



- (51) International Patent Classification: Not classified
- (21) International Application Number: PCT/US2013/052438
- (22) International Filing Date: 28 July 2013 (28.07.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
- | | | |
|------------|--------------------------------|----|
| 61/683,783 | 16 August 2012 (16.08.2012) | US |
| 61/700,317 | 12 September 2012 (12.09.2012) | US |
| 61/706,123 | 27 September 2012 (27.09.2012) | US |
| 61/707,983 | 30 September 2012 (30.09.2012) | US |
- (72) Inventor; and
- (71) Applicant : **GOLDSTEIN, Leonid** [IL/US]; 5280 Colodny Dr., Apt 8, Agoura Hills, California 91301 (US).
- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

[Continued on next page]

- (54) Title: AIRBORNE CONCENTRATED SOLAR PHOTOVOLTAIC SYSTEM

(57) Abstract: A photovoltaic solar system for energy production, comprising an inflatable parabolic reflector- concentrator inside of possibly lighter than air balloon and a solar panel outside of the balloon. The system tracks sun while overcoming wind impact. The system can be used in fixed or vehicular installations both in land and marine environments. Also disclosed a solar farm and an efficient air cooling system for solar cells.

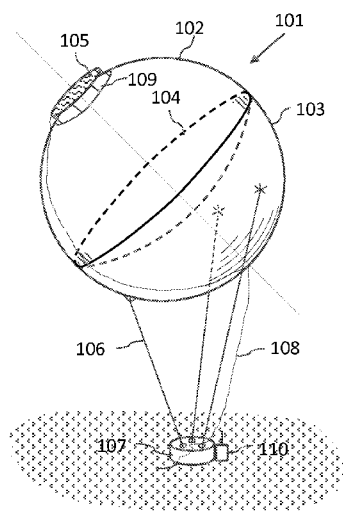


Fig. 1



-
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*
- Published:**
- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

AIRBORNE CONCENTRATED SOLAR PHOTOVOLTAIC SYSTEM

DESCRIPTION

BACKGROUND OF THE INVENTION

This invention is generally directed to solar photovoltaic energy conversion systems and methods.

Currently, solar energy is not cost competitive with fossil fuels or even with wind energy, even in the south of the US. The solar cells are still expensive, and the concentrated solar systems are expensive as well because of the combination of relatively high costs of metal parabolic reflectors and sun tracking means. A number of patents discuss solar photovoltaic cells in combination with inflatable means, including US Patent No. 4126123 by Frederick Hall, US Patent No. 8127760 and 7997264 by Mithra Sankrithi, US Patent No. No. 8074638 by Eric Cummings. These patents do not teach how such inflatable means would cope with winds, cloud overcast, tracking complexities, overheating and other related issues. Also, they are still too costly.

There is need in a cost effective photovoltaic solar energy system that solves the problems above. This invention is directed to teaching such a system.

SUMMARY OF THE INVENTION

This invention is generally directed to solar photovoltaic energy conversion systems and methods. Further, this description discloses a device and a method for converting solar energy into electrical energy and more. Many embodiments of the invention comprise methods and devices that concentrate sun light on a solar panel, using light and inexpensive inflatable reflectors-concentrators, while protecting them from the wind forces.

One embodiment of the invention is a device for converting solar energy into electric energy, comprising: at least one reflector-concentrator, formed by an inflated body, having a transparent skin in one part of its envelope and a reflecting surface on the internal side in the opposite part of its envelope; a solar panel, placed near the focus of said reflector-

concentrator; a solar tracking system, continuously aligning axis of said reflector-concentrator with direction to the sun.

The inflated body can be filled with lighter than air gas, or its internal air can be heated by solar energy. The inflated body can be streamlined, or to be a part of a (possibly streamlined) balloon, or to be enclosed in a streamlined balloon. A number of such devices can be placed close one to another and form a part of a solar farm.

Another embodiment of the invention is a device for converting solar energy into electric energy, comprising: a solar light concentrator; a non-planar solar panel with a plurality of solar cells with gaps; a fan placed to the rear of the solar panel, blowing both the solar panel's rear side and the solar panel's front side.

The description uses prior patent applications by the inventor:

International Patent Application PCT/US13/40666

Provisional US Patent Application 61/683,783 (PPA-31)

Provisional US Patent Application 61/700,317 (PPA-32)

Provisional US Patent Application 61/706,123 (PPA-33)

Provisional US Patent Application 61/707,983 (PPA-34)

that are incorporated herein by reference, except that in case of any conflicting term definitions or meanings the meaning or the definition of the term from this description prevails.

Various objects, features, aspects, and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments of the invention, along with the accompanying drawings in which like numerals represent like components.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the invention. The illustrations omit details not necessary for understanding of the invention, or obvious to one skilled in the art, and show parts out of proportion for clarity. In such drawings:

Fig. 1 is a perspective view of one embodiment of the invention, comprising a reflector-concentrator inside of a balloon.

Fig. 2 is a sectional view of some details of this embodiment and a scheme of the light reflection in it.

Fig. 3 is a sectional view of some details of this embodiment, including solar heating surfaces.

Fig. 4 is a view of sun tracking motion by this embodiment.

Fig. 5A is a sectional side view of a solar farm according to another embodiment of the invention.

Fig. 5B is a top view of the solar farm according to this embodiment of the invention.

Fig. 6 is a sectional side view of another embodiment of the invention, providing a balloon with an external tail.

Fig. 7A is a sectional side view of a rail and a roller in that embodiment of the invention

Fig. 7B is a perpendicular sectional view of the rail and the roller in that embodiment of the invention.

Fig. 8 is a sectional side view of another embodiment of the invention, comprising a streamlined balloon.

Fig. 9A is a schematic view of the optical subsystem in the that embodiment of the invention

Fig. 9B is a schematic view of forces in that embodiment of the invention.

Fig. 10 is a schematic view of another embodiment of the invention, in which the balloon is raised to an altitude.

Fig. 11 is a schematic view of another embodiment of the invention, comprising a vehicle.

Fig. 12 is a view of another embodiment of the invention with enhancements.

Fig. 13 is a view of another embodiment of the invention with rotating streamlined balloon.

Fig. 14 is a view of another embodiment of the invention with multiple reflectors in a streamlined balloon.

Fig. 15 is a sectional view of another embodiment of the invention with an internal solar panel.

Fig. 16 is a view of another embodiment of the invention with different placement of tethers.

Fig. 17 is a view of another embodiment of the invention with low placement of a solar panel.

Fig. 18 is a side sectional view of another embodiment of the invention.

Fig. 19 is a view of a surface of the solar panel in this embodiment of the invention.

GLOSSARY

The term 'solar panel', as used here, includes 'solar array' and 'solar module'.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows general view of one embodiment of the invention. It comprises an inflated balloon **101**, having transparent skin **102** in its top half and transparent or non-transparent skin **103** in its bottom half. The internal space of balloon **101** is divided into two gas tight compartments by a divider-reflector **104**, made of flexible fabric and having light reflective top surface. The gas pressure in the upper compartment is slightly higher than the gas pressure in the bottom compartment, which is slightly higher than atmospheric pressure. Divider **104** is made in such form, that in presence of the pressure difference between the upper and the lower compartments, divider **104** has a paraboloid form, with its concave side toward the upper compartment. Balloon **101** is filled with lighter than air gas, such as hot air, methane, hydrogen, helium, or some mixture of gases. Consequently, balloon **101** raises in the air, and is held by three tethers **106**, connected to it at some distance one from another. The connection points are reinforced. The other ends of tethers **106** are fed into a device **107**, installed on the ground. Device **107** contains actuators that can pull in and let out each tether **106** independently, changing their effective length. This can be done using small electric motors. A photovoltaic solar panel **105** is attached to the top of balloon **101** in such a way, that there is free air flow between it and the surface of balloon **101**. It can be done, for example, by attaching multiple plastic raisers, in the form of small cylinders, to the bottom of solar panel **105** and gluing them to the top of balloon **101**. In the top part of balloon **101**, just below solar panel **105**, skin **102** is replaced by a flat rigid transparent disk **109**, made of a transparent and heat-resistant material, such as acrylic or glass. Solar panel **105** can be attached to disk **109**. Electric wires **108** connect solar panel **105** to the electricity consumer or an inverter on the ground. Electric wires **108** are laid on the surface of balloon **101** and descend to the ground. A control system **110** is provided.

Balloon **101** has an imaginary main axis, passing through the center and the top of balloon **101**, and the center of reflector **104**. The system tracks apparent sun movement in two axis. In operation, control system **110** changes lengths of tethers **106** in such a way, as to point the main axis in the direction of the sun. In the presence of turbulent wind, these length changes are also used to keep the main axis pointed to the sun, despite disturbance, created by the wind.

Fig. 2 helps to explain the work of the system, described above. Paraboloid reflector **104** has a focal point or focus F, which can be inside or outside of balloon **101**. The sun beams, falling on reflector **104** parallel to the main axis, are reflected into the focus F. Solar panel **105** is placed slightly behind the focus F or slightly in front of it, so that the concentrated solar beams cover its surface uniformly. When concentrated solar light hits solar cells on it, solar panel **105** generates electric energy.

