Sept. 20, 1960 J. G. MacHUTCHIN ET AL 2,953,684

SELF-LUMINOUS LIGHT SOURCES

Filed June 20, 1957 2 Sheets-Sheet 1

FIG. 1

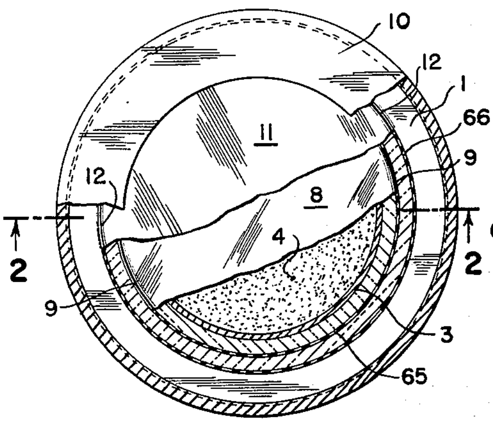


FIG. 3

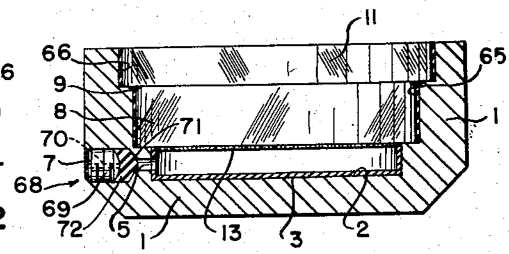


FIG. 2

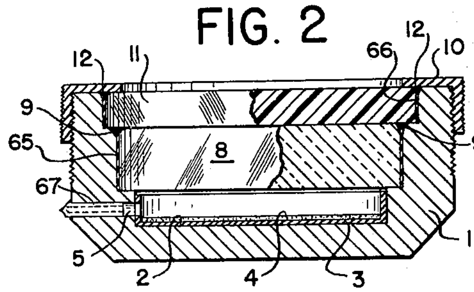


FIG. 4

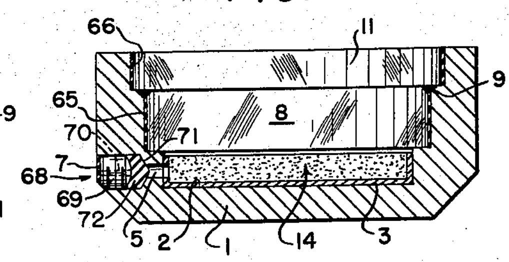


FIG. 5

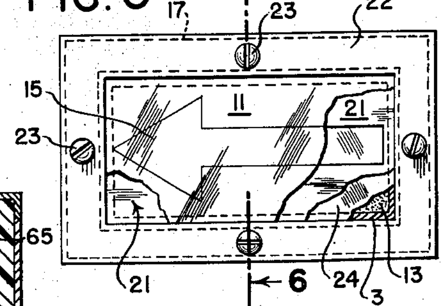
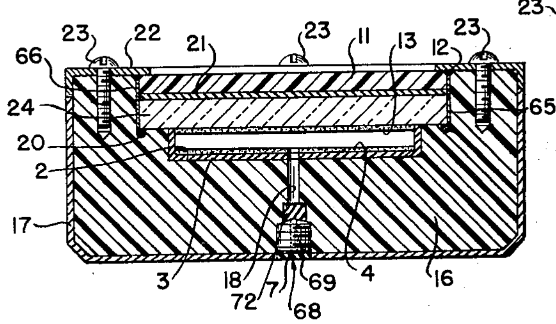


