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Mattsson

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[54] **APPARATUS FOR ALTERNATELY IRRADIATING AN OBJECT BY MEANS OF AT LEAST TWO RADIATION SOURCES**

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[52] **U.S. Cl.** **250/497,** 250/498, 250/494

[51] **Int. Cl.** **G21h 5/00**

[58] **Field of Search**........ 250/83.3 D, 106 R, 106 S, 250/494, 497, 498

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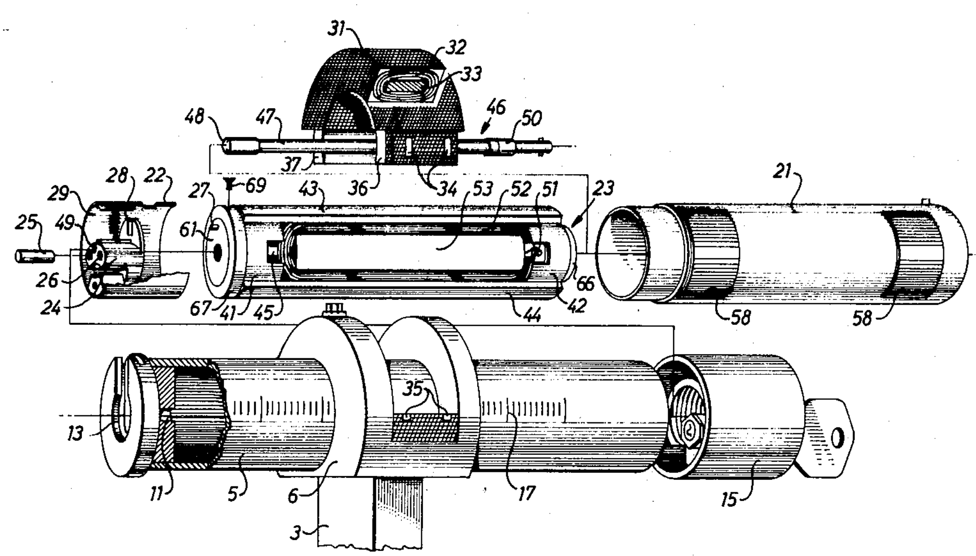
[57] **ABSTRACT**

This application discloses an apparatus for alternately irradiating an object by means of a radioactive source and at least one further radiation source. The sources are mounted in a holder pivotably arranged within a tubular housing being longitudinally diplaceable in a bracket and having a collimator opening, a selected source being brought into radiation position aligned with said collimator opening by turning said holder. The holder is turned by means of a longitudinal armature or permanent magnet system coupled to said holder in said housing and being pivotable around a longitudinal axis due to magnetic action at any portion of its length, said magnetic action being provided by an electromagnet arranged in connection with said bracket.

