Nov. 11, 1958 C. F. HENDEE 2,860,254

RADIATION DETECTOR

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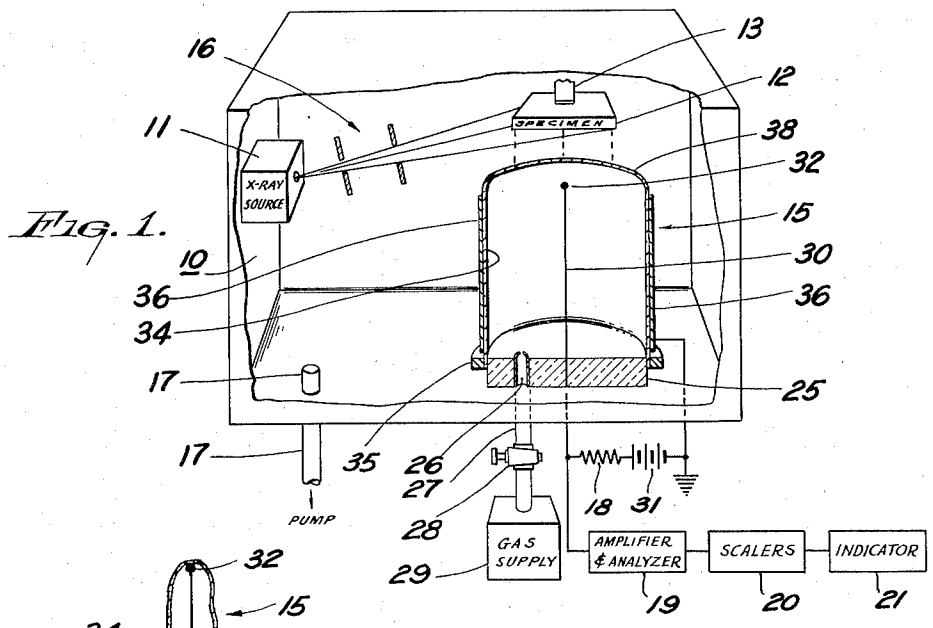


Fig. 1.

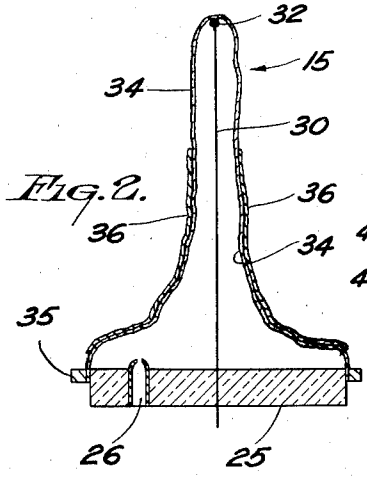


Fig. 2.

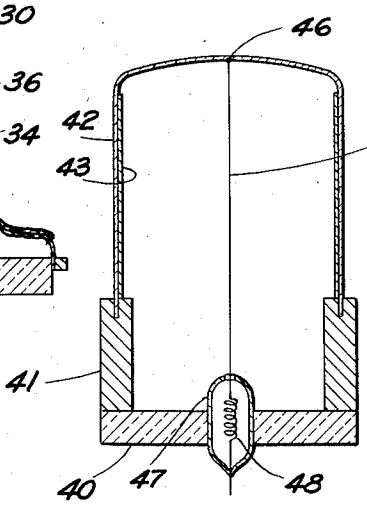


Fig. 3a.

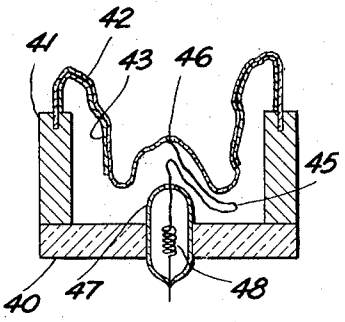


Fig. 3b.

