

To prevent a predetermined quantity (number of milliampere-minutes) of X-ray tube current from being exceeded, any suitable means may be used, such as an X-ray tube current counter, itself of conventional construction, to cut out the X-ray apparatus as soon as the number of milliampere-minutes reaches a predetermined limit. If the number of milliampere-minutes be allowed to increase with the X-ray tube voltage, any suitable device, such as a watt-hour meter or counter, itself of conventional construction, may be used which is acted upon by the X-ray tube current and by the X-ray tube voltage, or by a voltage which varies with the latter, and automatically cuts out the X-ray apparatus so soon as the electric energy consumed by the X-ray tube reaches a predetermined limit dependent on the voltage.

In the drawings:

Fig. 1 shows in part diagrammatically one illustrative embodiment of the invention for use in X-ray diagnosis.

Fig. 2 shows another illustrative embodiment of the invention, partly diagrammatic, for use in X-ray diagnosis.

Fig. 3 shows diagrammatically a modification of the illustrative embodiments shown in Figs. 1 and 2.

Fig. 4 shows in part diagrammatically an illustrative embodiment of the invention for use in X-ray therapy.

Referring more particularly to Fig. 1, an X-ray tube is indicated at 2 with its protective housing 4. A generally cone-shaped diaphragm box 6 contains a pair of diaphragms 8-8 and 10-10. 12 is the movable filter made of suitable material, herein aluminum. It is illustratively wedge-shaped in longitudinal vertical cross-section and extends transversely to said X-ray beam, so that by movement of said filter transversely to said beam, different thicknesses of said filter will be presented to be traversed by said beam. As operating means to move said filter, I use for instance an electro-mechanical means herein illustratively comprising a rack 14 secured to said filter and meshing with a rotary gear 16. To said gear 16 is coaxially secured a smaller gear or pinion 18 which meshes with a second rack 20 secured to the movable core or armature 22 of an electromagnet 24 having a winding 26 and carried by the exterior wall of said diaphragm box 6. A helical spring 28, having one end secured to said rack 20 and its other end to a fixed point 30, tends to move said rack 20 to the left in Fig. 1, and consequently, through the gearing described, remove the member 12 to the right in said figure. Conductors 32, 34 connect the terminals of said magnet windings 26 with points 36, 38 of the primary winding 40, 42 of the X-ray transformer. In the illustrative embodiment of the invention referred to an X-ray tube current meter 44 and an X-ray current counter 46 are in circuit between the point

38 and the earth connection 48. The armature 50 of said current counter 46 carries a contact 52 which, after passage of a certain quantity of current is caused to contact with an adjustable contact 54, thus energizing a relay 56 which attracts its armature 58 which forms a switch in the primary circuit 60 of the X-ray transformer, thus breaking said circuit. Said X-ray tube current counter is provided with a self-winding mechanism, not shown, itself of conventional construction, and by which said armature 50 is returned to its normal position whenever said X-ray apparatus is cut out.

The voltage between the points 36 and 38 of the primary winding of the X-ray transformer acts upon said magnet winding 26 and is practically proportional to the X-ray tube voltage in the case of the low power used for radioscopes. The higher the voltage, the further will said armature 22 be drawn into the winding 26 of said electromagnet 24, against the action of said spring 28, and consequently the further will said filter 12 be drawn to the left in Fig. 1 and the thicker will be the part or section thereof to be traversed by the X-ray beam, the more the voltage rises. The higher the voltage, therefore, the greater will be the weakening power of the filter.

In the modification illustrated in Fig. 2 the filter means comprises a disk 62 of aluminum or other suitable filter material, mounted for rotation to bring different parts of its marginal portion into the path of the X-ray beam, said marginal portion varying in thickness circumferentially of said disk. Herein the diminution in thickness of said filter is continuous but it will be apparent that it could vary by steps without departing from the scope of the invention. Any suitable means may be used to rotate said disk, but I preferably use electrical means. To this end said disk is mounted upon a shaft 64 of a device 66 in the nature of an electro-dynamic voltmeter, comprising fixed coils 72, 72 and a rotary coil 74 in series with the latter. The rotary part of said device carrying said shaft 64 will assume a certain balanced position for each voltage under the action of two springs 68 and 70. The three coils 72, 72, and 74 may be connected, as in Fig. 1 for example, to two fixed terminals of the primary winding 40 of the X-ray transformer, or to fixed terminals 76, 78 of an autotransformer 80 the transformation ratio of which may be varied in unison with that of the X-ray transformer, so that the voltage between the points 76 and 78 shall be proportional to the X-ray tube voltage. The filter adjusting means may also be in the nature of a rotary field voltmeter or a soft iron voltmeter, preferably the rotary part of said adjusting means will be so arranged that in rotating, responsive to X-ray tube voltage variations, it can turn through an arc of approximately 360° in passing from the lowest to the highest consumption value. In accordance with the invention, the means to adjust the filter may be separate from the latter, and the adjustment of the filter may be effected electrically or mechanically by any suitable conventional device for operating at a distance.

