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GB 1583868
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(54) Cyclotron radiation beam control

(57) Apparatus for attenuating a beam of particulate radiation comprising a series of modules (6), each module (6) being constituted by a sphere (1) having a passage (14), a cupola (8) covering said sphere (1) and a base (9) supporting said sphere (1), and means for causing movement of the spheres (1) for aligning said passages (14) with an axis of a beam line (3) and arranging said passages (14) out of alignment so as to attenuate the beam.

FIG. 2.

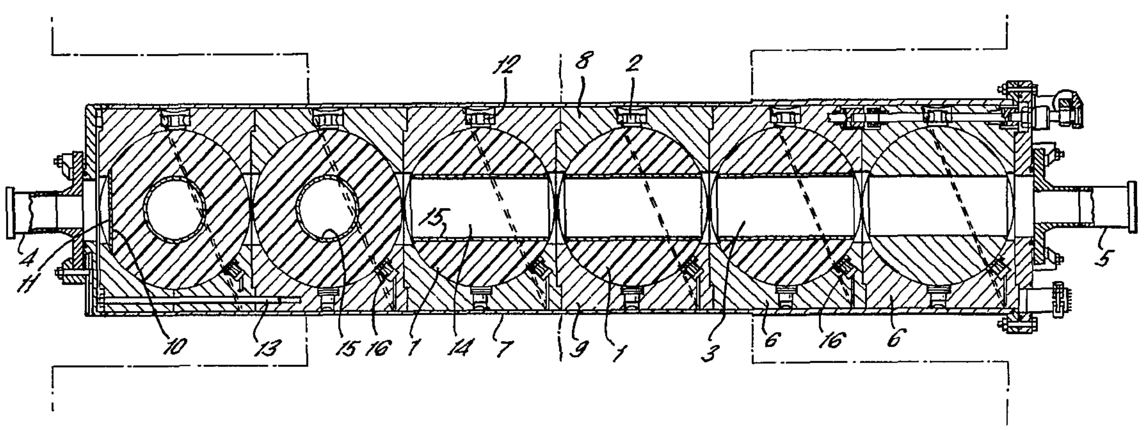

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FIG. 1a.

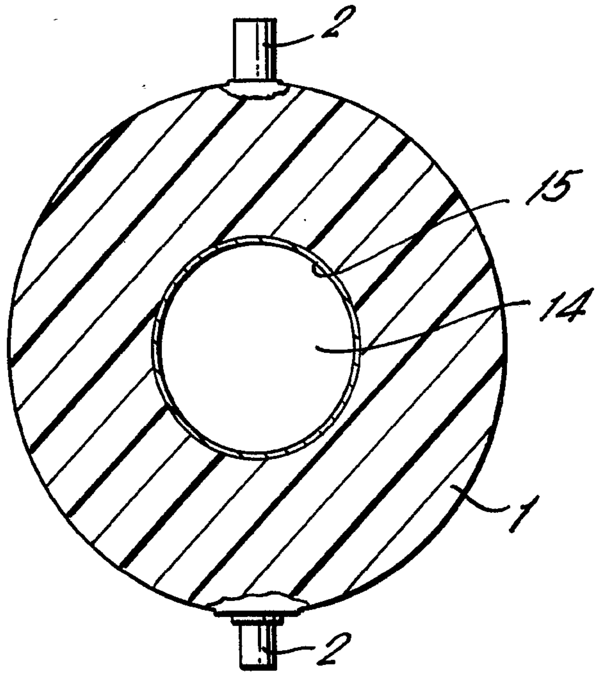

FIG. 1b.

