ARRANGEMENT INCLUDING A BETATRON FOR RADIATION OF THE HUMAN BODY

Rolf Widerije, Nussbaumen, near Baden, Switzerland, assignor to Aktiengesellschaft Brown, Boveri & Cie, Baden, Switzerland, a joint-stock company

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This invention relates to apparatus for radiating the human body in the treatment of diseases such as cancer, and more particularly to an improved arrangement of the type described wherein the source of the radiation is constituted by a ray generator which accelerates charged particles such as electrons to high velocity and hence high potential at which instant the accelerated particles are caused to impinge against a target anode to thereby produce the rays utilized in the treatment. One device of this kind is known as a "ray transformer" or "betatron" and a suitable description of the same can be found in my United States Patent No. 2,533,659 issued December 12, 1950, the radiation being produced by accelerating a stream of particles such as electrons repeatedly around an orbit until an extremely high velocity has been attained, and then causing the electron stream to impinge against a target anode to thus produce the radiation.

It is desirable to arrange the equipment in such a manner that it can be moved relatively to a patient being treated with X-rays, whether for adjustment of the optimum direction of radiation for the treatment, or for carrying out a so-called "movement radiation" wherein the source of rays is moved during the treatment. It is likewise known how to mount a betatron in a similar manner, in that it is arranged, for example, for vertical and horizontal displacement and rotation on a tripod, so that it can be swung around the patient during the radiation treatment.

When relatively large betatrons are utilized, the above described mounting arrangement proves difficult because of the massiveness and weight of the betatron unit itself. In accordance with the present invention, the betatron unit, which constitutes the heaviest single component of the apparatus, is mounted relatively stationary and the arrangement is such that the patient can be moved around the betatron unit.

A more specific object of the invention is to mount the betatron unit for angular adjustment about a fixed, horizontal axis and to mount the bed or table on which the patient is to lie horizontally and generally below the betatron in a frame which swings with the betatron, the bed being also mounted in the frame for rotation about a horizontal axis and the arrangement being such that the plane of the bed always remains horizontal for any angle of adjustment of the betatron and frame. Moreover, the bed is preferably adjustable longitudinally of the frame in which it is carried, as well as laterally of the frame and also vertically in the frame, such adjustments making it possible to bring any desired part of a patient's body into the axis of the ray pencil produced by the betatron and to remain in that ray also during rotation, i.e., angular displacement of the betatron about its horizontal mounting axis.

A further object of the invention is to provide a mounting for a betatron radiation apparatus of the type described in the preceding paragraph and which further includes an auxiliary apparatus comprising an X-ray tube mounted above the bed and a fluorescent screen below the bed which facilitates alignment of the patient for treatment with the rays produced by the betatron.

The principles of the invention will become more apparent from the following detailed description of different typical embodiments thereof when considered with the accompanying drawings.

In these drawings:

Fig. 1 is a view in perspective of one embodiment of the invention;

Fig. 2 is a side elevation of a second embodiment of the invention;

Fig. 3 is a vertical section taken on line 3—3 of Fig. 2.

With reference now to Fig. 1, the betatron unit is indicated generally by the numeral 1 and is suspended in an inverted U-shaped support 2 for rotation about a horizontal axis 3—3. No structural details of the betatron unit have been illustrated since these are well known and do not, per se constitute any part of the patentable novelty hereinafter claimed. The support 2 is stationary and may be secured, for example, to the ceiling of the room in which the patient is to be treated.

Secured to the betatron unit 1 and rotatable with it about axis 3—3 is a frame 4 which is comprised of two downwardly extending, parallel, spaced arms 5 which are bridged at their lower ends by two parallel, spaced rigid rods 6. The bed or table 7 on which the patient is to lie during the radiation treatment is supported atop a pair of parallel, spaced, horizontal beams 8 which are tied together at their opposite ends by two cross pieces 9. These two cross pieces are secured respectively to, and adjustable vertically along, two pendulums 10 mounted in the arms 5 of frame 4 for rotation about a horizontal axis 11—11 parallel to axis 3—3. The bed 7 is adjustable along the beams 8, i.e., parallel to the axis of rotation 3—3 of the betatron unit 1, and also crosswise there-to in the direction of the double headed arrow b. Also, since the end pieces 9 are adjustable vertically along the pendulums 10, by any suitable means, not shown, the bed 7 is also adjustable in a vertical direction.

The invention entails means for always maintaining the bed 7 in a horizontal attitude notwithstanding the fact that the frame 4 and betatron unit 1 can be swung about the axis 3—3. To this end, a lever 12 has one end rigidly connected to one of the pendulums 10, the opposite end of lever 12 is articulated to one end of a rod 13, and the opposite end of rod 13 is articulated to a stationary bracket 14 which can be secured to any fixed point that is convenient, such as the support 2, or the ceiling, or wall of the radiation room. Consequently, as the betatron 1 and frame 4 are swung in one direction about axis 3—3, the pendulums 10 and bed 7 will be swung through a corresponding compensating angle in the opposite direction about axis 11—11, thereby maintaining the bed 7 in a horizontal attitude or plane.

