United States Patent

Sauerwein et al.

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[54] **APPARATUS FOR GIVING MEDICAL TREATMENT BY IRRADIATION FROM RADIOACTIVE SUBSTANCES**

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[52] **U.S. Cl.** **128/1.1,** 250/106

[51] **Int. Cl.** **A61j 1/00,** A61n 5/10, G21f 5/00

[58] **Field of Search** 128/1.1, 1.2; 250/106, 108

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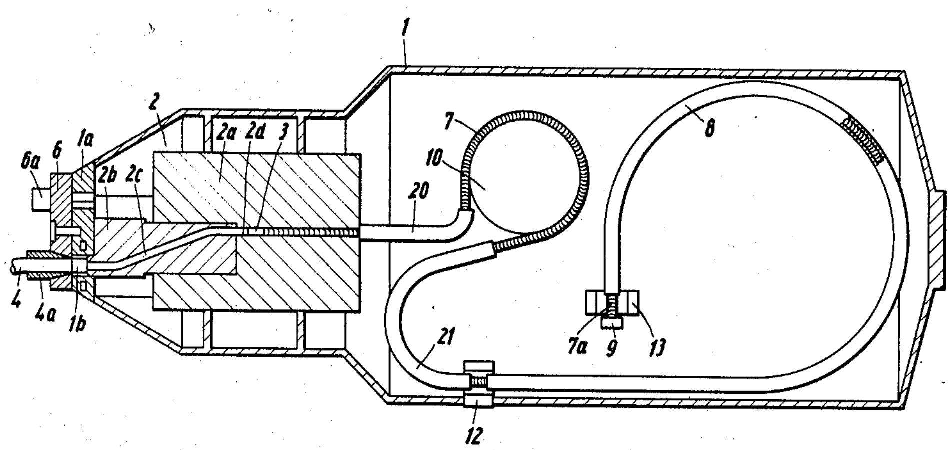
[57] **ABSTRACT**

Apparatus for treating human or animal patients by local irradiation from a radioactive substance comprises a hollow probe closed at one end for introduction into a natural or surgically produced opening in the body of the patient and a capsule which contains a quantity of the radioactive substance and is fixed to the end of a flexible but longitudinal thrust-transmitting cable which propels the capsule between the interior of a shielding block and the interior of the probe which is fixed to the block by a delivery tube through which the cable extends. The cable passes through a passage in the block and when the capsule is situated in the interior of the block the cable extends from the block through an opening in the end of the block remote from the delivery tube, around the greater part of the periphery of a driving wheel which is situated in the housing containing the shielding block, through a storage tube to a terminal stop. The cable is pressed against the driving wheel by spring-loaded rollers so that it is moved when the driving wheel rotates and the storage tube extends between the housings of two photo-electric assemblies which detect the movement of the end of the cable remote from the capsule and respond by controlling the movements of the driving wheel. The effective length of the storage tube, measured between the two photo-electric cell assemblies is equal to the distance traveled by the radiation capsule between the interior of the block and the end of the probe so that the two photo-electric cell assemblies stop the driving wheel when the capsule is either in its position at the closed end of the probe or in its position within the block.