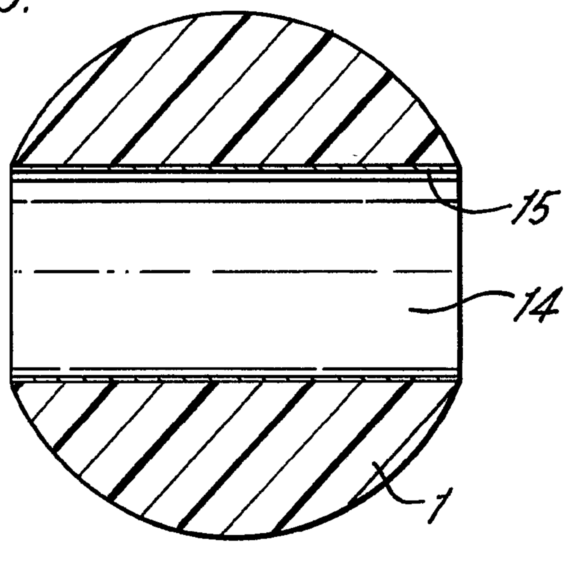

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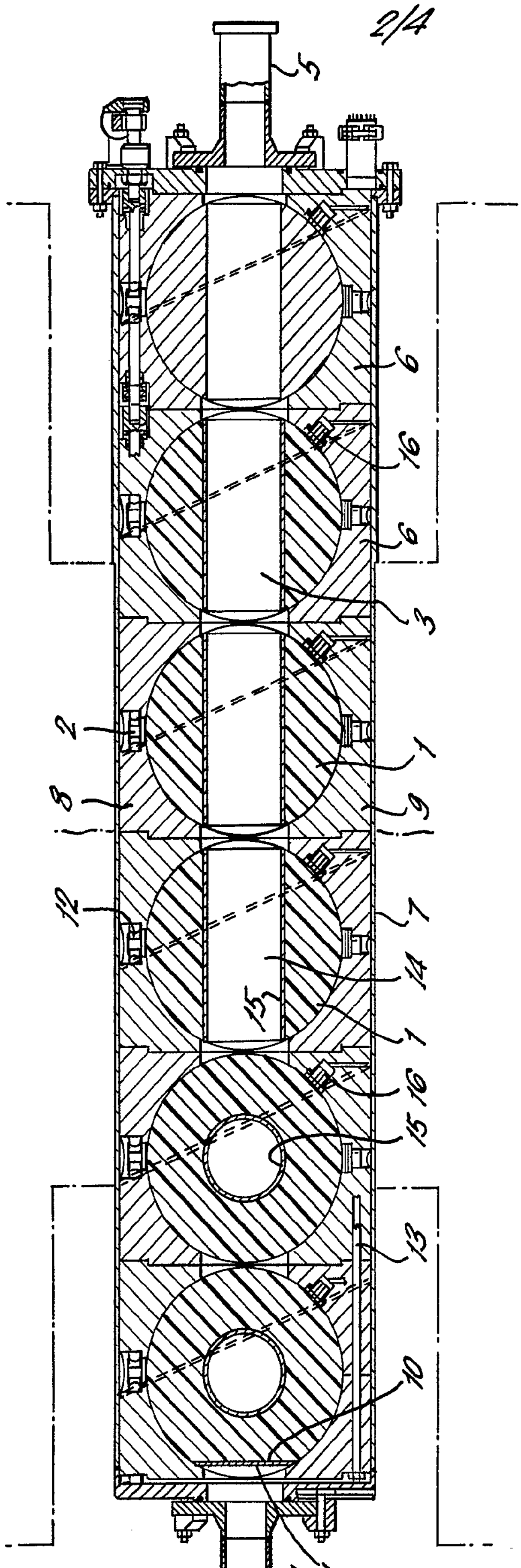
FIG. 2.



