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[11] **3,882,314**

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[54] **DEVICE FOR X-RAY TREATMENT**

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[52] **U.S. Cl.** **250/505;** 250/510

[51] **Int. Cl.** **G03b 41/16**

[58] **Field of Search** 250/505, 510, 511, 512, 250/513, 514

[56] **References Cited**

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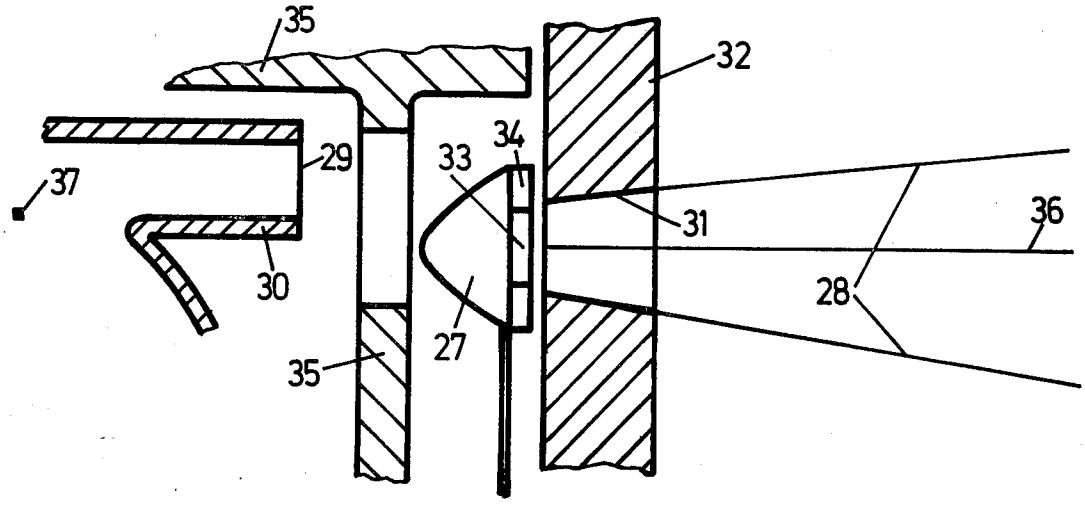
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Primary Examiner—James W. Lawrence
Assistant Examiner—C. E. Church
Attorney, Agent, or Firm—Richards & Geier

[57] **ABSTRACT**

A device for X-ray treatment comprising an electronic accelerator, an anticathode exposed to the accelerated electrons for producing X-rays, an adjustable collimator for the X-rays, and at least one member for equalizing the density of the X-rays passing the collimator. The invention is particularly characterized by the provision of two ray detectors for increasing the operational safety of the irradiating device, the ray detectors being connected to supervising devices and being located in the part of the X-ray cone which is not influenced by the screen. The first detector is located centrally to the X-ray cone passing the collimator and in the ray direction behind the equalizing member, while the second detector is located to the side of the central ray of said X-ray cone.

