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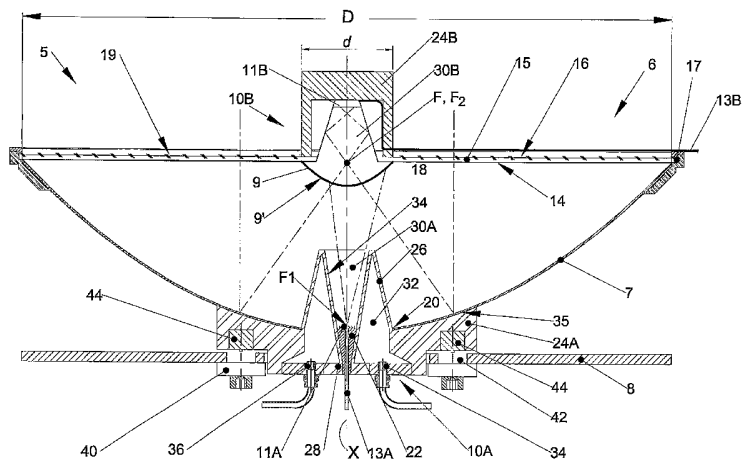
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(54) Title: SOLAR ENERGY UTILIZATION UNIT AND SOLAR ENERGY UTILIZATION SYSTEM



(57) Abstract: A solar energy utilization unit comprises a solar radiation concentrating optics and a solar radiation receiver including a first receiver component designed to convert into electric energy radiation in a first part of the solar spectrum, and a second receiver components designed to convert into electric energy radiation in a second part of the solar spectrum which is different from said first part. The solar radiation concentrating optics comprises a concave primary reflector adapted to reflect incident solar radiation towards the secondary reflector, and a convex secondary reflector adapted to reflect radiation in the first part of the solar spectrum into the first receiver component and also to transmit radiation in the second part of the solar spectrum into the second receiver component. The primary reflector is formed with a centrally disposed opening, via which the first receiver component is adapted to receive the radiation reflected by the secondary receiver. The primary receiver may have central and peripheral components, wherein the central component is made of a material which withstands heat better than the material from which the peripheral component is made.

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SOLAR ENERGY UTILIZATION UNIT AND SOLAR ENERGY UTILIZATION SYSTEM

FIELD OF THE INVENTION

This invention relates to the field of solar energy utilization systems and particularly, to such systems using solar radiation concentration optics of the cassegrainian type.

BACKGROUND OF THE INVENTION

A standard cassegrainian concentration optics comprises two reflectors, a primary reflector and a secondary reflector, which are coaxially aligned. The primary reflector captures and reflects incoming radiation to the generally smaller secondary reflector. The secondary reflector in turn reflects the radiation toward the focus of the concentration optics associated with a solar receiver. The primary and secondary reflectors may have different shapes, e.g., the primary reflector may be parabolic and the secondary reflector may be hyperbolic.

The solar receiver may be based on direct absorption of the heat of solar radiation by a working medium, e.g., water, or on a conversion of the solar radiation into another form of energy, e.g., as in photovoltaic cells, in which case the receiver is located with its entrance adjacent to or at the focus of the concentration optics. Alternatively, the receiver may be composed of a means for transmitting the concentrated radiation to a location spaced from the focal point, e.g., for use of solar energy in illumination systems.

In "*Path to Affordable Solar Electric Power*", JX Crystals Inc., 2004, Lewis M. Fraas describes the use of two different receivers with cassegrainian concentration optics, in which the secondary reflector is in the form of a beam splitter, which reflects concentrated solar radiation in the visible part of the solar spectrum towards fiber optic light guide for piping the radiation to an indoor illumination system, and transmits concentrated solar radiation in the IR part of the solar spectrum towards an array of

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photovoltaic cells located behind the secondary reflector, for converting the radiation to electricity.

The efficiency of a cassegrainian solar concentrator is highly dependent on the quality of the reflectors' reflecting surfaces. Reflectors exposed to the environment for extended periods, tend to lose their reflection abilities due to, for example, dust or sand erosion, oxidation or corrosion. US 4,166,917 and US 4,491,683 describe sealed solar collectors.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention there is provided a solar energy utilization unit with a solar radiation concentrating optics of a cassegrainian type, the unit being of a design allowing it to be manipulated by hand and modularly assembled in a solar energy utilization system, e.g., for domestic applications.

The solar energy utilization unit comprises a solar radiation concentrating optics, designed to concentrate incident solar radiation and split it into at least two parts having wavelengths in different parts of the solar spectrum, and a solar radiation receiver including first and second solar radiation receiver components, the first component being adapted to convert to electricity incident radiation within a first, and the second component being adapted to convert to electricity incident radiation within a second, of said two parts of the solar spectrum.

The first and second receiver components each have a solar radiation receiving portion, preferably in the form of a photovoltaic structure, e.g., one or more photovoltaic cells, with sensitivity in the corresponding part of the solar spectrum. The two parts of the solar spectrum may, for example, be its visible and IR parts.

Each receiver component may comprise a concentrator, e.g., a non-imaging concentrator known per se, designed for admitting radiation from the solar radiation concentrating optics and forwarding it to the radiation receiving portion of the receiver component in a uniformly distributed manner. The concentrator may be in the form of a converging, e.g., a frusto-conical, pipe with reflective internal surface, or a prism, within which radiation travels by means of total internal reflection.

The solar radiation concentrating optics has an optical axis and comprises a primary concave reflector and a secondary convex reflector whose centers and focal points are located along the optical axis. The secondary reflector is in the form of a

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spectral beam-splitter having two focal points, and it is designed to admit radiation concentrated by the primary reflector, to reflect towards its first focal point radiation in the first part of the solar spectrum, and to transmit towards the second focal point radiation in the second part of the solar spectrum, the first and second receiver components being respectively associated with the first and second focal points of the secondary reflector.

The primary reflector is formed with an opening in its center and the first focal point of the secondary reflector is normally disposed in or adjacent to the opening. The first receiver component is fixedly secured to the primary reflector's outer surface, so that either its radiation receiving portion or the concentrator associated therewith is disposed in or adjacent to the first focal point of the secondary reflector.

The secondary reflector has a convex surface facing the primary reflector, and its second focal point, which is located behind, has a convex surface, the second receiver component being fixedly secured behind the convex surface so that either its radiation receiving portion or the concentrator associated therewith is disposed in or adjacent to the second focal point of the secondary reflector.

In the case that any of the first and second receiver components include the concentrator, the latter may be formed integrally with its corresponding receiver component and/or with the reflector, primary or secondary, with which the receiver component is associated.

The second receiver component may further comprise a housing unit carrying the radiation receiving portion of the second receiver component, and the concentrator, if any, associated therewith.

Any or both of the first and second receiver components may further include a heat removal means to withdraw heat from the radiation receiving portion of the component. The heat removal means may be passive and be based on convection, which may be used in both receiver components; or they may be active and use cooling fluid, which may be particularly useful for the first receiver component.

By virtue of splitting the concentrated radiation into at least two parts and using corresponding receiver components, which are sensitive to these parts of radiation, to convert them into electric energy, and which are associated with different components (first and secondary reflectors) of the concentrating optics, in accordance with the present invention, a number of advantages may be achieved including:

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- the first and second receiver components may each be provided with a separate electric set up to operate at its optimal generated current;
- the characteristics of the receiver components may be chosen and optimized, independently from each other, to enable better efficiency and lower production costs of the components;
- each receiver component may perform at a different concentration level, which can be controlled by the design of the concentrator included in the component, whereby optimal concentration of radiation may be achieved for each receiver component and consequently maximum efficiency thereof;
- heat removal from the radiation receiving portions of the receiver component is better manageable, since each receiving portion is only getting the part of the radiation spectrum applicable to it.

The solar energy utilization unit of the present invention may further comprise a rigid cover firmly and sealingly attached to the primary reflector, along the circumference of the latter, thereby forming a closed volume between the cover's inner surface and the inner, reflecting surface of the primary reflector with the solar radiation receiver component secured thereto. The unit may comprise means to control environment of the closed volume for minimizing deterioration of the quality of the reflectors.

