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(54) CONCENTRATING SOLAR ENERGY SYSTEM

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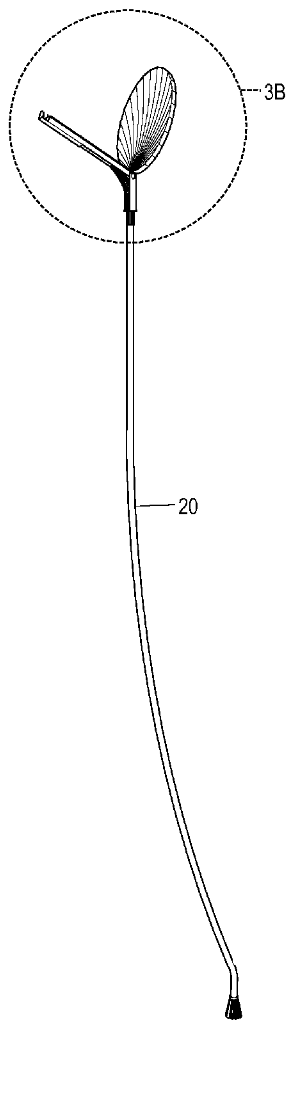
(57) **ABSTRACT**

Systems and methods for concentrating solar energy in the high earth atmosphere and transmitting the concentrated solar energy to the earth's surface. A system includes a light weight solar concentrator, supported by a light weight, rigid, buoyant, structure (**36**). The buoyant structure is suspended high in the earth's atmosphere above clouds and weather. Steerable mirrors, and/or a steerable structure, enable the concentrator to track the sun. In one embodiment, a buoyant light pipe (**20**) enables the transmission of concentrated solar energy from the high altitude concentrator to the earth's surface for further use. The system provides concentrated solar energy for use at any location on the earth, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat. A high solar concentration ratio enables high temperature, and hence high efficiency heat engine operation. With the provision of a thermal storage unit a system can provide utility scale continuous electricity generation at any location on the planet.