FIG. 6



INVENTORS

JOHN G. MacHUTCHIN

DAVID L. PROSSER

CHARLES H. WRIGHT

BY

Pennie, Edmonds, Morton, Barrows & Taylor

ATTORNEYS

FIG. 7

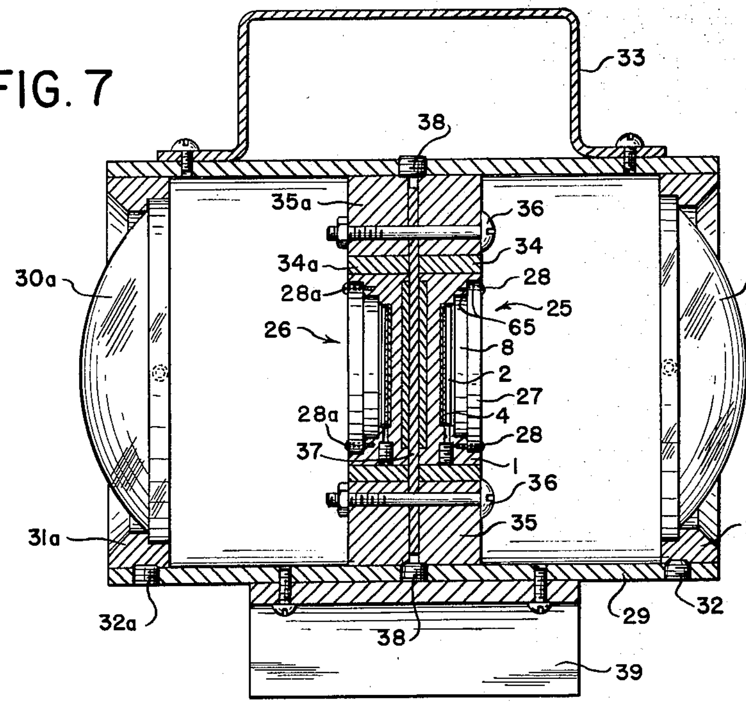
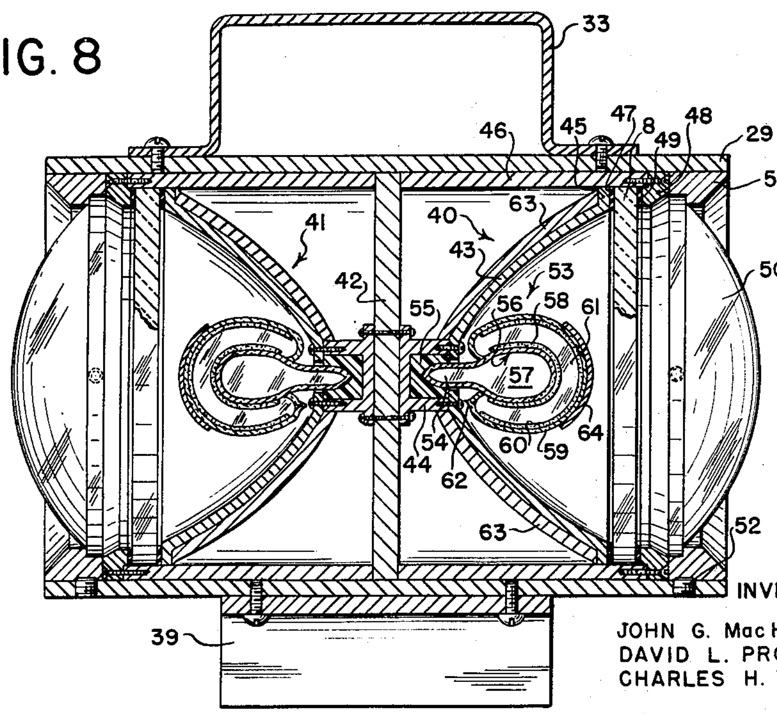


FIG. 8



INVENTORS
JOHN G. MacHUTCHIN
DAVID L. PROSSER
CHARLES H. WRIGHT
BY
Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

United States Patent Office

2,953,684

Patented Sept. 20, 1960

2,953,684

SELF-LUMINOUS LIGHT SOURCES

John G. MacHutchin, David L. Prosser, and Charles H. Wright, Berwick, Pa., assignors to United States Radium Corporation, Morristown, N.J., a corporation of Delaware

Filed June 20, 1957, Ser. No. 666,840

13 Claims. (Cl. 250—71)

This invention relates to light sources of the self-luminous type which comprise a phosphor excited by radioactive material.

Certain principles and features of the present invention are similar to those of our copending application Ser. No. 650,247, filed April 2, 1957, now abandoned, and the continuation thereof Ser. No. 778,220, filed December 4, 1958, of which the present application is a continuation in part.

In the past, self-luminous phosphors have been of low light intensity because of the nature of the radioactive material employed for exciting the phosphor, of the physical relationship between the radioactive material and the phosphor particles, and of the structure in which the self-luminous material was incorporated. It has been known that the light intensity could be increased somewhat by increasing the proportion of radioactive material to phosphor, but this shortened the useful life of the phosphor and also increased the radiation hazard. On the other hand, the present invention provides a great increase in visible light intensity while retaining ample effective life and safe radiation level. This improvement results from the novel combination of materials having certain characteristics, of their physical relationship, and of the structure in which they are employed.

The self-luminous light source structure according to this invention includes, briefly, a body member formed with a cavity therein, a plate of non-darkening glass or the like closing the cavity to form a gas chamber, at least one layer of phosphor within the chamber, a port extending from outside the body into the chamber through which the chamber can be evacuated and filled with radioactive gas, means to seal the port which may comprise self-sealing means including a soft rubber plug under longitudinal compression, advantageously a cover of transparent plastic material secured over the plate, and gas-impervious means sealing the plate and cover to the body. In a preferred embodiment the body is formed in steps which provide separate shoulders to which the plate and cover can be individually sealed. Additionally, the invention comprises certain physical relationships involving specified radioactive gases and gas pressures, the number of discrete layers of phosphor, the optimum thicknesses for the different layers depending upon their location and the characteristics of the gas, and the materials and thicknesses of the plate and cover which also serve to absorb radioactive emanations.

The invention will be understood from the following description considered in connection with the accompanying drawings, in which:

Fig. 1 is a plan view, shown partly cut away, of a preferred form of light source according to the invention;

Fig. 2 is a sectional view of the unit taken along the line 2—2 of Fig. 1;

Fig. 3 is a vertical section of a modification of the light source of Fig. 1;

Fig. 4 is a vertical section of an alternative light source according to the invention;

Fig. 5 is a plan view, partly cut away, of an alternative embodiment of the invention, especially useful as a sign or marker;

Fig. 6 is a sectional view of the unit taken along line 6—6 of Fig. 5;

Fig. 7 is an elevational view in section of a two-way lantern comprising two light sources similar to the source of Fig. 1; and

Fig. 8 shows a lantern of the type illustrated in Fig. 7, but which includes a different form of light source.

The figures are not drawn to scale.