The cover is made of a transparent material and it has a relatively small inoperative area whose inner surface is associated with the secondary reflector, either integrally formed therewith or fixedly attached thereto, and a relatively large operative area surrounding the reflector, via which area incident solar radiation passes towards the reflecting surface of the primary reflector.

The unit is preferably associated with a tracking mechanism that tracks the sun and it may comprise a self-aligning mechanism for additional precise alignment of the unit towards the sun.

The present invention further refers to a solar energy utilization system having a base plate and a plurality of solar unit seats adapted for detachably attaching a plurality of solar energy utilization units of the type described hereinabove, wherein in each unit the first and second receiver components are provided with their individual electric cables for withdrawing electricity therefrom, and wherein each unit is modular and is manufactured in mass production.

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According to another aspect of the present invention, there is provided a solar energy utilization unit comprising a solar radiation concentrating optics and a solar radiation receiver. The receiver is designed to convert radiation into another form of energy. The solar radiation concentrating optics comprises a concave primary reflector and a convex secondary reflector. The primary reflector is adapted to reflect incident solar radiation towards the secondary reflector, and the secondary reflector is adapted to direct concentrated radiation toward the receiver. The primary reflector is formed with a centrally disposed opening, via which said receiver is adapted to receive the radiation reflected by said secondary reflector. The primary reflector is made of a central component surrounding the receiver, and a peripheral component surrounding the central component. The central component is made of a material which withstands heat better than the material from which the peripheral component is made.

According to one embodiment, the peripheral component is a base and the central component is a metal disk. Surfaces of the base and metal disk are adapted to form a continuous surface to reflect the incident solar radiation. The base may be made of plastic and be plated with a reflective material, at least on the surface which is adapted, in use, to reflect the incident solar radiation.

According to another aspect of the present invention, there is provided an integral reflector assembly comprising a plurality of first reflectors and a single cover holding a plurality of corresponding secondary reflectors, to form a plurality of solar energy utilization units as described above.

According to a further aspect of the present invention, there is provided a reflector element comprising a first surface and a second surface adapted to carry a solar radiation receiver. The first surface is adapted to reflect radiation in a first part of the solar spectrum and to transmit radiation in a second part of the solar spectrum toward the receiver. The second surface comprises a groove adapted to receive a lead wire connectable to the solar radiation receiver. The second surface may comprise at least two portions being non-coplanar. The solar radiation receiver and the groove may be on portions of the second surface which are non-coplanar. The solar radiation receiver may be a photovoltaic cell. The element may be adapted for use with a solar energy utilization unit.

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BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, an embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

5 **Fig. 1** is a schematic sectional view of a solar energy utilization unit according to one embodiment of the present invention;

Fig. 2A is a schematic isometric view of the solar energy utilization unit shown in Fig. 1;

Fig. 2B is a schematic isometric view of a solar energy utilization unit according to
10 an alternative embodiment of the present invention; and

Fig. 3 is a schematic isometric view of a solar energy utilization system according to the present invention.

Fig. 4 is a top perspective view of a receiver structure for use with the solar energy utilization unit shown in Fig. 1, according to the present invention;

15 **Fig. 5A** is a partial top view of one embodiment of a rigid cover for use with the receiver structure shown in Fig. 4, according to the present invention;

Fig. 5B is a partial top view of another embodiment of a rigid cover for use with the receiver structure shown in Fig. 4, according to the present invention;

Fig. 6 is a top perspective view of the receiver structure shown in Fig. 4, with
20 lead wires fitted therein;

Figs. 7A and 7B are front and top views, respectively, of the receiver structure illustrated in Fig. 6 attached to the rigid cover;

Fig. 8 is a bottom perspective view of an infrared circuit according to the present invention;

25 **Fig. 9** is a bottom perspective view of the infrared circuit illustrated in Fig. 8 bonded to the bottom of an aluminum lid;

Figs. 10A and 10B are front and side views, respectively, of the aluminum lid illustrated in Fig. 9 bonded to the top of the receiver structure;

Fig 11A is a side view of the receiver structure, with the addition of a canister;

30 **Fig. 11B** is a cross-sectional view, taken along line II-II, of the receiver structure shown in Fig. 11A;

Fig. 11C is an enlarged view of the area indicated at 'A' in Fig. 11B; and

Fig. 12 is another embodiment of the receiver structure as illustrated in Fig. 6;

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Fig. 13 is a perspective view of a reflector assembly according to one embodiment of the present invention;

Fig. 14A is a perspective view of the reflector assembly illustrated in Fig. 13, with a modification according to the present invention;

5 **Fig. 14B** is a cross-sectional view taken along line IV-IV in Fig. 14A; and

Fig. 14C is an enlarged view of the area indicated at 'B' in Fig. 14B.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Fig. 1 shows a solar energy utilization unit **5** in accordance with one embodiment of the present invention. The unit **5** comprises a solar radiation concentrating optics **6** including a concave primary reflector **7** and a convex secondary reflector **9**, and a solar receiver designed to convert the radiation concentrated by the optics **6** into electric energy, the solar receiver comprising a first and second photovoltaic receiver components **10A** and **10B**, each associated with either primary reflector **7** or secondary reflector **9**.

Each receiver component **10A**, **10B** comprises a photovoltaic structure **11A**, **11B**, which may be a singular plate cell or an array of cells. The photovoltaic structures **11A** and **11B** have different sensitivity wavebands, e.g., one of them is sensitive to radiation in the IR part of the solar spectrum and the other – in the visible part, and are designed to convert radiation within their corresponding wavebands into electric energy. The structures **11A** and **11B** are provided with electric cables **13A**, **13B**, respectively, attached thereto, for piping the electric energy to necessary location for utilization. The photovoltaic structures **11A** and **11B** will be further referred to as 'photovoltaic cells'.

The primary and secondary reflectors are arranged in a cassegrainian design, wherein the primary reflector **7** has a parabolic reflecting surface with a point of focus **F**. The secondary reflector **9** has a surface **9'**, facing the primary reflector, which is of a hyperbolic shape, and it has two points of focus **F1** and **F2** at different sides of the hyperbolic surface. The points of focus of both reflectors are located on a common optical axis **X**. The point of focus **F** of the primary reflector **7** coincides with the point of focus **F2** of the secondary reflector **9**.

The secondary reflector **9** is in the form of a beam splitter, which reflects towards its first focus **F1** radiation in the sensitivity waveband of the photovoltaic cell **11A**, and which transmits towards the second focus **F2** radiation in the sensitivity waveband of the photovoltaic cell **11B**.

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Each receiver component **10A**, **10B** comprises a non-imaging concentrator whose entrance is located in or adjacent to the respective focus **F1**, **F2** of the secondary reflector, designed for admitting radiation reflected or transmitted by the secondary reflector **9** and forwarding it to the respective photovoltaic cell **11A**, **11B** in a uniformly distributed
5 manner. The concentrator may be in the form of a converging, e.g., such as a frusto-conical pipe **30A** with reflective internal surface, or in the form of a prism, e.g., such as prism **30B**, within which radiation travels by means of total internal reflection.

The reflectors **7** and **9** have a circular symmetry around the axis **X**, the circumference of the primary reflector **7** having a diameter **D** and defining the
10 circumference of the entire unit **5**. The circumference of the secondary reflector has a diameter **d**, essentially smaller than the diameter **D**.

The unit **5** further comprises a rigid cover **15** made of a transparent material and having a rim **17** firmly and sealingly attached to the primary reflector **7** at the circumference of the latter, to form a closed volume between the cover **15** and the reflector
15 **7**. The closed volume may be filled with inert gas such as Nitrogen.

The cover **15** has an inner surface **14** facing the primary reflector **7** and the first receiver component **10A**, an outer surface **16** generally facing the sun, an inoperative area **18** holding the secondary reflector **9** and the second receiver component **10B**, and an operative area **19** surrounding them.

20 As seen in Fig. 1, the inoperative area **18** of the cover **15** is in the form of an aperture (not illustrated), and the secondary reflector **9** and the second receiver component **10B** are formed as one unit mounted in the aperture. The second receiver component further comprises a housing **24B** which serves as an insulating substrate and a protecting cover for the photovoltaic cell **11B**, which is designed to enable passive cooling thereof.

