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Edholm et al.
[11] 3,755,672
[45] Aug. 28, 1973

[54] EXPOSURE COMPENSATING DEVICE FOR RADIOGRAPHIC APPARATUS

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[52] **U.S. Cl.** **250/322**, 250/358, 250/482
[51] **Int. Cl.** **H05g 3/00**
[58] **Field of Search** .... 250/86, 65 R

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Assistant Examiner—C. E. Church
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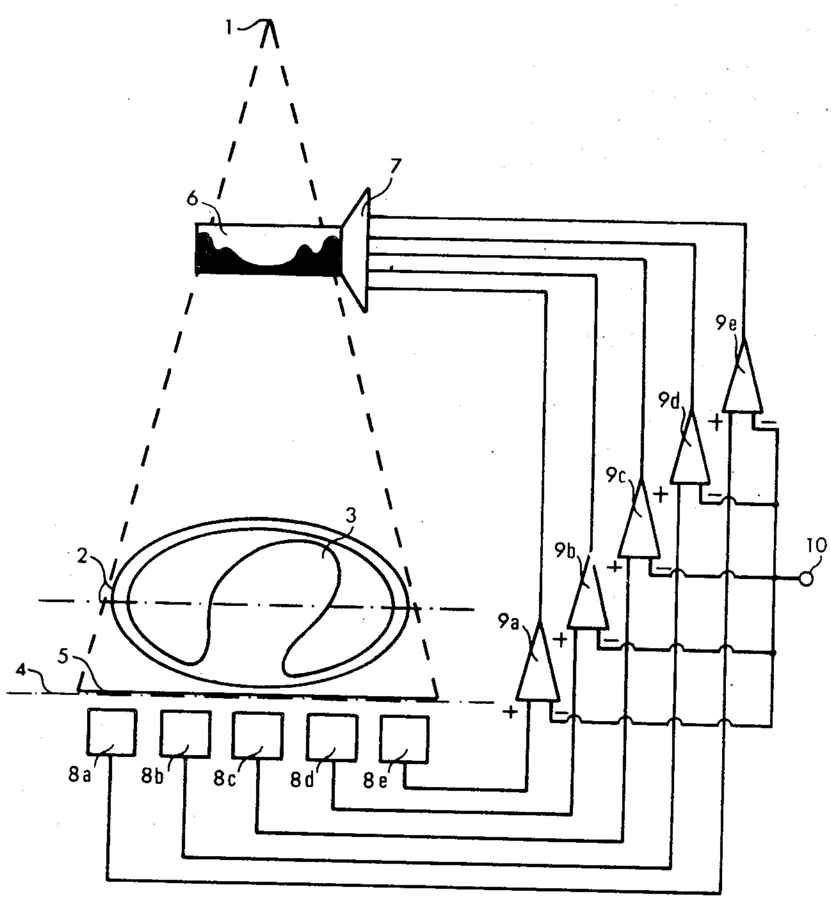
[57] **ABSTRACT**

A device in radiographic apparatuses for compensating the variations in thickness, density and absorption properties in different parts of an object being radiographed so as to produce a more uniform average exposure of the radiographic recording medium and thereby a more uniform image contrast in all parts of the radiograph of the object. The device comprises a compensating filter device inserted in the radiation path between the radiation source and the object and including radiation absorbing means, which has a variable shape or form such that its absorption values within different portions of the radiation beam can be varied substantially independently of each other. The shape of this radiation absorbing means is varied by automatically operating control means in response to output signals from radiation detecting means disposed on the opposite side of the object so as to sense the average intensity values in different sections of the radiation beam leaving the object to be radiographed.

