June 4, 1968 E. H. ACREE ET AL 3,387,136

"ON-OFF" X-RAY SOURCE

Filed Jan. 4, 1967 2 Sheets-Sheet 1

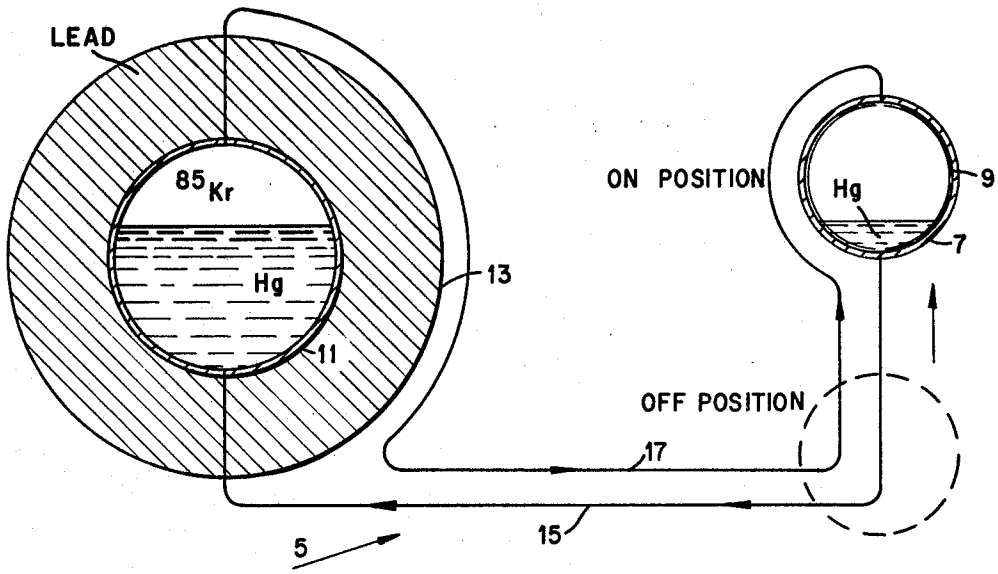


Fig. 1

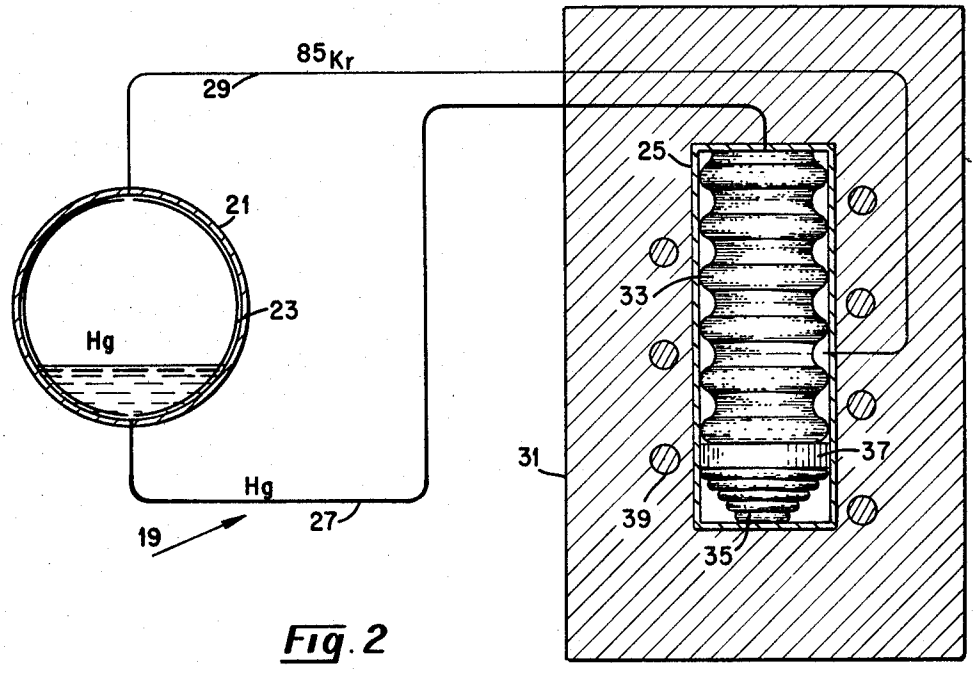


Fig. 2

INVENTORS.
Elick H. Acree
Forrest N. Case
John C. Dempsey

BY.

ATTORNEY.

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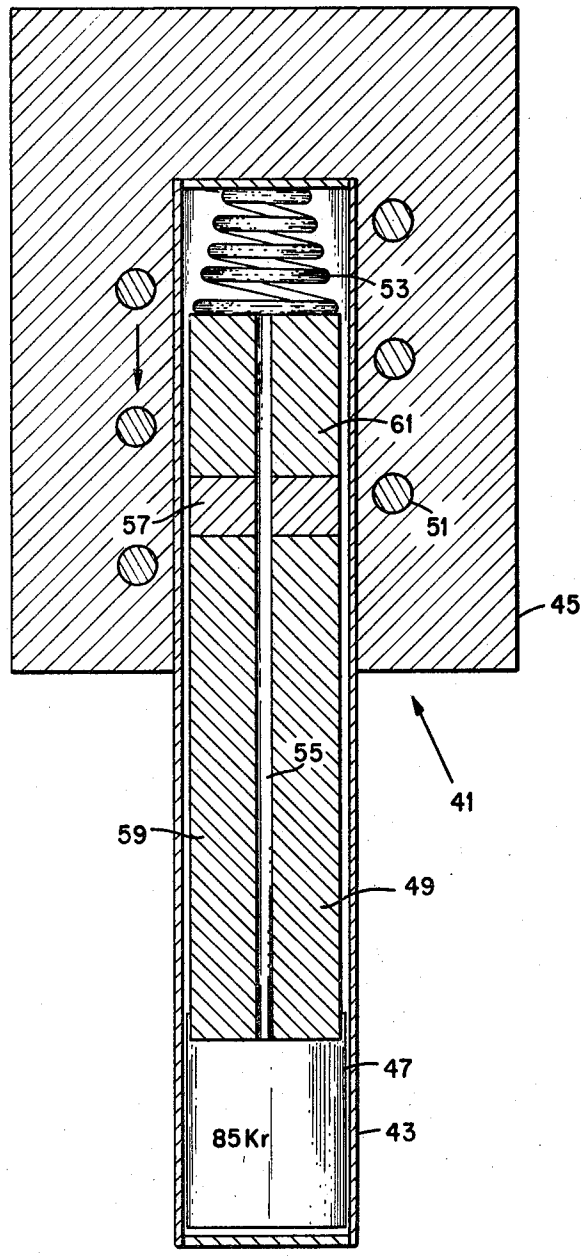


Fig. 3

INVENTORS.
Elick H. Acree
Forrest N. Case
John C. Dempsey

BY.

ATTORNEY.

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"ON-OFF" X-RAY SOURCE

Elick H. Acree and Forrest N. Case, Oak Ridge, Tenn., and John C. Dempsey, Frederick, Md., assignors to the United States of America as represented by the United States Atomic Energy Commission

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ABSTRACT OF THE DISCLOSURE

A beta-emitting gas is contained in a hermetically sealed system. The system consists of two chambers with a gas transfer apparatus connecting the two chambers. One chamber is unshielded and the inner surface is lined with a target material having a relatively high atomic number which emits secondary X-rays when bombarded with beta particles emitted from the gas. This X-ray emission can then be turned off by transferring the gas into the second chamber which is shielded by a suitable shielding material thereby providing a simple and compact "on-off" X-ray source for use where size and simplicity of operation are of considerable importance, such as aerospace communications.

This invention was made in the course of, or under, a contract with the U.S. Atomic Energy Commission.

Background of the invention

This invention relates to a controllable X-ray source and more specifically to a compact, "on-off" X-ray source in which a gaseous beta emitter is selectively brought into contact with a suitable target material to effect secondary X-ray emission.

X-rays have heretofore been produced by various means, such as X-ray tubes in which electrons are accelerated by use of a source of high potential and impinged on a target. The apparatus required to operate the X-ray tube is very bulky and complicated. Other X-ray sources have been provided with an associated beta emission source consisting primarily of solid bodies charged with radioactive isotopes such as thallium-204 or strontium-90, as disclosed in U.S. Patent to Leonard Reiffel, No. 2,797,333 issued on June 25, 1957. These sources are not easily turned off since they must be dismantled to remove the beta source from the target and the source must then be separately shielded and stored. Other modulated sources have been provided which require bulky shutter arrangements between the beta source and the target. Another disadvantage is that the solid isotope must be of relatively high emission strength due to inherent self-shielding; therefore, there is a danger that, if the solid bodies containing the radioactive material were exposed or broken, solid particles of the material would be left lying about unnoticed, or deposited on clothing, etc. Therefore, it has been established in the art that it is advanatgeous to use a gaseous beta source such as disclosed in U.S. patent to Willard E. Swift, Jr., No. 2,884,538, issued April 28, 1959. It has a safety factor which lessens the danger of careless handling. It is less self-shielding; therefore, it does not have to be of high emissive strength and its emissive strength can be varied by varying the gas pressure. In case of a containment rupture the gas is readily dissipated to the atmosphere.

Summary of the invention

The X-ray source of this invention provides relatively low energy X-rays by the action of a beta emitting fluid on a suitable metal target. The general concept of the invention involves containment of a beta particle emitting radioactive fluid in a pair of chambers in fluid communication one with the other. One of the chambers is lined with a suitable metal target which, when bombarded by the beta particles, emits bremsstrahlung radiation. The other chamber is surrounded by a suitable radiation shielding material so that any bremsstrahlung radiation which may be emitted from the inclosing chamber is absorbed when the fluid is contained in this chamber. A means is provided for selectively displacing the radioactive fluid from one chamber to the other, thus providing an "on-off" X-ray source.

A fluid such a krypton-85 is stored in the shielded chamber ("off" mode) and when transferred into the target chamber ("on" mode) a copious supply of X-rays is generated through secondary X-ray emission from the target. Since the secondary X-ray emission can be remotely switched "on" and "off," this source can be used for communication purposes or any other use where source shielding, weight, and personnel hazards are problems.

Accordingly, it is an object of this invention to provide a light-weight, compact, "on-off" X-ray source.

Other objects and many of the attendant advantages of the present invention will become evident from the following description when taken in conjunction with the accompanying drawings.

Brief description of the drawings

FIG. 1 is a schematic diagram of an "on-off" X-ray source according to the present invention.

FIG. 2 is a schematic diagram of an alternate "on-off" X-ray source.

FIG. 3 is a schematic diagram of another alternate "on-off" X-ray source.

Description of the preferred embodiments

Referring to FIG. 1, reference numeral **5** designates one preferred embodiment of an "on-off" X-ray source depicted in the "on" position according to the principles of the present invention. A vessel **7** is provided with a thin metal target **9** disposed on the inner surface. The target may be made of a number of heavy metals, such as tungsten, lead, uranium, etc., which readily emit bremsstrahlung radiation when bombarded with beta particles. A second vessel **11** is provided having a lead shield **13** surrounding the outer surface. Vessels **7** and **11** are in fluid communication by means of flexible lines **15** and **17**. As shown in the drawing, vessel **7** is filled with a beta particle emitting radioactive gas such as krypton-85 (^{85}Kr) while vessel **11** is filled with a non-radioactive liquid such as mercury (Hg). As long as vessel **7** is in the position shown, the source is "on" and X-rays are emitted from the target **9** through the walls of the target-containing vessel **7**. When vessel **7** is lowered to the "off" position (shown by dotted lines), which may be accomplished by means of a solenoid or similar device (not shown), mercury from the shielded vessel **11** flows through the line **15** by the force of gravity into vessel **7**, thus displacing the krypton which flows through line **17** into vessel **11**. Vessel **11** being shielded therefore absorbs any bremsstrahlung radiation which may be emitted from the vessel. When

all of the gas is displaced from vessel 7, the source is turned "off" and can subsequently be turned back "on" by raising vessel 7 to the "on" position. Vessels 7 and 11 may be constructed from the lighter metals such as beryllium, aluminum, etc., or alloys thereof which are X-ray permeable.

FIGURE 2 depicts an alternate "on-off" source indicated generally by reference numeral 19. A target vessel 21 with an inner metal target lining 23, similar to vessel 7 of FIGURE 1, is connected to a cylindrical container 25 for fluid communication therewith by means of lines 27 and 29. Container 25 is disposed within a lead shield 31. A stainless steel bellows 33 is disposed within container 25 with one end rigidly connected to one end of container 25 and adapted to receive line 27 internally. Line 29 is conected to container 25 externally of bellows 33. Bellows 33 is mechanically biased by means of spring 35. An iron disc 37 is connected to the other end of bellows 33 against which spring 35 urges bellows 33 to be normally contracted. Bellows 33 is held expanded (as shown in the drawing) by means of an energized solenoid 39, which can be remotely operated, forcing the iron disc 37 downward and compressing spring 35. With bellows 33 in the contracted position (solenoid 39 de-energized), vessel 21 is filled with mercury while container 25 is filled with krypton-85 gas external of bellows 33. The source is then turned "on" by energizing solenoid 39, thus causing the mercury from vessel 21 to be drawn into bellows 33 through line 27 and simultaneously forcing the radioactive gas into vessel 21 through line 29. The bombardment of target 23 by beta emission from the gas causes it to emit bremsstrahlung radiation. The source can be turned "off" simply by de-energizing solenoid 33 which forces the mercury back into vessel 21 displacing the gas.

Referring now to FIGURE 3, another alternate "on-off" source is shown indicated generally by reference numeral 41. A krypton-85 gas-filled, hermetically sealed capsule 43 is provided. One end of capsule 43 is disposed in a lead shield 45 which is approximately 1 inch thick surrounding approximately half of capsule 43. A portion of the other end of the capsule 43 is lined with a metal target 47 which may be made of uranium, lead, tungsten, etc., approximately 3 mils thick. The capsule is divided into a target chamber and a shielded chamber by a movable piston 49 disposed in capsule 43 which is moved back and forth by means of a remotely operated solenoid 51 embedded in shield 45. A spring 53 is provided which normally urges the piston into the target chamber to displace the gas. A central fluid passageway 55 is provided through the length of piston 49 to allow the gas to pass from one chamber of the capsule to the other as the piston is moved back and forth. A portion of piston 49 indicated by reference numeral 57, in the field of solenoid 51, is made of iron to allow the magnetic field of solenoid 51 to move the piston. Most of the remaining portion, indicated by reference numeral 59, is made of aluminum to conserve weight, while a portion 61, adjacent the shielded chamber, is made of lead for shielding purposes when the krypton is in the shielded portion of capsule 43. In the "on" position, as shown in the drawing, piston 49 is drawn back against spring 53 and displaces the gas from the shielded chamber of the capsule to the target chamber through passageway 55. The source is then turned "off" by de-energizing solenoid 51, allowing spring 53 to urge the piston 49 back into the target chamber, thus displacing the radioactive gas into the shielded chamber of capsule 43, thereby turning the source "off."

Capsule 43 of FIGURE 3, vessel 7 of FIGURE 1, and vessel 21 of FIGURE 2 may be of beryllium, aluminum, or some other lightweight metal which readily passes X-rays. If a very compact "on-off" source is desired, the capsule could be made of stainless steel approximately 10–20 mils thick, which is much stronger and would allow for higher gas pressure. Since the gas containment area is smaller, the pressure must be higher in order to provide sufficient beta radiation concentration in the target chamber. Since stainless steel is less X-ray permeable than beryllium, for example, some sacrifice of X-ray efficiency is made, but the sacrifice is of such a small degree that it would be considered negligible.

It will be seen from the foregoing disclosure that a lightweight, compact, "on-off" X-ray source is provided which can be used in numerous applications where source shielding, weight, and personal hazards are problems.

It will be understood that, while certain preferred embodiments have been set forth above, the invention is not limited thereto and various other physical embodiments, dimensions, and characteristics can readily be made without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An "on-off" X-ray source comprising: first and second chambers; a beta particle emitting radioactive fluid normally disposed within said first chamber; a target material disposed on the inner surface of said second chamber which emits bremsstrahlung radiation when exposed to beta particle bombardment from said radioactive fluid, forming a target chamber; a radiation shield disposed about said first chamber, forming a shielded chamber, fluid communication means connecting said target chamber to said shielded chamber; and movable means for selectively displacing said radioactive gas from either chamber to the other, thereby providing "on" or "off" conditions of said source.

2. An "on-off" X-ray source as set forth in claim 1 wherein said radioactive fluid is a gaseous beta emitter.

3. An "on-off" X-ray source as set forth in claim 1 wherein said movable means comprises a non-radioactive liquid normally disposed in said target chamber for displacing said radioactive fluid from the lower to the higher of said chambers when said target chamber is raised or lowered.

4. An "on-off" X-ray source as set forth in claim 3 wherein said non-radioactive liquid is mercury.

5. An "on-off" X-ray source as set forth in claim 4 wherein said fluid communication means comprises a first flexible line connected between the top of said target chamber and the top of said shielded chamber wherethrough said radioactive fluid communicates and a second flexible line connected between the bottom of said target chamber and the bottom of said shielded chamber wherethrough said mercury communicates.

6. An "on-off" X-ray source as set forth in claim 1 wherein said fluid communication means and said movable means comprises a metal bellows disposed within said shielded chamber, said bellows having one end rigidly connected to said target chamber, a spring disposed between the other end of said bellows and said shielded chamber for urging said bellows to be normally contracted, a solenoid disposed about said shielded chamber, a non-radioactive liquid normally disposed in said target chamber, a first fluid line connected between the top of said chamber and said shielded chamber wherethrough said radioactive fluid communicates, a second fluid line connected between the bottom of said target vessel and said bellows wherethrough said non-radioactive liquid communicates, a solenoid disposed about said shielded chamber, a magnetic member affixed to said bellows adjacent said spring in the magnetic field of said solenoid, whereby said bellows is held expanded when said solenoid is energized, thus drawing said non-radioactive liquid into said bellows and thereby forcing said radioactive fluid into said target chamber, thereby maintaining said source in said "on" condition.

7. An "on-off" X-ray source as set forth in claim 1 wherein said first and second chambers comprises a hermetically sealed, cylindrical capsule and a movable pis-

ton disposed within said capsule dividing said capsule into two chambers.

8. An "on-off" X-ray source as set forth in claim 7 wherein said movable means comprises a spring disposed between said piston and one end of said capsule for normally urging said piston into said target chamber, a solenoid disposed about said shielded chamber, and a magnetic member forming a portion of said piston in the magnetic field of said solenoid whereby when said solenoid is energized said piston is moved into said shielded chamber displacing said radioactive fluid into said target chamber.

9. An "on-off" X-ray source at set forth in claim 8 wherein said fluid communication means comprises a passageway through said piston wherethrough said fluid communicates when said piston is moved back and forth.

10. An "on-off" X-ray source as set forth in claim 9 wherein a portion of said piston adjacent said target chamber is made of a radiation shielding material.

No references cited.

RALPH G. NILSON, *Primary Examiner.*

A. B. CROFT, *Assistant Examiner.*