4 Claims, 5 Drawing Figures



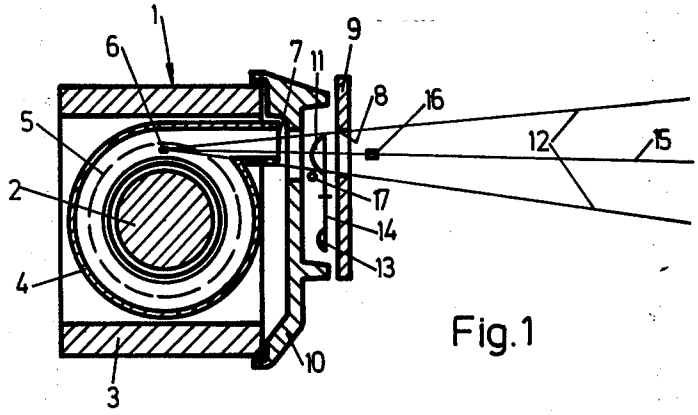


Fig.1

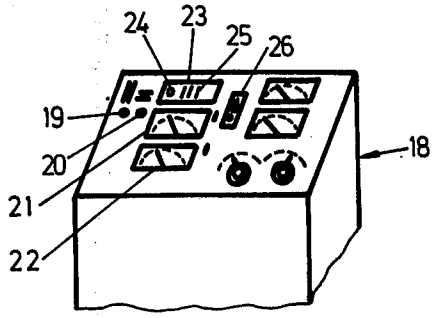


Fig. 2

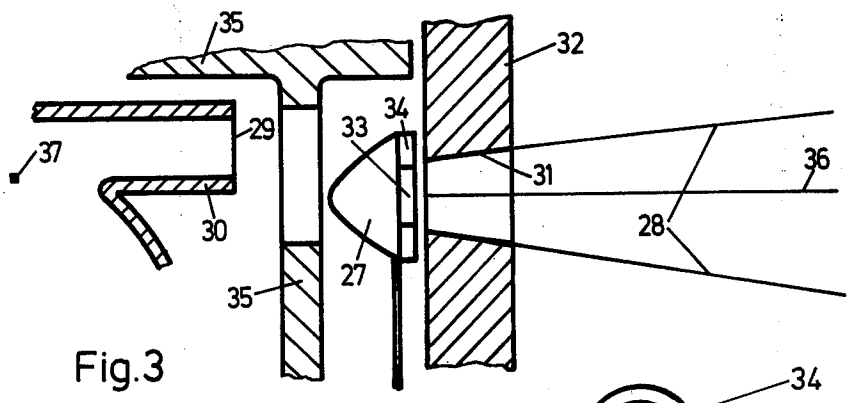


Fig.3

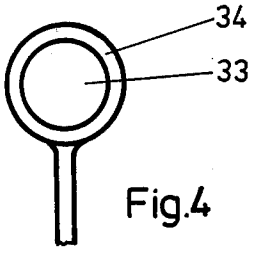


Fig.4

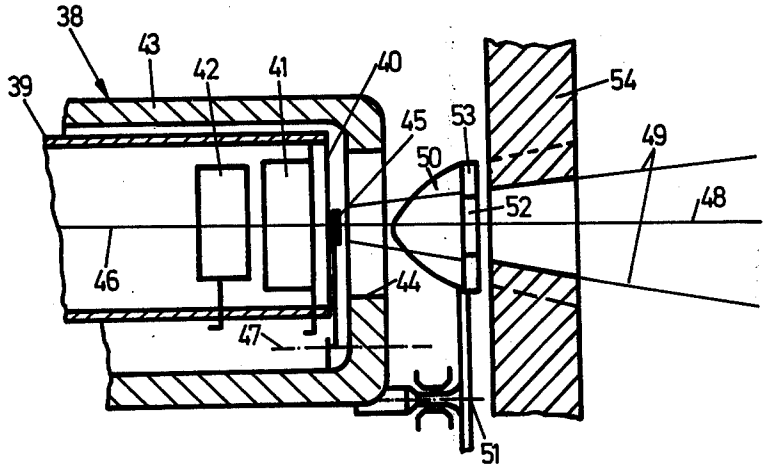


Fig.5

DEVICE FOR X-RAY TREATMENT

This invention relates to a device for X-ray treatment having an electronic accelerator, an anticathode exposed to electrons for producing X-rays, an adjustable collimator, and at least one equalizing member which can be shifted into the X-ray cone.

Such irradiating devices are known wherein are used an electronic accelerator and an anticathode consisting of heavy metal and located in the path of the accelerated electrons. If, in such an irradiating device, a dose rate of the X-rays is measured interdependent upon the space angle, then a maximum is measured substantially in the direction of the electron beam striking the anticathode. This part of the X-rays is used for X-ray treatment and is collimated with an adjustable collimator to the desired field size.

In distances and field sizes which are customary in human medicine, the diminution of applied ray dose within the field being X-rayed, with the increased distance from the central ray of the X-ray beam, was found to be disturbing. It is known to provide uniform dose outputs throughout the entire cross section of the X-ray beam by providing an equalizing member having the shape of a cone with a rounded tip within the X-ray cone; its own absorption is diminished with an increased distance from the central rounded tip to its sides traverse to the ray direction to the same extent as the dose output in this part of the X-ray cone. Due to the different weakenings of X-rays passing through the equalizing member in the direction parallel to its axis of symmetry, a corresponding centering of the equalizing member can provide behind it an X-ray cone which will always have the same dose output throughout its cross-section. In this procedure, the dose output in the center of the X-ray cone is reduced to values which otherwise would exist only on the edges of the cone. Therefore, in the case of small field sizes to be illuminated, equalizing members of smaller diameter are used, which do not reduce the dose output too much. It can happen in these irradiating devices that greatly excessive ray doses will be applied if the balancing member, by mistake, was not shifted into the X-ray cone, or was shifted relatively to the central ray.