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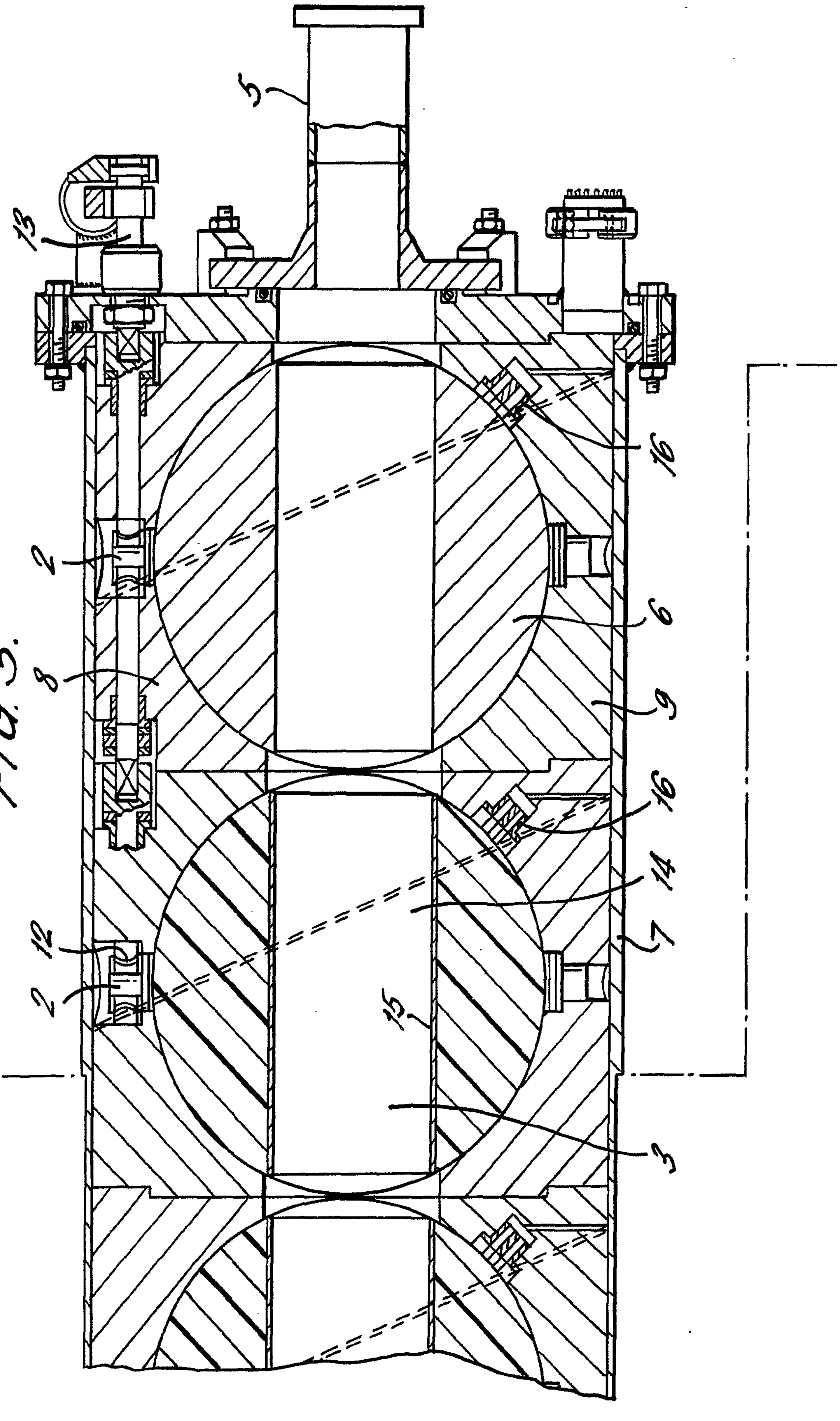

FIG. 3.