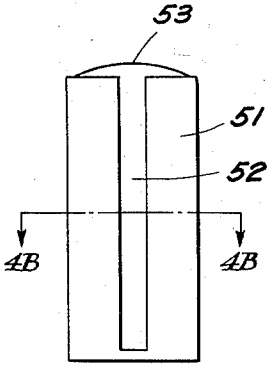


Fig. 4a.

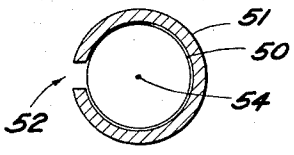


Fig. 4b.

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RADIATION DETECTOR

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13 Claims. (Cl. 250—83.6)

This invention relates to radiation detectors, and in particular to detectors for radiation in the soft X-ray region of the electro-magnetic spectrum or other readily-absorbable particles.

Most X-ray work utilizing soft X-rays must be done in vacuum to minimize absorption. A typical instrument for X-ray fluorescence analysis involving detection of the fluorescent radiation from the elements neon to manganese would therefore provide means for mounting its optics, that is, the X-ray source, specimen, and detector, in a closed chamber which may be evacuated. The detector for these soft X-rays would also have to be provided with a window through which the fluorescent radiation can pass with a minimum amount of absorption to be detected. Window materials employed in the past, like mica or beryllium, though mechanically suitable, have exhibited too high an absorption for soft X-rays. On the other hand, materials of higher transmission, such as thin collodion films, have not been of sufficient mechanical strength for an application in which the surrounding environment is periodically evacuated and then returned to atmospheric pressure. A further discussion will clarify this latter consideration.

The most suitable detectors for these X-ray applications are so-called Geiger or proportional counters. These devices generally comprise a cylindrical cathode and a thin coaxially-disposed anode wire, which cooperate with a radiation-absorbing gas-filling to provide the desired detection and counting action. The gas-filling, which may be air or a rare gas such as xenon, is generally provided at a pressure at which the desired absorption of the soft X-rays will occur within the active region of the counter. A typical pressure is, for example, about 10 mms. of Hg.

Thus, the gas pressure within the detector on one side of the detector window is of the order of $\frac{1}{10}$ to $\frac{1}{100}$ of an atmosphere. The pressure on the other side of the detector window, where the remaining optics are located, is varying between atmospheric and about 1 millionth of atmospheric. The former prevails when the specimen is inserted into position on its holder or is being replaced by some other specimen. The latter prevails during the actual analysis, when the chamber containing the optics will be pumped down to some very low value to minimize absorption of the soft X-rays being produced at the specimen. Detector windows of the thin, collodion film type are unable to withstand such repeated pressure differentials from opposite directions, unless means are provided, which are cumbersome and expensive, for controlling the pressure within the detector simultaneously with that of the chamber containing the optics.

The chief object of the invention is to provide a new type of radiation detector with a window portion not only capable of being continuously subjected to pressure differentials from opposite directions of the type described above without puncturing and without requiring elaborate pumping procedures, but also affording a minimum of absorption of soft X-radiation, as well as a suitable detector

geometry enabling high counting sensitivity and efficiency to be realized.

The invention is based on the realization that a balloon may be inflated not only by introducing air into the inside, but by reducing the pressure of the atmosphere surrounding the balloon. In other words, the balloon will assume an inflated position when the gas pressure on the inside is greater than that on the outside no matter how such pressure differential has been created, whereas it will assume a deflated or collapsed position whenever the gas pressure on the outside exceeds that of the inside.

