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3,409,770

SELF-LUMINOUS LIGHT-EMITTING UNITS

Filed Sept. 28, 1964

2 Sheets-Sheet 1

FIG. 1

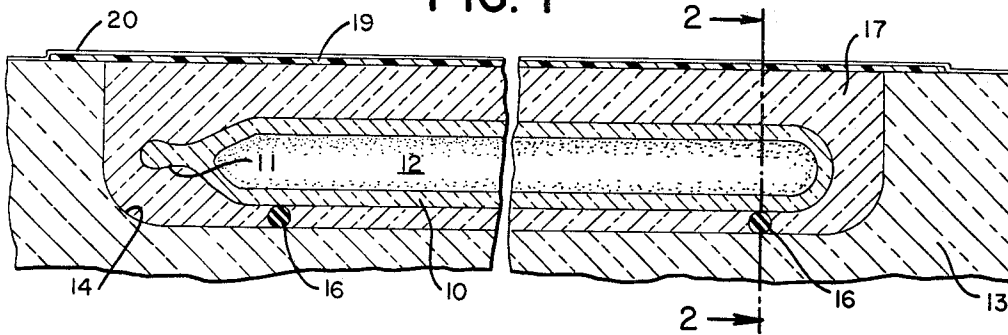


FIG. 3

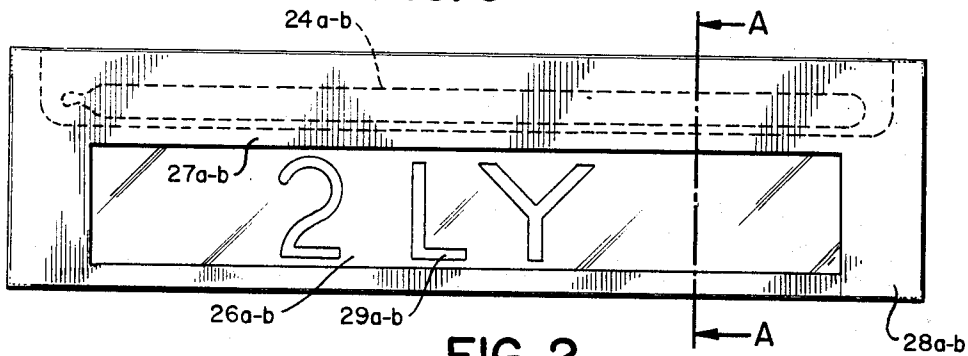


FIG. 2

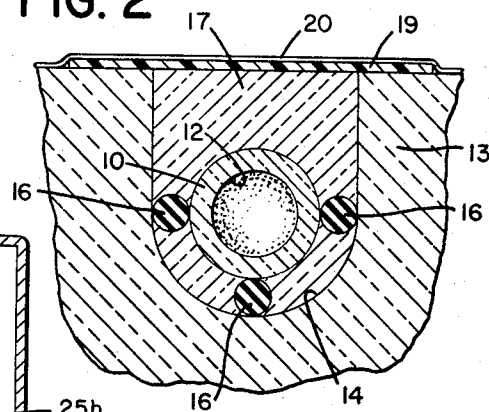


FIG. 4

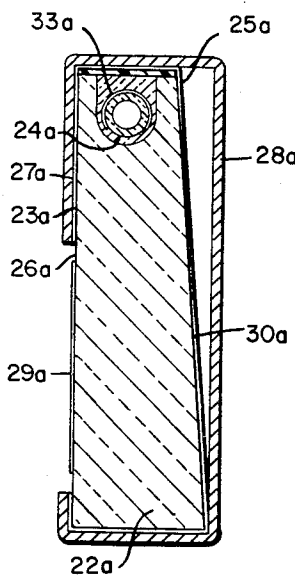
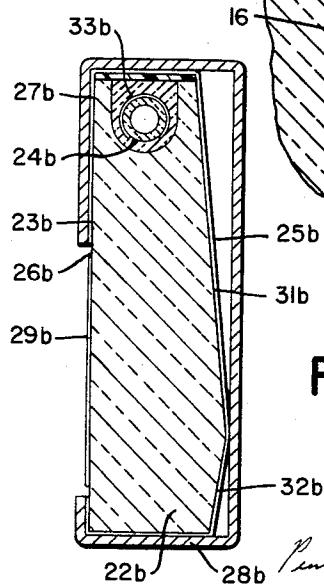