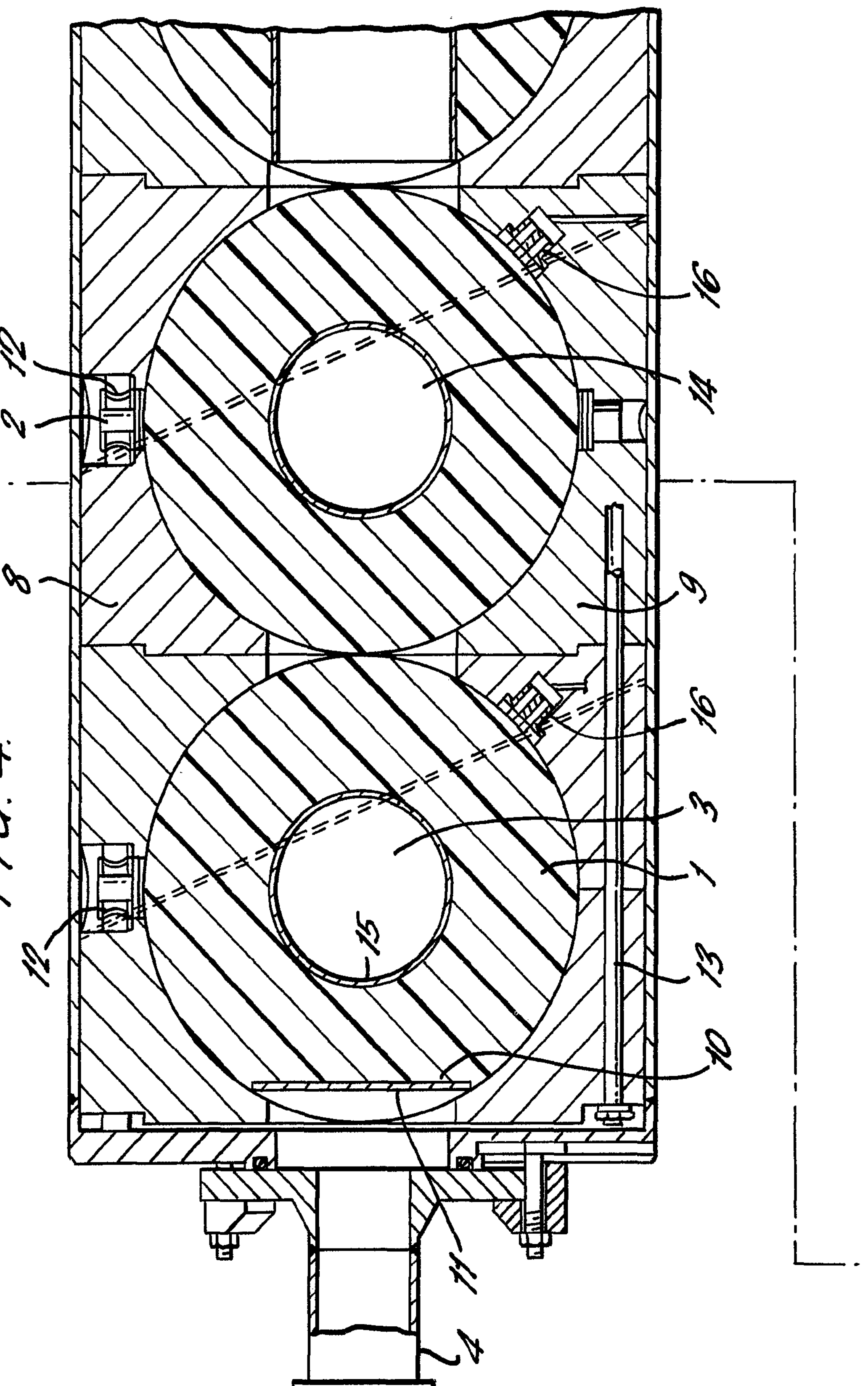

FIG. 4.

SPECIFICATION

Cyclotron radiation beam control

The present invention relates to apparatus for attenuating a beam of radiation produced by, for example, a cyclotron.

For the purpose of convenience, the essential characteristics of a cyclotron, and typical conditions for its operation, will be described hereinbelow.

