

[54] **A FLOW-THROUGH IRRADIATOR FOR THE EXTRA CORPOREAL IRRADIATION OF FLUID**

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[52] U.S. Cl. .... **250/44, 128/1.1, 250/43, 250/48, 250/106, 250/108**

[51] Int. Cl. .... **G01n 21/26**

[58] Field of Search.....**250/106 S, 43, 44, 48, 108; 128/1.1**

[56]

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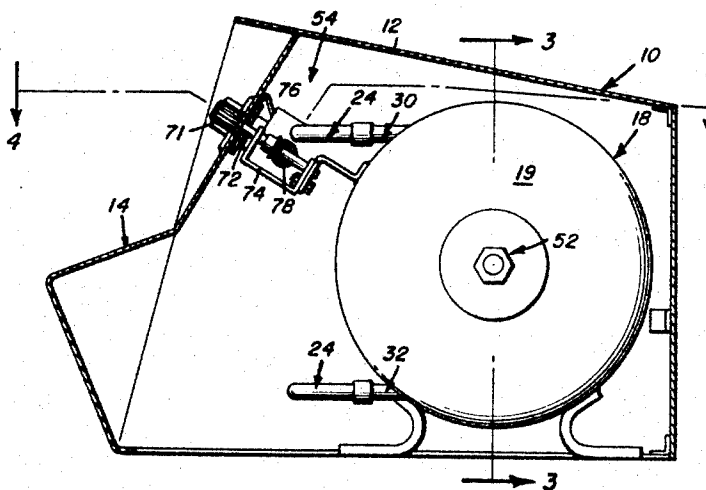
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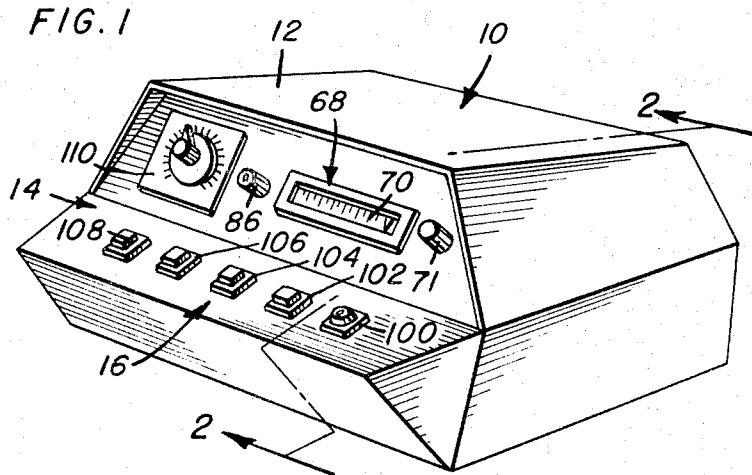
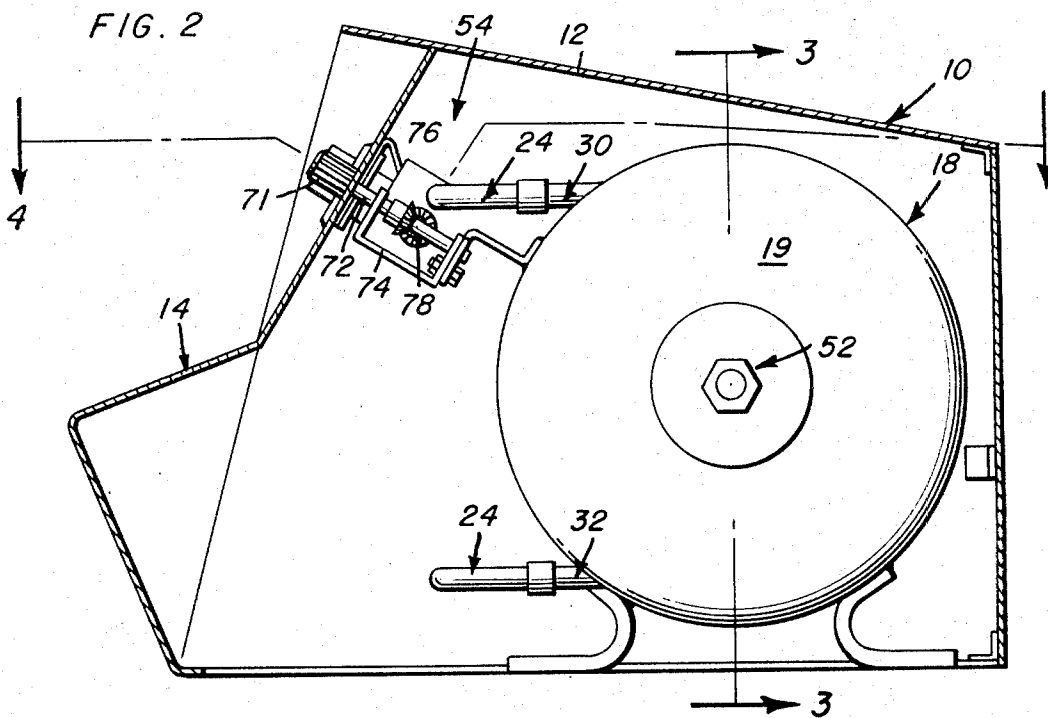
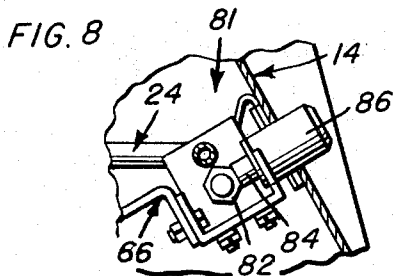
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**ABSTRACT**