FIG. 5

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FIG. 6

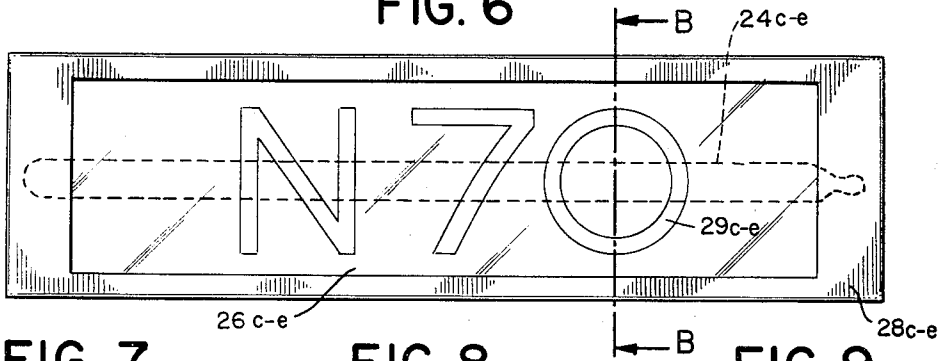


FIG. 7

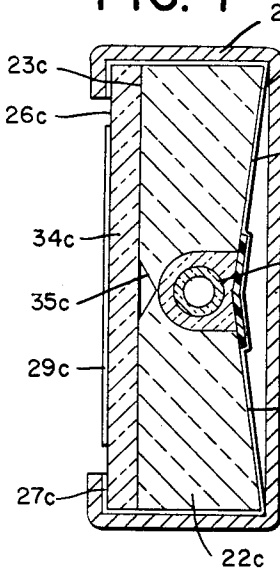


FIG. 8

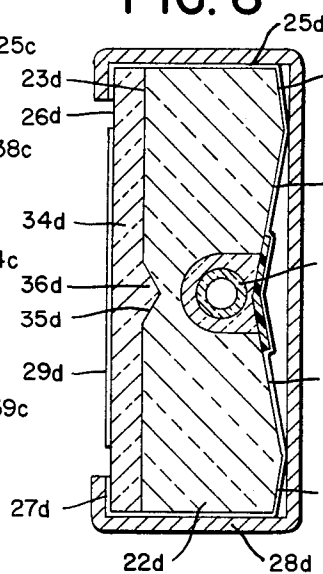


FIG. 9

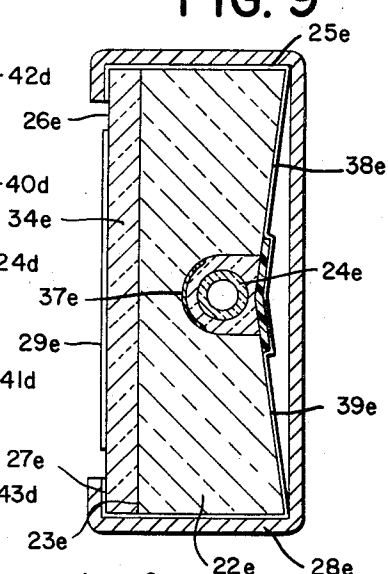


FIG. 10

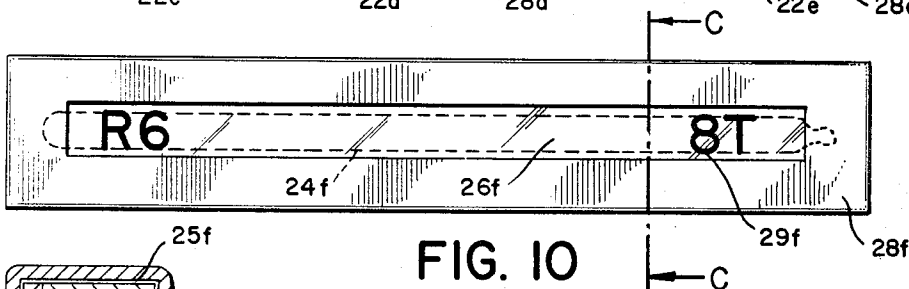
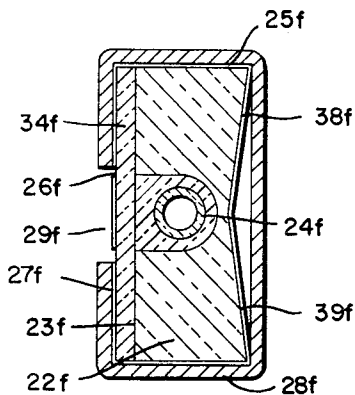


FIG. 11



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SELF-LUMINOUS LIGHT-EMITTING UNITS
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ABSTRACT OF THE DISCLOSURE

A self-luminous light-emitting unit wherein a sealed glass element is filled with a radioactive gas and coated interiorly with a film substantially of phosphoric acid on which is adhered and exposed a particulate phosphor, the element being embedded in shock absorbent transparent elastomeric potting material in a cavity formed in a transparent body within which light passes without substantial diffusion and which is coated with reflective white paint everywhere but at a window area on its front face.

This invention relates to self-luminous light-emitting units having a phosphor excited by radioactive material as the light source and, more particularly, to improvements in such units both in the light source itself and in associated means for optimum transmission of the light from the unit.

Phosphors excited by radioactive gas are becoming accepted as sources of light for compact self-contained luminous signs, instruction placards, decorative panels and similar lighted devices. Legends are often included in these devices to convey instructions, warnings or other information. Compared to incandescent light-emitting units such radioactive light sources have a relatively low light output in the absolute sense, but by experimentation the apparent brightness of radioactive light sources may be increased to the point where they can serve with complete satisfaction in a wide variety of uses. Optimum apparent brightness can be achieved by the application of empirical concepts frequently producing results which are quite