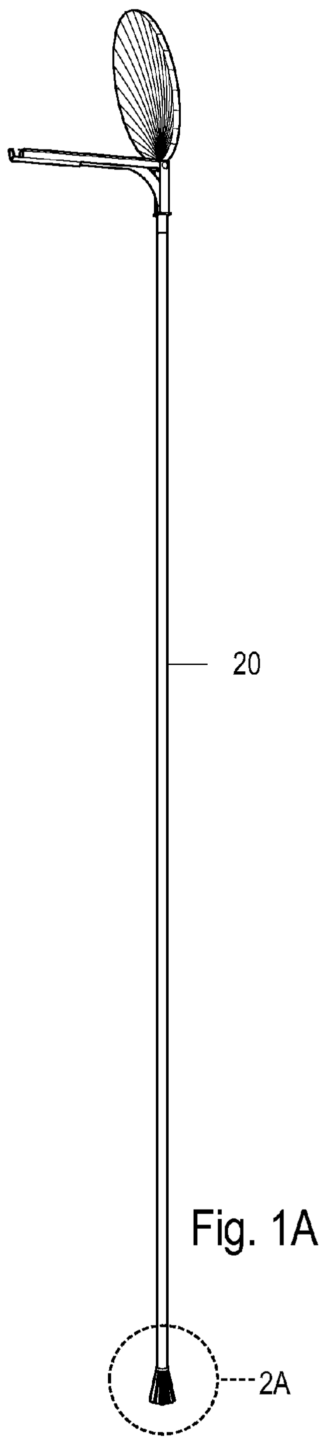


Fig. 1A

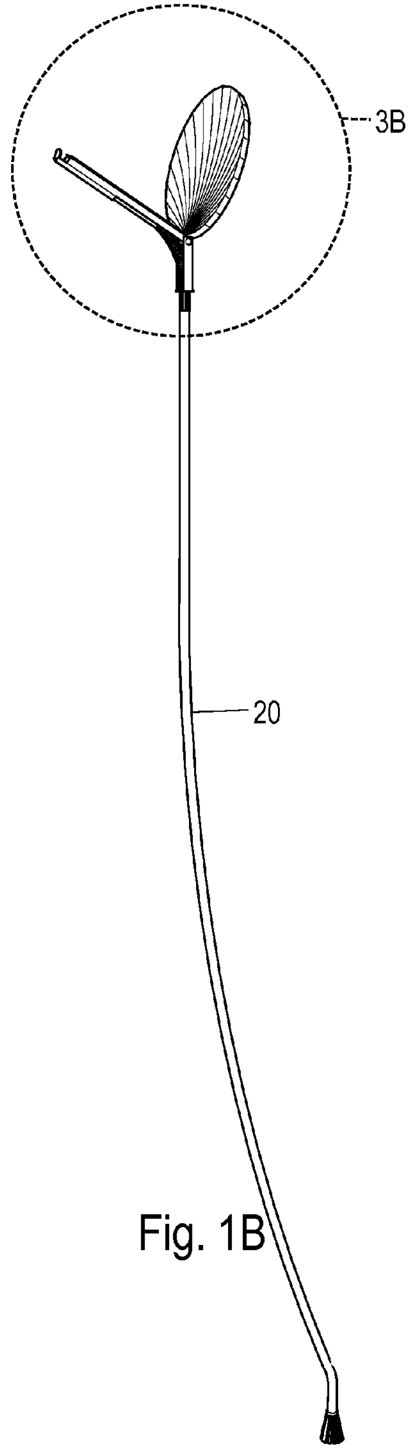


Fig. 1B

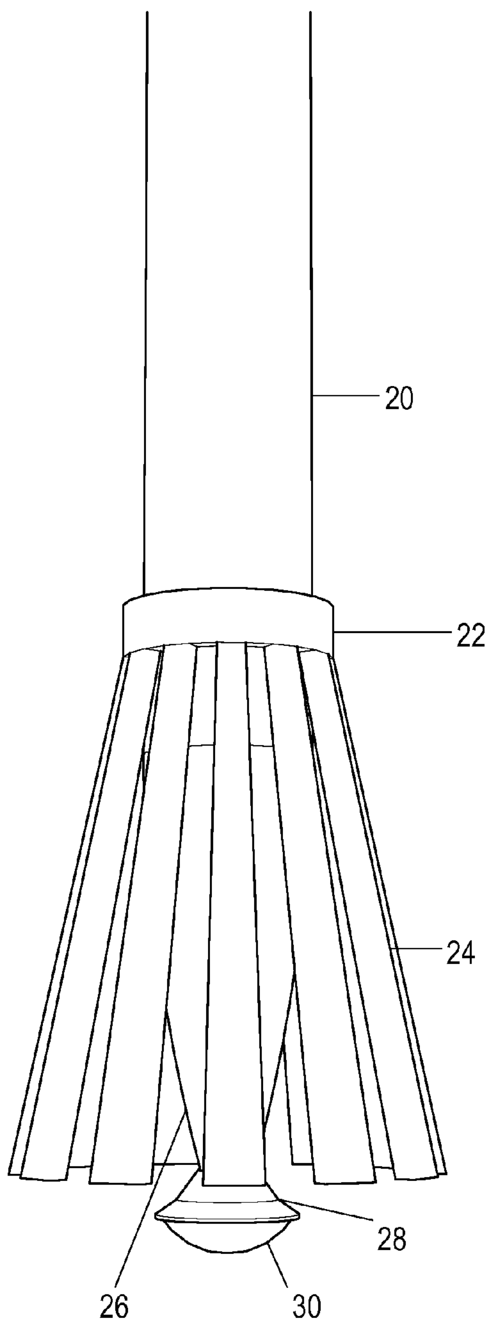


Fig.2A

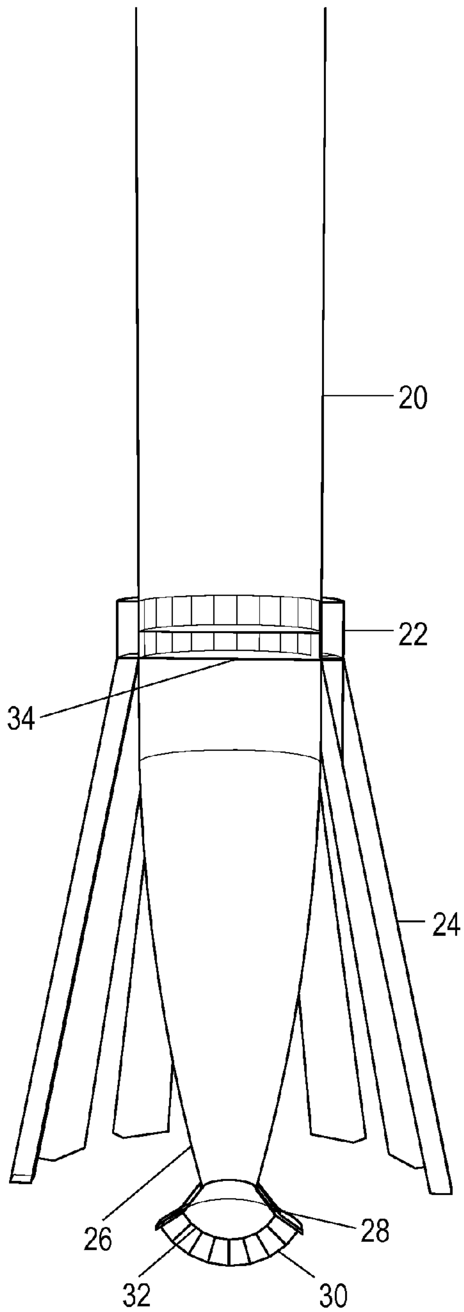


Fig. 2B

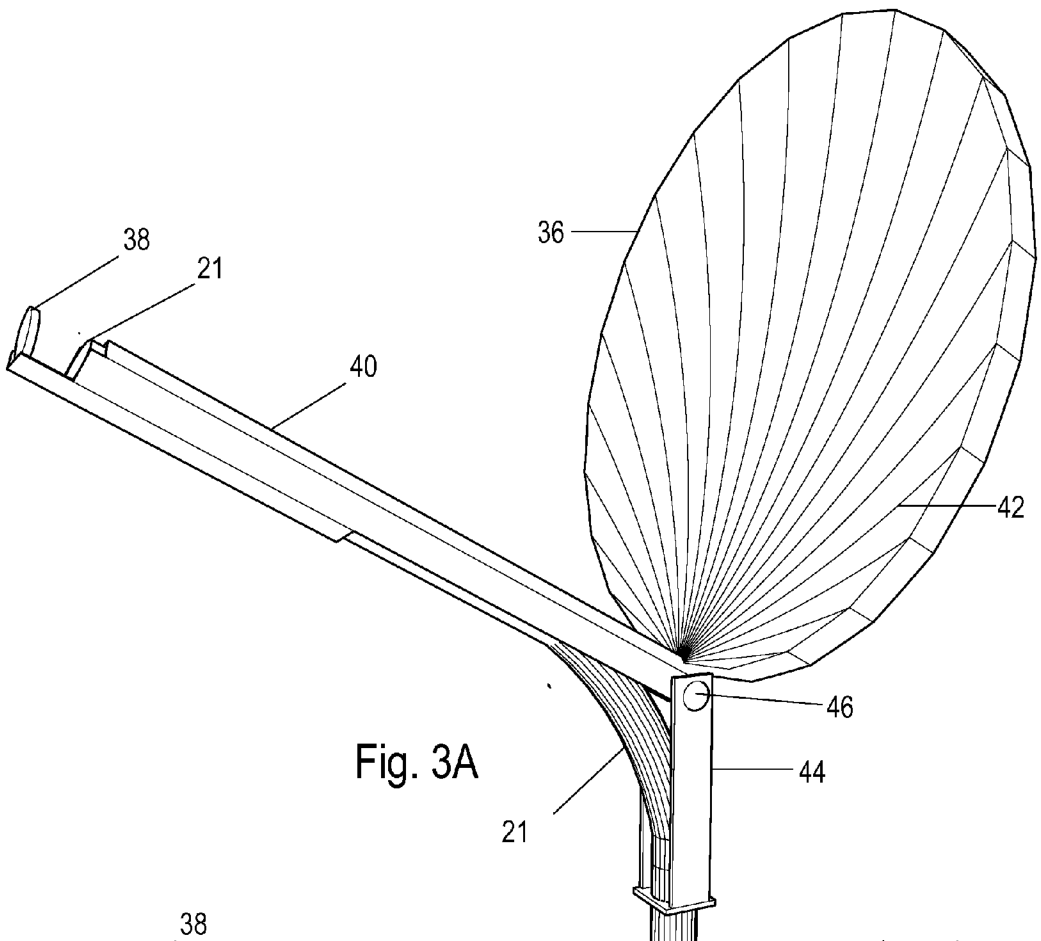


Fig. 3A

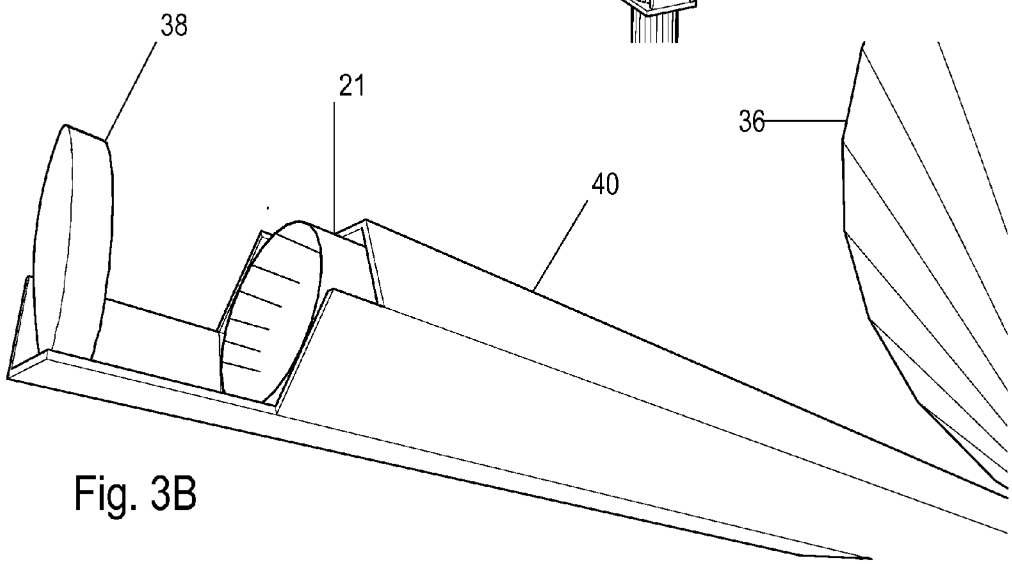


Fig. 3B

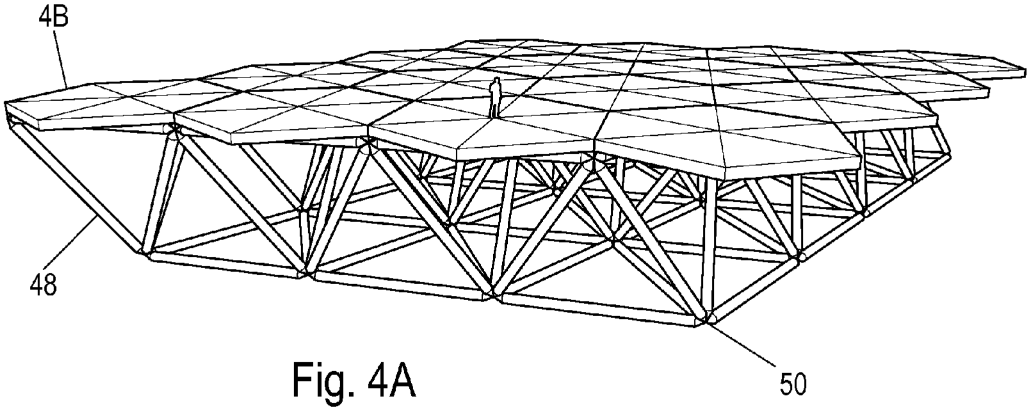


Fig. 4A

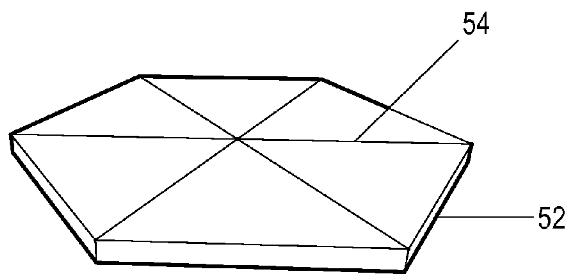


Fig.4B

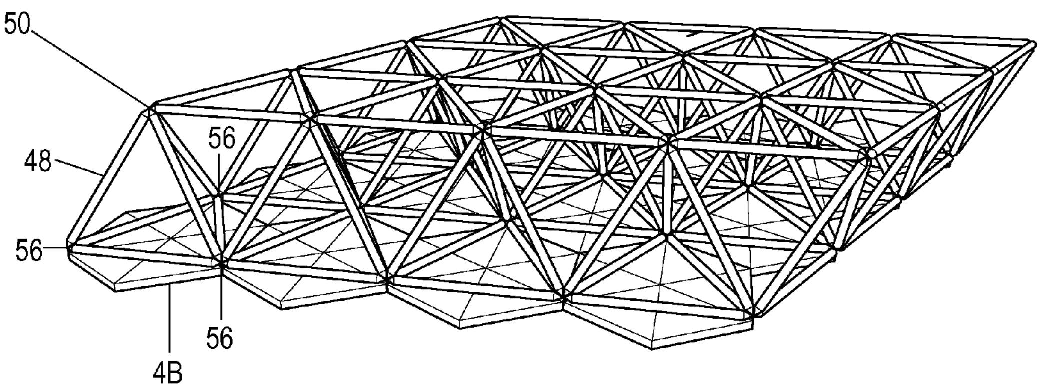


Fig.4C

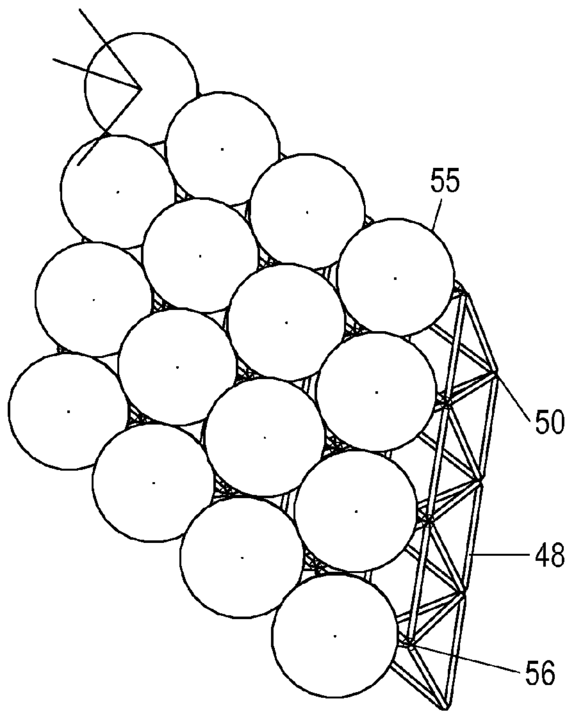


Fig. 5A

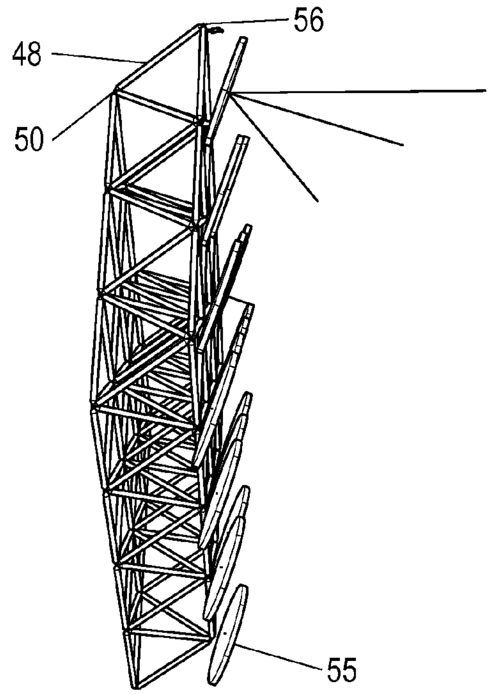


Fig. 5B

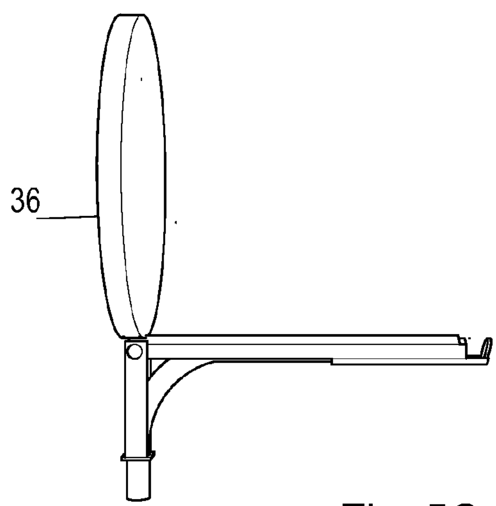


Fig. 5C

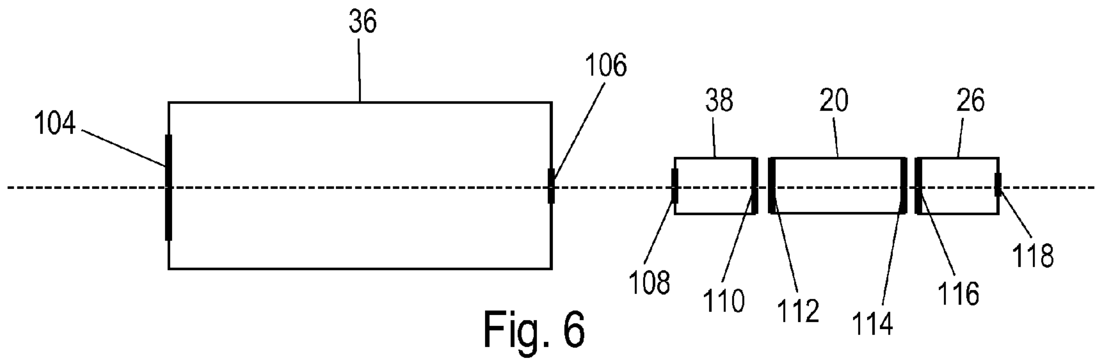


Fig. 6

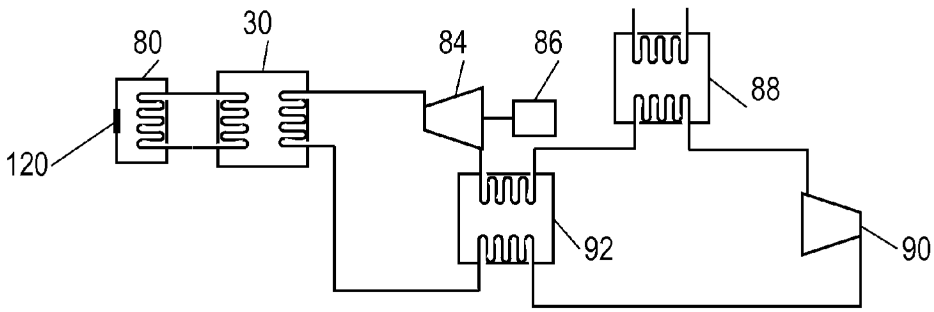


Fig. 7A

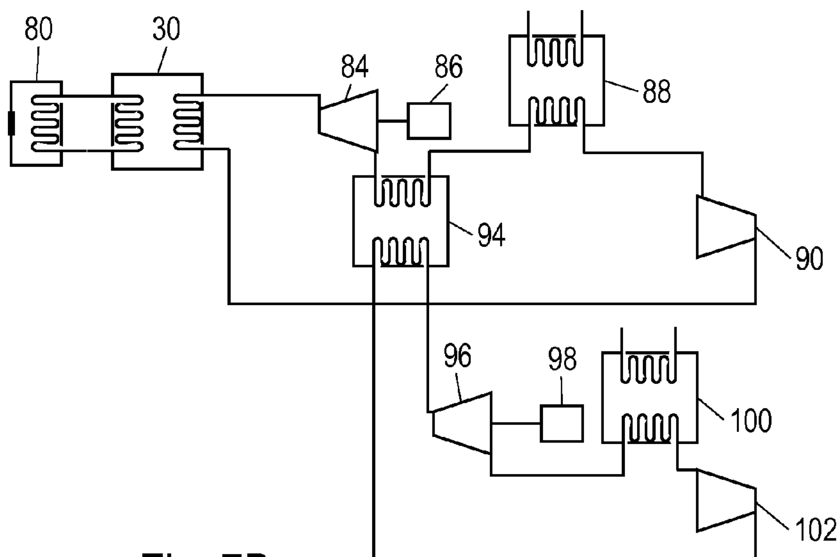


Fig. 7B

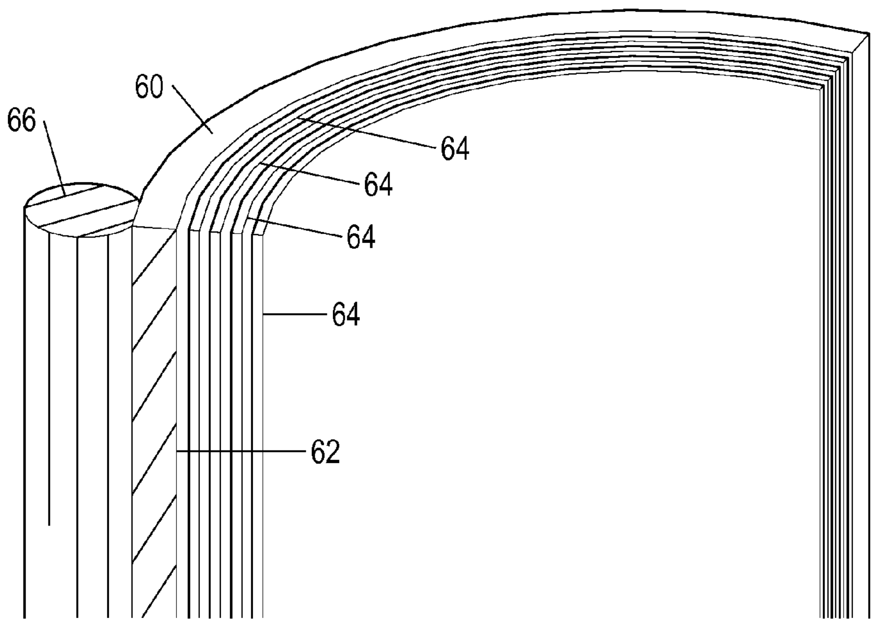


Fig. 9

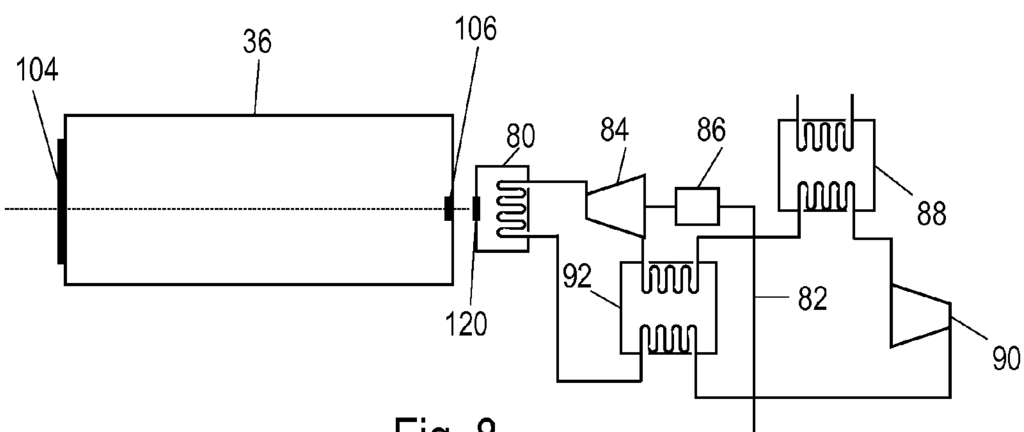


Fig. 8

CONCENTRATING SOLAR ENERGY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

FEDERALLY SPONSORED RESEARCH

[0002] Not Applicable

SEQUENCE LISTING OR PROGRAM

[0003] Not Applicable

BACKGROUND

[0004] 1. Field

[0005] This invention generally relates to solar energy systems, more particularly to, concentrating solar energy systems for power generation and other uses.

[0006] 2. Prior Art

[0007] Concentrating Solar energy systems use optical components such as lenses and mirrors to collect and concentrate the sun's radiation and then absorb it for practical use. The main practical use is to provide high temperature working fluids to drive heat engines that in turn drive electricity generators. Other uses for concentrated sunlight include high intensity photovoltaic electricity generation, direct high temperature "clean" process heat, and indirect high temperature process heat.