A flow-through irradiator for fluid comprising a radiation absorbing biological shield housing having a radioactive source therein, a non-linear conduit traversing the shield housing for passing a fluid therethrough in radiation receiving relation to the radioactive source, and a flexible radiation absorbing means movably interposed between the radioactive source and fluid to be irradiated to selectively vary the radiation dose rate received by fluid passing through the conduit.

**14 Claims, 10 Drawing Figures**





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FIG. 3

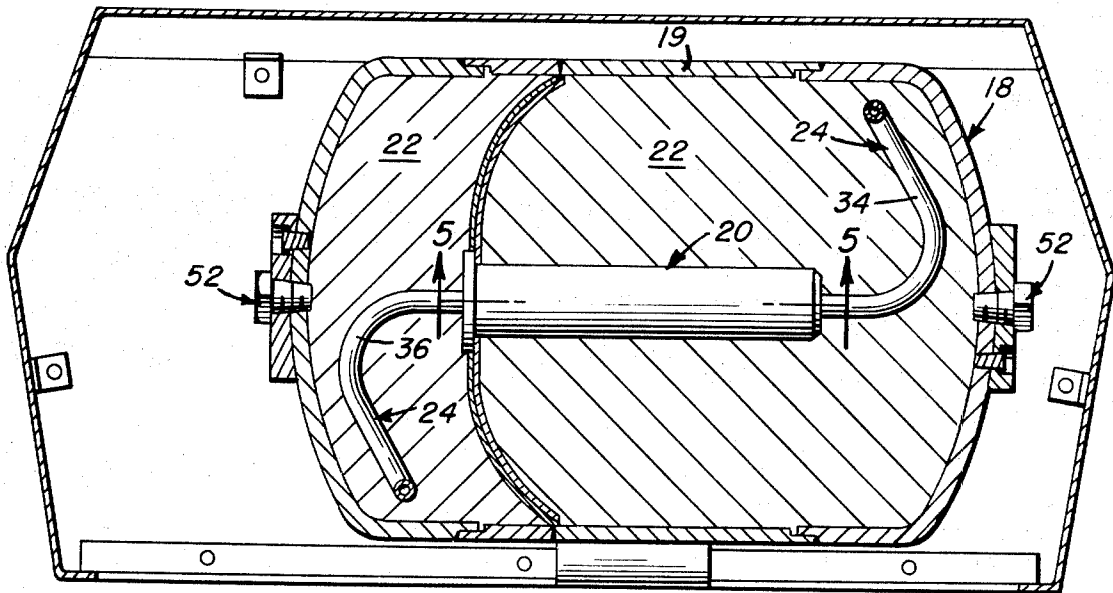


FIG. 5

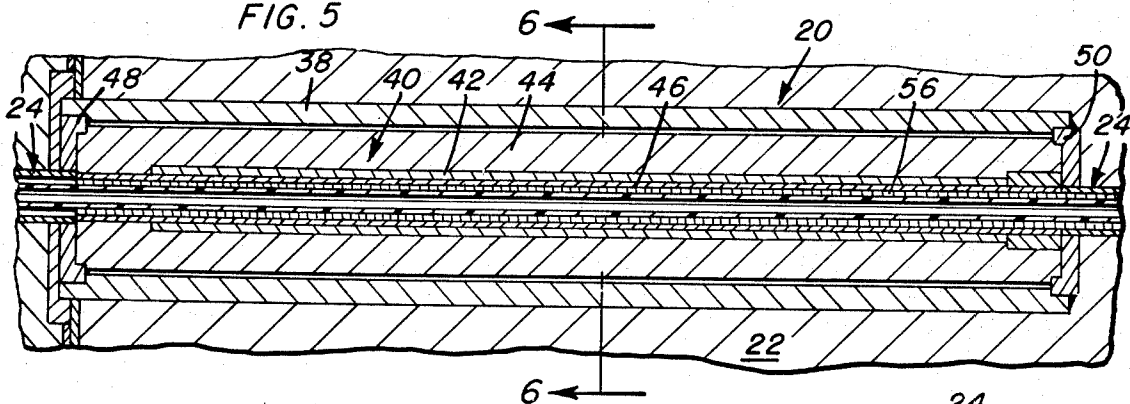


FIG. 6

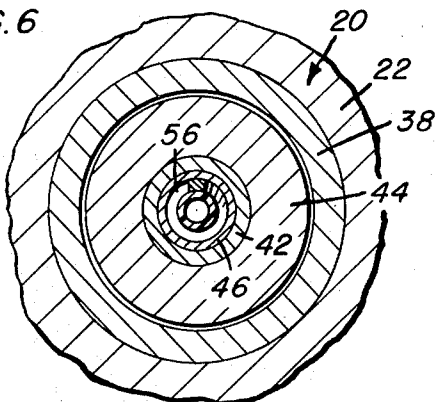
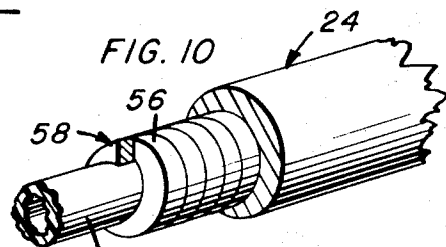


FIG. 10



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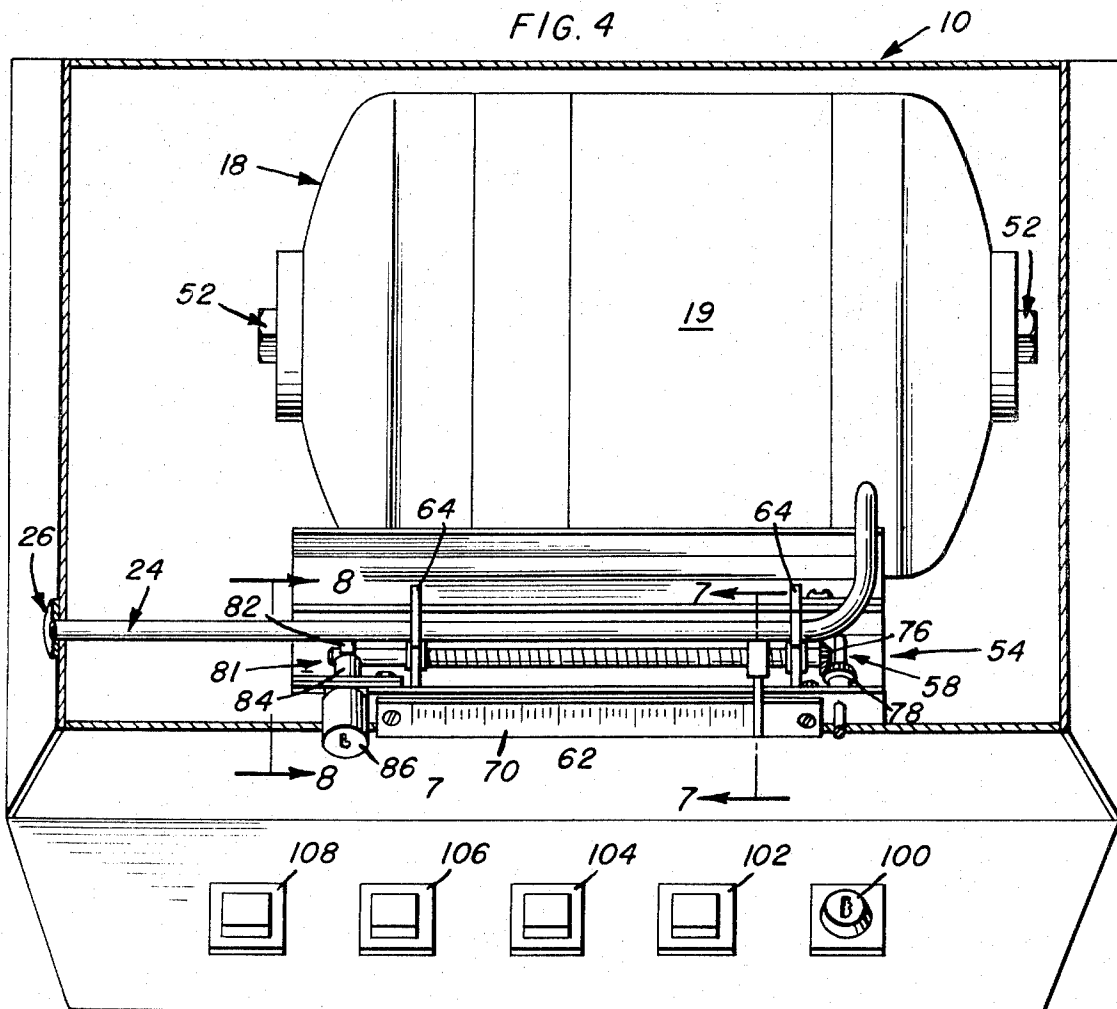