10 Claims, 10 Drawing Figures



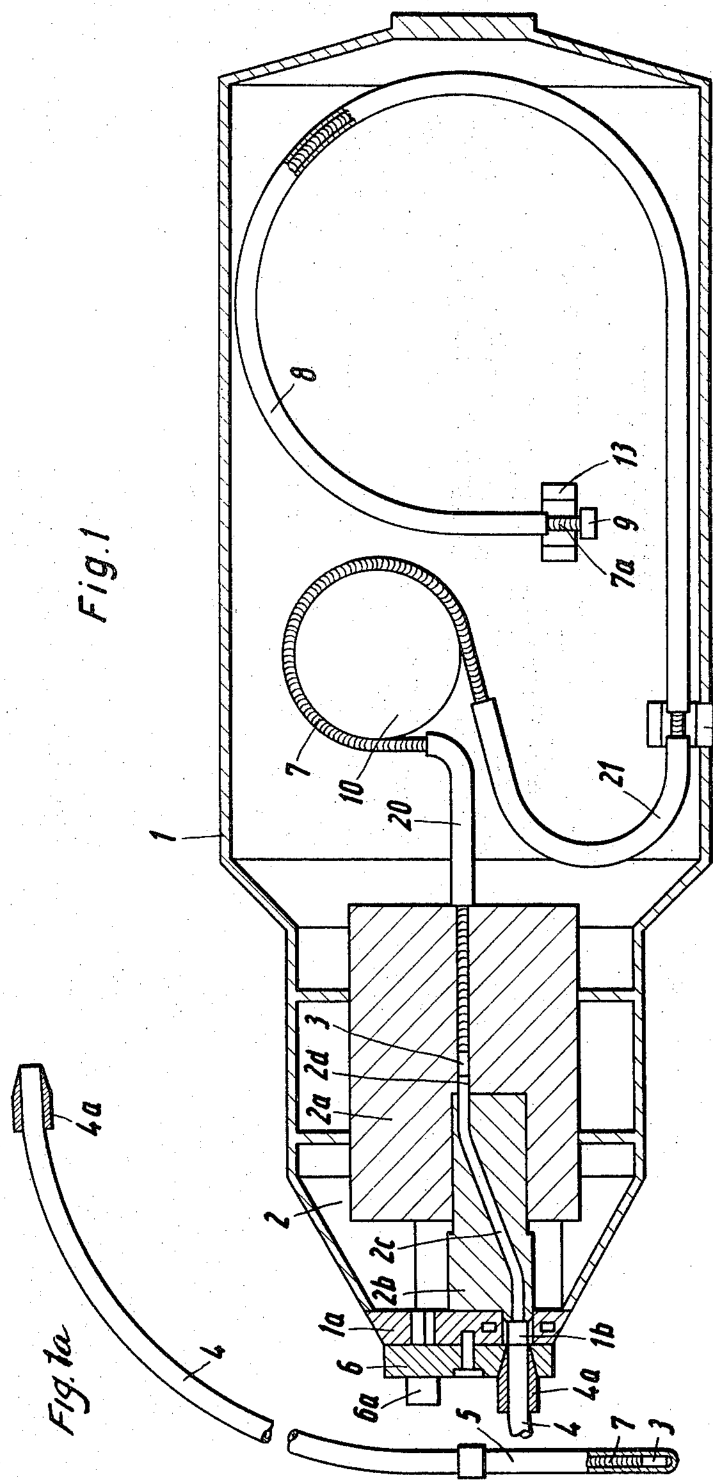


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Fig. 2

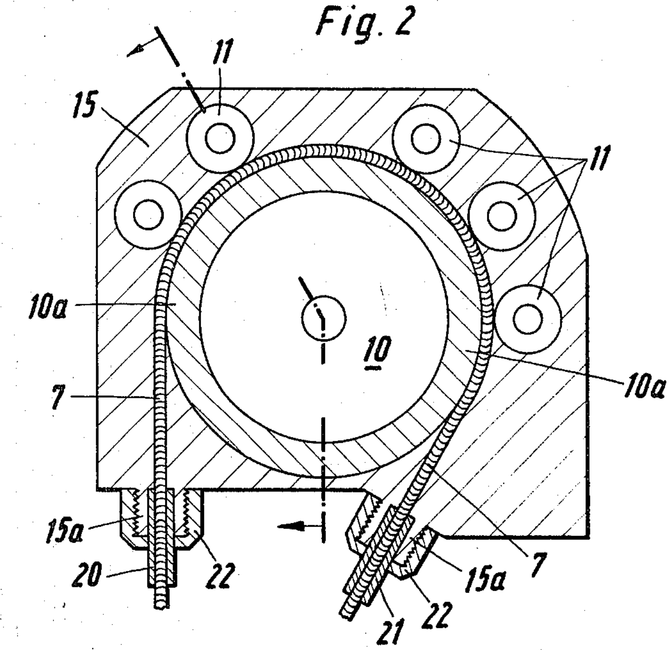

Fig. 3

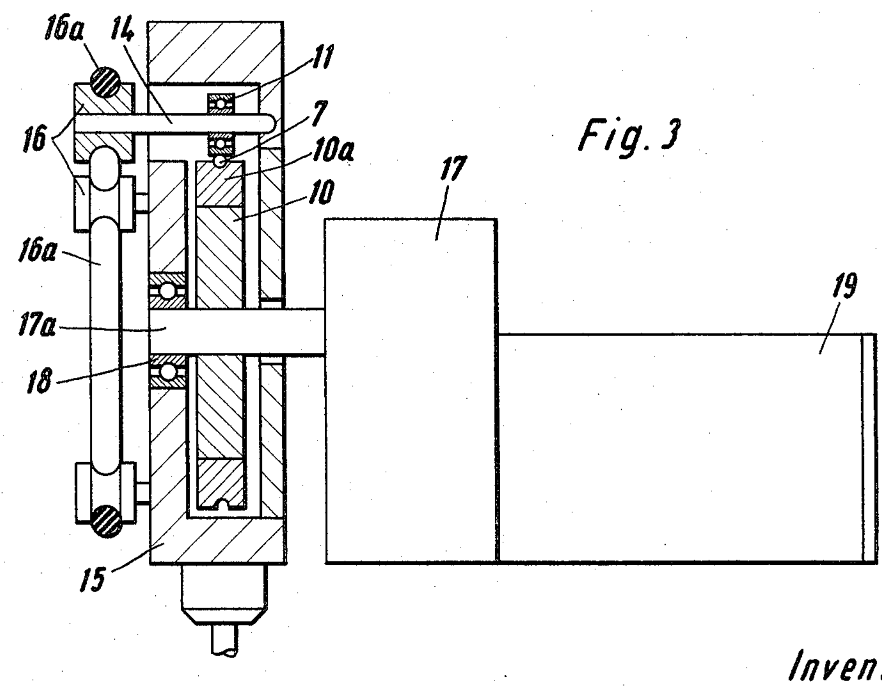

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Fig. 4

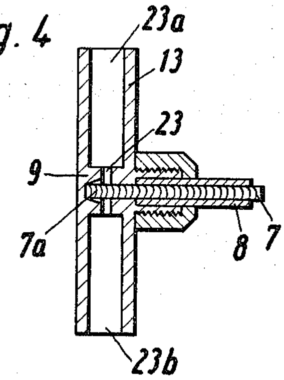


Fig. 5

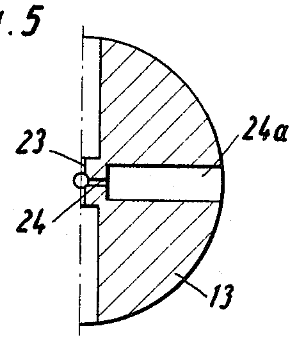


Fig. 6

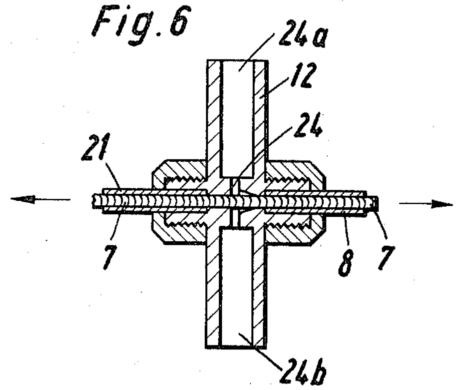


Fig. 7

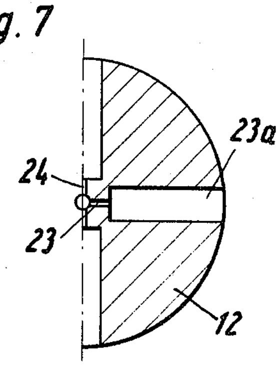


Fig. 8

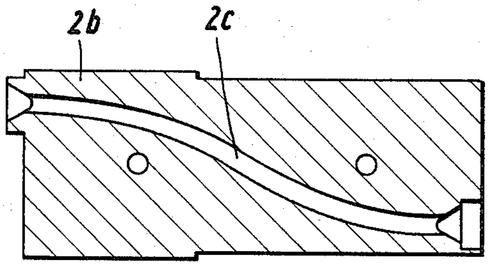
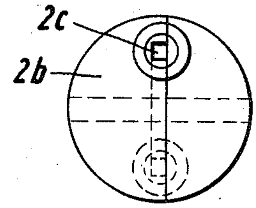


Fig. 9



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APPARATUS FOR GIVING MEDICAL TREATMENT BY IRRADIATION FROM RADIOACTIVE SUBSTANCES

This invention relates to apparatus for treating human or animal patients by local irradiation from a radioactive substance. It is particularly concerned with apparatus for this purpose of the kind comprising a hollow probe closed at one end for introduction into a natural or surgically produced opening in the body of the patient, and a capsule which contains a quantity of a radioactive substance (the radiator) and is fixed to the end of a flexible but longitudinal thrust-transmitting cable which moves the capsule from the interior of a shielding block, through a delivery tube into the interior of the probe which is fixed to the end of the tube. Apparatus of this kind must be capable of producing the highest possible irradiation intensity in the smallest possible space during