31 Claims, 12 Drawing Figures



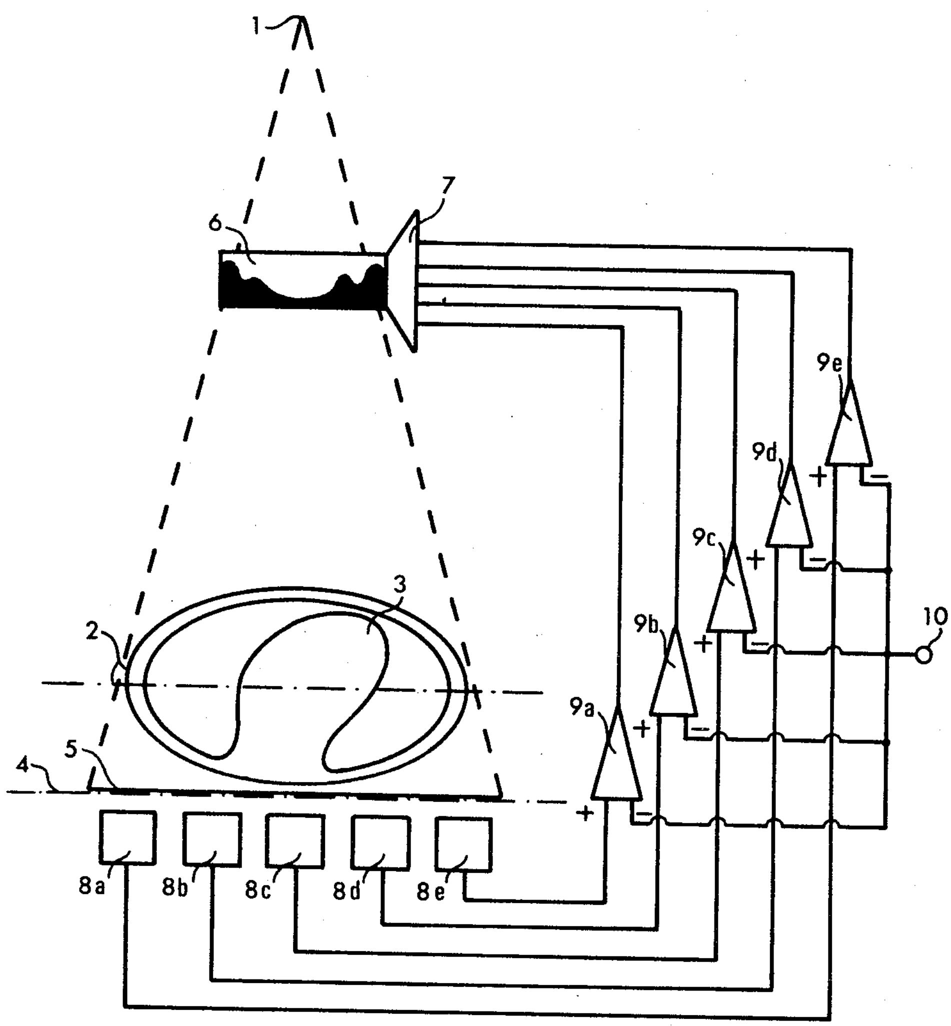


Fig. 1

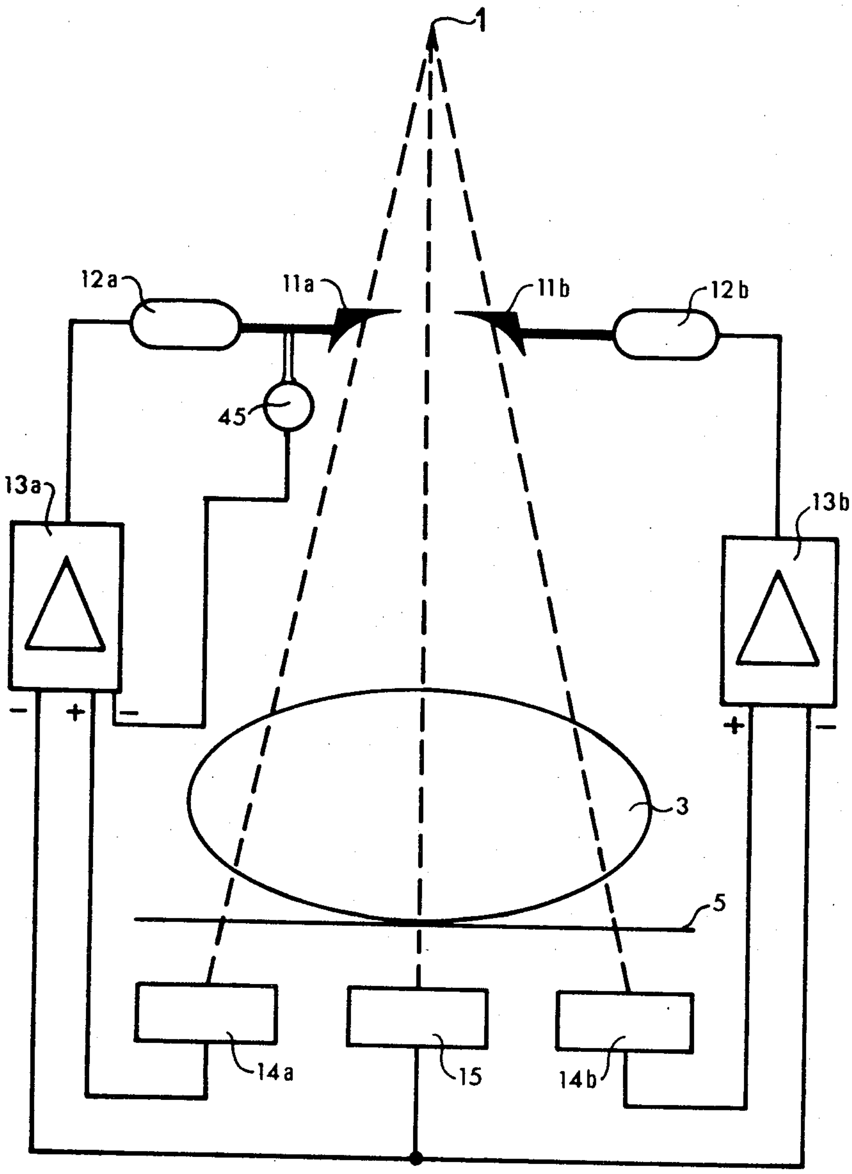


Fig. 2

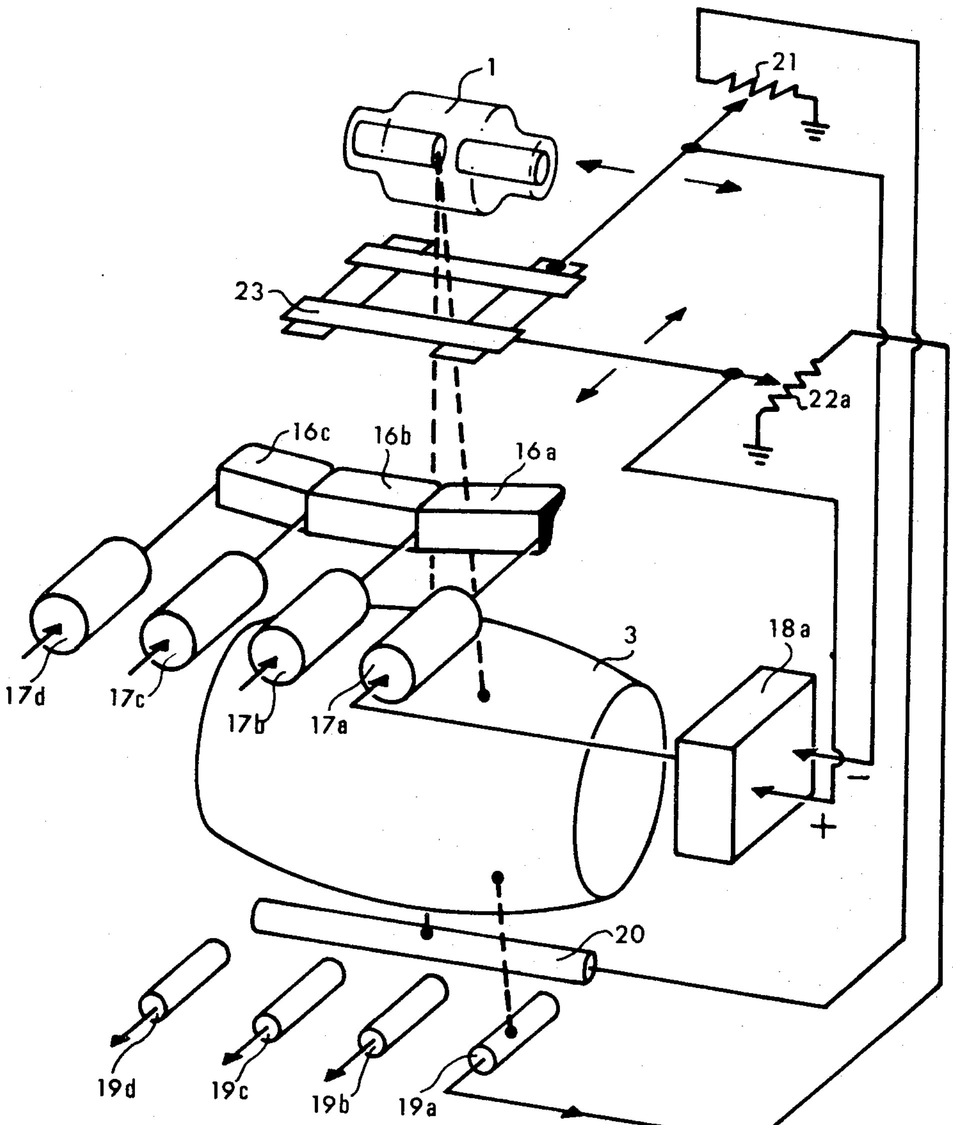


Fig.3

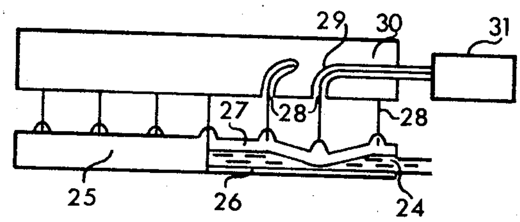


Fig. 4

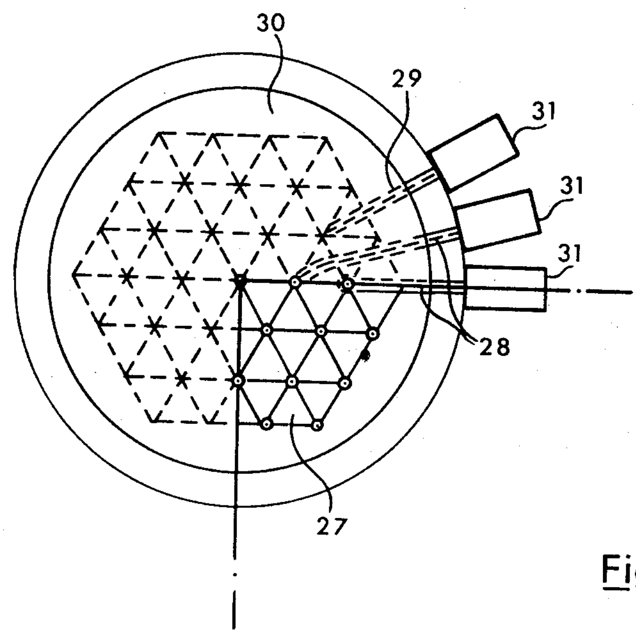


Fig. 5

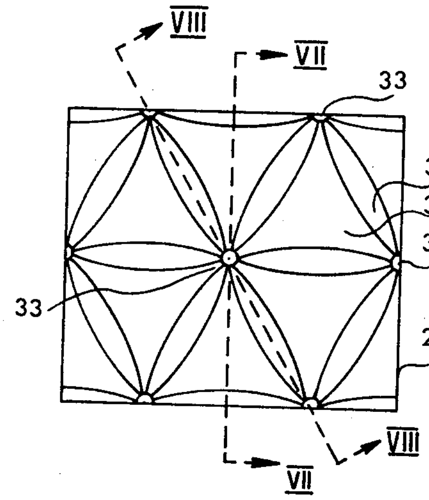


Fig. 6

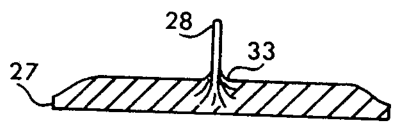


Fig. 7

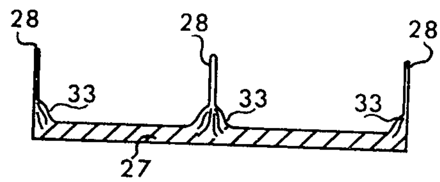
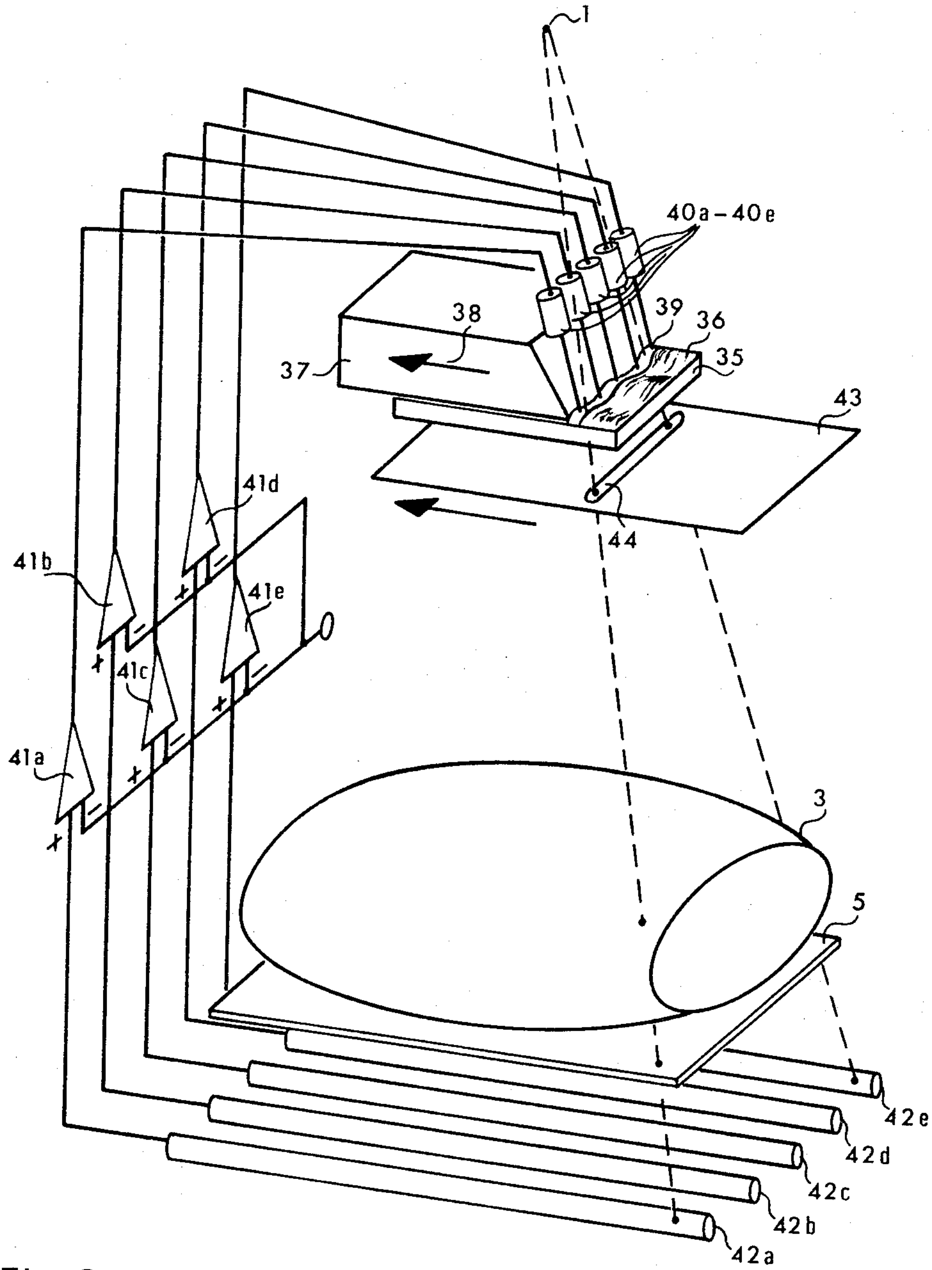