Referring now to Figs. 1 and 2, the self-luminous light source comprises a round housing or body **1**, preferably of metal such as aluminum or brass, centrally hollowed in steps of three different diameters, as shown. The bottom cavity **2** contains a cup **3** of aluminum in the base of which is deposited a thin layer of phosphor material **4** which is excited to luminescence by a suitable radioactive colorless gas which is injected into the cavity **2** after evacuation. The evacuation of this cavity and the subsequent filling thereof with radioactive gas is effected through port **5**. At the outer end of port **5** a small copper pigtail tube **67** is silver soldered to the body **1**. After evacuation of the cavity, and injection of the desired gas, this tube is crimped and either welded or soldered at its terminous to ensure a tight seal. An alternative means for sealing the port is described in connection with Fig. 3.

Immediately above the cavity **2** is a somewhat larger cavity, as shown, in which a glass disc or plate **8** is disposed. To make a gas-tight seal for cavity **2**, a continuous seal **65** of metal solder or of epoxy resin is provided in the annulus between the edge of the disc and the metal housing. Suitable resins of this type are Araldite #502 manufactured by Ciba, and Epon #6 manufactured by Shell Chemical Corporation. Above this seal, in the third and largest cavity, is a cover **11** of transparent shatterproof material, preferably methyl methacrylate, such as Plexiglas. The cover may be cemented in position by epoxy resin **66**, or if desired a retaining ring **10**, or both, may be utilized to retain the cover. Typical thicknesses of the Plexiglas cover would be from 1/16″ to 1/4″ depending primarily upon the use to which the unit is to be put. In some cases this cover can be omitted.

The disc **8** must, of course, be translucent and preferably transparent. It comprises the principal shield against the escape of radioactive emanations forwardly from the radioactive gas within cavity **2** and should be of material which is as nearly as possible non-darkening when subjected to the mentioned emanations. In connection with the radioactive gases below mentioned a suitable thickness for this disc may be between 1/8″ and 1/2″. It has been found that ceriumbearing glass is especially adapted to this use, the cerium therein usually being present as a salt or an oxide. Presently available commercial forms of this glass include Pittsburgh #6740, Corning #8362 and Penberthy Med-D, of which the respective densities are approximately 2.7, 3.2 and 4.0. The greater densities provide more effective shielding. Such glass is not only non-darkening, but, in the stated thickness, attenuates beta radiation to a much greater extent than it does visible light.

The phosphor layer **4**, when excited to luminescence, comprises the actual source of light from the unit. Various suitable phosphors have been developed in the art, and the selection will depend upon the brightness level and color of light desired. The greenish light provided by copper-activated zinc-cadmium sulfide is satisfactory for many purposes and is capable of producing high brightness levels when employed according to the present invention. Additional well known suitable phosphors include cadmium sulfide, cadmium tungstate, zinc silicate, zinc sulfide, and others referred to in connection with Figs. 7 and 8. It is customary to activate such phosphors with controlled, minute quantities of various metals.

The thickness of the phosphor layer in the bottom of the cup **3** is rather critical for maximum efficiency. As the layer thickness is increased, more beta energy is absorbed and more light produced up to the thickness at which all useful beta energy is absorbed. This thickness is thus the penetration distance in the phosphor of the beta particles. However, as the thickness is increased up to and beyond this amount, the light produced by phosphor particles near the bottom of the layer tends to be absorbed by the particles through which it passes. Hence, under given conditions of beta energy, particle type and size, binder material, etc., there is a definite optimum thickness for maximum light output which is most readily ascertainable empirically. As a rule, the thickness of the phosphor should correspond to approximately 50 to 150 milligrams of phosphor per square centimeter, the thickness of the individual phosphor crystals preferably being approximately 15–30 microns.

If desired, and if the metal of the housing **1** is aluminum, the cup **3** can be omitted and the phosphor coated directly on the bottom of the cavity **2**, although usually the cup is preferable. When tritium is used as the exciting gas, it has been found to undergo isotopic exchange with organic materials to various degrees, and this tends to decrease the light output. Therefore, if tritium is employed the structure should be designed so that the gas does not come in contact with organic materials such, for example, as rubber and certain plastics. It is preferable that the surface immediately beneath the phosphor layer be polished or otherwise treated to enhance its light reflecting properties.

The phosphor layer may be bound to the desired surface by any of several adhesives. Inorganic adhesives such as sodium silicate and potassium silicate are preferable because of their stable properties. Organic adhesives include the mentioned epoxy resins and Du Pont butyl methacrylate. As indicated, organic adhesives are avoided when tritium gas is utilized.

The radioactive material employed in connection with this invention comprises a radioactive gas, preferably colorless. Krypton–85 (Kr–85) and tritium (H–3) are both suitable and each is preferable for certain respective applications. With krypton gas, after the cavity **2** is evacuated to a sufficient extent through port **5**, the radioactive gas is injected through the same port to the desired pressure. Since this gas is in contact with the phosphor layer **4**, substantially all phosphor will be excited to luminescence. For a given phosphor layer and radioactive gas, the brightness level will depend upon the number of curies of exciting gas present and this, in turn, is a function of the quantity and purity of the gas, the pressure and, to some degree, of the depth of the cavity. In the structures of Figs. 1 to 7, this depth is from $\frac{1}{16}''$ to $\frac{1}{4}''$ and should not be greater than the effective trajectory range of the exciting particles. In the example of Fig. 2 the cup diameter is $1\frac{3}{4}$ inches. In other words, the number of square millimeters area of the luminous surface of the phosphor should be much greater than the number of millimeters depth of the gas-containing cavity.