[0008] A wide variety of designs have been developed to accomplish these goals. The following references provide a good overview of this technology. "Solar Engineering of Thermal Processes" by John A Duffie and William A Beckman, chapter seven and "Solar Energy" by G. N. Tiwari, chapter eight.

[0009] All current concentrating solar energy designs include two major elements:

- [0010] a) optical concentrators that accept and concentrate the incoming solar radiation
- [0011] b) receivers that absorb the solar energy and heat a working fluid.

[0012] Concentrators can use some of the following structural arrangements:

- [0013] a) single lenses with attached receivers as one moveable structure,
- [0014] b) rigid arrays of lenses or arrays of lens segments with an attached receiver, all on a common moveable structure,
- [0015] c) arrays of independently moving lenses on a stationary base (like the ground) with a central stationary receiver, such as heliostat arrays.

[0016] The lenses can use imaging optical elements and non-imaging optical elements. The lenses can use reflective optical elements and/or refractive optical elements. Regardless of their construction, concentrators are characterized by their entrance aperture and their exit aperture. In the case of multiple lens arrays or segments, the input aperture is the sum of the apertures of the elements of the array. The ratio of the area of the input aperture divided by the area of the exit aperture is the concentration ratio.

[0017] Receivers absorb the concentrated radiation from the concentrator and transfer this absorbed energy to a working fluid. This hot fluid is then either used to directly power a heat engine (such as a steam turbine), or is used to transfer heat via a heat exchanger to another working fluid which is then used to power a heat engine. The heat engine then drives a generator which produces electricity. Some systems first transfer heat from the working fluid to thermal storage, and then from thermal storage to a second working fluid in order to decouple when electrical energy is generated from when solar energy input is captured by a receiver.

[0018] Some hypothetical space based systems have been proposed that generate electricity via these processes in space and then convert the electrical energy to microwave energy to be beamed to the earth's surface and collected via large microwave antennae arrays.

[0019] Another unrelated area of prior art is light pipes. Glass and plastic versions of these have long been used in the area of telecommunications to transmit low power light signals over long distances. Light pipes using hollow tubes with various highly reflective inner surfaces are used to guide sunlight or artificial light over short distances for lighting purposes within buildings. A particularly efficient method used for lighting is described in U.S. Pat. No. 4,260,220, "Prism light guide having surfaces which are in octature" issued to Lorne A. Whitehead on Apr. 7, 1981. Another method used for lighting is described in U.S. Pat. No. 4,895, 420, "High reflectance Light Guide" issued to John F. Waymouth on Jan. 23, 1990.