Fig. 8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40a–40e
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42c
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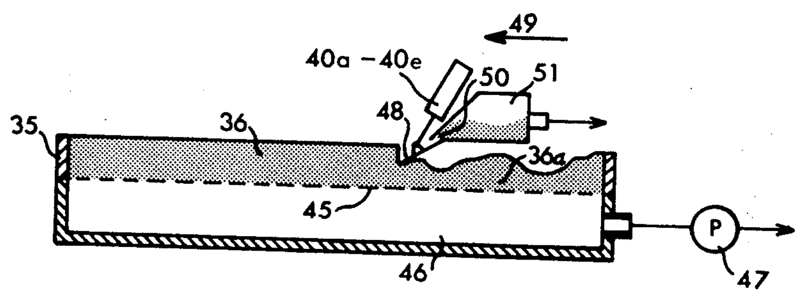
Fig. 9

Fig.10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40a – 40e
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Fig.12

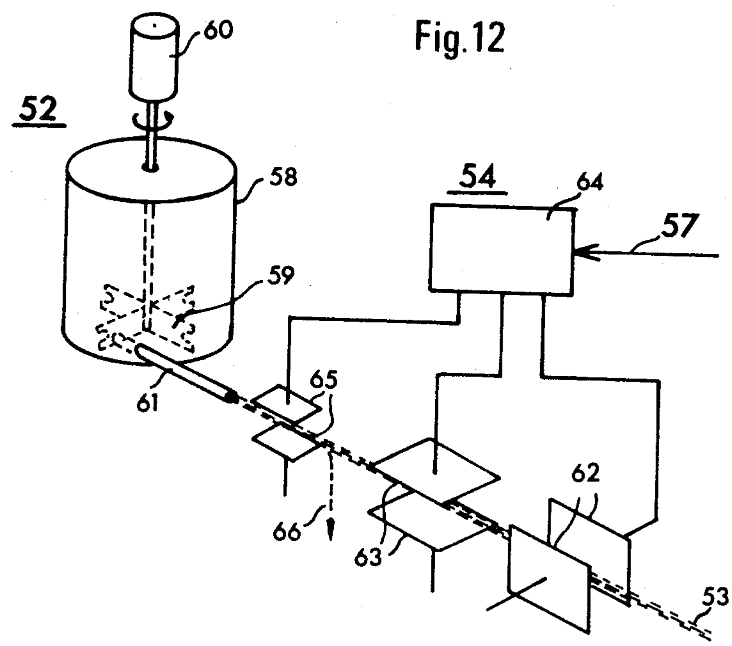
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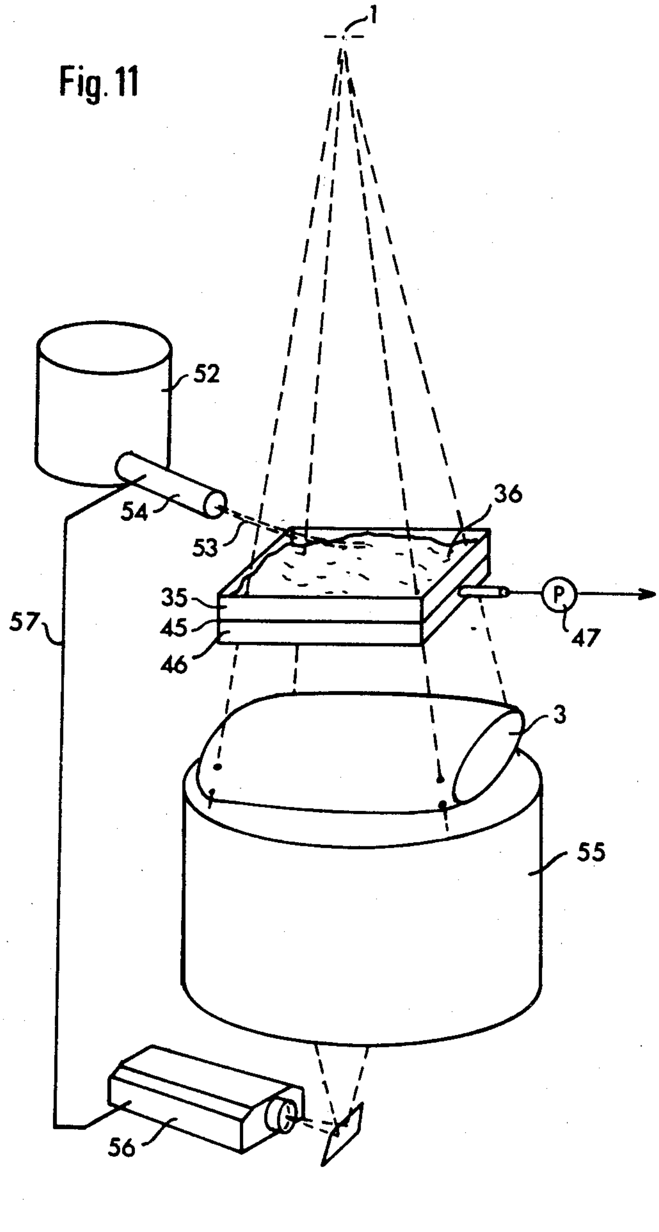
Fig. 11



EXPOSURE COMPENSATING DEVICE FOR RADIOGRAPHIC APPARATUS

The present invention relates to radiographic apparatuses and more particularly to a device in radiographic apparatuses for equalizing the average exposure or average radiation intensity in the image plane of the apparatus so that the average exposure is made substantially uniform over the entire area of the image recording medium being used.

As well known in the art, a radiographic apparatus comprises as its fundamental components a radiation source, normally an X-ray tube, an object plane in which the object to be radiographed is positioned, and an image plane on the opposite side of the object plane relative to the radiation source, in which image plane an image recording medium or device is disposed. This image recording medium may for instance be a film sensitive to the radiation, a fluorescent display screen or an electronic image intensifier. An important problem in radiographic apparatuses is caused by the fact that the average intensity in different portions of the radiation beam leaving the object being radiographed and thus the average exposure of the corresponding different portions of the image recording medium displays often very large variations caused by differences in thickness, density and absorption properties in different portions of the object. Due to this it is often impossible to obtain an exposure within the prescribed exposure range of the image recording medium, the so called exposure latitude, over the entire area of the image recording medium. Thus, some parts of the radiograph may be over-exposed, whereas other parts may be under-exposed, wherefore in these parts the image contrast is insufficient to give the desired and necessary information regarding the corresponding portions of the object being radiographed. The most widely used method of overcoming this problem is to make two or more radiographs of the object with different radiation intensities and/or different exposure times for the different radiographs. This method has, however, i.e. the disadvantages that the total time necessary for the radiographic examination is prolonged, that the film costs are increased and that the object, e.g. a human patient, is exposed to a larger total radiation dose. Further, when making a radiograph of the thickest portions of the object, in which case a high radiation intensity is used, the thinner portions of the object, e.g. the patient, are exposed to an unnecessarily large radiation dose. This unnecessarily high radiation intensity in the thinner portions of the object produces also a high level of scattered secondary radiation, which causes a diffused exposure or background fogging of the image recording medium, which also results in a reduced image contrast.

To overcome these disadvantages it has been suggested in the art to equalize the average radiation intensity in different portions of the image plane so that the average radiation intensity and thus the average exposure is made substantially uniform within different portions of the image plane and the image recording medium, respectively. For this object two different methods have been suggested. In the one method radiation absorbing bodies, generally of metal, are positioned in the radiation path between the radiation source and the object plane; the shape, the thickness in the direction of radiation and the position in the radiation beam of

these radiation absorbing bodies being selected in such a manner that the absorption of different portions of the radiation beam caused by these bodies is substantially inversely proportional to the absorption in the radiographed object of the corresponding portions of the radiation beam. Devices of this type are disclosed e.g. in the U.S. Pat. application Ser. No. 111 828, the U.S. Pat. specification No. 1 535 359, the German Pat. specification No. 1 079 448 and the Swiss Pat. specification Nos. 243 731 and 254 461.

