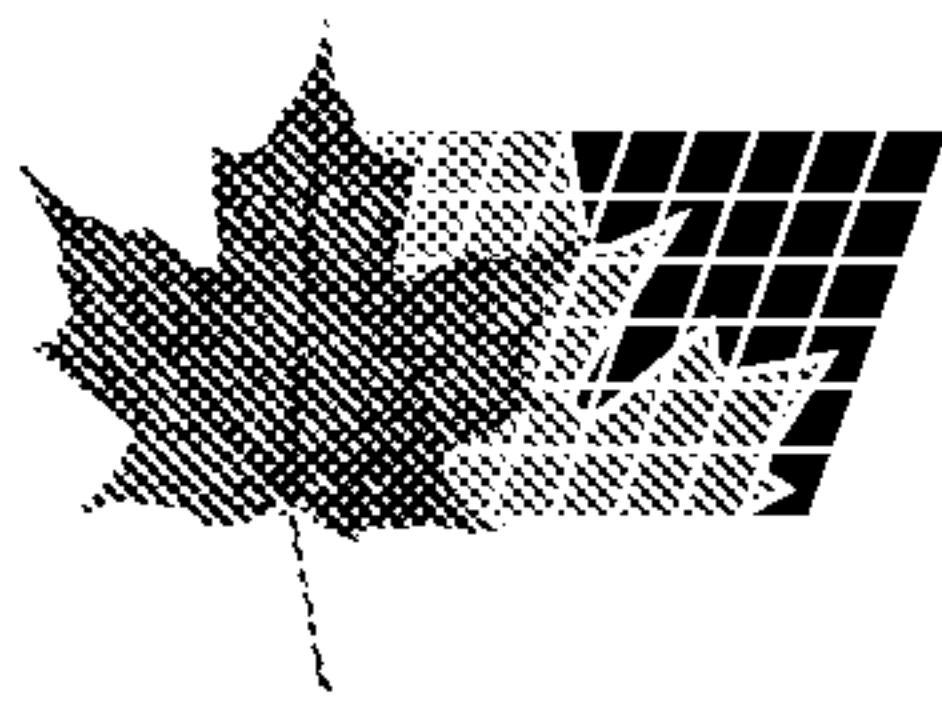
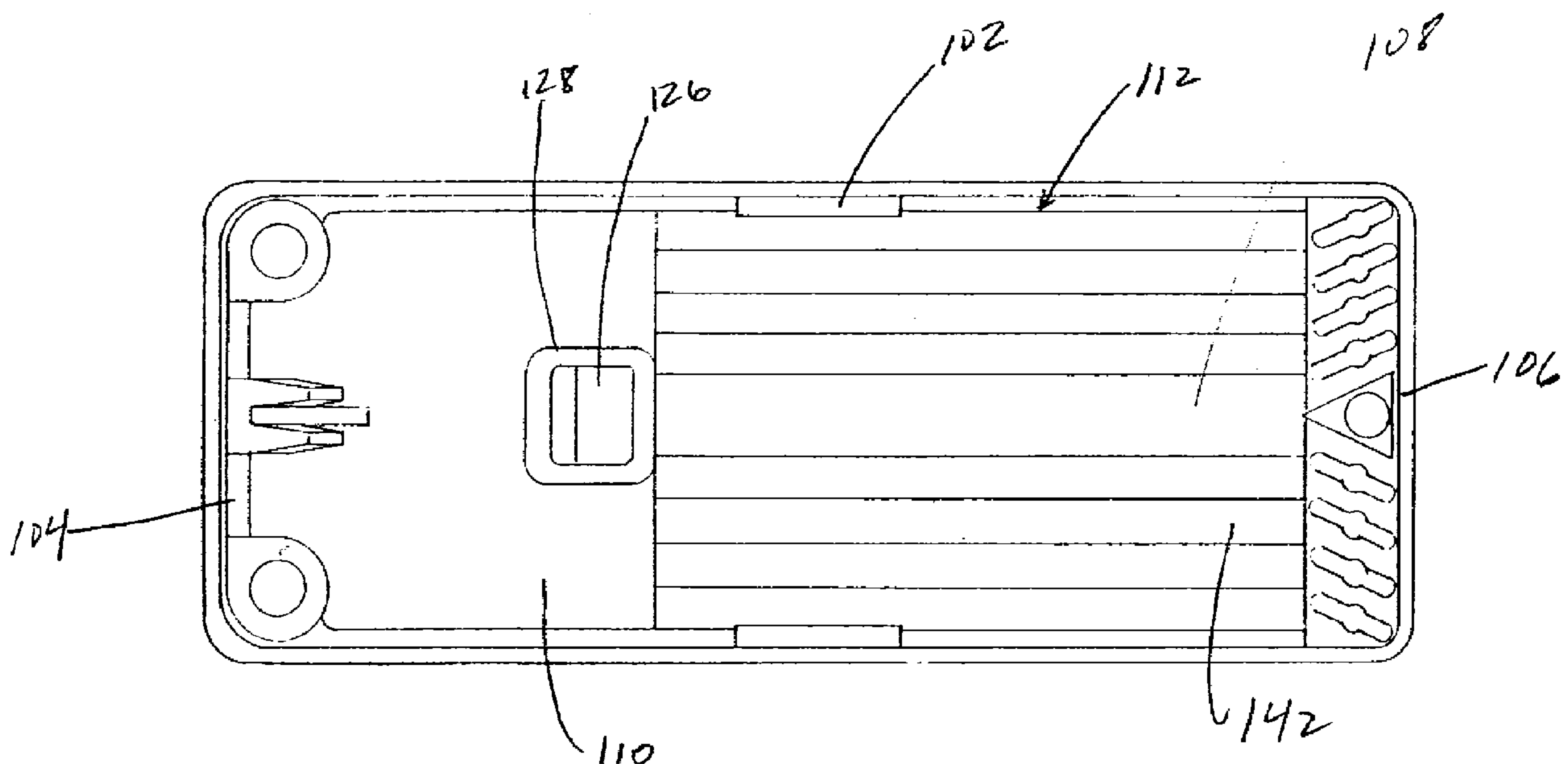