To achieve greatest security against leakage of radioactive gas it is advisable that the pressure of the gas within the cavity be less than the external or atmospheric pressure. In employing krypton-85, which is presently available from the U.S. Atomic Energy Commission at a purity of approximately 5%, gas pressures ranging from 150 to 400 millimeters of mercury will provide good brightness levels with the suggested types of phosphors in the described structures. The mentioned upper pressure would represent approximately 150 millicuries of krypton-85 in a typical example, and is safe in any of the structures described. However, the gas pressure can safely be increased to several atmospheres if the window, such as glass disc **8** is firmly soldered in position by solder **65** and the threaded retaining ring **10** of Fig. 2 or the screwed-on frame of Fig. 6 are employed. A further precaution against gas leakage, at high pressures, is afforded by a second seal **9** and a third seal **12** of epoxy resin. The annular space between the cover **11** and body **1** can also be sealed by resin **66**. By injecting the gas under higher pressures, for instance such as to provide 300 to 700 millicuries, brightness levels of from 1,000 to 2,000 microlamberts can readily be achieved. Such brightness levels have never previously been available from self-luminous sources.

As above mentioned, the brightness level depends to some extent on the depth of the gas cavity **2**, which obviously is a factor in determining the volume, and thus the number of curies, of gas. The greater the depth of this cavity the more curies of gas can be accommodated at a given pressure. However, the practical limit depends upon the trajectory or range of the effective radioactive emanations. This will vary with the type of gas employed, and in cases of extreme pressures appears to be related to the pressure.

Tritium gas being available in much higher purity than Kr–85, for instance 99%, several curies of tritium can be injected in the same volume while maintaining internal pressures less than atmospheric. At presently available purities the curies ratio of tritium to krypton–85 can be approximately 30 to 1. For these reasons brightness levels from tritium comparable to those from Kr–85 can be had at gas pressures between 50 and 400 mm. of mercury. As in the case of krypton–85, much higher tritium pressures can be safely employed in the stronger structures according to the invention, with some increase in brightness.

In most applications of the invention it is desirable that radiation from the radioactive gas be confined to the structure herein described. Therefore, the thickness of the walls of the body **1** and the thickness of the glass disc **8**, as well as the densities of the respective materials, should be selected to absorb sufficient radiation energy. At the same time it is obviously necessary that the emission of visible light be attenuated to a minimum extent. We have found that a self-luminous source constructed as illustrated in Figs. 1 and 2 is capable of producing brightness levels much greater than has heretofore been practicable and that this can be achieved safely and at less cost than previously possible.

The embodiment of Fig. 3 differs from that of Figs. 1 and 2 essentially in three respects. First, a thin phosphor layer **13** is fixed to the lower face of glass disc **8** instead of on the bottom of cup **3**, as shown in Fig. 2. However, as in Fig. 2 the inside bottom surface of cup **3** should have light-reflecting properties.

In this embodiment the radioactive gas within chamber **2** may be as above described but, as will be observed in the drawing, the radioactive gas is below the phosphor layer. Thus the phosphor particles which are in immediate contact with the radioactive gas and which, on the average, will produce the most light, are on the lower surface of the layer. Since the useful light derived from this unit passes upwardly through disc **8**, the light produced by the mentioned surface particles must pass through the remaining phosphor particles in the layer. For the reason above discussed, the thickness of the layer **13** should not be excessive. We have found that for this layer a thickness corresponding to approximately 50 to 150 milligrams of phosphor per square centimeter of surface is an optimum compromise, although ideally this layer would be only one phosphor crystal thick with no voids between the crystals. The average particle size of the phosphor used here lies in the range 8–10 microns.

Second, the structure of Fig. 3 also differs from that of Figs. 1 and 2 in that the retaining ring **10** has been omitted. As above suggested, the ring is not necessary for gas pressures up to approximately one atmosphere or so, depending on altitude, but for higher inside-to-outside pressure differentials it is advisable. However, in this as well as other embodiments, discs **8** and **11** should be cemented in place, as by a seal **65** of epoxy resin or metal solder, and by either or both of seals **9** and **66**. As in the other embodiments the plastic cover **11** may be omitted.

Third, in this embodiment (as in those of Figs. 4, 6 and 7) the filler tube of Fig. 2 is replaced by a self-sealing plug assembly **68**. This assembly includes the inner port **5**, as before. The outer portion is drilled to a larger diameter and threaded to accommodate a threaded metal plug or set screw **69**. This screw may conveniently be of the Allen type which has at its outer end an hexagonal recess adapted to receive a wrench. A small hole **70** is drilled longitudinally through this set screw. Between the inner end of the set screw and the shoulder **71** a cylindrical plug **72** of soft rubber, such as neoprene or the like is compressed longitudinally by the set screw. In use, a hollow needle of the hypodermic type which is sharpened on the front end, is inserted through hole **70** and forced through plug **72** into port **5**. Through suitable tubing connected to the needle, the cavity **2** is evacuated and the air replaced by the desired radioactive gas. The needle is then withdrawn, whereupon the puncture in the rubber plug instantly seals itself. The longitudinal compression of the rubber increases its density and resiliency, and thus the effectiveness of the seal, but with minimum opposition to inserting and withdrawing of the hollow needle, and with minimum damage to the rubber, because the compressive force is directed along the axis of the needle. The process is completed by sealing the set screw with a covering **7** of epoxy resin or solder. Because of the fact that rubber plug **72** is in contact with the confined radioactive gas, it is inadvisable to employ tritium with this type of seal, the type described in connection with Fig. 2 being preferable. Krypton–85 is apparently unaffected by contact with rubber.