The other method suggested in the prior art consists therein that a diaphragm, oscillating or rotating in a plane perpendicular to the direction of radiation, is disposed in the radiation path generally between the radiation source and the object plane. The shape, the positon relative to the radiation beam and the oscillating or rotating movement of this disphragm are selected in such a manner that the total exposure times for the different portions of the object become substantially proportional to the absorption values of said different portions of the object. Devices of this type are disclosed in e.g. the Swiss Pat. specification No. 154 209 and the German Pat. specification Nos. 1 023 315, 1 193 796 and 1 017 024.

Prior art devices of the two types discussed above have as a common serious disadvantage that specifically shaped absorption bodies or diaphragms, respectively, are necessary for each type of objects to be radiographed, as for instance skull, trunk, extremities, etc. Further, the absorption bodies or diaphragms, respectively, must be positioned manually relative to the radiation beam on the basis of an estimation of the absorption in different portions of the object to be radiographed. This manual operation is time-consuming and requires skilled personnel and gives, even in the best cases, only a rough and relatively unaccurate equalization of the absorption differences in different portions of the object and chiefly only of absorption differences due to differences in the dimension of the object in the direction of radiation, i.e., in the thickness of the object. Therefore, in this way it has not been possible to compensate for absorption differences caused by differences in the structure of different portions of the object. Further, it has only been possible to compensate for geometrically large absorption differences in the object, i.e., absorption differences having an extension within the object substantially corresponding to the extension of the object itself in the direction perpendicular to the direction of radiation. Geometrically more closely related absorption differences, i.e., with a higher spatial frequency, have not been possible to compensate.

The object of the present invention is therefore to provide an improved device in radiographic apparatuses for equalizing the average exposure in the different portions of the image plane, said device being of the general type known in the prior art and discussed above, which comprises a radiation absorbing compensating filter device inserted in the radiation path between the radiation source and the object plane and having different absorption values within different portions of a plane substantially perpendicular to the direction of radiation. However, the device according to the invention is automatic in its operation and provides a more accurate and a finer equalization of the average exposure in the image plane.

The device according to the invention comprises a compensating filter device including radiation absorbing means having a variable shape or form so that its absorption values within different portions of the radiation beam from the radiation source can be varied and selected independently; control means for determining the absorption values of said compensating filter device within different portions of the radiation beam by variation of the shape of said radiation absorption means in response to control signals supplied to said control means; and radiation detecting means located beyond the object plane as seen from the radiation source for sensing the average intensity values within different portions of the radiation beam and generating output signals representing said average intensity values; the control signals for said control means determining the absorption values of said compensating filter device within different portions of the radiation beam being derived from the output signals of said radiation detecting means.

As in the device according to the invention the compensating filter device includes radiation absorbing means with a variable shape so that its absorption values within different portions of the radiation beam can be varied substantially independently, and the control means varying the shape of said radiation absorbing means and thus determining said absorption values of the compensating device are responsive to the output signals of radiation detecting means measuring the average intensity values of different portions of the radiation beam leaving the object, an automatic equalization of the average radiation intensity in the image plane is provided with an accuracy as high as permitted by the design of the radiation absorbing means being used. Consequently, the average exposure is equalized completely automatically on the basis of a quantative measuring of the radiation intensity values within different portions of the radiation beam leaving the object. The limit for the equalization of the average exposure is determined substantially only by the design of the compensating filter device. With a filter device according to the invention consisting fundamentally of a layer of a formable radiation absorbing substance having a thickness in the direction of the radiation that can be varied within different portions or sections of the layer, it is possible to achieve a very accurate and complete compensation for different absorption values in different portions of the object being radiographed. As compared with prior art devices for the same object the device according to the invention has as additional advantages that it does not require any manual adjustments, which saves time and calls for a less skill of the personnel, that differently shaped absorption bodies are no longer necessary for different types of objects being radiographed, that a correct average exposure of the image recording medium being used can be obtained within all sections of the image so that structure details in the object can be discerned in all sections of the image in spite of the restricted working range of the image recording medium, and that the total radiation dose to which the object, the patient, is exposed will be lower than at a less complete equalization of the exposure.

In the following the invention will be further described with reference to the accompanying drawings, which show by way of example a number of embodiments of a device according to the invention. In the drawings

FIG. 1 illustrates schematically the fundamental layout of a device according to the invention;

FIG. 2 illustrates schematically a first simple embodiment of a device according to the invention, in which the radiation absorbing means in the compensating filter device consists of a number of solid bodies of radiation absorbing material, which can be moved to varying positions relative to each other and the radiation beam;

FIG. 3 shows schematically a somewhat more sophisticated device according to the invention with a compensating filter device comprising solid bodies of radiation absorbing materials, which can be moved relative to each other and the radiation beam;

FIG. 4 is a schematical side view partially in section of a compensating filter device according to the invention, in which the radiation absorbing means consists of a radiation absorbing liquid enclosed in a flat chamber, which is disposed substantially perpendicular to the direction of radiation and the thickness of which can be varied within different portions of the radiation beam;

FIG. 5 is a plan view partially in section of the compensating filter device illustrated in FIG. 4;

FIG. 6 illustrates schematically the design of the flexible diaphragm forming one wall in the liquid-filled chamber in the compensating filter device shown in FIGS. 4 and 5;

FIG. 7 is a section through said diaphragm along the line VII—VII in FIG. 6;

FIG. 8 is a section through said diaphragm along the line VIII—VIII in FIG. 6;

FIG. 9 illustrates schematically an embodiment of a device according to the invention, in which the compensating filter device includes a layer of a formable or moldable, radiation absorbing material disposed on a flat tray;

FIG. 10 illustrates schematically in cross-section a compensating filter device according to the invention, in which the radiation absorbing means consists of a layer of a radiation absorbing, intrinsically loose powder, which is supported on a flat tray and maintained in a stable, moldable or formable shape by an air-pressure gradient across the layer;

FIG. 11 illustrates schematically still another embodiment of a device according to the invention, in which the compensating filter device comprises radiation absorbing means consisting of a layer of a radiation absorbing, intrinsically loose powder, which is deposited with a varying thickness upon a flat tray and is maintained in a stable unmoving state by an air-pressure gradient produced across the powder layer on the tray; and

FIG. 12 illustrates schematically a device for depositing the radiation absorbing powdered material on the tray in the compensating filter device illustrated in FIG. 11.

FIG. 1 illustrates, only very schematically, a radiographic apparatus including a radiation source **1**, generally consisting of an X-ray tube, an object plane **2**, in which the object **3** to be radiographed is positioned, and an image plane **4**, in which the image recording medium **5** to be used is arranged. In the illustrated example the image recording medium is assumed to be a radiation sensitive film, but is is obvious that it could just as well consist of a fluorescent display screen or an electronic image intensifier or any similar device.

Due to the varying thickness and composition of the object 3 the average radiation intensity will, as discussed in the foregoing, be different within different portions of the radiation beam leaving the object 3, which can cause unacceptably large variations in the average exposure within the different portions of the film 5, resulting in the disadvantages discussed in the foregoing.

In order to compensate for the absorption differences in different portions of the object 3 and thus equalize the average exposure of the film 5 a device according to the invention is provided. This device comprises a compensating filter device 6 inserted in the radiation beam between the radiation source 1 and the object plane 2, preferably adjacent the radiation source 1. The compensating filter device 6 is illustrated only very symbolically in FIG. 1, but a number of different embodiments of such compensating filter device will be described in the following. The fundamental characteristic feature of this compensating filter device is that it includes absorption filter means, which can be varied as to shape or form in such a way that the absorption values within different portions of the radiation beam can be varied or selected substantially independently but without any local discontinuities in the absorption, which could produce corresponding shadow images on the film 5. Further, the compensating filter device 6 is provided with or coupled to electrically controlled control means 7, by means of which the absorption values of the compensating filter device 6 within different portions of the radiation beam can be determined in response to control signals supplied to the control means 7. The device according to the invention comprises also radiation detecting means *8a* – *8e* disposed beyond the object plane 2 as seen from the radiation source 1 so as to sense or measure the average intensity values in different portions of the radiation beam as affected by the compensating filter device 6 and the object 3. These radiation detecting means produce output signals representing said intensity values. In the example illustrated in FIG. 1 said radiation detecting means includes six separate radiation detectors *8a* – *8e*, which can sense or measure the radiation intensity within six different portions of the radiation beam; it being assumed that the control means 7 can vary the absorption values of the compensating filter device 6 within the same six different portions of the radiation beam. The output signals from the radiation detectors *8a* – *8e* are connected to corresponding differential amplifiers *9a* – *9e*, which also receive a common reference or datum signal from a terminal 10. The output signals from the amplifiers *9a* – *9e* are connected as control signals to the control means 7 for the compensating filter device 6.