(11) (21) (C) **2,159,755**
(22) 1995/11/09
(43) 1997/05/10
(45) 2001/01/23

(72) Rattman, William J., US
(72) Mi, Zhexin, CA
(73) DIGITAL SECURITY CONTROLS LTD., CA
(51) Int.Cl.⁶ G08B 17/103
(54) **CHAMBRE DE DETECTION DE FUMÉES**
(54) **SMOKE DETECTION CHAMBER**



(57) The present invention provides for a smoke detection chamber for use in a photoelectric smoke detector, the chamber being a generally parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber. A second end wall of the chamber opposite the mounting arrangement is shaped to provide communication between the interior and exterior of the chamber while appearing as a solid surface to external ambient light and allowing a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall to be reflected to the exterior of the chamber. In a preferred embodiment the second end wall is louvred to provide communication between the interior and exterior of the chamber such that a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall would be deflected by the louvred end wall to the exterior of the chamber.

ABSTRACT OF THE DISCLOSURE

The present invention provides for a smoke detection chamber for use in a photoelectric smoke detector, the chamber being a generally parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber. A second end wall of the chamber opposite the mounting arrangement is shaped to provide communication between the interior and exterior of the chamber while appearing as a solid surface to external ambient light and allowing a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall to be reflected to the exterior of the chamber. In a preferred embodiment the second end wall is louvred to provide communication between the interior and exterior of the chamber such that a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall would be deflected by the louvred end wall to the exterior of the chamber.

BACKGROUND OF THE INVENTION

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15 Smoke detectors based on light scattering by
smoke particles have been known for a number of years.
Such detectors at present utilize solid state components
including photoemitting diodes and photodiode detectors,
the two devices being incorporated in a fixed mounted
20 arrangement within a smoke detection chamber. In many of
the prior art chambers the photoemitting diodes and
photodiode detectors are mounted in either the sides of the
chamber or on the bottom of the chamber, most typically
with a 60 degree scattering angle along a horizontal plane
25 between the photoemitting diodes and photodiode detectors.
The smoke detection chambers are generally designed to
exclude most ambient light influences while providing
openings to permit entry of the smoke particles into the
sensing chamber. There have been many such designs
30 developed and patented which rely upon the walls of the
smoke chamber having labyrinth designs to allow the passage
of the smoke particles while excluding ambient light from
the interior of the chamber. Examples of such designs are
shown in United States Patents 3,914,616, 4,168,438,
35 4,315,158, 4,672,217 and 4,851,819. The walls of many of
these prior art chambers are also designed to attempt to
minimize the reflection of any light emitted by the

photoemitting diodes striking the wall from being seen by the photodiode detector. This is commonly accomplished by first providing that the walls have a flat black finish and by providing a structure to the wall which tends to absorb or scatter any reflected light within the chamber. The design of many of the prior art smoke detection chambers results in a generally horizontal flow of the smoke particles through the chamber. Ideally, the photoemitting diode and photodiode detector should be mounted in such a way that the intersection of the transmitted light from the photoemitting diode and the view of the photodiode detector falls within the horizontal path of the smoke particles. However, depending upon the laminar flow rate of the smoke particles through the chamber, the horizontal flow may be shifted from the intersection thereby affecting the sensitivity of the smoke detector. Also, the use of the 60° scattering angle increases the distance between the photodiode detector and photoemitting diode thereby affecting the sensitivity and increasing the potential for dust particle interference. In addition, many of the prior art mounting arrangements generally require the use of leads between the photodiode detector and/or the photoemitting diode and the printed circuit board carrying the other electrical and electronic components utilized in the detection and alarm circuitry. The use of such leads increases the potential susceptibility of the alarm units to radio frequency interference (RFI) with exposure to the increased number of radio frequency (RF) transmitters throughout the RF spectrum presently in use. As a result, there has been an increasing need to improve the designs to increase the immunity to radio frequency interference (RFI) to prevent unwanted false alarms. One means of achieving increased RFI immunity has been through the use of leadless, surface mounted components to improve RFI immunity over the older leaded designs. One example of such design is shown in Nagaoka, U.S. Patent 5,138,302, in which the photodetecting element is mounted directly on the

printed circuit board and provided with a prism element to focus the scattered light on to the photodetecting element.