The embodiment illustrated in Fig. 4 is structurally the same as that of Fig. 3, but differs therefrom in that no phosphor layer is coated on the bottom of the glass disc **8**. Instead, the metal cup **3** is filled with phosphor particles **14**. Since there are discrete spaces between these crystalline particles, an adequate volume of radioactive gas can be injected, and this gas will be in intimate contact with substantially all of the particles which will thereby be excited to a maximum degree. On the other hand, since the resulting light from a given phosphor particle must pass through the particles above it, some of the light will be absorbed. Nevertheless, if the cup **3** is comparatively shallow, for example 1/64 to 1/32 inch, very high brightness level can be secured with satisfactory economy of materials, because the cost of the phosphor is considerably less than that of the gas. In one embodiment in which only moderate light output was required, approximately 4 grams of phosphor of the mentioned zinc-cadmium-sulfide type filled the metal cup **3**. After evacuation, approximately 1.3 curies of tritium were injected; and this produced a brightness level of approximately 90 microlamberts. As above mentioned, krypton–85 could have been substituted; and either could be employed at higher pressure. However, this arrangement is not as efficient as are the other arrangements.

The embodiment of the invention illustrated in Figs. 5 and 6 is similar in many respects to that of Figs. 1 and 2, but includes structural features which better adapt it to other uses. As shown, the unit is a self-luminous marker or sign in the form of an arrow **15** comprising the translucent portion of an opaque panel **21**. Obviously any desired indicia or lettering could be substituted. Also, since this unit is capable of producing a very high brightness level, it is adapted to constitute a light source having considerable utility.

In this embodiment the body portion **16**, if Kr–85 gas is used, may be of plastic material such as methyl methacrylate. Preferably, however, for safer, longer-lived units, it should be of metal as shown in the previous figures. Surrounding the plastic body **16** is a metal casing **17**. The bottom cavity **2** in body **16** corresponds to the cavity **2** of Fig. 2, and in it is a metal cup **3**, here of aluminum having a polished inside bottom surface. In this case the evacuation of the cavity **2** and subsequent injection of radioactive gas is effected through port **18** which is closed by a self-sealing plug assembly **68** as before described. This port can be drilled from the bottom as shown or, if desired, from the side as illustrated in the previous embodiments. In the event that tritium is used as the exciting gas, a "pigtail" type filler tube as in Fig. 2 should be employed.

The cavity **2**, as before, is closed on the top by a plate **24** of cerium-bearing glass. To seal against gas leakage the window **24** is sealed around its edges with a seal **65** of epoxy resin, or of metal solder if body **16** is of metal. If required, a seal **20** of resin in a suitable groove may also be included in this as well as in the other embodiments.

An upper layer **13** of phosphor is applied to the undersurface of plate **24** in the manner described in connection with disc **8** of Fig. 3. This layer should be thinner than layer **4** for the reasons discussed in connection with Fig. 3. For maximum light output, using tritium gas, the top layer thickness should not exceed approximately 50 microns. When using tritium of the same purity as before, the additional top layer of phosphor will increase the light output by as much as 20 to 30 percent. If krypton–85 is employed, the layer should be thicker, because of the greater penetration of these particles, and approximately 5 to 10 percent increase in brightness can be expected. By increasing the gas pressure to 2 or 3, or even more, atmospheres, with consequent increase in radioactive radiation, the brightness level can be further increased with either gas.

As shown in Fig. 6, sign panel **21** is positioned on the upper surface of plate **24**. This panel may comprise cerium-bearing glass or any other suitable material, but it may be omitted if the unit is intended merely as a light source. If material such as sheet fiber or metal is used, the indicia are cut out as in stencils. Plastic cover **11** is employed to protect the elements beneath it. A retaining frame **22** of metal similar to that of casing **17** is secured to body **16** by screws **23**, as shown. Frame **22** extends over the edge of cover **11** thus securing cover **11**, panel **21** and plate **24** firmly in place. It may be sealed by a resin seal **12**.

When employing two phosphor surfaces in the light source it is preferable that they be disposed in parallel relation in order to obtain uniformity of light output over the entire area. This rule can be followed whether or not the phosphor layers are flat, and is applied to substantially parallel curved surfaces in the embodiment of Fig. 8.

The invention as incorporated in a two-way lantern is illustrated in Fig. 7. Here, two self-luminous light source units **25**, **26** similar to the unit illustrated in Figs. 1 and 2 are shown. Since they are alike, and component parts which correspond to those similarly numbered in Figs. 1 and 2 are the same, no detailed description of the units themselves is necessary. It will be noted that in the light source unit employed in the lantern, plastic cover disc **27** which corresponds to disc **11** of Figs. 1 and 2 is of slightly greater diameter in order to accommodate screw holes near its periphery. This permits screws **28** to pass through the cover into the body **1** of the unit, thus to retain the component parts in their correct positions. Although the unit of Figs.

1 and 2 is represented in the lantern of Fig. 7 it is to be understood that any of the features of the invention illustrated in the other previous figures can be substituted. For example, in many cases the increased light obtainable from the two-layer phosphor as illustrated in Fig. 6 would be desirable in a lantern of the type shown in Fig. 7.