unexpected in terms of optical principles and theories of fluorescence. It has been discovered that certain critical factors of a practical design nature when embodied in radioactive light sources produce an apparent light output far exceeding anything attained heretofore. Self-luminous light-emitting units comprising these features in combination, and certain subcombinations of the features, are the subject matter of this invention.

Broadly stated, the improved self-luminous light-emitting unit of the invention comprises a transparent body having a front face and being formed with a cavity. A light source is provided in the cavity which comprises a hollow sealed glass element, a phosphoric acid film on an inner surface of the element, a layer of a particulate phosphor adhered to the phosphoric acid film, and a radioactive beta-ray emitting gas within the element. The unit also includes shock absorbing transparent elastomeric potting material filling the cavity around the element. A coating of light reflective white paint is disposed around substantially the entire outer surface of the body except for at least one window area. A light-interrupting barrier of some form may be disposed over the element toward the window with respect to the element.

In general the standard of quality for a radioactive light source of this type is its ability both to emit the light en-

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ergy and thereafter transmit it from the unit as advantageously as possible considering the circumstances of use. Light emission occurs at the phosphor adhered within the hollow glass element where it is exposed to the beta-rays emanating from the radioactive gas. Phosphoric acid has never previously been used in a radioactive light source as a binder to hold the desired phosphor layer to the wall of the glass element, but I have discovered that it produces an effective emission of light from the glass element which considerably exceeds that obtained from light sources employing conventional binders, such as potassium silicate.