It is appreciated that the device according to the invention constitutes a closed-loop control system, which automatically operates the compensating filter device 6 to such a setting that the average intensity in the image plane 4 within the different portions of the radiation beam received by the radiation detectors *8a* – *8e* becomes substantially constant and assumes a value determined by the amplitude of the reference signal on the terminal 10.

It is also appreciated that the degree of accuracy and completeness in the equalization of the average exposure in the image plane 4 is mainly determined by the design of the compensating filter device 6 and in particular by the number of different sections of the radiation beam in which the absorption values of the compensating filter device can be varied or selected independently of each other.

In FIG. 1 the radiation detectors *8a* – *8e* are disposed beyond the image plane 4 as seen from the radiation source 1. In this case the compensating filter device 6 may be adjusted with the film 5 located in its recording position, provided that the film and the film casette are translucent to the radiation and the radiation detectors *8a* – *8e* have a sufficient sensitivity so that the adjusting of the compensating filter device can be carried out with such a low radiation intensity from the radiation source 1 that no image producing exposure of the film 5 results. Otherwise, the adjusting of the compensating filter device 6 must be carried out without any film 5 in the image plane 4, whereafter the film is positioned in the image plane and the actual radiographic exposure of the object is carried out. In order to avoid exposing the object 3, the patient, to an unnecessarily large radiation dose, the adjusting of the compensating filter device 6 is preferably carried out with a considerable smaller radiation intensity than the intensity used for the subsequent radiography of the object on the image recording medium being used.

Alternatively, the radiation detectors *8a* – *8e* could of course be disposed between the object plane 2 and the image plane 4, in which case the detectors could either be sufficiently translucent to the radiation not to produce any shadow images on the image recording medium 5, or they could be mounted in a manner permitting their removal from the radiation beam after the adjusting of the compensating filter device 6 but before the actual radiographic exposure of the image recording medium.

Further, a device according to the invention may be designed in a manner permitting the removal of the filter device 6 from the radiation beam, in which case the filter device may be adjusted when positioned outside the radiation beam, whereafter the filter device is moved to a well defined predetermined position within the radiation beam before the radiographic exposure of the object. In this case, however, there is obviously no closed-loop control system present during the adjustment of the compensating filter device, wherefore the different absorption values within the different sections of the filter device must be adjusted by the control means 7 in response of the control signals from the differential amplifiers *9a* – *9e* on values that are complementary to the absorption values of the object 3 within its corresponding different portions.

FIG. 2 shows a simple embodiment of a device according to the invention, in which the pre-adjustable compensating filter device consists of two solid bodies *11a* and *11b* of a radiation absorbing material, which can be moved relative each other and the radiation beam from the radiation source 1 in a plane substantially perpendicular to the direction of radiation. As the absorption bodies are wedge-shaped, the degree of absorption of the portions of the radiation beam passing through the absorption bodies can be varied by variation of the positions of the absorption bodies. The absorption bodies are moved by servomotors *12a* and *12b*, respectively, which are controlled by the output signals from the differential amplifiers *13a* and *13b*, respectively. These two differential amplifiers are driven on the one hand by the output signals from two radiation detectors **14***a* and **14***b*, respectively, which are affected by the portions of the radiation beam passing through the absorption bodies **11***a* and **11***b*, and on the other hand by a common reference signal from a radiation detector **15**, which is affected by the central portion of the radiation beam, which has an intensity which is substantially independent of the position of the absorption bodies **11***a*, **11***b*. Consequently, the two absorption bodies **11***a*, **11***b* are automatically moved to such positions that all radiation detectors **14***a*, **14***b* and **15** receive substantially equal radiation intensities, whereby an equalization of the average exposure of the peripheral and central portions, respectively, of the film **5** is achieved.

FIG. **3** shows an embodiment of the invention adapted for a so called back-table, that is an apparatus mainly for radiography of the trunk of a patient **3**. Also in this embodiment of the invention the compensating filter device consists of a number of solid bodies of radiation absorbing material, which are movable relative each other and the radiation beam. On each side of the central plane through the patient **3** there is provided a series of pivotally interconnected absorption bodies **16***a*, **16***b* and **16***c*. For the sake of simplicity the corresponding assembly of absorption bodies on the opposite side of the central plane through the patient **3** is not shown in the drawing. In the illustrated example three pivotally interconnected absorption bodies **16***a* – **16***c* are provided on each side. These pivotally interconnected absorption bodies may for instance be of the type described more in detail in the U.S. Pat. application Ser. No. 113 013. The pivot joints between the absorption bodies **16***a* – *16c* and the free ends of the two outermost absorption bodies **16***a* and **16***c* are connected to four servomotors **17***a*, **17***b*, **17***c* and **17***d*, respectively, in any suitable manner so that the absorption bodies can be moved in a direction substantially perpendicular to the radiation beam. Each of these servomotors **17***a* – **17***d* is driven by the output signal from an associated differential amplifier. For the sake of simplicity the drawing shows only the amplifier **18***a* for the servomotor **17***a*. In the same way as discussed in the foregoing, a number of radiation detectors **19***a*, **19***b*, **19***c* and **19***d* are located underneath the object plane, where the patient **3** is positioned, so as to sense the intensity values of the portions of the radiation beam which are affected by the positions of the absorption bodies **16***a* – **16***c*. In the illustrated example these radiation detectors **19***a* – **19***d* are elongate and extend parallel to the direction in which the absorption bodies **16***a* – **16***c* can be moved. Further, an elongate reference detector **20** is provided, which is positioned in the central plane through the patient **3** and consequently senses the intensity of the central portion of the radiation beam. The output signal from this reference detector **20** is used as a reference signal for all servomotors and is consequently connected e.g. to the differential amplifier **18***a* for the servomotor **17***a*. In the same way the output signals from the radiation detectors **19***a* – **19***d* are used as control signals for the servomotors **17***a* – **17***d*, respectively, wherefore e.g. the output signal from the radiation detector **19***a* is connected to the amplifier **18***a* for the servomotor **17***a*. However, the signals to the servomotor amplifiers, e.g. the amplifier **18***a*, are transferred to the amplifiers through a potentiometer **21** for the reference signal from the reference detector **20** and another potentiometer for the output signal from the associated radiation detector, e.g. the potentiometer **22***a* for the output signal from the detector **19***a*. These potentiometers are operated in response to the actual position of a primary diaphragm **23** used for restricting the radiation beam from the radiation source **1**. This diaphragm consists fundamentally of four diaphragm plates, which are movable pairwise relative to each other for determining the size of a rectangular diaphragm aperture. the potentiometer **21** for the reference signal from the reference detector **20** is operated in response to the position of the diaphargm plates determining the size of the diaphragm aperture in the longitudinal direction of the reference detector **20**, whereas the potentiometers for the output signals from the other radiation detectors, e.g. the potentiometer **20***a* for the output signal from the detector **19***a*, are operated in response to the position of the diaphragm plates determining the size of the diaphragm aperture in the longitudinal direction of the radiation detectors **19**. It should be noted that there is provided one potentiomter **22** for each radiation detector **19**. By means of these potentiometers **21** and **22** a compensation is made for the screening effect of the primary diaphragm **23** upon the detectors **20** and **19**. Such a compensation is necessary, as the detectors are not point-shaped but elongate. It is appreciated that without such a compensation dependent on the illuminated portion of the radiation detectors, the positions of the absorption bodies would be changed when the setting of the primary diaphragm **23** is changed, which is of course undesired, as this would give cause to an erroneous positioning of the absorption bodies.

From the embodiments of the invention shown in FIGS. **2** and **3** and described in the foregoing it is obvious that the degree of accuracy and completeness in the equalization of the exposure that may be obtained with a device according to the invention with solid absorption bodies is to a large extent dependent on the number of the absorption bodies, their shape, their mutual arrangement and the permissible variations in their mutual positions. It is also appreciated that it might be necessary to have different arrangements of absorption bodies for different types of objects to be radiographed. For a complete equalization of the exposure it may obviously be necessary to have a large number of mutually movable absorption bodies, which must have such a shape and be movable relative each other in such a manner that they do not produce any discontinuities in the absorption, as such discontinuities would result in corresponding shadow images. Consequently, a compensating filter device consisting of movable solid bodies of radiation absorbing material suffers from certain disadvantages.

These disadvantges are eliminated to a large extent in a compensating filter device of the type illustrated in FIGS. **4** to **8**. In this filter device the radiation absorbing medium consists of a liquid **24** enclosed in a thin flat chamber **25**, which is adapted to be disposed in a plane substantially perpendicular to the direction of radiation. The radiation absorbing liquid **24** may for instance be mercury or some other liquid metal or a solution or stable suspension of a radiation absorbing substance, as for instance an aqueous solution of cesium acetate. The flat chamber **25** has a plane bottom **26** and an upper wall consisting of a resiliently flexible diaphragm **27**, for instance of rubber. At its periphery the chamber **25** communicates with a container (not illustrated in the drawing) containing the radiation absorbing liquid 24 so that the chamber 25 is always filled with liquid. A number of stiff but flexible wires 28 are attached to the upper side of the rubber diaphragm 27 in different points distributed over the surface of the diaphragm 27 in a predetermined pattern, for instance a triangular grid pattern, as illustrated in FIG. 5. These wires 28 are guided in corresponding ducts 29 in a plate-shaped guide member 30 located directly above the liquid chamber 25. The opposite ends of the wires 28 are coupled to separate servomotors 31 disposed about the circumference of the guide member 30. It is appreciated that the wires 28 and the associated guide ducts 29 in the guide plate 30 cooperate in the same manner as Bowden cables. Thus, by means of the servomotors 31 and the wires 28 coupled thereto the different sections of the flexible diaphragm 27 can either be withdrawn from the bottom 26 of the chamber 25, whereby the thickness of the liquid layer 24 is increased, or be pushed towards the bottom 26, whereby the thickness of the liquid layer is reduced. In this way it is possible to vary the thickness of the liquid layer 24 in the chamber 25 and thus the absorption value of the filter device within each section of the filter device corresponding to the point of connection of a wire 28 to the diaphragm 27. As the diaphragm 27 is resiliently flexible, the thickness of the liquid layer 24 will vary smoothly so that no abrupt differences in absorption between adjacent portions of the filter device can be created.