[0020] Light pipes are characterized by their aperture, acceptance angle, and attenuation. Light pipes accept light travelling in the direction of the light pipe within their acceptance angle. Generally light from point or small area concentrated light sources needs to pass through a collimator in order to satisfy the acceptance angle criteria and reduce attenuation. Collimators are common optical elements and are effectively the reverse of optical concentrators with a smaller entrance aperture than larger exit aperture. As well as conditioning light for light pipes or guides, optical collimators are used for a variety of purposes. These include projector condensor lenses, parabolic reflector light bulbs, and telescope objective lenses.

[0021] Current Concentrating Solar systems suffer from several problems that have limited their success. Their high capital costs make the cost of the energy they produce uncompetitive without subsidy. They also have high ancillary costs to compensate for the unpredictability of their energy output and the long transmission distance from the system to the average power user.

[0022] Concentrating Solar systems make use of direct sunlight, i.e. light directly from the sun that is not scattered or absorbed in earth's atmosphere. Current systems are severely negatively affected by effects of weather such as rain, clouds, moisture and dust in the atmosphere. This restricts their geographical location to hot dry desert areas which are relatively scarce and far from consumers of electricity. In addition, even in deserts, bad weather sometimes restricts electric power output availability, necessitating the provision of alternate sources of supply.

[0023] Solar concentrators need to have large entry apertures to produce meaningful amounts of power. Utility scale systems have apertures measured in millions of square meters. Current systems consequently consume large areas of land and significant quantities of construction materials like glass and steel needed to fabricate this large aperture collector. Also weather in the form of dust, wind, rain, hail frost and snow require that structures be strong and durable which adds significantly to their cost.

[0024] Current large scale systems use large arrays of individually steered collecting elements. Robust motors, gears, electrical equipment etc are needed for each collector element, contributing significantly to overall cost.

[0025] The cost problem is compounded by the generally low overall energy conversion efficiency of current systems, which consequentially requires a larger surface area and more material to produce a given power output compared to higher conversion efficiency systems.

SUMMARY

[0026] The present invention is realized by suspending a solar energy concentrator at a high altitude in the earth's atmosphere, above clouds, moisture, dust, and wind. This is accomplished using a light-weight, rigid, buoyant, structure. The concentrated solar energy output from the concentrator can be used in a number of ways:

[0027] It can be passed through a collimator whose output is coupled to a light pipe. The solar energy is transmitted through the light pipe to the earth's surface where it is (optionally) further concentrated in order to better achieve high temperatures for high conversion and thermal storage efficiency. The energy output from this final stage concentrator is absorbed and converted to heat by a receiver, then (optionally) the heat is transferred to and stored in a thermal storage element. Heat from the thermal storage element is transferred to a separate working fluid which is used to drive a heat engine that drives a generator and produces electricity.

[0028] It can be converted directly to high voltage electricity by photovoltaic convertors and then transferred to earth's surface with high voltage transmission lines.

[0029] It can be collected by a receiver and then thermally converted to high voltage electricity via a conventional turbine, compressor and generator system, and then transferred to earth's surface with high voltage transmission lines.

[0030] These and other objects and features of the invention will be better understood by reference to the detailed description which follows taken together with the drawings in which like elements are referred to by like designations throughout the several views.

DRAWINGS—FIGURES

[0031] In the drawings, closely related figures have the same number but different alphabetic suffixes.

[0032] FIG. **1**A is a perspective view of an initial position of a first embodiment of the invention.

[0033] FIG. **1**B is a perspective view of a second position of the embodiment shown in FIG. **1**A.

[0034] FIG. **2**A is a perspective view of the ground based final stage optical concentrator, cavity absorber, and thermal storage unit of a first embodiment.

[0035] FIG. **2**B is a vertical cross section of FIG. **2**A.

[0036] FIG. **3**A is a perspective view of the Optical Concentrator and collimator assembly portion of a first embodiment.

[0037] FIG. **3**B is a close up perspective view of part of FIG. **3**A

[0038] FIG. **4**A is a perspective view of the structure of the mirror surface of the Optical Concentrator of a first embodiment.

[0039] FIG. **4**B is a perspective view of a hexagonal mirror segment of a first embodiment.

[0040] FIG. **4**C is a perspective view of the back of the structure of the mirror surface of the Optical Concentrator shown in FIG. **4**A.

[0041] FIG. **5**A is a perspective front view of a section of the structure of the mirror surface of a concentrator embodiment using circular mirror segments in a Fresnel fashion.

[0042] FIG. **5**B is a perspective side view of a section of the structure of the mirror surface of a concentrator embodiment using circular mirror segments in a Fresnel fashion showing the circular mirror tilt.

[0043] FIG. **5**C is a perspective view of the Optical Concentrator and collimator assembly portion of an embodiment using circular mirror segments in a Fresnel fashion.

[0044] FIG. **6** is a schematic of the optical elements of a concentrating solar energy system according to one embodiment.

[0045] FIG. **7**A is a schematic view of the thermal elements of a system for generating electrical power from solar energy according to one embodiment.

[0046] FIG. **7**B is a schematic view of the thermal elements of a system for generating electrical power from solar energy according to one embodiment.

[0047] FIG. **8** is a schematic view of the optical and thermal elements of an embodiment that directly couples a receiver to a concentrator.

[0048] FIG. **9** is a cross section view of a portion of a light pipe wall of one embodiment.

DRAWINGS—REFERENCE NUMERALS

[0049]

20	light pipe	21	light pipe segment
22	foundation anchor ring		
24	foundation anchor leg	26	second concentrator
28	cavity absorber cover	30	thermal storage unit
32	cavity absorber surface	34	transparent membrane
36	concentrator mirror	38	collimator mirror
40	connecting beam	42	mirror shading line
44	alt-azimuth mount	46	alt pivot
48	truss structure strut	50	truss structure joint
52	mirror segment frame	54	mirror segment surface
56	mirror to truss attachment		
60	light pipe wall	62	reflective layer
64	refractive layer	66	reinforcement cables
80	solar receiver	82	high voltage transmission line
84	heat engine	86	electricity generator
88	ambient heat exchanger	90	compressor
92	regenerator heat exchanger	94	boiler heat exchanger
96	steam turbine	98	second electricity generator
100	condensor	102	water pump
104	concentrator input aperture	106	concentrator output aperture
108	collimator input aperture	110	collimator output aperture
112	light pipe input aperture	114	light pipe output aperture
116	second concentrator input aperture		
118	second concentrator exit aperture		
120	receiver input aperture		

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0050] The description that follows is divided into separate sections with unique headings to help clarify the exposition. The system is first described with respect to schematic diagrams for the optical system and the solar energy conversion system, and then with more detailed perspective drawings, mostly for optical system elements of various embodiments.

DETAILED DESCRIPTION—FIG. 6 OPTICAL SYSTEM

[0051] FIG. **6** is a schematic view of the optical elements of a solar concentrator energy system. It consists of a solar concentrator **36** with input aperture **104** and output aperture **106**. Solar concentrator **36** is a rigid buoyant structure suspended high in the earth's atmosphere. Input aperture **104** is pointed continuously at the sun. Output aperture **106** is a physical aperture for some non imaging concentrators, but is the focal plane image of the sun for imaging concentrators using reflective or refractive lenses or arrays of lens segments. These lenses will mostly be formed from multiple segments attached to a rigid structure, and can be Fresnel or Fresnel like in construction.

[0052] The output aperture **106** of concentrator **36** is directly coupled to the input aperture **108** of collimator **38**. The output aperture **110** of collimator **38** is directly coupled to the input aperture **112** of light pipe **20**. Collimator **38** can be an imaging, reflective or refractive lens or a non imaging compound parabolic collimator or similar. Compound parabolic non imaging optical elements are well suited to this application as they are easy to couple to light pipes and can be constructed using the same materials and processes.

