

Dec. 12, 1950

R. D. WATT ET AL
COLLIMATING SHIELD

2,533,701

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4 Sheets-Sheet 1

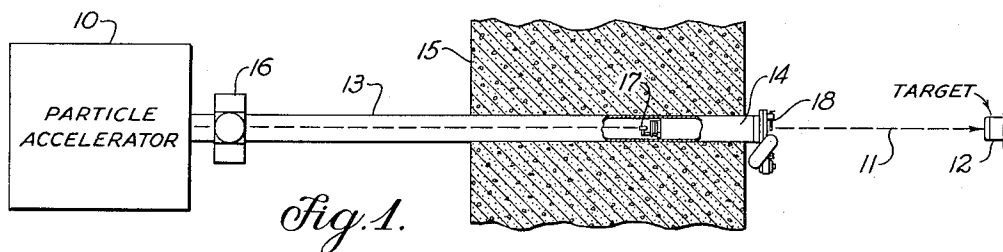


Fig. 1.

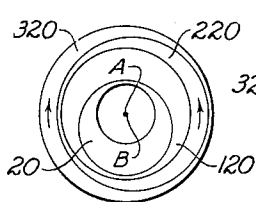


Fig. 8.

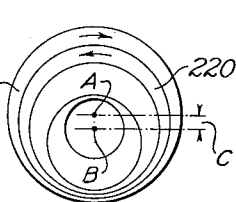


Fig. 9.

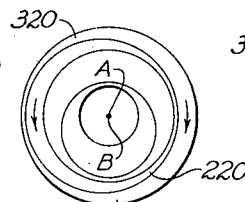


Fig. 10.

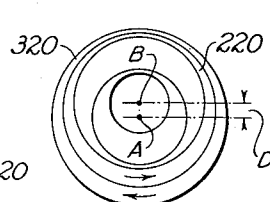


Fig. 11.

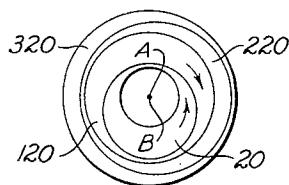


Fig. 12.

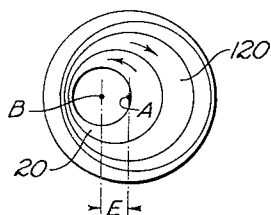


Fig. 13.

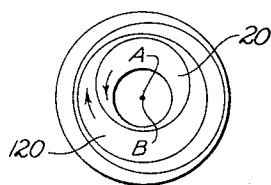


Fig. 14.

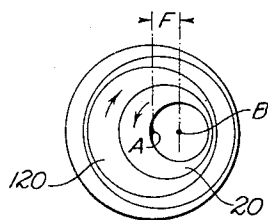


Fig. 15.

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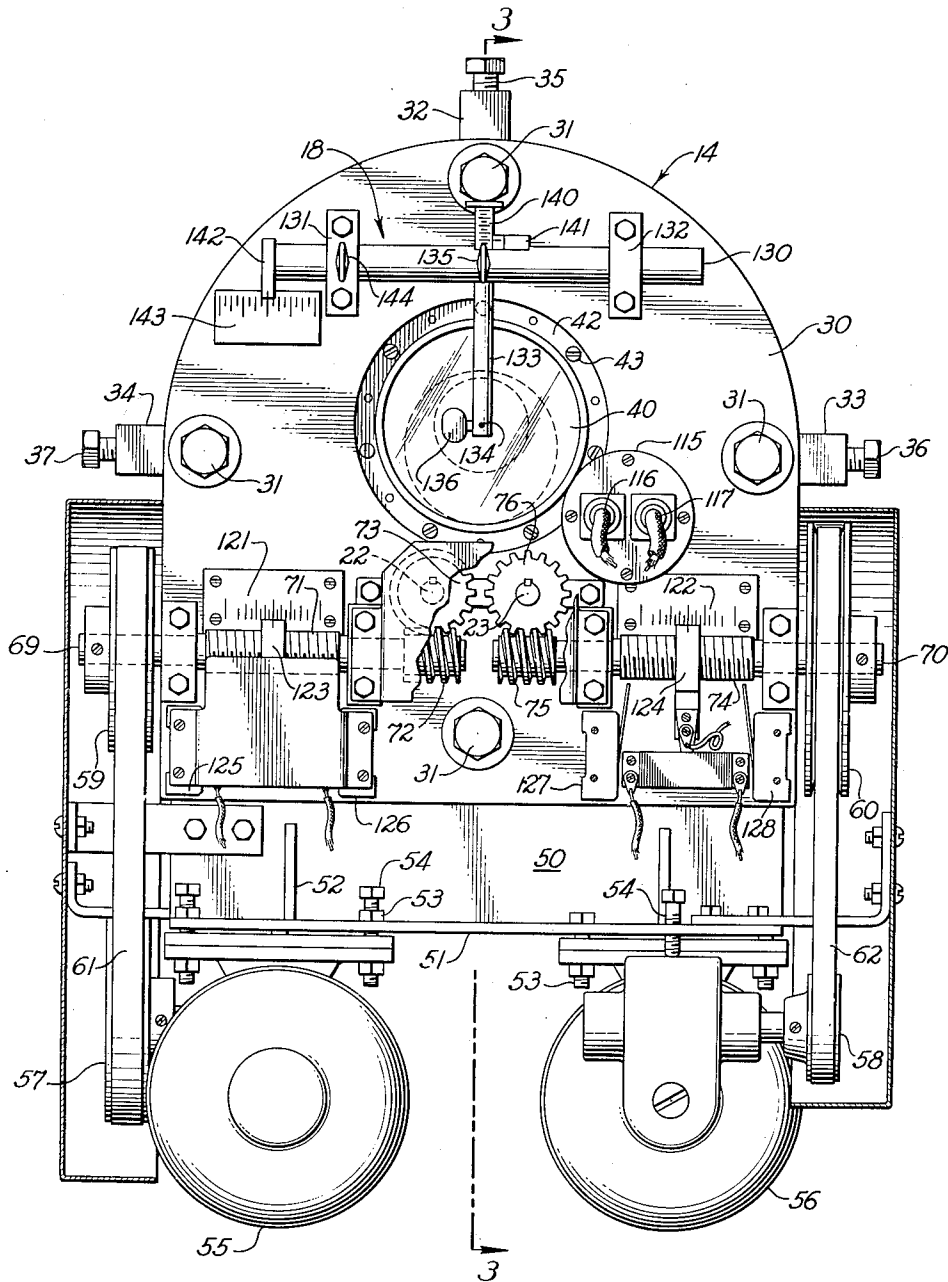