In one of possible embodiments, buoyancy is created by letting the sun to heat the air inside of balloon **101**. Multiple mechanisms can be used for heating. In one of them, some part of the reflector **104** is painted black or replaced with a black fabric. An example is the outer ring **301** in **Fig. 3**. It is heating up both upper and lower chambers of balloon **101**. In another mechanism, there is a body **302**, made of two cardboard rectangles, painted black and inserted one into another at right angle. Body **302** is hanging from the top of the balloon **101** on three lines **303**. Body **302** has normally vertical position. When the sun is in zenith, the surfaces of body **302** are parallel to the sun beams, and very little solar energy is captured by them. The lower is the sun on the horizon, the larger becomes the projection of body **302** to a plane, perpendicular to the sun beams. Thus, this simple device allows to capture more sun energy inside of the balloon **101** when the sun is low in the morning and in the afternoon, and reflect more energy to solar panel **105** in noon, when the sun is high. One more mechanism is shown in **Fig. 12**. In this mechanism, a light filter **1206** is provided in the path of the reflected light that blocks some of the light in the long wavelength range of the specter that cannot be converted to electric energy by solar cells, used in solar panel **105**, or can be harmful for them. Light filter **1206** is heating air inside of balloon **101** and in the same time decreases parasitic heat, generated in solar panel **105**. Fans, working from the current, generated by solar panel **105**,

can be provided inside of upper and/or lower chambers of balloon **101** to ensure convection of heated air inside of these chambers. In this embodiment, balloon **101** can cool at night, sink to the ground, but it will raise again in the morning, when sun heats up the air in it. The upper and the lower chambers of balloon **101** can have valves to let out extra air, when air pressure exceeds pre-defined value.

Fig. 4 helps to explain sun tracking using variable length tethers in two dimensional case. The pictured system has two cables for single axis tracking. The position of balloon **101** in the beginning of the motion is in the solid lines. The left cable **106** is shorter than the right cable **106**. The position in the end of the motion is shown in the dashed lines. To change the orientation of balloon **101**, device **106** lets out the left tether **106**, while pulling in the right cable **106**.

Control system **110** directs and controls all aspects of the system operation, including sun tracking. It can comprise multiple sub-systems, attached to either mount **107** or balloon **101**. Control system **110** comprises one or more processors or microcontrollers, sensors, communication means and actuators. The sensors may include anemometers, barometers, hygrometers, thermometers, cable tension meters, cameras, light sensors, pressure sensors, altitude meters, gyroscopes and other. Control system **110** can be connected to the Internet to receive general weather information, especially warnings of extreme weather events.

Fig. 12 shows this embodiment with additional enhancements. In one of them, the circular line, at which reflector **104** is connected to the skin of balloon **101** is additionally reinforced with a steel ring or a circular tube **1201**. Two or more cables **1202** connect opposite sides of ring **1201** and prevent it from deforming. This is done to minimize deformation of the form of reflector **104** in strong winds. Another enhancement is active cooling of solar panel **1205** with a top fan **1203** and/or a side fan **1204**. Fans **1203** and **1204** work from DC current, produced by solar panel itself.

The sun light concentration ratios can be anywhere between 4:1 and 2,000:1. Device **107** can be installed on a ground, on a bottom of a lake, a sea or an ocean, on a buoy or on a vessel or

on a moving vehicle. Balloon **101** can be deflated and folded to a very small package for transportation or storage.

Example parameters for this embodiment:

Diameter of balloon **101**: 20 m

Volume of balloon **101**: 4,000 m³

Reflecting area (perpendicular sunbeams): 300 m²

Concentration ratio: 25:1

Solar panel area: 12 m²

Solar module efficiency: 15%

Peak power output: 40 kW

Among advantages of this embodiment: The system allows to use much smaller amount of expensive solar cells, compared with direct photovoltaics. The reflector-concentrator is completely protected against environment impacts, such as sand, dust, dirt, flying debris wind, water etc. The reflector-concentrator and the tracking actuators are less expensive, than the corresponding parts in conventional concentrated solar systems. The solar panel and the transparent skin of the balloon are less susceptible to sand, dust, flying debris and vandalism, because they placed are at some height from the ground for most of the time. Also, the transparent skin of the balloon is less likely to accumulate dirt because of its convex form and motion in the wind.

Another embodiment of the invention is a solar farm, having multiple balloon based solar panels, connected to a common inverter and/or transformer and tied to the electric grid. Strong winds interfere with the balloons. Therefore, it is better to place such a farm in a place with predominantly light winds. Also, it is preferable to place the balloons only slightly above the ground and sufficiently close one to another, so that each balloon is somewhat shielded from the wind by the balloons upwind from it, but sufficiently far one from another in order to avoid collision of the balloons in the turbulent air and avoid or minimize shadowing of one balloon by another, when the sun is low on the horizon. There is an advantage in tight packing balloons in the farm: the same number of balloons occupies less land, and the wind pressure on each balloon is smaller because of partial aerodynamic shading by neighboring balloons. On

the other hand, in a too tight packing, balloon reflectors would partially hide sun from each other, when the sun is low on the horizon. An optimal packing of the balloons should find an optimum between these considerations. Let's call D the diameter of the balloon. In one embodiment, the balloons are placed in the vertices of a hexagonal structure with the distance between centers of the balloons, equal $3 \times D$, as shown in **Fig. 5A** and **5B**. Lower point of the balloon should be at the distance $0.1-0.5 \times D$ from the ground. To protect outside balloons from the wind, the balloon farm can be encircled by natural or artificial protection, or a combination of them. Natural protection can be hills, tall trees (comparable in height to the diameter of the balloon) etc. Artificial protection can be done in the form of an inflatable wall **501**. Inflatable wall **501** comprises inflatable panels **502**, filled with lighter than air gas or hot air, attached to the ground and spread by cables **503**.

In low latitudes, the balloons can be placed in a square grid with rows along the line North-East -- South-West and columns along the line South-East -- North-West. The distance between the centers of the balloons in columns and rows can be $1.5-2.0 \times D$.

Wind has high impact on a spherical balloon because a sphere has high drag coefficient. This drag is caused mostly by the area of separated or turbulent flow and low pressure behind the sphere. Another embodiment solves this problem by providing a spherical balloon with a self-aligning tail that eliminates this area of low pressure, while allowing the sphere to freely rotate around two axes and to track the sun.

Fig. 6 is a sectional view, showing details of this embodiment. It comprises balloon **101** with reflector **104** and solar panel **105**. Behind it (i.e., downwind) there is a tail **601**, consisting of a thin envelope inflated with lighter than air gas, such as hot air, methane, hydrogen or helium. Tail **601** has such a form, that when it adjoins balloon **101**, they together have a form with significantly lower drag coefficient, than sphere. Tail **601** is equipped with large horizontal and vertical stabilizers **602** that help it to maintain its position relative to the wind. To allow solar tracking independent of the direction of the wind, tail **601** and balloon **101** are attached through one or two semi-circular rails **603** (only one rail is shown for clarity). Two rails **603** are joined in the middle by a bar (not shown). Gap between tail **601** and the skin of balloon **101** is small compared with the diameter of balloon **101**. The line, passing through the back end of

tail **601**, the center of its front end and the center of balloon **101** is parallel to the wind. We will call it the long axis of the device in this description. In the plane, perpendicular to the long axis, tail **601** can have round or elliptical section, with horizontal axis slightly longer than the vertical one. Most of tail **601** is made of a transparent material. Rails **603** are attached to tail **601** on a bearing **604** with a small electric motor **605**, capable of rotating rails **603** around the long axis. Balloon **101** can move along rails **603** on rollers **606**, described below. Rollers **606** are affixed to the skin of balloon **101**, which is properly reinforced near the attachment points. The plane of rails **603** is perpendicular to the plane in which reflector **104** is attached to the skin of balloon **101**. Balloon **101** can be equipped with a counterweight on the end, opposite to solar panel **105**. Tail **601** is attached to a mount **607** with a front tether **608** and back tether **609**. Tethers **608** and **609** can have constant length, or back tether **609** can have variable length by using an actuator in mount **607**. A control system **610** is provided. Acting on stabilizers **602**, wind always turns the system balloon **101** - tail **601** to have its long axis along the wind, and balloon **101** heading into the wind. Control system moves bearing **604** and rollers **606** in such way that the main axis of balloon **101** always stays pointed to the sun, despite rotation of tail **601**.

Fig. 7A is a side view of roller **606**. It shows a body **701**, attached to balloon **101** and having four rubber wheels **702** in contact with rail **603**. A small electric motor **703** drives wheels **702** on command from control system **610**. **Fig. 7B** shows sectional view of the same device from the side of balloon **101** with body **701** removed. This embodiment has an additional advantage of lower forces, acting on balloon **101** in the wind.

In more embodiments, tail **601** can be cambered, creating vertical lift upward. Also, lift can be created by pulling tail **601** down, using tether **609**. Instead of mechanism with rail **601**, tail **601** can slide over surface of balloon **101**.

Other embodiments have simpler construction and provide even lower drag coefficient. **Fig. 8** shows another embodiment in a sectional view. It comprises a streamlined balloon **801**, having most of its skin made of a transparent material. Balloon **801** is filled with lighter than air gas, such as hydrogen, methane, helium or hot air. Balloon **801** is slightly asymmetrical in the vertical section. It has a slightly cambered profile and provides upward lift in the presence of the wind. Balloon **801** is equipped with an empennage **802**, providing horizontal and vertical

stabilizers. Because of the vertical stabilizer in empennage **802**, when the direction of the wind changes, balloon **801** moves and gets aligned with the wind, with empennage **802** on the downwind. A reflector assembly **803** is attached to some structural member of balloon **801**. Reflector assembly **803** has a tracking mechanism **804** with electrical engines and can rotate inside balloon **801** in two axis in the range plus/minus 180° in the horizontal plane and plus/minus 80° in the vertical plane. A solar panel **805** is installed on the top of balloon **801** in such a way that air flow between it and the skin of balloon **801** is permitted. Additionally, the balloon skin under solar panel is replaced with a material, having better transparency and heat resistance, such as acryl or glass. A tether **806** attaches balloon **801** to a mount **807**. Mount **807** can be installed on a ground, on a bottom of a lake, a sea or an ocean, on a buoy or on a vessel or a vehicle. A control system **810** is provided. Control system **810** controls reflector assembly **803** in such a way as to ensure that it tracks sun, despite motion of balloon **801** in the changing wind. Balloon **801** has a round form in the section, perpendicular to its long axis. The dash dotted circle in Fig. 8 shows movement of the extreme points of reflector assembly **803**, which comprise perimeter of the reflector. Reflector assembly **803** reflects sun light from a circle with a diameter, that is only slightly less than the diameter of the widest section of balloon **801** in the plane, perpendicular to the balloon's long axis, and the reflector's axis is always parallel to the sun beams.

