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[54] **ROTATABLE NEUTRON THERAPY IRRADIATING APPARATUS**

[75] Inventors: **Ernst-Gunther Hofmann; Klaus Meyerhoff; Bernd Peter Offermann; Rolf Barthel,** all of Hamburg, Germany

[73] Assignee: **Licentia Patent-Verwaltungs-GmbH.,** Frankfurt, Germany

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[58] **Field of Search** .250/105, 106 S, 108 R, 108 WS

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Primary Examiner—James W. Lawrence
Assistant Examiner—Davis L. Willis
Attorney—Spencer & Kaye

[57] **ABSTRACT**

A neutron therapy irradiating apparatus including a neutron source mounted within a collimator. The collimator can be opened by moving its two parts away from one another at a parting plane. The neutron source is accessible from the parting plane, and this moving of the two parts away from one another therefore renders the neutron source accessible from outside the collimator. The parting plane contain mutually interfitting steps, so that when the two parts are in abutment, neutrons cannot leak through the parting plane.

15 Claims, 2 Drawing Figures

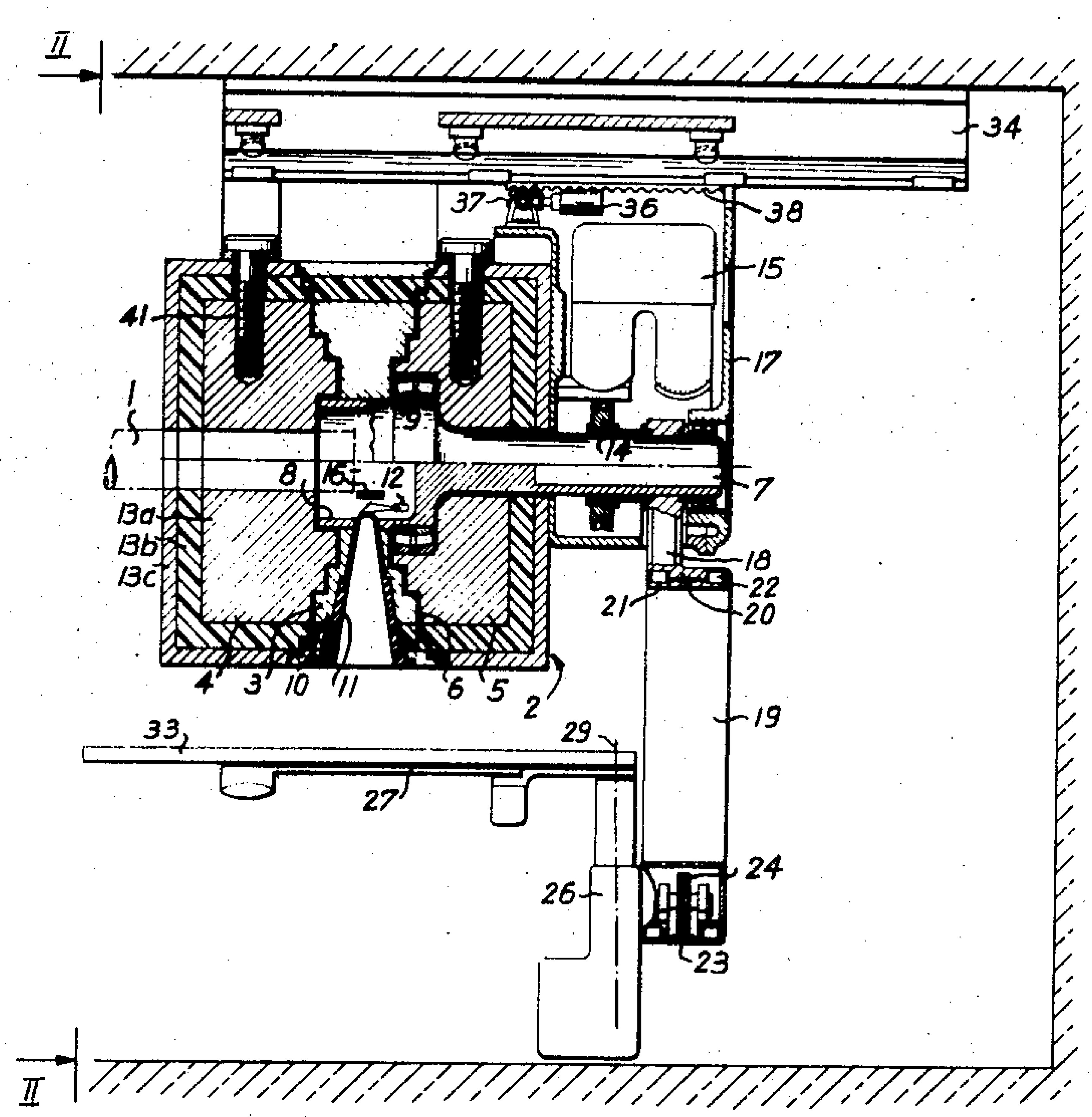
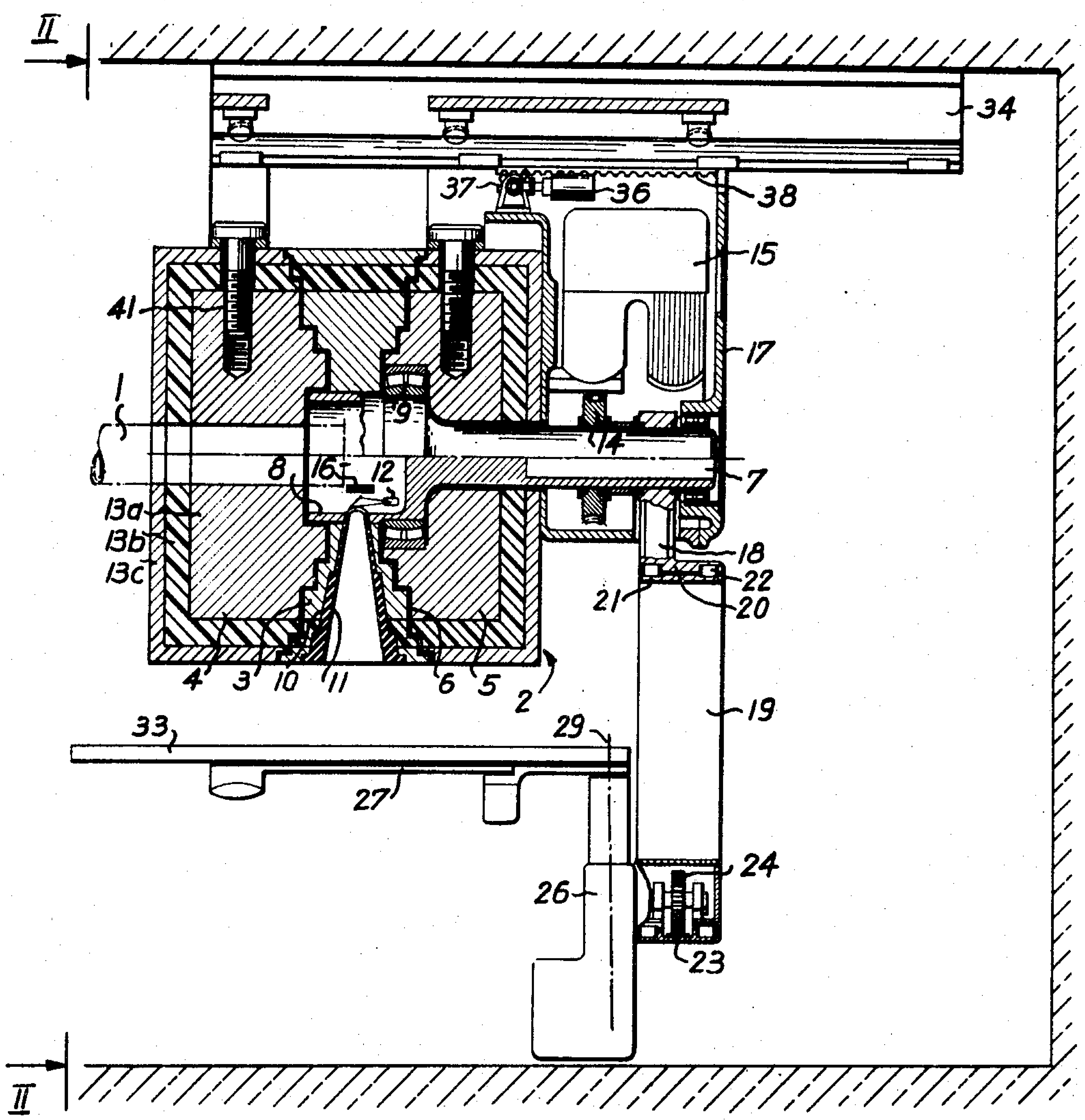
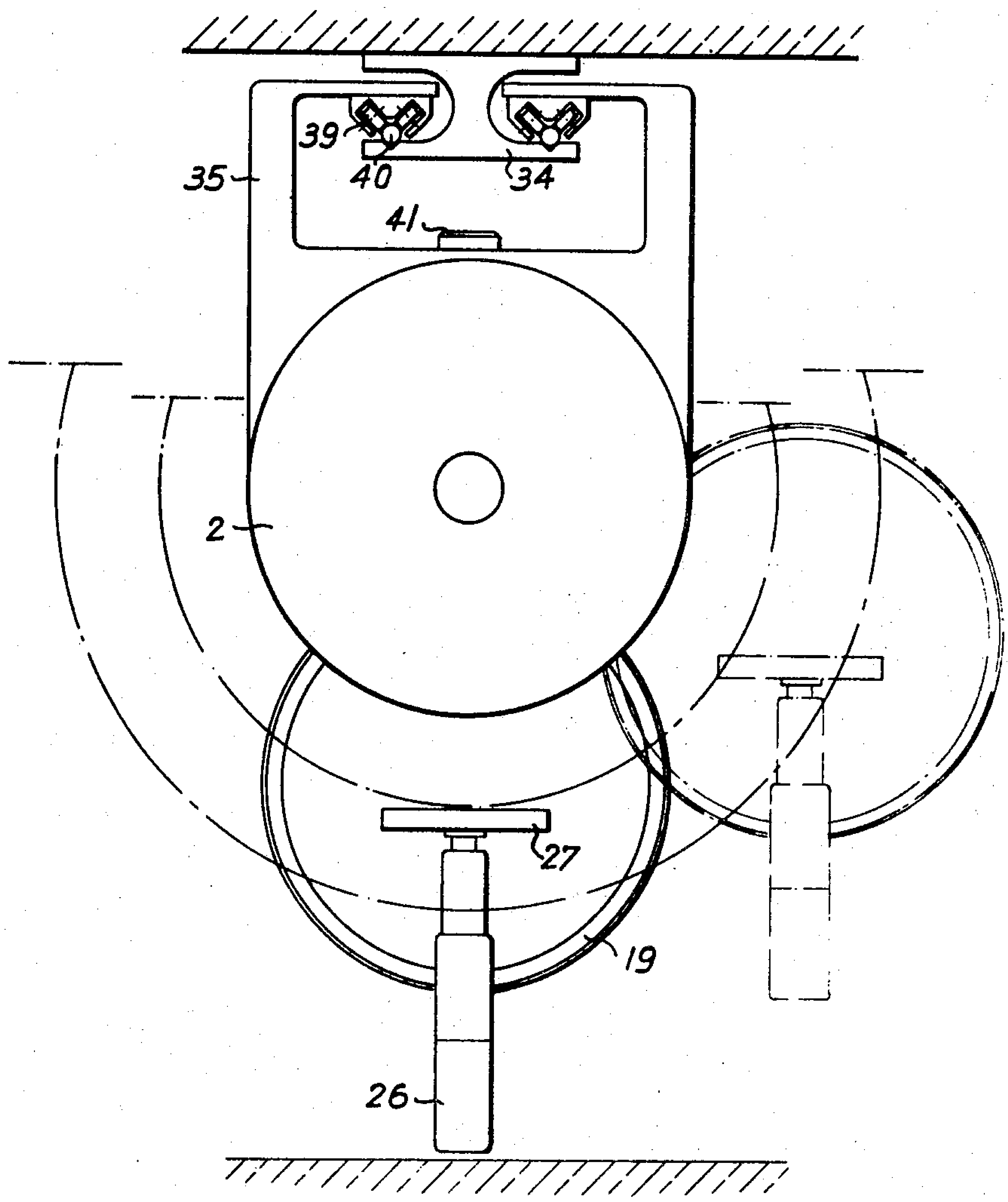