17 Claims, 6 Drawing Figures



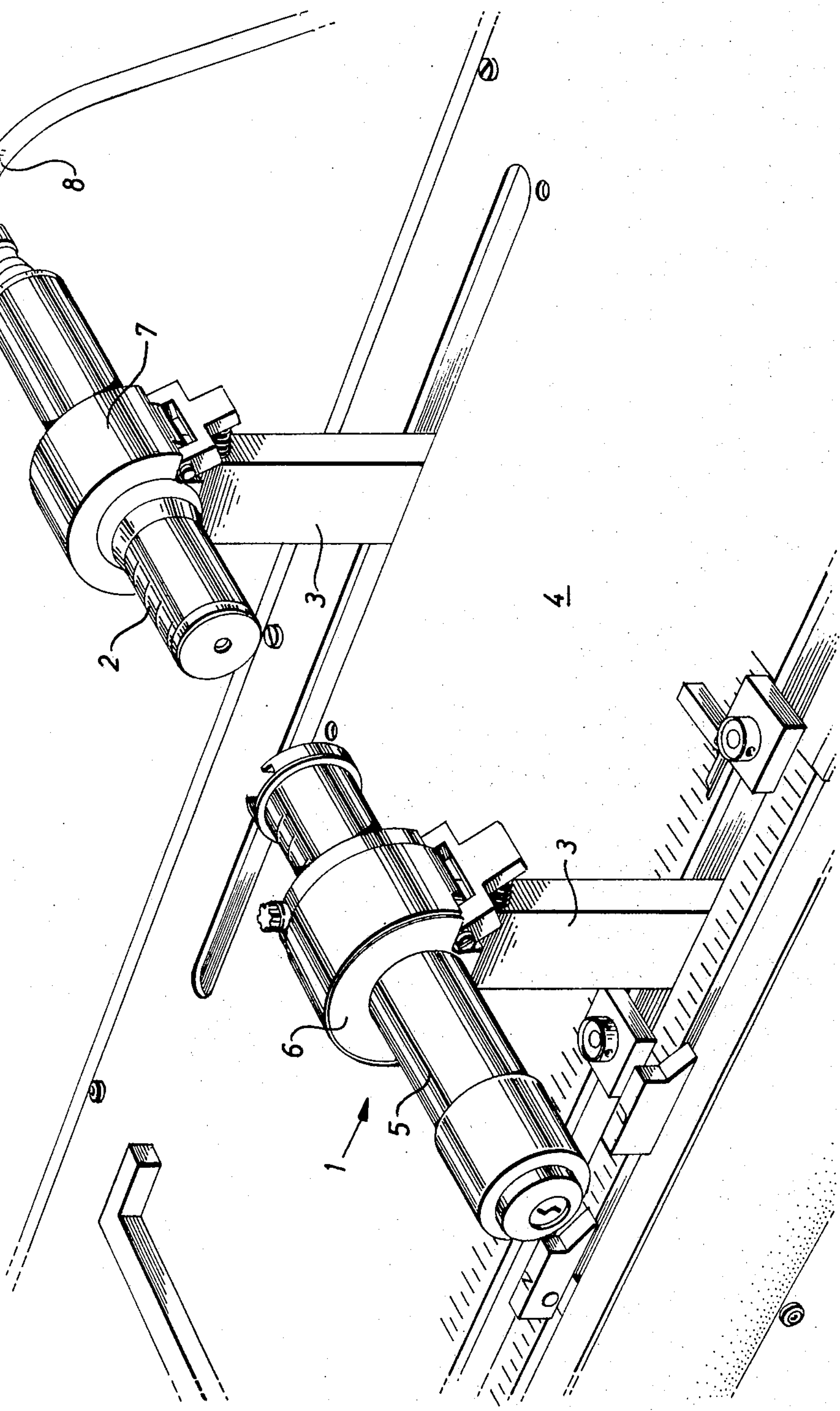


Fig. 1

Fig. 2

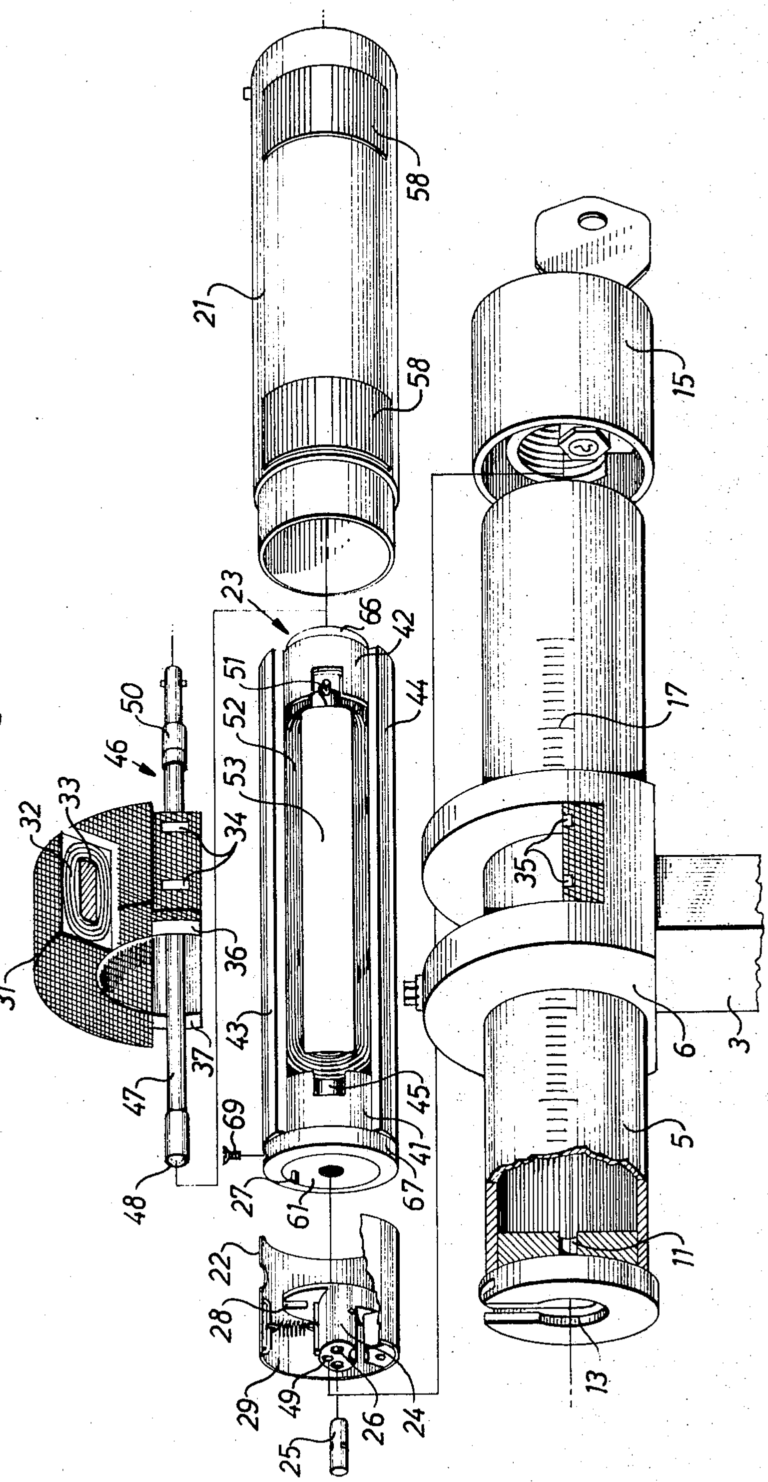

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