25 The primary reflector **7** is formed with an opening **20** for mounting therein the solar radiation receiver component **10A**.

The solar radiation receiver component **10A** is made of a heat-conducting material and includes a centrally located cell-holding portion **22**, a heat removal portion **26**, at least a part of which surrounds the cell holding portion, and a peripherally disposed mounting
30 arrangement **24A**.

The cell holding portion **22** comprises a cell seat **28** protruding outwardly from the opening **20**. The heat removal portion **26** protrudes inwardly from the opening **20** of the primary reflector **7**, defining the frusto-conical pipe **30A**, and it is formed with a cooling

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fluid cavity **32** surrounding the pipe **30A** and adapted to provide contact of cooling fluid disposed therein with the cell seat **28** to withdraw heat therefrom.

The heat removal portion **26** is designed to be located in the shade, cast by the secondary reflector **9**. The heat removal portion **26** has an inlet **34** and an outlet **36**
5 connected with the cooling fluid cavity **32**.

The unit mounting arrangement **24A** includes a support surface **35** fixedly attached to the outer surface of the primary reflector **7** at areas thereof adjacent the aperture **20**; means **40** preferably located at three peripheral areas of the solar radiation receiver component (of which only two are seen in Fig. 1), for mounting the unit **5** on the plate **8**
10 with a possibility to independently adjust the distance therebetween; and a self-aligning mechanism **42** with any suitable adjustment means **44** adapted to perform the adjustment (e.g., step motors, electromagnets, etc.), to align the position of the unit **5** with respect to the sun.

For this purpose, the self-aligning mechanism **42** may comprise a sensor (not
15 shown) located on the outer surface of the inoperative area **18** of the cover **15**, and connected with the adjustment means **44** and a controller (not shown) to control the adjustment means, based on data received from the sensor. Alternatively, a sensing device can be designed as part of the receiver component **10**, which will eliminate the need for the sensor **46**.

20 In operation, the unit **5** mounted on the plate **8** tracks the sun and solar radiation passes through the operative area **19** of the transparent cover **15** to impinge upon the primary reflector **7** in a direction parallel to the axis **X** and is reflected thereby in the direction of its focus point **F** coinciding with the focal point **F2** of the secondary reflector **9**. One part of the radiation, which is within the sensitivity waveband of the first
25 photovoltaic cell **11A**, is then reflected by the secondary reflector **9** towards its focal point **F1**, where the pipe **30A** further concentrates it and directs it to the photovoltaic cell **11A** in a uniformly distributed manner. Radiation within the sensitivity waveband of the second photovoltaic cell **11B** is not reflected by the secondary reflector **9** but is rather transmitted thereby towards the focal point **F2**, where the prism **30B** further concentrates it and directs
30 it to the photovoltaic cell **11B** in a uniformly distributed manner.

A large amount of radiation concentrated in the area of the photovoltaic cell **11A**, in the first receiver component **10A**, may cause a significant accumulation of heat around there, particularly in the cell seat **28**. The heat removing part **26** functions as a heat-

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exchanger unit by removing the heat from the cell seat **28** with the cooling fluid flowing from the inlet **34** to the outlet **36** through the cooling fluid cavity **32**. Similarly, the photovoltaic cell **11B** is cooled by means provided in the housing **24B** of the second receiver component **10B**.

5 The unit **5** can be in a variety of dimensions but, for domestic use, it is preferably compact and easily handled. Such unit may have a diameter of approximately twenty two centimeters and a thickness of approximately seven centimeters, with the diameter **d** of the secondary reflector **9** being approximately 4.4 centimeters and the corresponding shaded area on the primary reflector **7** being only four percent of the area of the reflector **9**.

10 The unit **5** may be unitarily manufactured in mass production and according to industrial standards of high precision. In particular, assembly of all its components into a precise, solid and durable construction may be performed at a relatively low cost.

 The firm mounting of the secondary reflector **9** in the aperture of the rigid cover **15** and the firm attachment of the cover **15** to the primary reflector **7**, assures that the desired
15 alignment of the primary reflector **7** and the secondary reflector **9** can be easily achieved during the manufacturing process and can be maintained for the duration of the unit service period. In addition, the cover **15** facilitates keeping the surfaces of the reflectors **7** and **9** environmentally safe.

 Thus, the use of the transparent rigid cover **15** is advantageous in both that it
20 enables constructing the unit **5** as one unitary rigid member of precise dimensions and at the same time protects the reflectors, thereby enabling its extended service period.

 Figs. **2A** and **2B** show two respective exemplary designs **5A** and **5B** of the solar energy utilization unit **5**, which are identical except for the shape of their circumference. In the unit **5A** this shape is circular and in the unit **5B** it is square, the latter enabling a more
25 efficient arrangement of a plurality of units in an array. Due to the concave shape of the primary reflector **7**, both units **5A** and **5B** appear to have a mushroom-like body **64** which may be formed with a leg **62** for facilitating mounting it in a standardized manner, in solar energy utilization systems. The legs **62** may house the unit mounting arrangement, the cell-holding portion and at least a part of the heat removal portion illustrated in Fig. **1**.

30 Fig. **3** shows an example of a solar energy utilization system **60** comprising the plate **8** and an array of units **5B** attached thereto. The plate **8** is provided with any known tracking mechanism (not shown) to follow the sun.

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The plate 8 is further provided with means **66** and **68** connected with inlets and outlets of the heat removal portion of all the units to enable the circulation of cooling fluid through the units **5B**, as previously shown. The cooling fluid, when withdrawn from the units, may be further used for any suitable purpose.

5 The units designed according to the present invention may easily be individually replaced, when needed, thereby facilitating the maintenance of the system.

One of the challenges of the solar energy utilization unit is routing the power generated by photovoltaic structure **11B**, which is part of a receiver structure **10B**, as seen in Fig 1. In order to overcome this challenge, additional developments to the
10 system have been introduced.

The receiver structure **10B** comprises a secondary reflector **9** and a prism **30B**. The receiver structure is received within a rigid cover **15**.

As seen in Fig. 4, the backside of the secondary reflector **9** is provided with a groove **100**. The groove **100** is located so that it is adjacent and parallel to one of the
15 bottom edges of the prism **30B**. It is sized so as to receive a wire lead **102** (seen in Fig. 6).

As seen in Fig. 5A, two openings **104** are provided in the rigid cover **15** adjacent an aperture provided for passage therethrough of the prism **30B**. The openings are located in a position corresponding to center of the groove **100** and are each sized so as
20 to allow for passage therethrough of the leads **102**. Alternatively, as seen in Fig. 5B, the aperture **105** may be round, leaving enough space adjacent the prism **30B** for passage of the leads **102** obviating the need for the openings **104**.

As seen in Fig. 6, two wire leads **102**, each with an end exposed, are fitted within the groove **100**. Each lead **102** bends near the middle of the groove **100** at
25 location corresponding to one of the openings **104**. The reflector **9** and prism **30B**, which are bonded together, are attached to the rigid cover **15**, with the prism passing through the aperture **105** provided therefor. The leads **102** are passed through the openings **104**, as seen in Figs. 7A and 7B.

As seen in Fig. 8, an infrared (IR) circuit **106**, in the form of a photovoltaic cell,
30 comprises several GaSb cells **108** mounted on an alumina substrate and connected in series. Two copper ribbons **110** protrude perpendicular therefrom and act as positive and negative leads. The IR circuit **106** is mounted to the bottom of a finned aluminum

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lid **112**, as illustrated in Fig. 9, which acts as a heat sink. The side edge **114** of the heat sink is beveled.

As shown in Figs. 10A and 10B, the IR circuit is bonded to the top side **116** of the prism **30B**. An appropriate bonding agent, such as silicone adhesive, is used. It is disposed so that the ribbons extend downwardly on the side of the prism **30B** which is adjacent the groove **100**, with the ribbons contacting the ends of the leads **102**.

As seen in Figs. 11A through 11C, an additional cylindrical heat sink is provided in the form of a canister **118**, in order to increase heat dissipation. The canister **118** is, at one end, beveled correspondingly to the side edge **114** of the aluminum lid **112**. Thermally conductive epoxy is placed on one or both of the beveled edges, and the canister **118** is placed on the aluminum lid **112**. A glue bead **120** may be applied between the bottom of the canister **118** and the top of the rigid cover **15**, as illustrated in Fig. 11B.

