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(54) ENCEPHALOGRAPHIC APPARATUS

(71) We, NORTH AMERICAN PHILLIPS CORPORATION, residing at 100 East 42 Street, New York 10017, New York, United States of America, a Corporation organised and existing under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to an apparatus for X-ray diagnosis, comprising an image recording device which arranged opposite an X-ray source, and a frame which is mounted on a tiltable patient table and which is rotatable with respect to the table, a patient support being arranged in said frame. Such an apparatus will be referred to herein as an apparatus of the kind specified. The invention notably relates to an apparatus for making tomograms during pneumoencephalography.

Pneumoencephalography is a medical procedure for determining the size and the location of brain tumors. A tumor in the brain normally distorts the shape of the ventricles or cavities in the brain. Accordingly, a picture of the exact shape of the brain ventricles would indirectly reveal to a great extent the size and the location of a tumor. Unfortunately, the brain ventricles are normally filled with cerebral fluid, which absorbs X-rays about as well as brain tissue, so that the ventricles cannot ordinarily be X-rayed well even with tomography. Tomography is an X-ray technique whereby the X-ray source and the film (image recording device) are moved about during exposure in a fashion so that only one plane through the body is clearly seen, and other planes are blurred and not distinctly seen. In pneumoencephalography a small amount of air is injected into the spinal column of an erect patient, so that it travels up the spinal column and into the brain ventricles where it displaces some of the cerebral fluid in the ventricles. The difference is sufficient between the X-ray absorption of brain tissue and of air to then make tomographic X-ray exposures showing the shape of the air bubble, which corresponds to the shape of the ventricles bounding the air bubble. Ordinarily, a series of many exposures is made during which the patient is positioned in different orientations with respect to gravity, so that the air bubble moves around to different ventricles and to different sides of the same ventricle. During this procedure, the patient is rotated about the so-termed isocentre which is situated inside the part of the skull to be examined.

It is to be noted that at least six, preferably nine, and possibly as many as twelve or more patient positions are required, and that each time a given point in the head must be accurately positioned in the so-termed isocentre of the apparatus. Pneumoencephalography is a very traumatic and painful experience for the patient, so that repetition of the examination, necessitated by incorrect positioning, is very undesirable. Since the entire procedure is also very time consuming, and reduction in time required for the procedure is also very desirable.

In an apparatus for X-ray diagnosis of the described kind which known from United Kingdom Patent 1,463,526 the patient support consists of an elongate plate having an axis of rotation which is parallel to the plane of the table. The plate can be displaced in a direction perpendicular to the plane of the table and also parallel to the plane of the table, the table itself being rotatable and displaceable relative to the plate in the stationary condition of the patient support (plate).

Even though a so-termed isocentre can be realized by means of the known apparatus, it is less suitable for encephalographic examination, because a patient's head is situated comparatively far from the film plane. This is due to the fact that the longitudinal axis of the patient support, consisting of an elongate plate, always remains parallel to the table.

The invention has for an object to provide an improved apparatus for X-ray diagnosis in which said drawback is substantially mitigated.

According to the invention there is provided an apparatus of the kind specified, wherein the frame is rotatable with respect to the stationary table about a first axis, extending perpendicularly to the plane of the table, in a plane parallel to the plane of the table, the patient support being rotatable with respect to the frame about a second axis which intersects the first axis in an isocentre situated above the plane of the table, said second axis enclosing an acute angle greater than 6 degrees and preferably approximately 11 degrees with the plane of the table, the X-ray source being mounted on support means arranged to be displacable relative to said table about an effective pivotal point coinciding with said isocentre so that the central ray of said X-ray source extends through the isocentre for all mutual positions of X-ray source, frame and patient support.

An embodiment of the invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, of which:—

Figure 1 shows an embodiment of an apparatus in accordance with the invention in perspective, the patient support (chair) being mounted on a vertically positioned table of a tomography apparatus,

Figure 2 is a top view of the patient chair mounted on a tomography table which is in a horizontal position,

Figure 3 is a more detailed side view of the chair mounted on a vertically positioned tomography table,

Figure 4 is a cut-away top sectional view of the chair mounted on a vertically positioned table,

Figure 5 is a cut-away top sectional view of a mechanism for restraining the shin of a patient,

Figure 6 is a side cross-sectional view of the telescopic column which supports the chair and a supporting arm for the chin, arm and shin restraints,

Figure 7 is a side cross-sectional view of a chin restraint,

Figure 8 is a cut-away top view of a supporting mechanism for the chair,

Figure 9 is a cross-sectional view of a worm wheel drive for rotating the chair about its supporting column,

Figure 10 is a view of a lever assembly which releases the chair for rotation about its supporting column,

Figure 11 is a top view of the annular bearing for the frame in which the patient chair is mounted,

Figures 12 and 13 are top and side views respectively of the mounting of the annular bearing on the table,

Figure 14 is a cross-sectional view of a portion of the annular bearing,

Figure 15 is a partly sectional top view of a portion of the annular bearing,

Figure 16 is a sectional view taken along the line 16–16 in Figure 15,

Figure 17 is a sectional view taken along the line 17–17 in Figure 15,

Figures 18 and 19 are diagrammatic side and front views respectively of the position of a patient relative to the axes of rotation,

Figure 20 illustrates a child's chair which may be mounted on the telescopic column in place of the larger chair for adults, and

Figure 21 illustrates a chair supporting a patient in a position where all degrees of movement freedom have been exercised.

The figures, notably the Figures 1, 2 and 21, show a patient chair 10 which is mounted on a telescopic column 11 which is rotatably secured in the two parallel supporting arms 12. An annular bearing 13 is detachably mounted on two parallel rails 14 in a tomography table 15 and supports the supporting arms 12 in cantilever fashion. The supporting arms 12 are secured near one end in diametrically oppositely situated points of the annular bearing 13, their other end supporting the rotatable telescopic column 11. In conjunction with the column 11, the supporting arms constitute a frame on which the chair 10 is mounted. The column 11 is symmetrically situated with respect to the supporting arms, the axis of the column 11 enclosing an acute angle with the plane of the table and intersecting the axis of rotation of the frame in the so-termed isocentre which is situated approximately 20 cm above the plane of the table. A motor 16 at the base of the column 11 rotates the column 11 and is controlled with hand control 17 (Figure 2). A lever 18 releases the bearing 13 for rotation. A flat rod parallelogram 19 associates the motion of an X-ray source 20 to the motion of an X-ray film holder 21 for making tomograms. The movement traject followed by the source and the holder in this embodiment is geometrically variable and may adjusted by means of a gearbox device which is generally indicated by the reference numeral 22. The tomography table 15 may be tilted from horizontal to vertical with hand control 17 (Figure 2) and the source 20 and the film holder 21 are rotated simultaneously with the table, so that the mutual orientation does not change during the tilting of the table.