Smoke is generally classified as black or grey. Grey smoke particles are generally much easier to detect as they tend to scatter the light from the photoemitting diode very well. Hence, most designs of photoelectric smoke detectors are reasonably effective at detecting grey smoke. Black smoke particles, on the other hand, do not generally scatter the light as well and many designs of photoelectric smoke detectors have difficulty properly detecting the presence and level of black smoke. This is particularly the case with those detectors utilizing a 60° scattering angle as, at this angle, the grey smoke to black smoke sensitivity is only 4:1. In these detectors which are usually set to detect grey smoke at about 3% per foot obscuration, the level of black smoke required to indicate an alarm state would be 12% per foot obscuration or higher. Thus, there still exists a need to provide very sensitive smoke detection of both black and grey smoke particles with minimal radio frequency interference.

SUMMARY OF THE INVENTION

In one aspect, the present invention provides for a smoke detection chamber for use in a photoelectric smoke detector, the chamber comprising a generally parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber, a second end wall opposite the mounting arrangement being shaped to provide communication between the interior and exterior of the chamber while appearing as a solid surface to external ambient light and allowing a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall to be reflected to the exterior of the chamber.

2159755

In another aspect, the present invention provides for a smoke detection chamber for use in a photoelectric smoke detector. The chamber comprises a generally parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber, a second end wall opposite the mounting arrangement being louvred to provide communication between the interior and exterior of the chamber such that a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall would be deflected by the louvred end wall to the exterior of the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

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The above as well as other advantages and features of the present invention will be described in greater detail according to a preferred embodiment of the present invention in which:

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Figure 1 is a perspective view of a preferred embodiment of the smoke detection chamber according to the present invention;

Figure 2 is a bottom plan view of the smoke detection chamber of Figure 1;

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Figure 3 is a side view in cross section of the smoke detection chamber of Figure 1 illustrating the intersection of the fields of view of the photodiode detector and photoemitting diode; and

Figure 4 is an end view in cross section of the louvred end wall of the smoke detection chamber of Figure 1.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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The smoke detection chamber of the present invention is designed for use in a photoelectric smoke

2159755

detector. Such smoke detectors are generally ceiling or wall mountable units having a case of extruded polymeric material. The case generally has a base to which is releasably attached a cover having openings to permit entry of smoke into the interior of the case while preventing entry of insects and other large particulate matter into the interior of the case. Generally a printed circuit board is provided having electronic components, preferably surface mounted components, which typically make up the smoke alarm circuitry mounted to one or both sides of the printed circuit board. The smoke detection chamber of the present invention is generally mounted on the printed circuit board. The details of the smoke detector and the alarm circuitry utilized therein are not shown as the design of such detectors and circuitry is within the knowledge of ordinary workers in the art of smoke alarm design.

A preferred embodiment of a smoke detection chamber of the present invention is illustrated in the figures generally indicated by the numeral 100. The smoke detection chamber 100 is generally parallelepiped in shape preferably having dimensions of about 1 inch by 1 inch by 2.5 inches, however other shapes and dimensions are possible. As shown in the figures, the smoke detection chamber has side walls 102, a first end wall 104, a second end wall 106, a top 108 and a bottom 110. As will be appreciated, when the smoke detection chamber 100 is mounted in a smoke detector case (not shown) and the case in turn mounted on the ceiling, the bottom 110 of the chamber 100 will in fact form the upper surface of the chamber, while the top 108 of the chamber 100 will form the lower surface. However for ease of understanding, these parts are named in relation to their attachment to a circuit board.

The sidewalls 102 of smoke detection chamber 100 are provided with openings 112 for ingress and egress of smoke particles into the smoke detection chamber 100. The

2159755

openings 112 are clear in that they do not have any obstructions for the free flow of smoke particles such as labyrinths or the like and are provided with a fine mesh screen 114 to reduce the entry of insects and large particulate matter into the smoke chamber 100 while allowing passage of smoke particles into the chamber 100.

Smoke detection chamber 100 in a first end wall 104 is provided with a mounting arrangement 116 for a photoemitting diode 118. Mounting arrangement 116 has extending walls 120 to provide a tunnel within which is mounted the photoemitting diode 118. Extending walls 120 preferably extend beyond the end of the photoemitting diode 118 to bound or limit the outer rays of the beam of light 122 emitted by the photoemitting diode 118 to provide for a relatively narrow beam of light broadcasting along the length of the smoke chamber 100. The mounting arrangement 116 preferably restricts the light beam 122 of the photoemitting diode 118 so that the beam 122 only impinges upon the opposite end wall 106 and not on either the top 108, bottom 110 or sidewalls 102. The extending walls 120 also provide for shielding of the light beam 122 of the photoemitting diode 118 to reduce the possibility of stray light from the photoemitting diode 118 shining directly onto the photodiode detector 124.

The bottom 110 of the smoke detection chamber is provided with an opening 126 having a shielding arrangement 128 to overlay a photodiode detector 124 mounted on the printed circuit board. The shielding arrangement 128 is of a shape to reduce the possibility of incident light falling onto the photodiode detector 124. The shielding arrangement 128 may be of any suitable shape, for example a right circular cylinder having openings in the top and bottom or a rectangular or square structure with an open top and bottom. In the embodiment illustrated in the figures, the shielding arrangement 128 is a square shaped structure having an open top and bottom. One wall 130 of the shielding arrangement 128 closest to the position of

2159755

the photoemitting diode 118 is of a height to prevent any stray incident light from the photoemitting diode 118 from falling directly on the photodiode detector 124. This wall 130 may be provided with a double knife edge reticulated groove 132 for holding any dust particles which may come in contact with the shielding arrangement 128 and hiding such dust particles from the field of view of the photodiode detector 124. The opposite wall 134 of the shielding arrangement 128 has a height or shape to prevent any incident light which may enter the chamber 100 through the openings 112 for ingress and egress of smoke particles from falling on the photodiode detector 124. Wall 134 may also be provided with an inclined portion 136 to provide for increased shielding of the photodiode detector 124 from any incident light which may enter the smoke chamber 100.