An object of the present invention is to provide an irradiating device for medical X-ray treatment of the described type wherein incorrect and excessive irradiations are avoided, and wherein the introduction and proper centering of the equalizing body in the X-ray cone are controlled.

Other objects of the present invention will become apparent in the course of the following specification.

In the accomplishment of the objectives of the present invention, it was found desirable to increase the operational safety of the irradiation device by the provision of two ray detectors connected to supervising devices and located in the part of the X-ray cone which is not influenced by the X-ray collimator. The first of these detectors is located centrally to the central ray and in the ray direction behind the corresponding equalizing member. The second detector is located to the side of the central ray.

Such an arrangement of ray detectors makes it possible to determine the applied ray dose with the first ray detector located in the central ray of the X-ray cone passing the collimator. Then the second ray detector located to the side of the central ray will determine a ray dose in the case of a properly set equalizing member which has a specific positive ratio to the ray dose determined by the first ray detector. Deviations from this ratio indicate a wrong centering of the balancing member relatively to the central ray.

According to a further advantageous development of the present invention, the two ray detectors can be arranged in ray direction in front of the X-ray collimator and behind the corresponding equalizing member. This makes it safe that a change in the opening of the X-ray collimator will have no effect upon the ratio of measured values of the two ray detectors. Thus, the supervision of the correct position of the equalizing member is also possible with an X-ray collimator which is opened only by a slit, or which is even closed.

The operational safety can be further increased when, according to an advantageous construction of the present invention, the first ray detector located centrally to the central ray is shaped as a round disk and is surrounded by the second ray detector, shaped as a ring. In that case, deviations of the equalizing member relatively to the central ray can be determined with the same precision independently from the direction of this deviation due to the concentrical arrangement of the second ray detector.

According to a further development of the present invention, a constructively particularly simple structure is provided when the two detectors are fixed to the same equalizing member. Then the equalizing member is used to provide the build-up effect by generating secondary electrons necessary for an adequate X-ray sensibility of the ray detectors. This has the further advantage that the otherwise necessary metal plate need not be used.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawings, showing, by way of example only, preferred embodiments of the inventive idea.

In the drawings:

FIG. 1 shows in section an irradiating device having two separate ray detectors.

FIG. 2 is a perspective view of the operational desk of the irradiating device.

FIG. 3 is a diagrammatic sectional view of a different irradiating device wherein the two ray detectors are fixed.

FIG. 4 shows the two ray detectors of FIG. 3 in view from the side of the X-ray collimator.

FIG. 5 is a sectional view showing the arrangement of the two ray detectors in an irradiating device having a linear electron accelerator.

FIG. 1 shows in section a betatron **1.** An accelerating tube **4** is shown between the poles **2** of an electromagnet **3.** A theoretical path **5** is shown by broken lines within the accelerating tube **4,** upon which the electrons are held and accelerated by the magnetic field. The accelerated electrons are deviated upon an anticathode **6,** made of heavy metal, by a not shown deviating device known in prior art. X-rays produced in the anticathode leave through the window **7** of the accelerating tube **4** and can proceed into the open through the opening **8** of an adjustable X-ray collimator **9** to be used for irradiating an object. To diminish stray rays, the accelerating tube **4** is provided with a ray-protecting screen **10.** A socalled equalizing member **11** is pushed into the X-ray cone **12** in front of the X-ray collimator **9** in ray direction, which provides for a uni-

form dose output in the cross-section of the outgoing X-ray cone. This equalizing member **11** and a second equalizing member **13**, provided for a smaller field to be irradiated, are fixed upon a swingably mounted lever **14** with two arms, and can be swung selectively into the X-ray cone **12**. A first small pill-like ray detector **16** is provided in the central ray **15** of an X-ray cone emerging from the X-ray collimator **9**. A second ray detector **17** is located on the side of the central ray in a section of the X-ray cone, which is not influenced by the X-ray collimator.

FIG. **2** shows a control panel **18** for the betatron of FIG. **1**, wherein the irradiating parameters can be set. Among others, the control panel carries switches **19**, 20 for preliminary setting of the opening of the X-ray collimator **9**, as well as separate indicating instruments **21, 22** for the ray dose measured by the two ray detectors **16, 17** (FIG. **1**). Above the two indicating instruments is shown an alarm device **23** with optical and acoustical signal givers **24, 25**. A switching-off automat **26** is provided upon the panel **18** close to the alarm device **23**. The automat **26** switches off the betratron automatically when a maximal preset ray dose has been reached in one of the two ray detectors.