The tomography apparatus 15, 19, 22 is of a known type. In this tomography apparatus, the movement trajectory may be linear, circular, elliptical or hypocycloidal. A detailed understanding of such a tomography apparatus is not required for a full understanding of the invention. However, it is to be noted that the rod parallelogram 19 is rotatable about a tomographic axis (so-termed slice axis) which is parallel to the plane of the height-adjustable table 15 and which extends through said isocentre, as well as about an axis which is perpendicular to the plane of the rod parallelogram 19 and to the former axis (slice axis).

As is shown in the Figures 3 and 4, the bearing 13 supports two tubular supporting arms 12 which in turn carry the column 11 on which the chair 10 is mounted. The chair 10 includes a padded seat 23 (Figure 4) with an integral back support 24. A shoulder support 25 wraps around the patient and is secured on the front with one or more closure straps. The shoulder support 25 may be adjusted up and down and is secured to the back support 24 by a semi-flexible band 26, connected to the back support 24, by a pin 27 which is inserted into one of a number of different holes in the band 26. A bar 28 serves to lock the pin 21 in a hole in the band 26. This arrangement functions like the buckle of a belt. A strap 29 keeps the patient's thighs against the seat 23. A strap 30 engages the patient's abdomen and forces his lower back against the back support 24. Two crossing straps 31 extend across the patient's chest and hold the upper back and shoulders against the shoulder support 25.

A supporting arm 32 which carries an auxiliary supporting arm 33 is mechanically rigidly linked to the seat of the chair or to the shaft supporting the chair seat. A shin restraint 34 is supported by the column 11. A member 36 constitutes, together with a member 37 which integral therewith, a helmet-like head support. The member 37 comprises four straps 38, 39, 40 and 41 which hold the patient's head in a fixed position relative to the member 37. Ordinarily, padding is placed for comfort between the head and the member 37 and between the head and the straps 38, 39, 40 and 41. The member 37 may be moulded in different forms so long as it functions to hold the head firmly in a fixed position. The head support also includes a chin support 43 and both the members 36, 37 as well as the chin support 43 are supported by a supporting arm 44 which has ball joints 45 and 46 on either end for adjustment freedom. The supporting arm 44 furthermore is adjustable in length, as will be described in further detail below with reference to Figure 7.

A tray 47 of sterilizable material is detachably mounted to the rear of the seat 23 *via* thumb screws 48 to hold medical supplies and tools during the spinal surgical procedure. An opening 49 (Figure 2) in the back support 24 of the chair permits access to the lumbar region of the spine where a puncture is made, cerebral spinal fluid removed and small amounts of air injected.

The height of the chair 10 is adjustable by turning a crank 50. As appears from Figure 3, all body supporting elements, except a toe guard 51, are mechanically attached to the chair, so that adjustment of the height *via* the crank 50 moves all supporting elements together. It is alternatively possible, though not preferred, so to secure certain supporting elements directly to the column 11. The Figures 1, 2 and 21, for example, show an embodiment where the shin supports 34 are mechanically attached to the lower part of the column 11 and do not, therefore, move up or down with the chair 10. Casters 52 are used to roll the entire patient support to and from the table 5 for mounting and after removal in wheel barrow fashion.

Figure 5 shows in cross-section a shin restraint supporting mechanism which clamps onto the auxiliary supporting shaft 33. A hand crank 53 is used to rotate a shaft 54 which turns a screw 55 to reduce spaces 56. A supporting member 57 is thus clamped onto the auxiliary supporting shaft 33 and further shaft 58. Rods 59 are secured to the shaft 58 by pins 60. The shin restraints 34 are provided on the rods 59 as shown more clearly in Figure 8. A simple turn of the crank 53 thus secures or releases the shin restraints.

Figure 6 is a side view of the telescopic column 11. A crank rod 60 drives bevel gears 61 which rotate a jack screw 62, the seat 23 thus being raised or lowered. Anti-rotation shoes 63 link the rotation of the seat 23 to the rotation of the worm wheel 64 which is driven by a motor as is more clearly shown in Figure 9. A crank 65 operates similarly to the previously described crank 53 to clamp the supporting arm 32 on the auxiliary supporting arm 33 which *inter alia* supports the head support.

Figure 7 is a cross-sectional view of the supporting arm 44 which supports the member 37 of the head support. The auxiliary supporting arm 33 is mechanically secured to the chair 10 *via* the crank 65 as described above. A nut 67 cooperates with a thrust bearing 68 to simultaneously lock the positions of the ball joints 45 and 46 as well as the telescopic supporting arm 44.

Figure 8 shows a cut-away top view of the mechanism supporting the chair 10 (Figure 1). The seat 23 is attached to a bracket 32 by four hand screws 70. The bracket 32 supports the auxiliary supporting arm 33 which, *via* the supporting member 57 and the shaft 58 (Figure 5), supports shafts 59. The shin restraints 34 can be mounted on the shafts 59 in an arbitrary position by spring-loaded pins. The crank rod 60 (Figure 6) is turned by a crank 72 to raise or lower the seat 23 as previously described. An additional crank rod 73 and crank 74 serve the same purpose and facilitate hand adjustment of the height of the seat 23 from the opposite side.

Figure 9 illustrates the worm wheel drive for the column 11. The motor 16 turns the worm wheel 64 which thus turns the seat 23. A cable 77 whereby the motor 16 is controlled is connected to the bearing 13 *via* one of the supporting arms 12. A lever 18 pulls a bowden wire 76 to release the main bearing 13.

Figure 10 is a more detailed view of the construction which connects the lever 18 to the bowden wire 76. The lever 18 turns a shaft 78 and swings an arm 79 which is connected to the shaft 78 by means of pins. The bowden wire 76 is attached to the arm 79 so as to be pushed or pulled by this arm 79.