Fig. 9A shows some details of reflector assembly **803** and explains how it works optically. The main reflecting surface is created by an internal surface of the lower skin **903** of an internal inflated balloon **901**. Lower skin **903** has a form of paraboloid and light reflecting internal surface. Upper skin **902** is transparent. It should be noted, that the envelope of balloon **801** protects internal balloon **901**, so its skins can be made from very thin and light materials. The gas pressure inside internal balloon **901** is higher than the gas pressure inside balloon **801** which is higher than outside air pressure. A rod **904** passes through internal balloon **901**, and a small paraboloid mirror **905** is attached to its another end in such way, that main paraboloid reflector **901** and small paraboloid mirror **905** share the same axis and the same focal point F. A flat mirror **906** with its actuators is attached to rod **904** at the center C, around which reflector assembly **803** rotates. Solar beams fall on reflector **901** parallel to its axis, reflect and

hit mirror **905**, reflect again parallel to the mentioned axis and hit mirror **906**. Control system **810** changes the angle of mirror **906** in two axis in such a way as to reflect the parallel beams, falling on it, onto solar panel **805**. Thus, sun light is concentrated on solar panel **805** at any position of the sun and direction of the wind. It should be noted, that reflector assembly **803** is very light, and tracking mechanism **804** can be very light and inexpensive. Electric wires are present but not shown in Fig. 8. Tether **806** can split into multiple thin lines, attached to balloon **801** in many points for better force spreading.

Fig. 9B is a diagram of forces, acting on balloon **801**. Buoyancy F_B and weight F_W (of balloon **801** and everything it carries) are constant and the buoyancy exceeds the weight. But the aerodynamic forces are strongly dependent on the wind and can grow significantly larger than either buoyancy or weight. If the balloon has only drag, total of this drag and tether's tension F_T would result in a large downward force, which would eventually overcome excess buoyancy and bring balloon **801** down. This is why this embodiment utilizes a balloon form that provides aerodynamic lift. Relation of lift F_L to drag F_D remains nearly constant in a wide range of wind speed. In the figure, value of F_L is two times value of F_D , therefore resultant aerodynamic force F_A is directed at angle 60° , and tether **806** will have angle of at least 60° to the horizontal plane in any wind.

Control system **810** directs and controls all aspects of the system operation, including sun tracking. It can comprise multiple sub-systems, attached to either mount **807**, balloon **801**, or reflector assembly **803**. Control system **810** comprises one or more processors or microcontrollers, sensors, communication means and actuators. The sensors may include anemometers, barometers, hygrometers, thermometers, cable tension meters, cameras, light sensors, pressure sensors, altitude meters, gyroscopes and other. Control system **810** can be connected to the Internet to receive general weather information, especially warnings of extreme weather events. Reflector assembly **803** can be equipped with a large gyroscope to maintain axis direction to the sun despite motion of balloon **801**. In addition to the advantages of the embodiments above, this embodiment is also resistant to the wind.

In more embodiments, mirror **905** can be replaced with a Fresnel lenses between reflector **901** and flat mirror **906**. In other embodiments, balloon **801** can be symmetrical (non-cambered).

Horizontal and/or vertical stabilizers **802** can be movable, allowing steering balloon in one or two dimensions.

Balloons **801** and **101** can have buoyancy, significantly exceeding what is necessary to keep reflectors, solar panels and tracking mechanisms in the air. **Fig. 10** shows another embodiment, in which one of previously described devices is raised to a substantial altitude above the ground. It comprises balloon **801**, attached by tether to mount **807**. An inverter-transformer **1001** is attached from below to mount **807**. It is tethered to the ground by three long tethers **1002** that are anchored in the vertices of an equilateral triangle. Such arrangement allows to keep mount **807** in the same place in any direction of wind and minimize power cable length. Electric wires from solar panel **805** enter inverter-transformer **1001**. Aluminum cable **1003** exits inverter-transformer **1001**, descends vertically to the ground and is connected to another piece of power conversion equipment or to an energy consumer. Inverter-transformer **1001** converts DC from solar panel **805** into AC, increases its voltage and transfers it to the ground over cable **1003**. Inverter-transformer **1001** and cable **1003** are kept in the air by buoyancy and aerodynamic lift of balloon **801**.

Example parameters for this embodiment:

Diameter of balloon **801** (in the plane, perpendicular to the long axis): 30 m

Length of balloon **801** (in the plane, perpendicular to the long axis): 90 m

Volume of balloon **801**: 25,000 m³

Reflecting area (perpendicular sunbeams): 500 m²

Concentration ratio: 100:1

Solar panel area: 5 m²

Solar module efficiency: 20%

Peak power output: 100 kW

Additional lift capacity at 5,000 m, (hydrogen filling): 8,000 kg

Additional lift capacity can be used for inverter-transformer and/or power cable.

At altitudes from 50 m and above, the solar panel and the balloon are protected from sand, dust, flying debris, vandalism and other harmful impacts that exist on the ground. This allows to make them lighter and decreases need for periodic maintenance. If balloon **801** is placed at higher altitudes (such as 3,000 to 10,000 meters), additional advantages are achieved.

- 1) The solar cells can be cooled more efficiently because of the lower air temperature at the altitude.
- 2) There is more energy in the solar radiation at the altitude, and larger part of it comes in the form of direct beams that can be efficiently concentrated (rather than diffused radiation, that cannot be concentrated). The concentrator and the solar panel can be also above most of the weather and clouds. Thus, this system can be deployed in the areas, where ground based systems are not efficient because of clouds or fog.
- 3) The system can track sun at lower angles, than the ground based tracking systems, and generate more energy with lower losses at such angles. This allows generating substantial power even in the high latitudes and throughout the whole day. This covers the late afternoon peak in the energy consumption, existing in most countries.
- 4) When the balloon is above most of the weather, energy production is regular and predictable. This allows to overcome the problem of the intermittency, which plagues scalable renewable energy sources.
- 5) A large number of such devices, placed in proximity one to another, can be used for local climate improvement, such as creating an oasis in a desert. It is achieved because of decrease of direct solar irradiation, reaching ground. The density of such devices should decrease from the center to the periphery, in order to decrease effect of the temperature gradient near the ground, and resultant winds.

In some embodiments, inverter-transformer **1001** is not used, and the direct current is transformed through cable **1003** at the voltage, received from solar panel **805**. In more embodiments, multiple balloons **801** are supporting a single cable **1003**. In more embodiments, balloon **101** with or without tail **601** can be used in place of balloon **801**. In more embodiments, a single tether **1002** is used, combined with cable **1003**. This is especially

efficient, when inverter-transformer **1001** increases voltage to a value, at which increase of length of cable **1003** does not cause significant losses.

Embodiments, shown in Fig. 1, 6, and 8, can be used in vehicles and vessels to replace fossil fuels with free solar energy. **Fig. 11** shows an embodiment, in which balloon **801** is attached to a tractor **1101**. Electricity, generated by solar panel **805**, is transferred by wires **1102** and drives electric motor **1103**, which powers tractor **1101**. Electric motor **1103** can be combined with a usual diesel motor in a hybrid arrangement. When tractor **1101** is not moving, solar panel **805** on balloon **801** can be used to charge an internal or an external electric battery, to provide electric energy to consumers or to feed the grid (through an inverter). Balloon **801** can be flown at high enough altitude to avoid collisions with other vehicles and most buildings in rural areas. Almost any agricultural machine can be modified into solar powered one by adding the device from Fig. 8, electric engine **1103** and wires **1102**. It should be noted, that device from Fig. 8 can operate completely automatically. Such sun powered equipment is especially effective in the areas, where direct sun light is available on most of days and there is little or no infrastructure for delivery of fuel and/or electricity, such as in many developing countries. Additional advantage is that balloon **801** can create substantial lift, allowing the vehicle to carry larger loads.

Another embodiment of the invention is a solar powered blimp. It is obtained from embodiment on Fig. 8 by deleting tether **806** and mount **807**, adding an electric motor and a propeller, driven by that motor, and placing a control system on the blimp itself.

Fig. 13 shows another embodiment, in which a balloon **1301** can rotate around its long axis. Only a part **1302** of the balloon skin is transparent. The inflatable reflector rotates around one axis only, having a rotational mechanism **1303**. A solar panel **1305** is installed on an arm **1304**, that can change position of solar panel **1305** in two dimensions in the plane of view, and rotate it in order to always put it near the focus of concentrated sun light, reflected from the inflatable reflector. Balloon **1301** is tethered by a front tether **1306F** and back tether **1306B** attached in such way as not to inhibit rotation of balloon **1301**. In other respects, this embodiment is similar to the embodiment in Fig. 8.

