Sept. 29, 1964 L. E. WILSON, JR 3,151,245

X-RAY BEAM COLLIMATING APPARATUS

Filed Nov. 21, 1961 3 Sheets-Sheet 1

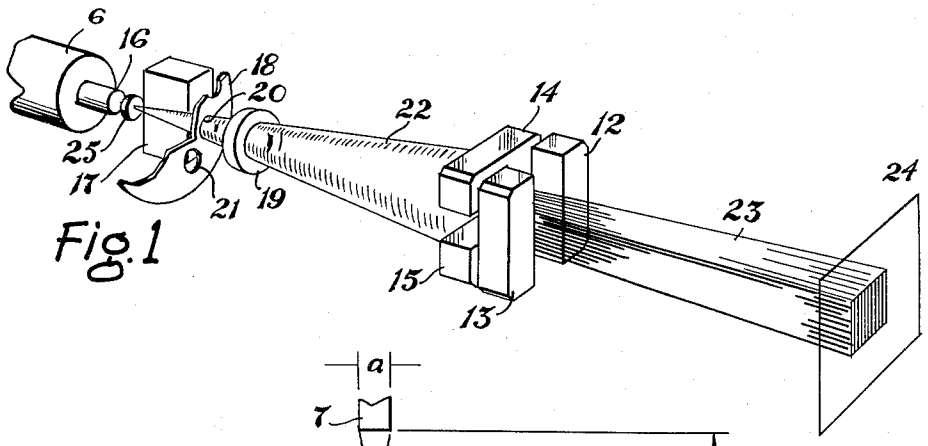


Fig. 1

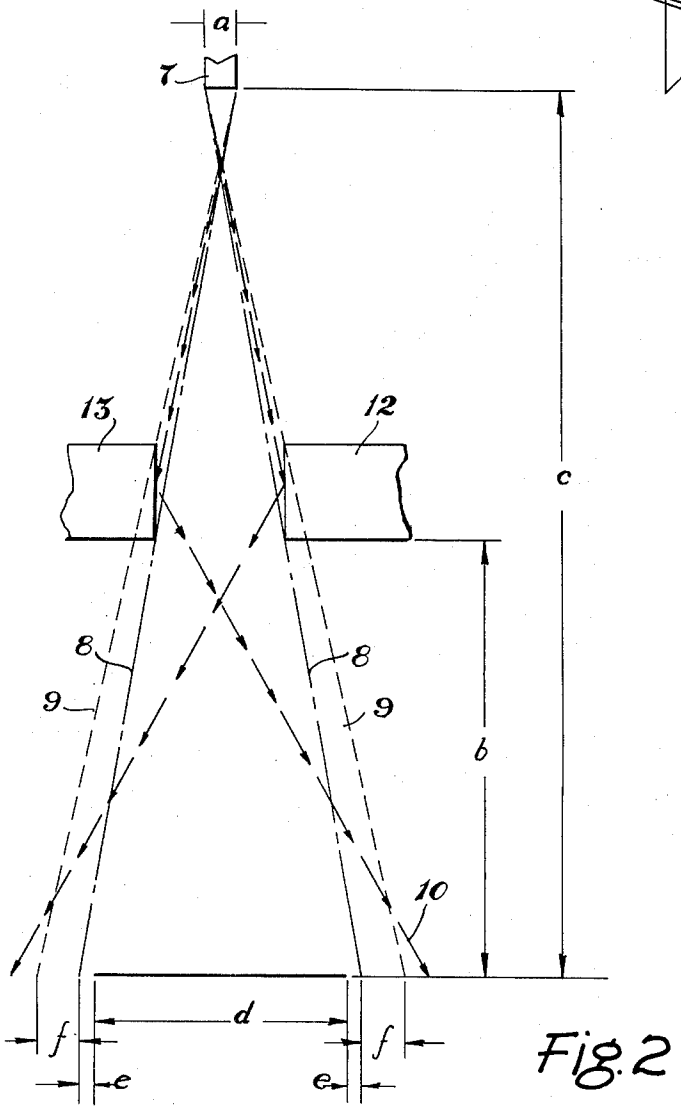


Fig. 2