Figure 11 is a top view and Figure 14 is a cross-sectional view of the bearing 13. The bearing 13 comprises an aperture 80 which is substantially larger than a patient's head, so that the metal of the bearing does not interfere with tomography. A first bearing portion 81 is detachably mounted on the table 15 *via* rails 14. The bearing portion 81 is annular with an inward flange portion 82 (Figure 14). A second bearing portion 83 which is also annular is rotatably mounted inside of the bearing portion 81 and rides on the flange portion 82 by means of rollers 84 spaced around the flange portion 82. The bearing portion 83 comprises a top annular portion 85 and a bottom annular portion 86 which are connected to each other with screws 87. A cable 88 contains electrical wires for powering the motor 16 and for sensing the condition of a micro-switch 89 (Figure 15). A hollow channel 90 in the bearing 13 carries electrical wires which extend from the cable 88 to the micro-switch 89 and further to the motor 16 *via* the supporting arm 12. Holes 91 (Figure 11) are spaced at intervals of approximately 15° around half of the circumference of the bearing portion 81. The bearing portions 81 and 83 are locked in a predetermined position. In order to rotate the bearing portion 83, a pin 92 must be withdrawn from the relevant hole 91 by actuation of the lever 18 (Figure 9) and the bowden wire 76. When the bowden wire 76 is withdrawn by the lever 18, the micro-switch 89 is triggered to cause a visual indication of the pin release. Withdrawal of the bowden wire 76 causes rotation of a bracket 93 about an axis 94 to lift the pin 92 against the force of a spring 95 (Figures 15, 16 and 17).

The bearing 13 may be secured to the rails 14 in various manners. Preferably, use is made of bars 96 (Figures 12 and 13) which fit into the rails 14 and which are locked against displacement in the direction perpendicular to the table. A bar 96 comprises two wedge-shaped recesses 97 and 98 which cooperate with wedge-portions 100, 101 and 102 and a wedge-shaped latch 99 which are rigidly connected to the bearing 13. The portions 100, 101, 102 and the latch 109 fit in the recesses 97, 98 and can be lifted from the bar 96, together with the bearing 13, when a lever 103 is in the position shown in Figure 13. When the lever 103 is depressed, the bar 96 is clamped in the rails 14. To this end, the lever 103 has a pivot 104 which is situated so that a central position (so-termed dead point) is passed, so that the lever remains depressed until manually raised again. An arm 105 is adjustable so that the portions 99 and 102 are properly spaced to achieve the above aims. A spring-loaded pin 106 fits in a hole 107 to accurately position the locking mechanism with respect to the tomographic (slice) axis of the tomography apparatus.

As is clearly shown in the Figures 1, 3, 21 and the diagrammatic Figures 18 and 19, the so-termed isocentre remains in the same position in space for all positions of table, patient chair and X-ray source relative to each other. Because the patient is positioned so that the part of his head to be examined includes the isocentre, the patient is in fact rotated in all directions of rotation around the isocentre during the examination. The patient is preferably positioned so that the isocentre is situated substantially in the position shown in the Figures 18 and 19. Preferably, $R=20$ cm and $\theta=11°$ (see Figures 18 and 19). It has been found that at least 99% of the adult patients fit within the cone region shown in the Figures 18 and 19. The embodiment for the examination of children which is shown in Figure 20 utilizes comparatively short supporting arms and an adapted patient chair.

Even though the invention has been described with reference to an apparatus in which the X-ray source and the film are secured in a rod construction which is rotatable about two mutually perpendicularly axes, the invention is not restricted to such apparatus. Actually, the frame with the patient chair can also be mounted on tiltable tables of simpler X-ray apparatus, such as linear tomography apparatus and apparatus which do not utilize a tomography technique.

WHAT WE CLAIM IS:—

1. An apparatus for X-ray diagnosis, comprising an image recording device which is arranged opposite an X-ray source, and a frame which is mounted on a tiltable patient table and which is rotatable with respect to the table, a patient support being arranged in said frame, characterized in that the frame is rotatable with respect to the stationary table about a first axis, extending perpendicularly to the plane of the table, in a plane parallel to

the plane of the table, the patient support being rotatable with respect to the frame about a second axis which intersects the first axis in an isocentre situated above the plane of the table, said second axis enclosing an acute angle greater than 6 degrees and preferably approximately 11 degrees, with the plane of the table, the X-ray source being mounted on support means arranged to be displacable relative to said table about an effective pivotal point coinciding with said isocentre so that the central ray of said X-ray source extends through the isocentre for all mutual position of X-ray source, frame and patient support.

2. An apparatus as claimed in Claim 1, characterized in that the frame comprises two parallel supporting arms which are secured near one end in diametrically oppositely situated points of an annular bearing which is mounted on the table, their other end supporting a telescopic column on which the patient support is mounted, the axis of said column coinciding with said second axis which intersects said first axis in the isocentre.

3. An apparatus for X-ray diagnosis as claimed in Claim 1 or Claim 2, wherein the X-ray source and the image recording device are respectively mounted spaced apart on a rod parallelogram assembly which defines a characteristic plane of the parallelogram in which a parallelogram type displacement will occur as a result of pivotal displacement of rods forming said rod parallelogram assembly about corner pivots linking adjacent ends of pairs of said rods, said rod parallelogram assembly being rotatable about a tomographic axis extending through said isocentre parallel to the plane of the table and lying in said characteristic plane between the X-ray source and the image recording device, said rod parallelogram assembly also being rotatable in a parallelogram manner about further axes which are perpendicular to said characteristic and said tomographic axis.

4. An apparatus for X-ray diagnosis substantially as herein described with reference to the accompanying drawings.

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Sheet 1

Fig. 1.