Fig. 3

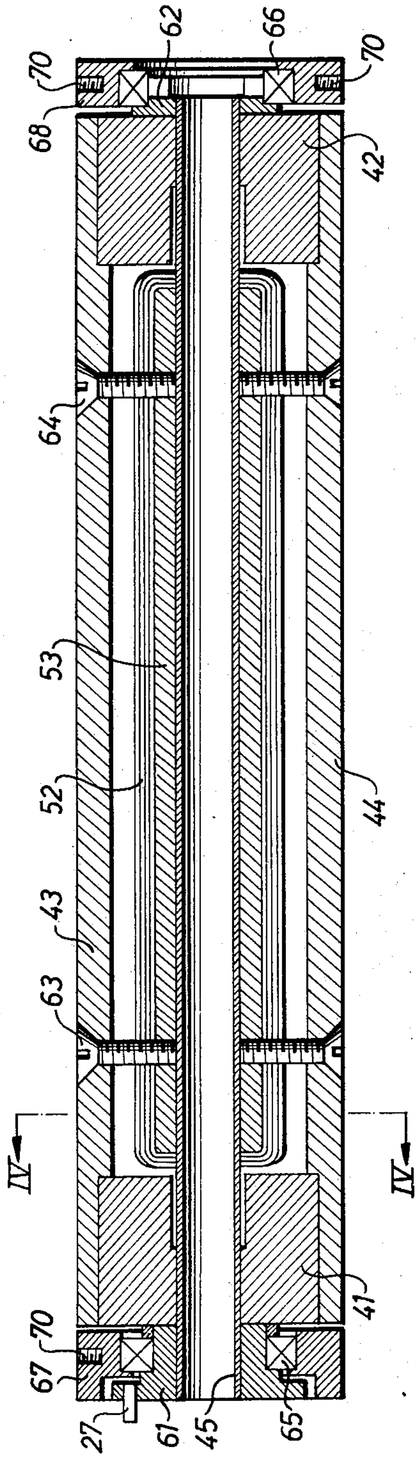


Fig. 5

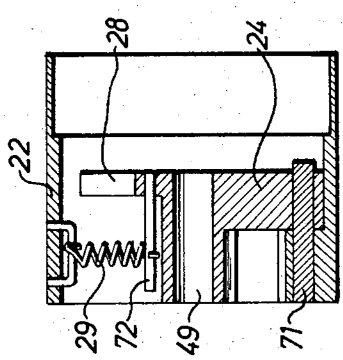
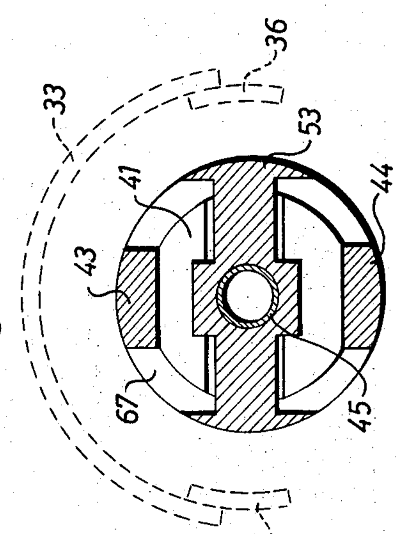