The flexible diaphragm 27 has preferably a larger rigidity within those portions that are enclosed by the junction lines between the connection points of the wires 28 than within the portions along and directly adjacent said junction lines. This may be achieved with a diaphragm designed in the manner illustrated in FIGS. 6 to 8. In this diaphragm the portions 32 located between the junction lines between the connection points 33 of the wires 28 are thicker and consequently more rigid and those portions 34 that are located along and directly adjacent the junction lines between the connection points 33 of the wires.

The liquid chamber 25, the wires 28 and the guide member 30 are made of materials having a low radiation absorption factor and as the total dimension of these members is substantially uniform and constant over the entire filter device, these members will not give cause to any substantial absorption differences in the radiation beam.

The servomotors 31 for the wires 28 are of course controlled from corresponding radiation detectors located beyond the object plane, substantially in the same way as described in the foregoing in connection with FIG. 1. Consequently, for each servomotor 31 there must be provided a corresponding radiation detector and these radiation detectors should be arranged in a pattern corresponding to the pattern of the connection points of the wires 28 to the flexible diaphragm 27. It is realized that the degree of accuracy and completeness of the exposure equalization can be increased or reduced by increasing or reducing, respectively, the number of wires 28 connected to different points on the flexible diaphragm 27.

This compensating filter device has the disadvantage that it consists of a large number of components, as the number of radiation detectors and the number of servo circuits must be equal to the number of different sections of the filter device, in which the absorption values shall be variable independently of each other. In this respect a compensating filter device of the type illustrated in FIG. 9 should be more advantageous.

FIG. 9 shows schematically, in the same way as in the foregoing, a radiographic apparatus including a radiation source 1, the object 3 to be radiographed and the image recording medium in the form of a radiation sensitive film 5. The pre-adjustable compensating filter device includes in this case a flat tray 35 mounted in a plane substantially perpendicular to the radiation beam and supporting a layer of a formable or moldable compound 36 containing a radiation absorbing substance. The moldable compound 36 may for instance consist of a powder mixed with a suitable binding agent so that the particles in the powder adhere to each other, a paste or a jelly. The absorption values of the filter device within different sections of the radiation beam are determined by the thickness of the layer 36 in the corresponding sections of the tray 35, and the thickness of the radiation absorbing layer can be varied by molding or forming the upper surface of the layer. For this purpose the illustrated embodiment comprises a container or dispenser 37, which contains the moldable radiation absorbing compound and which can be moved above the tray 35 in the direction indicated by an arrow 38. At its lower rear edge the dispenser 37 is provided with an elongate slot-shaped discharge opening for the radiation absorbing compound, extending across the tray 35. The lower edge of this discharge opening may preferably be constituted by the plane bottom of the tray 35, whereas the upper edge of the discharge opening is formed by a resiliently flexible lip or slice 39, for instance consisting of a rubber band. A number of servomotors 40*a* – 40*e* are connected to this slice 39 so that it can be moved substantially in the direction of radiation to different spacings from the bottom 35 of the tray at different sections along its length. In that the servomotors 40*a* – 40*e* continuously vary the spacings between the different sections of the slice 39 and the bottom of the tray 35, while the dispenser 37 is at the same time moved in the direction 38 relative the tray 35, it is possible to produce in the tray 35 a layer of the moldable radiation absorbing compound 36 with a varying thickness and thus a varying absorption.

The servomotors 40*a* – 40*e* are controlled by signals from corresponding differential amplifiers 41*a* – 41*e*, which receive on the one hand a common datum or reference signal and on the other hand the output signals from corresponding elongate radiation detectors 42*a* – 42*e*, which are located underneath the image plane 5 parallel to each other and to the direction of movement 38 of the dispenser 37.

Further, a diaphragm plate 43 with a slot-shaped aperture 44 is arranged underneath the tray 35. The aperture slot 44 is parallel to the slice 39 of the dispenser 37 and the diaphragm plate 43 is moved in the same direction as the dispenser 37 in synchronism therewith in such a manner that the portion of the radiation beam passing through the aperture slot 44 is identical with the portion of the radiation beam passing through the tray 35 and the radiation absorbing layer 36 adjacent the slice 39 of the dispenser 37.

This compensating filter device is pre-adjusted in the following manner: When starting the molding or forming of the layer of the radiation absorbing compound 36 in the tray 35 the dispenser 37 is in a position furthest to the right in the drawing. The portion of the radiation beam from the radiation source **1** passing through the aperture slot **44** illuminates then the right hand portion of the object **3** to be radiographed and the right hand portions of the radiation detectors **42***a* – **42***e*. In response to the control signals from the amplifiers **41***a* – **41***e* the servomotors **40***a* – **40***e* will move the slice **39** to such a position that the moldable layer **36** in the tray **35** is given such a thickness that the sum of the absorption in this layer and the absorption in the object **3** becomes substantially constant and uniform over the entire portion of the radiation beam passing through the aperture slot **44**, which means that all detectors **42***a* – **42***e* receive substantially equally large radiation intensities. As the dispenser **37** and the diaphragm **43** are moved to the left in the drawing, the position of the slice **39** is varied successively by the servomotors **40***a* – **40***e* so that the radiation absorbing layer **36** in the tray **35** will within all portions of the tray be molded to have absorption values which are substantially inversely proportional to the absorption values of the object **3** within corresponding portions of the radiation beam.

After this pre-adjustment of the compensating filter device the diaphragm **43** is removed from the radiation path so that the whole object **3** can be exposed to the radiation beam for the radiography of the object.

After the radiographic exposure of the object the dispenser **37** is returned to its initial position, and the dispenser has such a design that during this return movement the layer of radiation absorbing compound **36** in the tray **35** is made level.

In the compensating filter device illustrated in FIG. **9** and described above it has been assumed that the radiation absorbing compound disposed as a formable layer **36** in the tray **35** has intrinsically such a consistency, for instance consisting of a paste or a jelly or a powder mixed with a suitable binding agent, that the upper surface of the layer can easily be molded or formed and subsequently maintain its form. However, it has been found that it is also possible to use an intrinsically loose and freely moving powder of a radiation absorbing material, e.g. a plastic material containing a radiation absorbing substance. The upper surface of a layer of such an intrinsically loose powder can of course not, without special steps, be molded or formed to the extent required by the invention with depressions and elevations with comparatively steep sides. It has been found, however, that it is possible to transfer such a layer of an intrinsically loose and freely moving powder into a very stable state, in which the upper surface of the layer can be formed or molded with depressions and elevations with very steep sides, which remain substantially unchanged after the forming or molding process, by creating an air-pressure gradient across the layer from its upper side to its lower side. Such a pressure gradient can preferably be produced by providing the tray supporting the powder layer with a bottom which is air-permeable but impervious to the powder and providing means for generating a reduced air-pressure underneath this foramenous bottom of the tray. The air-permeable bottom of the tray may for instance consist of a stretched, finely woven fabric.

FIG. **10** in the drawing illustrates schematically and in section a compensating filter device according to the invention based upon the above discussed principle. This compensating filter device may be used fundamentally in the same way as the filter device illustrated in FIG. **9.**

Thus, the filter device illustrated in FIG. **10** comprises a tray **35**, which in the same way as in the filter device according to FIG. **9** is adapted to support a layer **36** of radiation absorbing material, which in this case consists of an intrinsically loose and freely moving powder. By contrast with the filter device according to FIG. **9**, however, the tray **35** in the filter device according to FIG. **10** has a foramenous bottom **45**, which is permeable to air but impervious to the powder material **36.** Further, a suction chamber **46** is provided underneath the air-permeable bottom **45.** This suction chamber **46** is in any convenient manner only schematically illustrated in the drawing connected to an air pump **47**, by means of which a reduced air-pressure can be created within the suction chamber **46.** As a result of this reduced pressure in the chamber **46** and the resulting air flow through the powder layer **36** and the air-permeable bottom **45** an air-pressure gradient is created within the powder layer **36.** Under the effect of this pressure gradient the powder layer assumes a very stable state so that the upper surface of the powder layer can easily be molded or formed with remaining depressions and elevations with very steep sides.