FIG. 7

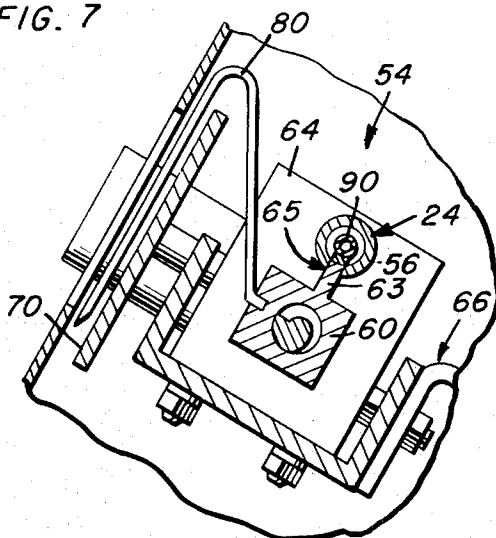
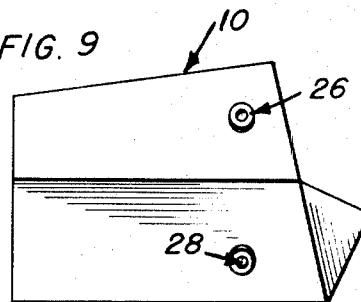


FIG. 9



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## A FLOW-THROUGH IRRADIATOR FOR THE EXTRA CORPOREAL IRRADIATION OF FLUID

The present invention relates generally to a flow-through irradiator for fluid. More particularly, the present invention relates to a flow-through radioactive source-containing irradiator for liquid. More specifically, the present invention relates to a beta ray emitter source irradiator for the flow-through extracorporeal irradiation of body fluids.

Extracorporeal irradiation of blood and lymph has been utilized in suppression of immune antibody response to transplants and in management of some forms of leukemia. Extracorporeal irradiation of blood and lymph is advantageous in that the effect of the radiation treatment is localized in the blood or lymph as it flows through a conduit outside the body, thus minimizing or eliminating exposure of the other organs of the patient to a radioactive source. However, while the value of immunosuppression and leukemia management by extracorporeal irradiation has been recognized, the utilization of such a therapeutic technique has been limited due to the fact that heretofore the apparatuses suitable for carrying forth such an irradiation technique generally consisted of expensive immobile fixed irradiators characterized by extremely heavy shielding thus necessitating movement of the patient to the irradiator. Furthermore, and even a more significant disadvantage, is the fact that the radiation level within such "irradiators," which often comprised a room, is of such magnitude that the attending physician could not safely remain within the immediate vicinity of a patient undergoing extracorporeal irradiation therapy.

It is an object of the present invention to provide an efficient portable flow-through irradiator for fluid, particularly suitable for the extracorporeal beta irradiation of body fluids.

Another object of the present invention is to provide an efficient portable flow-through irradiator for fluid capable of providing a relatively high radiation dose rate to fluid flowing therethrough while reducing the radiation reaching the outside surface of the unit to such a low value that the irradiator can be used safely in an unrestricted area, i.e., an area in which the radiation levels are such that if an individual were continually present in the area, it could not result in his receiving a radiation dose in excess of 2.0 mr in any one hour.

A further object of the present invention is to provide an efficient portable flow-through irradiator for fluid including an radiation dose rate attenuator means for selectively varying the radiation dose rate to which fluid is subjected in its passage through the irradiator.

Still another object of the present invention is to provide an efficient portable flow-through irradiator for fluid having a biological radiation shield housing traversed by a generally non-linear conduit having a generally linear intermediate portion about which is positioned radioactive material and whereby the non-linear portions of the conduit significantly reduce the amount of shielding material necessary to provide maximum radiation protection by causing a sufficient number of angular changes in the path of travel of rays emitted from the radioactive source so that the energy level of rays exiting from the generally non-linear conduit does not exceed the aforementioned safe level.

Still another object of the present invention in accordance with the aforesaid objects is to provide a radiation dose rate attenuator means which is generally housed within the generally non-linear conduit and selectively movably by drive means operable from the exterior of the main biological shield means to selectively uncover a predetermined portion, or all, of a radiation emitter material positioned adjacent the generally linear portion of the conduit so as to selectively vary the radiation dose received by the fluid in its flow through the irradiator.

Still another object of the present invention in accordance with the aforesaid objects is to provide a radiation dose rate attenuator means which is of a tubular cross-sectional configuration so as to permit passage of a disposable flexible tubular member therethrough so as to provide a readily replaceable flow containment means for fluid being passed through the irradiator.

Still another object of the present invention is to provide a fluid irradiator having a dose rate attenuator means having a drive means operable from the exterior of the irradiator and further provided with permutation lock means for preventing unauthorized irradiation of fluid or unauthorized variation of the dose rate during irradiation of fluid.

Still another object of the present invention in accordance with the aforesaid objects is to provide a fluid irradiator wherein the radiation emitter source is of a generally tubular configuration surrounding and extending along at least a portion of the generally linear portion of the generally non-linear conduit through which fluid flows to be irradiated.

Still a further object of the invention is to provide a novel fluid irradiator which is highly efficient, portable, in the sense of being readily movable from one area to another without requiring an undue amount of handling equipment, which irradiator can be advantageously utilized in an unrestricted area as determined by Atomic Energy Commission regulations.

Numerous other objects and advantages of the invention will be apparent as will be better understood from the following description, which taken in connection with the accompanying drawings, discloses a preferred embodiment thereof.

Referring to the drawings:

FIG. 1 is a perspective view of an exemplary embodiment of a housing for a fluid irradiator constructed according to the present invention;

FIG. 2 is an enlarged vertical cross-sectional view taken on line 2—2 of FIG. 1 and further showing an end view of an exemplary embodiment of a fluid irradiator constructed according to the present invention positioned within the housing of FIG. 1;

FIG. 3 is a vertical longitudinally extending cross-sectional view taken on line 3—3 of FIG. 2 showing certain interior details of the exemplary fluid irradiator;

FIG. 4 is a generally horizontal cross-sectional view taken on line 4—4 of FIG. 2 and showing the general organization of an exemplary embodiment of a drive means for a radiation dose rate attenuator means of the exemplary fluid irradiator illustrated therein;

FIG. 5 is a still further enlarged fragmentary longitudinal cross-sectional view showing additional interior details of the exemplary embodiment of the fluid irradiator and particularly certain interior details of the

radiation emitter source, source holder, primary fluid flow conduit and radiation dose attenuator means, taken along line 5—5 of FIG. 3;

FIG. 6 is a still further enlarged transverse cross-sectional view taken on the line 6—6 of FIG. 5;

FIG. 7 is an enlarged vertical cross-sectional view taken on line 7—7 of FIG. 4 showing additional details of the exemplary embodiment of the dose attenuator drive means shown in FIG. 4;

FIG. 8 is a vertical cross-sectional view taken on the line 8—8 of FIG. 4 and showing certain details of a lock means for the dose attenuator drive means;

FIG. 9 is a side elevational view of the exemplary housing of FIG. 1 further showing inlet and outlet openings for the primary fluid flow conduit; and

FIG. 10 is an enlarged fragmentary perspective of the primary fluid flow conduit, flexible dose attenuator means and removable flexible secondary fluid flow tube within the dose attenuator.

Referring now to the drawings in greater detail, and in particular FIGS. 1, 2, 4, and 9, the irradiator for fluid indicated generally by the numeral 10 comprises a housing 12, generally provided for aesthetic reasons but also including a panel as indicated by the numeral 14 for supporting a plurality of controls, indicators, etc., as designated by the numeral 16. Inasmuch as the controls 16 may, for the most part, be selectively varied depending upon the specific utility of the irradiator 10, the controls 16 will for the most part only be generally described in connection with the following description of the structure and operation of the irradiator 10. Mounted within the housing 12, is a primary radiation absorbing shield means indicated generally at 18 comprising a generally cylindrical vessel for housing a radiation emitter source indicated generally by the numeral 20 generally centrally disposed therein. The shield means 18 is filled with a dense radiation absorbing material 22, i.e., lead, such as conventionally utilized for the fabrication of radiation absorbing biological shields. A primary flow tube means indicated generally by the numeral 24 is provided for conducting fluid to be irradiated into the shield means 18, past the source 20 and out of the shield means 18. Toward this end, and as best appreciated by a simultaneous consideration of FIGS. 2, 4 and 9, the opposed ends of the primary flow tube means 24 in addition to passing through the outer wall of the shield means 18 continues to and passes through the housing 12 to provide inlet and outlet ports 26 and 28, respectively, for fluid to be introduced into and withdrawn from the irradiator 10. The designation of the inlet and outlet ports is merely exemplary and it will thus be understood that the inlet port 26 could function as an outlet port and the outlet port 28 could function as an inlet port.