the shortest possible period, particularly when using radioactive sources of high and very high specific activity. It is therefore important to ensure that the capsule, containing the radioactive substance, is propelled with the utmost reliability and precision from its position of rest in the middle of the shielding block to the location of treatment, that is to say the location where the closed end of the probe has been positioned by the surgeon before the capsule is introduced into the probe. It is equally important to ensure that on the expiry of the period of time specified by the surgeon, that is to say at the end of the precisely timed treatment period, the capsule containing the radioactive substance is returned precisely to its initial position of rest in the shielding block. This movement of the radiation capsule, from the shielding block out to the closed end of the probe and back again into the shielding block, must take place automatically and by remote control, because nobody except the patient can be allowed to remain within the effective range of the radiation capsule when it is outside its shielding block. The operator of the apparatus therefore cannot observe the movements of the capsule.

To this end, according to this invention in an apparatus of the kind described the cable extends from the radiation capsule when this is situated in the interior of the shielding block, out of the shielding block through an opening in the end of the shielding block remote from the delivery tube around the greater part of the periphery of a driving wheel which is situated in a housing containing the shielding block, the cable being pressed against the driving wheel by spring loaded rollers distributed around the periphery of the driving wheel, through a storage tube to a terminal stop, the storage tube extending between the housings of two photo-electric cell assemblies which detect the movement of the end of the cable remote from the capsule and respond by controlling the movements of the driving wheel, the effective length of the storage tube, measured between the two photo-electric cell assemblies being equal to the distance traveled by the radiation capsule between the interior of the block and the end of the probe.

The driving wheel which drives the cable is itself preferably driven, in a manner which is conventional in apparatus of this kind, by a reversible motor which is switched off as soon as the radiation capsule reaches the end of the probe whereupon the motor has its polarity reversed so that when it is switched on again it rotates in the opposite direction. By means of the arrangement in accordance with the invention when the apparatus is put into operation by switching on the motor, the radiation capsule is propelled from a location precisely in the middle of the shielding block out to a location precisely at the closed end of the probe. The motor is then stopped automatically. When it is started again, the capsule moves back again equally precisely.