The most desirable transmission of light from the unit in terms of uniformity and apparent brightness is determined by virtually all the elements of the unit which surround the light source. Of course, no transmission at all occurs if the relatively fragile light source cannot be safely contained in the unit and therefore the invention contemplates a special potting material in which the glass element is embedded to serve as a firm yet shock-resistant mounting and to act as a secondary seal against escape of the radioactive gas in the event the element is broken under conditions of extreme abuse. The potting material also fulfills a direct function in the transmission of light emitted from the source, inasmuch as it masks out the discontinuities in the wall of the body cavity which otherwise would disrupt the desired transmission of light. Optimum transmission from the unit is further enhanced by a feature which has proven itself through experience, and that is the contemplated light-diffusing flat or flats on the rear of the transparent body angled up to six degrees with respect to the front face. In like manner, the light-reflective white paint coated over all of the body except the window area, and the barrier directly in front of the light source which interrupts the straight-line transparent paths from the source to the viewer, are features which produce demonstrable advantages in the operation of the unit though they do not in all instances lend themselves to precise theoretical explanation.

Preferred embodiments of the invention are described hereinbelow with reference to the accompanying drawings, wherein:

FIG. 1 is an enlarged fragmentary section taken longitudinally through that part of the body of the unit containing the light source;

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

FIG. 3 is a front elevation of an embodiment of the overall unit having one form of light-interrupting barrier;

FIG. 4 is one form of a lateral section taken along the line A—A of FIG. 3;

FIG. 5 is another form of a lateral section taken along the line A—A of FIG. 3;

FIG. 6 is a front elevation of another embodiment of the overall unit;

FIG. 7 is one form of a lateral section taken along the line B—B of FIG. 6;

FIG. 8 is another form of a lateral section taken along the line B—B of FIG. 6;

FIG. 9 is yet another form of a lateral section taken along the line B—B of FIG. 6;

FIG. 10 is a front elevation of another embodiment of the overall unit; and

FIG. 11 is a lateral section taken along the line C—C of FIG. 10.

Referring first to FIGS. 1 and 2, the improved light source of the invention is illustrated together with its shock absorbing means. The envelope for the light source is a glass tube 10, which may be of circular cross section,

pinched off at 11 and sealed at both ends. In most commercial forms of radioactive light sources, a tube of this sort is usually provided with metal caps at its opposite ends to effect the seal, but it is preferable to employ integral glass seals at both ends, such as the rounded and pinched off closures shown in FIG. 1, to avoid the bulky caps and contribute substantially to the compactness of the unit. It has also been believed necessary to use a cerium nonbrowning glass for the tube 10, but while such a material is satisfactory it is not always necessary and more heat-resistant glasses such as Pyrex or Vycor (trademarks for heat-resistant glass of the Corning Glass Works) can be used instead. Actually, the description herein for the material of the tube 10 as being glass is to be understood to include any inorganic transparent material of suitable strength and not necessarily the common silicate-based glasses.

Before it is sealed at its ends, the glass tube 10 (which may typically have a 6 mm. inside diameter and about one-quarter inch outside diameter) is rinsed with hydrofluoric acid and then dried at about 110° C. A solution of 1½ to 1¾% phosphoric acid in a solvent such as methanol or acetone and a small amount of wetting agent is then poured through the tube. One end of the tube is temporarily plugged and a vacuum is applied at the other end to evaporate the solvent until the phosphoric acid film left on the wall of the tube evidences interference colors. This indicates that it is of the desired thickness.

An excess of a particulate phosphor is then poured through the tube after the temporary plug at one end has been removed. The phosphor should have a particle size of from about 3 to 30 microns with about an 8 to 12 micron average. A single component phosphor is preferred and it may be selected from various suitable phosphors developed in the art depending upon the brightness level and color of light desired. Zinc-cadmium sulfide, cadmium sulfide, cadmium tungstate, zinc silicate and zinc sulfide are some of the well-known phosphors which can be used. As the excess phosphor falls through the tube, some is adhered to the glass by means of the underlying phosphoric acid film. A satisfactory phosphor layer 12 produced in this manner may be of one particle size thickness extending uniformly over the area which had been coated with the phosphoric acid binder. The tube is then baked at 450° C. for about twenty minutes so that the phosphoric acid binder provides a firm and permanent base for the phosphor layer. The tube is filled with a beta-ray emitting radioactive gas such as tritium or krypton-85, and is sealed by being pinched off in the desired length with the gas left in the tube at a predetermined pressure which may vary from about 300 to 2000 mm. of mercury depending upon the ultimate circumstances of use.

The critical feature in this light source per se made in accordance with the invention is its use of phosphoric acid as a binder and it has been established that gains of 100% in apparent brightness are possible because this new binder has been substituted for those previously used.

In each of the embodiments of the new radioactive light source shown in the drawings, the tube 10 is to be disposed in an extended transparent plastic body 13 formed with a groove 14 extending longitudinally in the body. The groove 14 is shown in FIGS. 1 and 2 to have rounded ends and a circular cross section and to be slightly deeper than the outside diameter of the light source tube 10. The plastic body 13 in which the groove is formed is transparent and polymethylmethacrylate, particularly Plexiglas (a trademark for acrylic resin of Rohm & Haas Co.), is quite advantageous for this purpose.

To center the tube 10 within the groove 14 a few small drops of an elastomeric material, such as natural or synthetic rubber, plastic foam or preferably silicone rubber, are applied to each end of the tube to form discrete cushions 16 holding the tube spaced from the walls of the groove 14. A transparent elastomeric potting material 17

is then filled in the groove 14 around the tube 10 and the elastomeric cushions 16. A low-temperature curing transparent silicone gel is especially suitable for the potting material, and it is poured into the groove around the tube in the form of a clear liquid containing a catalyst. As it sets, the silicone potting material may be subjected to a vacuum to eliminate air bubbles. It produces a clear water-white bed for the tube (though it may be tinted for various color effects if desired) which is resistant to vibration and shock, effects a good secondary seal against escape of the radioactive gas if the tube happens to break, and fills all discontinuities in the wall of the groove 14 which otherwise would have to be polished to control transmission of the light emitted from the tube. The silicone potting material is also highly resistant to moisture. Its surface at the opening of the groove 14 evidences an average Shore A durometer hardness of about 15 and is preferably covered by an adhesive-backed sheet 19 of polyethylene terephthalate which covers the groove 14 and extends over a peripheral portion of the surrounding body 13.

Except at a window area or areas where light is to be transmitted from the unit as described hereinafter, the entire exterior surface of the body 13 is coated with a light-reflective white paint 20, the practical effect of which is to greatly enhance the uniformity and efficiency of the distribution of light within the unit. Gains of 30% in apparent light output can be achieved by using a paint having a titanium dioxide primary pigment, and particularly a pigment having a particle size from 0.1 to 0.5 micron with a pigment-volume concentration of 10 to 50%. Titanium dioxide has a refractive index of about 1.9 and establishes suitable optical continuity from the polymethylmethacrylate body 13 which has a refractive index of about 1.5. The function of the white paint 20 is to provide an opaque coating about the entire body of the unit which reflects as much of the light as possible back into the body and eventually permits it to be transmitted undiminished through the window area.

To avoid repetition in the following description of the different forms the overall light-emitting unit may take, the similar elements common to the various forms will be described together. A suffix *a* on each reference numeral refers to the FIG. 4 form of the FIG. 3 unit, *b* refers to the FIG. 5 form of the FIG. 3 unit, *c* refers to the FIG. 7 form of the FIG. 6 unit, *d* refers to the FIG. 8 form of the FIG. 6 unit, *e* refers to the FIG. 9 form of the FIG. 6 unit, and *f* refers to the FIG. 11 form of the FIG. 10 unit.

Each form comprises an extended transparent body 22*a* to 22*f*, as described in reference to the body 13 of FIGS. 1 and 2, having a flat front face 23*a* to 23*f* and one or more flats to the rear of and angled up to six degrees (preferably three to five degrees) with respect to the front face 23*a* to 23*f*. A groove containing a light source 24*a* to 24*f* in shock-absorbing means is provided in each body 22*a* to 22*f* as described in reference to FIGS. 1 and 2. A coating 25*a* to 25*f* of the light-reflective white paint discussed previously is disposed over the entire outer surface of each body 22*a* to 22*f* except for at least one window area 26*a* to 26*b* on the front face 23*a* to 23*f*. A light-interrupting barrier is disposed parallel to the light source 24*a* to 24*f* throughout the length thereof toward the front face 23*a* to 23*f* of the body with respect to the light source. A casing 28*a* to 28*f*, preferably of aluminum, fits around each body 22*a* to 22*f* except at the window area 26*a* to 26*b* thereof. (Such a casing may be dispensable because its prime function is to provide attachment means for the unit and in some instances to meet certain regulatory requirements.) Legends 29*a* to 29*f*, either in light-on-dark or dark-on-light form, may be included in each window area 26*a* to 26*b*.

In the FIGS. 4 and 5 forms of the FIG. 3 unit, the light-interrupting barrier is the upper front edge portion 27*a* and 27*b* of the paint coating 25*a* and 25*b* above the win-

dow area 23a and 23b. The groove for the light source 24a and 24b is formed in the upper edge of the body 22a and 22b behind this barrier.

In the FIG. 4 form, one light diffusing flat 30a defines the entire rear face of the body 22a and diverges with respect to the body front face 23a away from the upper body side portion in which the light source 24a is located. In the FIG. 5 form, a first light diffusing flat 31b defines the greater part (perhaps four-fifths) of the rear face of the body 22b and diverges with respect to the body front face 23b away from the upper body side portion in which the light source 24b is located. In addition a second flat 32b intersects the first flat 31b along a line parallel to the body front face 23b to define the remainder of the rear face of the body 22b and converges with respect to the body front face 23b away from the upper body side portion in which the light source 24b is located. The arrangement of dual flats in FIG. 5 is employed with wider window areas where the lower portion of the window area 26b would otherwise be less brightly lighted.

In both the FIGS. 4 and 5 forms, a coating 33a and 33b of the aforementioned light-reflective white paint is disposed on the tubular light source 24a and 24b throughout substantially the entire length thereof around all but about a sixty degree segment of the tube facing downwardly into the center of the body 22a and 22b. This method of directing the emitted light from the light source adds to the light output when the light source is in a side portion of the body as in FIGS. 4 and 5.

In the FIGS. 7, 8, 9 and 11 forms, the light source 24c to 24f is located in its groove along a central portion of the body 22c to 22f behind the window area 26c to 26f. The groove is formed in the rear face of the body 22c to 22e in FIGS. 7, 8 and 9, and in the front face of the body 22f in FIG. 10.

In each of the FIGS. 7, 8, 9 and 10 forms, a flat plastic plate 34c to 34f through which light can pass is disposed over the front face 23c to 23f of the body 22c to 22f in the entire window area 26c to 26f. This plate is transparent in the FIGS. 7 and 8 forms (perhaps of the same material as the body 13 described in reference to FIGS. 1 and 2) and is translucent in the FIGS. 9 and 11 forms (perhaps a milky white material or transparent plastic formed with a rough beaded or sand-blasted surface). The legend 29c to 29f may be located inside or outside the plate 34c to 34f, and it is preferred that the coating 27c to 27f extend around the front of the plate 34c to 34f rather than between the plate and the front face 23c to 23f of the body 22c to 22f. In the FIG. 11 form, the plate 34f directly overlies the open face of the groove in which the light source 24f is located and therefore no cover similar to the sheet 19 in FIGS. 1 and 2 is required for the potting material in the groove in FIG. 11.

In the FIGS. 7 and 8 forms, the light-interrupting barrier comprises a V-shaped longitudinal indentation 35c and 35d in the body front face 23c and 23d covered by the plate 34c and 34d. The indentation should have an included base angle of 84° or less to reflect light back into the unit. This barrier is augmented in the FIG. 8 form by an integral V-shaped longitudinal ridge 36d on the plate 34d which extends rearwardly into the indentation 35d without filling it. Thus in each of the FIGS. 7 and 8 forms, a V-shaped air pocket is provided directly in front of the light source 24c and 24d having a different index of refraction than the surrounding plastic material to eliminate a band of more intense brightness which otherwise would be apparent across the center of the window area 26c and 26d directly over the light source 24c and 24d. The same result is achieved in the FIG. 9 form by an opaque screen 37e fixed to and covering the forward portion of the groove wall behind which the light source 24e is located, though the screen is less effective than the groove and thus the plate 34e must be translucent. In the FIG. 11 form, the translucent plate 34f alone serves as the light-interrupting barrier, which is an effective

though still less satisfactory means of avoiding a bright band in the center of the window area, and therefore the window area 26b in the FIG. 11 form should not be appreciably wider than the diameter of the light source 24f behind it.

In the FIGS. 7, 9 and 11 forms, the light-diffusing flats comprise a pair of adjoining flats 38c-39c, 38e-39e, and 38f-39f which together define the entire rear face of the body 22c, 22e and 22f and diverge with respect to the body front face 23c, 23e and 23f away from a line where the pair of flats intersect behind and parallel to the light source 24c, 24e and 24f. In the FIG. 8 form, a first pair of adjoining flats 40d-41d define the greater part (perhaps four-fifths) of the rear face of the body 22d and diverge with respect to the body front face 23d away from a line where with the two flats 40d-41d intersect parallel to and behind the light source 24d, and another pair of flats 42d-43d intersect the respective first flats 40d-41d along respective lines parallel to the body front face 23d and define the remainder of the rear face of the body 22d. Each of the second flats 42d-43d converge with respect to the body front face 23d away from the central portion of the body. The single pair of flats shown in FIGS. 7, 9 and 11 is suited for relatively narrow window areas while the double pair shown in FIG. 8 is designed for relatively wide window areas.

The structures represented by FIGS. 4, 5, 7, 8, 9 and 11 can be varied by substituting various sub-combinations of their respective features. For example, the ridge 36d in FIG. 8 could be used with a body having only two flats such as the flats 38c-39c in FIG. 7. This and other evident modifications of the structures shown come within the scope of the invention as it is defined in the following claims. It should also be noted that certain liberties have been taken in the drawings for purposes of clarity. For example, the wall of the glass tube 10 in FIGS. 1 and 2 would actually be thinner than that shown and the cushion 16 would not necessarily assume the circular cross section indicated. Also, in FIGS. 4, 5, 7, 8, 9 and 11 the angle of flats on the rear of the body have been exaggerated in the drawing, and the same is true of the thickness of such elements as the coatings of white paint and the outer metal casings.

I claim:

1. A self-luminous light-emitting unit comprising:
 - (a) a transparent body within which light travels without substantial diffusion and in which a cavity is at least partly defined;
 - (b) a light source in the cavity comprising:
 - (i) a hollow sealed glass element,
 - (ii) a film on an inner surface of the element consisting essentially of phosphoric acid,
 - (iii) a layer of a particulate phosphor adhered to and exposed on the phosphoric acid film, and
 - (iv) a radioactive beta-ray emitting gas within the element;
 - (c) shock absorbing transparent elastomeric potting material filling all voids in the cavity around the element; and
 - (d) a coating of light-reflective white paint disposed around substantially the entire outer surface of the body except for at least one substantially clear non-diffusing window area on a front face thereof.
2. A light-emitting unit according to claim 1 which includes a light-interrupting barrier disposed over the element toward the window area with respect to the element.
3. A light-emitting unit according to claim 2 wherein the cavity is located in one side portion of the body behind an edge portion of the coating of white paint to one side of the window area, said edge portion of the coating constituting the light-interrupting barrier.
4. A light-emitting unit according to claim 1 wherein the potting material is of silicone rubber.
5. A light-emitting unit according to claim 1 wherein the transparent body is formed with at least one light-

diffusing flat to the rear and angled up to six degrees with respect to the front face.

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