With more specific regard to the generally non-linear primary flow tube means 24, it will be understood that the phrase "generally non-linear" specifically relates to the general configuration of that portion of the tube means 24 within the shield means and extending between the locations 30 and 32, which locations generally indicate the locations where the tube means 24 passes through the outer wall 10 of the primary shield means 18. It will thus be appreciated that the portions of the primary flow tube means 24 external to the shield means 18 are by no means limited to any par-

ticular linear configuration, except as may be dictated by virtue of the configuration of the housing 12 for coaction of the exteriorly disposed portions of the flow tube means 24 with respect to other components of the irradiator 10 which are disposed exteriorly of the shield means 18.

With the foregoing qualification of the term generally non-linear primary flow tube means 24 in mind, and again specifically referring to FIGS. 3 and 5, it will be seen that the intermediate portion of the tube means 24 is "generally linear" while the end portions 34 and 36 respectively extend in a generally tortuous manner from their juncture with the intermediate generally linear portion and the locations 30 and 32 where the tube means 24 passes through the wall 19 of the shield means 18. It will thus be understood that for reasons that will become more apparent during the following discussion with regard to an exemplary construction of the source 20, and the cooperation thereof with the tube means 24 of which it actually comprises a part, it will be understood that the "generally non-linear" configuration of the primary flow tube means 24 comprises a significant aspect of an irradiator constructed according to the present invention.

Turning now in greater detail of the source means generally designated at 20, and as best seen in FIGS. 5 and 6, the exemplary construction illustrated consists of a cylindrical source holder tube 38 within which is positioned a radiation emitter source indicated generally at 40 consisting of a radiation emitter source material 42 encapsulated between a relatively thick tubular outer source wall 44, the radiation passing characteristic of which is not critical, and a relatively thin inner source wall 46 which is of sufficiently low density to permit a useful amount of radiation to pass from the source material 42 into the bore defined by the inner wall 46. The source 40 is, for example, retained and centered within the source holder 38 by a pair of source centering rings 48 and 50. An exemplary beta ray source material 42 comprises strontium-90 (in equilibrium with yttrium-90) which radioactive material may be embedded within an inert matrix such as conventionally utilized in the fabrication of an encapsulated radioactive source material.

From a further consideration of FIG. 6, it will be seen that the diameter of the bore defined by the tubular wall member 46 is complementary to, and axially aligned with, the diameter of the bore of the primary flow tube means 24 and in fact comprises the "generally linear intermediate portion" of the primary flow tube means 24. However, it will be understood that the linear portion of the flow tube means is not specifically limited to being coextensive with the source 40 and could thus, if desired, be shorter or longer and extend past the centering rings 48 and 50.

Turning once again to FIG. 3, it will also be noted that the outer wall 19 of the main radiation absorbing biological shield means 18 is fabricated, such as from steel for example, in a plurality of components to facilitate fabrication of subassemblies prior to introduction of shielding lead 22 through ports which are subsequently plugged as indicated at 52. Inasmuch as the manner by which the housing components are assembled does not comprise a salient aspect, a further description of the manner of assembling the main

biological shield is not considered necessary inasmuch as the mode of fabricating the shield means 18 will be readily apparent to a person of ordinary skill in the metal working arts.