As is well-known, a cyclotron is an apparatus for producing a beam of radiation consisting of high velocity positively charged particles such as, for example, protons, deuterons, ^{3}He or α-particles, which particles are subsequently accelerated by a particle accelerator.

Typically, the particles issue from the cyclotron as a beam and, and after acceleration of the particles, the beam is applied to a target in order, for example, to study the effect of irradiation on the target. Typical effects studied are the production of shortnuclides from the target, radiation damage in metallic and other materials and the effect of irradiation on biological materials.

A cyclotron is usually arranged in a heavily shielded room. The targets are usually arranged in rooms surrounding the central cyclotron room, these rooms being also heavily shielded. Other targets may, in addition, be arranged in the central cyclotron room. Each target room is connected to the central cyclotron room by a channel which passes through the shielding wall, along which channel the radiation may be directed from the cyclotron to the target.

The provision of a number of target rooms is designed to allow the setting-up of a target for experimental analysis in one target room during a period when a beam from the cyclotron cannot penetrate that room, while a beam from the cyclotron is being applied to another target in another target room.

A compact cyclotron for providing multipurpose radiation typically has a number of channels, each of which can channel a beam of charged particles in a direction parallel to the longitudinal axis of the respective channel. The channels are also known as beam lines.

During the setting-up of a target, it must be ensured that no radiation penetrates the target room in which engineers may be working.

Heretofore, to the uncertainty regarding the degree of attenuation of radiation in a beam line resulting from the incomplete attenuation provided by known systems as described hereinbelow, it has been necessary to switch off one beam line when the cyclotron is in operation, in order to ensure full protection from direct and indirect radiation for engineers working in the respective target room.

A beam line must be capable of interruption when required, such that no direct or indirect radiation is allowed to enter the respective target room.

A known system for beam line interruption consists of the rolling of a "pearl string" of polyethylene balls into the beam line when a door to the target room is opened. The balls are retained in a second channel prior to use, an open end of which channel connects with the beam line. During operation of this beam line interruption system the balls are allowed to descend under the action of gravitational force so as to enter the beam line and interrupt the beam of radiation. With this system however, due to the provision of a gap between the surface of a sphere and the interior surface of the channel, which gap is essential for the balls to freely enter the channel, there is a substantial probability of the escape of particles between successive gaps and so enter the target room either as direct or indirect radiation.

Another known system for beam line interruption consists of three eccentric electrical windings, which are employed to deviate the beam of charged particles. This system has a severe disadvantage in that it requires the provision of additional channels disposed in the shielding walls for allowing passage of the particles deviated by operation of the eccentric windings.

The present invention provides apparatus for attenuating a beam of particulate radiation comprising a series of modules, each module being constituted by a sphere having a passage, a cupola covering said sphere and a base supporting said sphere, and means for causing movement of the spheres for aligning said passages with an axis of a beam line and for arranging said passages out of alignment so as to attenuate the beam.

The present invention further provides apparatus for attenuating a beam of radiation comprising one or more members, a housing having one or more enclosures, each of the members being associated with a respective enclosure in the housing and means for moving each of the members from a first position, at which position the member does not attenuate the beam of radiation to a second position, at which position the member does attenuate the beam of radiation and at which position the surface of the member is closely disposed against the surface of the respective enclosure. An embodiment of the present invention will now be described by way of example with reference to and as illustrated in the accompanying drawings in which:-

Figure 1a shows a plane section of a spherical member of a preferred embodiment of the present invention;

Figure 1b shows a plane section, orthogonal to the plane section of Figure 1*a*, of a spherical member of a preferred embodiment of the present invention;

Figure 2 shows a plane section through a beam channel of a preferred embodiment of the present invention, the direction of the beam of radiation being parallel to the channel and being in the plane of the diagram;

Figure 3 shows an enlarged view of a plane section of an end of the beam channel shown in Figure 2; and

Figure 4 shows an enlarged view of a plane section of an end of the beam channel shown in Figure 2.