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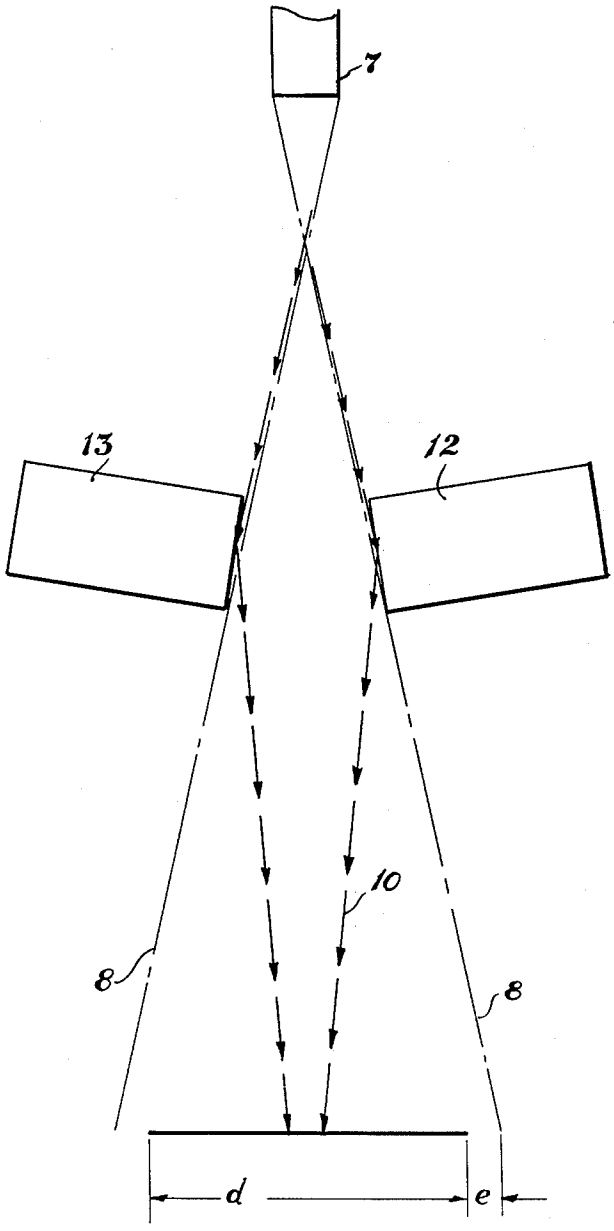


Fig. 3

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X-RAY BEAM COLLIMATING APPARATUS

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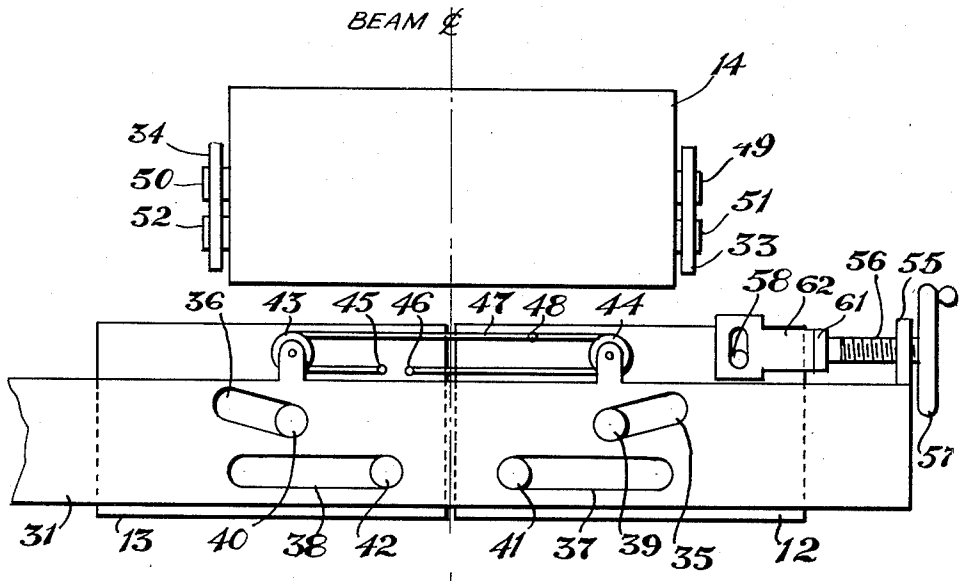


Fig. 4

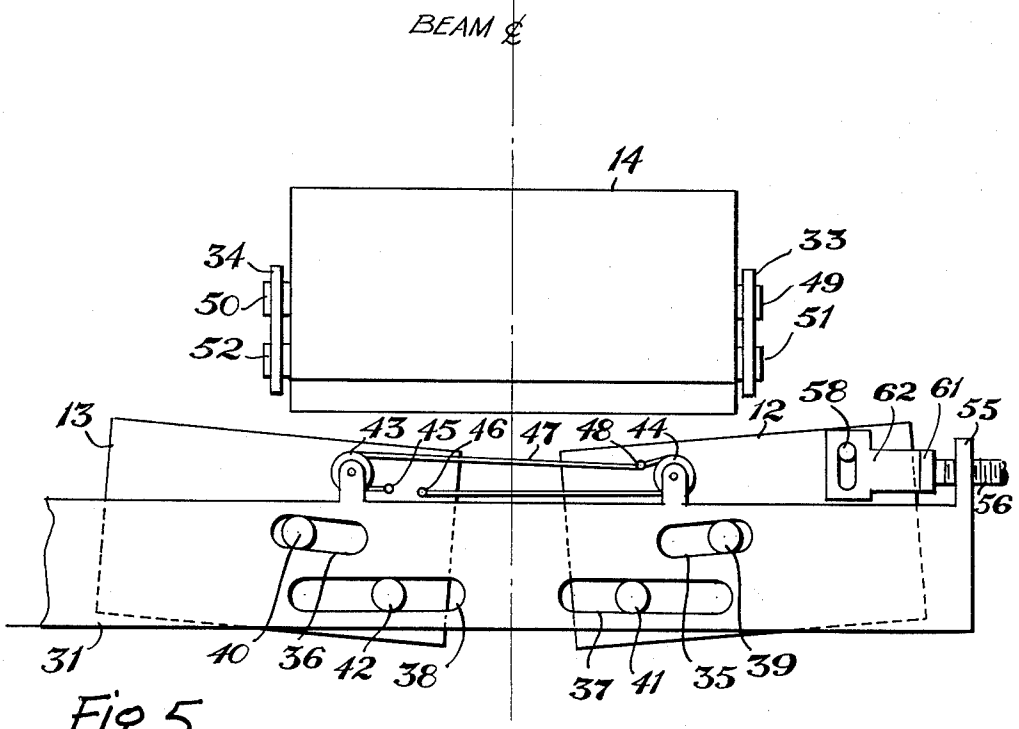


Fig. 5

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X-RAY BEAM COLLIMATING APPARATUS

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5 Claims. (Cl. 250—105)

This invention relates to X-ray beam collimating devices and more particularly to novel apparatus adapted to position and align the beam defining blocks thereof in optimum relationship with the beam being collimated.

A principal object of this invention is to provide a new and improved X-ray beam collimator.

A further object of this invention is to provide an X-ray beam collimator having adjustable beam defining blocks whereby the area to be irradiated is more sharply defined.

A further object of this invention is to provide simple and reliable mechanical apparatus for adjusting the beam defining blocks of an X-ray beam collimator, said apparatus being adapted to position the defining blocks in optimum alignment with the X-ray beam for any degree of beam divergence.

A further object of my invention is to provide, for use in radiation therapy, X-ray beam collimating apparatus that minimizes penumbra effects while maintaining a distance between the target to be irradiated and the surface from which the beam emanates that complies with medical standards.

A further object of my invention is to provide, in an X-ray beam collimator, beam defining block apparatus adapted to effectively reduce penumbra effects due to partial shielding.

A further object of my invention is to provide, in an X-ray beam collimator, beam defining block apparatus adapted to effectively reduce penumbra effects due to beam reflection from the defining block face surfaces.

A further object of my invention is to provide X-ray beam defining apparatus that is compact, reliable and relatively inexpensive.