In accordance with the invention, the envelope or gas-confining medium for my new radiation detector, which also constitutes the detector window, is constituted mainly by a thin, pliant, substantially gas-tight material. By "pliant" material, I mean to include materials, such as rubber or a synthetic resin, whether or not elastic, which, by virtue of their thinness, flexibility or any of their other properties, are incapable of supporting themselves in other than a collapsed position, but which may be readily deformed or extended or stretched by gas pressure alone to assume a distended position. That is to say, if such material were provided in hollow form, it would collapse when the external gas pressure slightly exceeded the gas pressure on its interior. By the term "substantially gas tight," I mean that gas leakage through the material is either negligible or so slight that the total pressure on the inside of the envelope remains fairly constant for a reasonable period of time. A very suitable material for this purpose, which exhibits low absorption to soft X-rays, is known as "mylar" plastic, which is a transparent, highly flexible, polyester film, the reaction product of ethylene glycol and terephthalic acid. "Mylar" is manufactured and sold by E. I. du Pont de Nemours & Co., Inc.

The invention resides in constructing at least about half of the detector envelope out of this thin, substantially gas-tight, pliant material, after which it is filled in the usual way with a suitable low pressure gas-filling. A central anode wire is positioned within the envelope, and a suitable cathode surface is provided on the envelope or external to the envelope. When a detector of such construction is placed in a chamber in which the gas pressure is subsequently reduced, the pliant material begins to swell-up or inflate to assume a shape fixed either by some external support or by its own construction, which shape is conducive to the detection of radiation in a manner similar to that of any ordinary Geiger or proportional counter. The final shape assumed by the envelope will depend upon the equilibrium established between the pressure differential on the envelope and the tensile forces within the envelope material resisting this differential. The pliant material, being of necessity quite thin, and possibly even thinner by reason of being stretched in its distended position, absorbs very little of the incident radiation and thus serves admirably as the entrance window for the radiation to be detected. Hence, as will be evident from the preceding discussion, evacuation of the chamber containing the optics will cause the detector envelope to assume the shape required for service as a counter. On the other hand, when atmospheric pressure is restored within the optics chamber to change or remove the specimen, the excess gas pressure now existing on the outside of the envelope, relative to the low pressure gas-filling, will collapse the pliant material down to a volume at which the pressure of the confined detector gas-filling will be raised to match the atmospheric pressure on the other side of the envelope. Thus, equilibrium will be established between the envelope and the gas atmospheres on its opposite sides in both the inflated and collapsed positions of the envelope. This resultant displacement of the envelope in response to pressure changes enables the envelope to more successfully resist these heavy pres-

sure forces, even though constituted of extremely thin and even fragile material, thereby enabling a better compromise to be achieved between window strength and absorption to the incident radiation.

The invention will now be described with reference to the accompanying drawing, wherein:

Fig. 1 is a diagrammatic view of an X-ray analysis instrument employing my new radiation detector, the latter being shown in inflated operative position;

Fig. 2 is a view of the detector shown in Fig. 1 in the collapsed position;

Figs. 3*a* and 3*b* are views of another form of radiation detector of the invention in, respectively, the inflated and collapsed positions;

Figs. 4*a* and 4*b* are front and top views of still another form of radiation detector according to the invention.

Referring now to the drawing, Fig. 1 shows an X-ray fluorescence analysis instrument of the type disclosed in my copending application, Serial No. 432,793, filed May 27, 1954. The instrument comprises a closed, vacuum-tight chamber **10** containing an X-ray optical system. This system includes an X-ray source **11** producing a continuous spectrum of X-radiation, such as an X-ray tube or radioactive source, a specimen **12** to be analyzed mounted on a suitable support **13**, and a detector **15**. Between the source **11** and specimen **12** is mounted a collimating system **16**, shown only diagrammatically, for preventing X-radiation from the source **11** from impinging directly on the detector **15**. The specimen **12** is irradiated by X-radiation from the source **11**, and can thus be excited into producing its characteristic fluorescent radiation. If the atomic numbers of the specimen elements are, for example, in the range of 10 to 25, then its characteristic fluorescent radiation will lie in the soft X-ray region of the spectrum. The fluoroescent radiation will then impinge on the detector **15**, which, in accordance with my aforementioned copending application, is a proportional counter in order to enable separation of the various wave-lengths contained in the fluorescent radiation from the specimen. Alternatively, however, the detector may be a Geiger type of counter, in which case a single crystal and goniometer or the like will have to be employed to obtain the desired separation of wave-lengths.