Referring to Figure 1*a*, a spherical member 1 has two pins 2, one pin 2 being disposed on the surface of spherical member 1 at each end of a first diametrical axis of spherical member 1, about which axis spherical member 1 may be rotated. The spherical member 1 has a cylindrical cavity 14 along a second diametrical axis of the spherical member 1, the second diametrical axis being perpendicular to the first diametrical axis.

A tube 15 may be disposed along the length of cylindrical cavity 14, which tube 15 has substantially the same length and diameter as that of cylindrical cavity 14. Spherical member 1 may, for example, be composed of polyethylene or steel. Tube 15 may, for example be composed of stainless steel.

Figure 1*b* shows a diametrical section or spherical member 1, the plane of view being orthogonal to that shown in Figure 1*a*.

Figure 2 shows a preferred arrangement for a beam line along which a beam of radiation may be allowed to pass.

A beam line 3 cmprises a cylindrical channel tube 7, a first cylindrical channel 4 and a second cylindrical channel 5, said channels 4 and 5 constituting the entrance and exit, respectively, for a beam of radiation which may be allowed to pass through beam line 3. Said channels 4 and 5 have a diameter less than that of channel tube 7.

Beam line 3 further comprises a number of modules 6, disposed in the beam line 3 as shown and successively positioned along the longitudinal axis of beam line 3. Each module comprises a spherical member 1, a base portion 9 and an upper portion (or cupola) 8.

Preferably the modules 6 are arranged in channel tube 7 such that pins 2 on spherical members 1 are aligned parallel with each other.

In accordance with a preferred embodiment of the invention, the beam line 3 comprises eight modules 6. In the embodiment illustrated in Figure 2, the spherical member 1 nearest to the second cylindrical channel 5 is composed of steel and the remaining spherical members 1 are composed of polyethylene. Preferably, spherical member 1 composed of steel does not have a tube 15 disposed along the length of the respective cylindrical cavity 14.

The upper portion 8 and base portion 9 of each module 6 may be composed of, for example, boron, lead paraffin or graphite. A different one of these materials for different portions 9 and 8 of any module 6 may be employed. The arrangement is such that the portions 9 and 8 of modules 6 may be easily interchanged with other portions 9 and 8, respectively, which other portions are composed of different or of similar material.

Each spherical member 1 is arranged in a respective module 6 such that the said spherical member 1 may be rotated about the respective axis between respective pins 2.

Each spherical member 1 has a diameter slightly greater than that of the spherical cavity formed by portions 8 and 9 of module 6 such that it may be rotated inside each module, with a light pressure being present at the interface between the internal surface of base portion 9 and the external surface of spherical member 1, and the internal surface of upper portion 8 and the external surface of spherical member 1, respectively. The presence of the light pressure ensures that substantially no clearance gap may be present at the said interface between the said internal surfaces, of the base portion 9 and the upper portion 8, and the external surface of spherical member 1.

In Figure 2, the two spherical members 1 nearest to the first cylindrical channel 4, which channel 4 constitutes the entrance for a beam of radiation, are shown in a position such that the longitudinal axis of each cylindrical cavity 14 of each of the said two spherical members 1 is perpendicular to the longitudinal axis of beam line 3. The said two spherical members 1 in this position do not allow the beam of radiation to pass through the beam line 3.

The remaining spherical members 1 in Figure 2 are shown in a position such that the longitudinal axis of each cylindrical cavity 14 of each of the said remaining spherical members 1 is parallel to the longitudinal axis of beam line 3. With this arrangement, the cylindrical cavity 14 of each of the said remaining spherical members 1 is aligned along the longitudinal axis of beam line 3 so as to form a continuous cavity.

When a beam of radiation is to be passed along beam line 3, all of the spherical members 1 are rotated to a position such that the longitudinal axis of each cylindrical cavity 14 is parallel to the longitudinal axis of beam line 3.