Fig. 2.

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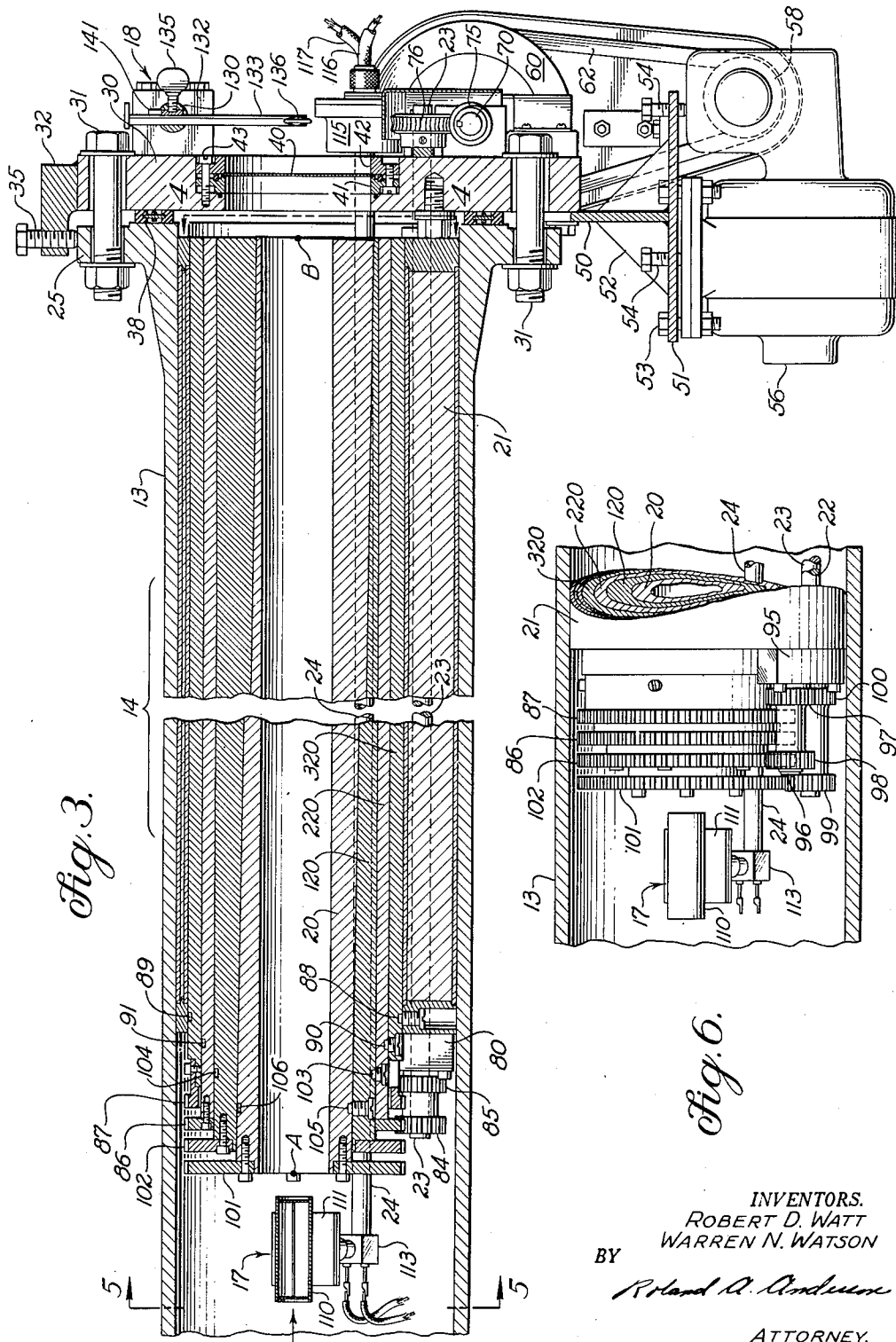
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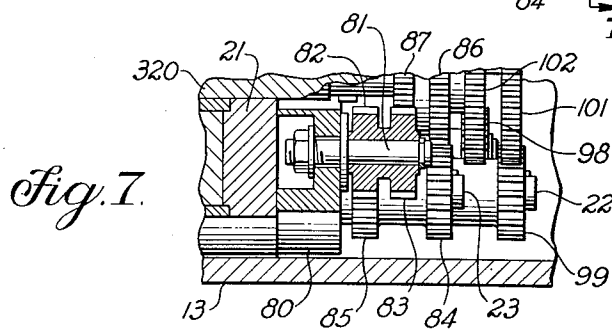
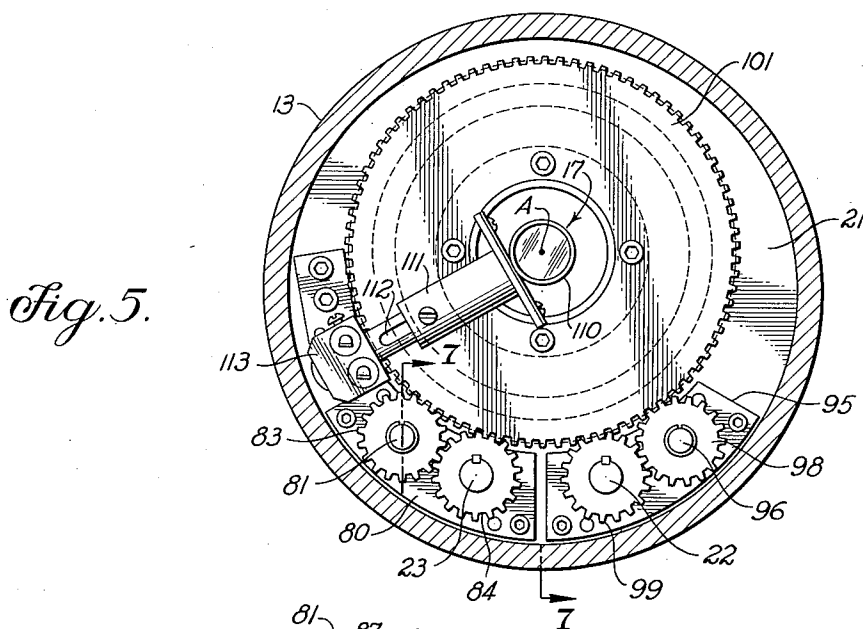
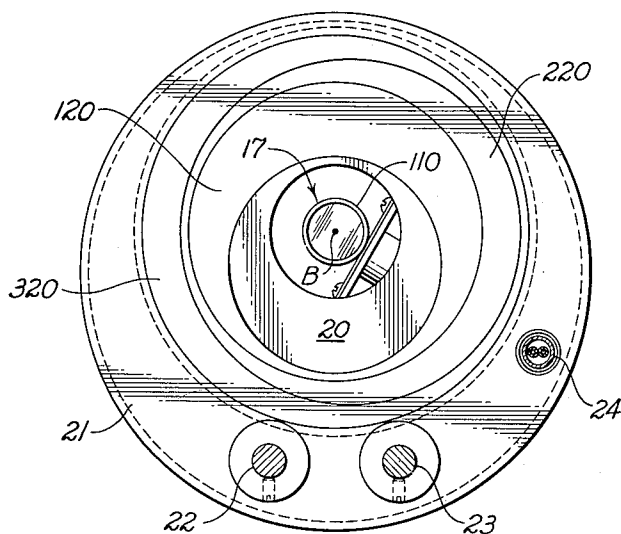
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UNITED STATES PATENT OFFICE

2,533,701

COLLIMATING SHIELD

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Application January 11, 1950, Serial No. 138,024

19 Claims. (Cl. 250-108)

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This invention relates to collimating apparatus and more particularly to collimating apparatus adapted for use in conjunction with beams of accelerated charged particles requiring shielding against radiation therefrom.