Fig. 4



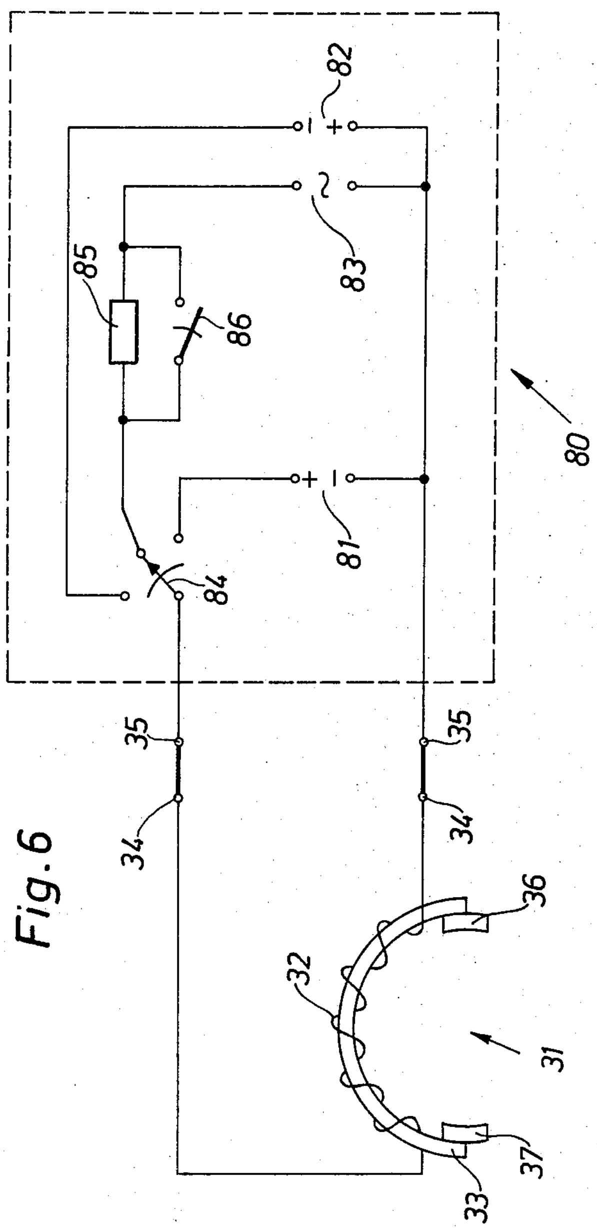


Fig. 6

APPARATUS FOR ALTERNATELY IRRADIATING AN OBJECT BY MEANS OF AT LEAST TWO RADIATION SOURCES

This invention relates to an apparatus for selectively alternately irradiating an object by means of at least two radiation sources, at least one of which is a radioactive source. The apparatus according to the invention is particularly adapted to be used in an osteodensitometer, that is when measuring bone density. In such a case the part of the body to be examined is placed between a radioactive source and a detector and the absorbtion of the radioactive radiation in the bone of said part of the body is measured. The apparatus according to the invention is particularly advantageous when using the so-called two-isotope method which premises alternate reproducable measurements by means of two different radioactive isotopes.

When designing an apparatus of the type mentioned in the beginning, current rules of radiation protection must be followed. Furthermore, it is desirable that the portion of the apparatus in which the radiation sources are arranged can be removed and has no direct connection with the control means for effecting the switching of the radiation sources, which means that the sources can be easily kept locked up when they are not used. It is also desirable that said portion is displaceable so that the distance between the sources and the object to be irradiated — or the detector used — can be easily varied.

According to the invention there is provided an apparatus that meets the abovementioned requirements and objects desired. The apparatus according to the invention is characterized in that it comprises a tubular housing having a collimator or diaphragm opening, said housing being longitudinally displaceable in a bracket; a pivotable means arranged within the housing in connection with said collimator opening, the two radiation sources being mounted in said pivotable means, so that when said pivotable means is in a first position one of said radiation sources is in radiation position aligned with the collimator opening, and when said pivotable means is in a second position the other radiation source is in radiation position aligned with the collimator opening; an armature or permanent magnet system arranged in said housing and extending in the longitudinal direction of said housing and being pivotable around a longitudinal axis into two extreme positions due to magnetic action at any portion of its length, said pivotable system being coupled to said pivotable means so that one of said extreme positions of the pivotable system corresponds to said first position of the pivotable means and so that the other extreme position of the pivotable system corresponds to said second position of the pivotable means; and at least one electromagnet arranged outside said housing in connection with said bracket for selectively turning said pivotable system by magnetic action independently of the axial position of the housing in said bracket.