This precision in the movement of the radiation capsule can be still further improved, for the purpose of compensating any inaccuracies or changes in the lengths of the cable or tubes, by making the cable slightly longer than the distance between the closed end of the probe and the beam of the photo-electric cell assembly nearest to the driving wheel, and by providing the cable with a lateral clearance in the delivery tube and in the storage sufficient to allow the cable to flex elastically in the tubes, to a certain extent, adopting a slightly wavy shape. The effect obtained is that when the cable has been driven outwards the capsule is thrust firmly and accurately against the closed end of the probe, the cable adopting a slightly wavy shape in the delivery tube, and similarly when the cable is fully retracted its rear end is thrust firmly against the terminal stop, the cable adopting a slightly wavy shape in the storage tube. The end thrusts are applied by the elastic resiliency of the cable.

For the same purpose the duct which guides the cable passages in the part of the shielding block extending between the position of the capsule in the interior of the block and the delivery opening changes direction a number of times and is enlarged in diameter at least at the bends, to allow a free passage for the capsule and cable.

According to a further preferred feature of the invention, in order to ensure that a reliable, slip-free drive is obtained under all circumstances between the driving wheel and the cable the diameter of which may be only 2 mm the periphery of the driving wheel is covered with a layer of frictional material, for example the kind of material usually used for brakes and clutches. It should however be observed that these materials are often electrically conductive. In order to prevent the cable itself, or other parts which might come into contact with the cable, from acquiring electric potential, the frictional material is electrically insulated from the driving wheel, which is itself electrically connected through its driving shaft to the shaft of the electric motor.

The radiation capsule preferably has the same diameter as the cable, to ensure that both these parts can move easily through the guiding passages. A further precaution to ensure easy movement is that wherever one end or the other of the cable passes from one part of the apparatus to another the guiding passage is enlarged in diameter to form a double cone.

Reliable and easy movement is ensured not only by giving the capsule and the cable the same diameter but also by joining the two together in such a way that a smooth transition is obtained. For this purpose the radiation capsule consists of a hollow cylinder with a closed bottom and containing the radioactive substance interposed between the bottom and a partition and the open end of the capsule receives the end of the cable which is locally reduced in diameter to allow insertion. This can be done, for example in the case of a cable consisting in a conventional way of a core made of one or more coiled steel wires, surrounded by an outer coil, by cutting off from the end of the cable a short length of the outer coil and inserting the projecting length of core into the open end of the capsule, the joint being made secure by brazing.

As a safety precaution, to ensure that the control system which controls the drive cannot fail, each photocell assembly preferably contains a number of light sources and a number of photo-electric cells, the light beams crossing each other in the same transverse plane in the path of movement of the cable.

An example of an apparatus constructed in accordance with the invention is illustrated diagrammatically in the accompanying drawings in which:

FIG. 1 is a longitudinal section through the complete apparatus, constructional details and parts which do not form part of the present invention having been omitted for greater clarity;

FIG. 1*a* is a longitudinal section through a delivery tube and through the probe, showing the radiation capsule in its terminal operative position;

FIG. 2 is a cross section through a driving mechanism for the cable;

FIG. 3 is a longitudinal section through the driving mechanism for the cable;

FIG. 4 is a longitudinal section through a housing forming a rear end stop for the cable;

FIG. 5 is a half cross section through the housing forming the rear end stop for the cable;

FIG. 6 is a longitudinal section through a housing for a photo-electric cell assembly;

FIG. 7 is a half cross section through the housing for the photo-electric cell assembly;

FIG. 8 is a longitudinal section through a part of the radiation shielding block; and,

FIG. 9 is a cross section through the part of the radiation shielding block.