The forming of the upper surface of the powder layer **36**, so as to give the powder layer the desired varying thickness, is carried out in a manner similar to that in the filter device according to FIG. **9**, in that an elongate resiliently flexible scraper or knife **48**, which extends across the tray **35**, is moved above the tray in the direction indicated by an arrow **49** at the same time as the scraper **49** is adjusted by servomotors **40***a* – **40***e* to a desired spacing above the bottom **45** of the tray. As described in the foregoing, this spacing between the scraper **48** and the bottom **45** of the tray can be different in different sections along the length of the scraper. During its movement over the tray **35** in the direction **49** the scraper **48** cuts down in the powder layer **36** and leaves behind it a molded or formed powder layer **36***a* with a varying thickness. The excessive powder material at the surface of the original powder layer **36** is removed by suction into a container **51** through an elongate suction nozzle **50** located along the upper side of the scraper **48.** The servomotors **40***a* – **40***e* controlling the position of the scraper **48** are controlled in the same manner as in the filter device illustrated in FIG. **9** by means of signals from the radiation detectors **42***a* – **42***e;* the scraper **48** being moved over the tray **35** in synchronism with the slotted diaphragm **43.** After the forming or molding of the powder layer **36** the radiographic exposure of the object is carried out in the manner described in the foregoing. Before a repeated forming of the powder layer **36** in the tray **35** for radiography of another object, the powder material removed from the tray **35** at the previous forming of the layer **36** is replaced so that a powder layer **36** of substantially uniform thickness is recreated, which layer can be formed in the manner described above.

In the compensating filter device according to the invention illustrated in FIG. **10** and described above the radiation absorbing powdered material is initially arranged in a layer of uniform thickness in the tray **35**, whereafter this layer is given the desired varying thickness by removal of a varying portion of the initial layer. However, it is also possible to deposit the radiation absorbing powdered material upon the air-permeable bottom 45 of the tray 35 already from the beginning in a layer with the desired varying thickness, at the same time as an air pressure gradient is maintained across the deposited powder layer in the manner described in the foregoing so that the powder layer remains in a stable state and maintains its varying thickness.

FIG. 11 in the drawing illustrates schematically and by way of example a compensating filter device operating in this manner.

The compensating filter device in FIG. 11 comprises, just as the filter device in FIG. 10, a tray 35 having a foramenous bottom 45, which is permeable to air but impervious to the radiation absorbing powdered material, and a suction chamber 46 arranged underneath the bottom 45 of the tray and connected to an air pump 47. For depositing the desired radiation absorbing powder layer 36 with a varying thickness in the tray 35 a device 52 is provided for producing a narrow jet 53 of the radiation absorbing powder directed into the tray 35. This device 52 is associated with means 54 for moving the powder jet 53 over the entire area of the tray 35 along a predetermined scanning pattern and also for varying the intensity of the powder jet, that is the flow rate of powdered material in the jet. By moving the powder jet 53 over the tray 35, e.g. along a linear scanning pattern, e.g. of the same type as used in a TV picture tube, and simultaneously modulating the intensity of the powder jet 53 it is consequently possible to deposit upon the bottom 45 of the tray 35 a powder layer having a varying thickness, which is maintained in a stable unmoving state due to the pressure gradient established across the layer.

The radiation detecting means for sensing or measuring the intenstiy of the radiation beam leaving the object 3 consists in this case of a device for electronically scanning the radiation image of the object 3 along a predetermined scanning pattern aand generating a video signal, which is proportional at any moment to the intensity of the presently scanned portion of the radiation image. As schematically illustrated in FIG. 11 this device for electronically scanning the radiation image of the object 3 may as known per se in the prior art include an image intensifier 55, which converts the radiation image into a corresponding optical image, and a suitable TV camera tube 56 viewing said optical image. As well known in the art the camera tube 56 produces a video signal, which has an amplitude proportional to the intensity values of the scanned points in the radiation image of the object 3. This videosignal from the camera tube 56 is transferred via a signal communication cable 57 to the device 54. Sync signals or other signals representing the image scanning of the camera tube 56 are also transferred to the device 54 via the signal communication cable 57. In the device 54 the scanning signals and the video signal from the camera tube 56 are used for controlling on the one hand the scanning motion of the powder jet 53 over the tray 35 and on the other hand the varying intensity of the powder jet in such a manner that the powder jet 53 is moved over the tray 35 along a scanning pattern corresponding to the scanning pattern of the camera tube 56 and the intensity of the powder jet 53 is varied in correspondence with the varying amplitude of the video signal.

FIG. 12 shows schematically and by way of example an embodiment of the devices 52 and 54 for generating and controlling the powder jet 53 in a filter device of the type illustrated in FIG. 11 and described above. The device 52 for generating the narrow powder jet 53 comprises a cylindrical container 58, which is filled with the powdered material and in which a rotateable paddle wheel driven by a suitable motor 60 is mounted. A narrow tube 61 extends into the container 58 through its circumferential wall so that the inner end of the tube is passed by the blades of the wheel 59. The tips of the blades are provided with notches for the passage of the end of the tube 61. By rotation of the paddle wheel 59 the powdered material in the container 58 will be forced out through the narrow tube 61 as a narrow restricted powder jet.

The device 54 for controlling the powder jet 53 comprises two pairs of deflection plates 62 and 63, respectively, for electrostatic deflection of the jet 53 in two orthogonal directions. By applying appropriate electric potentials to the deflection plates 62 and 63 it is possible to deflect the powder jet 53 in a desired direction and by a desired angle, whereby the powder jet 53 can be moved over the tray 35 along a desired scanning pattern. The necessary deflection voltages for the deflection plates 62 and 63 are provided by a control unit 64, to which the video signal from the camera tube 56 is conveyed via the signal communication 57. For the intensity modulation of the powder jet 53 an additional pair of electrostatic deflection plates 65 is provided, which can be supplied from the control unit 64 with a deflection voltage with such a large amplitude that the powder jet 53 is deflected very sharply in the direction indicated by a dotted arrow 66, whereby the powder jet will not reach the tray 35 at all but instead be collected in a suitable container not illustrated in the drawing. By pulse modulation of the voltage supplied to the deflection plates 65 with a pulse rate or a puls ratio varying in response to the video signal from the camera tube 56 it is obviously possible to vary the total amount of powder in the powder jet 53 reaching the tray 35 in accordance with the amplitude of the video signal.

Instead of modulating the intensity of the powder jet 53 in the manner described above it would also be possible to use a powder jet with a constant flow rate and instead to vary the sweep velocity of the jet over the tray 35 in such a manner that the amount of powder deposited in the tray 35 within any given portion of the scanning pattern of the powder jet becomes proportional to the amplitude of the video signal for said given portion of the scanning pattern. It should be noticed that in a filter device of this type the final radiation absorbing powder layer 36 in the tray 35 is built-up successively over an interval including several scanning cycles of the camera tube 56 and thus of the powder jet 53.

As a device according to the invention makes it possible to achieve a very good equalization of the average exposure of the different portions of the image recording medium, it becomes possible to use an automatic exposure control system in the radiographic apparatus with a very good result. Previous attempts in using automatic exposure control systems in radiographic apparatuses have often given unsatisfactory results, as the automatic exposure control has frequently been based on the radiation intensity in a section of the image being of minor importance, which has resulted in an erroneous exposure of the most interesting portions of the image, as the average exposure has not been uniform within all portions of the image. In combination with a device according to the invention, however, which gives a very good equalization of the average exposure over the entire image, the automatic exposure control system can without difficulties be controlled correctly in response to signals from the radiation detectors sensing the radiation intensity in the image plane.

In some cases it might be advantageous to have a possibility of varying the degree of exposure equalization so that only a partial equalization is obtained. In this way it might be easier to recognize anatomical structures from experiences gained from viewing images without any contrast equalization. Such a variable and partial exposure equalization can be obtained with a device according to the invention in that the sevomotors controlling the pre-adjustment of the compensating filter device are provided with a negative feed-back from their outputs to their inputs. In FIG. 2 this is illustrated schematically and by way of example for the servomotor **12***a*, which has its mechanical shaft coupled to the absorption body **11***a* and also to a suitable signal transducer **45**, which produces an electric signal proportional to the angle of rotation of the servomotor **12***a* and thus to the position of the absorption body **11***a*, this signal being fed back in opposition to the differential amplifier **13***a* for the servomotor **12***a*. By variation of the degree of feed-back it is obviously possible to vary the degree of exposure equalization in the radiographic image.

It is also possible to vary the degree of exposure or contrast equalization by using a radiation with a different energy, that is a different voltage on the X-ray tube, for the pre-adjustment of the compensating filter device before the radiographic exposure of the object than the radiation used for the subsequent actual radiographic exposure of the object. In this way the degree of contrast equalization in the radiographic image is changed, as a change in radiation energy results in unequal absorption changes in the object being radiographed and in the heavy elements constituting the radiation absorbing substance in the compensating filter device.

The selection of the radiation absorbing substance used in the compensating filter device is also an important factor for a correct exposure equalization over the entire radiographic image. In the prior art one has generally used absorption bodies of aluminium. This has the disadvantage, however, that those portions of the radiation that pass through thin and low-absorbing portions of the object being radiographed and that consequently pass through portions of the compensating filter device having a high absorption will be subject to a displacement of the energy distribution spectrum of the radiation towards higher energy values, that is towards a harder radiation. As this harder radiation penetrates the object more easily, the portions of the object having a low absorption, that is generally the thinner portions of the object, will be reproduced on the radiograph with a lower image contrast then the portions of the object having a higher absorption, that is generally the thicker portions of the object. This can be avoided, however, by selecting as radiation absorbing substance in the compensating filter device a substance having a K-absorption edge located within the energy distribution spectrum of the radiation used for the radiographic exposure and preferably close to the energy value of the intensity maximum of the radiation being used. For X-ray radiation this means that the radiation absorbing substance shall have an absorption edge corresponding to an energy, which multiplied with a factor of 1.2 to 2.0, preferably a factor of about 1.4, gives the voltage used on the X-ray tube during the radiographic exposure. However, this value is not critical, but the tube voltage may vary within a comparatively wide range without the contrast improving effect being lost. Suitable radiation absorbing substances are the rare earth metals, which satisfy the above conditions for tube voltages normally used for radiography of skeleton structures and also for many soft tissue structures.