As is known, the requirements for shielding against radiation from the beams of high energy particle accelerators presents the anomalous problem of simultaneously providing a small aperture for such beam through the shielding structure and yet providing for variations in the axis of the beam, which latter normally requires a larger aperture. Various forms of apparatus enabling adjustment of the axis of a small aperture through shielding structure have been suggested, but so far as known, all such arrangements have required time-consuming methods of adjustment whenever the axis of the beam shifts and adjustment of the aperture becomes necessary. In some high energy accelerator installations, shielding by means of concrete having thicknesses in the order of ten feet is employed and as a consequence the shielding provided by the collimating means should approximate this same shielding value since otherwise a danger zone might exist through an otherwise safely shielded area. Accordingly, the rapid adjustability of the collimating shield should not be obtained at the expense of adequate overall shielding. Moreover, the functional relationship between the collimating shield and the particle accelerator, as for example, the maintenance of the vacuum of the accelerator tank upon the collimating structure, must be considered even while providing the above-mentioned shielding and adjustability factors.

An important object of the invention therefore, is to provide a new and improved combination of a particle accelerator and a collimating shield.

A second object is to provide a rapidly adjustable collimating shield.

Another object is to provide an elongated adjustable collimating shield affording a shielding effect commensurate with the surrounding structural shielding effect.

Still another object is to provide an improved combination of collimating shield and beam position determining means.

A further object is to provide an improved means for adjusting the relative positions of the component parts of a collimating shield.

Still a further object is to provide an improved mounting for a collimating shield maintained under high vacuum conditions.

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Other objects and advantages will become more apparent as the description proceeds when considered in conjunction with the accompanying drawings in which

Figure 1 is a diagrammatic view showing the relation of the several elements of our improved particle accelerator system.

Fig. 2 is an end elevation of the collimating shield assembly, the surrounding structural shielding being omitted;

Fig. 3 is a longitudinal sectional view taken on line 3-3 of Fig. 2;

Fig. 4 is an end elevation of the inner portion of the shield taken on line 4-4 of Fig. 3;

Fig. 5 is a sectional view taken on line 5-5 of Fig. 3;

Fig. 6 is a view, partly in section, of the drive end of the shield;

Fig. 7 is a detail view, partly in section and taken on line 7-7 of Fig. 5, showing the gear arrangement at the drive end of the shield;

Figs. 8, 9, 10 and 11 are schematic views showing the displacement of the axis of the innermost tube of the shield during rotation of the two outermost tubes through successive quadrants, while the two innermost tubes are restrained from rotation; and

Figs. 12, 13, 14 and 15 are schematic views showing the displacement of the axis of the innermost tube of the shield during rotation of the two innermost tubes through successive quadrants, while the two outermost shields are restrained from rotation.

Referring first to Fig. 1 a preferred arrangement for employing our invention is diagrammatically illustrated in which a conventional particle accelerator 10 is to be used to direct a beam 11 of charged particles upon a target 12. Such an accelerator may comprise either the well-known linear accelerator or similar type in which the charged particles are directed in a substantially straight path, or may comprise the well-known cyclotron, synchrocyclotron, betatron, bevatron, synchrotron or analogous types wherein the charged particles are deflected toward the target after traversing a rotary path within the accelerator. In any event the high vacuum employed within such accelerator is maintained in the practice of our invention within an elongated hollow conduit 13 connecting the accelerator with the collimating shield indicated generally at 14 and disposed within a massive shielding structure 15.

Whenever required a suitable beam focusing means 16 of conventional construction may be

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employed to narrow the beam from the accelerator 10 and to direct the same upon the aperture aligning target 17, later to be described. As will appear later from the description, a suitable marking means 18 also may be adjustably secured upon the outer end of the collimating shield 14 for the purpose of providing an indication of the precise spot at which the beam emerges from the properly positioned collimating aperture and thus serve in the positioning of target 12 in intersecting relation to beam 11.

Passing now to Fig. 3 it will be noted that the collimating shield 14 includes a plurality of nested elongated hollow rotatable tubes 20, 120, 220 and 320, respectively, of larger diameters. For a purpose later to become apparent, the axis of the bore of each tube is inclined with respect to the axis of the tube and in the assembled structure these axes intersect at the same end of each tube. Moreover, in their assembled relation the ends of the tubes at which their bore and tube axes intersect, hereinafter called the common concentric ends, are disposed facing the direction from which the beam enters the collimating shield.