It has turned out to be advantageous to use a permanent magnet system arranged to provide at least one longitudinal northmagnetic pole and one longitudinal southmagnetic pole for active force interaction with poles produced by an electromagnet when energized by direct current in order to turn the permanent magnet system. According to a preferred embodiment the permanent magnet system includes two permanent magnets rotatably journalled at the ends of the tubular housing and two longitudinal pole pieces that connect the two permanent magnets to each other to form said longitudinal poles. In this case the apparatus advantageously includes a single U-shaped electromagnet that partly surrounds the tubular housing.

Particularly when both of the radiation sources consist of radioactive isotopes the apparatus according to the invention can include means for affecting said pivotable means and/or said pivotable system to bring the pivotable means and the pivotable system into a neutral position between said extreme positions, whereby uncontrolled radioactive radiation — for instance due to external mechanical action which might bring the pivotable system into any of the extreme positions — is prevented. For instance, said means can include springs.

When using a permanent magnet system, one or more iron pieces can be secured within the tubular housing or in the wall of the tubular housing — preferably at the ends of the housing so that the field of the electromagnet or electromagnets are influenced as little as possible — so that the interaction between the permanent magnet system and said iron pieces tends to bring the permanent magnet system to said neutral position.

When using a pivotable permanent magnet system, it is also possible to provide an active stabilization of the permanent magnet system in said neutral position by letting said system include an iron core which in neutral position is symmetrically located relative to an electromagnet used for turning said system when energized by direct current and by supplying alternating current to said electromagnet in order to produce a pulsating magnetic field that tends to keep the iron core and thus said system in the neutral position.

In order to facilitate an exact determination of the spot on the object which is struck by the emitted radiation a source of directional light can be provided in the tubular housing, so that a light beam can be emitted through the collimator opening when the pivotable system and thus the pivotable means is in the above mentioned neutral position. Obviously, it is also possible to let one of the two radiation sources be a source of directional light.

In accordance with a preferred embodiment of the apparatus according to the invention a source of directional light is provided axially aligned with the collimator opening, said pivotal means having an opening permitting light emission when said means is in the neutral position. Advantageously, the source of directional light can be supplied with current from a coil arranged in the tubular housing and preferably wound on a longitudinal iron core, said core being arranged to be turned together with the pivotable system. In this case, means for producing a pulsating magnetic field passing through said coil when directional light it to be emitted are arranged outside the housing, preferably in connection with the bracket. Said means might include the electromagnet or electromagnets and a device for supplying alternating current to said electromagnet or electromagnets.

When using a permanent magnet system including an iron core intended for stabilization in the neutral position, as mentioned above, suitably, said coil can be wound on said iron core. In this case one and the same electromagnet can be used for producing the necessary stabilizing pulsating magnetic field and for inducing a voltage in the coil. Preferably the electromagnet is supplied with a low alternating current for stabilization, as soon as the electromagnet is not supplied with direct current in order to turn the pivotable system. This low alternating current is not large enough to produce a pulsating magnetic field that makes the source of directional light radiate noticeably. When directional light is wanted, the electromagnet is supplied with a substantially higher alternating current. In this way a substantially longer life of the source of directional light is obtained.

The invention will now be described more closely by an example with reference to the accompanying drawings in which

FIG. 1 shows an apparatus according to the invention used in an osteodensitometer,

FIG. 2 is an exploded view of the apparatus used in FIG. 1.

FIG. 3 shows an axial vertical sectional through the permanent magnet system **23** disclosed in FIG. 2.

FIG. 4 shows a cross section taken at lines IV—IV of FIG. 3 and, furthermore, in broken lines the relative position of a used electromagnet,

FIG. 5 shows an axial vertical section through the front tube portion disclosed in FIG. 2, said portion enclosing a tilting holder for the radiation sources, and

FIG. 6 schematically shows a circuit for supplying current to the electromagnet used.

The osteodensitometer partly shown in FIG. 1 comprises an apparatus **1** according to the invention for selective alternate irradiation of a part of a body (not shown) by means of two different radioactive isotopes, for instance I **125** and Am **241**, a detector **2** for detecting the radiation that has passed through said part of a body, a fork **3** supporting the apparatus **1** and the detector **2**, and a frame construction **4** in which said fork **3** is suspended. The construction **4** contains means for displacing the fork **3** in accordance with a programmable scanning pattern and means for automatically switching from one to another of the isotopes located within the tubular housing **5** of the apparatus **1** by means of an electromagnet arranged in the bracket **6**, as will be described more closely below. The housing **5** is axially displaceable in its bracket **6** and the detector **2** is axially displaceable in a corresponding bracket **7**. Furthermore, the detector **2** is connected to a calculating device, for instance a computer, via a cable **8**.