In Figs. 1 and 2, the filter weakens the X-rays within the X-ray cone in varying degrees according to the points of said filter traversed by said rays. This is all the more so the greater the length of the field is that is cut out by the diaphragm in the direction of movement of the filter. In Fig. 3 a fixed filter is provided in addition to a movable filter. The thickness of

said fixed filter diminishes longitudinally in the same or approximately the same ratio or degree as that of the electrically adjustable filter increases in the same direction. The sum of the thicknesses of said two filters will thus be constant throughout the field for each adjustment of the movable filter. Referring to said Fig. 3, the X-ray tube anode is shown at 82 and the ray diaphragm at 84. The adjustable wedge-shaped filter is shown at 86 and may be similar to that in Fig. 1, and an additional fixed, wedge-shaped filter is shown at 88. The thickness of the latter diminishes in the direction $a-b$ in the same degree per unit of length as the thickness of said adjustable filter increases per unit of length in the same direction. The equalizing or balancing of variation and thickness of the filter 86 by the filter 88 within the field of vision is independent of the angle α of increase of the wedge-shaped filter 86. Said angle α may thus be relatively large and the movable filter 86 relatively short.

In X-ray therapy aluminum filters or copper filters are used which are of different thickness according to the case to be treated, but they have always been inserted by hand. It is not unusual to make a mistake in selecting the filter to be used. If the filter used in X-raying a patient be too weak, the patient will suffer injury. Heretofore the only measures taken to protect a patient were for the purpose of preventing the treating of a patient without a filter.

The movable filter forming the object of the present invention is used in therapy to enable the desired filter to be adjusted in the X-ray apparatus from the switchboard of the apparatus without having to go to the X-ray projecting device for that purpose. A filter will be used comprising for example a part of aluminum and another part of copper, the thickness of the aluminum part as well as that of the copper part being varied either continually or interruptedly. In such case, the electrical means for moving the filter will be actuated by a manually controlled auxiliary voltage. As to each voltage value impressed upon said means for adjusting the filter will correspond a definite weakening power of the filter, or in other words a definite aluminum or copper equivalent thickness, a voltmeter for measuring the voltage impressed upon said adjusting means may be provided with a scale, the graduations of which give the aluminum equivalent and copper equivalent values of the different corresponding parts of the movable filter. Said values can thus be read off directly from said scale. If a recording voltmeter be used the aluminum or copper equivalents of the filters used in each case can be recorded by said voltmeter.

The movable aluminum-copper filter may also comprise a shutter consisting for example of a piece of lead that is impenetrable by the X-rays. This additional part serves completely to close the opening through which the effective X-rays emerge, during the breaking-in of the X-ray tube. To this shutter corresponds the zero or lowest value of the adjustable auxiliary voltage used for adjustment of the filter, while to the highest value of said voltage corresponds that part of the filter which is weakest or least absorbent. Should the operator overlook or omit to set the filter adjusting means in operation, or should the circuit be broken for any reason, the patient will thus not receive any rays at all, or at all events no insufficiently weakened rays.

Referring to Fig. 4, the X-ray tube is shown

at 90, its container at 92, a conical diaphragm at 94 and the adjustable filter at 96. This filter comprises a lead part 98, a stepped copper part or section 100 and a wedge-shaped aluminum part or section 102. The filter adjusting means, herein comprising electromagnet 104 with its core 106, spring 108 and racks 110 and 112 with their gearing 114, may, and preferably will be similar to the corresponding parts shown in Fig. 1. A fixed wedge-shaped supplementary aluminum filter 101, similar to that of Fig. 3, may be provided to counteract the local unequal filtering of the rays when the wedge-shaped section 102 is used. A regulating transformer 118 is connected to the network 120 and the voltage of the latter between the terminal 122 and the adjustable contact 124 is impressed upon the winding 126 of the electromagnet 104. When said voltage is adjusted to predetermined values, for example 10, 20, 30, 40, etc., volts, the adjustable filter will be adjusted so that successively the separate sections of the stepped copper filter of say 2, 1, and 0.7 mm. thickness, then the different sections 102 of wedge-shaped aluminum, are presented in front of the opening for the effective X-rays, said aluminum filter section providing, with the fixed aluminum filter, resultant weakening thicknesses of, for example, 3, 2 and 1 mm. To the terminal 122 and the adjustable contact 124 are connected in parallel the winding 126, a voltmeter 128 and a recording voltmeter 130, said voltmeters being preferably mounted upon the switchboard of the X-ray apparatus. Upon the scales of both voltmeters and upon the strip of paper 132 fed through the recording apparatus 130 will be marked the symbols Pb, Cu3, Cu2, Cu1, Cu0.7; Al3, Al2 and Al1, corresponding to voltages 10, 20, 30, etc., so that from the scales of both voltmeters and said paper strip can be read directly the copper and aluminum thicknesses or weakening values of the corresponding filter sections.

It will be apparent that wedge-shaped filters could be substituted for stepped filters, and vice versa. If stepped filters are used the adjusting mechanism will of course be such as to move the filter step by step in increments corresponding to the spacing of the steps of the filter, instead of continuously. The adjustable therapeutic filter of Fig. 4 could be made in the form of a rotary filter according to Fig. 2.