For clarity, Figure 2 shows spherical members 1 rotated to different positions. However, when no beam of radiation is to be allowed to pass along beam line 3, in normal operation the longitudinal axis of the cylindrical cavity 14 of each spherical member 1 is rotated so as to be perpendicular to the longitudinal axis of beam line 3.

Preferably, as shown in Figure 2, a portion of the spherical member 1 nearest to the first cylindrical channel 4 has a plane surface 10, against which surface is disposed a radiation attenuating plate 11. When that spherical member 1 is rotated to a position such that the longitudinal axis of the respective cylindrical cavity 14 is perpendicular to the longitudinal axis of the beam line 3, plare 11 enhances the attenuation of a beam of radiation which passes through the first cylindrical channel 4. Plate 14 may be composed of, for example, tantalum.

Figure 3 shows an enlarged view of the exit end of the beam line 3 shown in Figure 2. Exit channel 5 is at the end of the beam line 3. The in 2 of each spherical member 1, which pin 2 is disposed on that portion of the spherical member 1 which is disposed against upper portion 8, is attached to a gearwheel 12. Each gearwheel 12 engages a worm, not shown, and can be caused to be rotated by rotation of rod 13. The arrangement is such that preferably all the spherical members 1 may be rotated simultaneously by the rotation of rod 13.

Against each spherical member 1 is disposed a microswitch 16, which microswitch 16 may detect the position of the spherical member 1. The output of the microswitches 16 may be used to control the operation of the beam line 3.

Figure 4 shows an enlarged view of the entrance end of the beam line 3 shown in Figure 2.

Channels 4 and 5 may be of a non-cylindrical shape so as to follow the line of the beam of radiation before entrance into and after exit from respectively, the beam line 3.

In the proximity of a target to be irradiated (not shown), means may be provided to accurately align the beam of radiation with the target before the beam impinges on the target, in which means the pressure is preferably, approximately 10^{-6} atmospheres.

An embodiment of the present invention provides apparatus for attentuating a beam of particulate radiation, which apparatus provides full protection from direct radiation from the cyclotron.

CLAIMS

1. Apparatus for attenuating a beam of particulate radiation comprising a series of modules, each module being constituted by a sphere having a passage, a cupola covering said sphere and a base supporting said sphere, and means for causing movement of the spheres for aligning said passages with an axis of a beam line and for arranging said passages out of alignment so as to attenuate the beam.

2. Apparatus according to claim 1 wherein each passage is diametral.

3. Apparatus according to claim 1 or claim 2 wherein rotational movement aligns the passages of the spheres with the axis of the beam line.

4. Apparatus according to claim 1 or claim 2 wherein rotational movement aligns the passages of the spheres parallel with each other and normal to the axis of the beam line.

5. Apparatus according to claim 1 wherein means are provided for centralisation of the beam of particulate radiation.

6. Apparatus for attenuating a beam of radiation comprising one or more members, a housing having one or more enclosures, each of the members being associated with a respective enclosure in the housing and means for moving each of the members from a first position, at which position the member does not attenuate the beam of radiation to a second position, at which position the member does attenuate the beam of radiation and at which position the surface of the member is closely disposed against the surface of the respective enclosure.

7. Apparatus as claimed in claim 6 wherein each member is rotated from the first position to the second position.

8. Apparatus as claimed in claim 6 or claim 7 wherein each member has a cavity, through which cavity a beam of radiation may pass when the member is in the first position.

9. Apparatus as claimed in claim 8 wherein each member is associated with a module in the housing, each module comprising a base portion and an upper portion and having the enclosure for the member formed between the base portion and the upper portion.

10. Apparatus as claimed in claim 9 wherein each member is spherical.

11. Apparatus as claimed in any preceding claim wherein the means for moving comprises a worm drive, which worm drive may cause simultaneous rotation of the members.

12. Apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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