The entire arrangement, therefore, is such that any desired part of the patient's body may be brought into the electron ray 15 produced by the betatron unit 1 and simultaneously into the axis 11—11. Moreover, because the ray 15, directed downwardly from unit 1 in the direction of the bed 7, also passes through the axis 11—11 during rotation of the betatron about axis 3—3, the body part always remains in the ray as required for execution of the so-called "movement radiation" treatment.

The embodiment of the invention illustrated in Figs. 2 and 3 is similar in many respects to that of Fig. 1 and hence corresponding structural components have been designated the same reference numerals but with primes added for purposes of distinction. The construction in Fig. 2 presents a different, but functionally equivalent arrangement for maintaining the bed 7' in a horizontal plane as the frame 4' is swung about axis 3'—3'. In lieu of the linkage 12, 13 shown in Fig. 1, the compensating
organization includes a pair of discs or pulleys 16 and 17 of identical diameter, one of which, such as pulley 16 is mounted on the axis 3'-3' to rotate with the betatron unit 1. The other is mounted to one of the pendulums 10' on axis 11'-11'. The two pulleys 16, 17 are connected by an endless rope or wire belt 18 which is guided between the pulleys such as by the two sets of rollers 19, 20 mounted at opposite sides of a horizontal portion of the frame 4'. This arrangement makes it possible to move the frame 4' and betatron unit 1' through angles as high as 90° and more from the central vertical position shown in Figs. 2 and 3.

It has proven quite advantageous, as an aid in aligning the body of the patient with the betatron ray, to have an X-ray tube above the bed and a fluorescent screen below it for observation. Thus in Fig. 2 it will be seen that an X-ray tube 21 is connected rigidly with the betatron unit 1'. The arrangement is such that the rays 22 produced by tube 21 run parallel to the rays 15' produced by the betatron unit 1' but separated from the latter by a small distance d as indicated on the drawing, and the rays 22 also parallel to the axis 11'-11'. The plane containing the rays 22 is parallel to the rotation axis 3'-3' and may, as Figs. 2 and 3 show, contain the axis of rotation itself. The anti-cathode of the X-ray tube 21 should preferably be at the same distance from the rotation axis 3'-3' as the point at which the rays 15' produced by betatron 1' originate. In Figs. 2 and 3, the rays sources are present on the rotation axis 3'-3'. Beyond the patient, i.e. on the under side of the bed 7' a fluorescent screen 23 is secured to the rods 6' and is preferably surrounded by ray protection plates 24. Alignment of the patient can now be effected while observing the fluorescent screen 23. When the alignment of the proper part of the body to be radiated has been completed, the bed 7' is then shifted to the right by the distance d. This displacement may be effected with reference to a graduated scale, not shown, or a stop, also not shown may be provided. When the X-ray tube is used, it is, of course, necessary that the bed 7' be made from a material which is permeable to the X-rays. If the betatron unit 1' is equipped with an adjustable device such as a collimator for limiting in a special manner the rays produced by it, it is advantageous to arrange collimators of a similar kind also in front of the X-ray tube and to couple the collimators of the X-ray tube and betatron together for operation in a simultaneous manner. In this way, a ray of the same geometric configuration is available for alignment of the patient as well as for the radiation itself by the betatron unit.

It may happen at a slanting position of the frame 4' that the image produced on the fluorescent screen 25 is disturbed by the shadow of one of the horizontal bed supports or beams 8'. It is then advantageous, as shown in Fig. 2 to interrupt the supports 8' in the zone of the X-ray 22 produced by the tube 21. In such event, the pendulums 10' and cross pieces 9' must be designed for absorption of the resulting high torques. It is also advantageous if care is taken to see that displacements of the two cross pieces 9' in the vertical direction occur simultaneously and similarly.

When the frame 4' is disposed in the vertical position indicated in Figs. 2 and 3, it is quite probable that the fluorescent screen 25 will be located too close to the floor for direct observations. Thus, to facilitate observations, a mirror 25 may be pivotally mounted along one side of the screen 23.

In order to maintain a certain balance of the rotatable parts of the apparatus without resort to the use of counterweights, the betatron unit may be so suspended that the axis of rotation 3'-3' does not pass through its center of gravity but rather the latter is disposed between the axis 11'-11' and the point of ray generation.

The principles of the invention as hereinafter defined may also be employed in situations where the betatron unit is of the double ray type as shown in my United States Patent No. 2,538,718 issued January 16, 1951, wherein the second ray is in a direction opposite to the betatron ray 15. It is to be noted that for example, in treating patients located on the side of the betatron away from the frame 4, the inclinability of the second ray about the axis of rotation 3'-3' facilitating the adjustment.