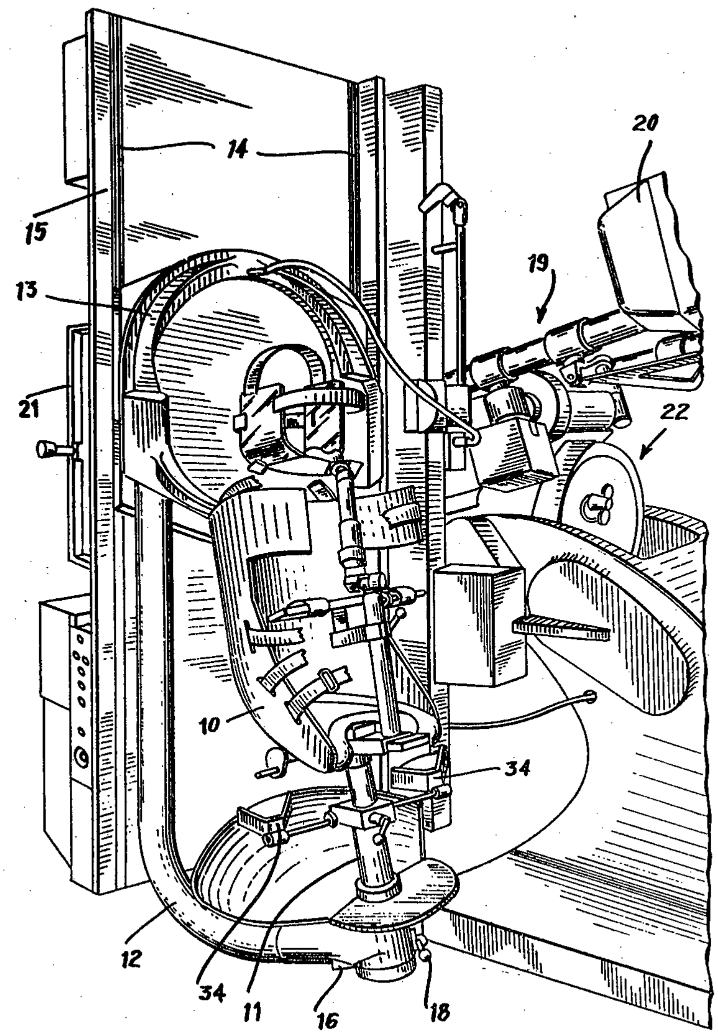

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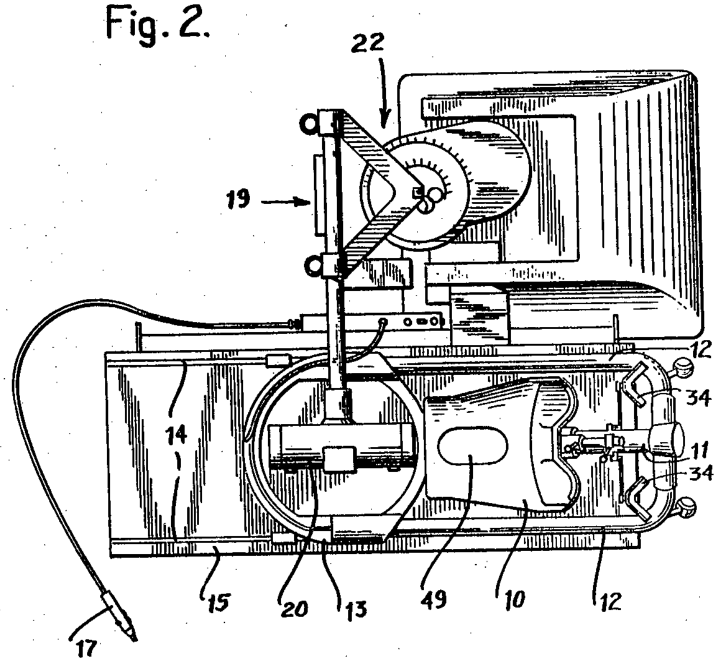
Fig. 2.



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Sheet 3

Fig. 3. Fig. 5.