When using the osteodensitometer the part of the body to be examined is placed between the apparatus **1** and the detector **2**, after which the housing **5** and the detector **2** are adjusted so that suitable distances between the apparatus **1** and the part of the body and between the part of the body and the detector, respectively, are obtained. By means of a source of directional light enclosed in the apparatus **1** it is checked that the radioactive radiation will strike the right spot on the part of the body, after which a programmed scanning operation is made using each of the two radiation sources.

In FIG. 2 the apparatus according to invention is shown in more detail. As already mentioned the apparatus includes a tubular housing **5** displaceably arranged in a bracket **6**. The housing **5** is made of non-magnetic material and in accordance with current rules as to radiation protection. One end of the housing is provided with a collimator or diaphragm opening **11** and with an external slot **13** for a filter, if wanted. The other end of the housing is provided with a closure means **15** which can be locked. When said closure means is removed, the housing **5** can be easily inserted into or withdrawn from the annular bracket **6**. Furthermore, the housing is provided with external position marks **17**.

Within the housing **5** there is secured a non-magnetic inner tube including a main tube portion **21** and a front tube portion **22**. A permanent magnet system **23** is rotatably journalled in said main tube portion **21** (more closely described in connection with FIG. 3) and a tilting holder **24** for two radioactive sources **25, 26** is pivotably mounted in said front tube portion **22** (more closely described in connection with FIG. 5). The radioactive isotopes are arranged in casings, that are sealed by means of a thin titanium film. The casings are inserted into borings in the tilting holder **24**, said borings being located on a circle passing through the tube center and havings its centre on the axis of rotation of the tilting holder. A further boring **49** is a through-hole intended for the emission of directional light in a neutral position, as will be described later on. The tilting holder is arranged to be kept in the neutral position by means of a spring **29**. Furthermore, the tilting holder **24** is coupled to the permanent magnet system **23** by means of a slot **28** and a pin **27**, said pin being secured to an inner rotatable bearing cage **61**. A ball bearing **65** (FIG. 3) is mounted between the inner bearing cage **61** and an outer fixed bearing cage **67**. Corresponding bearing cages **62, 68** (FIG. 3) enclose a ball bearing **66** at the other end of the permanent magnet system **23**.

A detachable electromagnet **31** is arranged in the bracket **6** for turning the permanent magnet system **23** and consequently the tilting holder **24** in order to bring one or other of the radiation sources **25, 26** into radiation position in front of the collimator opening **11**. The winding **32** of the electromagnet is wound on a core **33** and supplied with current from a control device via contacts **34, 35** and cables through the bracket **6** and the fork **3**. The electromagnet is provided with pole pieces **36, 37** located on diametrically opposed sides of the cylindrical housing **5** and substantially in a horizontal plane.

The permanent magnet system **23** includes two cylindrical permanent magnets **41** and **42**, the magnets being provided with grooves and being connected with each other by two soft iron pole pieces **43, 44**, one of said pieces forming a longitudinal north-magnetic pole and the other one of said pieces forming a longitudinal south-magnetic pole. When in neutral position the two poles which are diametrically opposed to each other are in a substantially vertical plan, that is in a plane normal to the plane in which the poles produced by the electromagnet **31** appear. Thus, when the electromagnet **31** is DC-energized the permanent magnet system **23** will be turned from the neutral position into an extreme position in which one of the radiation sources **25, 26** is aligned with the collimator opening due to active force interaction between the two longitudinal poles of the permanent magnet system and the poles produced by the electromagnet. The turning direction will be determined by the direction of the current in the electromagnet **31**, that is reversing the direction of the current means a switching from one radiation source to the other. Due to the fact that the poles of the permanent magnet system are longitudinal ones the above mentioned interaction will be independent of the axial position of the tubular housing **5** in the bracket **6.**