The forward end of a housing **1** contains a radiation shielding block **2** which, for manufacturing reasons, consists of two parts **2*a*** and **2*b***. The part **2*a*** of the shielding block contains an axial bore **2*d***. When the apparatus is not being used a capsule **3** containing the radioactive substance rests in this bore, in the middle of the shielding block, shielded in all directions by the radiation absorbing mass of the shielding block. When a patient is to be given treatment, the capsule is propelled from the middle of the shielding block **2**, through a delivery tube **4** into a hollow closed-ended probe **5**, connected to the other end of the delivery tube. The capsule **3** is moved as far as the closed end of the probe, which has been inserted by the surgeon in position with its closed end at the location of treatment. The bore **2*d*** is connected at its forward end to a passage **2*c*** passing through the part **2*b*** of the shielding block, with several changes in direction an outlet end **1*b*** of the passage **2*c*** being located in a cover plate **1*a*** which forms the forward closure of the housing **1**. The outlet **1*b*** can be closed by a cover **6** mounted rotatably on the closure plate **1*a***, the cover **6** being lockable in two positions by means of a lock **6*a***. When the cover **6** is in the position shown in FIG. **1**, the outlet opening **1*b*** is open, ready to receive a terminal coupling **4*a*** of the delivery tube **4**, whereas by rotating the cover **6** through 180° the opening **1*b*** can be closed. The radiation capsule **3** is attached to the forward end of a cable **7** which extends backwards, from the middle of the shielding block **2*a***, **2*b***, through the axial bore **2*d*** into the interior of the rear part of the housing **1**, passing through a storage tube **8** as far as stationary stop plate **9**. Between the shielding block **2** and the storage tube **8** the cable **7** passes around most of the periphery of a driving wheel **10**, the cable being thrust firmly against the peripheral surface of the driving wheel by several spring loaded thrust rollers **11**, as shown in FIG. **2**. The storage tube **8** extends between the housings of two photo-electric cell assemblies **12**, **13** which sense the movements of the rear end **7*a*** of the cable **7** and respond by controlling the driving wheel **10**, the forward cell assembly **12** stopping the driving wheel as soon as the cable end **7*a***, during the delivery of the capsule **3**, ceases to interrupt the beam path of the cell assembly **12**. The photo-electric cell assembly **13**, on the other hand, stops the driving wheel **10**, during the return movement of the capsule **3** into the shielding block **2** as soon as the rear end **7*a*** of the cable interrupts the beam path of the cell assembly **13**. The effective distance between the two cell assemblies **12** and **13**, measured along the storage tube **8**, is exactly equal to the length of the path followed by the capsule **3** between its position of seat in the middle of the shielding block and its terminal position at the closed end of the probe **5**, the capsule advancing through this distance during its forward stroke and returning through the same distance on its return stroke.

The thrust rollers **11** consist of the outer rings of ball bearings, the inner rings of which are mounted on axle pins **14**. One end of each axle pin **14** is radially movable with respect to the axis of the driving wheel **10** in the interior of a driving wheel housing **15**. The outer end of each axle pin **14** projects outwards from the housing **15** and supports a pulley wheel **16**. An endless elastic cord **16*a***, for example a rubber band or an endless helical spring passes around the outside of all the pulley wheels **16**. The cord **16*a*** applies an inward thrust to all the pulley wheels **16**, thrusting them radially inwards towards the axis of the driving wheel **10** and so thrusting the rollers **11** inwards against the outer surface of the cable **7**, to the effect that the cable **7** is thrust firmly against the peripheral surface of the driving wheel **10**.

In order to increase the frictional grip between the cable and the driving wheel **10**, so as to ensure a slip-free drive for the cable, the peripheral surface of the driving wheel **10** carries a frictional layer **10*a*** which has a groove in its outer surface to accommodate the cable, the depth of the groove being approximately half the cable diameter. The driving wheel **10** is mounted on the driving shaft **17*a*** of a gear box **17**, the outer end of the driving shaft **17*a*** being supported by an auxiliary ball bearing **18** mounted on the driving wheel housing **15**. The layer **10*a*** is electrically insulated from the wheel and this insulates the cable from the shaft **17*a***.

The driving wheel **10** is driven, in both directions, through the gear box **17** by a reversible motor **19** which can be directed, by a conventional remote control device which need not be described here in detail, to an external source of electric power situated outside the apparatus housing **1**.