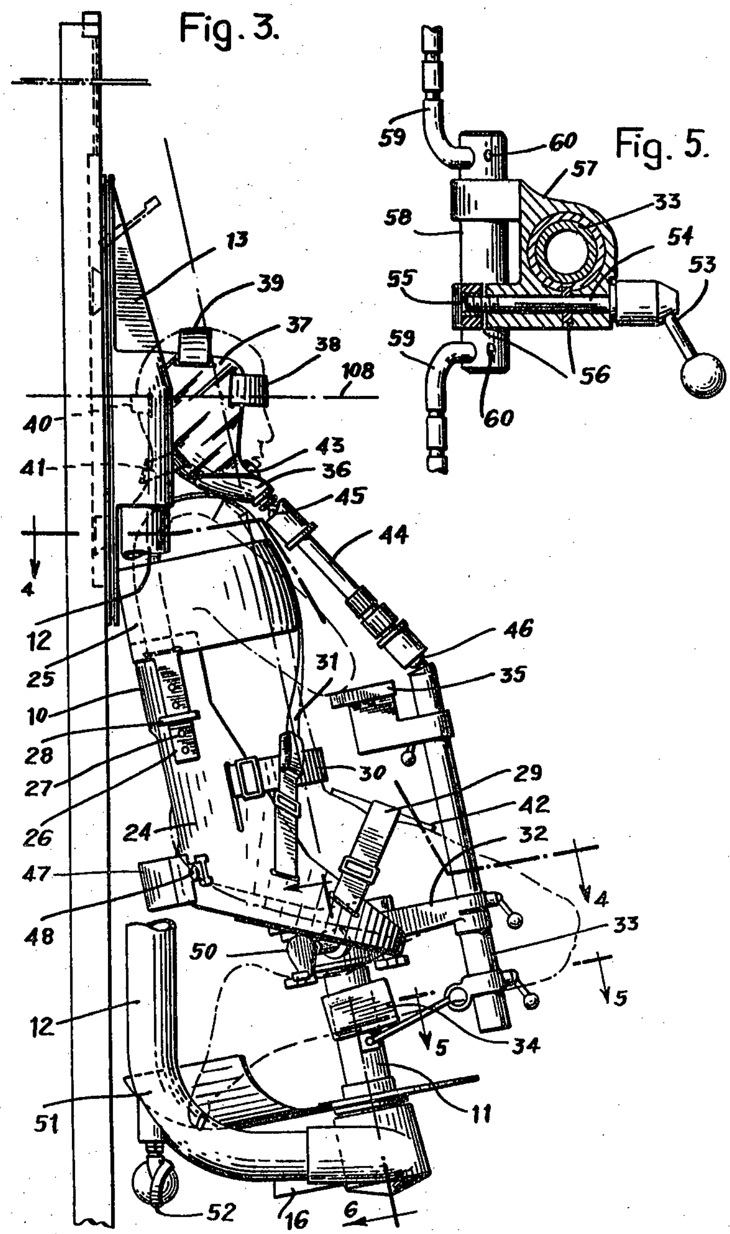

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Fig. 7

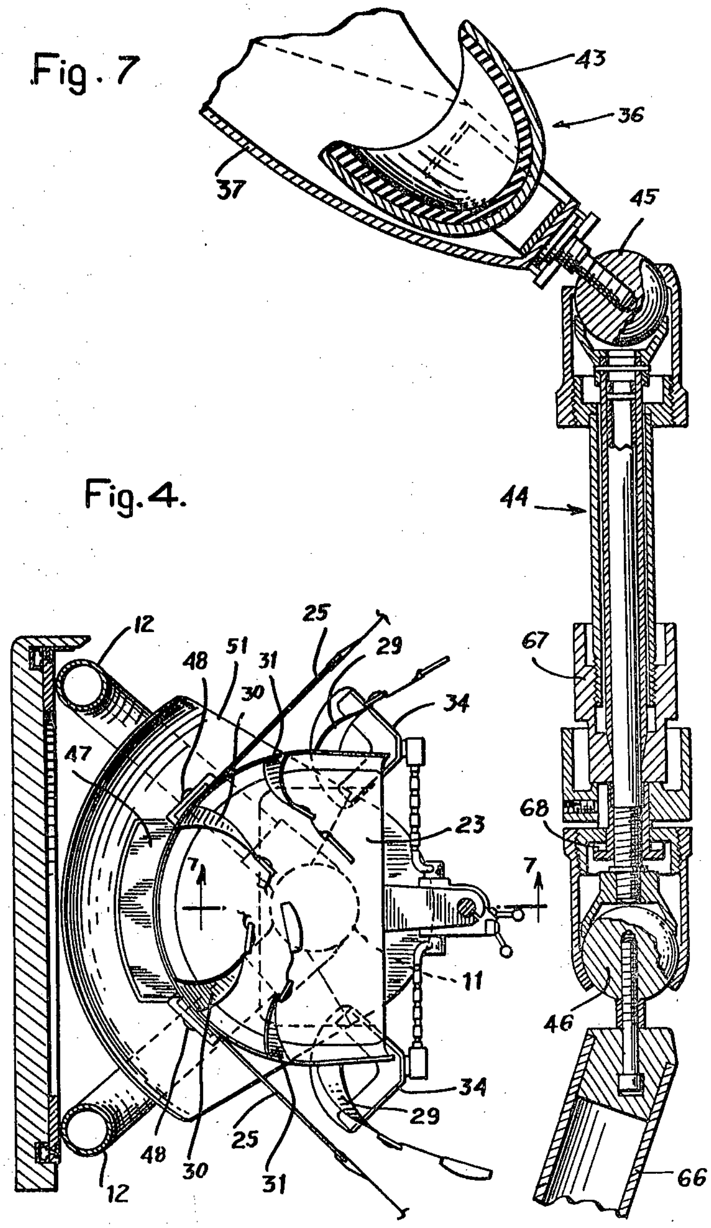

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Fig. 6.

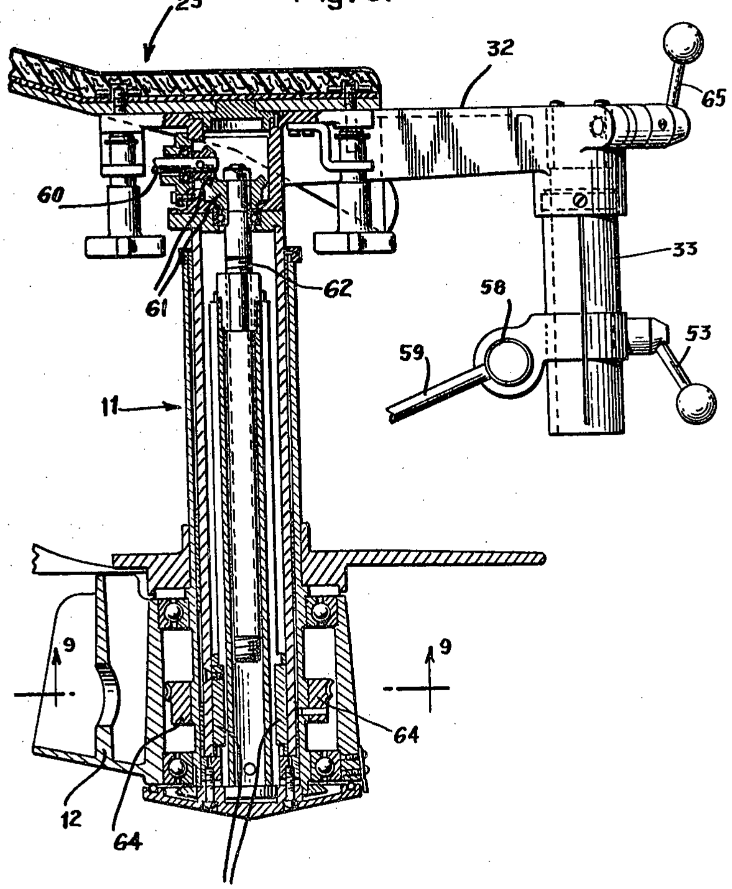

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Fig. 8.

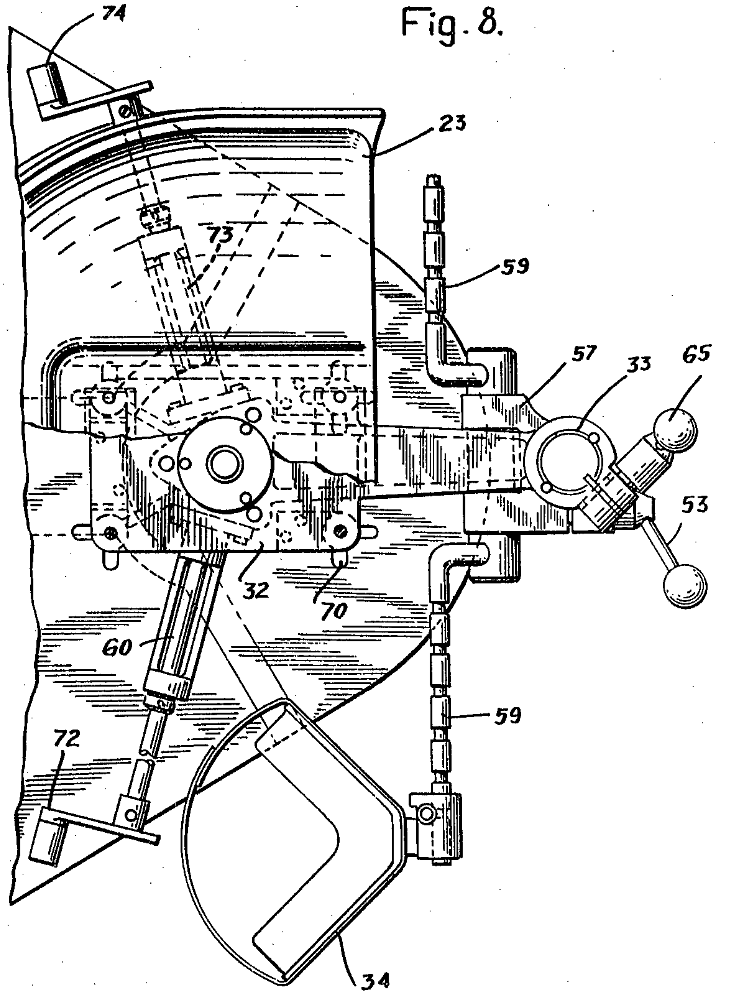


Fig. 9.