[0053] Light pipe **20** is a flexible, buoyant, thin walled tube structure that stretches from the earth's surface to the concentrator **36** and collimator **38** assemblies high in the earth's atmosphere. Its length is typically in the region of 20 km, and its length to width aspect ratio is in the region of 100. Its thin structural skin is airtight, maintains a circular cross section through an internal gage pressure, and is stabilized against high wind and gravity forces. It excludes weather effects like rain, snow, moisture and dust from the transparent gas in the pipe interior. The primary stabilizing force that counteracts wind forces and gravity is buoyancy from hydrogen or helium within high altitude sections of the pipe. Stability is augmented with stiffness in the structural wall, and cable stays when appropriate. Its interior wall surface is highly reflective and provides a low loss transmission path for the concentrated collimated solar energy input through aperture **112**.

[0054] Second stage concentrator **26** has input aperture **116**, directly coupled to light pipe **20** output aperture **114**. Concentrator **26** can be an imaging reflective or refractive lens or a non imaging compound parabolic concentrator or similar. Compound parabolic non imaging optical elements are well suited to this application as they are easy to couple to light pipes and can be constructed using the same materials and processes.

DETAILED DESCRIPTION—FIG. 7 SOLAR ENERGY CONVERSION SYSTEM

[0055] FIG. 7A is a schematic view of one embodiment of a solar energy conversion system that receives the solar energy delivered by concentrator **26** shown in perspective drawings FIG. **2**A and FIG. **2**B, and schematic drawing FIG. **6**. It consists of receiver **80** with input aperture **120** coupled to the exit aperture **118** of second concentrator **26**. Other elements are thermal store **30**, heat engine **84**, and electricity generator **86**. Heat engine **84** might typically be a Brayton cycle gas turbine but other types of expansion engines, including Stirling cycle heat engines are possible

[0056] The thermal store **30** decouples the arrival of solar energy from the use of electrical energy, and allows for 24 hour delivery of electricity despite the much shorter duration of daylight. One embodiment of thermal store **30** uses large graphite blocks with integral cooling channels. Graphite has long been used in this form in a variety of nuclear reactor cores. In that application graphite's advantages as a thermal storage medium were secondary to its benefits as a neutron moderator. Graphite has good thermal capacity, and can tolerate higher temperatures than almost any material. It maintains structural integrity at high temperature and can withstand severe thermal cycling. It is abundant and relatively inexpensive.

[0057] Other elements of this electricity generation system are ambient cooler heat exchanger **88**, compressor **90** and regenerator heat exchanger **92**. A common working fluid for high temperature Brayton cycles is helium at high pressure and temperature.

[0058] FIG. **7**B is a schematic of a second embodiment of a solar energy conversion system that absorbs the solar energy delivered by concentrator **26** from exit aperture **118** shown in FIG. **6** and converts it into electricity. This embodiment is a combined cycle electricity generation system which uses both a Brayton gas turbine cycle, and a Clausius-Rankine water/steam cycle. This embodiment is more efficient at energy conversion but adds additional cost for the steam cycle elements. The additional elements are boiler heat exchanger **94** that is heated with the exhaust gas from heat engine **84**, steam turbine **96**, second electricity generator **98**, condensor heat exchanger **100**, and water pump **102**. Ambient heat exchanger **88** is probably not needed or can be much simpler for this combined cycle system.

[0059] A particular advantage of the use of a combined cycle system with a high temperature concentrating solar system is the improved thermal capacity of sensible heat storage system **82**. The thermal storage capacity of thermal store **82** is dependant on the average temperature difference between the high temperature gas delivered to heat engine **84** from high temperature storage and the low temperature gas returned to thermal store **82**. For the Brayton cycle with regeneration shown in FIG. **6**A this temperature delta is approximately 500 degrees Celsius. For the combined cycle of FIG. **6**B this temperature delta approaches 1000 degrees Celsius. This approximately doubles the thermal capacity of thermal store **82**, which effectively halves the cost of thermal storage. This comes at the cost of using a thermal fluid that accommodates this large temperature range, which in one embodiment might entail the use of high pressure helium gas as opposed to low pressure liquid fluoride salts.

[0060] FIG. **8** is a schematic of a solar concentrator and solar energy conversion system where all solar energy conversion system elements are suspended in the stratosphere with the concentrator and electrical power is transmitted to the earth's surface using buoyant high voltage transmission lines. As with the other embodiments, light is concentrated by buoyant concentrator **36**. In this embodiment the output aperture **106** of concentrator **36** is directly coupled to input aperture **120** of receiver **80**. The other elements of this solar energy conversion system are similar to those of the embodiment shown in FIG. **7**A, with the removal of thermal store **30**, and the addition of buoyant high voltage transmission lines **82**. Heat engine **84** could be a Stirling engine in this application.

[0061] Another embodiment not shown in FIG. **8**, but similar in function, employs an array of photovoltaic solar energy convertors electrically connected in series to convert the concentrated solar energy from aperture **106** of concentrator **36** directly into high voltage electricity. The high voltage electrical power is transmitted to the earth's surface using buoyant high voltage transmission lines.

[0062] Due to its large mass, it would be difficult to suspend a thermal store in the stratosphere with these embodiments. These embodiments would need a ground based energy storage system to provide continuous electrical power.

DETAILED DESCRIPTION—FIGS. 1, 2 GROUND ELEMENTS

[0063] FIG. **1**A and **1**B are perspective views of two positions of a solar concentrator energy system of a first embodiment. It consists of the following:

[0064] 1) A large, buoyant, segmented, reflecting, parabolic, mirror concentrator, and collimator assembly detailed in FIG. **3**B.

[0065] 2) A flexible hollow buoyant light pipe **20**.

[0066] 3) A ground based foundation, anchor, optical concentrator and receiver assembly detailed in FIG. **2**A.

[0067] FIG. **2**A and FIG. **2**B show the ground structures of a first embodiment in more detail. Light pipe **20** is attached to anchor ring **22** which is supported by foundation legs **24**. Light pipe **20** is a hollow buoyant tube which exerts a considerable vertical upward force on this anchor structure. Transparent membrane **34** is fabricated from polyethylene terephthalate (PET) or other similar transparent film and contains the pressurized gas within the light pipe **20**. As is typical for inflated structures the gage pressure is quite low, only a small fraction of an atmosphere. The section of the light pipe at this bottom end is filled with dry air. Buoyancy gas such as hydrogen and Helium are contained within the top section of light pipe **20**.

[0068] Light pipe **20** connects to the entry aperture on the top of Compound Parabolic Concentrator (CPC) **26** shown in cross section in FIG. **2**B. The reflective surface of the upper portion of CPC **26** can be constructed from the same reflective materials as the inner surface of light pipe **20**. The bottom portion of CPC **26** is fabricated from heat resistant material with a highly reflective inner surface and has provision for air or water cooling. One embodiment of the exit portion of a CPC is fabricated using carbon composite replica mirror panels. CPC **26** is a small part of the overall system and easily replaced. This allows the concentration factor of the whole system to be adjusted by using different versions of CPC **26**. This is flexibility not present in prior art solar concentrating systems where the concentration factor is a fixed feature of the whole system.

[0069] In one embodiment a Cavity absorber receiver assembly is attached to the bottom of CPC **26**. This is shown as receiver **80** in FIG. **7**. The embodiment shown in FIG. **2** blends the receiver and thermal storage functions, and so the receiver is not explicitly diagrammed. The cavity absorber of the receiver assembly consists of thermal insulating top cover **28** and absorber surface **32**. Top cover **28** has receiver input aperture **120** which admits the light from the exit aperture of CPC **26** into the cavity absorber. The inner surface of lid **28** is highly reflective, and constructed from high temperature resisting ceramic material such as fire brick.

