Nov. 10, 1970 L. RESNICK 3,539,813

BEAM WIDTH DEFINING STRUCTURE FOR LINEAR ACCELERATOR RADIOTHERAPY DEVICES

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FIG. 1

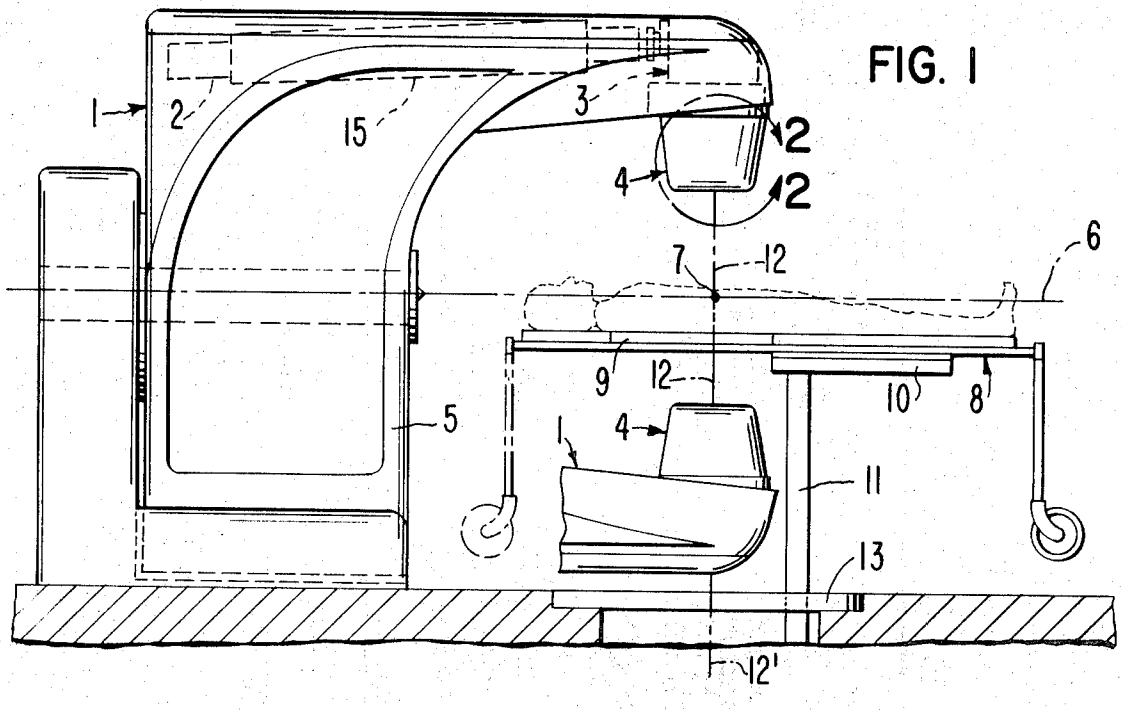
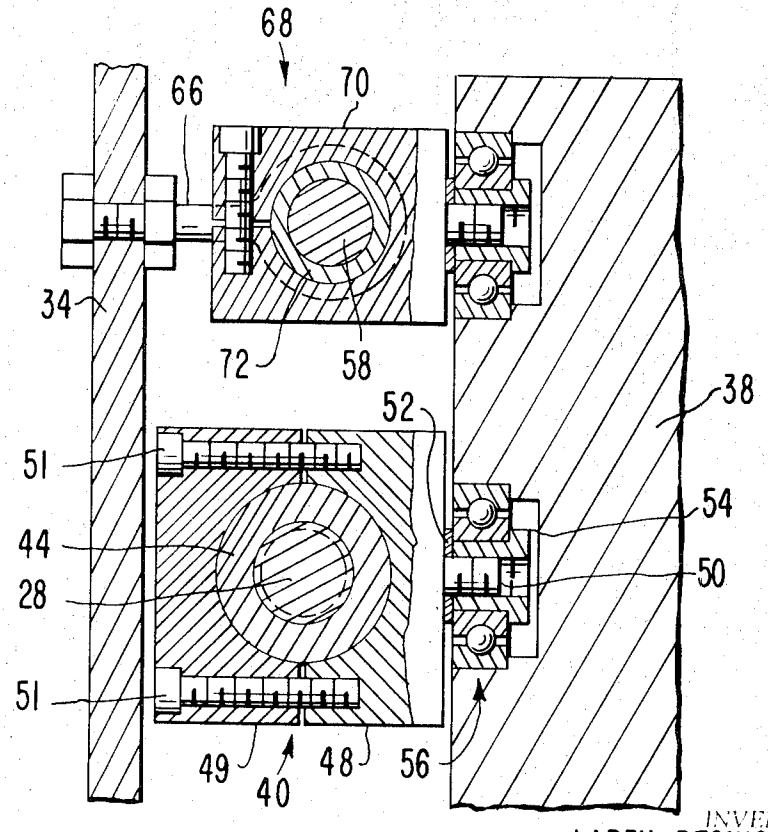