In front of the driving wheel housing **15**, the cable **7** passes through a tube **20** which connects the housing **15** to the radiation shielding block **2**. Rearward from the driving wheel housing **15** the cable passes through a tube **21** which connects the housing **12** to the housing of the photocell assembly **12**. As shown in FIG. **2**, the tubes **20** and **21** are attached to the driving wheel housing **15** by cap nuts **22** screwed onto externally threaded projections **15*a*** on the housing **15**.

The cable **7** runs with a small amount of lateral clearance in the tubes **4** and **8** so as to allow the capsule **3** to be thrust firmly against the closed end of the probe by lateral elastic deflection of the cable, which has enough room to flex into a slightly wavy shape in the tubes. Similarly the rear end **7*a*** of the cable is thrust firmly against the stop plate **9** by the resilient action of the cable.

The passage **2*c*** inside the part **2*b*** of the shielding block also has excess diameter beyond what would be necessary for practice guiding of the cable. This is not only to allow the cable to adopt a slightly wavy shape, but allows sufficient room for the capsule **3**, which is a rigid body, to move almost frictionessly through the duct.

The passage **2*c*** in the part **2*b*** of the shielding block has ends which expand conically in diameter. There are similar conically expanded openings in the coupling **4*a*** and in the shielding block **2*a*** where the axial bore **2*d*** meets the passage **2*c*** in the shielding block part **2*d***. This is to ensure that wherever the capsule **3** passes, on its journey, from one part of the apparatus into another part it is able to travel freely and without encountering obstructions. The same precaution to ensure easy movement is taken where the rear end **7*a*** of the cable, in its return movement, passes through the photocell assembly housing **12** into the storage tube **8** (FIG. **6**).

As shown in FIGS. **8** and **9**, the shielding block part **2*b*** is subdivided into two unequal parts by a separation plane extending parallel to the axis of the part **2*b*** but displaced away from the axis through a distance equal to half the diameter of the passage **2*c***. The passage **2*c*** is cut as a groove occupying an axial plane in the larger of the two separated parts, the smaller of the two separated parts having a flat separation surface and acting as a closing cover to enclose the groove, forming a closed passage.

As shown in FIGS. **4** to **7** each of the photo-electric cell assemblies **12** and **13** contains two light sources and two photocells, the light beams crossing each other on the same cross section of the cable path. For this purpose each cell housing has two bores **23**, **24** which cross each other in the middle of the cable path. Each bore **23**, **24** has an outward extension **23*a***, **24*a*** extending from one end of the bore and an opposite extension **23*b***, **24*b*** extending from the other end of the bore. Each of the first two extensions **23*a***, **24*a*** contains an electric lamp and each of the opposite extensions **23*b***, **24*b*** contains a photocell, so that in effect each photocell assembly contains two independent photo-electric cell sensors the light beams of which cross. The terminal cell assembly **13** is shown in FIG. **4**. Only one side of this assembly is connected to the storage tube **8**, the other side of the assembly forming the stationary terminal stop plate **9** for the rear end **7*a*** of the cable.

In order to minimize frictional resistance in the tubes and bores and at their transition the capsule **3** has the same diameter and the same cross section as the cable **7**. For the same purpose the cable duct is expanded in diameter conically at the transitions between one part of the apparatus and another.

The radiation capsule 3 preferably consists of a hollow cylinder closed at one end and containing the radioactive substance interposed between its bottom and a second bottom forming a partition which is brazed in place or otherwise secured. The end of the cable 7, which is locally reduced in diameter is inserted into the open end of the capsule 3. The cable 7 consists, in the known way, of a core of one or more coiled wires, surround by a sheath which is also in the form of a coiled wire. The cable is joined to the radiation capsule 3 by cutting away a short terminal length of the outer coil and inserting the projecting end of the core into the open end of the capsule 3. To ensure that a perfectly reliable joint is obtained the core is securely anchored in the capsule, preferably by brazing . If desired however other methods for securing the joint can be used for example welding or adhesive bonding.