What we claim is:

1. In a radiographic apparatus including a radiation source, an object plane for an object to be radiographed and an image plane for an image recording medium (**5**), a device for equalizing the average exposure of different portions of said image recording medium, comprising a compensating filter device disposed in the radiation path between said radiation source and said object plane and including radiation absorbing means having a variable form such that the absorption values of said radiation absorbing means within different portions of the radiation beam from said radiation source can be varied substantially independently of other portions, control means (**7**) for varying the absorption values of said compensating filter device within different portions of the radiation beam by varying the form of said radiation absorbing means in response to control signals supplied to said control means, and radiation detecting means located beyond said object plane as seen from said radiation source for sensing the average intensity values of different portions of the radiation beam and generating output signals representing said average intensity values, the control signals for said control means determining the absorption values of said compensating filter device (**6**) within different portions of the radiation beam being derived from the output signals of said radiation detector means.

2. A device as claimed in claim **1**, wherein said radiation absorbing means of said compensating filter device include a plurality of solid bodies of radiation absorbing material mounted so as to be movable relative to the radiation beam and each other in a plane substantially perpendicular to the direction of radiation, and said control means include servomotor means coupled to said absorption bodies for determining their positions.

3. A device as claimed in claim **1**, wherein said radiation absorbing means of said compensating filter device include a layer of a formable radiation absorbing material disposed in a plane substantially perpendicular to the direction of radiation, and said control means include means for varying the thickness of said layer in the direction of radiation within different sections of the layer.

4. A device as claimed in claim **3**, wherein said radiation absorbing means include a flat chamber arranged in a plane substantially perpendicular to the direction of radiation and filled with a radiation absorbing liquid, one of the major walls of said chamber consisting of a resiliently flexible diaphragm, and said control means being coupled to said diaphragm in a plurality of spaced points on the surface of the diaphragm for varying the distance of the diaphragm at said points from the opposite major wall of said chamber.

5. A device as claimed in claim 4, wherein said control means include a plurality of servomotors and associated Bowden cables, each of said Bowden cables having its one end coupled to the associated servomotor and its opposite end attached to said flexible diaphragm in one of said points thereon, whereby each servomotor can through its associated Bowden cable exert alternatively a pulling or a pushing force substantially parallel to the direction of radiation upon said diaphragm in the point of connection of the Bowden cable to the diaphragm.

6. A device as claimed in claim 4, wherein the points of connections of said control means to said diaphragm are arranged in a triangular grid pattern array.

7. A device as claimed in claim 4, wherein said flexible diaphragm has a smaller rigidity within portions of the diaphragm located along the junction lines between the connection points of said control means to the diaphragm than within portions of the diaphragm enclosed by said junction lines.

8. A device as claimed in claim 3, wherein said radiation absorbing means include a flat tray mounted in a plane substantially perpendicular to the direction of radiation and a moldable layer of a radiation absorbing material supported on said tray, and said control means include means for varying the thickness of said layer by molding the upper surface thereof.

9. A device as claimed in claim 8, wherein said means for molding the upper surface of said moldable layer of radiation absorbing material on said tray include an elongate resiliently flexible scraper means extending across said tray perpendicularly to the direction of radiation and movable relative the tray in a direction perpendicular to the direction of radiation and the longitudinal direction of the scraper means, and said control means include a plurality of servomotors (40*a*–40*e*) coupled to said scraper means in spaced points along its length for varying the distance between the bottom of said tray and the scraping edge of said scraper means.

10. A device as claimed in claim 9, comprising dispensing means movable over said tray for dispensing said radiation absorbing material onto said tray through an elongate slot-shaped dispenser opening, said flexible scraping means forming the upper edge of said dispenser opening.

11. A device as claimed in claim 9, wherein said radiation absorbing material consists of an intrinsically loose and freely moving powder, said tray is provided with a foramenous bottom premeable to air but impervious to said powder, means are provided for producing a reduced air pressure underneath said bottom, whereby an air pressure gradient is established across the powder layer on said tray maintaining said powder layer in a substantially stable state, said scrapping means is adapted when moving over the tray to cut down into said powder layer (36) to a depth determined by the distance between said bottom of the tray and said scraping means, and means are provided for removing the portion of said powder layer located above the cutting edge of said scraping means.

12. A device as claimed in claim 11, wherein said means for removing said portion of said powder layer include an elongate suction nozzle extending along said scraping means above the cutting edge thereof.

13. A device as claimed in claim 9, wherein said radiation detecting means include elongate radiation detectors extending parallel to each other and to the direction of movement (38) of said scraping means (39), a diaphragm (43,44) provided with a slot-shaped aperture extending parallel to the longitudinal direction of said scraping means being movable relative to the radiation beam in the same direction as said scraping means and in synchronism therewith in such a manner that the portion of the radiation beam passing through said diaphragm aperture is identical with the portion of the radiation beam passing through said layer of radiation absorbing material on said tray close to said scraping means.

14. A device as claimed in claim 1, wherein said radiation absorbing means include a flat tray mounted in a plane substantially perpendicular to the direction of radiation for supporting a layer of an intrinsically loose and freely moving, radiation absorbing powder, said tray being provided with a foramenous bottom permeable to air but impervious to said powder, and means for producing a reduced air pressure underneath said bottom, whereby an air pressure gradient is established across said powder layer on said bottom maintaining said layer in a substantially stable state, and said control means include means responsive to said signals from said radiation detecting means for depositing said powder upon said bottom of said tray in a layer having a thickness within each portion of said tray determined by the radiation intensity beyond said object plane of the portion of the radiation beam passing through said portion of the tray.

15. A device as claimed in claim 14, wherein said powder depositing means include means for producing a narrow jet of said powder directed towards said tray and means for moving said powder jet over the bottom of the tray along a predetermined scanning pattern.

16. A device as claimed in claim 15, wherein said means (54) for moving said powder jet include means (62,63) for electrostatic deflection of the powder jet.

17. A device as claimed in claim 15, wherein said radiation detecting means include means for electronically scanning the radiation image of said object beyond said object plane along a predetermined scanning pattern and producing an electric video signal representing the intensity value of the portion of the radiation image being scanned at any moment, said means for moving said powder jet being controlled by said radiation image scanning means to move the powder jet along a scanning pattern over said tray corresponding to the scanning pattern for said radiation image, and said powder jet being controlled in response to said video signal so as to deposit an amount of powder upon said tray during its scanning motion determined by the amplitude of said video signal.

18. A device as claimed in claim 17, comprising means for varying the flow rate of said powder jet in response to said video signal.

19. A device as claimed in claim 1, wherein said control signals supplied to said control means are proportional to differences between the output signals of said radiation detecting means and a reference signal.

20. A device as claimed in claim 19, comprising a radiation detector located beyond said object plane as seen from said radiation source for generating said reference signal.

21. A device as claimed in claim 20, wherein said radiation detector generating said reference signal is disposed to be affected by a portion of the radiation beam

having an intensity which is substantially independent of the varying absorption values of said compensating filter device.

22. A device as claimed in claim **1**, wherein said control means are associated with signal generating means responsive to the operation of said control means for generating signals representing the absorption values of said radiation absorbing means determined by said control means, said signals being supplied as a negative feedback to the input of said control means.

23. A device as claimed in claim **22**, wherein the feedback factor is variable.

24. A device as claimed in claim **1** for a radiographic apparatus including a variable pirmary diaphragm for restricting the radiation beam from said radiation source, comprising signal modifying means affected by the setting of said primary diaphragm for modifying said control signals supplied to said control means from said radiation detecting means in a manner making the adjustment of said compensating filter device by said control means substantially independent of the setting of said primary diaphragm.

25. A device as claimed in claim **1**, wherein said radiation detecting means are located beyond said image plane as seen from said radiation source.

26. A device as claimed in claim **1**, wherein said radiation detecting means are disposed between said object plane and said image plane and are removable from the path of the radiation beam.

27. A device as claimed in claim **1**, in a radiographic apparatus including an automatic exposure control system operating in response to the output signals of said radiation detecting means.

28. A device as claimed in claim **1**, wherein said radiation absorbing means comprises at least one element having a K absorption edge within the energy spectrum of the radiation used for the radiographic exposure of the object.

29. A device as claimed in claim **28**, wherein the K absorption edge of said radiation absorbing element is located close to the energy value for the intensity maximum of the radiation being used for the radiographic exposure of the object.

30. A device as claimed in claim **28**, wherein the K absorption edge of said radiation absorbing element corresponds to an energy which multiplied with a factor of 1.2 to 2.0, preferably a factor of about 1.4, corresponds to the voltage of an X-ray tube used as said radiation source for the radiographic exposure of the object.

31. A device as claimed in claim **28**, wherein said radiation absorbing element is a rare earth metal.

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