It should be noted that while the groove has been illustrated as being linear, other arrangements are possible. For example, the groove may bend 90° around the corner of the prism **30B**, as seen in Fig. 12.

The developments according to the present invention allow for routing the lead wires on the interior portion of the rigid cover, through a portion associated with, and preferably formed within, the receiver structure, and along the side of the prism, where it meets with a portion of the IR circuit.

Fig. 13 illustrates an embodiment of the present invention wherein a number of primary reflectors **7** are molded as a single reflector assembly **130**. The reflector assembly **130** comprises the primary reflectors **7** arranged in a tessellated pattern, such as a grid. The reflector assembly **130** comprises one receiver component **10A** associated with each primary reflector, as described above. The reflector assembly **130** is fitted within an enclosure **132**, and a single cover **15** is used to enclose the volume above the reflector assembly. The cover **15** comprises a number, equal to the number of primary reflectors **7**, of secondary reflectors (not seen) and receiver components **10B**, arranged such that the point of focus of each primary reflector **7** coincides with the point of focus **F2** of a corresponding secondary reflector.

The interfaces between the reflector assembly **130** and the enclosure **132** and between the cover **15** and the enclosure are sealed, allowing, if desired, the volume

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defined between the reflector assembly and the cover to be filled with an inert gas as described above.

By molding the primary reflectors as a single piece, the costs of manufacture and assembly are reduced. The lowering of these costs are also lowered by forming the
5 cover for all of the primary reflectors from a single piece.

It will be appreciated that other configurations of the tessellated pattern are possible, such as a honeycomb pattern, etc.

According to one modification, the unit **5** is designed such that the primary reflector can withstand heat which may result from some of the concentrated light from
10 the secondary reflector being reflected onto the surface of the primary reflector. As illustrated in Figs. 14A through 14C with respect to the embodiment described with reference to Fig. 13, this may be accomplished by each primary reflector **7** comprising a plastic base **134** with a hole (not seen) in the center. The hole is bigger than would be necessary to receive the receiver component **10A**. A shelf **135** (only seen in Fig. 14C),
15 concentric with the hole, is located immediately adjacent it. The plastic is selected such that silver plating, or any other reflective material, may be applied to it by any conventional means, such as vapor deposition within a vacuum chamber.

A curved metal disc **136** is provided to complete the surface of the primary reflector **7**. The disc **136** is sized so that its outer perimeter **138** matches the outer
20 perimeter **140** of the shelf **135** (best seen in Fig. 14C). The base **134** and disc **136** are formed so that their respective upper surfaces **142a**, **142b** cooperate to form a continuous surface constituting the primary reflector, as described above.

By manufacturing the primary reflector **7** in this manner, plastic may be utilized for a majority of the reflector, which may be manufactured by a simpler and cheaper
25 process. It also results in an overall lighter unit. The area in the vicinity of the receiver component **10A**, which may get very hot due to some of the concentrated solar energy reflected by the secondary reflector **9** not being directed, for whatever reason, exactly toward the non-imaging concentrator of the receiver component **10A**. Thus, the metal disc **136** is provided to withstand the heat which would be generated in this eventuality,
30 without disrupting the normal operation of the unit **5**.

While an example of the above embodiment was presented in use with the embodiment described in reference to Fig. 13, it should be noted that it not thus limited, and may be applied to any solar energy unit designed according to the present invention.

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It can be appreciated that there are various solar energy utilization units and solar energy utilization systems devisable according to the present invention and that the above descriptions are merely explanatory. Thus, the solar energy utilization unit and solar energy utilization system can be embodied in a variety of aspects, falling
5 within the scope of the present invention *mutatis mutandis*.

CLAIMS:

1. A solar energy utilization unit comprising a solar radiation concentrating optics and a solar radiation receiver including first and second receiver components, the first receiver component being designed to convert into electric energy radiation in a first part of the solar spectrum, and the second receiver component being designed to convert into electric energy radiation in a second part of the solar spectrum different from said first part, said solar radiation concentrating optics comprising a concave primary reflector and a convex secondary reflector, the primary reflector being adapted to reflect incident solar radiation towards the secondary reflector, the secondary reflector being adapted to reflect radiation in said first part of the solar spectrum into said first receiver component and to transmit radiation in the second part of the solar spectrum into the second receiver component, said primary reflector being formed with a centrally disposed opening, via which said first receiver component is adapted to receive the radiation reflected by said secondary reflector.
2. A solar energy utilization unit according to Claim 1, wherein both first and second receiver components comprise respective first and second photovoltaic structures.
3. A solar energy utilization unit according to Claim 2, wherein said first and second parts of the solar spectrum are its visible and IR parts.
4. A solar energy utilization unit according to Claim 3, wherein said first part of the solar spectrum is the visible part, and said second part of the solar spectrum is the IR part.
5. A solar energy utilization unit according to Claim 2, wherein at least one of the first and second receiver components comprise a non-imaging concentrator for forwarding incident concentrated radiation to the corresponding photovoltaic structure in a uniformly distributed manner.
6. A solar energy utilization unit according to Claim 1, further comprising a cover made of a transparent material, said cover being firmly attached to said primary reflector to cover the entire reflecting surface thereof, and holding the secondary reflector at a predetermined position relative to the primary reflector and the first and second receiver components.
7. A solar energy utilization unit according to Claim 6, wherein a volume, formed between the cover, the primary reflector and the solar radiation receiver component, is sealed.

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8. A solar energy utilization unit according to Claim 7, wherein said volume contains an inert gas.
9. A solar energy utilization unit according to Claim 1, wherein said unit comprises a self-aligning mechanism for directing the unit toward incoming solar radiation.
- 5 10. A solar energy utilization unit according to Claim 2, wherein said first receiver component comprises the photovoltaic structure and a heat removal portion adjacent thereto, the heat removal means being either active or passive.
11. A solar energy utilization unit according to Claim 2, wherein said second receiver component comprises the photovoltaic structure and a housing protecting and insulating
10 said structure and providing it passive cooling.
12. A solar energy utilization unit according to Claim 10, wherein said heat removal portion extends inwardly from said primary reflector.
13. A solar energy utilization unit according to Claim 1, wherein the unit is of dimensions allowing it to be held, carried and manipulated by hand.
- 15 14. A solar energy utilization system, comprising at least one seat and at least one solar energy utilization unit according to any of Claims 1 to 13, detachably attachable thereto.
15. A solar energy utilization system, comprising an integral reflector assembly comprising a plurality of first reflectors according to Claim 1, and a single cover.
- 20 16. A solar energy utilization unit comprising a solar radiation concentrating optics and a solar radiation receiver, said receiver being designed to convert radiation into another form of energy, said solar radiation concentrating optics comprising a concave primary reflector and a convex secondary reflector, the primary reflector being adapted to reflect incident solar radiation towards the secondary reflector, the secondary reflector being
25 adapted to direct concentrated radiation toward the receiver, said primary reflector being formed with a centrally disposed opening, via which said receiver is adapted to receive the radiation reflected by said secondary reflector, wherein the primary reflector is made of a central component surrounding said receiver and a peripheral component surrounding said central component, the central component being made of a material which withstands heat
30 better than the material from which the peripheral component is made.
17. A solar energy utilization unit according to Claim 16, wherein said peripheral component is a base and said central component is a metal disk, surfaces of the base and

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metal disk being adapted to form a continuous surface to reflect said incident solar radiation.

18. A solar energy utilization unit according to Claim 17, wherein the base is made of plastic and is plated with a reflective material, at least on the surface which is adapted, in use, to reflect said incident solar radiation.

19. An integral reflector assembly comprising a plurality of first reflectors, a single cover holding a plurality of corresponding secondary reflectors, to form a plurality of solar energy utilization units according to Claim 16.

20. A reflector element comprising a first surface and a second surface adapted to carry a solar radiation receiver, the first surface being adapted to reflect radiation in a first part of the solar spectrum and to transmit radiation in a second part of the solar spectrum toward the receiver, wherein the second surface comprises a groove adapted to receive a lead wire connectable to the solar radiation receiver.