We claim:

1. In apparatus for providing medical treatment for patients by local irradiation from a radioactive substance, said apparatus including a hollow probe for introduction into an opening in the body of said patient, means closing one end of said probe, a radiation capsule, a quantity of radioactive substance in said capsule, a radiation shielding block, means defining a passage through said block, a delivery tube fixing said probe to said block, a flexible and longitudinal thrust transmitting cable fixed to said capsule and extending through said delivery tube and said passage and means for moving said cable to move said capsule between a first position in the interior of said block and a second position at the closed end of said probe, the improvement wherein said means for moving said cable includes a driving wheel, means rotatably mounting said driving wheel on the side of said block remote from said delivery tube, means for rotating said driving wheel and spring-loaded roller means for pressing said cable against said driving wheel around the greater part of the periphery thereof, and further comprising a storage tube for said cable extending from said driving wheel on the side thereof remote from said block, terminal stop means at the end of said storage tube remote from said driving wheel and two photo-electric detecting means for detecting movement of the end of said cable remote from said capsule, said cable extending from said capsule when said capsule is in said first position out of said block through an opening, around said driving wheel and through said storage tube, the effective length of said storage tube measured between said two photo-electric detecting means being equal to the distance traveled by said radiation capsule between said first position and said second position and said photo-electric detecting means being operative to control said means for rotating said driving wheel whereby said rotating means is stopped by one of said photo-electric detecting means when said capsule reaches said first position from said second position and said rotating means is stopped by the other of said photo-electric detecting means when said capsule reaches said second position from said first position.

2. Apparatus as claimed in claim **1**, wherein said photo-electric detecting means at the end of said storage tube nearer said driving wheel measured along the path of said cable, is situated at a predetermined distance from said closed end of said probe measured along the path of said cable around said driving wheel, through said block and through said delivery tube and said cable has a length slightly longer than said predetermined distance, and means defining a lateral clearance between said cable and said delivery tube and said storage tube, said lateral clearance being sufficient to allow said cable to flex elastically under longitudinal compression whereby said cable adopts a wavy shape within aid tubes.

3. Apparatus as claimed in claim **1**, further comprising means defining a delivery opening at the junction between said passage through said block and said delivery tube, the part of said passage extending between said first position and said delivery opening having a plurality of changes in direction, and means defining enlargements in diameter of said passage at said changes in direction to allow free movement of said capsule and said cable through said part of said passage.

4. Apparatus as claimed in claim **1**, further comprising a layer of frictional material and means fixing said layer of frictional material around the periphery of said driving wheel.

5. Apparatus as claimed in claim **4**, wherein said means fixing said layer of frictional material to said periphery of said driving wheel includes electrical insulating means whereby said cable is electrically insulated from said driving wheel.

6. Apparatus as claimed in claim **1**, wherein said capsule and said cable have the same diameters and cross sections as each other.

7. Apparatus as claimed in claim **1**, further comprising means forming an enlargement in said passage through said block and in said delivery and storage tubes at transitions between said passage and said tubes.

8. Apparatus as claimed in claim **1**, wherein said radiation capsule comprises a hollow cylinder, means closing one end of said cylinder, partition means extending across said cylinder adjacent said one end, said partition means and said means closing said one end defining a space containing said radioactive substance and the other end of said cylinder being open, said end of said cable which is fixed to said capsule being of reduced diameter and being received in said open end of said cylinder.

9. Apparatus as claimed in claim **8**, wherein said cable comprises a plurality of intercoiled wires forming a core and a coil of wire surrounding said core, an end portion of said coil of wire being removed to bare said core to form said reduced diameter portion of said cable and said bared core being received in said open end of said cylinder, and means securing said bared end in said cylinder.

10. Apparatus as claimed in claim **1**, wherein each of said photo-electric detection means includes a plurality of light sources and a plurality of photo-electric cells, said light sources being adapted to produce beams of light shining on said cells and said beams crossing each other in a common transverse plane in the path of movement of said cable.

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