As shown in Fig. 4 the nested tubes are mounted within a stationary tubular bushing 21 having its bore axis parallel to the bushing axis and such bushing is disposed securely within the outermost end of the conduit 13 leading from the accelerator. For convenience, the bushing 21 is shown as having its bore displaced from the bushing axis thereby to provide an enlarged cross section suitable to mount rotatable shafts 22 and 23 and an elongated rotatable conduit 24. Insofar, however, as the function of bushing 21 is concerned, a bushing of sufficiently large cross section disposed concentrically within conduit 13 would be equally well adapted and the invention therefore is not intended to be limited to the form of bushing as shown. Since the shielding effect of the collimating apparatus with respect to energetic particles striking the same along the longitudinal axis thereof preferably should approximate the shielding effect of the shield structure 15, the relatively short bushing 21 may be formed of a good shielding material such as lead, preferably molded within a suitable casing, and the rotatable tubes may be formed of brass. In one satisfactory arrangement employing a concrete shield 15 ten feet thick, adequate shielding was secured when the casing for bushing 21 had a length of 44½ inches and the rotating tubes had lengths commensurately longer and of the order illustrated by the drawings.

Although not shown in Fig. 3 it will be appreciated that the concrete shielding 15 surrounds closely the conduit 13 adjacent the end which terminates in flange 25. To this flange a massive mounting plate 30 having a centrally disposed aperture is adapted to be detachably secured as by bolts 31, assisted during assembly and disassembly by means of overhanging brackets 32, 33 and 34 through which extend set screws 35, 36 37, respectively. Interposed between said flange and plate is a sealing gasket 38 adapted to be compressed upon tightening of bolts 31 but having an internal abutment section preventing undue deformation of the gasket. One form of seal which is suitable for this purpose and is satisfactory for sealing the high vacuum existing inside plate 30, is disclosed in the copending application of Warren W. Chupp, Serial No. 50,721, filed September 23, 1948.

Within the aperture of plate 30 a suitable

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thin diaphragm 40 which is pervious to the beam of charged particles but which has sufficient strength to withstand the pressure difference between the interior and exterior of the evacuated system, is securely mounted. Such diaphragm may be secured in clamped relation between two adjoining discs 41 and 42 which in turn may be held in place on the exterior of the plate aperture as by set screws 43. The diaphragm may be of any conventional material for this purpose and is of a diameter greater than the largest diameter occupied by any part of the bore of the innermost tube 20 during displacement thereof in operation of the apparatus.

In addition to providing a sealed cover for the collimating shield, plate 30 also serves to support the driving means for the internal mechanism of said shield and is provided with a depending framework having a vertical sheet 50 and a horizontal sheet 51 with strengthening web sections 52 welded therebetween to insure rigidity of the composite structure. By means of suitable bolts 53 and adjusting set screws 54, housings for reversible electric motors 55 and 56 are mounted upon said framework. These motors preferably are identical in rating and are mounted in such a manner that a balancing of torques upon the supporting framework may be effected during simultaneous rotation of such motors. Through conventional motor pulleys 57 and 58 driving shaft pulleys 59 and 60 by means of belts 61 and 62, the respective motors 55 and 56 may thus transmit a rotary movement to the collimating shield elements now to be described.

As best shown in Fig. 2, pulleys 59 and 60 are rigidly affixed to shafts 69 and 70 which are mounted for rotation within brackets affixed to the exterior of plate 30. Shaft 69 is provided with a threaded section 71 intermediate its length and terminates in a worm section 72 adapted to mesh with a worm gear 73 affixed to the elongated shaft 22 which is mounted in sealed relation, not shown, within plate 30. Similarly, shaft 70 is provided with a threaded section 74 intermediate its length and terminates in a worm section 75 adapted to mesh with a worm gear 76 affixed to the elongated shaft 23 which likewise is mounted in sealed relation, not shown, within plate 30.

As shown in Figs. 3, 5 and 7, a recessed mounting plate 80 is affixed to the end of bushing 21 and provides a cantilever support for a short stub shaft 81 having gears 82 and 83 thereon. The projecting end of elongated drive shaft 23 is provided with dual gears 84 and 85 adapted to mesh respectively with the periphery of a flat gear plate 86 affixed to the end of tube 220 and with the gear 82 on said stub shaft. In turn, the gear 83 on said stub shaft is adapted to mesh with a flat gear plate 87 affixed to the end of tube 320, whereby upon rotation of shaft 23 by motor 56 the respective outermost tubes 220 and 320 may be rotated in opposite directions at a uniform rate. For purposes of avoiding any lengthwise slippage of one tube with respect to the other, a stationary projection 88 affixed to stationary bushing 21 rides in groove 89 in the outer periphery of tube 320 while a similar projection 90 affixed to tube 320 rides in groove 91 on tube 220.