Mounted exteriorly of the primary radiation absorbing shield means 18 and indicated generally at 54 is one portion of a radiation dose rate attenuator means for selectively varying the dose rate of radiation from the radiation emitter source material 42 which passes into the bore of the tube 46. The radiation dose rate attenuator means 54 includes a flexible radiation absorbing member 56, which in the exemplary form illustrated, as best seen in FIG. 10, consists of a helical spring, such as formed of stainless steel for example, and preferably, although not necessarily, having a square cross-sectional configuration as indicated generally by the numeral 58. From a simultaneous consideration of FIGS. 4 and 5, it will be seen that the flexible radiation absorbing member 56 is sized so as to be slidably received within the bore defined by the primary flow tube means 24 and the extension thereof as defined by the inner wall member 46 of the source 40. For reasons which will become more apparent hereinafter, the flexible radiation absorbing member 56 is of sufficient length so as to extend at a minimum at least the length of the cylindrical emitter source material 42. In such a case an operating link such as a Bowden wire. In addition, the density, i.e., radiation absorbing capability, of the flexible member 56 is such that when in the position shown in FIG. 5, it will significantly, or substantially, reduce the amount of radiation reaching the effective inner bore of the contiguous portion of the primary flow tube means 24, i.e., the reduced diameter portion of the flow tube as defined by the inner bore of the flexible member 56. Further, the radiation dose rate attenuator means 54 includes a dose rate attenuator drive means indicated generally by the numeral 58 for reciprocating the flexible member 56 to selectively withdraw the member 56 from the generally linear intermediate portion of the primary flow tube 24 and into the tortuous portion 34 thereof so as to selectively and progressively "uncover" the emitter source material 42 so as to selectively vary the radiation dose delivered to the fluid passing through the primary flow tube means 24. Thus, and to facilitate reciprocation of the flexible member 56 by the drive means 58, the member 56 is preferably of sufficient length to extend in its normal radiation absorbing position from the end of the radiation emitter source material 42 distal to the tortuous portion 34 of the flow tube means 24 to be fixedly secured to an internally threaded member 60 having a post 63 extending through a slot 65 in the tube means 24 and fixedly secured to the flexible member 56, such as by welding, for example. The internally threaded member 60 is non-rotatably journaled on an attenuator control shaft 62 provided with a constant lead helical thread complementary to the thread on the interior of the member 60. The shaft 62 is rotatably journaled by suitably apertured journal members 64 fixed relative to the shield means 18 by brackets indicated generally by the numeral 66, as best seen in FIG. 7. It will thus be seen that rotation of the shaft 62 effects reciprocation of the drive member 60 thereby permitting withdrawal of the flexible member 56 from the radiation absorbing position shown by movement of the attenuator drive

member 60 to the left, as viewed in FIG. 4. To facilitate selectively and controllably positioning the flexible member 56 to uncover a predetermined portion of the emitter source material 42 there is preferably provided a radiation dose rate indicator means indicated generally by the numeral 68 which includes a graduated scale 70 such as directly readable in the percentage of radiation dose between a minimum and maximum value which is attainable by positioning the flexible member 56 at any point between the full radiation absorbing position, as shown in FIG. 5, and a position where it is completely withdrawn from the entire length of the emitter source material 42 whereby full radiation dosage is transmitted to the interior of the primary flow tube means 24. Further, and to facilitate rotation of the threaded shaft 62, there is provided a manually operable dose attenuator positioning control including an exteriorly disposed knob 71 carried by a shaft 72 rotatably journaled in a bifurcated bracket 74. The shaft 72 is provided with a beveled gear 76 engaged with a complementary beveled gear 78 non-rotatably fixed to one end of the threaded shaft 62. In addition, the member 60 is provided with an indicator pointer 80 to permit a readout of the position of the flexible member 56 directly in relation to the percentage radiation, dose rate, or readout in any other suitable unit of measure.

Still further, the attenuator drive means 58 includes a dose setting lock as indicated generally by the numeral 81, as best seen from a simultaneous consideration of FIGS. 4 and 8, wherein it will be seen that the shaft 62, on the end distal of the beveled gear 78 is provided with a non-rotatably secured member 82 of non-circular cross-sectional configuration, which coacts with a selectively reciprocable plunger 84 such as comprising a portion of a conventional key operated tumbler lock 86 whereby it will be appreciated that in the position shown in FIG. 8 the plunger 84 prevents rotation of the non-circular member 82, thus preventing rotation of the shaft 60 and thereby precluding reciprocation of the attenuator drive member 60 so as to prevent unauthorized or accidental movement of the flexible shield member 56 relative to the emitter source material 42. Although not necessary, the interior wall 46 of the source 20 may be plated with a relatively hard substance, i.e., chrome, and at least the exterior portion of flexible shield member 56 plated with a soft substance, i.e., gold, so as to preclude abrasion of the member 56 through the wall 46.

Inasmuch as the irradiator 10 is primarily, although not necessarily exclusively, intended for the extracorporeal irradiation of body fluids, i.e., the irradiation of blood and lymph external to the body such as by passage of the fluid through tubing connected to an artery of a person and back into a vein of the person, a secondary, and normally single service disposable flexible tube, is passed inwardly through the inlet port 26 of the primary flow tube means 24, through the inner bore of the flexible radiation absorbing member 56 and outwardly through the outlet port 28 so as to provide a sterile environment for the passage of such body fluids through the primary flow tube means 24. As will be readily appreciated, the tubing 90 formed of a suitable inert resinous substance, such as a silicon rubber, for example, which preferably has an effective inner

diameter which will not deleteriously affect the cells of the body fluid flowing therethrough and wherein the density of the wall of the tubing 90 is such that the passage of a useful amount of radiation from the radiation emitter source material 42 to the fluid within the tube 90 is not precluded.

Merely for a more complete understanding of an exemplary mode of operation to be described hereinafter, the panel 14 of the housing 12 may further be provided with an electrical power "on-off" key switch 100; electrical power "on" light 102; electrical timer starter switch 104; timed cycle completion indicator light 106; timer on indicator light 108; and an electrically actuated exposure timer 110. Inasmuch as the aforementioned elements 100-110 are merely ancillary to the irradiator 10, it will be understood that they derive their power from line current through a suitable conventional electrical cord set, not shown.

An exemplary mode of operation of the fluid irradiator, such as in conjunction with the treatment of a person, comprises plugging the cord set into a line current outlet, unlocking the power key switch 100, setting the desired radiation exposure dose rate by means of the control knob 71, followed by locking the selected dose rate by means of the lock 86. A suitable length of secondary tubing 90 is passed into the inlet 26, through the primary tube 24 and flexible shield 56 and outwardly from the outlet 28. The tubing 90 is then connected to the appropriated blood vessels, etc., of the patient and the timer 110 started by actuation of the switch 104. When the preset exposure time has elapsed, the light 106 is illuminated. The tubing 90 is then removed from the patient and the power turned off by means of the key switch 100. The flexible shield 56 is then returned to the full shielding position shown in FIG. 5 by unlocking the dose setting lock 86, and operating the attenuator drive knob 71, after which the setting lock 86 is again locked.

Although we have described our invention in detail, it will be appreciated that many changes and modifications can be made by those skilled in the art without departing from the spirit of our invention. The detailed description here given is therefore not to be considered as limiting the scope of the invention.

We claim:

1. A flow-through irradiator for the extracorporeal irradiation of fluid which comprises a primary radiation shield means housing a radiation emitter source material, a primary flow tube means fixedly encased in said primary shield and traversing said primary shield for the through flow of fluid to be irradiated, said primary flow tube means having tortuous end portions within said primary shield, said radiation emitter source material portions encased in said primary fixed shield in coextensive contiguous fixed relation to a portion of said primary flow tube intermediate said tortuous end portions, a secondary flexible radiation absorbing shield member slidably received within and extending exteriorly of said primary flow tube for selective operation from the exterior of said primary shield for selectively precluding and varying the amount of radiation passing into said primary flow tube, wherein said flexible radiator absorbing shield member comprises a helical spring.

2. The combination of claim 1 wherein said primary flow tube means comprises a tube having a linear intermediate portion and sinuous end portions.

3. The combination of claim 1 wherein said radiation emitter material comprises a beta ray source having a tubular configuration positioned in encompassing relation to said primary flow tube means.

4. The combination of claim 2 wherein said radiation emitter material comprises a beta ray source having a tubular configuration positioned in encompassing relation to at least a portion of said linear intermediate portion of said primary flow tube means.

5. The combination of claim 1 wherein said helical spring formed of a member having a square cross-sectional configuration.

6. The combination of claim 1 wherein said radiation emitter material comprises strontium 90.

7. The combination of claim 1 wherein said means for reciprocating said flexible radiation absorbing member includes a permutation key operated lock means for releasably securing said flexible member in a preselected attenuating position.

8. A flow-through beta ray irradiator for the extracorporeal irradiation of body fluid which comprises a primary radiation shield means housing a beta ray emitter source material, a primary flow tube means fixedly encased in said primary shield and traversing said primary shield for the through flow of fluid to be irradiated, said primary flow tube means having tortuous end portions within said primary shield, said radiation emitter source material encased in said primary shield in coextensive contiguous fixed relation to a portion of said primary flow tube intermediate said tortuous end portions, a secondary flexible radiation absorbing shield member slidably received within and extending exteriorly of said primary flow tube for selective operation from the exterior of said primary shield for selectively precluding and varying the amount of radiation passing into said primary flow tube, wherein said flexible radiator absorbing shield member comprises a helical spring.

9. The combination of claim 8 wherein said primary flow tube means comprises a tube having a linear intermediate portion and sinuous end portions.

10. The combination of claim 8 wherein said radiation emitter material comprises a beta ray source having a tubular configuration positioned in encompassing relation to said primary flow tube means.

11. The combination of claim 10 wherein said radiation emitter material comprises a beta ray source having a tubular configuration positioned in encompassing relation to at least a portion of said linear intermediate portion of said primary flow tube means.

12. The combination of claim 8 wherein said helical spring formed of a member having a square cross-sectional configuration.

13. The combination of claim 8 wherein said radiation emitter material comprises strontium-90.

14. The combination of claim 8 wherein said means for reciprocating said flexible radiation absorbing member includes a permutation key operated lock means for releasably securing said flexible member in a preselected attenuating position.

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