The photoemitting diode 118 is mounted in the sidewall 102 such that the light beam 122 from the photoemitting diode 118 is broadcast along the long dimension of the rectangular shape. The end wall 106 of the chamber 100 opposite the photoemitting diode 118 is shaped to provide communication between the interior and exterior of the chamber while appearing as a solid surface to external ambient light and allowing a light beam from a photoemitting diode 118 located in the mounting arrangement 116 striking the second end wall 106 to be reflected to the exterior of the chamber. Preferably, the end wall 106 is made up of a series of overlapping vanes or louvres 138 which are open to the outside of the chamber 100. These vanes or louvres 138 both permit easy passage of smoke particles into the interior of the chamber 100 as well as acting to cause the light beam 122 from the photoemitting diode 118 to be reflected to the outside of the chamber 100 as it strikes the end wall 106 rather than back into the chamber 100 as may be the case if the end wall 106 were solid in this region. The overlap of the louvres or vanes 138 gives the end wall 106 the appearance of a solid surface to ambient light exterior to the chamber 100 while

2159755

providing openings for the reflected light from the photoemitting diode 118 to exit the chamber 100.

Preferably, to maximize the dispersion of the reflected light to the exterior of the chamber 100, the louvres 138 are arranged to reflect the light to either side of the centerline of the chamber 100 as the reflected light exits the chamber 100. This is achieved by angling the louvres or vanes 138 outwardly from the centerline of the chamber 100 as illustrated in the figures, particularly Figures 1 and 2. In order to aid in the reflection of the light from the photoemitting diode 118, the surface of the vanes or louvres 138 are very smooth to maximize their reflective properties. The overlap of the vanes or louvres 128 also aids in blocking any light which may be reflected by the surrounding insect screen 140 from entering the interior of the chamber 100.

To further reduce the possibility of reflection of light within the chamber 100, the smoke detection chamber 100 is provided with reticulated structures 142 in the top 108. These reticulated areas 142 of the smoke detection chamber 100 reduce the possibility of reflection of light from the the top 108 and in addition provide an area where any dust which may enter the smoke detection chamber 100 may collect without causing scattering of light to reflect and impinge upon the photodiode detector 124. These dust hiding areas are located such that they are not both in the path of the light beam 122 from the photoemitting diode 118 and also within the view 144 of a photodiode detector 124 as described. While these areas 142 may be in one or the other of these locations, they are not located so as to satisfy both conditions. Once again to aid in the dispersion of any light which might strike these reticulated structures 142, they are designed to slope away from the centerline of the chamber 100 as shown in particular in Figure 4.

To further reduce the possibility of reflected light from decreasing the sensitivity of the smoke

2159755

detector, the smoke detection chamber 100 is constructed by molding from a dark colored plastic, usually a black plastic preferably having a smooth finish. A particularly preferred material for the smoke detection chamber 100 is
5 black ABS plastic.

The smoke detection chamber 100 may be molded in more than one piece depending upon the complexity of the structures contained therein. For example, the side walls 102, end walls 104 and 106 and bottom 110 may be molded in
10 one piece and the top 108 may be molded as a separate piece which may be releasably attached to the other section of the smoke chamber 100 for ease of cleaning and replacement.

The photodiode detector 124 contained within the shielding arrangement 128 has a field of view 144 which
15 intersects the light beam 122 of the photoemitting diode 118 generally perpendicularly in a vertical plane to provide for the detection volume 146 to be located within the smoke detection chamber 100 close to both the photoemitting diode 118 and photodiode detector 124 yet
20 spaced from the surfaces of the smoke detection chamber 100 to minimize the effect on the photodiode detector 124 of light from the photoemitting diode 118 which is reflected exterior to the detection volume 146. The arrangement of the photoemitting diode 118 and photodiode detector 124
25 with a scattering angle at a generally right angle in the vertical plane permits the detection volume 146 to be located close to the photoemitting diode 118 where the intensity of the light beam from the photoemitting diode 118 is higher and close to the photodiode detector 124
30 where its sensitivity is higher thereby increasing the overall sensitivity of the smoke alarm. In addition the use of the scattering angle at a generally right angle results in a black smoke to grey smoke sensitivity ratio of about 3.5:1, increasing the sensitivity to the presence of
35 smoke particles of many colors, particularly black smoke particles.

To achieve the above, the shielding arrangement 128 is preferably located such that its centerline is between the centerline of the smoke detection chamber 100 and the mounting arrangement 116. Preferably the shielding arrangement 128 is located such that its centerline is located approximately 20% to 40% of the dimension of the smoke chamber 100 away from the mounting arrangement 116, more preferably approximately 25% to 35%, most preferably approximately 30%. This location is possible because of the use of the scattering angle at a generally right angle and places the photodiode detector 124 close to the photoemitting diode 118 to view the tightly bunched rays and far away from the opposite end wall 106 to reduce the possibility of reflected light falling on the photodiode detector 124. The combination of the location of the shielding arrangement 128 with the mounting of the photodiode detector 124 on the circuit board and the location of photoemitting diode 118 in the end wall 104 provides for a very broad field of view 144 of the photodiode detector 124 and hence increased sensitivity without having to resort to the provision of additional optical elements such as lenses for focusing of the light. This expanded field of view 138 of the photodiode detector 124 provides for a large area of intersection 146 with the light beam 122 of the photoemitting diode 118 to define the detection volume.