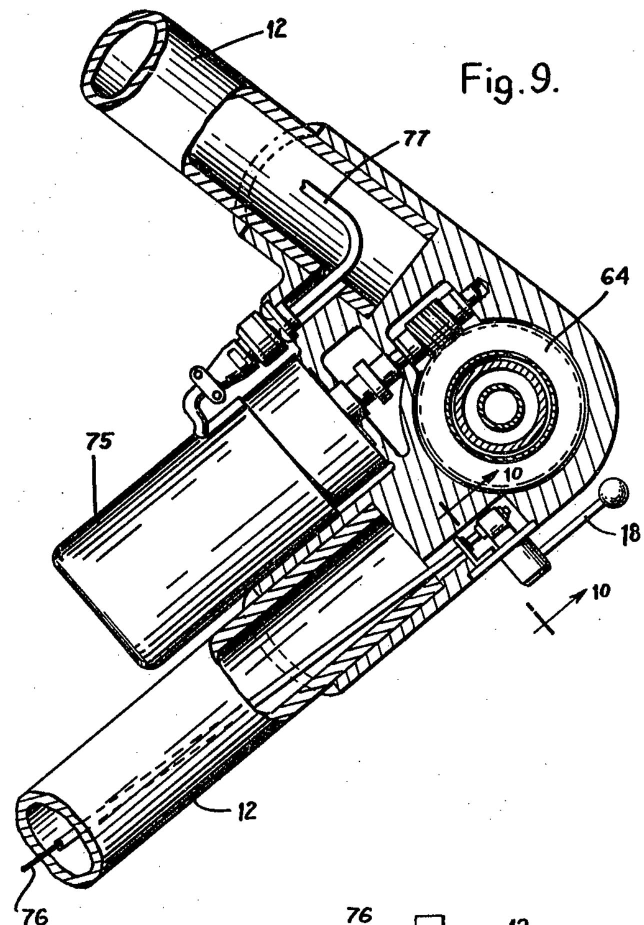
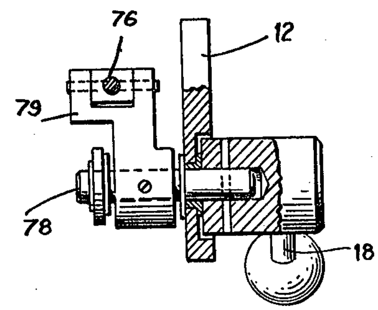


Fig. 10.



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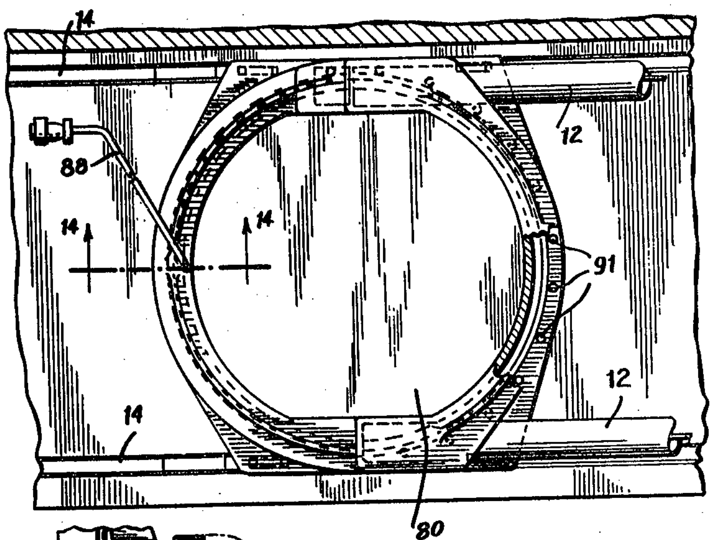

Fig. 11.

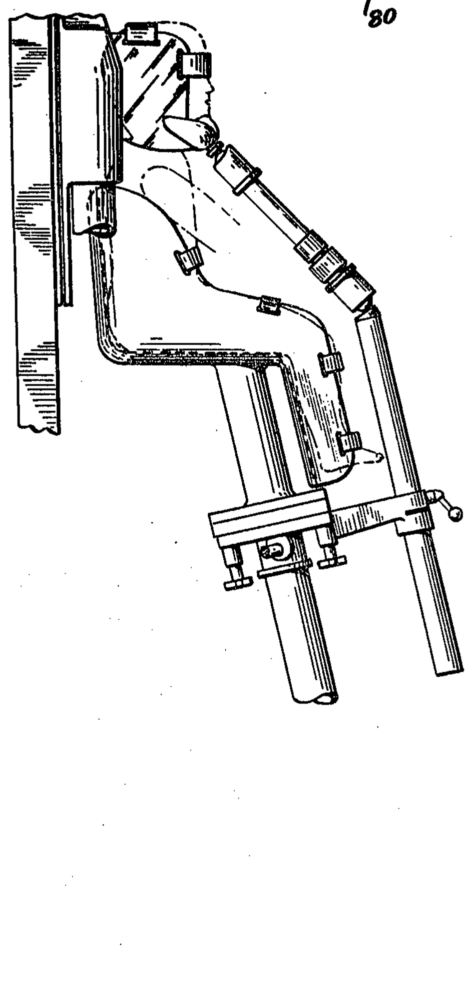

Fig. 20.