In conclusion, it will be understood that while particular structural embodiments of the invention have been described a number of minor changes in the specific construction and arrangements of components may be made without, however, departing from the spirit and scope of the invention as defined in the appended claims. Moreover, while the invention has been explained in connection with the use of a betatron as the source of radiation, it is understood that the underlying principles are equally applicable to an arrangement employing a functionally equivalent ray generator which is similarly characterized in that its massiveness makes it desirable to move the patient about the source to radiate a particular part of the patient's body rather than vice versa.

Claim 1:

1. In an arrangement for radiating the human body, the combination comprising a ray generator such as a betatron unit in which rays are produced by accelerating charged-particles to high velocity and then causing the accelerated particles to strike a target anode, means mounting said ray generator for rotation on a horizontal axis, said rays being directed downwardly from said ray generator supporting means carried by and generally below and rotatable with said ray generator, a bed for the support of the patient mounted on said supporting means for rotation thereon about a horizontal axis parallel to the axis of rotation of said ray generator, and means maintaining said bed in a horizontal plane as said supporting means and ray generator are rotated.

2. An arrangement as defined in claim 1 for radiating the human body and which further includes an X-ray tube rigidly connected with said ray generator and which produces an X-ray extending parallel with the rays produced by said ray generator, and a fluorescent screen disposed beneath said bed.

3. An arrangement as defined in claim 2 wherein said bed is mounted on said supporting means by means including horizontally extending beam means and said beam means are interrupted in the zone of the X-ray produced by said X-ray tube.

4. An arrangement as defined in claim 2 and which further includes a mirror pivotally mounted at one side of said fluorescent screen.

5. An arrangement as defined in claim 2 wherein said ray generator and X-ray tube are each provided with an adjustable collimator mechanism for limiting the rays and means coupling said shutter mechanisms for simultaneous operation.

6. An arrangement as defined in claim 1 for radiating the human body wherein said means for maintaining said bed in a horizontal plane as said supporting means and ray generator are rotated include a first pulley mounted on the axis of rotation of said ray generator and rotatable with said generator, a second pulley mounted on the axis about which said bed is rotatable, means mounting said bed, said pulleys being of the same diameter and an endless belt interconnecting said pulleys so that as said first pulley is rotated by rotation of said ray generator said second pulley will be caused to also rotate and hence rotate said bed through a compensating angle.

7. An arrangement as defined in claim 1 for radiating the human body wherein said bed is arranged for movement longitudinally and transversely and also vertically with respect to said supporting means.

8. An arrangement as defined in claim 1 for radiating the human body wherein said rays from said ray generator.
pass through said horizontal axis about which said bed is rotatable as said ray generator is rotated.

9. In an arrangement for radiating the human body, the combination comprising a ray generator such as a betatron unit in which rays are produced by accelerating charged particles such as electrons to high velocity and then causing the accelerated particles to strike a target anode, means mounting said ray generator for rotation about a horizontal axis said rays being directed downwardly from said ray generator, supporting means carried by and generally below and rotatable with said ray generator, a bed for the support of the patient mounted on said supporting means for rotation about a horizontal axis parallel to the axis of rotation of said ray generator, and means interconnecting said mounting means for said ray generator with said supporting means for said bed such that said bed is maintained in a horizontal plane as said ray generator is rotated.

10. In an arrangement for radiating the human body, the combination comprising a ray generator such as a betatron unit in which rays are produced by accelerating charged particles to high velocity and then causing the accelerated particles to strike a target anode, means mounting said ray generator for rotation about a horizontal axis, said rays being directed downwardly from said ray generator a frame secured to and rotatable with said ray generator, a pair of pendulums mounted at opposite sides of said frame and which is parallel to the axis of rotation of said ray generator for rotation about a horizontal axis with respect to said frame, supporting means carried by said pendulums, a bed mounted on said supporting means, and means maintaining said bed in a horizontal plane as said ray generator and frame are rotated.

11. An arrangement as defined in claim 10 for radiating the human body wherein said means maintaining said bed in a horizontal plane comprises a lever secured at one end to one of said pendulums, a rod having one end thereof articulated to the opposite end of said lever, and the opposite end of said rod being articulated to a stationary support.

12. An arrangement as defined in claim 10 for radiating the human body wherein said means maintaining said bed in a horizontal plane comprises a first pulley mounted on the axis of rotation of said frame and rotatable with said frame and ray generator, a second pulley mounted on the axis of rotation of one of said pendulums and rotatable with said pendulum, said pulleys being of the same diameter, and an endless belt interconnecting said pulleys.

13. An arrangement as defined in claim 10 for radiating the human body wherein said supporting means are adjustable along said pendulums to thereby vary the height of said bed.

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