The permanent magnets **41, 42** are fastened to an axial tube **45** passing all through and being fixed to the inner bearing cages. A source of directional light **46** is intended to be inserted into the axial tube **45.** Said source of directional light **46** includes a lamp **48** mounted in a lamp tube **47,** the lamp being able to emit a beam of directional light through a hole **49** in the tilting holder and the collimator opening **11** when the permanent magnet system **23** and the tilting holder **24** are in neutral positions. One terminal of the lamp **48** is connected to the lamp tube **47,** the lamp tube being connected to the axial tube **45** via a contact not shown, and the other terminal of the lamp is connected to an annular contact **50** on the lamp tube **47** via a cable within said lamp tube. The annular contact **50** connects said other terminal of the lamp to an insulated contact **51** in the axial tube **45.** The lamp is supplied with current from a coil **52** arranged in the permanent magnet system, the end terminals of said coil being connected to said axial tube **45** and the contact **51,** respectively. The coil **52** is wound on an iron core **53** secured to the axial tube **45,** said core being arranged so that a voltage bringing the lamp **48** to give light is induced in said coil when an alternating current is supplied to the electromagnet **31** due to the fact that a pulsating magnetic field passes through the coil.

The design of the iron core **53** will be better understood from FIG. **4** that shows a cross section through the permanent magnet system **23,** the coil **52** being omitted for the sake of clearness. Also the relative position of the electromagnet **31** has been illustrated by showing the core **33** and the pole pieces **36, 37** of the electromagnet in broken lines. When the electromagnet is energized, the iron core **53** will be affected by the magnetic field between the pole pieces **36, 37** and, consequently, tend to remain symmetrically between the pole pieces, that is in the neutral position. Therefore, the iron core must be designed so that when the electromagnet is DC-energized in order to turn the permanent magnet system the above-mentioned retaining effect will be comparatively unessential relative to the force interaction between the poles appearing on the pole pieces **36, 37** of the electromagnet and the longitudinal poles appearing on the pole pieces **43, 44** of the permanent magnet system **23.**

However, the above mentioned retaining effect can be advantageously used for positiv stabilization of the permanent magnet system **23** in the neutral position. Thus, it is suitable to supply stabilizing alternating current to the electromagnet **31** as soon as the electromagnet is not supplied with direct current for bringing a radiation source into radiation position. In order to decrease the time during which the lamp **48** emits light and consequently to increase its life, said stabilizing alternating current is essentially less than the alternating current supplied when a beam of directional light is wanted.

In order to further stabilize the permanent magnet system **23** and thus also the tilting holder **24** in the neutral position, two sheets of soft iron **58** are inserted in the main tube portion **21** (FIG. **2**). The sheets are arranged so that the effect of the permanent magnet system thereon will be asymmetrical and tend to reset the permanent magnet system as soon as the system is not in the neutral position. The sheets are positioned as close to the ends of the tube portion **21** as possible in order to influence the field of the electromagnet **31** slightly.

In FIG. **3** there is shown an axial vertical section through the permanent magnet system illustrating the construction and support of the permanent magnet system in more detail. The permanent magnets **41, 42** are fitted onto the axial tube **45** and are fixed by means of the inner bearing cages **61, 62** tightly fitted onto the axial tube **45,** the pole pieces **43, 44** which are cemented to the permanent magnets acting as spacer means. The iron core **53** of the coil **52** is mounted between the permanent magnets and fixed relative to the axial tube **45** by means of screws **63, 64.** The inner bearing cages **61, 62,** one of which **61** supports the pin **27** that cooperates with the slot **28** in the tilting holder, support the bearings **65, 66.** On the outside the bearings are arranged in the outer bearing cages **67, 68** (the bearing cage **68** not shown in FIG. **2**), which are secured to the main tube portion **21** by means of screws **69** (FIG. **2**) and corresponding screw holes **70** in the outer bearing cages **67, 68.**

FIG. **5** illustrates the mounting of the tilting holder **24** in the front tube portion **22.** As evident from said figure the tilting holder is mounted at its lower end on a pivot pin **71** secured to the tube portion **22.** Furthermore, the filting holder is connected to one end of a spring **29** by a pin **72** at its upper end, the other end of said spring being connected to the tube portion **22.** The spring tends to bring the tilting holder into the neutral position, in which the directional light opening **49** is aligned with the collimator opening **11.**

Finally, FIG. **6** shows a simple circuit for supplying direct or alternating current to the winding **32** of the electromagnet **31.** The winding **32** is connected to a control device **80** via the contacts **34, 35.** The control device **80** includes two DC-sources **81, 82** and an AC-source **83,** said sources being selectively connectable by means of a control switch **84.** The DC-sources **81, 82** are coupled so as to give direct currents of opposite directions in the winding **32.** The AC-source **83** is normally connected via a resistor **85** for supplying stabilizing alternating current to the winding **32.** The resistor **85** can be shunted by means of a switch **86** for supplying the winding **32** with an alternating current of such a strength that directional light is emitted.

What is claimed is:

1. In an apparatus for selectively alternately irradiating an object by means of at least two sources of radiation and wherein at least one of said sources is a radioactive one, the combination comprising a bracket, a tubular housing having a collimator opening, said housing being longitudinally displaceable in said bracket, pivotable means arranged within said housing in connection with said collimator opening, said two radiation sources being mounted in said pivotable means such that when said pivotable means is in a first position one of said radiation sources is in radiation position aligned with said collimator opening, and when said pivotable means is in a second position the other radiation source is in radiation position aligned with said collimator opening, a magnetically operable system arranged in said housing and extending in the longitudinal direction of said housing and being pivotable around a longitudinal axis into two extreme positions due to magnetic action at any portion of its length, said magnetically operable system being coupled to said pivotable means such that one of the extreme positions of said magnetically operable system corresponds to said first position of said pivotable means and the other extreme position of said magnetically operable system corresponds to said second position of said pivotable means, and at least one electromagnet arranged outside of said housing in connection with said bracket for selectively turning said magnetically operable system by magnetic action independently of the axial position of said housing in said bracket.

2. Apparatus according to claim **1** wherein said magnetically operable system is a permanent magnet system arranged to produce at least one longitudinal north-magnetic pole and one south-magnetic pole for interaction with poles produced by said electromagnet when energized with direct current for turning said permanent magnet system.

3. Apparatus according to claim **2** wherein said permanent magnet system includes two permanent magnets rotatably mounted at the ends of said tubular housing and two longitudinal pole pieces connecting said permanent magnets to each other to form said longitudinal poles.

4. Apparatus according to claim **2** wherein said electromagnet is U-shaped and partly surrounds said tubular housing.

5. Apparatus according to claim **1** and which further comprises means for bringing said pivotable means and said magnetically operable system to a neutral position between said two extreme positions.

6. Apparatus according to claim **5** wherein said means for bringing said pivotable means and said magnetically operable system to said neutral position is constituted by a spring arrangement.

7. Apparatus according to claim **2** and which further comprises at least one iron piece fixed to said tubular housing such that the interaction between said permanent magnet system and said iron piece tends to bring said permanent magnet system to a neutral position between said two extreme positions.

8. Apparatus according to claim **2** wherein said permanent magnet system includes a longitudinal iron core symmetrically located relatively to the poles of said electromagnet when in a neutral position between said two extreme positions and wherein means are provided for supplying alternating current to said electromagnet for stabilizing said permanent magnet system in the neutral position.

9. Apparatus according to claim **1** wherein one of said radiation sources is a source of directional light.

10. Apparatus according to claim **1** wherein both of said radiation sources are of the radioactive type.

11. Apparatus according to claim **5** and which further comprises a source of directional light arranged within said tubular housing such that a beam of light can be emitted through said collimator opening when said magnetically operable system and consequently said pivotable means are in a neutral position.

12. Apparatus according to claim **11** wherein said source of directional light is axially aligned with said colimator opening and wherein said pivotable means is provided with an opening permitting light emission when said pivotable means is in a neutral position.

13. Apparatus according to claim **11** wherein said source of directional light is arranged to be supplied with current from a coil mounted in said tubular housing, and means arranged outside of said tubular housing in connection with said bracket for producing a pulsating magnetic field passing through said coil.

14. Apparatus according to claim **13,** wherein said coil is wound on a longitudinal iron core, said core being arranged to rotate together with said magnetically operable system.

15. Apparatus according to claim **13** wherein said means for producing a pulsating magnetic field includes said electromagnet and means for supplying alternating current to said electromagnet.

16. Apparatus according to claim **14** wherein said magnetically operable system is a longitudinal permanent magnet system including said longitudinal iron core, said core being symmetrically located relative to the poles of said electromagnet when in the neutral position, means being provided for supplying alternating current to said electromagnet for stabilizing said core and thus said permanent magnet system in the neutral position, said means for supplying alternating current to said electromagnet being arranged to produce a first alternating current for stabilizing said permanent magnet system in a neutral position and a second substantially higher alternating current for producing a direction light voltage in said coil.

17. An osteodensitometer comprising an apparatus according to claim 1 wherein said bracket is mounted on one arm of a fork, a radiation detector being mounted on the other arm of said fork, the object to be examined being fixed between the arms of said fork, and means being provided for displacing said fork in accordance with a predetermined scanning pattern.

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