[0070] In one embodiment, absorber surface **32** is directly attached to thermal storage graphite blocks that form thermal store **30**. Graphite is particularly suited to high temperature sensible heat thermal storage, as its melting point is extremely high (3652-3697 degrees Celsius) and it maintains its structural integrity close to its melting point. Large graphite blocks with integral cooling channels have long been used in the core of a variety of nuclear reactors. Integrating cooling channels and heat exchangers into the graphite storage blocks eliminates large amounts of high temperature piping and enables higher temperature operation than is feasible with current high temperature piping materials.

[0071] As an example to illustrate the scale, 50,000 cubic meters of solid graphite using a thermal delta of 500 degrees Celsius can store over 8 million kilo-Watt hours of thermal energy (28,800,000,000 kJ), and provides sufficient thermal storage capacity to average out the day to night fluctuation in input solar energy for the system described in the first embodiment at mid latitudes. This provides a 24 hour continuous source of thermal energy with considerable flexibility in when during the 24 hour period the stored thermal energy can be withdrawn for use in generating electricity.

[0072] The thermal storage capacity required varies with latitude, and the electrical demand curve it is desired to satisfy. The most thermal storage is needed for systems at high latitude. Continuous constant electrical power requires more storage than a system with more electrical output during daylight hours. While thermal storage is a technology that helps make solar energy a practical alternative for all electric power generation, it is also a considerable expense, perhaps half the total system cost, and perhaps the single biggest cost element.

[0073] In one embodiment, absorber surface **32** transfers heat to pressurized steam which is used to directly drive Rankine cycle steam turbines. This embodiment is particularly useful when built beside an existing fossil fueled power plant and uses the existing turbines, generators, cooling, and distribution facilities etc. This embodiment acts as a supplement to the existing power plant, reducing its operation to non daylight hours and thus reducing fuel consumption and carbon generation by large percentages. This is potentially a very economic alternative as it re-uses existing infrastructure and avoids the costs of a thermal storage unit.

[0074] It should be noted that FIG. **2** illustrates the only part of the system that consumes any land on the earth's surface. The land area needed to house elements found at conventionally fueled power plants, such as turbines, generators, heat exchangers and electricity distribution equipment which are not shown in FIG. **2** easily fits in the area within the foundation and anchor structure.

DETAILED DESCRIPTION—FIGS. 3, 4, 5 HIGH ALTITUDE ELEMENTS

[0075] FIG. **3**A and FIG. **3**B are perspective views of the solar concentrator and collimator assembly shown as part of the entire system in FIG. **1**. Offset parabolic mirror concentrator **36** is rigidly attached to offset parabolic mirror collimator **38** with beam structure **40**. The assembly is neutrally buoyant. Curved shading lines **42** illustrate the offset parabolic curved surface of mirror **36**. Beam **40** serves two main purposes. It accurately positions mirrors **36** and **38** at a common optical focus, and it acts as a structural support for light pipe segment **21**, enabling its entry aperture to be positioned very close to mirror **38**. As the concentrated light reflected off mirror **38** has a wide divergence angle, positioning the light pipe entry close to mirror **38** ensures the capture of most of the collected solar energy.

[0076] In one embodiment, mirror **36** is approximately 2.3 km in diameter. The mirror **38** is approximately 180 m in diameter. The light tube **20** is also approximately 180 m in diameter and approximately 20 km long. These dimensions are in the range appropriate for a one Giga Watt (GW), continuous output electricity generation system. The mirrors **36** and **38** are rigid, lightweight, buoyant, gas filled, structures. The light tube **20** is a flexible, buoyant, gas filled, pressurized, structure. The buoyancy gas is either helium or hydrogen. In one embodiment the light tube stores the buoyancy gas within a portion of the light tube to avoid the need for additional buoyancy elements attached external to the light tube.

[0077] Alt-azimuth mount **44** is used to enable the solar receiver assembly to accurately track the sun while compensating for wind forces on the concentrator and collimator assembly, and motion in the base of the mount **44** attached to the top of light pipe **20**. Altitude and azimuth motors within mount **44** are controlled by a closed loop feedback sun tracking system. The structure consisting of concentrator **36**, collimator **38** and beam **40** pivots in altitude around altitude pivot **46**. The structure pivots in azimuth around the axis of alt azimuth base attached to the top of light pipe **20**.

[0078] In addition to, or as a replacement for motors in the alt azimuth mount, fan thrusters on the solar concentrator structure can provide the forces that move the concentrator assembly in order to track the sun.

[0079] Light pipe segment **21** is flexible and is slightly narrower in diameter than light pipe **20**. The end of light pipe segment **21** attached to the mount **44** telescopes within light pipe **20**. This allows it to lengthen as the angle of altitude is increased and the amount of bend is reduced, and also to rotate freely within light pipe **20** as the angle of azimuth is adjusted.

[0080] In a first embodiment, parabolic concentrator **36** is designed to have 200 times the aperture of parabolic collimator **38** in order to achieve a concentration factor of 200. The concentration factor used in the first embodiment is an engineering design choice constrained by several factors, primarily the reflection efficiency and acceptance angle of the material on the inner surface of the light tube **20**, and the light tube aspect ratio, and is not a fixed feature of the invention. As the concentration factor is increased the dispersion angle of the concentrated light beam also increases. This results in more light absorption in the light tube as more reflections occur in the path down the tube to the earth's surface.

[0081] The other variable that affects the transmission effectiveness of the light pipe is the length to width ratio, or aspect ratio, of the light pipe. The larger this number is, the higher the energy losses are, as more reflections occur on average as light traverses the light pipe. Numbers for this aspect ratio are usually in the region of 100 for light pipes with efficient reflective surfaces.

[0082] So in summary, a combination of the optical design, the concentration factor, the light pipe wall reflectivity, and the light pipe aspect ratio, all influence the overall transmission efficiency of the light pipe.

[0083] Very high reflectivity light pipe wall material with reflective efficiency exceeding 99.9% enables embodiments that do not need collimator **38**. The acceptance angle of the light pipe then sets the limits for concentrator **36**.

[0084] FIG. **4**A and FIG. **4**C show one method for constructing concentrator mirror **36** and collimator mirror **38**. FIG. **4**A shows a small section of the surface structure of mirror **36**, the rest of which is identical in form. It consist of a rigid tetrahedral truss made from struts **48** and connecting nodes **50**, which support hexagonal mirror segments shown in FIG. **4**B. FIG. **4**C shows a back view of FIG. **4**A and more clearly illustrates the attachment of mirror segments **4**B to the truss at three surface nodes **56**. As can be seen from FIG. **4**A and FIG. **4**C there are nine struts **48** and two nodes **56** for each hexagonal mirror segment.

[0085] The struts **48** are light weight hollow tubes. Nodes **50** in one embodiment are dodecahedral and have connectors on each face to attach struts **48**. Struts **48** and nodes **50** are standardized elements and mass producible at low cost. The parabolic curvature of the truss is created by slightly increasing the length of the inner layer of struts. The degree of lengthening required is small and is accomplished in one embodiment with spacers. Another embodiment uses linear actuators to adjust strut lengths and more accurately control the structure's shape. This helps compensate for factors that affect the structure's accuracy, such as wind load and thermal expansion and contraction.

[0086] Mirrors **36** and **38** are shown in FIG. **3** as approximately **150** meter thick structures. The structural elements shown in FIG. **4**A are used to fashion the surface skins of mirrors **36** and **38**. The same structural elements without the mirror segments fashion the back skin of mirrors **36** and **38**. Clearly the struts and nodes used to fashion the structures for mirror **36** are longer than those used to fashion the structures for mirror **38**.

[0087] The back and front skins of mirrors **36** and **38** are connected via long struts arranged in the same tetrahedral fashion used to form the skin layers. These long struts are fashioned from the same small truss elements consisting of struts **48** and nodes **50**. Thus the overall structure of mirrors **36** and **38** can be considered as a "sandwich" of two stiff thin skins separated by a substantially hollow core with interior tetrahedral and octahedral spaces formed within a tetrahedral truss. This is the same structure used to fashion the mirror skins repeated at a larger scale.