The lantern of Fig. 7 includes a cylindrical housing **29** in which is inserted at either end a lens **30**, **30***a*, of plano-convex type. In some cases other lenses, such as the well-known fresnel type, for instance, would be preferable. These lenses are maintained in position by lens mountings **31** and **31***a* which are locked in place in the housing by means of set screws **32** and **32***a*. A handle **33** and a supporting base **39** are secured to the top and bottom of the cylindrical housing as shown.

The two light source units **25**, **26** are secured back-to-back in the center of the housing **29**. Each unit is surrounded by a lead ring **34**, **34***a* for shielding purposes. This ring, with its enclosed unit, is disposed in the central opening through supporting rings **35**, **35***a* which are tightly fitted within the lantern housing. These rings are locked together by means of bolts **36** which pass through them. The resulting double unit is locked in the central position, as shown, by two opposed set screws **38**. Between the two units **25**, **26** is a shielding disc **37** of lead. Thus, rings **34**, **34***a* and disc **37** absorb radioactive emanations emitted toward the rear and the sides of each unit. The dimensions of the lantern and the use of appropriately dense glass (cerium or lead) in disc **8** and lens **30** provide sufficient absorption of radioactive emanations to the front, while permitting the desired emission of light.

In the foregoing description, the lantern of Fig. 7 has been represented as employing two light sources and two lenses, although three-way or four-way constructions are equally useful. Lanterns of this type have a wide variety of applications such as for railway and signalling purposes. In some cases it is desirable to provide phosphors which emit substantially white light. For this a suitable phosphor would comprise a blend of silver-activated zinc sulfide and copper activated zinc-cadmium-sulfide containing 2–3% cadmium. For railway use, one light source and lens might produce green light and the other one red. For these copper-activated zinc sulfide and copper-activated zinc-cadmium sulfide containing 10% to 20% cadmium, respectively, would be suitable. The latter produces an orange light which looks red through red glass. For blue, silver-activated zinc sulfide is suitable.

The lantern illustrated in Fig. 8 is useful for many of the same purposes to which that of Fig. 7 is adapted. However, in this embodiment self-luminous reflector lamps of the type described in our mentioned copending application are employed. Because of the use of the combination of a self-luminous element which approximates a point source, an optically suitable reflector, here represented as parabolic, and a lens, a well-concentrated light beam of considerable brightness is emitted.

In this embodiment the cylindrical casing **29** encloses two identical self-luminous light sources **40** and **41**. Hence only one will be described. These two sources are mounted back-to-back, as shown, and are supported at the rear on a central supporting post **42** of metal. The reflector **43**, of aluminum having a polished inside surface, is screwed to the metal cup **44** which supports it in the rear. The peripheral edge of the reflector is bent outwardly to form a short flange **45** which forms a tight fit in metal sleeve **46**. A glass disc **8**, preferably cerium-bearing as above described, is placed in front of the reflector and is separated from flange **45** by a resilient gasket **47**. This gasket should be of material which retains its properties in the presence of radioactive emanations. A material, known as Wisoid has been found suitable for this purpose. The mentioned glass disc is retained in place by a locking ring **48**, and between the locking ring and the glass disc is another Wisoid gasket **49**. Lens **50** is held in position in front of glass disc **8** by means of retaining ring **51** which is secured in casing **29** by one or more set screws **52**. As mentioned previously, lens **50** may have any optical properties necessary to meet the requirements; or it may be omitted.

The light source **53** which, as above stated, is similar to one embodiment of the invention described in our mentioned copending application, comprises a double-walled bulb preferably of transparent cerium-bearing glass. The neck **54** of this bulb is anchored in cup **44** by means of a cementing material **55**, one of the mentioned epoxy resins being suitable.

The inner portion of bulb **53** comprises a bulbous core **56**. The cavity **57** has no special function and may contain air. The exterior surface of core **56** is coated with a layer **58** of phosphor which corresponds to and may therefore be similar to phosphor layer 4 of Fig. 6, for example. Enclosing the coated portion of core **56** is a bulb-shaped envelope **59** which is sealed to the core **56** near where neck **54** begins. On the inside surface of envelope **59** a second layer of phosphor **60** is affixed, and this layer corresponds, and may be similar to, layer **13** of Fig. 6 for example. Gas chamber **61** formed between core **56** and envelope **59** may be evacuated through a glass tube at point **62**, after which the required quantity of radioactive gas may be injected to the desired pressure and the tube sealed off at this point. The phosphor layers and the radioactive gas employed to excite them may be as described in connection with any of the preceding figures, especially Fig. 6. It is to be understood that either of phosphor layers **60** and **58** may be omitted, and that in this event the light source will have the characteristics above described in connection with Fig. 2 and Fig. 3, respectively. Alternatively, both of these layers may be omitted and the cavity **61** filled with phosphor particles as described in connection with Fig. 4.

If krypton-85 is employed in bulb **53** it would usually be advisable to supplement the radiation-absorbing qualities of the components already described. For this reason a lead shield **63** is shown in Fig. 8 to be positioned so as to enclose the sides and most of the rear of bulb **53**. If necessary, additional shielding material may be secured to post **42** between units **40**, **41**, as in Fig. 7. The shielding properties of glass disc **8** and lens **50** are similar to those of disc **8** and lens **30** of Fig. 7, and are likely to be adequate to shield the radioactive emanations in the forward direction, but, of course, without impeding light radiation. However, if gas having a high radiation level is employed, it may be necessary to supplement the shielding in the forward direction by securing to the front of bulb **53** a lead shielding cap **64**. Although this cap will intercept some light which is emitted from the bulb in a forward direction it will not interfere appreciably with light reflected from the surface of reflector **43**. The emitted light will be somewhat increased by introducing a light reflecting surface between envelope **59** and cap **64**.