Fig. 14 shows another embodiment, similar to one in **Fig. 8**, but having elongated body and multiple reflector assemblies. The centers of the neighbor reflector assemblies are at the distance, equal two times diameter of the main reflector in the assembly. If two assemblies have different diameters, then the distance equals two times the largest diameter.

In more embodiments of the invention, solar panel **105** or **805** can be placed inside of balloons **101** and **801**, correspondingly, and parasitic heat from them is used to heat the air in the balloons for buoyancy. In these embodiments, solar cells with low sensitivity for heat are preferred. One such embodiment can be similar to the embodiment in **Fig. 8** with a small reflector **905** replaced by a high temperature solar panel **1505** and flat mirror **906** eliminated, as shown in **Fig. 15**. Typical temperature inside such balloon can be 90°C and fans can be used to cool solar panel **1505**, spreading hot air evenly inside the balloon.

Another embodiment, shown in **Fig. 16**, utilizes balloons **101**, similar to those in **Fig. 1**. Instead of being attached to and moved by multiple tethers, connected to one device **107**, each balloon **101** in this embodiment is attached to and moved by three or more tethers, connected to three or more devices **1607**, placed at a distance, exceeding diameter of balloon **1607** from each other. Device **1607** changes available length of the tether, similarly to device **107**. When multiple balloons **101** are utilized, a single device **1607** can be attached to three or four tethers, connecting three or four balloons **101**, and extend or pull them in independently. In a variation of this embodiment, balloon **101** is inflated with air at ambient temperature, and rolls on the ground.

Fig. 17 shows another variant of balloon **101**. The thin lines in the picture show a solar beam. The embodiment has a solar panel **1705** in the low part of an inflated balloon. The balloon has transparent skin **102** in its upper half, gas tight paraboloid reflector-concentrator **104**, a paraboloid mirror **1701** on the same axis and with the focus in the same point as reflector **104**. There is a transparent glass disk **1707** instead of the central part of reflector **104**. The axis of the device tracks the sun. Sun beams, parallel to the axis, reflect from reflector **104**, then from paraboloid mirror **1701**, pass through transparent disk **1707** and hit the surface of solar panel **1705**. Solar panel **1705** is equipped with a cooling device **1706**, which can contain a liquid heat exchanger or a Stirling engine, utilizing heat to produce additional electric power. Reflector **104**

and mirror **1701** can be replaced with a Fresnel lens. This embodiment has an advantage that the solar panel and associated cooling equipment is located low and attached to the envelope of the balloon in a place, where it does not have to be transparent and can be made from stronger material.

It should be also noted, that reflector-concentrator can have a form of a spherical cap for some small concentration ratios, and that the form of reflector-concentrator can be approximated by other curved surfaces.

In various embodiments, described above, a Fresnel lens can be used instead of the paraboloid reflector, with corresponding changes in placement of the solar panels and some other details. For example, the focus of the Fresnel lens is behind it, not in front of it, so the solar panel or a smaller Fresnel lens is placed behind the first Fresnel lens.

Reflectors **104** and **903** can be made of metalized BoPET, or of nylon, covered by aluminum foil, among other options. Transparent skin of balloons can be made of transparent BoPET, polyethylene, polyester, polyvinyl etc. Non-transparent parts of balloon envelopes can be made of nylon, polyethylene, BoPET or other fabric. Tethers **106**, **608**, **609**, **806** and others can be made of strong and light synthetic fibers, such as aramids, para-aramids or ultra high molecular density polyethylene. Solar panels can use inexpensive single junction solar cells (such as silicon solar cells), multi junction solar cells or other.

Concentrated light solar panels frequently require active cooling. It is preferable to cool both front and back surfaces of the solar cells, but usual cooling means cannot be placed in front of the solar cells because they would create a shadow. The following embodiment of the invention solves this problem and provides an additional benefit of higher air speed and increased turbulence of the air near the solar panel surfaces.

Fig. 18 shows this embodiment of the invention, sectional side view. This embodiment comprises a solar concentrator **1801**, a rod **1802** and a solar panel **1803**, attached to rod **1802**. Solar concentrator **1801** can have a paraboloid form. Solar panel **1803** comprises multiple concentric circular strips **1804** with solar cells, placed on them. Strips **1804** are connected mechanically by bars **401**, which also contain electric wires, connecting solar cells from

different strips **1804** into a single panel, having outgoing wires **402**, as shown on **Fig. 4**. A fan **1806**, having blades with airfoil cross section, gradually decreasing from the center to the ends, is installed on the end of rod **1802**. The motor of fan **1806** is driven by electricity, generated by solar panel **1803**. A conical airflow shaper is installed in front of solar panel **1803**. When solar panel **1803** is lighted, the blades of fan **1806** rotate with high speed and generate strong air flow in the direction of solar panel **1803**. Air flows in gaps **1903** between strips **1804**, and is directed with high speed and high turbulence around both front and back surfaces of the solar cells in strips **1804**, ensuring very efficient cooling. The air flow is shown in curved arrows in the right side of **Fig. 18**. Light reflection is shown in straight lines with arrows. In this embodiment, the focal point F of parabolic concentrator **1801** is in front of solar panel **1803**, and the tilt of strips **1804** helps to put the surface of the solar cells close to normal angle to the incoming light beams.

Fig. 19 is a view of the solar module from the rear without the fan. It highlights gaps **1903** between strips **1804** of solar cells and connecting pieces **1901**, holding strips **1804** together and containing power transmitting wires. It shows also an electric cable **1902**, transferring electric current, generated in solar panel **1803**.

Obviously, other embodiments with different placement, form and tilt of solar strips are possible. For example, in some embodiments, solar panel **1803** can be rectangular, rather than circular, with flat strips of the solar cells and multiple fans. In this variation of that embodiment, solar concentrator **1801** can have parabolic cross section.

Thus, an airborne concentrated solar PV system is described in conjunction with one or more specific embodiments. While above description contains many specificities, these should not be construed as limitations on the scope, but rather as exemplification of several embodiments thereof. Many other variations are possible.

What is claimed is:

- [Claim 1]** A device for converting solar energy into electric energy, comprising:
at least one reflector-concentrator, formed by an inflated body, having a transparent skin in one part of it and a reflecting surface on the internal side in the opposite part of it;
a solar panel, placed near the focus of the reflector-concentrator;
a solar tracking system, continuously aligning axis of the reflector-concentrator with direction to the sun.
- [Claim 2]** The device of Claim 1, wherein the reflector-concentrator has a paraboloid form.
- [Claim 3]** The device of Claim 1, wherein the inflated body is filled with a lighter than air gas.
- [Claim 4]** The device of Claim 1, wherein the inflated body is filled with air, heated by solar energy.
- [Claim 5]** The device of Claim 1, wherein the inflated body is aerodynamically streamlined.
- [Claim 6]** The device of Claim 1, wherein the inflated body is enclosed into an aerodynamically streamlined balloon.
- [Claim 7]** A plurality of the devices of Claim 1, placed close to each other and combined into a solar farm.
- [Claim 8]** A device for converting solar energy into electric energy, comprising:
a solar light concentrator;
a non-planar solar panel with a plurality of solar cells with gaps;
a fan placed to the rear of the solar panel, blowing both the solar panel's rear side and the solar panel's front side.
- [Claim 9]** The device of Claim 8, wherein the solar light concentrator has a paraboloid form.
- [Claim 10]** The device of Claim 8, wherein the solar light concentrator has a parabolic form in its cross section.