Fig. 1



INVENTORS.
Ernst-Günther Hofmann
Klaus Meyerhoff
Bernd Peter Offermann
Rolf Barthel
BY Spencer & Kaye
ATTORNEYS.

Fig. 2



INVENTORS.
Ernst-Günther Hofmann
Klaus Meyerhoff
Bernd Peter Offermann
Rolf Barthel

BY Spencer & Kaye
ATTORNEYS.

ROTATABLE NEUTRON THERAPY IRRADIATING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an irradiating apparatus for neutron therapy using stationary and/or rotating field irradiation. The apparatus includes a neutron source and a collimator for forming a beam of neutrons from the neutrons given off by the source.

In the technology of radiation therapy for the treatment of tumors and the like, it is known to use X-ray, gamma, or electron radiation. In order, however, to equalize the varying sensitivity of the cells of the body - cells high in oxygen are known to be more sensitive than cells free of oxygen - treatments using these radiations are carried out in chambers having an excess oxygen pressure. This technique is, however, neither simple nor without danger. If fast neutrons are instead used for irradiating, these varying sensitivities are absent so that chambers with excess oxygen pressure are not needed.

The use of fast neutrons must, however, be predicated upon the availability of a suitable collimator. Since the target arranged in the collimator for the production of high energy neutrons has only a limited life, it must be easily accessible so that it can be readily replaced. On the other hand, the neutron beam must be limited exactly to the particular diseased portion, and the remaining portions of the patient's body must be adequately protected against an overly high radiation level.

SUMMARY OF THE INVENTION

An object of the present invention, therefore, is to provide a neutron irradiating apparatus having a new and improved collimator for neutron irradiation therapy.

This as well as other objects which will become apparent in the discussion that follows are achieved, according to the present invention, in that the collimator is provided in two or more parts separated by parting planes, in that a neutron source within the collimator is accessible from the parting planes, in that means are provided for moving the parts relatively away from one another out of mutual abutment along the parting planes whereby the neutron source becomes accessible from without the collimator, and in that the parting planes are provided with steps for blocking neutron leakage through the parting planes when the parts are in abutment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational cross section of an apparatus according to the invention.

FIG. 2 is a view taken along the plane II—II of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A particularly advantageous feature of the present invention is that the separate parts of the collimator can be driven aside so that the target becomes quickly and easily accessible. Also, steps provided in the parting planes between the separate parts guarantee that the patient is largely protected from stray radiation which could leak through if the parting planes were completely planar.

According to a further development of the invention, the walls of the collimator are made of a material or a combination of materials having the property of reducing the neutron radiation emitted from the neutron source in directions other than that of the beam to be used to a safe radiation level for the treatment room. Advantageously, the collimator of the present invention is built of several layers, of which, essentially speaking, a first layer acts to slow down the high-energy neutrons, a second further slows down and absorbs the scattered neutrons, and a last absorbs the produced gamma radiation. Shielding of neutrons produced for example according to the nuclear reaction T $(d,n)^4$He, where T stands for tritium, is especially effective if the collimator is made from a first and third layers of steel with the second layer being of a material having a high hydrogen content per unit volume. In order to reduce the energetic hydrogen and iron capture radiation, the second and third layers also contain boron additives, such as B or B_4C.

Advantageously, the collimator contains an opening to receive a window insert for controlling the exact cross section of the neutron beam to be used.

