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B. MANNING ET AL

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FLUID IRRADIATOR AND PROCESS FOR ITS MANUFACTURE

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Fig. 1

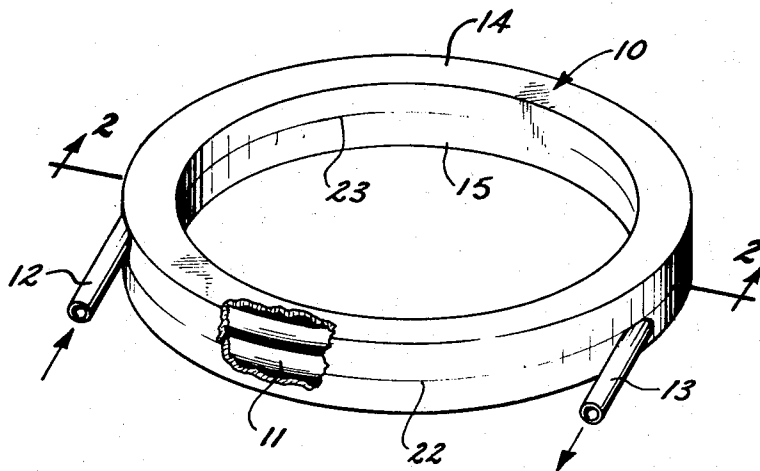
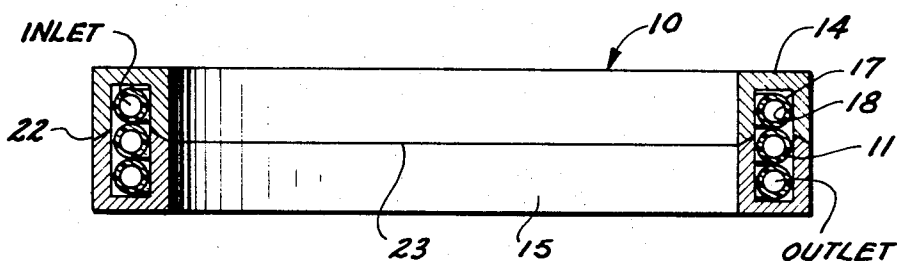


Fig. 2



INVENTORS

SIGURD E. NELSON
BERNARD MANNING

BY

ATTORNEY

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FLUID IRRADIATOR AND PROCESS FOR ITS MANUFACTURE

Bernard Manning, Annandale, and Sigurd E. Nelson, Springfield, Va., assignors to Nuclear Associates, Inc.

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7 Claims

ABSTRACT OF THE DISCLOSURE

An article for irradiating a fluid comprising a continuous tubular matrix in curvilinear form having a fluid inlet and a fluid outlet; a radioactive material dispersed substantially uniformly in the matrix to provide an annular radiation source; and a protective shield surrounding the matrix to prevent escape of radioactive energy to unwanted locations. A process for the preparation of a fluid irradiating article comprises in combination the steps of providing a material capable of being made radioactive; providing a porous tubular matrix which will have a half-life less than said material capable of being made radioactive when said matrix and said material are made radioactive by the same means for the same period; depositing said material substantially uniformly in at least a part of the porous portion of the porous tubular matrix; sealing at least the outer surface of the material containing tubular matrix to prevent escape of deposited material therefrom; and subjecting the resulting sealed tubular matrix to a means for making the deposited material radioactive.

BACKGROUND OF THE INVENTION

This invention pertains to an article for irradiating a fluid and a process for its manufacture, and more particularly, this invention pertains to an article for the extracorporeal irradiation of body fluid.

Studies of extracorporeal irradiation of blood or lymph have shown that there is a marked and prolonged reduction in the leukocyte and lymphocyte population as a result of radiolysis; and when extracorporeal irradiation of body fluid is applied to the preparation of patients for renal allografts and the treatment of rejection crisis, the results have been very encouraging. Also, the application of extracorporeal irradiation to the management of chronic granulocytic, chronic lymphocytic and acute myeloblastic leukemia has been shown to be a very promising adjunct to chemical therapy treatment.

A parameter often used as a quantitative measure of extracorporeal irradiation (ECI) is the transit dose which is defined as the amount of radiation absorbed by a unit volume of body fluid while in transit through the radiation field. The dose rate being delivered to a total volume of bloods while flowing through an extracorporeal shunt determines the transit dose in accordance with the following expression:

$$R \text{ Equals } (V/V') R'$$

wherein R is equal to the transit dose, R' is equal to the dose rate being delivered to the total volume, V, of body fluid flowing through the extracorporeal shunt at a flow rate, V'. It can be seen, therefore, that the transit dose may be varied by changing the shunt fluid volume, V, the flow rate, V', or the dose rate, R', of the extracorporeal shunt. In most instances changes in flow rate are not easy or desired when the body fluid is blood; and therefore, to vary the transit dose a means to vary the dose rate while maintaining the shunt volume at a minimum would be a worthwhile advance in the art.