In operation of the illustrated instrument, a cover plate, not shown, can be removed from the chamber **10** enabling access to the holder **13**. After a specimen **12** has been mounted in position on the holder **13**, the chamber **10** may be evacuated through a conduit **17** by a suitable pump (not shown). Then, the source **11** is energized and the specimen excited into fluorescence. The fluorescent radiation is detected by the proportional counter **15** producing pulses in an output circuit **18** whose magnitude is proportional to the energy of each wave-length of X-radiation detected and whose repetition rate depends upon the intensity of that wavelength. These pulses are then amplified by suitable amplifiers **19** and separated according to amplitude by a suitable pulse analyzer **19**. Thereafter, the pulses at particular amplitude levels are counted by means of suitable scaler circuits **20** and the results recorded by a mechanical register or strip-chart recorder **21**.

The new radiation detector **15** of my invention, illustrated in Fig. 1 as a proportional counter, comprises an insulating base member **25** supporting a nozzle **26**. The nozzle **26** preferably has a very small orifice to prevent implosion of the pliant material into the nozzle during the evacuation and filling of the detector **15**. The base member **25** is mounted on the floor of the chamber **10**, and a tube **27** communicates with the nozzle **26**. A stopcock **28** or suitable pressure regulating means is mounted on the tube **27**, one end of which communicates with a gas supply **29** containing a substantial quantity of gas for the detector filling. A rigid, thin wire **30** is mounted on the base **25** and extends vertically through the center of the counter. The bottom end of the wire **30**, which wire serves as the detector anode electrode, passes through the chamber floor and is electrically connected to a high voltage source **31**. The other, upper end of the anode wire **30** is capped off by a spherical field-forming member **32**.

The cylindrical, hollow envelope **34** of the detector **15** is constituted of a thin, pliant, substantially gas-tight material, such as the "mylar" plastic referred to earlier. The envelope **34** is secured in a gas-tight manner to the base **25** by means of a retaining ring **35** or may be simply cemented or otherwise fastened directly to the supporting base **25**. The outer cylindrical surface of the envelope **34**, but not the top end, is metallized **36** with aluminum, for example, which is then electrically connected to the negative side of the potential source **31**. This metal film **36** serves as the detector cathode electrode. The fact that an insulating material, for example, the "mylar" plastic, intervenes between the counter volume and the cathode surface only denotes that the counting action will be of the so-called "Maze" type. This is of no consequence, since the metal film could just as easily be provided on the inside of the pliant envelope. The interior of the envelope is then filled with some gas, for example, neon plus a small quantity of a suitable quench gas, at a desired pressure through the nozzle **26** from the supply **29**. The reason for the supply **29** is to replenish any gas which may escape through the envelope **34** if it happens to be slightly permeable. On the other hand, if the envelope **34** is completely gas-tight, the supply **29**, as well as the tube **27** and nozzle **26**, may be dispensed with, and the detector permanently sealed off once the correct gas pressure has been provided therewithin. In any case, during operation of the instrument, the stopcock **28**, if present, will always be in the closed position to completely seal off the interior of the envelope **34**. When employing ultra-thin "mylar," the supply **29** will probably be required to maintain the gas pressure for long periods of time.

In accordance with the invention, the detector envelope **34** is constructed of such thin and pliant material that it is not self-supporting, i. e., is collapsible, unless a suitable pressure differential exists. Fig. 1 illustrates the inflated or operative position of the counter. The pressure of the detector gas on the inside of the envelope **34** is for example about 10 mms. of Hg. The chamber **10** has been evacuated down to some suitably low pressure, for example, about 0.001 mm. of Hg, so that the gas on the inside of the detector envelope has expanded and caused the latter with its metal film to be blown up like a balloon and thus assume the position shown. The pressure chosen enable the envelope to be fully distended, and it can be made to assume the cylindrical shape shown by proper construction, in the same manner as rubber balloons can be caused to assume different shapes after inflation. In the position shown in Fig. 1, the gas in the envelope is at a low pressure sufficient to absorb incident X-rays and perform an electrical discharge counter action with the cathode and anode electrodes, but yet not at such a value as to fracture or puncture the envelope wall. Control of the final pressure within the detector **15** by means of the stopcock or other pressure regulating means will readily enable the obtention of this result.