1/12

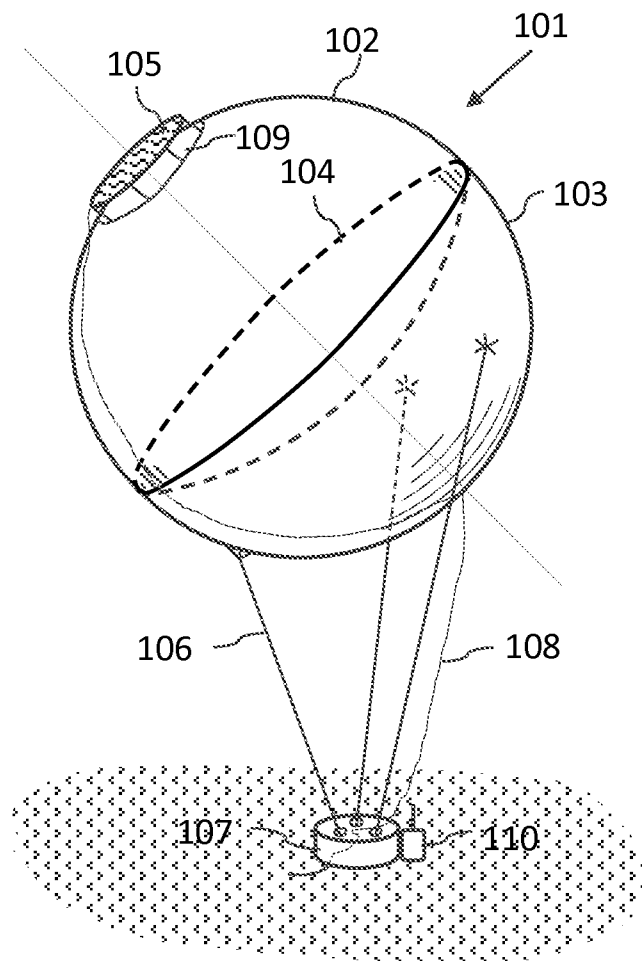


Fig. 1

2/12

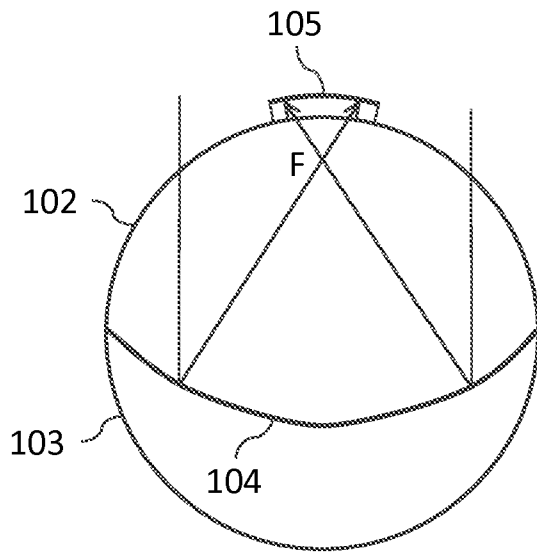


Fig. 2

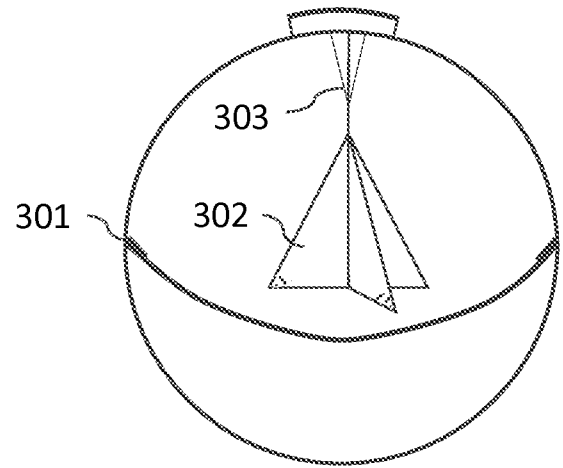


Fig. 3

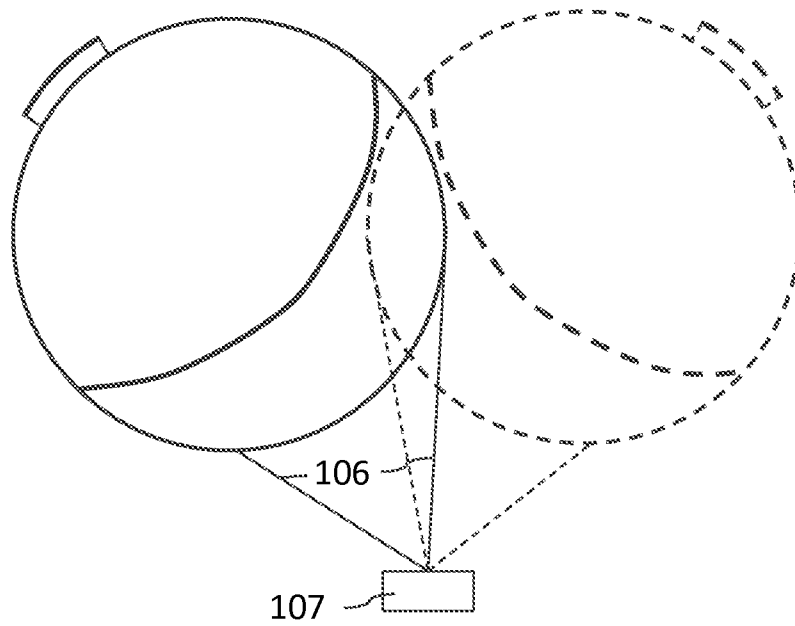


Fig. 4

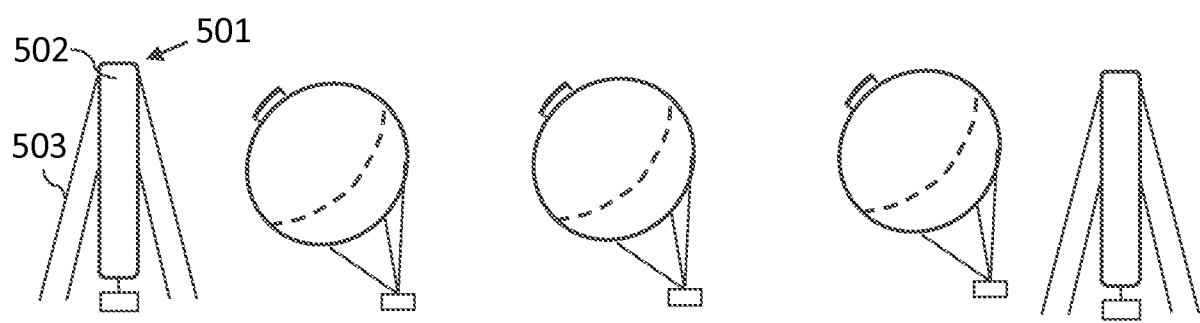


Fig. 5A

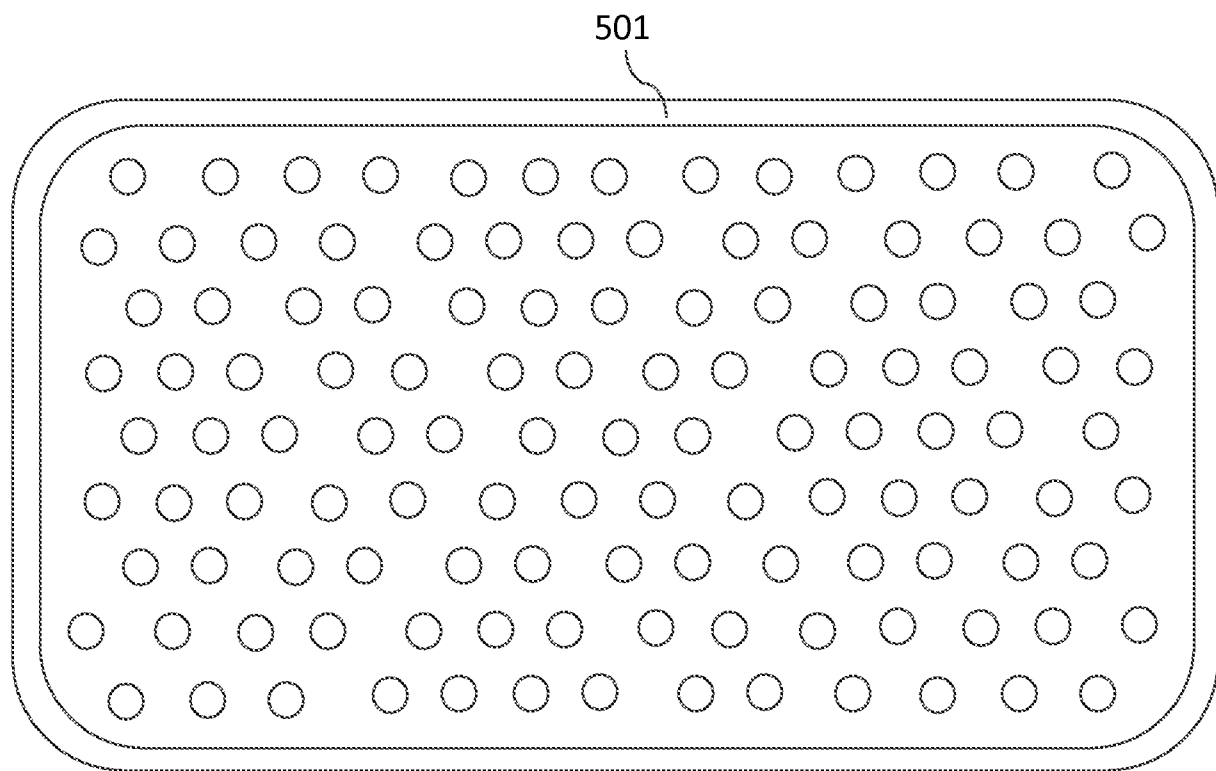


Fig. 5B