ECI studies using machine X-ray and high energy beta and gamma radiation at transit doses of from about 15

10 rads to over 1200 rads have shown that a transit dose approaching 900 rads is generally higher than is needed to produce a desirable degree of leukopenia or lymphopenia and that continuous ECI at this dose level may produce severe hemolysis due to radiation injury of the red blood cells. It has been found also that although transit doses as low as 15 rads may produce lymphopenia or leukopenia, there is evidence that physiological mechanisms may be initiated which produce or cause production of white blood cells more rapidly. Further, continuous ECI for several days at low dose levels may cause the development of more radioresistant cells. Many investigators in this field agree that a transit dose of 200 to 500 rads absorbed over a period of approximately 24 hours appears to be sufficient to produce a near maximum depletion of white cells and that short repetitive applications of ECI over a period of several days are more efficient and produce better results than continuous ECI. Therefore, an article for efficient irradiation of a fluid at a desired or controllable transit dose level is a worthwhile advance in the art. Also, an article, and its process for manufacture, for providing ECI which is inexpensive, light weight, easily portable, safe and easy to use and store is a most desirable and a novel advance in the art.

SUMMARY OF THE INVENTION

In accordance with this invention, there is disclosed a portable article, and a process for its manufacture, for irradiating a fluid comprising, in combination, a continuous tubular matrix in curvilinear form having a fluid inlet and a fluid outlet; having a radioactive material dispersed substantially uniformly in the matrix to provide an annular radiation source; and a protective shield surrounding the matrix to prevent escape of radioactive energy to unwanted locations. Also disclosed is an article for irradiating a fluid comprising a continuous tubular porous matrix having at least a sealed outer surface and a material capable of being made radioactive deposited substantially uniformly in at least a part of the porous portion of said matrix with the sealed surface being substantially free of the material capable of being made radioactive. A process for the preparation of a fluid irradiating article comprises, in combination, the steps of providing a material capable of being made radioactive; providing a porous tubular matrix which will have a half-life less than the material capable of being made radioactive when the matrix and the material are made radioactive by the same means for the same period; depositing the material substantially uniformly in at least a part of the porous portion of the porous tubular matrix; sealing at least the outer surface of the material containing tubular matrix to prevent escape of deposited material therefrom; and subjecting the resulting sealed tubular matrix to a means for making said deposited material radioactive.

The article of this invention for providing ECI presents impressive advantages. A maximum possible radiation dose rate is obtained by providing the radioactive source in an annulus around the fluid to be irradiated. A relatively inexpensive source is possible by the preplanned activation of an inactive element deposited in the tubular matrix. Inactivated sealed tubular sources may be stored safely and conveniently without radiation protection and then activated as needed in a level of radioactivity as desired. A maximum degree of portability is obtained by the reduction of shielding to a minimum necessary to cover a curvilinear radioactive annulus. A high degree of safety is provided by the sealed encapsulation of the source which prevents major radiation hazards if the source is damaged physically. The use of a flexible tubing shunt through the prepared annulus in curvilinear form reduces the possibility of clotting or other body

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fluid damage to a minimum when the fluid being treated is blood.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 is a perspective view of one form of a fluid irradiating article of this invention with a partial section removed; and

FIG. 2 is a vertical section of the article taken along line 2—2 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown one embodiment of the article of this invention for irradiating a fluid. Protective shield 10 surrounds continuous tubular matrix 11 in curvilinear form having inlet 12 and outlet 13. The protective shield may be in two or more sections, such as top half 14 and bottom half 15, divided along lines 22 and 23, to permit the insertion and removal of continuous tubular matrix 11 in and from the protective shield. Also, inlet 12 and outlet 13 may be in any location with respect to each other that is both convenient and desired so long as the change in direction of the fluid to be irradiated is gentle and areas which may permit fluid stagnation or cause fluid turbulence are kept to a minimum. Further, the number of turns of the curvilinear matrix which are used is dependent upon the dose rate of the matrix and the transit dose needed or desired for the fluid irradiation application.