Electrons accelerated upon the theoretical path **5** are guided against the anticathode **6** in a manner not shown herein. In the anticathode, X-rays are produced by the braking of electrons. These X-rays, due to the ray-protecting screen **10**, can leave only through the opening **8** of the adjustable X-ray collimator **9**. The intensity of X-rays emitted by the anticathode **6** has a maximum in the direction of the electron ray striking the anticathode. The X-ray collimator **9** is centered to this maximum of the dose output. The central ray **15** of the X-ray cone leaving the X-ray collimator thus coincides with this maximum.

To avoid that during irradiation of larger surfaces, those surface parts of the area being irradiated, which are located in a distance from the central ray of the X-ray cone, would receive a reduced X-ray dose, namely, to make possible uniform irradiation of larger areas, so-called equalizing members **11, 13** are shifted into the X-ray cone **12**. These cone-shaped equalizing members have into their center a greater X-ray absorption than at their edges. Their shape is adapted to the distribution of the dose output over the corresponding angular areas of the X-ray cone of the respective accelerator in such manner that the X-ray cone **12** passing the equalizing member and leaving the X-ray collimator has the same dose outputs per space angle unit within the maximal opening angle given by the diameter of the equalizing member. It follows that a precise centering of the equalizing members **11, 13** to the central ray **15** is absolutely necessary. The equalizing members **11** must equalize the X-ray intensity in the larger opening angles of the X-ray cone, and therefore, they must weaken the intensity of the X-rays in the center of the cone **15** corresponding to the lower X-ray intensity on the sides of the cone. Therefore, the intensity of the X-ray cone behind such a larger equalizing member **11** is weaker than behind a smaller equalizing member **13**, which must equalize only a smaller opening angle of the X-ray cone. Therefore, in order not to produce a too large intensity loss for smaller opening angles, an equalizing member with a smaller diameter is swung into the X-ray cone when a corresponding small collimator opening has been preselected.

When an equalizing member has been set correctly, namely, centrally to the central ray **15** of the X-ray cone, the dose outputs measured by the two ray detectors **16, 17** must be related to each other in a predetermined ratio which is specific for each of the equalizing members **11, 13**. A differential amplifier, which is not shown herein, is connected to the two ray detectors **16,** 17 and to the alarm device **23**; for that purpose, it is correspondingly switched over when the corresponding equalizing member is swung. Thus, the alarm device **23** is actuated only when the ratio of the measured ray dose deviates from the value which had been given to the respective equalizing members **11, 13**. After the maximum ray dose given by the doctor has been reached, the illuminating device is switched off by the known automatic switching member **26** through the first ray detector located in the central ray. If no equalizing member has been shifted into the X-ray cone, if a wrong equalizing member has been shifted, or if the equalizing member has been shifted incompletely, then the ray detector **16** located in the central ray **15** of the X-ray cone receives a larger ray dose per time unit in relation to the ray detector **17** located to the side of the central ray. Consequently, the irradiating device will be timely switched off due to the above operational disturbances by the ray detector **16**, which lies in the central ray **15**. Independently thereof, the differential amplifier will release, in that case, the alarm device **23**. Thus, there is no danger at all for the patient.

In the embodiment shown in FIG. **1**, the X-ray collimator **9** must remain open at least to such an extent that the ray detector **16**, located in the central ray **15**, remains completely exposed to X-rays. However, this is not necessary in the embodiment of FIGS. **3** and **4**, showing a different improved arrangement of the ray detectors. As in the embodiment of FIG. **1**, in the embodiment of FIGS. **3** and **4**, different equalizing members **27** (only one of which is shown), depending upon selected ray parameters, can be shifted into the X-ray cone **28** between the window **29** of the accelerating tube **30** and the opening **31** of the X-ray collimator **32**. However, according to FIG. **3**, the two ray detectors **33, 34** are fixed directly to the corresponding equalizing member **27**, which is different from the embodiment of FIG. **1**. Thus, according to FIG. **3**, the two ray detectors are located both in the ray direction in front of the X-ray collimator **32**. FIG. **4** shows the two ray detectors **33, 34** of FIG. **3** in view from the X-ray collimator **32**. It is apparent that the first ray detector **33**, arranged in the central ray **36**, has the shape of a circular disk and is enclosed by the second ring-shaped ray detector **34**, located to the side of the central ray. The first and the second ray detectors have equal surfaces directed to the anticathode **37**, and are equally sensitive to X-rays.