4/12

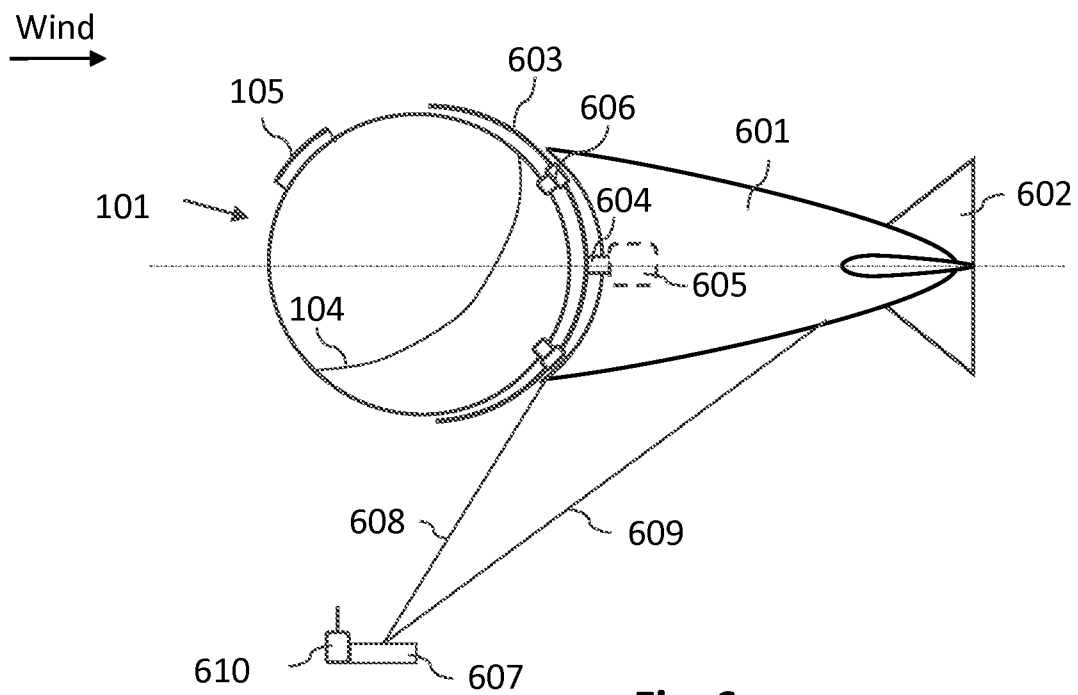


Fig. 6

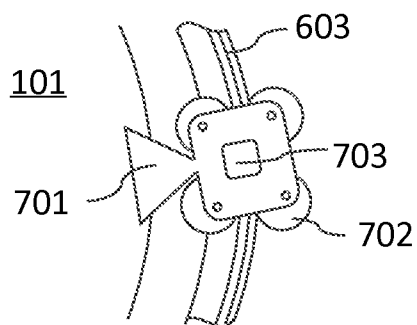


Fig. 7A

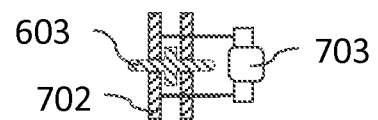
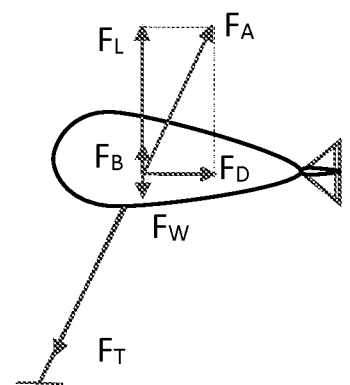
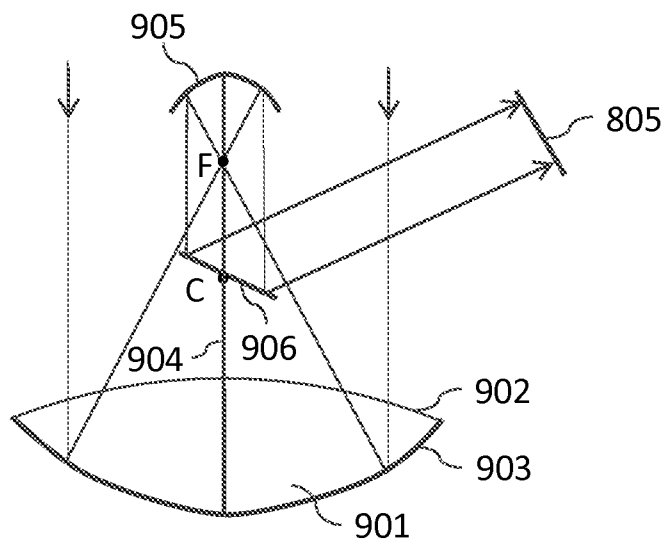
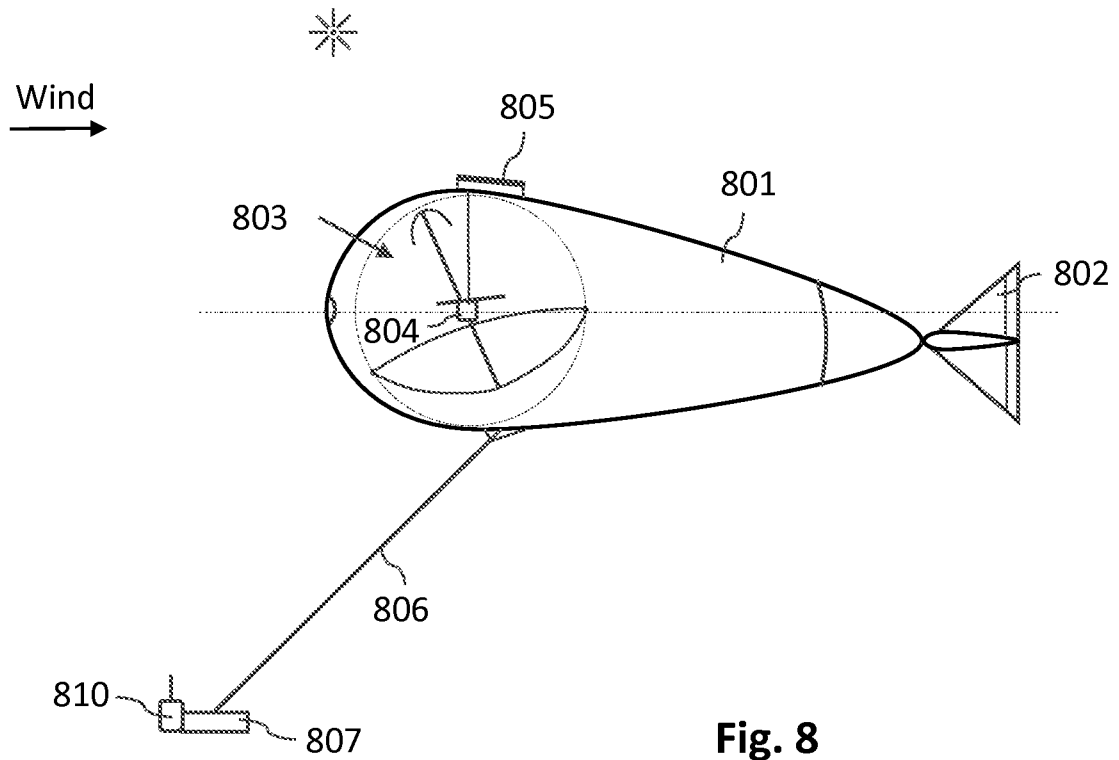
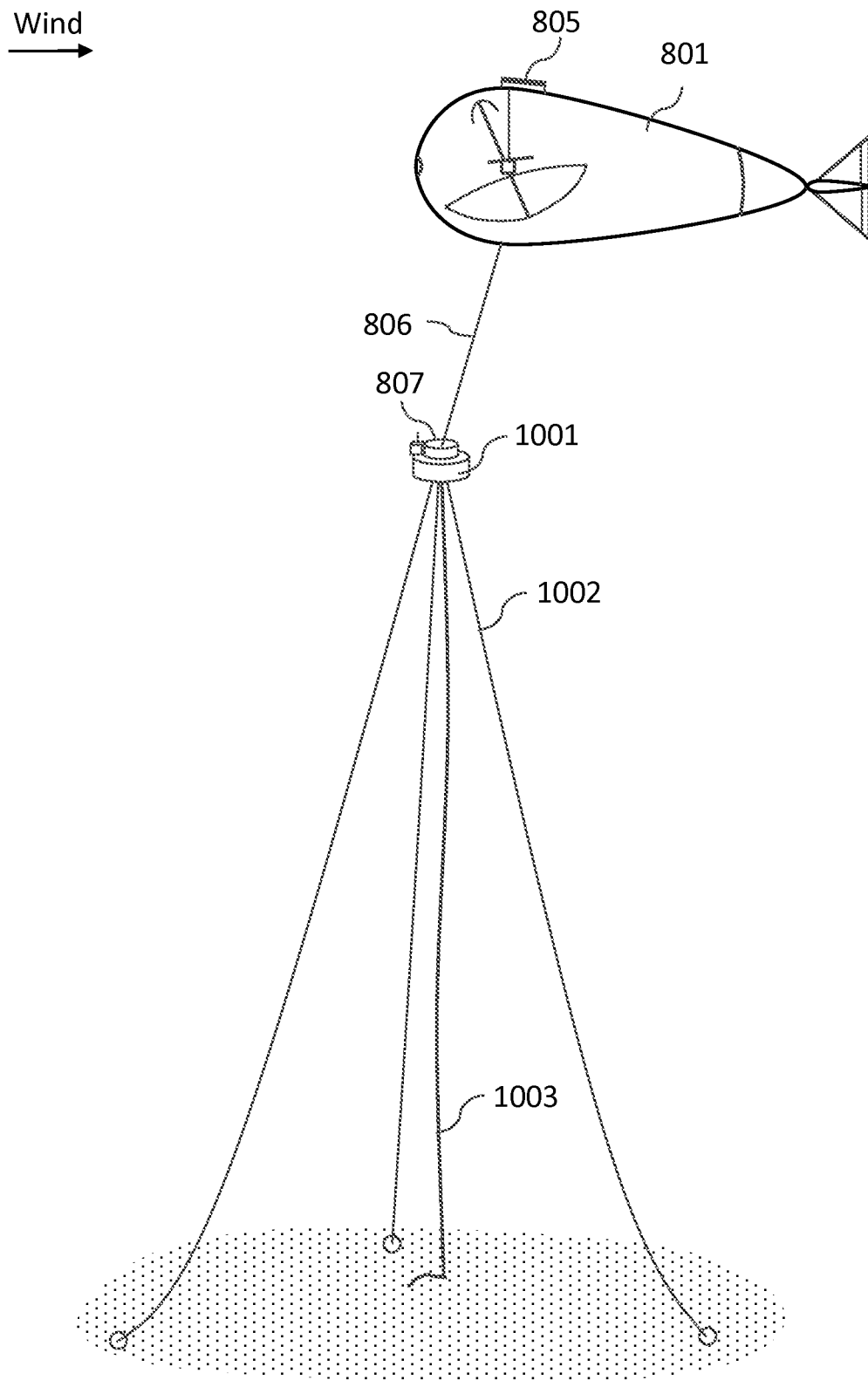


Fig. 7B

5/12



6/12

**Fig. 10**

7/12

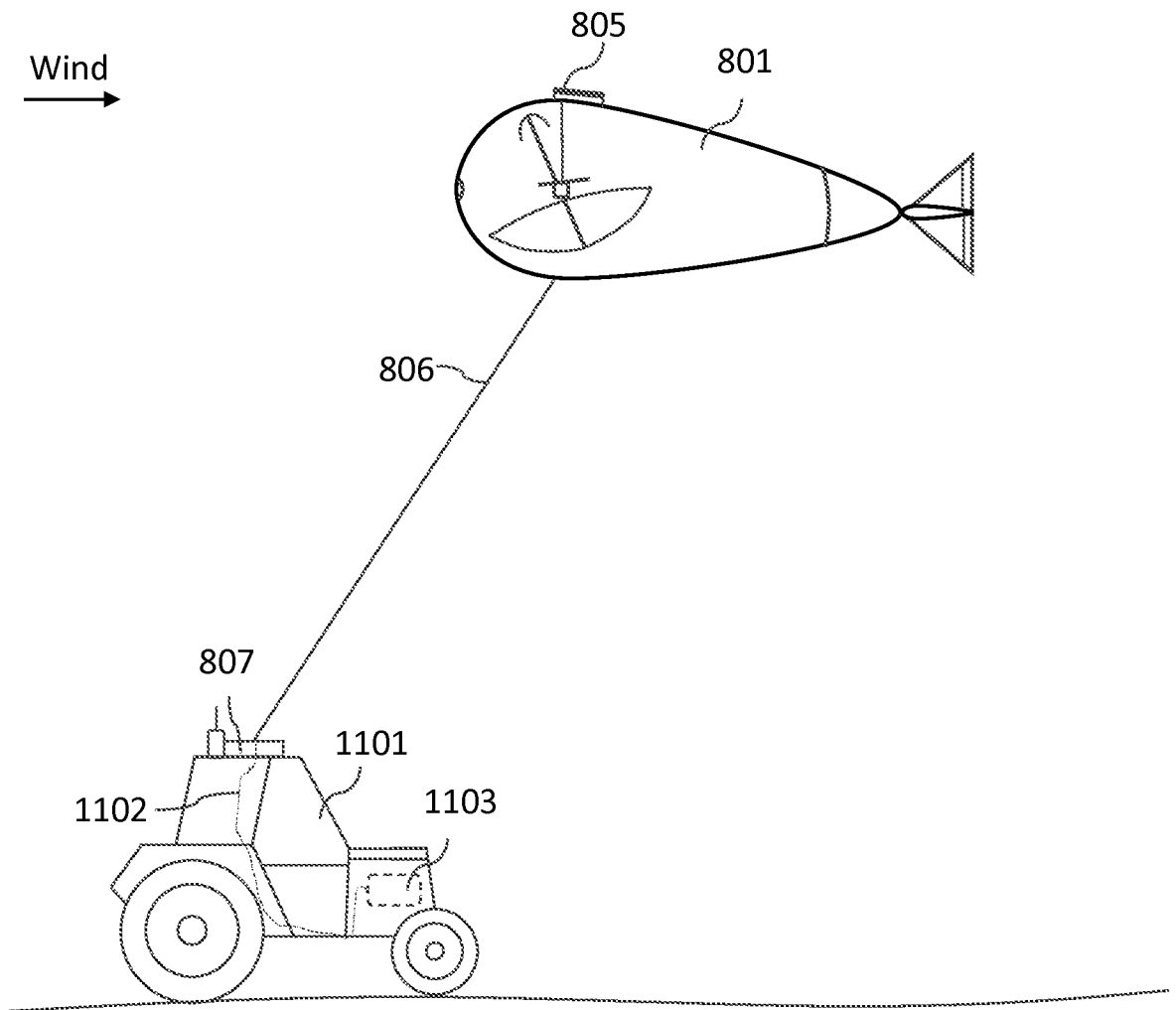


Fig. 11

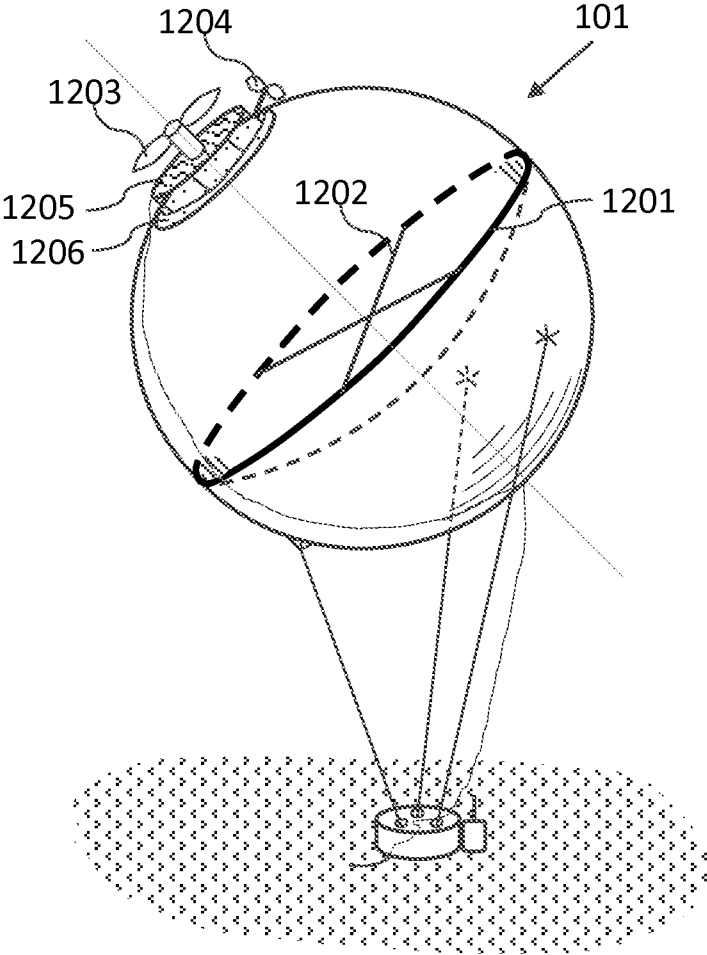


Fig. 12

9/12

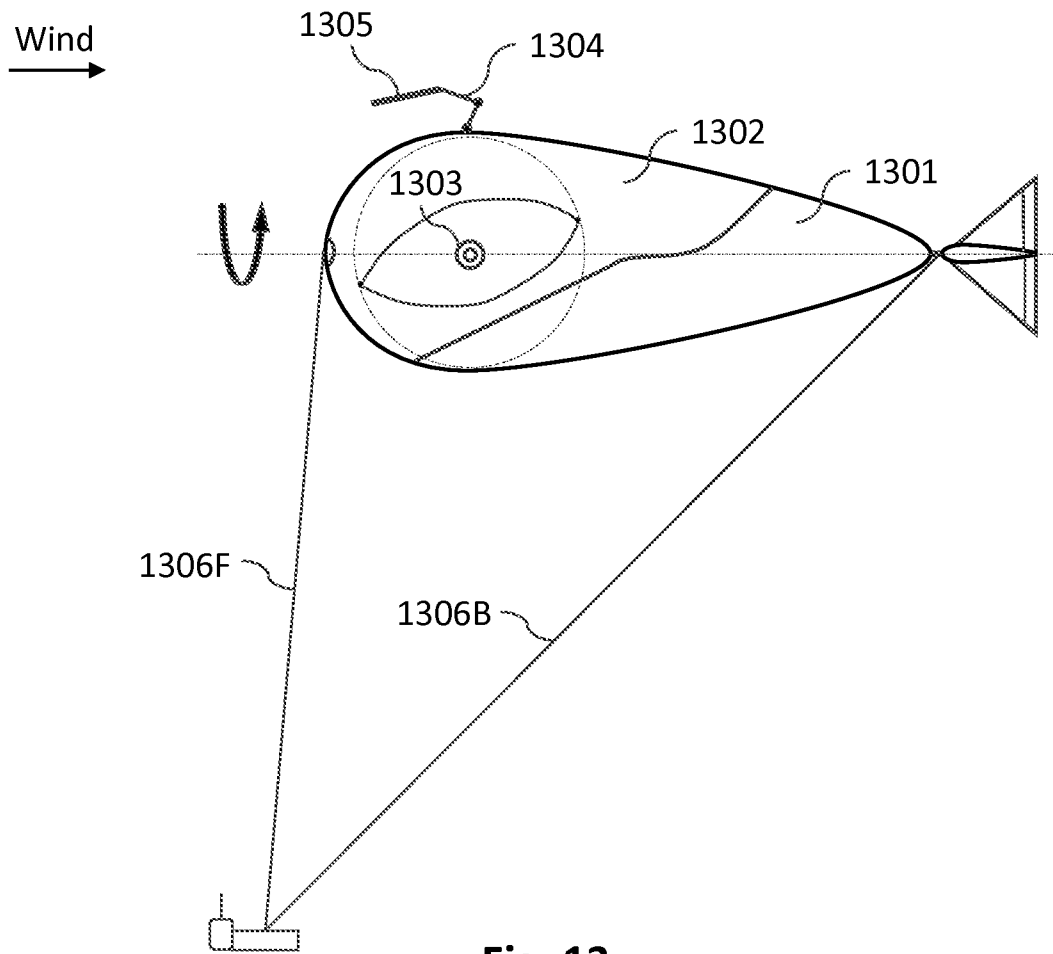


Fig. 13

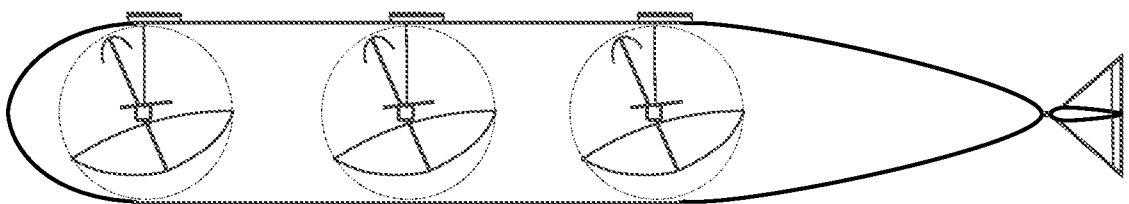


Fig. 14



10/12

Wind
→

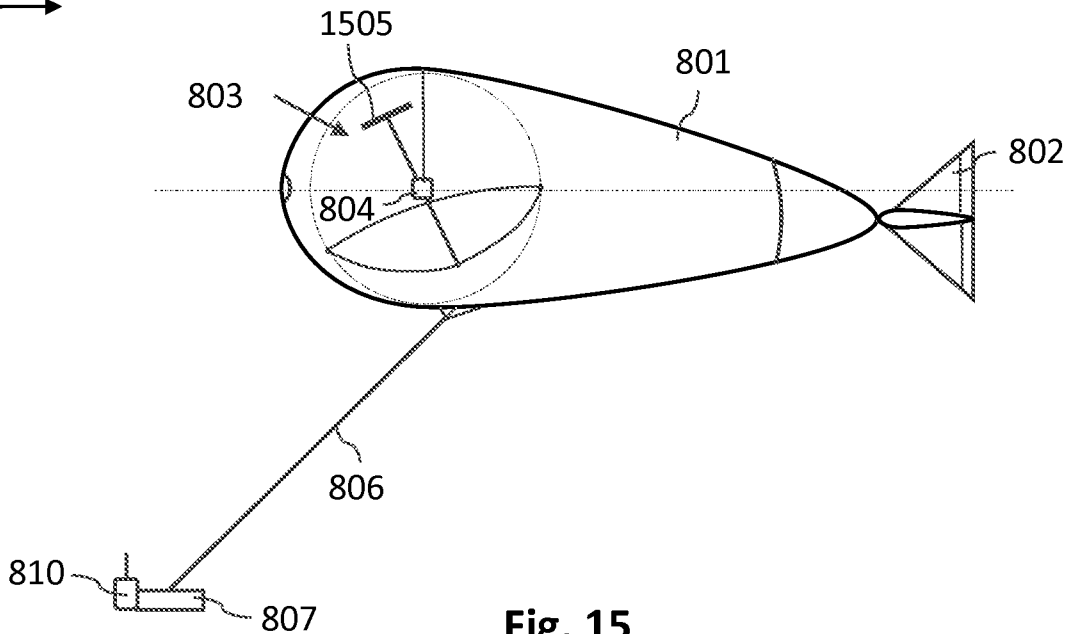


Fig. 15

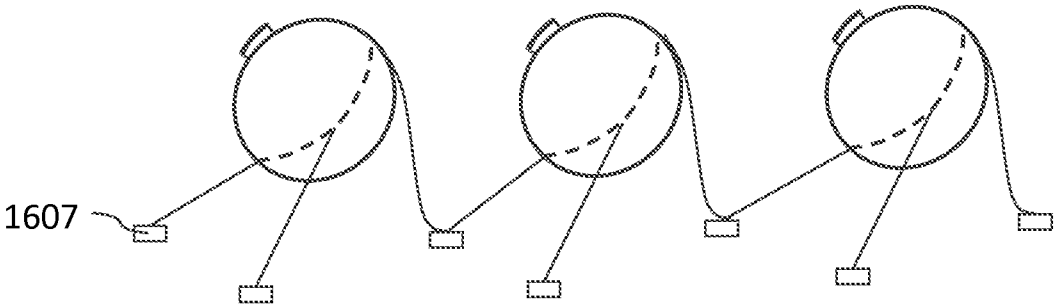


Fig. 16

11/12

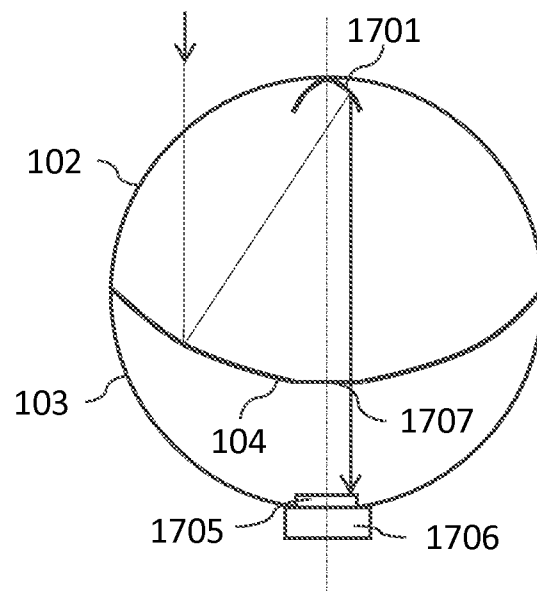


Fig. 17

12/12

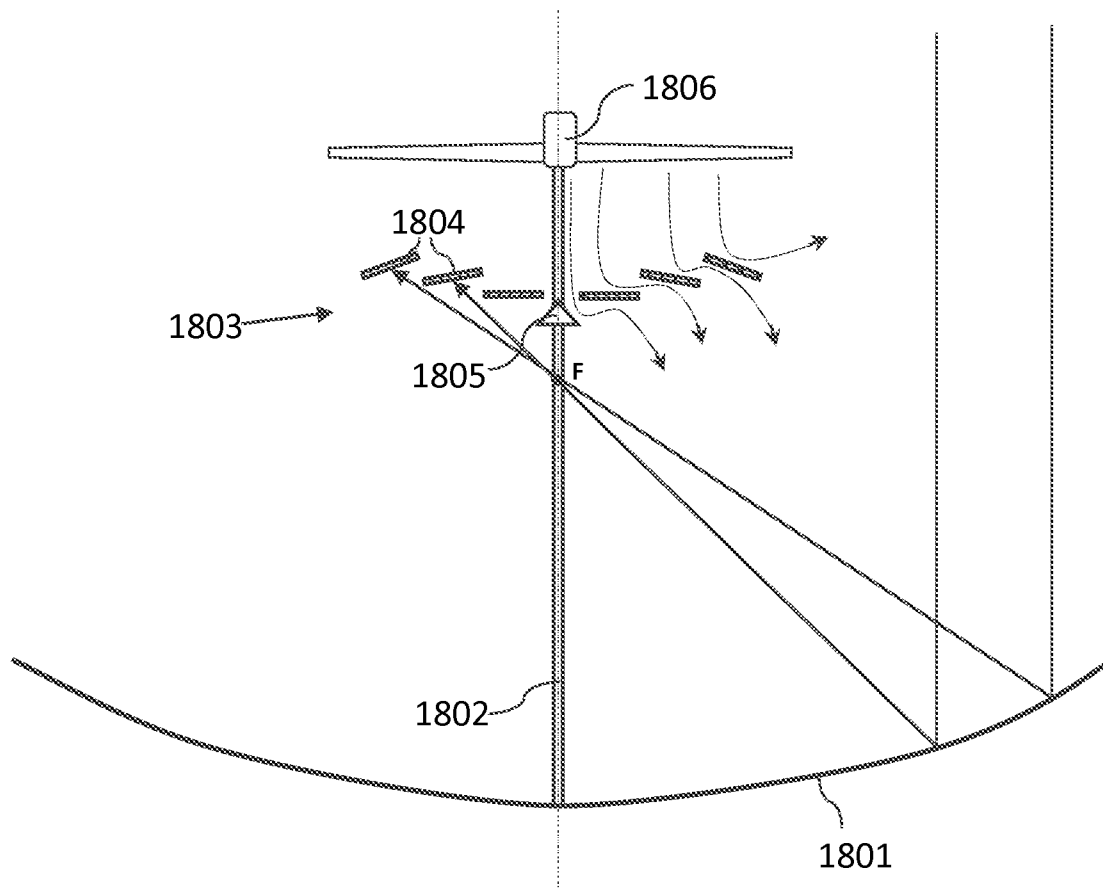


Fig. 18

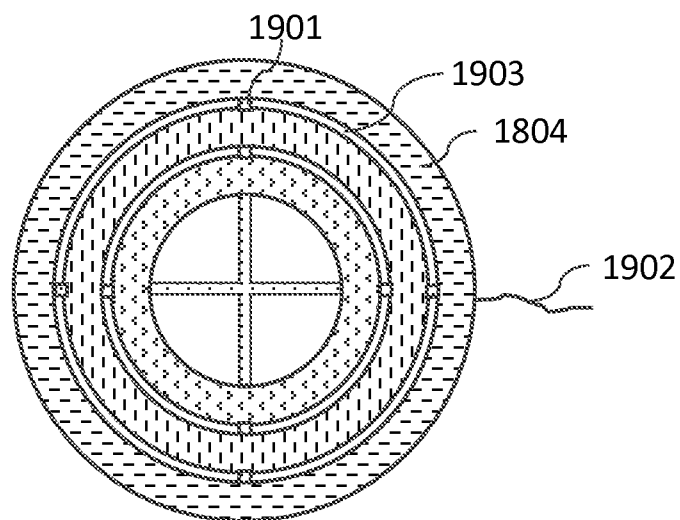


Fig. 19