FIG. 3



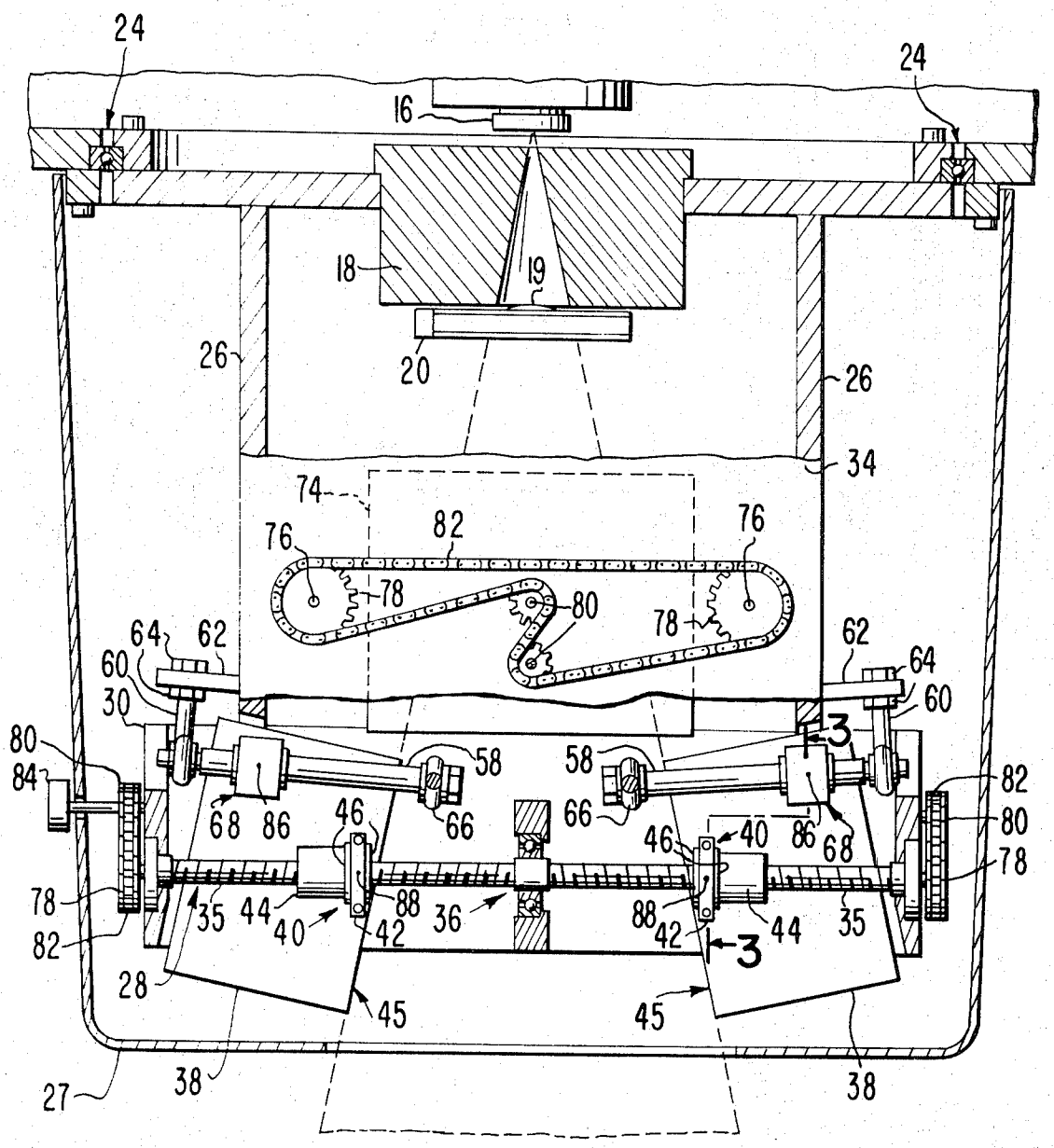
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FIG. 2



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BEAM WIDTH DEFINING STRUCTURE FOR LINEAR ACCELERATOR RADIOTHERAPY DEVICES

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U.S. Cl. 250—105 2 Claims

ABSTRACT OF THE DISCLOSURE

A pair of heavy metal jaws have facing surfaces which define the width of an X-ray beam passing between the jaws. Each jaw is supported on (1) a threaded shaft perpendicular to the beam axis and (2) a shaft which forms an angle with the threaded shaft. The angle and the positions of attachment between jaws and shafts are selected so that the facing surface on each jaw is maintained substantially parallel to the beam edge as the jaws are moved, thus reducing stray radiation at the beam edges.

BACKGROUND OF THE INVENTION

The present invention relates in general to a novel X-ray or charged particle beam width defining apparatus for use in high energy X-ray therapy, diagnostic radiography, electron therapy and other irradiation techniques. In particular, the invention relates to means for eliminating the stray or penumbral radiation which exists at the beam edges in some prior art X-ray apparatus.

Modern methods of treating cancer and other related diseases demand high intensity levels of radiation for deep X-ray therapy applications. Therefore, high energy devices in the range of 4 to 8 mev. are employed to obtain the desired intensity and quality of radiation.

In order to effectively irradiate a deep seated tumor, for example, techniques such as arc, multiple port and patient rotation therapy have evolved. Each of these techniques, when used in conjunction with high energy X-radiation, requires that the cross sectional dimensions of the X-ray beam be accurately controllable. Furthermore, the increasing awareness of the danger of stray radiation has brought about requirements that the beam edges be sharply defined in order to reduce the amount of radiation falling outside the desired beam limits.

For the purpose of defining the beam edges prior art high energy X-ray machines use large and heavy movable jaws disposed in pairs on opposite sides of the X-ray beam axis. Such a machine is described in U.S. Pat. 3,322,950, issued May 30, 1967, and assigned to the assignee of the present invention. The jaws are typically made of lead and dimensioned so that the thickness of the lead in the direction of X-radiation is sufficient to reduce the intensity of X-rays passing through the block by a factor of $1/1000$. Motion of the jaws is generally in a direction toward or away from the X-ray beam axis in order to define beam width.

To ensure that the beam of X-rays is sharply defined near the beam edges or, alternatively stated, that the radiation intensity falls off abruptly at the beam edge, it is necessary that the beam defining inner surfaces of the jaws be parallel to the beam edges. Stated another way, the beam defining surfaces must lie in planes intersecting the X-ray target. When the beam edge defining surfaces lie in planes intersecting the target, X-rays passing near the beam edge either miss the jaw completely thus forming part of the desired beam or else intersect the jaw at the upstream edge thereof and are attenuated by the full thickness of the jaw. In this way, substantially all of the X-rays striking the jaws must pass through the

entire thickness of the jaw and will thus be attenuated by a factor of $1/1000$.

In order to satisfy the above condition throughout the range of movement of the jaws, the apparatus of the above mentioned patent used curved tracks comprising portions of a circle centered on the target. Rollers mounted on the jaws rode on the track and caused the beam-defining surfaces to be parallel to the beam edges throughout the range of jaw motion.

Although this prior system worked well, it was complex and expensive. Double tracks were required in order to support the jaws, since the X-ray head moved 360° in a vertical plane for arc or multi-port therapy. The tracks and rollers had to be precisely made and the tolerances carefully adjusted in order to prevent undesirable shifting or rocking of the jaws when the head was rotated.

SUMMARY OF THE INVENTION

According to the present invention a novel linkage system is used to support the jaws and to constrain the motion thereof so that the beam-edge-defining facing surfaces lie in planes intersecting the target. A single horizontal shaft extends between the jaws and has two oppositely threaded portions thereon which act as lead screws to simultaneously move both jaws when the shaft is rotated. A second shaft on each jaw is angled toward the horizontal shaft. Each jaw of the pair is mounted on the horizontal shaft by a pivot which engages the threads and also permits pivotal motion of the jaw about an axis intersecting the shaft. A second pivot on each jaw is carried on the second shaft and permits pivotal motion of the jaw about an axis intersecting that shaft and linear sliding motion along the shaft.

A second set of jaws, rotated 90° from the first set, is disposed about the beam axis adjacent the first set of jaws and is operated in a similar fashion.

By suitable arrangement of the angles between the shafts and the locations of the pivots with respect to the jaws, the facing surfaces of the jaws can be made to move substantially in arcs of a circle centered upon the target.

The principal object of the present invention is to provide improved apparatus to adjustably define the width of a beam of radiation while substantially reducing stray or penumbral radiation at the beam edges.

Another feature of the present invention is to provide a novel linkage system, comprising two rigid non-parallel shafts, which moves a heavy metal jaw disposed adjacent the beam axis of an X-ray beam toward or away from the beam axis while maintaining the beam-limiting surface of the jaw parallel to the edge of the beam.

Another feature of the present invention is to provide a novel linkage system for supporting a pair of heavy metal jaws and simultaneously moving the jaws toward or away from an X-ray beam passing between the jaws while maintaining the facing surfaces of the jaws parallel to the edges of the beam, wherein the linkage includes a threaded shaft on either side of each jaw to move the jaws in response to rotation of the shafts and means to couple the rotation of the shafts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a radiotherapy linear accelerator utilizing the novel beam defining apparatus of the present invention;

FIG. 2 is an enlarged partially sectional view of a portion of the structure of FIG. 1 delineated by the line 2—2 in FIG. 1;

FIG. 3 is an enlarged sectional view taken along lines 3—3 of FIG. 2 showing details of the pivots used to support the beam defining jaws.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring in more detail to FIG. 1, there is shown a side view of a radiotherapy linear accelerator **1**, having a main accelerator section **15**, an electron gun **2** and colinear termination such as shown and described in U.S. Pat. 3,264,515 assigned to the same assignee as the present invention, beam bending end section **3**, rotatable beam defining head **4** and counterweighted modulator portion **5**. The main accelerator section **15** is designed to rotate 360° about horizontal axis **6**, which is located, by way of example, approximately 117 cm. above the floor level. The main accelerator section can be fixed in any radial position about horizontal axis **6** for therapy treatment of a patient as shown. The rotatable beam defining head **4** is designed to rotate 360° about central beam axis **12** and can easily be moved into any desired position with respect to the patient such as the positions shown.

A special treatment couch **8** with detachable wheel assemblies is provided which is clamped or otherwise suitably attached to float table **10** which is supported by post **11** which is arranged for dual speed vertical movement and which in turn is mounted on a rotatable floor level platform **13** designed for circular movement about the central beam axis **12**. Couch **8** has a thin Mylar or other suitable supporting material **9** attached thereto whereby the patient can be irradiated from a posterior position as shown wtihout danger of ionization build-up and severe skin reactions. The float table **10** is provided with a means for translational movement of the patient in the horizontal plane.

It is readily seen that the spatial relationships between the accelerator horizontal rotational axis **6**, the central axis **12** of the X-ray beam and the vertical rotational axis **12'** of the patient support assembly result in the intersection of the above three axes at a fixed point, the isocenter **7**.

The above indicated relationships facilitate patient setup procedures and provide a radiotherapy linear accelerator system which is capable of multiple port, patient rotation and arc therapy treatments in a manner which is extremely advantageous from a clinical standpoint as well as from time, space, and monetary considerations.

FIG. 2 illustrates in detail the novel beam width defining apparatus of the present invention. An X-ray target **16** is bombarded by a downwardly directed beam of electrons (not shown) thereby producing a downwardly directed X-ray beam. A tungsten collimator **18** has a conically shaped central aperture through which the beam passes to strike a field flattener **19**, and an ionization chamber **20**. Chamber **20** may be used to measure total radiation intensity while field flattener **19** promotes a uniform beam intensity throughout the beam cross section.

A 360° rotatable circular mounting plate **22** is supported from the remainder of accelerator **1** by a ball bearing **24**. Side support members **26** are fastened to plate **22** and serve to support the remainder of the structure of FIG. 2. A bowl shaped cover **27** is supported from support members **26** by suitable means (not shown) and rotates therewith. A horizontal support shaft **28** is supported by a bracket **30** in ball bearings **32**, and from a front cover plate **34** (partially broken away) by a central bearing **36**. Bracket **30** and plate **34** are rigidly attached to side support members **26**.

Shaft **28** has two oppositely threaded portions **35** which act as lead screws to move a pair of heavy metal lower jaws **38** when shaft **28** is rotated. As seen in FIGS. 2 and 3, jaws **38** are supported on shaft **28** by lower pivots **40** comprising trunnion supports **42** and nuts **44** which engage the threads of threaded portions **36** and are held within trunnion supports **42** by end flanges **46**. Jaws **38** have facing surfaces **45** which serve to define beam width.

Trunnion supports **42** comprise a lower shell **48** and an upper shell **49** fastesned to lower shell **48** by screws **51**. Lower shell **48** has a pivot shaft **50** extending through a

washer **52** and into an adapter **54** which is located together with a ball bearing **56** in jaw **38**. When screws **51** are tightened nut **44** is prevented from turning relative to the trunnions.

Angled support shafts **58** are held on their outer ends by ring anchors **60** which are fastened by arms **62** to side support members **26**. A pair of lock nuts **64** provide for height adjustment of the outer ends of shafts **58** to thereby change the angle of shafts **58**. The inner ends of shafts **58** are supported in similar fashion by ring anchors **66** passing through front cover plate **34**.

As seen in FIGS. 2 and 3 jaws **38** are supported upon shafts **58** by upper pivots **68** which comprise a trunnion shell **70** which encloses a bushing **72**, and a pivot shaft extending through a washer, adapter and ball bearing in similar fashion to lower pivots **40**.

A second set of horizontal and angled shafts, upper and lower pivots, etc. (not shown) is disposed on the opposite side of jaws **38**.

Upper jaws **74** identical to lower jaws **38**, together with horizontal shafts **76** and angled shafts, upper and lower pivots, etc. (not shown) are positioned rotated 90° about the beam axis from jaws **38**. Upper and lower drive mechanisms, used to provide adjustment of either set of jaws, comprise drive sprockets **78**, idler sprockets **80** and drive chains **82**. An adjustment wheel **84**, shown only on the lower drive mechanism but included also on upper drive mechanism, is provided on one of idler sprockets **80** whereby the horizontal shafts may be turned, causing synchronous motion of the corresponding jaws by driving nuts **44** along shaft **28**. When nuts **44** are driven along screw shaft **28**, the resulting movement of the jaws will cause pivots **68** to slide along shafts **58**.

In operation the motion of lower jaws **38** toward or away from the beam axis is accompanied by simultaneous pivotal movement of the jaws about the pivot axes **86** and **88** of the upper and lower pivots **68** and **40** respectively. When jaws **38** are moved away from the beam axis they are thus simultaneously rotated in a direction such that the lower edges of jaws **38** are tilted away from the beam axis.

By suitable selection of the angle between horizontal shaft **28** and angled shafts **58**, and the distance between pivot axes **86** and **88**, the facing surfaces **45** can be maintained substantially parallel to the beam edges throughout the range of adjustment of beam widths. In other words, the faces **45** stay in planes which substantially intersect the center of source **16**.

Although the invention has been described with some particularity in reference to a specific example, it will be obvious to the skilled worker in the art that many modifications could be made without departing from the scope of the invention.

Accordingly, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for defining the width of a beam of radiation about a central axis comprising first and second jaws of a radiation absorbing material having facing surfaces thereon for defining the edges of said beam, both said first and second jaws being movable toward and away from said central axis to vary the width of said beam within a preselected range; motion defining means connected to said jaws to constrain the motion thereof so that the facing surfaces thereof are maintained substantially parallel to the beam edges defined thereby at any location of said jaws within said preselected range, said motion defining means comprising a first support shaft extending between said jaws and being connected to each of said jaws by first pivot means permitting pivoting of said jaws about axes intersecting said first shaft, a pair of second support shafts, each of which is respectively associated with a corresponding one of said jaws and each of which is connected to its

associated jaw by second pivot means permitting pivotal motion of said jaws about an axis intersecting its associated second shaft and permitting linear motion of said jaws along their corresponding second shafts, said first shaft being threadably received within said first pivot means associated with each of said jaws by threads of opposite pitch whereby upon rotation of said first shaft said first pivot means and thereby said jaws are moved simultaneously toward or away from said central axis and whereby said first shaft acts not only to constrain the motion of said jaws but also to impart motion thereto; and means for providing rotation of said first shaft.

2. Apparatus for defining the width of a beam of radiation according to claim 1 wherein said motion-defining means is at one side of said first and second jaws and a second motion-defining means identical to the first motion-defining means is on the opposite side of said jaws, and rotation coupling means are provided coupling the first shafts of said motion defining means to rotate such shafts synchronously.

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