The end **38** of the counter in the distended position shown in Fig. 1 now serves as the window through which incident radiation may enter into its active volume and be absorbed by the gas filling therein. The absorption of radiation by the window area will be slight for the following reasons. First, the window will be exceedingly thin, of the order of 0.001 and preferably of 0.00025 inch or less. If constructed of "mylar" plastic or cellophane, for example, it will consist primarily of low atomic number materials, which also tends to minimize absorption. Finally, the envelope, when distended, and when constructed of the proper materials, will be

stretched, further reducing the thickness of the window area. To attain counting action in the end region of the counter, the window area **38** could also be covered with the metal cathode film. If a low atomic number material, like aluminum, is employed, and if the film is kept thin, the additional absorption in the metal film itself will not be prohibitive.

When the analysis is completed, the vacuum in the chamber **10** is broken, and atmospheric pressure restored, resulting in a reversal of the pressure differential and causing the gas filling within the detector to be compressed, thereby collapsing the pliant envelope material **34** about the central anode wire **30**. The final form of the detector resulting from this action is illustrated in Fig. 2. The reduction in volume of the detector gas filling will naturally cause an increase in its pressure. At some point during the reduction, the pressure of the filling will be raised to atmospheric, thereby balancing the external pressure within the chamber **10** and enabling equilibrium to be restored to the envelope. Thus, in the collapsed position, no pressure differential on the envelope wall will exist.

It will be realized that the pliant material need not constitute the entire envelope as shown in Figs. 1 and 2. The only requirement which needs be satisfied is that, when the envelope collapses, a sufficient reduction in volume of the detector gas filling will occur to build up its pressure to a value approaching atmospheric or the external pressure within the chamber **10**, whatever it may be. In general, this requirement will be satisfied when the pliant material constitutes at least about half of the surface area of the total envelope. Such a construction is illustrated in Figs. 3*a* and 3*b*. In the latter figures, an insulating base **40** supports a cylindrical metal body **41**. To the cylindrical body **41** is secured a pliant material **42** in a gas-tight manner. In this case, the inner surface of the pliant material **42** is metallized to form a conductive film **43**. The film **43** is connected to the metal cylinder **41**, and both serve as the cathode for the detector. Fig. 3*a* shows the inflated position of the envelope, and Fig. 3*b* the collapsed position.

Figs. 3*a* and 3*b* also illustrate a different form of anode construction from that of Figs. 1 and 2. In this case, the anode is constituted by a completely flexible thin wire **45** secured at **46** to the top of the pliant material **43**, which is, of course, electrically insulating. To the bottom end of the wire **45** is secured a very light spring **48**, which is maintained in position by a cap-like member **47**. Collapse of the envelope, as illustrated in Fig. 3*b*, now causes collapse also of the anode wire **45**. Upon inflation (Fig. 3*a*), the dimensions of the spring **48** are chosen so that the wire **45** is held taut by a slight spring pressure. The member **47** can also serve as the exhaust and filling tubulation for the interior of the envelope.