Referring now to FIG. 2, the continuous tubular matrix 11 is contained within shielding 10 which may be opened into top half 14 and bottom half 15 to permit the insert and removal of the curvilinear tubular matrix. The tubular matrix may be plated on its outer surface 17 or inner surface 18, or both, by a suitable non-corrodible material such as gold, nickel, or aluminum or other as desired or needed, and the shielding material 10 may be lead, aluminum or plastic or combinations of aluminum, lead and plastic or other shielding materials to provide light-weight shielding in compact form.

A continuous tubular matrix of this invention which is or may be made radioactive by proper treatment may be in any curvilinear form; and for purposes of this description, the circular or spiral form is chosen to provide a maximum amount of continuous tubular matrix in a minimum volume. Any length of continuous tubular matrix may be used depending upon the irradiation treatment to be applied to a fluid. In use, a fluid to be irradiated may be passed directly through the continuous tubular matrix or the fluid to be irradiated may be passed through a flexible tube which has first been threaded through the annular opening of the continuous tubular matrix. As can be seen readily, in a one pass radiation treatment of a fluid using the article or apparatus of this invention, at a given dose rate for the matrix and a given flow rate for the fluid, the greater the number of turns the greater the transit dose. Also, the transit dose may be increased or decreased by control of the dose rate from the annular tubular matrix which provides a radiation source encircling the fluid to permit maximum utilization of the source.

The location of the inlet and outlet for the annular continuous curvilinear tubular matrix may be at any point relative to each other such as shown in the drawing; with the inlet and outlet adjacent to each other; or any other suitable location for the application considered. When the article or apparatus of this invention is used for irradiating blood, it is preferred that the inlet and outlet be located in respect to each other and the matrix to provide a flow substantially tangential to the curve of the matrix so that no rapid changes in blood flow direction occur which may cause clotting, hemolysis or other blood damage.

The article or apparatus of this invention provides many distinct advantages including a maximum possible radiation dose by containing a radioisotope in an annulus

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around a fluid to be irradiated; a maximum degree of portability by providing an efficient form for the source requiring less shielding—a curvilinear or coiled annulus can be confined in a smaller volume than a straight annulus of the same length; a high degree of safety for the apparatus by providing encapsulation of the radioactive material in the annular matrix; and, an inexpensive apparatus with the added advantage of obtaining preplanned activations by incorporating an inactive element in the annular matrix and forming the radioisotope within the sealed matrix.

The continuous tubular matrix which provides the annular radioactive source of this invention may be prepared by several methods. One such method is disclosed in U.S. Pat. 3,364,148 wherein an active isotopic salt in liquid form is absorbed into the interstices of a porous silica matrix and the matrix is dried and heat sealed at 1100° C. to close at least the surface of the matrix pores and provide a mechanical seal for the isotopic salt. Another method for the production of sealed sources is disclosed in U.S. Pat. 3,457,181 wherein a part of the porous matrix is first coated or filled with a non-radioactive material prior to introducing the radioactive material into the porous matrix.

A method for the preparation of the annular source for the irradiation apparatus in accordance with this invention comprises the incorporation of an inactive salt of an isotope, such as ^{31}P or ^{169}Tm or other, into a porous matrix which has been preshaped into a desired curvilinear annular form or configuration such as a coil, spiral or other. A preferred porous matrix is a silica matrix containing at least about 92% silica as described in U.S. Pat. 3,364,148 in detail. The inactive salt may be absorbed into the porous matrix or placed there by any other suitable method; and after deposition, the salt may be changed to an insoluble form, if desired. Following the deposition, at least the surface of the matrix is sealed to retain the salt within the matrix. If desired, substantially all of the porous area of the matrix may be sealed by heat or other means to provide a substantially closed pore structure which will give maximum protection from leaching or radiation if the matrix is broken or suffers other physical damage.

After sealing of the matrix, the radioisotope may then be formed, such as ^{32}P or ^{170}Tm by neutron (n, γ) reaction in a reactor or other suitable means. Further encapsulation may be provided, either before or after activation, by plating the annulus with a non-corrodible metal such as gold or nickel or other.

When preparing the radioisotope in accordance with this method, it is critical that the porous matrix used has a half-life less than the material capable of being made radioactive which is deposited in at least a part of the porous section of the tubular matrix when both the matrix and the material deposited are made radioactive by the same means for the same period. It is preferred also that the half-life of the porous matrix, after being subjected to the activation conditions described, be relatively short so that the prepared source may be used and handled with relative safety following activation and a minimum period of exhaust the half-life activity of the matrix.