A further object of my invention is to provide X-ray beam defining block control apparatus which, through a novel cam arrangement, aligns the defining block face surfaces parallel to rays emanating from the center of the X-ray source for any angle of beam divergence.

These, together with other objects and features of my invention, will be readily understood from an inspection of the following specification wherein one presently preferred embodiment is described in detail. It is to be understood however that such description is by way of example only and is not to be taken in a limiting sense, the scope of the invention being defined in the appended claims.

In the accompanying drawings, wherein like numerals refer to like parts throughout;

FIGURE 1 is a pictorial representation of an X-ray beam collimator of the type comprehended by my invention;

FIGURE 2 illustrates the penumbra effects associated with a conventional X-ray beam defining block arrangement;

FIGURE 3 illustrates the penumbra effects associated with the X-ray beam defining block arrangement taught by my invention;

FIGURE 4 illustrates one presently preferred embodiment of my invention; and

FIGURE 5 illustrates the relative position of the parts of said embodiment at another stage of its operation.

The radiating source of any X-ray apparatus, whether it be therapeutic or diagnostic, must be of some finite size. Consequently, any attempt to define the area projected on

a given target by an X-ray beam by placing an opaque surface between the source and the target will result in a partially illuminated fringe area, or penumbra. The penumbra, or shadow surrounding the desired target area, results from the failure of the opaque surface to block off the radiation from the entire source area, thus providing an illuminated fringe area which varies in intensity from zero at the outer extremity to a maximum at the edge of the full illuminated portion. It is desirable to eliminate or substantially reduce this penumbra effect since it constitutes a source of unwanted radiation from which a therapeutic patient is largely unprotected. In addition to being a health hazard, such spurious radiation also adversely affects diagnostic X-rays.

The extent to which penumbra effect can confound the sharp focusing of conventional X-ray beam collimators is illustrated clearly by the geometry of FIGURE 2. Horizontally disposed defining blocks 12, 13 are arranged to illuminate target area *d* from radiation source 7. Since radiation source 7 has a finite width *a*, it is apparent that rays emitted from the outer edge of the source may fall anywhere within reference lines 8 and, therefore, outside of area *d*, thus partially illuminating fringe area *e*. Defining blocks 12, 13 are usually made of lead and have a thickness sufficient to present an opaque surface to the X-ray beam. However, rays emanating from the outer edge of source 7 which are directed between reference lines 8 and 9 are opposed by less than the full thickness of the defining blocks. The partial shielding thus presented to this portion of the beam results in further penumbra effects extending through area *f*. Still further illumination of the fringe area results from the reflection of certain of the rays, designated by arrows 10, from the inner faces of defining blocks 12, 13.

An examination of the optics involved at once suggests decreasing dimensions *a* and *b* and increasing dimension *c* as the obvious means for reducing unwanted penumbra. However, the practicalities of therapeutic and diagnostic X-ray beam application dictate that these parameters be substantially fixed. The area of the emitting source is determined by the capacity of the X-ray beam. The distance between the emitting source and the surface to be irradiated is conventionally one meter by medical standards. Furthermore, since a certain amount of low energy electrons are produced by the X-ray beam, which electrons constitute a health hazard to the patient being treated, it is desirable to maintain a maximum distance between the surface from which the X-ray beam emanates, in this instance defining blocks 12, 13, and the surface being irradiated. This consideration, which is paramount and controlling, is completely incompatible with optimum focusing geometry and therefore further aggravates the penumbra problem.

In consideration of the above stated problem, I have found that by positioning the defining blocks such that their inner face surfaces are aligned with radii emanating from the center of the emitting source, the penumbra is effectively reduced. Having reference now to FIGURE 3, it is seen that defining blocks 12, 13, thus oriented, provide complete shielding to substantially all of the beam, thereby eliminating virtually all of the penumbra resulting from partial shielding. It is further noted that penumbra resulting from reflected rays is completely eliminated since such rays either miss the defining block face surfaces entirely or strike them at an angle that directs the reflected ray to illuminated portion *d*. Finally, such a defining block arrangement provides optimum geometric beam defining relationships by maintaining the lower edges of the defining blocks a minimum distance, in accordance with medical standards, from the surface to be irradiated.