According to the embodiment of FIG. **3**, when the equalizing member **27** is correctly positioned, the two ray detectors **33, 34** will also be correctly positioned. Due to the equal surfaces of both ray detectors, they will always deliver equally large measuring signals, and their corresponding indicating instruments **21, 22** upon the control panel **18** will always have equal deflections. This greatly facilitates the control. Thus, the measuring signals of the two ray detectors **33, 34** can be transmitted without any switching through a fixedly set differential amplifier to the alarm device **23** (FIG. **2**). If, in such an arrangement of the ray detectors, the equaliz-

ing member is placed excentrically to the central ray **36** as the result of an error, then this takes place also to the two ray detectors fixed to the equalizing member. In such a case, the central ray of the X-ray cone having a stronger intensity will pass through the less strongly absorbing edge portions of the equalizing member, and will produce a comparatively larger measuring signal in the second ring-shaped ray detector **34.** The measuring signal of the first ray detector located centrally to the equalizing member **27** will be weaker due to the greater absorption of the balancing member in that region and due to the lower intensity of the X-rays passing through it to the side of the central ray **36.** These two influences are superposed and result in a very great sensitiveness of the device shown in FIG. **3.**

The above statements pertaining to FIG. **3** are equally applicable to the embodiment shown in FIG. **5.** FIG. **5** differs from FIG. **3** substantially only by the use of a linear accelerator **38** instead of a betatron **1.** FIG. **5** shows, in partially broken-off representation, such a linear accelerator **38.** The accelerating tube **39** of the linear accelerator is closed by a thin but vacuumtight outgoing window **40** for the accelerated electrons. Two of the accelerating electrodes **41, 42** of the accelerating tube are shown in front of the window in ray direction. The accelerating tube is surrounded by a ray-protecting casing **43,** which is provided with a break **44** for the ray passage opposite the outgoing window 4o of the accelerating tube **39** of the linear accelerator **38.** A so-called target **45** is located in ray direction directly behind the outgoing window; it is swingably mounted in the electronic ray leaving the accelerating tube open upon an axle **47** fixed in the ray-protecting casing **43** and extending parallel to the symmetry axis **46** of the accelerating tube **39.** In case of a linear accelerator **38,** the axis of symmetry **46** of the accelerating tube **39** coincides with the central ray **48** of the X-ray cone **49.** An equalizing member **50,** having the shape of a truncated cone, is located in ray direction and directly behind the break **44;** it is swingable at the ray-protecting casing **43** about an axle **51** extending parallel to the symmetry axis **46** of the accelerating tube **39.** Two concentrical ray detectors **52, 53** are located symmetrically to the ray direction upon the side of the equalizing member **50,** which is away from the target **45.** An adjustable collimator **54** is located in the ray direction behind the equalizing member.

In the described embodiments, it is also possible to connect additionally the automatic switch-off device **23** to the outlet of the differential amplifier. In that case, the irradiating device would be switched off automatically directly after having been switched on if the equalizing member was incorrectly pushed in.

What is claimed is:

1. A device for X-ray treatment, comprising an electronic accelerator, an anticathode exposed to the accelerated electrons for producing X-rays, an adjustable collimator for X-rays, at least one member for equalizing the density of the X-rays in the cone of X-rays passing the collimator adapted to be shifted into the X-ray cone, supervising devices for the correct positioning of said member, and two ray detectors connected to said supervising devices in the part of the X-ray cone which is not influenced by said collimator for increasing operational safety, the first one of say ray detectors being located centrally to the central ray of the X-ray cone passing the collimator behind said equalizing member, the second of said ray detectors being located to the side of said central ray, wherein, in the ray direction the two ray detectors are located in front of said collimator and said equalizing member, wherein said first ray detector, located centrally to the central ray of the X-ray cone, has the shape of a circular disk, and wherein the second ray detector surrounds annularly the first ray detector, the two ray detectors being fixed to said equalizing member, and wherein the two ray detectors are equally sensitive toward X-rays and have equal surfaces directed to the X-ray source, said supervising devices comprising an alarm device and a differential amplifier connected to the two ray detectors and to said alarm device.

2. A device for X-ray treatment according to claim **1,** said supervising device comprising separate ray-indicating instruments connected to each of said ray detectors.

3. A device for X-ray treatment according to claim **1,** said supervising device comprising an automatic switching-off device connected to the two ray detectors for switching off said accelerator when a maximum preset X-ray dosage has been reached in one of said two ray detectors.

4. A device for X-ray treatment according to claim **1,** comprising an automatic switching-off device connected to said alarm device for switching off said accelerator.

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