Preparation of the radioactive source in accordance with this method has many advantages. The dangers of working with radioisotopes are eliminated in the preparation of the annular source; the material to be made radioactive which is entrapped in the matrix may be distributed substantially homogeneously throughout the matrix; and the deposited material remains permanently and safely fixed in position after heat-sealing. Sources prepared in this manner may be handled and stored prior to activation in a nonradioactive condition with a minimum of difficulty and protection. A source so prepared when made radioactive is solid so that if catastrophic destruction of the source occurs, only the exposed ends of

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the broken matrix are accessible to a leaching. Further, by using a radioisotope with a relatively short half-life, the irradiation apparatus becomes readily disposable in a relatively short time. Another advantage which may be derived in the use of a short-lived radioisotope is in applications where a high transit dose rate is needed in a beginning treatment and a lower dose rate is desired at a later time. Also this method of the invention permits the safe and easy deposition of more than one material to be made radioactive within a given matrix.

Aside from eliminating the dangers associated with working with radioisotopes, the possible activity of the inactive form of the material within the matrix of the annular source will provide a very accurate and simple method of obtaining preplanned activities, that is, transit dose rates. Once a suitable beta ray emitter is selected, such as ^{32}P or ^{170}Tm which have high average beta energy and short half-lives, the amount of activity needed for a particular application of a fluid irradiation apparatus can be obtained simply by irradiating the inactive annulus for a precise length of time. Multicurie levels of activities can be obtained by irradiating several coils of a silica annulus containing either ^{32}P or ^{170}Tm for periods of less than 60 days. It has been found that a transit dose of 200 rads may be obtained by incorporating approximately 6 curies of a ^{170}Tm source in a silica annulus having a length of 160 centimeters which comprises three coils having an 0.6 centimeter I.D. and an 0.7 centimeter O.D. Since a saturation activity of 18 curies is formed from the neutron, gamma reaction of ^{169}Tm in this length, a maximum transit dose approaching 600 rads is obtained. It is apparent that instruments or articles of this invention may be fabricated to deliver a transit dose ranging from 200 to 500 rads by varying either the dose rate, i.e. the activity in a given source length, or by varying the source length for a given dose rate, (i.e. the number of coils). As is well known, a transit dose rate of an annulus or apparatus prepared in accordance with this invention may be determined easily by pumping a standard Fricke solution (ferrous sulfate) through the source. Other dosimetric techniques may be used to determine the axial uniformity of transit dose rate such as exposing thermoluminescent dosimeters along the axis of the annulus. The amount of shielding necessary for the apparatus may be determined after determination of the activity, or the desired activity, of the source.

We claim:

1. An extracorporeal irradiator for irradiating a body fluid comprising in combination,

- (a) a continuous tubular porous matrix in curvilinear form having a fluid inlet and a fluid outlet and having a radioactive material dispersed substantially uniformly in the matrix to provide an annular radiation source,
- (b) said radioactive material being a beta ray emitter, and
- (c) a protective shield surrounding said matrix to prevent escape of radioactive energy to unwanted locations.

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2. The irradiator of claim 1 further characterized by said tubular matrix comprising at least about 92% silica.

3. The irradiator of claim 1 further characterized by said curvilinear form being a spiral.

4. The irradiator of claim 1 further characterized by said continuous tubular matrix having at least the peripheral portion substantially free of said radioactive material.

5. The irradiator of claim 1 further characterized by said continuous tubular matrix having a flexible tubing material inserted through the annular portion for carrying said fluid to be irradiated.

6. An extracorporeal irradiator for irradiating a body fluid comprising, in combination,

- (a) a continuous tubular porous matrix having at least a sealed surface,
 - (b) a material capable of being made a beta ray emitter deposited substantially uniformly in at least a part of the porous portion of said matrix,
 - (c) said matrix having a half-life less than said material capable of being made a beta ray emitter when said matrix and said material are subjected to the same irradiating source for the same period of time, and
 - (d) said sealed surface being substantially free of said material capable of being made radioactive.
7. A process for the preparation of an extracorporeal irradiator comprising in combination the steps of:
- (a) providing a material capable of being made a beta ray emitter,
 - (b) providing a porous tubular matrix which will have a half-life less than said material capable of being made a beta ray emitter when said matrix and said material are made radioactive by the same means for the same period,
 - (c) depositing said material substantially uniformly in at least a part of the porous portion of said porous tubular matrix,
 - (d) sealing at least the outer surface of the material containing tubular matrix to prevent escape of deposited material therefrom, and
 - (e) subjecting the resulting sealed tubular matrix to a means for making said deposited material a beta ray emitter.

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JAMES W. LAWRENCE, Primary Examiner

D. L. WILLIS, Assistant Examiner

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