The smoke detection chamber 30 is preferably mounted directly on the printed circuit board by means of mounting clips 150 inserted through openings provided in the printed circuit board. The photodiode detector 124 is mounted such that it views into the smoke detection chamber 100 as has been described.

In operation, when smoke particles enter the smoke detection chamber through the openings 112 provided in the side walls 102 of the smoke detection chamber 100, as well as between the louvres 138 of the second end wall 106, the smoke particles fall within the light beam 122 of

the photoemitting diode 118. Smoke particles which are present in the detection volume 146 defined by the area of intersection of the light beam 122 from the photoemitting diode 118 and the field of view 144 of the photodiode detector 124, cause the light from the photoemitting diode 118 to be scattered such that it is directed through the shielding arrangement 128 and on to the photodiode detector 124. When the amount of light detected by the photodiode detector 124 passes a predetermined threshold the smoke alarm circuitry is activated and the detector indicates the alarm condition in the usual manner. The provision of the second end wall 106 with its louvres or vanes 138 far removed from the detection volume 146 reduces the possible interference by reflected light as the intensity of any light reflected back from this area would be diminished. Additionally, the angling of the louvres or vanes 138 reflects the light striking this area to the exterior of the chamber 100, thereby greatly reducing the potential for light to be reflected back toward the detection volume 146. These features greatly increase the sensitivity and stability of the smoke detector while reducing significantly the background signal. As most or all of the light striking the louvres or vanes 138 is reflected to the exterior of the chamber 100, the presence of dust on the surfaces of the smoke chamber does not result in the large increase in background signals levels associated with many prior designs of smoke chambers. This reduction in background is also aided by the dust hiding capabilities of the knife edge groove 132 of the shielding arrangement 128 as well as the reticulated area 142 of the top 108.

A prototype smoke detector has been constructed having a smoke detection chamber 100 as shown in the figures, in which the photoemitting diode 118 and photodiode detector 124 are mounted in a smoke detection chamber 100 having an interior length, i.e. along the beam of light of the photoemitting diode 118, of 2.5 inches. The photoemitting diode 118 broadcasts along the chamber

8916-1CA

100 and the photodiode detector 124 views axially with a 90° scattering angle from its mounting position directly on the printed circuit board with the centerline of the photodiode detector 124 and shielding arrangement 128 being
5 located 0.706 inches away from the end wall 104 in which the mounting arrangement 116 is located. The prototype utilized a SiemensTM BPW34FATM silicon photodiode, a polysulfone-bodied detector with visible light rejection characteristics. The photoemitting diode utilized was a
10 SiemensTM SFH484TM light emitting diode which operates at a wavelength of 880 nm in the infrared range. The alarm and control circuitry employed a MotorolaTM MC145010TM IC chip along with required circuitry for operation. The prototype alarm exhibited a high sensitivity and high RFI immunity to
15 false alarms through the UV spectrum to 1 GHz. The large smoke detection chamber with reticulated top achieved low background reflection with good dust hiding capability. The prototype design of the preferred embodiment of the present invention had a normalized figure of merit (NFM)
20 which is a measure of the smoke detection sensitivity to background reflection ratio greater than unity. This translates to smoke alarm signals being three times greater than the background reflection for alarm point settings of three percent per foot obscuration. This high NFM affords
25 exceptional immunity to false alarms from dust accumulation.

Excellent smoke access to the smoke detection chamber is afforded by the smoke detection chamber having screened openings around its periphery. The
30 smoke detection case is similarly vented around the circular periphery both at the top and the bottom. The design of the present invention has smoke detection sensitivities of both low and high air velocity within ten percent of each other thus indicating

2159755

the detector's excellent smoke entry design and the positioning of the detection volume defined by the intersection of the transmitted light from the photoemitting diode and the view of the photodiode
5 detector.

The provision of the surface mounted photodiode detector allows the detector to be mounted directly to the printed circuit board along with the other surface mounted devices in a single step, thus reducing manufacturing
10 costs. The surface mounted photodiode detector is able to view upwards through the opening 126 of the smoke detection chamber 100 directly at the smoke reaction volume. This smoke reaction volume is located in the lower portion of the smoke sensing chamber immediately accessible to the
15 smoke flow.

The smoke detection chamber of the present invention improves alarm response consistency and reduces manufacturing steps and costs. The design of the smoke detection chamber as described herein provides for a very
20 uniform detection sensitivity for various smoke types and colors under varying conditions with high RFI immunity. To further increase the RFI immunity of the smoke detector, the photodiode detector may be mounted on the side of the circuit board opposite the smoke chamber along with the
25 other SMT components. In this situation an aperture may be provided in the circuit board between the photodiode detector and the opening in the bottom of the smoke detection chamber such that the photodiode detector views into the smoke chamber through the aperture in the circuit
30 board and the opening in the bottom of the smoke detection chamber.

Although various preferred embodiments of the present invention have been described herein in detail, it will be appreciated by those skilled in the art, that
35 variations may be made thereto without departing from the spirit of the invention or the scope of the appended claims.