The foregoing descriptions of specific embodiments of the invention are given merely by way of example, it being understood that no limitations are intended thereby, except as defined in the appended claims.

We claim:

1. In an illumination device, the combination which includes a body having a cavity therein, a separate shallow metal cup in said cavity, a layer of phosphor material covering the bottom inside surface of said cup, a plate of transparent cerium-bearing glass covering said cup so that said cavity forms a chamber adapted to retain radioactive gas, a cover of transparent plastic material on the exterior side of said plate, the material of said glass and of said plastic having the characteristic

of attenuating radioactive radiation from said radioactive gas to a greater extent than light radiation from said phosphor, gas-sealing means interposed in the gas leakage paths between said plate and said body and between said cover and said body, means affixed to said body for retaining said cover in position over said plate, a duct in said body extending between said chamber and the exterior of said body, and means for sealing said duct comprising a plug of soft-rubber-like material disposed in said duct, said duct being provided with opposed means therein secured to said body and disposed at both ends of said plug to retain the same in place in said duct, said opposed means being adapted to apply compressive force to said plug in a direction longitudinally of said duct, and being so disposed as to provide a substantially straight path through said material between the exterior of said body and said chamber.

2. A device according to claim 1, characterized in that the inner portion of said duct comprises a hole of small diameter opening into said chamber, a threaded counterbore of diameter larger than said hole comprising the outer portion of said duct, a removable screw in said counterbore having a small longitudinal passage therethrough, a recess at the outer end of said passage, gas-sealing means in the recess in said screw, and a shoulder formed at the junction of said counterbore and hole, said rubber-like material being expansible by compression between said shoulder and the end of said screw.

3. A self-luminous light source comprising in combination, a body member formed with a cavity therein, a layer of phosphor of substantially uniform thickness disposed in the bottom region of said cavity, a translucent plate spaced equidistantly from the bottom of said cavity and disposed so as to form therewith a closed chamber containing said phosphor, said plate being of cerium-bearing glass having a density of at least 2.7 and a thickness of between approximately ⅜ inch and ½ inch whereby to constitute a light-transmitting medium and radiation shield effective to intercept substantially all radioactive beta emission tending to pass therethrough, a cover of translucent plastic material over said glass plate, means retaining said cover in position over said plate, a gas-injection port extending from the outside of said body into said chamber, gas-tight means for sealing said port, retaining means including gas impervious means in contact with said plate and with said body for securing said plate in position and for forming a gas seal between said plate and said body, gas-sealing means between said cover and said body, and radioactive gas in said chamber in contact with the phosphor therein, said gas being of beta-emitting type and of concentration and pressure such as to excite said phosphor to luminescence.

4. A self-luminous light source according to claim 3 which includes a shallow aluminum cup disposed in said cavity, having a polished bottom and an open top, said phosphor layer being disposed on the bottom of said cup.

5. A self-luminous light source according to claim 4 in which a second layer of phosphor is disposed on the undersurface of said plate within said chamber, said first-mentioned layer is of thickness of the order of magnitude of the penetration range therein of beta particles emanating from tritium gas, said second layer is of thickness of the order of magnitude of 30 to 50 microns, and the radioactive gas in said chamber comprises tritium at a pressure of at least 100 millimeters of mercury.

6. A self-luminous light source structure comprising in combination, a body member of solid gas impervious material formed with a cavity therein, said cavity being formed in successively stepped portions, the smallest portion being at the bottom and the largest at the top, and with a shoulder in the plane separating the contiguous portions, a shallow metallic cup disposed in the bottom portion of said cavity, said cup having a light-reflecting inside bottom surface and an open top, a layer of phosphor of substantially uniform thickness disposed on said surface, a translucent plate spaced from and parallel to the bottom of said cup so as to form a closed chamber within said cup, said plate comprising rigid material resistant to darkening when subjected to radioactive emanations and being wider than said cup so as to be supported on said shoulder, a second layer of phosphor disposed on the undersurface of said plate within said chamber, said second layer being of thickness corresponding to the order of 50 milligrams of phosphor per square centimeter of surface, so as to enhance light transmission therethrough, a sealable duct extending from the outside of said body into said chamber through which to exhaust the chamber and charge the same with gas, retaining and sealing means including gas-impervious means in continuous contact with said plate and with said body for securing said plate in position and for forming a gas-tight seal between said plate and said body, and radioactive colorless gas in said chamber in contact with the phosphor therein, said gas being of beta-emitting type and of concentration and pressure such as to excite said phosphor to luminescence.

7. A self-luminous light source according to claim 6 in which said cavity is formed in three stepped portions, and with two shoulders, the upper shoulder extending into the body beyond the lower shoulder, a cover of transparent plastic gas-sealed to the upper shoulder, and krypton-85 gas in said chamber at a pressure exceeding atmospheric.

8. A self-luminous light source according to claim 6 in which said cavity is formed in three stepped portions and with two shoulders, the upper shoulder extending into the body beyond the lower shoulder, said plate comprising transparent cerium-bearing glass having a density exceeding 2.5 and a thickness exceeding ⅛ inch, gas-sealing means in continuous contact with said lower shoulder and the periphery of said plate, a cover of transparent plastic supported on the upper shoulder, gas-sealing means in continuous contact with the upper shoulder and the periphery of said cover and the radioactive gas in said chamber being selected from the beta-emitting group comprising tritium and krypton-85 at a pressure of at least 100 millimeters of mercury.