Since the neutron production in a target falls sharply with increased usage, the particular irradiation time needed to achieve a given neutron dose consequently exhibiting large variations, another development of the present invention provides a neutron-dose measuring instrument combined with a switching device for switching off the neutron source when a predetermined neutron dose has been achieved.

In order that the effective radiation beam impinging on the skin of a patient can be shown by a visible light beam, another feature of the present invention provides a lighting system to send a beam of visible light through the window insert.

In another feature of the present invention, the neutron source is spatially fixed and the collimator together with the treatment table are swingable about an axis passing through the neutron source. During such sweeping movement, the treatment table remains horizontal.

In the case of X-ray, gamma, and electron irradiating apparatus, it is known to swing the radiation source about the point to be irradiated in a stationary patient. However, in the case of neutron sources, this can be done, technologically speaking, only with great difficulty and expense, and because of the great weight of the neutron source and collimator it is not sensible. With the help of the present invention, such difficulties are skirted. A uniform sweeping movement of collimator and treatment table assures that the radiation beam is automatically held on the point in a patient to be irradiated during a rotating field irradiation.

Advantageously, this is effected utilizing a collimator middle part, which contains a window insert. This middle part is rotated by a motor-driven actuating shaft. By switching the motor on for rotation in a forwards or backwards direction and then off, any angular position within an entire range of sweeping movement can be chosen as the initial position for the irradiation. Because only this middle part is moved, equipment need not be provided for moving the entire weight of the collimator. The parts of the collimator lying to the sides of the middle part need only serve as shielding.

During rotating field irradiation, the collimator may be swept with the treatment table about the initial position with adjustable angle and adjustable angular velocity.

A further feature of the present invention includes a sweep arm mounted on the actuating shaft of the collimator. The sweep arm has a large diameter carrying ring which is linked to a support housing of the treatment table. The carrying ring is made out of an inner ring and an outer ring. The inner ring is rotatably mounted within the outer ring, and the support housing of the treatment table is attached to the inner ring.

In order that, despite the direction in which the collimator is sending the neutron beam at the diseased point in the body of the patient, the treatment table always remains horizontal, the invention provides a pinion drive engaging with internal gear toothing on the inner circumference of the outer ring. This pinion drive rotates and translates the support housing during a sweeping movement of the sweep arm so that the support housing always remains vertically below the axis of the carrying ring, while the treatment table is kept horizontal.

In order that the treatment table be prevented from tipping in the event of a malfunction in the pinion drive, a switch is provided which locks the apparatus if a deviation of the treatment table from the horizontal is sensed.

Referring now to FIG. 1, steel tube 1 is the tube of an ion accelerator. Contained within this tube is a target forming the neutron source. The target is located at the midpoint of the cylindrical collimator 2, generally at the intersection of the axis of tube 1 with the axis of the conically, hollow window insert 11, but it is not illustrated in greater detail since such is known and is not essential for a proper understanding of the invention. Neutrons are given off from the neutron source, for example 14 MeV neutrons from a tritium target in a T $(d,n)^4$e reaction.

The collimator 2 is divided by two generally vertical parting planes 6 into an annular middle part 3 and two disc-shaped side parts 4 and 5. The faces of the parts coincident with the parting planes 6 contain annular steps, as shown in cross section in FIG. 1, to prevent neutron leakage from the source through the parting planes. While tube 1 pierces centrally through side part 4, side part 5 carries centrally situated actuating shaft 7. A ring flange 8 is integrally attached to the inner end of the actuating shaft. Middle part 3 is rigidly attached to the ring flange 8, so that middle part 3 rotates positively with flange 8. Roller bearing 9 mounted between shaft 7 and side part 5 makes possible relative rotation between shaft 7 and part 5.

Opening 10 in the middle part receives window insert 11 whose function it is to accurately define the cross section of the neutron beam to be cast on, for instance, a tumor of a patient. Opening 10 extends right into the central chamber of the collimator as formed by the ring flange 8.

Numeral 12 indicates generally an optical system for casting a beam of visible light through the window insert to provide a visible indication of the area being irradiated by the neutron beam.

A whole series of window inserts 11 having differently sized windows are provided with the apparatus, so that an optimum adjustment of the cross section of the neutron beam to the size of the tissue area to be irradiated can be made.

The collimator 2 is built out of three layers 13*a*, 13*b*, and 13*c*, of which in an example 13*a* and 13*c* are steel, while layer 13*b* is polyethylene (a material having a high hydrogen content per unit volume).

Neutron-dose measuring instrument and switching device 16 measures the neutron-dose of a representative radiation cross section and switches off the ion accelerator upon the reaching of a predetermined neutron dose.

In housing 17, a gear 14 is affixed to the actuating shaft 7. Gear 14 is rotated by a gear on the output shaft of variable-speed, electrical motor 15. Also affixed to the actuating shaft 7 is a sweep arm 18 having a carrying ring 19 eccentric to the axis of the shaft. Carrying ring 19 is made of an outer ring 20, which is integrally connected to the sweep arm 18, and an inner ring 21 rotatably mounted in the outer ring 20 by way of rollers 22. An internal ring gear 23 is integrally connected to the inner circumference of outer ring 20. Engaging in this internal ring gear is a pinion gear 24, which is driven by a motor mounted within the support and height adjuster housing 26. Housing 26 is affixed to inner ring 21. The motor in housing 26 includes controls to rotate gear 24 oppositely to arm 18 at just that speed needed to keep table 27 horizontal. Also mounted within the housing 26 is a drive for positioning the treatment table 27 at different heights relative to the housing 26.

Numeral 33 indicates a treatment bed on the treatment table. The treatment table 27 can be swung about a vertical axis 29, so that the treatment bed with a patient can be placed simply and easily on the treatment table without obstruction from the collimator 2. This feature also makes it possible to irradiate some point in a patient's body while the patient is sitting.

The motor which drives pinion gear 24 functions in a manner similar to a gear transmission utilizing the relative movement between part 5 and shaft 7 to drive inner ring 21 and thus table 27 with an angular velocity, relative to the center of ring 19, equal to the negative of the angular velocity of arm 18.

The entire irradiating apparatus is mounted to the ceiling or to a side wall using beam 34.

Using the motor 36, which drives a gear 37 engaging a stationary gear rack 38, the housing 17 together with middle part 3, side part 5, and treatment table 27 can be moved to the right in FIG. 1, away from side part 4, so that the neutron source becomes accessible to an operator, who can then for instance exchange its target. The gear rack 38 is mounted fixedly to the beam 34. Housing 17 together with collimater 2 are supported on beam 34 by way of frames 35 (FIG. 2) and roller guides 39, 40. The collimator side parts 4 and 5 are connected to the frames 35 by bolts 41.

FIG. 2 illustrates the treatment table 27 in an angularly displaced position by the dot-dashed representation.

The term "stationary field irradiation" identifies a treatment method where the positions of the radiation source and the seat of the disease in the patient are fixed. In the case of "rotating field irradiation" the beam from the radiation source is moved continuously over a larger field of the patient's body surface. The latter method is used primarily when the seat of the disease is in the interior of the patient's body and has the advantage that the healthy surface regions of the patient's body are not subjected to an overly high radiation level.

For treatment according to the stationary field irradiation method, a patient lying on the treatment bed 33 is positioned on the treatment table 27 by longitudinal and lateral shifting of the bed until the part to be irradiated lies in the light beam of the optical system 12. Such adjustment can be carried out directly or with the help of television cameras used also to supervise the patient during irradiation. In contrast, for rotating field irradiation, the table must be brought to a height such that the seat of the disease lies exactly on the axis of the carrying ring 19. As starting point for both stationary field and rotating field irradiation, that position of the treatment table lying vertically below the axis of the actuating shaft 7 can be chosen. However, any other position in the possible angular sweep range can be chosen by momentary actuation of the motor 15. Consequently, the patient, for example for irradiation from the side, does not have to be turned on the treatment table; he is merely swung with the table into the desired irradiation position, for instance into the position indicated by the dot-dashed representation in FIG. 2.

In the case of rotating field irradiation, the angles of sweep of arm 18 and thus of the treatment table and of the collimator 2 from the starting position and the angular velocity of the sweeping movement are adjustable in the variable-speed motor 15. The motor 15 includes switches which reverse its direction of rotation at the ends of the selected angular sweep range and a voltage divider for varying its speed. It is therefore possible to vary treatment in the present apparatus within wide ranges and to make optimum adjustments for particular situations. During rotating field irradiation, the drive of pinion 24, along with inner ring 21 rotatably mounted in outer ring 20, assure that the treatment table 27 always remains horizontal. Rotation of inner ring 21 oppositely to the rotational direction of arm 18 always keeps the housing 26 vertically below the axis of the carrying ring 19. During such sweeping movement, the beam from the collimator always stays pointed right at the seat of the sickness.

Should, because of any malfunction, the treatment table leave the horizontal, a gravitational switch in the table 27 shuts off the power to the entire apparatus.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

We claim:

1. An irradiating apparatus for neutron therapy, comprising: neutron source means for emitting neutrons; said neutron source means being spatially fixed in position; collimator means positioned for forming into a beam the neutrons emitted by said source means; a treatment table; and sweeping means for moving said collimator means and said treatment table in sweeping movement on circular paths about an axis through said neutron source means and for maintaining said treatment table in a horizontal position during such movement.

2. An apparatus as claimed in claim 1, said collimator means including: two parts fitting together in mutual abutment along a parting plane, said neutron source means being accessible from said parting plane; drive means for moving said two parts relatively away from one another for providing access to said neutron source means from without the collimator means; and step means on said two parts, in said parting plane, for blocking neutron leakage through the parting plane when said parts are in abutment.

3. An apparatus as claimed in claim 2, further comprising wall means in said collimator means for reducing the neutron radiation to a safe level in all directions other than that of the beam.

4. An apparatus as claimed in claim 3 wherein said wall means includes first layer means for slowing down high-energy neutrons, second layer means for further slowing down and absorbing scattered neutrons, and last layer means for absorbing produced gamma radiation.

5. An apparatus as claimed in claim 4 wherein said first and last layer means are of steel and said second layer means is of a material having a high hydrogen content per unit volume.

6. An apparatus as claimed in claim 5 wherein said second and third layer means contain boron additives.

7. An apparatus as claimed in claim 6 wherein said collimator means has an opening for the reception of a window insert means for determining the exact cross section of the neutron beam, and window insert means in said opening.

8. An apparatus as claimed in claim 7, further including a neutron-dose measuring and switching means for switching off said neutron source when a predetermined neutron dose has been achieved.

9. An apparatus as claimed in claim 8, further including an optical system means for the visual determination of the area covered by the neutron beam.

10. An apparatus as claimed in claim 1, wherein said collimator means has a middle part containing said opening and said window insert means, said sweeping means including means for moving the middle part, and a beam issuing therefrom, into any initial position in an angular sweep range.

11. An apparatus as claimed in claim 10 wherein said sweeping means includes means for adjusting the angles of sweep of said collimator means and said treatment table from an initial position and for adjusting the angular velocity of their sweeping movement.

12. An apparatus as claimed in claim 11 wherein said sweeping means includes: an actuating shaft having an axis passing through said neutron source means; a sweep arm affixed to said actuating shaft and extending laterally therefrom; carrying ring means affixed to said sweep arm eccentrically to said axis of said actuating shaft, said carrying ring means including an inner ring and an outer ring and being arranged for carrying support housing means for supporting the treatment table; and support housing means mounted on said carrying ring means.

13. An apparatus as claimed in claim 12 wherein said inner ring is rotatably mounted in said outer ring and said support housing means is affixed to said inner ring.

14. An apparatus as claimed in claim 13, further comprising an internal ring gear integrally connected to the inner circumference of said outer ring, and pinion drive means in said support housing means engaging said internal ring gear for rotating said sweep arm oppositely to said inner ring for keeping said treatment table horizontal and vertically beneath the axis of said carrying ring means.

15. An apparatus as claimed in claim 14, further comprising electrical switch means for sensing a deviation of said treatment table from the horizontal.

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