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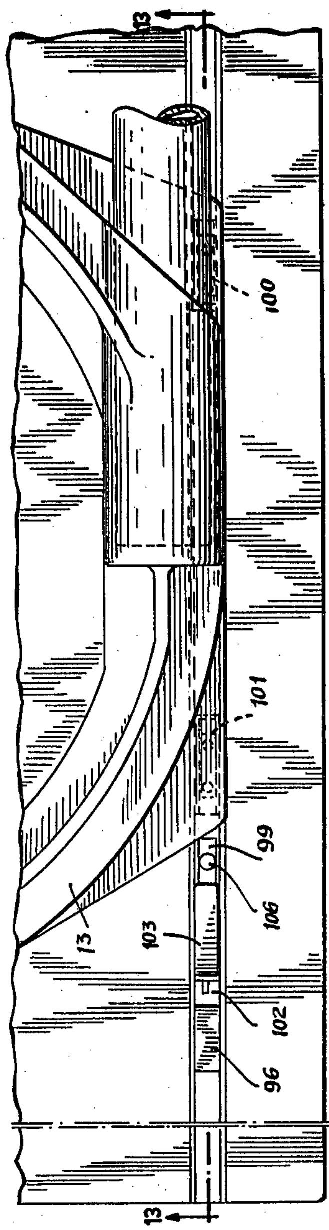


Fig 12

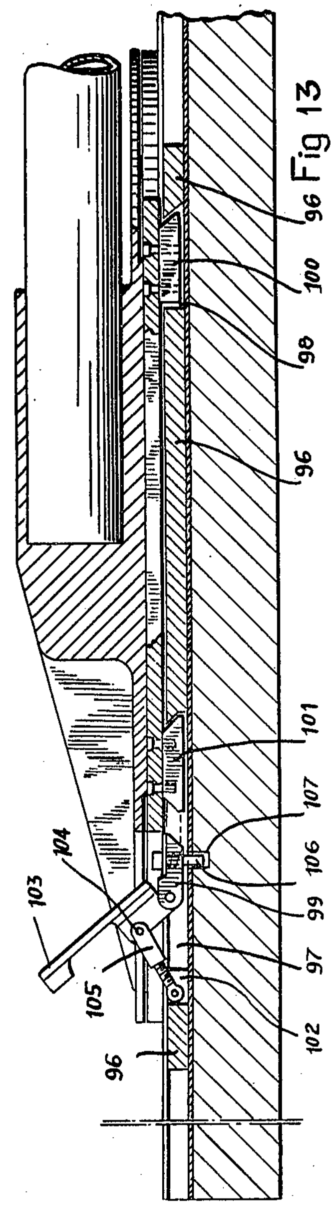
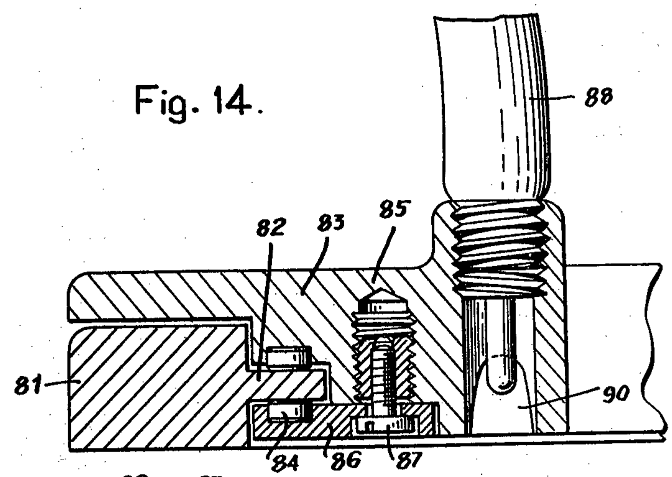


Fig 13

Fig. 14.



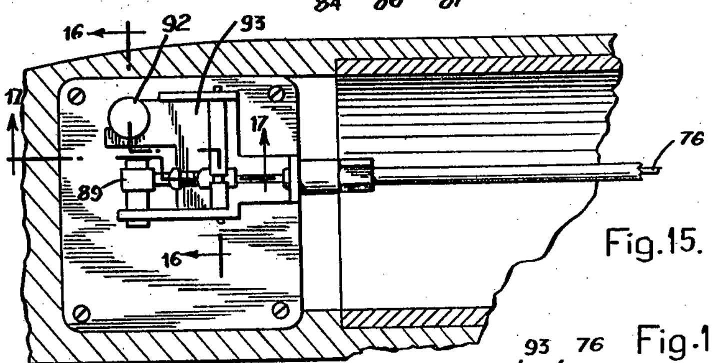
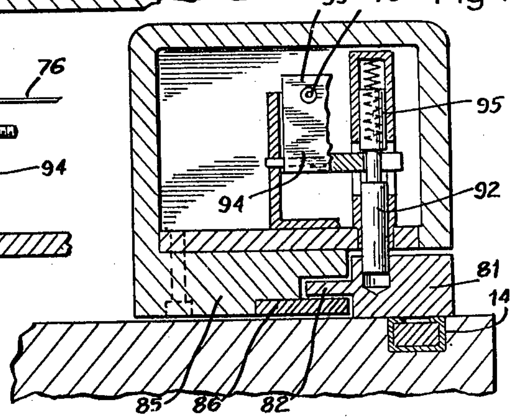


Fig.15.

Fig.16.



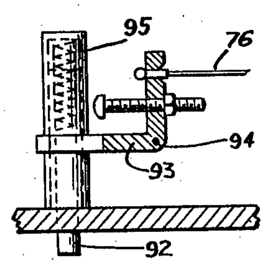


Fig.17.

Fig. 18.