9. A self-luminous light source structure including in combination, a body of gas-impervious solid material formed with a cavity therein, a light reflecting surface at the bottom of said cavity, a first layer of phosphor disposed on said surface, a flat shoulder surrounding said cavity, a transparent plate of non-darkening glass having a density of at least 2.7, spaced from the bottom of said cavity and supported on said shoulder so as to form a shallow closed chamber containing said phosphor, radioactive gas in said chamber selected from the beta-particle-emitting group, tritium and krypton-85, at a pressure of at least 100 mm. of mercury, a second layer of phosphor disposed on the surface of said plate within the chamber so as to be substantially parallel to the surface of said first layer and spaced therefrom by a distance no greater than the average trajectory range of beta particles emitted by the gas in said chamber, the thickness of said first layer being of the order of magnitude of the penetration range therein of beta particles from said gas, the thickness of said second layer corresponding to approximately 50 to 150 mg. of phosphor per square centimeter, gas-sealing means disposed around the periphery of the plate between said plate and said body for securing said plate in position against said shoulder and for forming a gas-seal between said plate and body, a transparent cover of beta-absorbing material over said plate, gas-sealing means disposed around the periphery of the cover between said cover and said body, and a sealed gas evacuation and injection port

extending through the body from the outside of said body into said chamber.

10. A self-luminous light source structure comprising in combination, a body member of gas-inpervious solid material having a cavity therein, said cavity being formed in successively stepped portions, the smallest portion being at the bottom and the largest at the top, and with a shoulder in the plane separating the contiguous portions, a first layer of phosphor of substantially uniform thickness disposed at the bottom of the smallest portion, a transparent plate spaced from and parallel to the bottom of said smallest portion so as to form a closed chamber, said plate comprising rigid material resistant to darkening when subjected to radioactive emanations and being wider than said smallest portion so as to be supported on said shoulder, a second layer of phosphor disposed on the undersurface of said plate within said chamber, said second layer being of thickness corresponding to the order of 50 milligrams of phosphor per square centimeter of surface, so as to enhance light transmission therethrough, a sealable duct extending from the outside of said body into said chamber through which to exhaust the chamber and charge the same with gas, sealing means including gas-impervious means in continuous contact with said plate and said shoulder for forming a gas-seal between said plate and said shoulder, second sealing means around the periphery of said plate in continuous contact with said plate and said body, and radioactive colorless gas in said chamber in contact with the phosphor therein, said gas being of beta-emitting type and of concentration and pressure such as to excite substantially all of said phosphor to luminescence.

11. A self-luminous light source structure according to claim 10 in which said cavity is formed in three stepped portions, and with two parallel shoulders, the upper shoulder extending into the body beyond the lower shoulder, a cover of transparent plastic supported on the upper shoulder, and gas-sealing means in continuous contact with the upper shoulder and the periphery of said cover, the radioactive gas in said chamber being at a pressure exceeding atmospheric.

12. A self-luminous light source structure according to claim 10 in which said cavity is formed in three stepped portions and with two parallel shoulders, the upper shoulder extending into the body beyond the lower shoulder, said plate comprising transparent cerium-bearing glass having a density of at least 2.7 and a thickness of at least ⅛ inch, gas-sealing means in continuous contact with the lower shoulder and the periphery of said glass plate, a cover of transparent plastic supported on the upper shoulder, and gas-sealing means in continuous contact with said body and the periphery of said cover, the radioactive gas in said chamber being selected from the beta-emitting group comprising tritium and krypton-85 at a pressure exceeding atmospheric.

13. A self-luminous light source structure according to claim 12 which includes clamping means secured to said body and overlaying a portion of said cover so as to press said cover against the shoulder beneath it and to press said plate against the shoulder beneath it, and sealing means disposed at the junction of said lower shoulder and the peripheries of said plate and said cover, the last-named sealing means being in continuous sealing contact with said plate, cover and body.

References Cited in the file of this patent

UNITED STATES PATENTS

332,210	Progler	Dec. 8, 1885
1,312,312	Dodds	Aug. 5, 1919
2,361,319	Paul	Oct. 24, 1944
2,490,091	Reardon	Dec. 6, 1949
2,761,069	Brayer	Aug. 28, 1956
2,892,086	Carter	June 23, 1959

OTHER REFERENCES

Wallhausen: "Use of Radioisotopes in the Production of Self-Luminous Compounds," Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, United Nations, New York, V15, pages 307–309, August 1955.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,953,684 September 20, 1960

John G. MacHutchin et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 21, for "Ser. No. 778,220" read -- Ser. No. 778,202 --; column 2, line 23, for "pigtail" read -- "pigtail" --; column 3, line 52, after "all" insert -- the --.

Signed and sealed this 4th day of April 1961.

(SEAL)

Attest: ERNEST W. SWIDER

XXXXXXXXXX

Attesting Officer

ARTHUR W. CROCKER

Acting Commissioner of Patents

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,953,684 September 20, 1960

John G. MacHutchin et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 21, for "Ser. No. 778,220" read -- Ser. No. 778,202 --; column 2, line 23, for "pigtail" read -- "pigtail" --; column 3, line 52, after "all" insert -- the --.

Signed and sealed this 4th day of April 1961.

(SEAL)

Attest: ERNEST W. SWIDER

XXXXXXXXXXX
Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents