July 25, 1939. J. KIEFFER 2,167,116

SPHERICAL MOVEMENT RADIATION METHOD AND APPARATUS

Filed Sept. 10, 1937 3 Sheets-Sheet 1

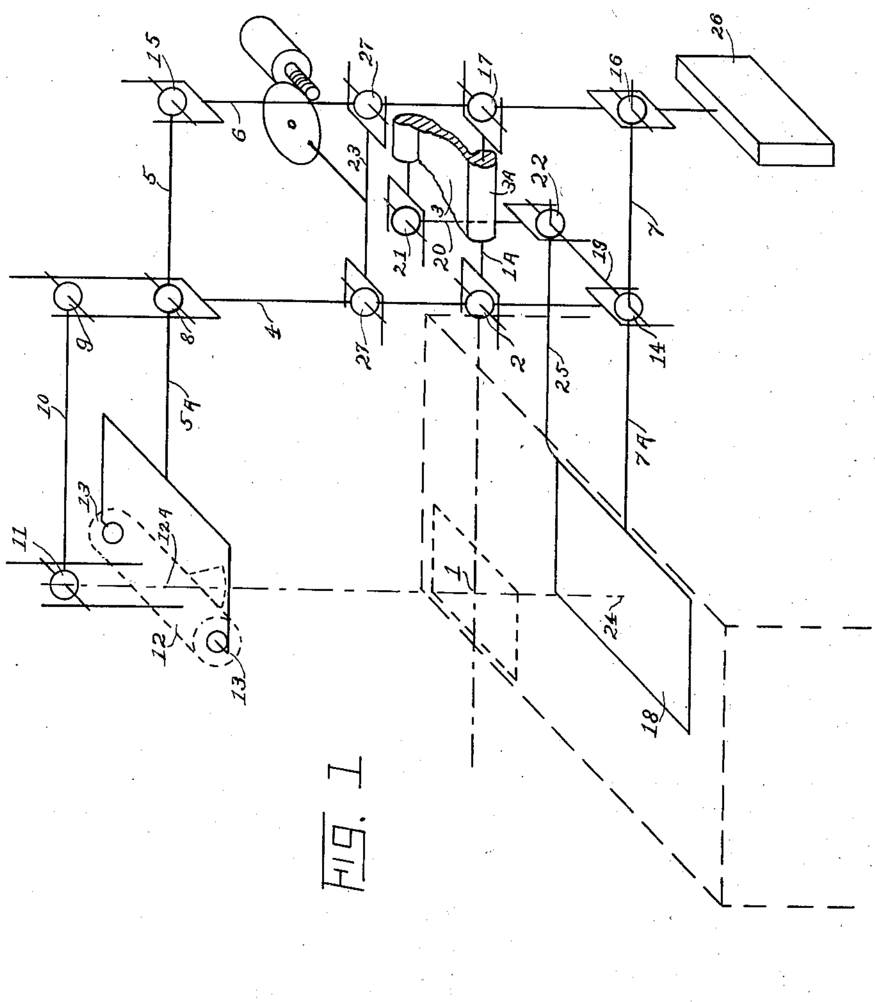

FIG. 1

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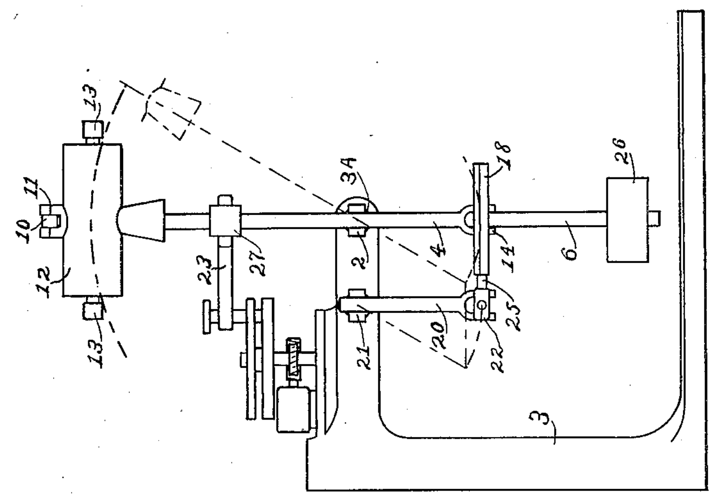

FIG. 3

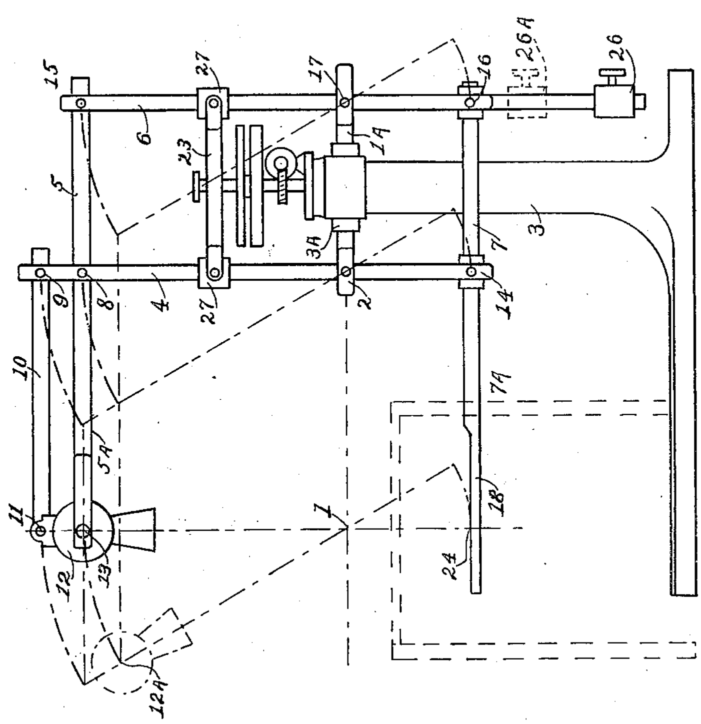

FIG. 2

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FIG. 4

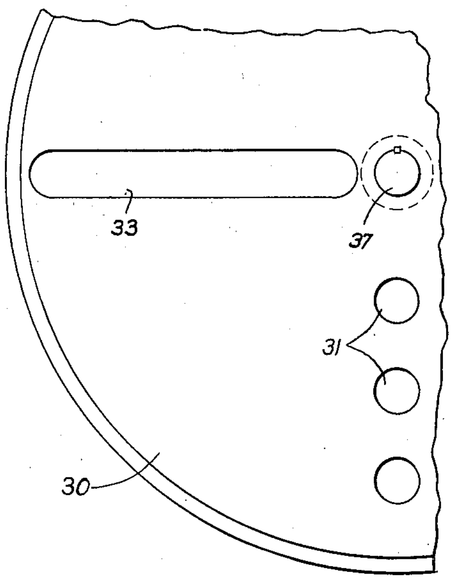


FIG. 5

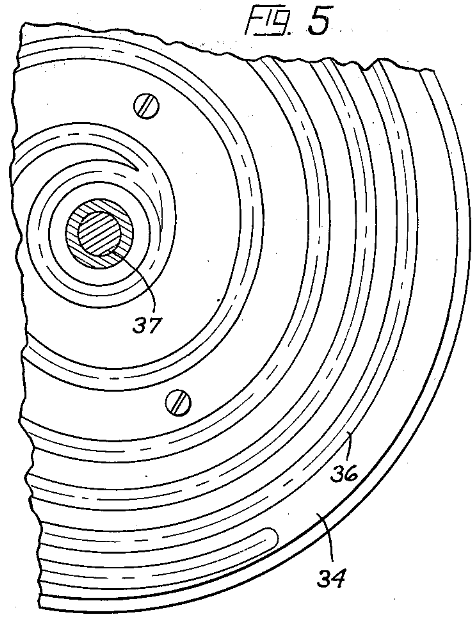
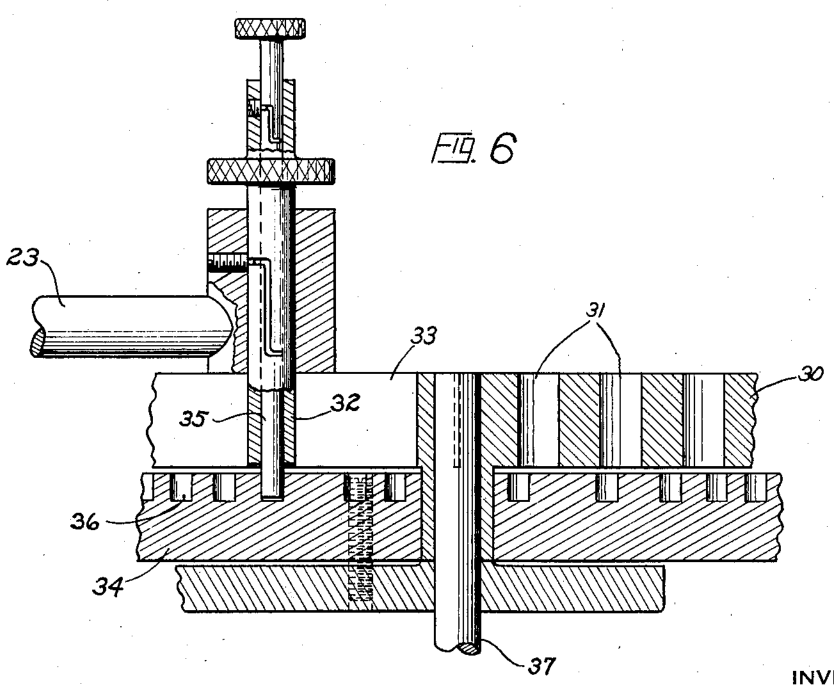


FIG. 6



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SPHERICAL MOVEMENT RADIATION METHOD AND APPARATUS

Jean Kieffer, Norwich, Conn.

Application September 10, 1937, Serial No. 163,220

12 Claims. (Cl. 250—58)

This invention relates to a method of, and an apparatus for, radiation visualization, or treatment, and, while here disclosed as being adapted for conventional X-ray practice, it will be understood that the principles of the invention may be applied to other types of radiation.

While the invention is disclosed as being directed to a method of, and an apparatus for, visualizing the interior points of the body through radiographic impressions, it is understood that the invention is also adapted for therapeutic treatment, the adaptation being simply provided for by utilizing the herein described method of moving the source of radiations without the use, or movement, of the conventional sensitive receiving medium and its associated structure.

The invention partakes of the desiderata of my prior patent, No. 1,954,321, and of my co-pending applications, including my application filed May 19, 1937, Serial No. 143,445; and, therewith, it is among the general objects to provide means for the virtual focusing of rays.

Another object of the present invention is to provide an alternative method and apparatus from that shown in my prior patent whereby such virtual focusing may be accomplished.

A further object is to provide a simplified structure for accomplishing such virtual focusing of rays.

From a consideration of the following specification and drawings, it will be noted that further objects of the invention are to provide a method of, and an apparatus for, virtual ray focusing which avoids the necessity of a superstructure for guiding the tube movement, and further provides a machine in which guides for film, or plate, movement are unnecessary.

This invention is, therefore, concerned with a simplification of the method and apparatus set forth in my prior patent and co-pending applications.

Numerous other objects and features of the invention will be apparent from a consideration of the following specification taken in conjunction with the accompanying drawings in which:

Figure 1 is a diagrammatic illustration of one form of the present invention.

Figure 2 is an end elevation of a machine built in accordance with the present invention; and

Figure 3 is a front elevation of the machine shown in Figure 2.

Figure 4 is a fragmentary plan view of an operating disk for use in the present invention,

Figure 5 is a similar view of a guide disk or templet, and

Figure 6 is a detail view showing a preferred arrangement of operating disk, templet, and link for imparting spherical movement to the tube.

The present invention provides for the virtual focusing of rays by movement of the emanating source along a spherical surface above the body as distinct from my prior patent which provides for the movement of a radiating source in a flat plane. When the device is used for radiographic work, a simultaneous and opposite movement in three dimensions over proportional concentric spherical surfaces is provided for in the film, or plate holder, which movement thus causes a blurring of bodies other than in a predetermined plane which contains the axis of the system and is parallel to the surface of the film.

It will be understood that the blurring phenomenon, which renders sharp shadows of objects in the pivotal plane and minimizes obscuring by other objects, is a result of simultaneous and opposite movement of tube and plate while retaining the tube to object distance at a fixed ratio with the object to the film distance. In my former patent, these ratios were maintained although the actual distances varied. In the present invention, the movement of the tube and plate on a spherical surface in three dimensions avoids any practical variation of tube to object distance and object to plate distance.

I am familiar with past suggestions that the tube might be moved arcuately, but such a method, or apparatus, therefor, would fail to give the focusing effect except in a rectilinear line in the plane of the arc of movement. By providing for sperical motion in three dimensions, a virtual focusing, symmetrical to any axis contained in the plane, may be achieved.

This device is adapted to the use of planigraphic movement along portions of spherical surfaces. The target and film move with spherical motions in three dimensions in such a way that the center of the target and a point of the surface in which the film lies move around a point on the visualized plane as a common center, that the film surface always remains parallel to the visualized plane, and that the center of the target and that point of the film surface are always opposite, and in a straight line with the point of the visualized plane used as a rotational center for the target motion.

Throughout the specification and in the claims the term "spherical motion" or "movement" has been utilized as has been the expression to movement "on the surface of a sphere". By such terms and expressions, reference is made to motion of the tube and/or plate other than in a single plane, but yet confined to the surface of a sphere and such terminology is used to differentiate from either circular or arcuate movement on the surface of the sphere. Circular motion which, while being motion on the surface of a sphere, is motion confined to a single horizontal plane, arcuate motion which would result from a rectilinear movement imparted to the structure is also motion in only a single plane in this instance the plane being vertical or at right angles to the plane in which movement would occur in circular motion. It will be noted that with the structure shown, any motion other than simple rotary or rectilinear motion, imparted to the tube must of necessity provide motion departing from the plane of its origin and yet confined to the surface of a sphere.

Prior art has suggested planar motion on the surface of a sphere both in a horizontal plane (circular motion) and in a vertical plane (arcuate motion). The present invention departs from prior teachings by providing "spherical motion" which may be further defined as a motion on the surface of a sphere in a curved line, the curve of which is a twisted or gauche curve, also referred to as a curve of double curvature. Spherical motion as here used, may also be defined as motion on the surface of a sphere involving a continual departure from any given plane. Spiro-spherical motion as used herein may be defined as such motion the projection of which on an equatorial plane is a spiral.

For the sake of simplicity, the drawings show these points to be at the center of the film surface and on the perpendicular passing through this center, respectively.

In the figures referred to, the numeral **1** is a point in the visualized plane, and **2** is the pivotal point in the whole system, located on a continuation of the visualized plane and stationary in respect to it, to support **3** and to the body radiographed. Hung at point **2**, which is the center of a system of gimbals, is a rod **4** forming part of the parallelogram system of links of which **5**, **6** and **7** are the remainder. Near the upper part of the rod **4** is a pivot **8** whose axis is perpendicular to both rods **4** and **5**.

The upper part of the rod **4** terminates in another pivot having an axis **9** parallel to the axis **8** and on which a rod **10** rotates. The rod **10** engages a pivot **11** on top of a tube supporting structure **12**, this structure being pivoted at **13** on an extension **5A** of the rod **5**, the distance between the axis **11** and the axis **13** being equal to that between **9** and **8**, and the pivots **8**, **9**, **11** and **13** forming the angles of another parallelogram system. The distances from **11** to **9** and **13** to **18** are also equal.

At the lower end of the rod **4** is a gimbal **14** which serves as a pivot for the rod **7** at that point. The rod **6** has a pivot **15** at its upper end which engages the rod **5**, and a gimbal **16** at its lower end which engages the rod **7**, as well as a gimbal **17** at a point which is such that the distances from the pivot **2** to the pivot **8**, and from the pivot **17** to the pivot **15** are equal, as well as the distances from the pivot **2** to the pivot **14** and from the pivot **17** to the pivot **16**. The distances of the pivot **8** to the pivot **15**, of pivot **2** to pivot **17**, and of the pivot **14** to the pivot **16** are also equal. All the above pivot points are so fixed to the rods that these distances remain constant during movement of the system.

The gimbals **2** and **17** are connected by a shaft **1A**, rotating in a sleeve **3A** in the support **3**, which keep their rotation coordinated and the relation of their centers to the support **3** and the point **1** constant.

An extension **7A** of the link **7** holds a plate carrier **18**, a center **24** of which is on an axis parallel to the link **4** and passing through the target of the tube and the center of the pivot **11**. The distance of the plate carrier **18** to the center of the gimbal **14** remains constant during motion. A link **19** and a link **20**, in conjunction with the lower part of the rod **4** and of the support **3** with gimbals **2**, **14**, **21** and **22**, form another system of parallelogram links which remains, at all times, at right angles to any plane that the parallelogram system, composed of links **4**, **5**, **6** and **7**, may assume. The parallelogram link system formed by gimbals **2**, **14**, **21** and **22** and acting through a rod **25** connected with the gimbal **22** and to the film carrier **18** will hold the latter, at all times, parallel to any initial position given to it, the axial point of the gimbal **21** being held stationary by the support **3** in regard to the pivot **2**.

A motor and turntable system can impart, through a link **23** and a sliding gimbal **27**, any predetermined motion to the rod **4** and consequently to the entire system. The motor and turntable system can be positioned anywhere in a stationary position relative to the pivot **2** and the support **3**; and the link **23** and the gimbal **27**, or equivalent means, can be positioned anywhere in the linkage system shown except, of course, at the stationary pivot points **2** and **21** and **17**.

Details of the structure which may be utilized for imparting an irregular, non-rotary or spiral motion to the link **23** is disclosed in Figures 4, 5, and 6 of the drawings, the same having been more fully set forth and claimed in my copending application, 143,445. In the drawings, Figure 4 is a fragmentary detail view of the rotary disk **30** shown in Figures 2 and 3. The disk **30** is provided with aperture **31** which may receive a pin **32** carried by the link **23** (see Fig. 6) and with the pin **32** engaging one of the apertures **31**, simple rotary motion will be imparted to the system and the tube or tube and plate will be moved in a rotary motion in a single plane. Such motion forms no part of the method of my present invention, although the apparatus is universal in being designed to permit such motion. It is to be noted that with a simple rotary motion imparted to the tube, the distance of the tube to the point **1** (see Figures 1, 2 and 3) will be constant as will be the plate distance, however, the angle of the ray impingement with respect to the point, one will also remain constant and since many X-ray practices both for theroptic and roentgenographic work prefer a motion in which distance remains constant but the angle of ray impingement is moved means are here provided for imparting other than simple rotary motion.

For imparting an irregular or non-circular motion to the link **23**, the disk **30** is provided with a radial slot **33** into which the pin **32** extends to receive its moving impulse from rotation of the disk **30** but being free for radial movement in the slot. Radial movement of the pin **32** in the slot **33** is provided for by a fixed guide plate, cam or templet, **34**, (see Figures 2, 3, and 5). The pin **32** is provided with an inner slidable guide pin **35** which as shown in Figure 6 may be moved to protrude from the pin **32** downward to engage in a guiding cam or groove, **36**, formed in the stationary templet **34**. It will be obvious that when the plate 30 is rotated with the pin 32 in the slot 33 and with the pin 35 engaging the groove 36, the groove will modify the circular motion of the link 23 so as to produce many desired types of irregular or non-circular rotary motion. A specific and preferred type of non-circular motion is provided by the spiral formation of the groove shown in Figure 5. With this spiral the concentration of rays passing through the surface of a body towards a given point 1 will be distributed over the surface so as to insure a maximum ray impingement of the point 1 with minimum ray impingement at any point on the surface of the body. The motion thus produced may be defined as spiro-spherical motion, as previously defined.

It will be further noted that since the linkage system is rigid that the tube will at all times be at a fixed distance from the point 1 as will be the center of the plate. This is accomplished by the present system in which the tube and plate travel is on the surface of a sphere, the center of which is the point 1 and in so moving the tube and plate depart from the plane of their starting point. With the spiral path shown, the tube will describe a spiral on the surface of the sphere. In Figures 1, 2 and 3, the position of parts shows the tube and plate lying in a common axis through the sphere, any movement from this position would involve a movement out of the plane of this position, and any irregular movement imparted to the link 23 will produce a spherical curve.

By further reference to Figure 6, it will be seen that the templet 34 is secured stationally while the disk 30 is adapted to be rotated by shaft 37 passing through templet 34 and driven by a motor as shown in Figures 2 and 3.

It is evident that, with such a system, any motion given to any part of it, relative to the pivot point 2, will carry the target of tube and the point 24 on the film surface through motion in three dimensions over spherical surfaces having their common center at 1; and that the tube, with its attending limiting cone, or diaphragm, will always remain pointed toward point 1. If the tube is energized during such motion, a planigraphic representation of the plane, passing through point 1 and parallel to the film surface, will result. A counterbalance 26 is of such weight and can be so adjusted that in a position 26A, closer to the gimbal 16 than that shown, it will exactly counterbalance the system so that the tube and film can be moved without much effort and in a smooth manner. With this in the full line position, it may act as a pendulum which can be used to give the system a rhythmic motion. The system may be so locked that motion in one plane only may be given to it, in which case, the resulting motion will be along circular arcs.

It is to be understood that, when the words "tube" and "target" are used, they are to be construed so as to mean not only the conventionl X-ray tube with its target, but also any device which can furnish suitable radiations. The word "tube" in this case is to mean any suitable supporting, holding, or generating means, and the word "target" is to mean the center of emission of the radiation.

It is also to be understood that a simplified device, consisting only of parts 1A, 2, 3, 4, 5, 5A, 6, 8, 9, 10, 11, 12, 13, 15, 17, 23, 26 and 27, will effect the focusing of the radiations in a small field in a body as for therapeutic use, the size of this field being controlled by the size of the opening through which the radiations leave the supporting, holding or generating structure 12, and by the distance of this aperture from the center of radiation 12A. This focusing effect will be obtained because the link system will keep the beam of radiation oriented at all times toward point 1, no matter how the structure may be displaced. The point 1 will then become the center of the above mentioned field.

With regard to "decentering" and plane selection, both of which are applicable to the present invention, reference may be had to my co-pending application Serial Number 163,219 filed herewith. For instance, by rotating the plate holder 18, with respect to 7A, various planes may be selected.

From the foregoing, it will be seen that the present invention provides a novel method, and means, for carrying out the objects of the present invention. Obviously numerous changes and modifications, and the full use of equivalents, may be resorted to without departure from the spirit, or scope, of the invention.

Having set forth the nature of my invention, what I claim is:

1. A method of subjecting a given point in a body to a concentration of X-rays which includes the step of subjecting the body to X-rays emanating from a moving source of ray emanation which is moving with non-planar spherical motion.

2. A method of subjecting a given point in a body to a concentration of X-rays which includes the step of subjecting the body to X-rays emanating from a moving source of ray emanation which is moving with non-planar spherical motion, the center of spherical curvature of which is the point in the body at which the total ray impingement is to be concentrated.

3. A method of subjecting a given point in a body to a cencentration of X-rays which includes the step of subjecting the body to X-rays emanating from a moving source of ray emanation which is moving with spiro-spherical motion.

4. A method of taking radiographic pictures which includes the step of simultaneously moving a source of ray emanation and a receiving medium on opposite sides of the body to be radiographed with non-planar spherical motion.

5. A method of taking radiographic pictures which includes the step of simultaneously moving a source of ray emanation and a receiving medium on opposite sides of the body to be radiographed with spiro-spherical motion.

6. A method of taking radiographic pictures which includes the step of simultaneously moving a source of ray emanation and a receiving medium on opposite sides of the body to be radiographed with motion in a spiral path on the surface of a sphere the center of which is approximately at the point in a body of which the radiographic picture is desired.

7. A method of radiographic visualization of a predetermined internal portion of a body which includes the step of subjecting the body to ray emanations from a source of radiations while the source is moving with spiral motion on the surface of a sphere the center of which is approximately the center of the predetermined internal portion of the body to be visualized and simultaneously moving on the opposite side of the body a receiving medium which is moved with similar motion 180 degrees out of phase with the motion of the tube.

8. A radiological apparatus comprising a struc-

ture adapted to support a source of ray emanation for movement in all directions over the surface of a sphere and means for imparting non-planar spherical motion to said support.

9. A radiological apparatus comprising a structure adapted to support a source of ray emanation for movement in all directions over the surface of a sphere and means for imparting spiro-spherical motion to said support.

10. A radiological apparatus comprising a structure adapted to support a source of ray emanation on one side of a body and to support a receiving medium on the opposite side of the body and to permit movement of said source of emanation and said receiving medium in all directions over the surface of a sphere and means for imparting non-planar spherical motion to said source of ray emanation and to said receiving medium.

11. A radiological apparatus comprising a structure adopted to support a source of ray emanation on one side of a body and to support a receiving medium on the opposite side of the body and to permit movement of said source of emanation and said receiving medium in all directions over the surface of a sphere and means for imparting spiro-spherical motion to said source of ray emanation and to said receiving medium.

12. In a radiological apparatus, a tube support, a plate support, a pivoted connecting device between said support adopted to move said supports in all directions over the surface of a sphere and means for imparting spiral motion to said support whereby said tube and plate will be simultaneously moved with spiro-spherical motion 180° out of phase.

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