Figs. 4*a* and 4*b* depict another construction of the invention in which the cathode is not mounted on the pliant envelope. In this case, the pliant envelope **50** is mounted within a rigid, cylindrical, conductive body **51**, which now serves as the cathode surface. Once again, since the envelope material intervenes between the gas volume and the metal cathode, counting action will be of the "Maze" type. Entrance of radiation into the detector is afforded through a slit **52** provided in the wall of the cylindrical body **51**. Alternatively, the body **51** may be complete, and radiation permitted to enter the detector through the top, exposed end **53** of the envelope **50**. Collapse of the envelope **50** will not, of course, affect the position or shape of the solid body **51**. For counting action, potentials are applied across the conductive body **51** and a central anode wire **54** indicated in Fig. 4*b*. The construction illustrated would provide an additional advantage if the envelope **50** were slightly gas-permeable, because, under these circumstances, the pressure of the inflated envelope **50** against the cylindrical body **51** would provide a seal, preventing extensive escape of the gas on the interior of the envelope **50**, except through the small area located at the slit **52**. As a further alternative, the cylindrical body may be composed of a rigid, wire mesh or a series of circularly-arranged parallel rods rather than of the solid material depicted in the figures.

In describing the invention, basically cylindrical-geometry types of detectors have been illustrated. However, those skilled in the art will realize that the principles enunciated above apply equally well to other geometrical types of radiation detectors. It will also be realized that though the invention has been described specifically in connection with the detection of soft X-radiation, it will be equally useful in the detection of other rays or particles which are readily absorbed by the walls or windows of conventional detectors, for example, beta particles or alpha particles.

While I have described my invention in connection with specific embodiments and applications, other modifications thereof will be readily apparent to those skilled in this art without departing from the spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A radiation detector comprising a pair of electrodes, a radiation-absorbing gaseous medium between the electrodes, and an envelope enclosing said gaseous medium, at least half of said envelope being constituted of a thin pliant collapsible substantially gas-tight material.

2. A radiation detector comprising a pair of electrodes, a radiation-absorbing gaseous medium between the electrodes, and an envelope enclosing said gaseous medium, said envelope comprising rigid and collapsible portions, said collapsible portion having an area at which when collapsed the confined gaseous medium may be reduced in volume to an extent at which its pressure is increased to match an external pressure causing the collapse.

3. A radiation detector comprising a pair of electrodes, a radiation-absorbing gaseous medium between the electrodes, and an envelope enclosing said gaseous medium, said envelope including a thin pliant portion capable of alternately assuming an inflated position and a collapsed position, said pliant material constituting the entrance window for radiation into the detector.

4. A radiation detector comprising a cylindrical envelope at least half of which is constituted of thin, pliant, collapsible, substantially gas-tight material, a radiation-absorbing gaseous medium within said envelope, a central anode wire extending through the center of said envelope, and a conductive cathode integral with said envelope.

5. A detector as set forth in claim 4 wherein the anode wire is rigid.

6. A detector as set forth in claim 4 wherein the anode wire is flexible, and one end is secured to the end of the pliant portion of the envelope.

7. A detector as set forth in claim 4 wherein the cathode constitutes a metal coating on the outside of the pliant envelope.

8. A detector as set forth in claim 4 wherein the cathode constitutes a metal coating on the inside of the pliant envelope.

9. A radiation detector comprising a rigid cylindrical conductive cathode body, a thin, pliant collapsible, substantially gas-tight envelope within said cathode body, a central anode wire within said envelope and concentric with the cathode, and an ionizable gaseous medium within the envelope.

10. In combination, a substantially gas-tight chamber, means for evacuating said chamber to reduce the pressure below atmospheric to a predetermined value, a source of radiation within said chamber, and a detector for said radiation within said chamber, said detector comprising electrodes, a radiation-absorbing gas at a given pressure, and an envelope enclosing the gas, said envelope includ-

ing a portion constituted of thin, pliant, substantially gas-tight material, said material being constructed such that said portion assumes a fully distended position without fracturing when said chamber is evacuated to the predetermined value, said envelope portion assuming a collapsed position when said chamber is at atmospheric pressure.

11. The combination as claimed in claim 10 wherein the electrodes include a central anode wire mounted within the envelope and a metal coating on the pliant envelope portion.

12. The combination as set forth in claim 10 wherein the source produces soft X-radiation, and the pliant portion is constituted of a flexible polyester film.

13. The combination as set forth in claim 10 including means for replenishing any gas lost through the pliant portion of the envelope.

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