Neglecting for the moment the drive for the remaining set of tubes and referring now to Figs. 8 to 11, inclusive, it will be noted that point A representing the point in space corresponding to the axis of the aperture of the innermost tube 20 at its end nearest the accelerator 10, coincides

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in a vertical plane of elevation with point B representing the point in space corresponding to the axis of the aperture of that same tube at its end farthest from such accelerator, whenever the several tubes occupy the respective positions shown in Fig. 8. In the event that the axis of the beam coming from accelerator 10 fully coincided with the axis between such points A and B, the location of the tubes shown in Fig. 8 accordingly would represent the position of the collimating shield for optimum performance. As is known to those skilled in the art, however, the axis of the beam may vary and should this variance be in a vertical plane, rotation of tubes 220 and 320 in opposite directions with the tubes 20 and 120 being restrained from rotation, will serve to bring the axis A—B of the innermost tube into coincidence with said beam axis variation. As seen in Fig. 9, by moving tubes 220 and 320 through 90 degrees in opposite directions and with the gearing arrangement above described, the point B may be dropped a distance C below the point A which remains fixed due to the mounting arrangement of the several tubes with their common concentric ends. Further opposite rotation of said tubes 220 and 320, as indicated in Fig. 10, serves to bring points A and B again into coincidence in the vertical plane of elevation while still further opposite rotation of said tubes 220 and 320 serves to raise point B a distance D which is equal in scalar value to distance C. As will thus be apparent, by focusing a beam upon point A, which beam tends to vary in a vertical plane no greater distance than C below point A or distance D above point A, it now becomes possible to collimate the variable beam by means of the structure above described.

Referring again to Figs. 3, 5, 6 and 7 it will be seen that drive shaft 22 extends through a recessed mounting plate 95 affixed to the end of bushing 21, which plate provides a cantilever support for a short stub shaft 96 having gears 97 and 98 thereon. The projecting end of drive shaft 22 contains dual gears 99 and 100 which are adapted to mesh respectively with the periphery of a flat gear plate 101 affixed to the end of tube 20 and with the gear 97 on said stub shaft 96. In turn, the gear 98 on said stub shaft is adapted to mesh with a flat gear plate 102 affixed to the end of tube 120, whereby upon rotation of motor 55 the respective innermost tubes 20 and 120 may be rotated in opposite directions at a uniform rate. For purposes of avoiding any lengthwise slippage of these tubes a projection 103 on tube 220 rides in groove 104 of tube 120 while a projection 105 on tube 120 rides in groove 106 of tube 20.

Referring now to Figs. 12 to 15, inclusive, and assuming the outermost pair of tubes represented therein are restrained from movement while the innermost pair of tubes 20 and 120 are oppositely rotated by shaft 22, it will be noted that in Fig. 12 with the tubes occupying the respective positions shown, the points A and B in space coincide in a vertical plane of elevation. Upon opposite rotation of tubes 20 and 120 through 90 degrees as shown in Fig. 13, point B may be moved horizontally to the left a distance E. Further opposite rotation of tubes 20 and 120, as indicated in Fig. 14, again brings the points A and B into coincidence in a vertical plane of elevation while still further opposite rotation of tubes 20 and 120, as shown in Fig. 15, serves to move point B a distance F horizontally to the right. Distances E and F are equal in scalar value, but are not

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necessarily and not preferably equal to the distances C and D, since such distances are dependent essentially upon the angles between the axis of the bore and of the tube in each case.

It will now be evident that by appropriate rotation of the respective tubes the point B representing the axis at the outlet end of the inner tube 20 may be positioned at any point within a rectangular area which has one axis equal to the distance $C+D$, and the other axis equal to the distance $E+F$. This effective area, however, may be further enlarged as will be noted from an inspection of Fig. 4 wherein it is shown that tubes 320 and 220 have their maximum and minimum eccentricities disposed on the horizontal plane while tubes 120 and 20 have their maximum and minimum eccentricities disposed on a vertical plane. In other words, the outer pair of tubes are shifted 90 degrees from the companion inner pair of tubes.

In order to increase the effective area scanned by point B it is possible, firstly, to mount the two sets of tubes at some angle other than 90 degrees between their extreme eccentricities, or secondly to position the outer tubes 320 and 220 with their maximum eccentricities in a plane other than horizontal with respect to the bushing 21. Such modifications are intended to be comprehended within the scope of our invention as well as the use of only a single set of two tubes arranged to scan through a single plane as shown in Figs. 8 to 11 or in Figs. 12 to 15, or the use of two or more tubes moving to scan through a polar coordinate rather than through a rectangular procedure.

Having thus disclosed a collimating shield structure suitable for rapid adjustment without sacrifice of shielding effect, it will be noted that the employment thereof requires that the accelerator beam be directed accurately upon point A. As seen in Figs. 1 and 3, a movable aligning target 17 is cooperatively mounted upon the collimating shield adjacent the point A and comprises a conventional ionization chamber 110 affixed to a platform 111 which is adjustably secured in a slot 112 of block 113. This block in turn is rigidly mounted upon the hollow elongated, rotatable conduit 24 which extends through bushing 21 and terminates in a vacuum sealed housing 115 mounted on the external surface of plate 30. Suitable electrical leads 116 and 117 connected to conventional radiation measuring means, not shown, serve to provide an accurate reading of the ionization occurring within the ionization chamber serving as the beam aligning target 17. By suitable adjustment of the focusing means 16, as well as of any beam deflecting or other focusing means normally incorporated in the structure of accelerator 10, the beam may be focused until a maximum reading is secured by the ionization chamber 110 indicating the focusing of the most intense portion of the beam plasma at point A. Thereupon, by manipulating housing 115 the entire target means 17 may be rotated into the lower portions of conduit 13 out of the trajectory of said beam.

Having thus focused the beam upon point A, a photographic film, not shown, may then be placed adjacent diaphragm 49 and the location of the center of the beam determined with respect to point B. After this, suitable rotation of the several tubes of the shield is effected until the point B is brought into coincidence with the center of the beam thus indicating optimum collimation of the beam. As noted in Fig. 2, scales 121 and 122 affixed to plate 30 adjacent shafts 69

and 70 indicate the displacement of the innermost and outermost sets of tubes respectively. By means of suitably mounted travelling nuts 123 and 124 engaging the intermediate threaded portions 71 and 74 of these shafts a marker cooperating with said scales shows at all times the positions occupied by such tubes. Appropriate sets of limit switches 125, 126, 127, and 128 connected to a source of power driving motors 55 and 56, respectively, may be adapted to stop rotation or to reverse the rotation of said motors whenever the travelling nuts 123 and 124 contact any of said switches.

By the above described structure it now is possible to collimate the beam and to secure a rapid measured determination of the precise point on diaphragm 40 at which the center of the beam is emerging. For convenience in establishing the location of the effective target 12 the following procedure may then be employed.

By use of a marking means 18 comprising a movable horizontally mounted rod 130 disposed in brackets 131 and 132 on the face of plate 30, a vertically movable rod 133 having a small aperture 134 at its lower end may be disposed at a location corresponding to the center of the collimated beam. This second rod 133 passes through a hole in rod 130 and is adjustably secured therein by a set screw 135, a second set screw 136 being provided at the small aperture 134 in the vertical rod whereby a wire or other marking means may be mounted. Rod 133 is provided with a scale 140 cooperating with a suitable marker 141 carried by rod 130 adjacent the mounting of rod 133 therein, said scale 140 corresponding to the values of scale 122. Moreover, rod 130 is provided adjacent one end with a scale marker 142 cooperating with scale 143 on plate 30, said scale 143 corresponding to the values of scale 121. A set screw 144 in bracket 131 serves to position rod 130 in a desired operating position. Accordingly, after the beam has been collimated, the marking means 18 may be adjusted until scales 140 and 143 show the readings of scales 122 and 121 at which time the aperture 134 will provide an accurate aiming point upon which the target 12 may be directed. In the event that the target aligning procedure employs the use of a stretched wire or the like, aperture 139 and set screw 136 provide a convenient retaining means for one end of said wire. When target 12 is properly positioned, the aligning means 18 may be withdrawn from the trajectory of the beam and the beam 11, as shown in Fig. 1 thereupon strikes target 12 in an unimpeded, properly collimated and mode of travel.

While a preferred arrangement of structure embodying our invention has been described in detail, it is intended that no limitation should be placed upon the scope of the invention by reason of such illustrative examples except as such limitations may appear in the appended claims:

What is claimed is:

1. In a particle accelerator adapted to provide a beam of charged particles, the combination comprising a fixed shield, a collimating tube rotatably mounted in said shield, said tube having a bore with the axis thereof inclined to the tube axis, means focusing the beam upon the bore axis at one end of said tube, means for rotating said tube thereby to render the bore axis thereof parallel to said beam, and target means disposed exteriorly of the shield in intersecting relation to said beam passing through the tube.

2. In a particle accelerator adapted to provide

a beam of charged particles of high energy, the combination comprising a fixed shield, an elongated collimating tube having a shielding effect in the direction of the beam substantially equivalent to the shielding effect of the fixed shield in the direction of the beam, said tube having a bore with the axis thereof inclined to the tube axis and being rotatably mounted in the fixed shield, means focusing the beam upon the bore axis at one end of said tube, means for rotating said tube thereby to render the bore axis thereof parallel to said beam, and target means disposed exteriorly of the shield in intersecting relation to said beam passing through the tube.

3. In a particle accelerator adapted to provide a beam of charged particles, the combination comprising a fixed shield, a collimating tube rotatably mounted in said shield, a conduit connecting said accelerator and said tube and maintained at sub-atmospheric pressure, said tube having a bore with the axis thereof inclined to the tube axis, a diaphragm sealing one end of the tube bore, means focusing the beam upon the bore axis at one end of said tube, means for rotating the tube thereby to render the bore axis thereof parallel to said beam, and target means disposed exteriorly of the shield in intersecting relation to the beam passing through the tube.

4. Collimating apparatus comprising an elongated tube having a collimating aperture there-through and adapted to occupy a fixed position at a first end thereof and a selected adjustable position in space at a second end of the tube, means for shifting the aperture at the second end of the tube along a first predetermined plane, means mounting the tube for movement of the aperture at the second end of the tube in a second predetermined plane intersecting said first plane, and means for shifting said tube mounting means for movement of said second end of the tube in said second plane.

5. Apparatus as defined in claim 4, wherein said means for shifting the aperture in said first plane includes means for rotating said tube.

6. Apparatus as defined in claim 4, wherein said means for shifting said tube mounting means includes means for rotating said tube mounting means.

7. Collimating apparatus comprising in combination, a wall having an aperture therein, a movable collimating means positioned in said aperture and including a pair of nested elongated tubular members having bores concentric at a common end, each member having an inclined bore with the axis thereof intersecting the axis of the tube at said common end and displaced from the axis of the tube at the nonconcentric end, and means for rotating said tubular members in opposite directions thereby to reciprocate the axis of the bore of the inner tube member across a predetermined plane.

8. Apparatus as claimed in claim 7, wherein said means for rotating said tubular members is adapted to rotate the members in opposite directions at a uniform speed.

9. Apparatus as claimed in claim 7, wherein the nonconcentric ends of said members are located adjacent the outer surface of the wall and the common concentric ends thereof are displaced from the outer surface of the wall.

10. Apparatus as claimed in claim 7, wherein the tubular member of smaller diameter is longer than the tubular member of larger diameter.

11. Apparatus as claimed in claim 7, wherein said tubular members are driven by gearing af-

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fixed thereto adjacent the concentric ends of said members.

12. Apparatus as claimed in claim 7, wherein the tubular member of greater diameter provides a mounting bearing adjacent its ends for the tubular member of smaller diameter.

13. Apparatus as claimed in claim 7, wherein the tubular member of greater diameter is provided with guide means engaging a recess in the tubular member of smaller diameter thereby to prevent relative longitudinal shifting of one member with respect to the other member.

14. In combination, a stationary wall comprising a radiation shield and having an aperture therein, a bushing disposed in said aperture and having a tubular opening therethrough, a movable collimating means positioned in said opening and including a pair of nested elongated tubular members having bores concentric at a common end, each member having an inclined bore with the axis thereof intersecting the axis of the tube at said common end and displaced from the axis of the tube at the nonconcentric end, means for rotating said tubular member in opposite directions, adjustable radiation detecting means positioned adjacent the concentric ends of said tubes, and means extending through said bushing for adjusting said detecting means.

15. In combination, a stationary wall having an aperture therein, a bushing disposed in said aperture and having a tubular opening therethrough, a movable collimating means positioned in said opening and comprising an elongated tube having a collimating aperture therethrough, a cover plate affixed to said wall, a thin diaphragm mounted in said plate and adapted to cover the collimating aperture, a shaft extending through said bushing and adapted to rotate said collimating means by engagement therewith interiorly of said wall, and shaft driving means mounted upon said cover plate exteriorly of said wall.

16. Collimating apparatus comprising in combination, a wall having an aperture therein, a movable collimating means positioned in said aperture and comprising a first pair of nested

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tubular members having bores concentric at a common end, a second pair of nested tubular members having bores concentric at a common end, said second pair being disposed within said first pair and each pair having their common concentric ends mounted adjacent each other, each tubular member having an inclined bore with the axis thereof intersecting the axis of the tube at the concentric end and displaced from the axis of the tube at the nonconcentric end, said second pair of tubular members being mounted in non-symmetric angular relation within said first pair, means for rotating the members of the first pair in opposite directions and means for rotating the members of the second pair in opposite directions.

17. Apparatus as claimed in claim 16, wherein said second pair of members are longer than said first pair of members.

18. Apparatus as claimed in claim 16, wherein each of said members is provided with a driving gear disposed adjacent the concentric bore end.

19. Apparatus as claimed in claim 16, wherein the means for rotating the members within each pair are adapted to rotate said members at the same speed.

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