8916-1CA

WE CLAIM:

1. A smoke detection chamber for use in a photoelectric smoke detector, the chamber comprising a
5 generally hollow parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber, a second end wall opposite the mounting arrangement being louvred to provide communication between the interior and exterior of the chamber such that a light beam from the
10 photoemitting diode located in the mounting arrangement striking the second end wall would be deflected by the louvred end wall to the exterior of the chamber.
2. A smoke detection chamber as claimed in claim 1
15 wherein the mounting arrangement in the end wall of the smoke detection chamber bounds or limits the outer rays of the beam of light transmitted by a photoemitting diode mounted therein such that such light beam is transmitted along the smoke detection chamber without directly
20 impinging upon a side, a top or a bottom surface.
3. A smoke detection chamber as claimed in claim 2 wherein the mounting arrangement is a tunnel having walls extending beyond the photoemitting diode.
25
4. A smoke detection chamber as claimed in claim 1 wherein said smoke detection chamber is provided with a bottom, said bottom of said smoke detection chamber having an opening therein for mounting of a photodiode detector,
30 said opening having a shielding arrangement thereabout open to said chamber, said opening and shielding arrangement being located between the centerline of the smoke detection chamber and the mounting arrangement in the first end wall of the chamber.
35

5. A smoke detection chamber as claimed in claim 4 wherein the shielding arrangement is generally rectangular having upstanding walls to shield a photodiode detector mounted therein from incident light and a light beam of a photoemitting diode mounted in the mounting arrangement.

6. A smoke detection chamber as claimed in claim 5 wherein the shielding arrangement is located such that its centerline is located approximately 20% to 40% of the length of the smoke detection chamber away from the mounting arrangement.

7. A smoke detection chamber as claimed in claim 4 wherein said smoke detection chamber is mounted on a printed circuit board, said circuit board overlying said bottom surface and including a photodiode detector mounted directly thereon and positioned generally in said opening so that it views into the smoke detection chamber through the opening and through said shielding arrangement, the shielding arrangement shielding the photodiode detector from incident light which may be present in the smoke detector chamber while providing for a diverging field of view of the photodiode detector, the diverging field of view of the photodiode detector intersecting the light beam of the photoemitting diode to define a detection volume contained within the smoke detection chamber located close to the photoemitting diode and the photodiode detector and spaced from the surfaces of the smoke detection chamber to minimize the effect on the photodiode detector of light from the photoemitting diode which may be reflected exterior to said detection volume.

8. A smoke detection chamber as claimed in claim 7 wherein the photodiode detector and photoemitting diode are mounted to have a generally perpendicular scattering angle of a generally right angle therebetween.

8916-1CA

9. A smoke detection chamber as claimed in claim 1 wherein the top of the chamber is reticulated to reduce reflection of light and provide a dust hiding area.

5

10. A smoke detection chamber for use in a photoelectric smoke detector, the chamber comprising a generally hollow parallelepiped having a mounting arrangement for a photoemitting diode located in a first end wall of the chamber, a second end wall opposite the mounting arrangement being shaped to provide communication between the interior and exterior of the chamber while appearing as a solid surface to external ambient light and allowing a light beam from a photoemitting diode located in the mounting arrangement striking the second end wall to be reflected to the exterior of the chamber.

11. A smoke detection chamber as claimed in claim 10 wherein the mounting arrangement bounds or limits the outer rays of a beam of light transmitted by a photoemitting diode mounted therein.

12. A smoke detection chamber as claimed in claim 10 wherein the chamber is provided with a top having a reticulated area to reduce reflection of light and provide a dust hiding area.

13. A smoke detection chamber as claimed in claim 10 wherein the shielding arrangement is generally rectangular having upstanding walls to shield the opening from incident light and the mounting arrangement for a photoemitting diode.

14. A smoke detection chamber as claimed in claim 10 wherein the shielding arrangement is located such that its centerline is located approximately 20% to 40% of the

8916-1CA

length of the smoke detection chamber away from the mounting arrangement.

15. A smoke detection chamber as claimed in claim 14
5 wherein the shielding arrangement and mounting arrangement are located to provide a scattering angle between a photodiode detector and a photoemitting diode respectively mounted therein of a generally right angle.
- 10 16. A smoke detection chamber as claimed in any one of claims 1 to 15 wherein the side walls of the chamber between the end walls are provided with one or more unobstructed openings to allow free flow of smoke particles with the interior of the chamber.

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FIGURE 2

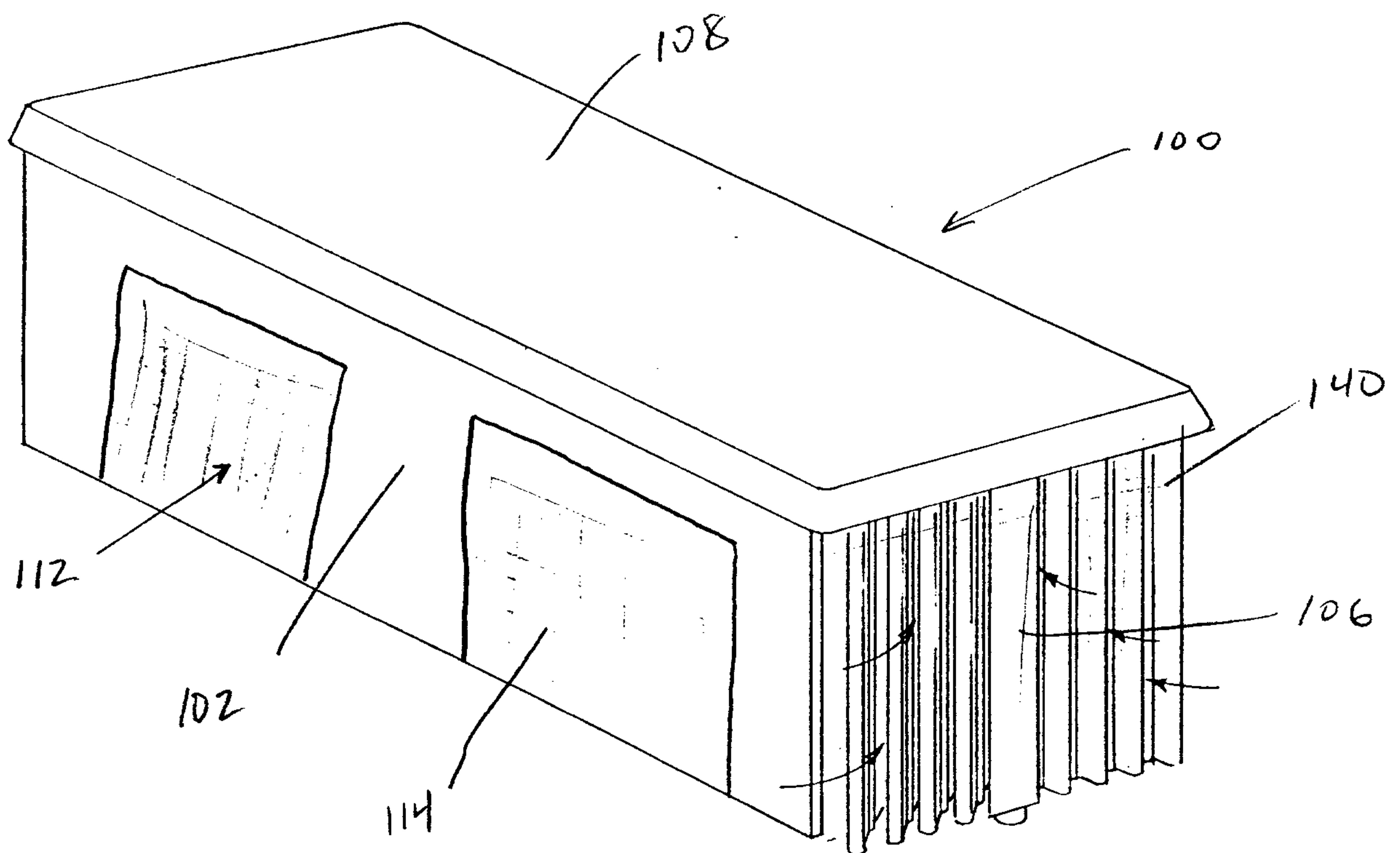
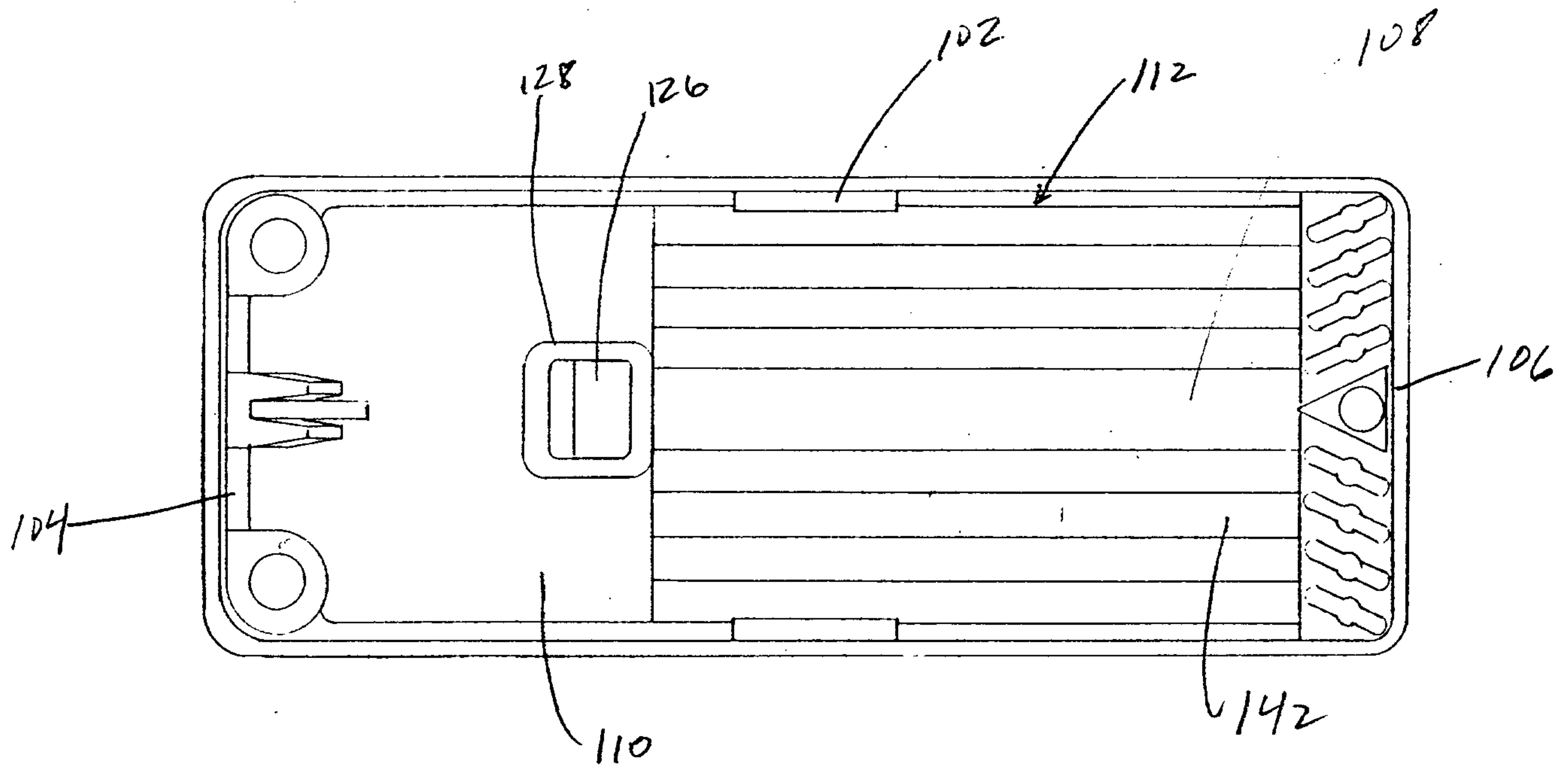