The practical application of these principles in an operable X-ray beam collimator will, of course, require realigning the defining blocks with every change in beam angle. My invention, then, comprehends certain novel apparatus adapted to accomplish this in an efficient, reliable manner.

Referring now to FIGURE 1, there are illustrated the essential elements of an X-ray beam collimator of the type wherein my invention resides. In operation, accelerated particles from some source such as linear accelerator 6 are projected through vacuum window 16 and impinge upon gold target 25. The X-ray beam 22 produced thereby is shaped in part by means of beam flattening disc 18. Said disc 18 is provided with a plurality of X-ray field flattening members 20, 21 adapted to determine the length of beam 22 when placed in intercepting relationship therewith. Shield 17 of high density material guards against stray X-ray emission in the area of gold target 25. Ionization chamber 19 provides for the registration of the dose rate and total dose being applied to irradiated surface 24. The X-ray beam 22 is then further shaped to the desired dimensions, indicated by beam portion 23, by beam defining blocks 12, 13, 14, 15. The apparatus thus described is enclosed in a cylindrical metal housing (not shown).

It is towards the control and manipulation of these beam defining blocks in accordance with the geometric principles hereinbefore stated that my invention is directed, and a detailed description thereof with reference to FIGURES 4 and 5 will follow. FIGURE 4 illustrates the collimator in a closed position, that is, lower defining blocks 14, 15 are arranged to have their inner faces flush together on the center line of the X-ray beam, thus preventing the passage of any portion of the beam therethrough. FIGURE 5 conversely illustrates the collimator in a full open position wherein said defining blocks have been parted to allow the projection of an X-ray beam having maximum divergence. Defining block positioning members 31, 32, 33, 34 are in fixed relationship to the collimator housing (not shown) and have slots therein adapted to guide said blocks in the desired manner, said blocks being operably connected therewith through various knob members. More specifically, horizontal slots 37, 38 of positioning member 31 are seen to impart transverse movement to knobs 41, 42 for any movement of blocks 12, 13. Inclined slots 35, 36 on the other hand impart both transverse and lateral movement to knobs 39, 40. In the above, and in subsequent discussion, transverse movement refers to movement across or perpendicular to the X-ray beam, and lateral movement refers to movements parallel to said X-ray beam. Since the various knobs are in fixed relationship to the defining blocks and have discrete positions relative to each other, they cause said defining blocks to rotate as they are moved apart. The exact degree of such rotation is determined by the angle of the inclined slots 35, 36 and the relative positions of knobs 39, 41 and knobs 40, 42. In accordance with the principles of my invention, slots 35, 36 are inclined at an angle adapted to maintain the defining block faces in alignment with radii emanating from the center of the radiating source for any block position. This angle of inclination may be determined by placing defining blocks 12, 13 first in the closed position as indicated by FIGURE 4 and then in the most extreme open position as indicated by FIGURE 5 and marking, on positioning members 31, 32, the points at which knobs 39, 40 occur. Slots 35, 36 may then be cut therein connecting these points. The slots thus provided will, when in operable connection with knobs 39, 40, cause the defining blocks to substantially align themselves with the beam in any position. If greater alignment accuracy is desired, a plurality of points may be taken for various block positions thereby providing slightly arcuate slots. It has been found however that linear slots have produced a

practical, effective device wherein the several objects of my invention are accomplished.

The defining blocks may be transversely positioned by any conventional means. They may also be operated severally, in pairs, as in the present illustrative embodiment, or collectively. By way of example, with reference to FIGURE 4, adjusting knob 57 is provided with threaded portion 56 on the shaft thereof. The other end of said shaft is connected through swivel joint 61 and forked member 62 to defining block 12. Coupling fitting 58 is provided to allow lateral movement of the defining block. Any rotation of adjusting knob 57 then will cause the shaft thereof to thread itself through threaded member 55, said member 55 being in fixed relationship with positioning member 31, thereby transversely displacing defining block 12. Pulleys 43 and 44 are in fixed relationship with positioning member 31 and carry steel belt 47. Steel belt 47 is attached to defining block 12 at point 48 and to defining block 13 at points 45 and 46. It can be readily seen that this arrangement will provide equal and opposite motion of defining block 13 for any transverse displacement of defining block 12. The arrangement for defining blocks 14 and 15 is identical, thus providing co-acting pairs of defining blocks and hence a wide variety of irradiation patterns.

There has thus been described what is presently considered to be a preferred embodiment of my invention. It will be obvious to those skilled in the art that other changes, embodiments and variations may be made without departing from the spirit and scope of the invention. Therefore it is intended that such description be taken in an illustrative sense, and the invention be limited by the appended claims only.

I claim:

1. In an X-ray beam collimator having four rectangular beam defining blocks with the common inner face surfaces thereof arranged to provide a variable closed-perimeter aperture for the passage of the X-ray beam therethrough, a defining block operating mechanism comprising means for varying said aperture, and means responsive to said aperture variation for aligning said inner face surfaces parallel to the rays emanating from the center of the X-ray beam source for any angle of beam divergence, said means for aligning said inner face surfaces comprising a first cam means operably connected to said defining blocks and adapted to impart linear motion thereto normal to the center line of the X-ray beam, and second cam means, co-acting with said first cam means, operably connected to said defining blocks and adapted to impart thereto rotary motion responsive to the angular displacement of said defining blocks from the center of said X-ray beam source.

2. In an X-ray beam collimator, apparatus for positioning a beam defining block comprising first and second knob members, said knob members being affixed to one side of said defining blocks and spaced apart in diagonal relationship therewith, first and second slot means in fixed relationship to the X-ray beam source, said first slot member having a perpendicular relationship to the center line of the X-ray beam and in operable connection with said first knob, said second slot having an inclined relationship with said first slot and in operable connection with said second knob, and means for imparting transverse motion to said defining block, said first and second slot means in cooperation with said first and second knob members being adapted to rotate said block in response to said transverse motion so as to align the inner face surface thereof with said X-ray beam.

3. In an X-ray beam collimator having first and second movable beam defining blocks disposed in a plane transverse to the center line of the X-ray beam passing therethrough, means for cooperatively positioning said defining blocks comprising first and second knob members

affixed to one side of said first defining block and spaced apart in diagonal relationship therewith, first and second slot means in fixed relationship to said X-ray beam, said first slot means having a perpendicular relationship to the center line thereof and in operable connection with said first knob, said second slot means having an inclined relationship with said first slot means and in operable connection with said second knob, third and fourth knob means affixed to one side of said second defining block and spaced apart in diagonal relationship therewith, third and fourth slot means in fixed relationship to said X-ray beam, said third slot means residing in a common plane with said first slot means and in operable connection with said third knob, said fourth slot means having an inclined relationship with said third slot means and in operable connection with said fourth knob, means for imparting transverse motion to one of said defining blocks, and means responsive thereto for imparting equal and opposite transverse motion to the other of said defining blocks.

4. In an X-ray beam collimator, means for cooperatively positioning first and second defining blocks as defined in claim 3 wherein said means for imparting equal and opposite transverse motion comprises first and second pulley means, said first pulley means being spaced from

and in fixed relationship with said X-ray beam, said second pulley means being spaced from and in fixed relationship with said X-ray beam in a plane with and diametrically opposite to said first pulley means, and a flexible steel tape operably engaging said first and second pulley means, said tape being fixedly attached to said first defining block on one side of said pulley means and to said second defining block on the other side of said pulley means.

5. In an X-ray beam collimator, means for cooperatively positioning first and second defining blocks as defined in claim 3 wherein the inclined relationships of said second and fourth slot means are adapted to rotate said blocks in response to the transverse motion thereof so as to align the inner face surfaces with the X-ray beam.

References Cited in the file of this patent

UNITED STATES PATENTS

1,285,283	McClintock	Nov. 19, 1918
2,542,196	Haupt	Feb. 20, 1951
2,904,692	Gscheidlen	Sept. 15, 1959
2,959,680	Green	Nov. 8, 1960
3,088,031	Varga et al.	Apr. 30, 1963