The apparatus described has the advantage among others over those heretofore used, that the filter desired may be selected at any time from the switchboard of the X-ray apparatus, under control of an indicating device, and the aluminum or copper thickness of the filter recorded by the recording device.

The invention may also be used to adjust a movable filter in such manner that the X-ray dose per second, measured at any point, shall remain constant. To this end an ionization chamber is provided at the point where the delivered X-ray dose per second is to be kept constant and the ionization current which is strengthened in the conventional manner by a reinforcing device, is used to drive a servo-motor which controls the adjustment of the filter in such manner that any variation in the dose due to changes in the X-ray tube voltage or the X-ray tube current, will be neutralized or compensated by the variation in the filtering action.

Within the scope of the invention a movable filter in which the weakening power is varied step by step instead of continuously, whether for use in diagnosis or for therapeutic purposes, could

consist of a plurality of separate parts separately movable. For example it could consist of four square filter plates mounted one at each side of the square opening through which the X-rays are projected, said plates being movable in parallel planes into registration with said opening, thus permitting from one to four degrees of weakening power to be used by causing either one of said plates to register with said opening or by superposing one, two, three or four of said plates in registration with said opening. The electrical means for moving these filter plates must be so constructed and must operate in such manner that they respond each to the electrical magnitude by which they are controlled when said magnitude reaches a predetermined limit for each one of said plates, to move the corresponding filter plate into registration with said opening.

I am aware that the invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and I therefore desire to present embodiments of my invention to be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than to the foregoing description to indicate the true scope of the invention.

I claim:

1. Apparatus for protecting patients from injury by X-rays, comprising a movable and adjustable protective filter of varying absorption power; and electrical means, subjected to a voltage substantially proportional to the X-ray tube voltage, so to adjust said filter that the absorption power of the part thereof traversed by the X-ray shall increase with increasing voltage.

2. Apparatus for protecting patients from injury by X-rays, comprising movable and adjustable protective filter means of varying thickness; and electrical means, subjected to a voltage substantially proportional to the X-ray tube voltage, to adjust said filter means so that the thickness of that part thereof traversed by the X-ray shall increase with increasing voltage.

3. Apparatus for protecting patients from injury by X-rays, comprising a filter of continuously increasing thickness to be located in the path of the X-rays between their source and the patient, said filter being adjustable by movement thereof; and electrical means, subjected to a voltage substantially proportional to the X-ray tube voltage, to adjust said filter automatically with the variable X-ray tube voltage by moving said filter, to cause the incidence dose milliamperemeter tube current quantity, and with a given focal distance, to remain constant.

4. Apparatus for protecting patients from injury by X-rays, comprising movable and adjustable protective filter means of varying thickness; electrical means, subjected to a voltage substantially proportional to the X-ray tube voltage, to adjust said filter means by moving the same so that the thickness of the part thereof traversed by the X-ray shall vary directly with

variations in the X-ray tube voltage; and a current counter adapted to cut out the X-ray apparatus so soon as the X-ray tube current quantity reaches a predetermined limit value of milliamperes-minutes.

5. Apparatus for protecting patients from injury by X-rays, comprising movable and adjustable protective filter means of varying absorption power; electrical means supplied with electrical energy from a source which can be regulated at a remote location to adjust said filter means to vary its absorption power; and a voltmeter mounted in parallel to said source and having a scale graduated in absorption degrees, and controlled by said source.

6. Apparatus for protecting patients from injury by X-rays, comprising movable and adjustable protective filter means of varying absorption power; electrical means supplied with electrical energy from a source which can be regulated at a remote location to adjust said filter means to vary its absorption power; and a recording voltmeter, mounted in parallel to said electrical means and provided with a scale graduated in absorption power degrees of said filter means, to record the kind of filter used for each X-ray treatment.

7. Apparatus for protecting patients from injury by X-rays, comprising a movable filter of continuously variable thickness and adjustable by movement thereof; a fixed filter of which the thickness increases in substantially the same ratio as that of said movable filter but in a direction opposite to that in which the thickness of said movable filter increases; and means to adjust said movable filter by moving the same substantially parallel to said fixed filter to present different thicknesses thereof to be traversed by the X-rays.

8. Apparatus for protecting patients from injury by X-rays, comprising a filter of continuously increasing thickness, said filter being adjustable by movement thereof; and electrical means, subjected to a voltage substantially proportional to the X-ray tube voltage, to adjust said filter automatically with the variable X-ray tube voltage, by moving said filter to cause the incidence dose per milliamperemeter tube current quantity, and with a given focal distance, to diminish as the tube voltage increases.

9. Apparatus for protecting patients from injury by X-rays, comprising adjustable filter means comprising a plurality of parts of different materials of varying absorption power; and electrical means, supplied with electrical energy from a source which can be regulated at a remote location to move said filter means to adjust the same to bring said different materials into the path of the X-ray, one of said parts, at one end thereof, being capable of practically totally absorbing the X-rays, said part thus corresponding to the zero or lowest value of the energy from said source.

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