FIGURE 1

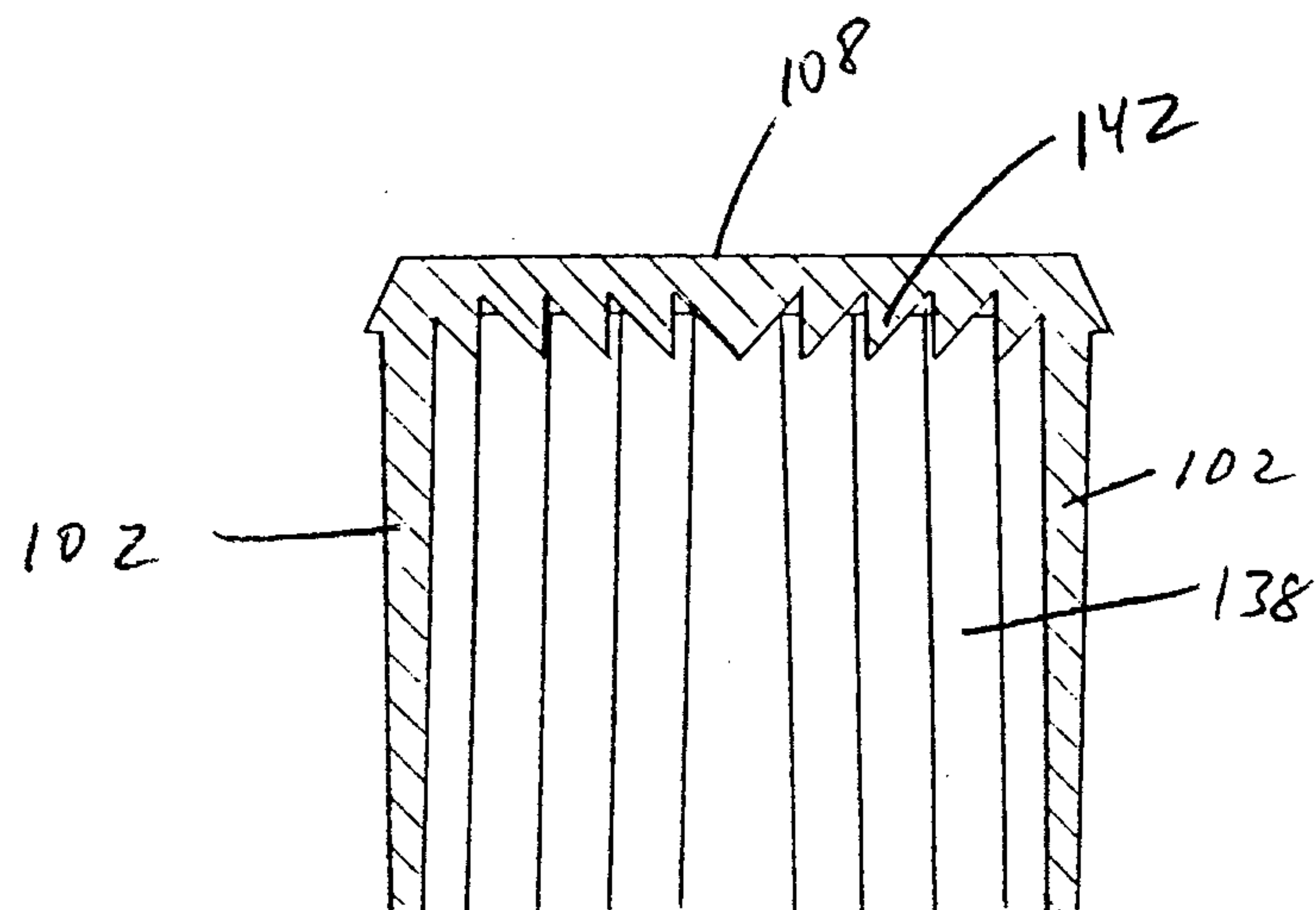
[illegible]

FIGURE 4