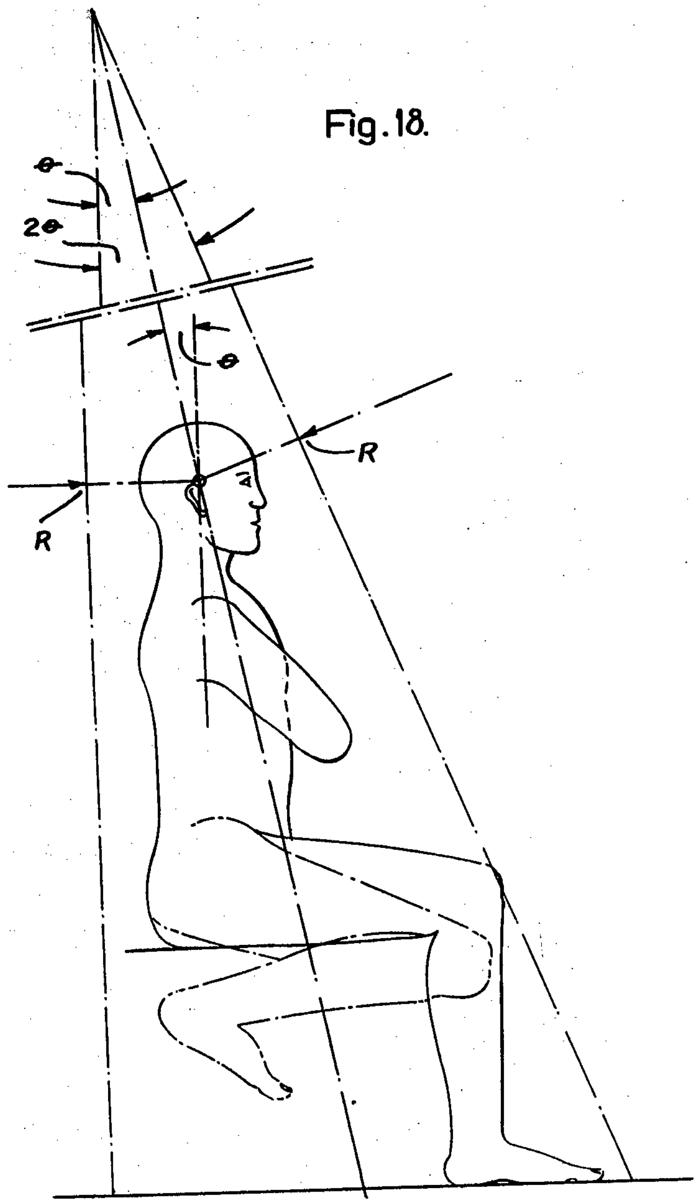
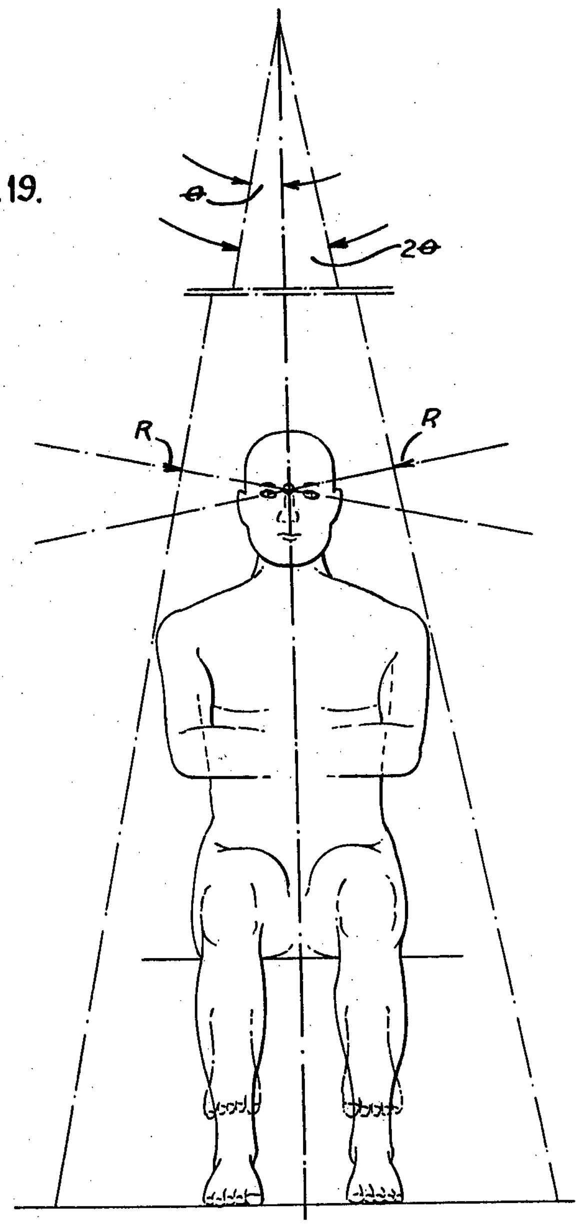


Fig. 19.



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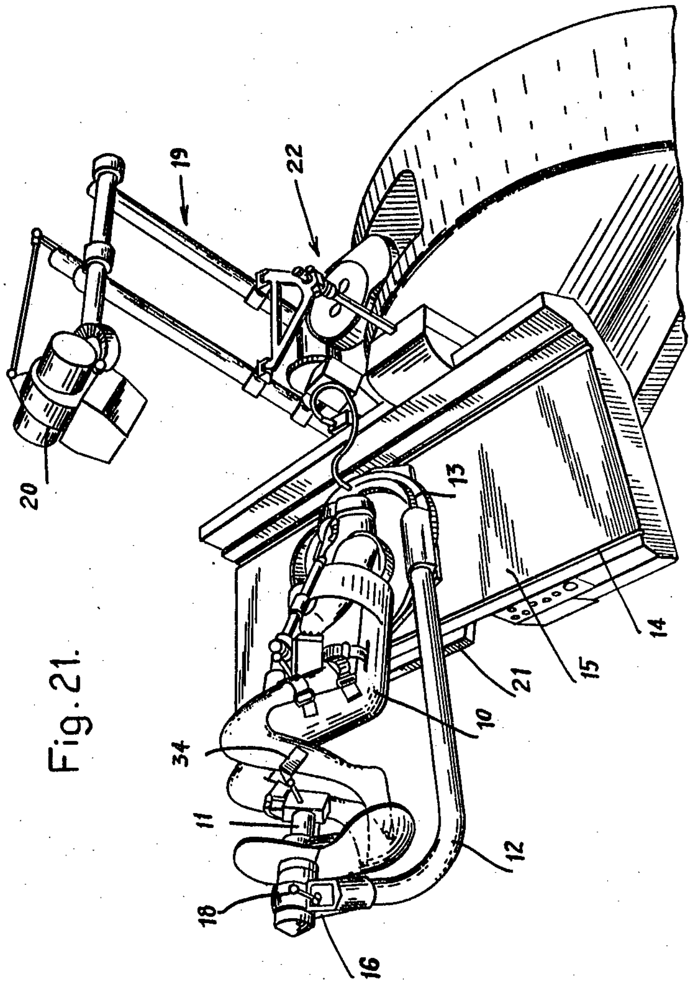

Fig. 21.