21. A reflector element according to Claim 20, wherein the second surface comprises at least two portions being non-coplanar.

22. A reflector element according to Claim 21, wherein the solar radiation receiver and the groove are on portions of the second surface which are non-coplanar.

23. A reflector element according to Claim 20, wherein the solar radiation receiver is a photovoltaic cell.

24. A reflector element according to Claim 20, for use with a solar energy utilization unit.

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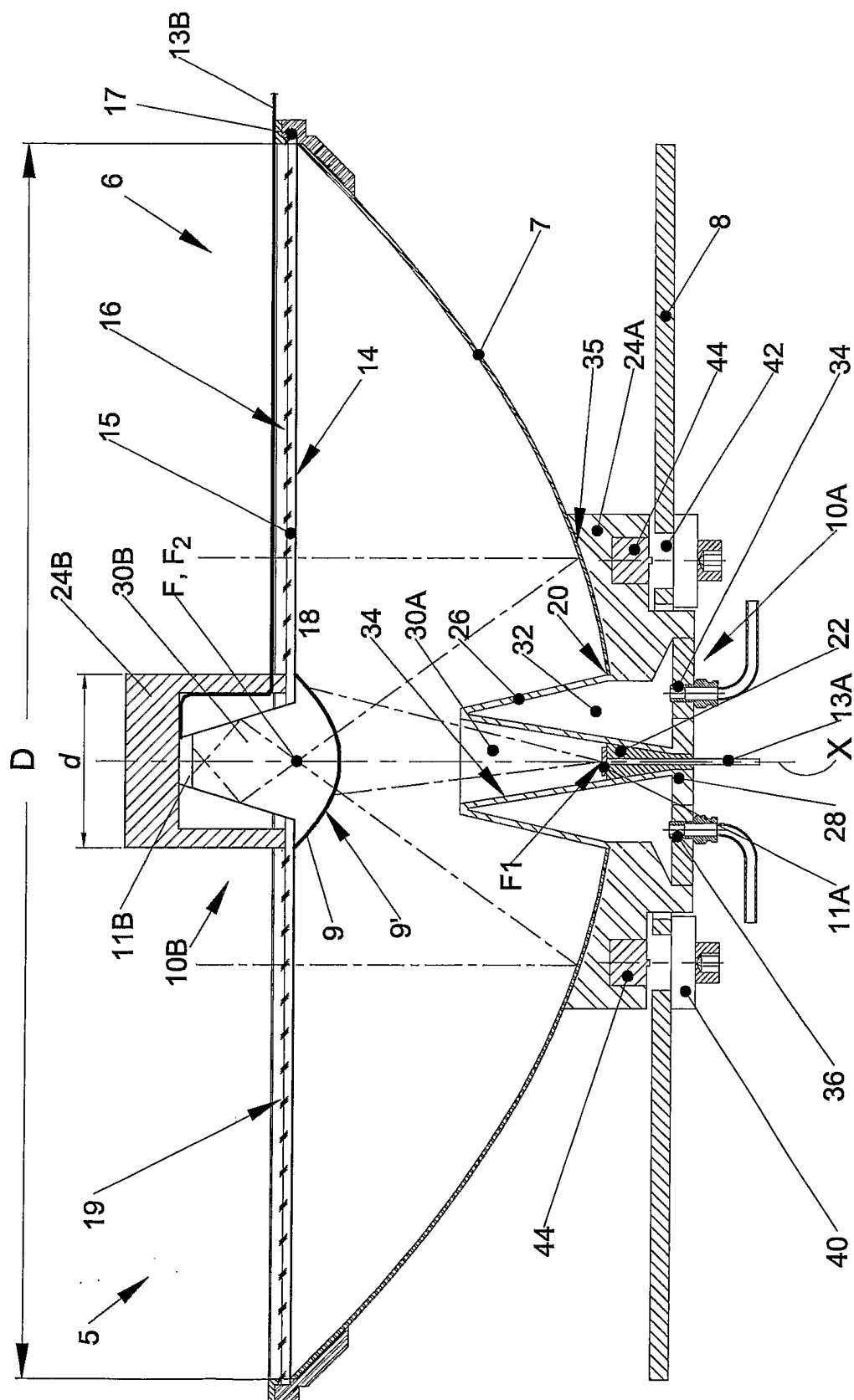


Fig. 1

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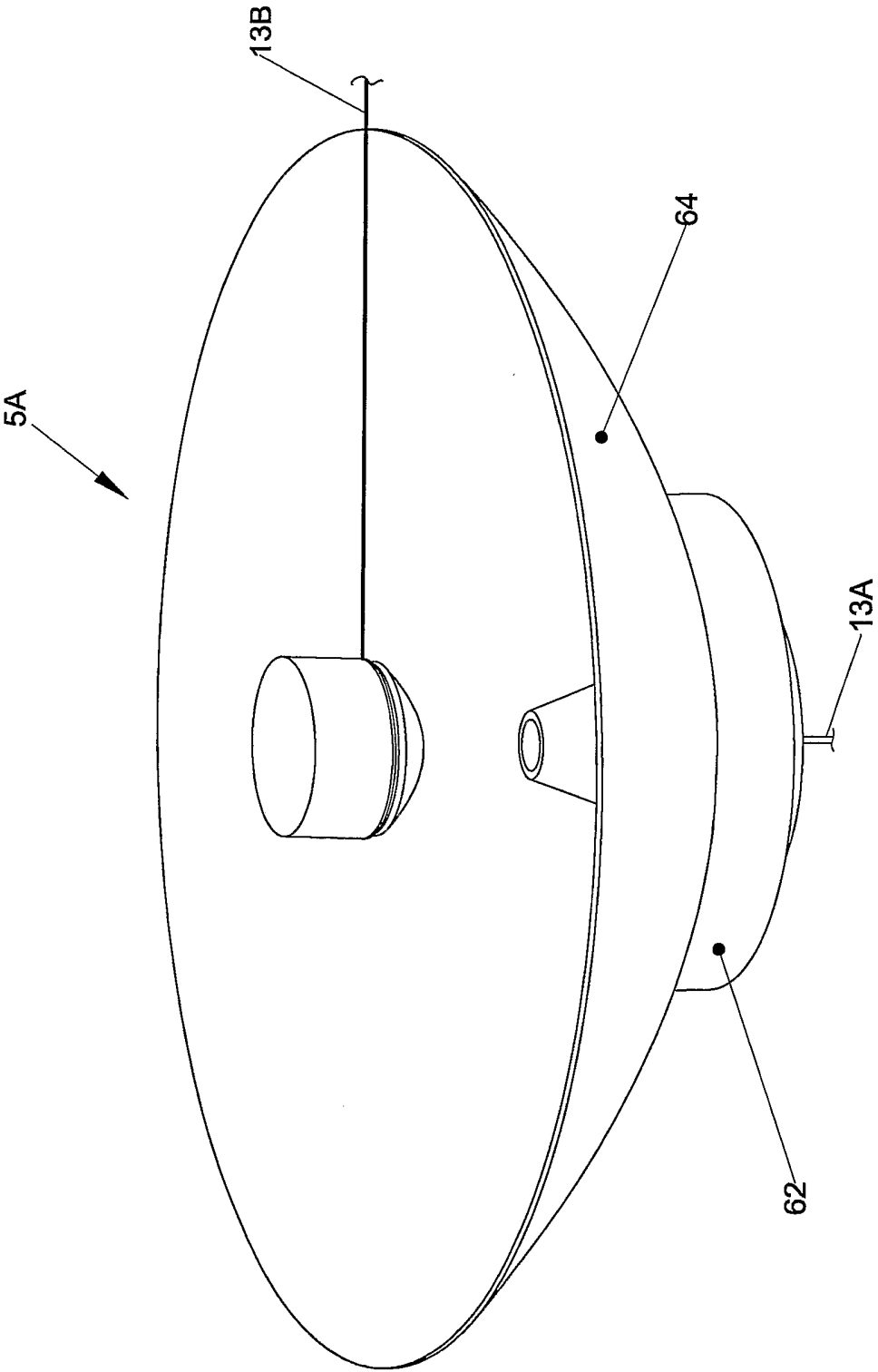


FIG. 2A

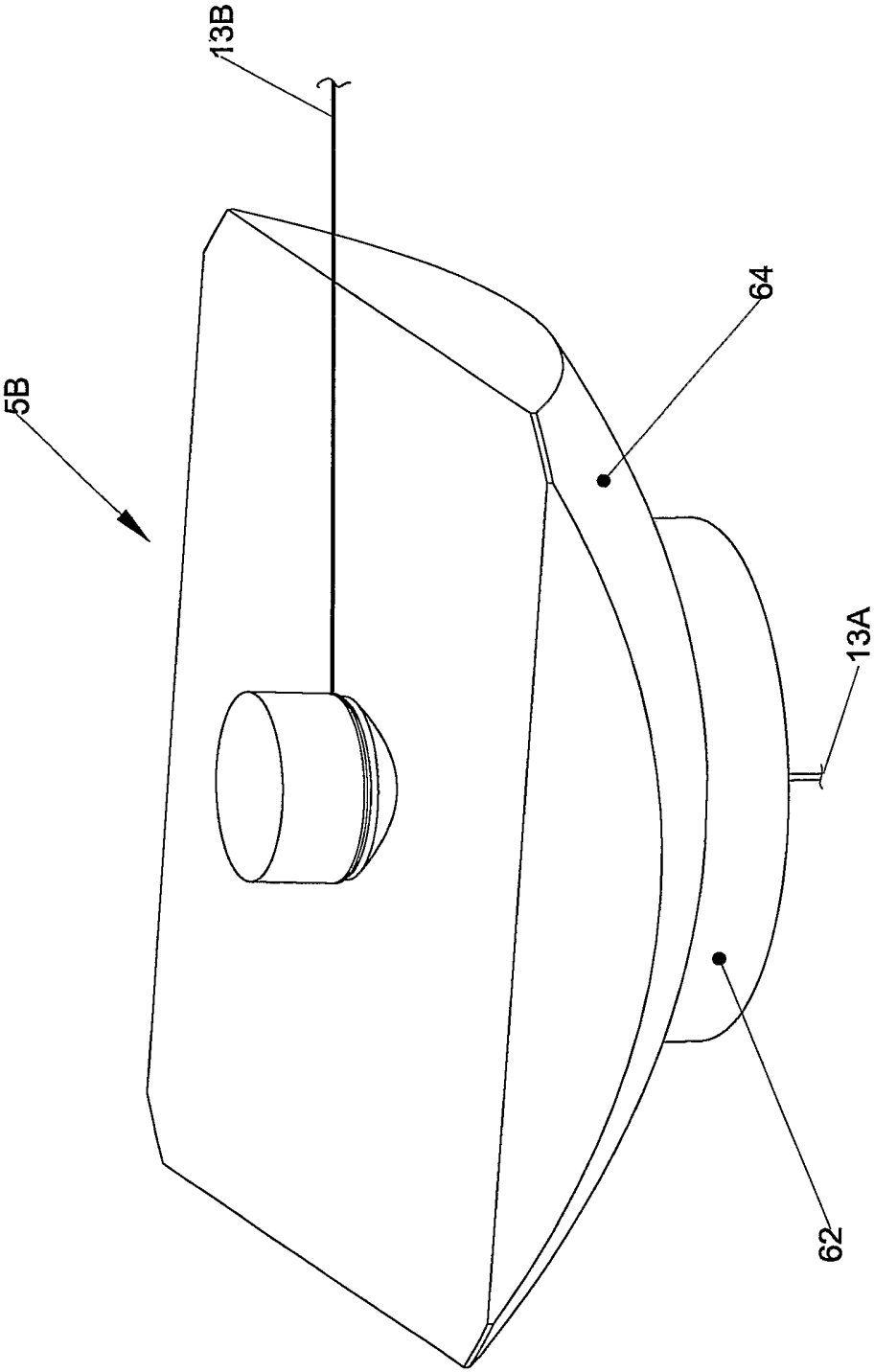


FIG. 2B

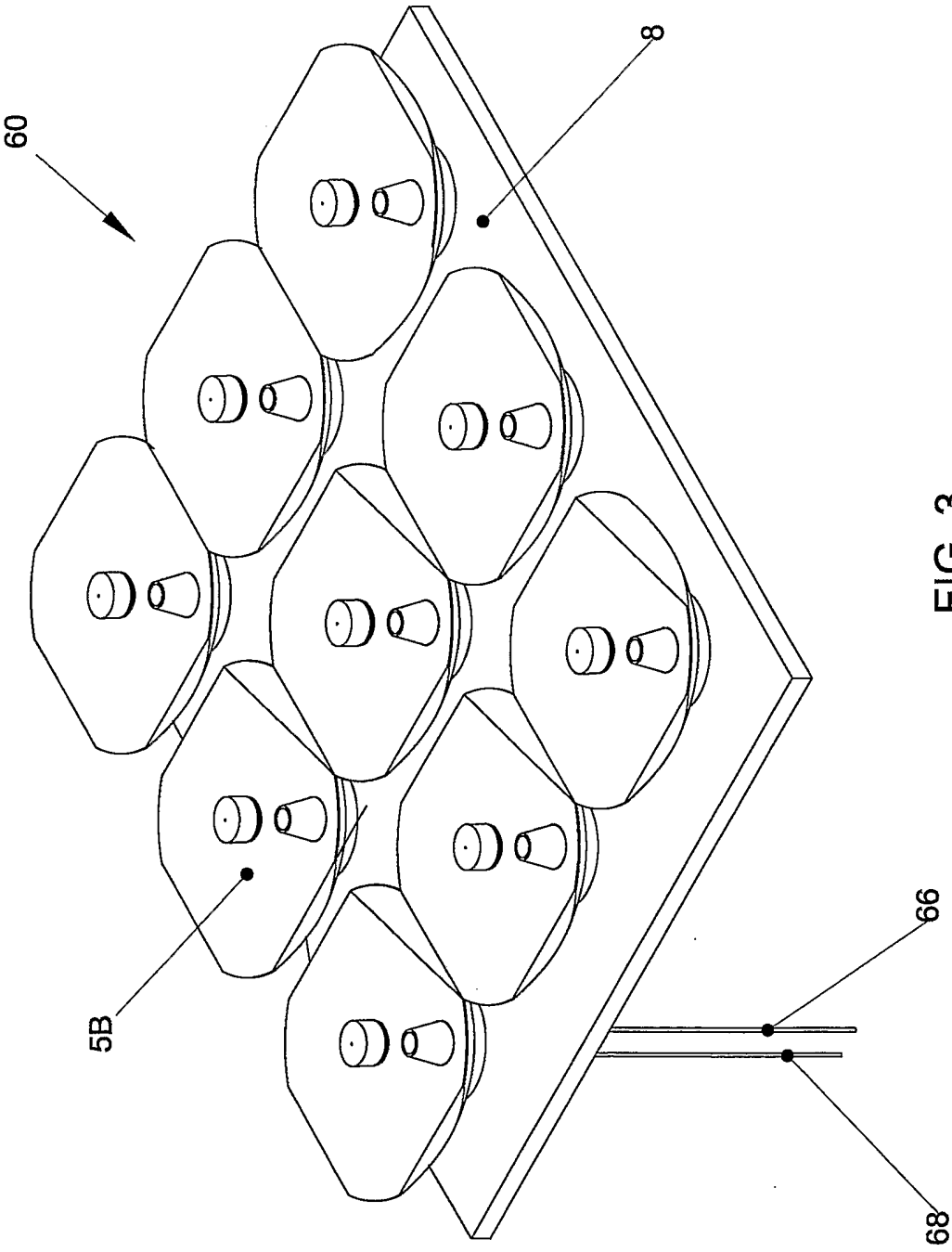


FIG. 3

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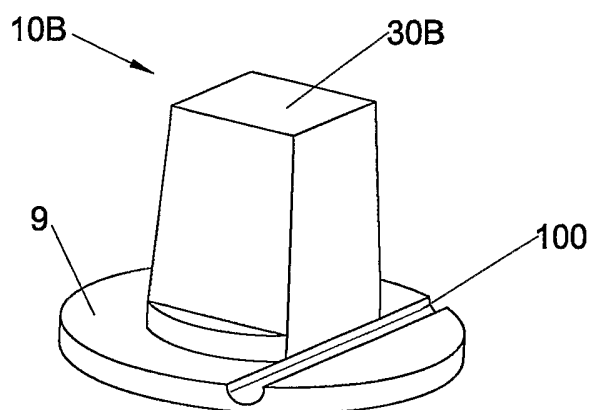


FIG. 4

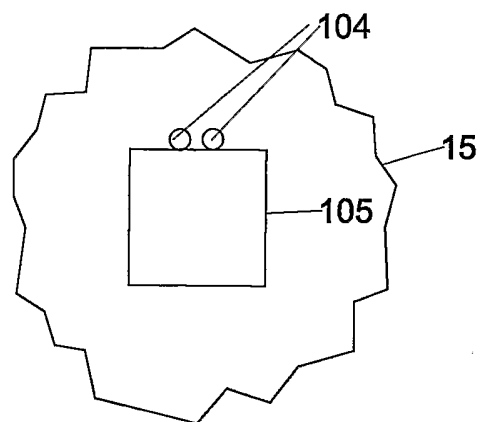


FIG. 5A

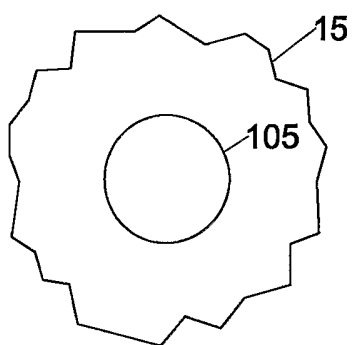


FIG. 5B

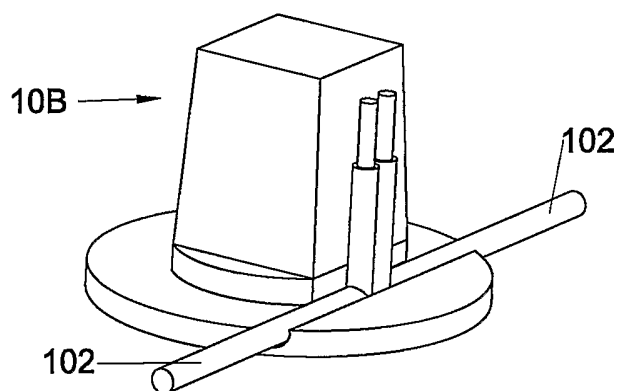


FIG. 6

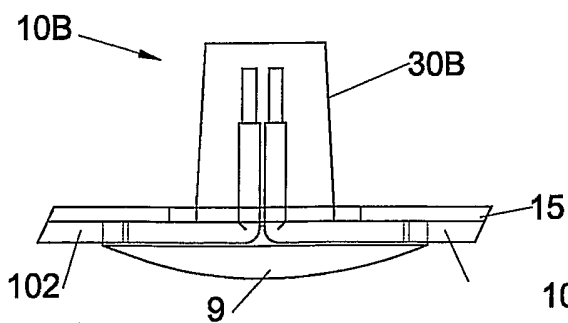


FIG. 7A

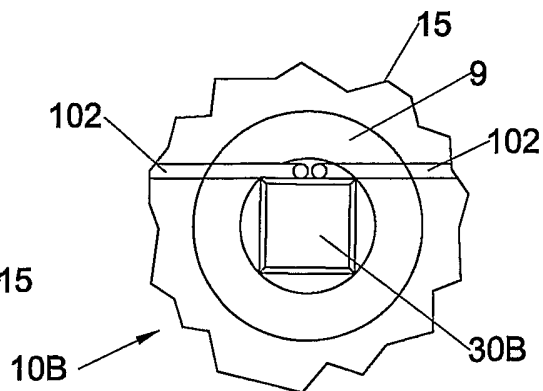


FIG. 7B

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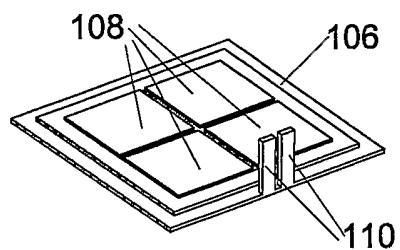


FIG. 8

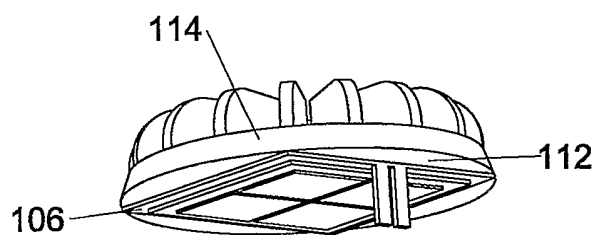


FIG. 9

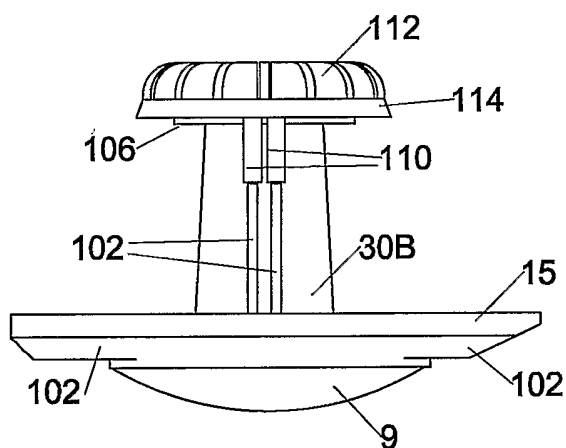


FIG. 10A

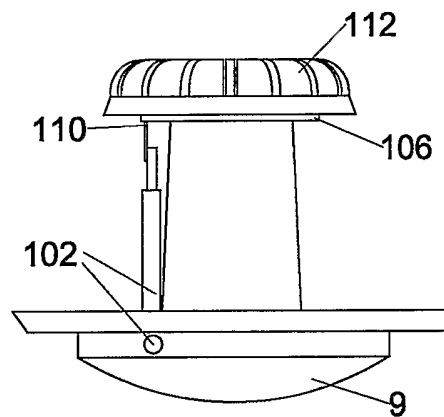


FIG. 10B

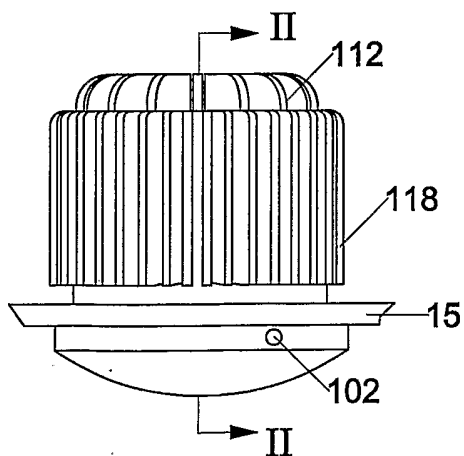


FIG. 11A

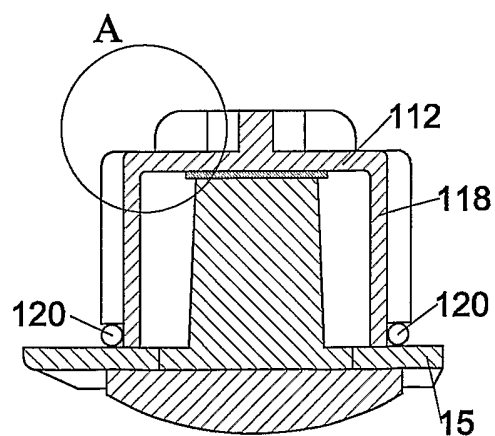


FIG. 11B

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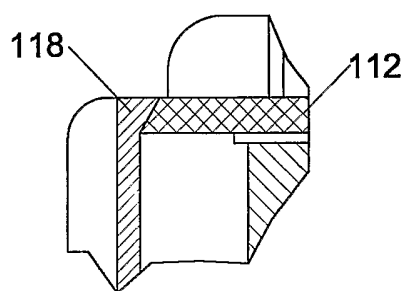


FIG. 11C

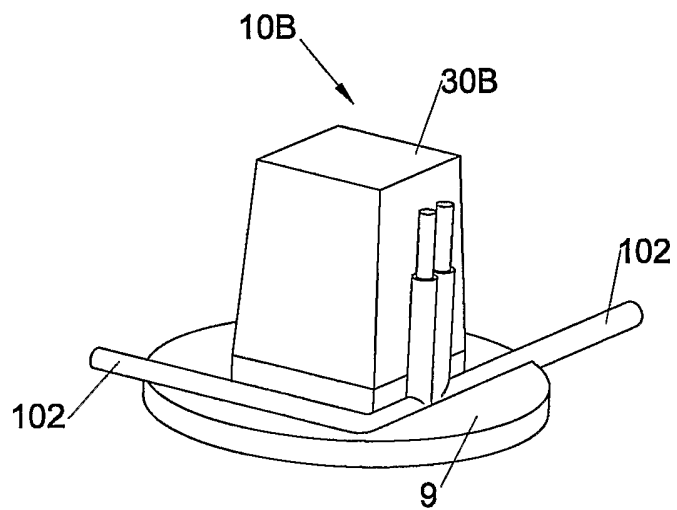


FIG. 12

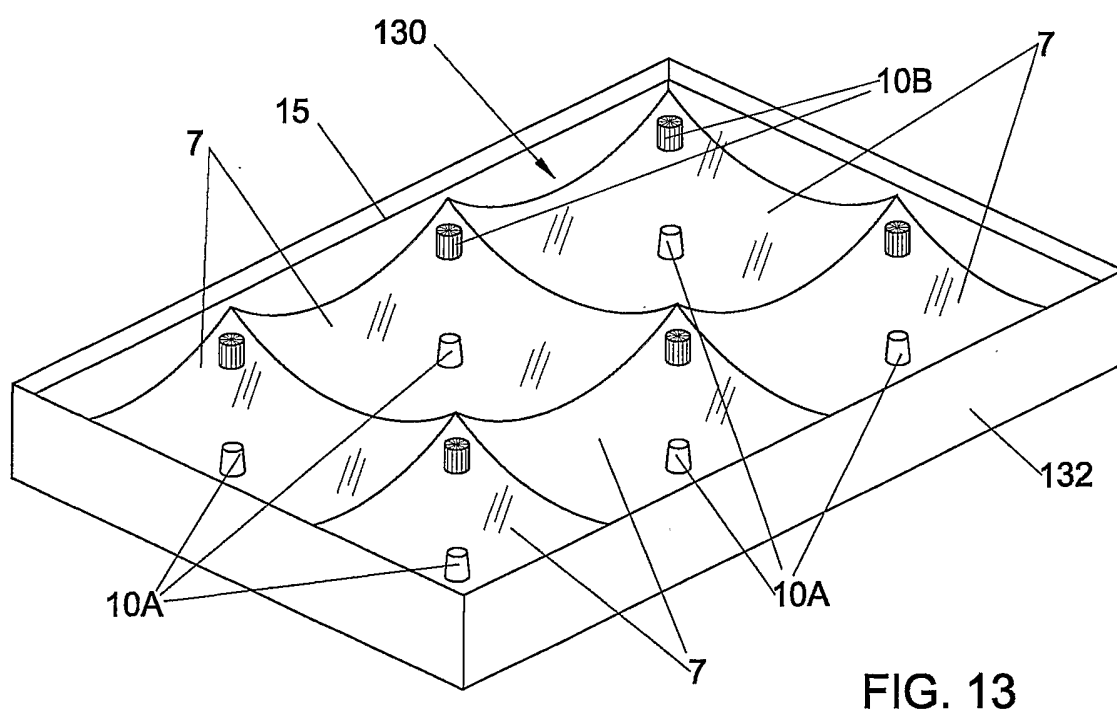


FIG. 13

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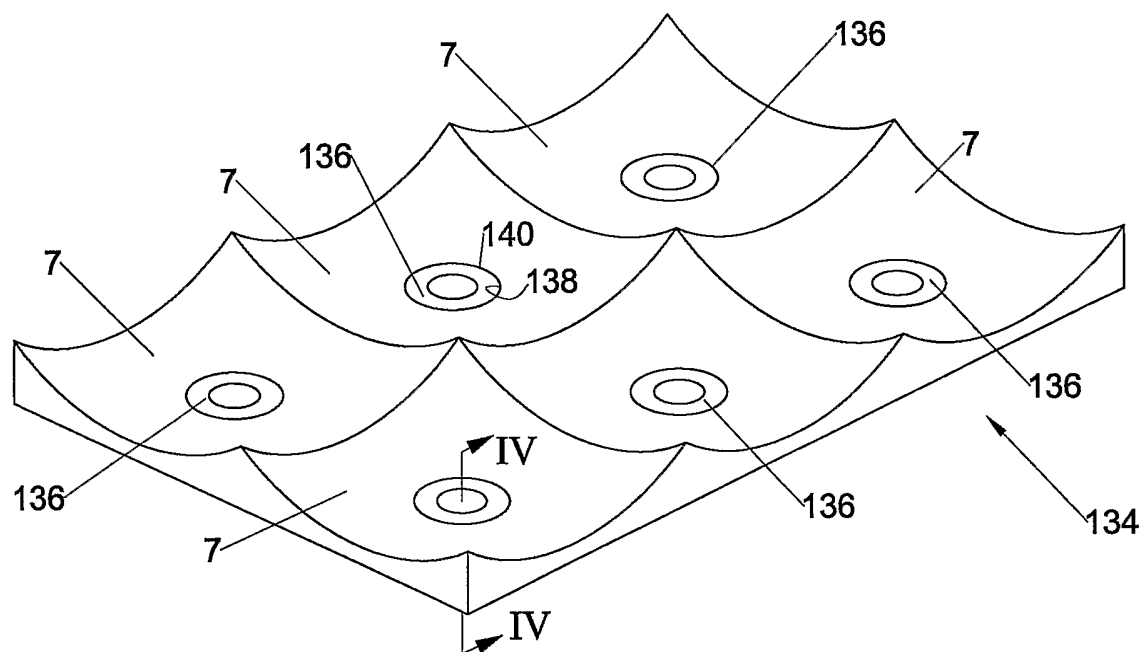


FIG. 14A

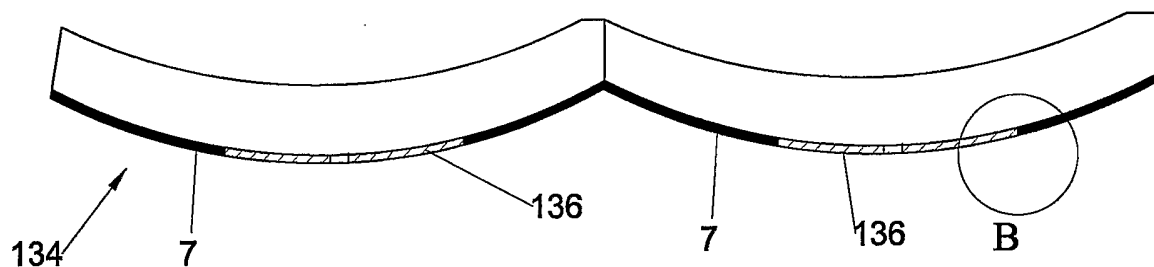


FIG. 14B

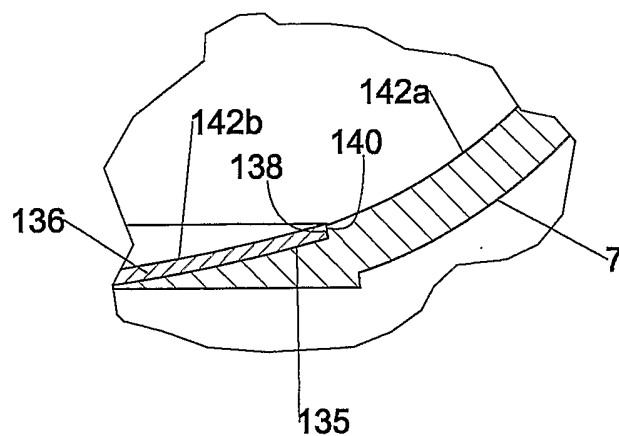


FIG. 14C