[0088] The large interior octahedral and tetrahedral spaces within the tetrahedral truss are filled with like shaped gas bags fashioned from thin impermeable film material such as PET film, and filled with buoyancy gas such as helium or hydrogen maintained at ambient pressure and temperature. For mirror **36**, these gas bags will have edge lengths measured in hundreds of meters. The edges are attached to the nodes on the interior struts and the surface skin and provide the buoyancy that supports the overall structure.

[0089] In one embodiment, the mirror segments **4**B are made from an air tight, lightweight, reflective, pressure tensioned membrane **54** attached to a light rigid air tight frame **52**. In one embodiment the membrane is fashioned from aluminized PET film. This relatively fragile material is commonly used in space based inflated structures, and it and similar thin film materials can be used in this application because of the benign "space like" weather free environment in the stratosphere.

[0090] The curvature of the mirror **4**B surface membrane is controlled by providing reduced air pressure within the frame, thereby stretching the membrane into an approximate spherical curvature. This can be accomplished to a high degree of accuracy because the degree of curvature required is very small. A common measure of the degree of curvature of an optical element is its focal length to aperture ratio, (f/D). For example a 20 meter aperture mirror segment with a focal length of one kilometer has an f/D of 500, which is very large. At such large ratios, spherical surfaces are practically indistinguishable from parabolic surfaces, and are easily formed to high accuracy.

[0091] An optical feedback system within the mirror segment measures the mirror depth of curvature on the back of the mirror membrane via an accurate distance measuring device, and adjusts the internal air pressure via a feedback control system to establish and maintain the desired depth of curvature for the mirror segment **4**B. In this way a common mirror segment can be manufactured, and then adjusted during operation to a particular curvature depending on its position within the larger mirror assembly. The feedback control system also compensates for manufacturing variability in film thickness etc. It can maintain the desired curvature despite varying conditions such as atmospheric temperature and pressure, segment wall and membrane surface expansion and contraction under heating and cooling cycles, and gas leakage through the surface membrane.

[0092] In another embodiment mirror segment **4**B is fabricated using very thin carbon composite replica mirror technology that has been developed for large space based optical telescopes. This requires many unique fabrication molds, but does not need active control of the membrane and is more durable. It is a suitably lightweight fabrication technology.

[0093] Each mirror segments **4**B is attached to the tetrahedral truss at three surface connecting nodes **56** using linear actuators. Each surface node thus acts as an attachment point for three different mirrors and thus three linear actuators. An optical measurement system measures the precise orientation of each mirror segment with respect to the common focus, and the sun. Each mirror segment orientation is then controlled via feedback control adjustment of the length of its three attached actuators, to reflect light to the common focus with great accuracy. This type of system is used in large segmented mirror optical astronomical telescopes to position mirror segments to extremely high accuracy. The mirror segments and linear actuators described in this embodiment are much larger and less accurate than those used in astronomical telescopes, but the positioning method is the same, and pointing accuracy in the order of 0.1 mrad is easily achievable using simple stepper motor linear actuators.

[0094] The use of linear actuators to position mirror segments serves additional purposes:

[0095] 1) The actuators can be adjusted to ensure that light from some mirror segments is not directed from mirror **36** to mirror **38** and is "dumped". This is useful when it is desired to reduce the amount of light collected.

[0096] 2) With sophisticated control software the actuators can be used as a fine grained sun tracking mechanism for each mirror segment. This is like the systems used in heliostat arrays, but for a much smaller range of motion. This mechanism can compensate for inaccuracies or slow response in the alt azimuth control of the overall mirror structure **36**.

[0097] The rigid truss framework forms the stiff and accurate reaction structure that enables the mirror segments to maintain their position with sufficient accuracy. It also provides the framework to hold the ambient pressure, buoyancy gas filled bags. At 20 km altitude, atmospheric pressure is low and substantial volume is needed to provide meaningful lift. The design of both struts and mirror segments emphasizes light weight. For example for an average structural weight of 1 kg/m^2 of mirror aperture area, a volume of approximately 10 m^3 of Helium is needed to provide neutral buoyancy at an altitude of 20 km. A mirror structure 100 meters thick can thus provide lift for an average structural mass of approximately 10 kg/m^2.

[0098] Light weight rigid structures are practical for this application because the structural loads are very light. Wind speed is very low and steady at 20 km, and buoyancy removes much of the stress of supporting gravitational forces. At 20 km altitude, mirrors **36** and **38** are safely in the stratosphere and above all weather in the troposphere, including clouds, moisture, dust, wind, and the jet stream.

[0099] The 20 km height of the mirrors in the atmosphere is illustrative. The actual height of individual systems may vary with geographic location. The height of the boundary between the troposphere and the stratosphere varies with latitude, season of the year and local weather conditions. The boundary height is generally lower at higher latitudes and in the winter.

[0100] FIG. **5** Illustrates another embodiment similar to FIG. **4**, but using circular mirror segments **55** arranged in a Fresnel fashion. The supporting structure **36** is a flat thin circular cylinder and the attached circular mirror segments **55** are each mounted tilted from structure **36** to reflect light to a common focus. The structural elements, struts **48**, nodes **50** and **56**, and linear actuators are identical to those in embodiment shown in FIG. **4**. The method of construction of circular mirror segments **55** is similar to that described for hexagonal mirror segments **4**B.

[0101] Circular segments are easier to fabricate than hexagonal segments, but they cover less area due to their non space filling shape. The Fresnel approach simplifies the supporting structure, but is slightly less efficient due to shading or extra spacing requiring a larger structure with more mirrors and struts than the hexagonal segments approach.

DETAILED DESCRIPTION—FIG. 9 LIGHT PIPE

[0102] FIG. **9** is a perspective cut-out view that illustrates the structure of a portion of the wall of the light pipe tube **20**. The first embodiment uses a fiber reinforced fabric as the main wall structural element **60**. Structural fabrics have long been used to construct large inflatable structures. Among the most widely used materials are polyester fabric laminated or coated with polyvinyl chloride (PVC), and woven fiberglass coated with polytetrafluoroethylene (PTFE). The light tube is an inflated structure filled with a gases that provide buoyancy and light transparency. Dry air, nitrogen, and either helium or hydrogen are some viable options. Several transparent membranes **34** fabricated from polyethylene terephthalate (PET) or other similar transparent film, like that depicted in FIG. **2**B are positioned at points along the length of the light pipe. They contain the pressurization of the light pipe **20** and act as separators between buoyancy gas filled regions and air filled regions.

[0103] In one embodiment, vertically oriented steel cables **66** attached to the outer side of the structural fabric carry the vertical pre-tension load provided by the buoyancy of the light pipe. Cables from other materials or stronger fabrics without external reinforcement are viable alternatives.

[0104] The vertical force acts to stabilize gravity forces and the horizontal displacement of the light pipe caused by wind forces. These horizontal forces are very large, especially at the higher altitudes of the jet stream. In effect this section of the light pipe behaves approximately like a hanging catenary cable.

[0105] The diameter of the steel cables can be reduced as the tension load diminishes with height in buoyant regions of the light pipe. Ultimately, at the top of the light pipe the tension is close to zero.

[0106] At the bottom section of the light pipe **20** that connects to the second concentrator **26** and anchor structure it is beneficial to add additional structural reinforcement in a manner that enhances the stiffness of the light pipe. In one embodiment this is done using steel cable hoop reinforcement attached to the vertical steel reinforcement. This section of the light pipe **20** behaves more like a cantilever beam attached to the foundation structure, than the catenary cable of the upper portion of light pipe **20**. This stiffness helps to keep the light pipe vertical at the CPC entry which optically aligns the light pipe with the CPC without resort to complex mechanical methods. This takes advantage of the light pipes ability to accommodate gradual bends while still maintaining high transmission efficiency.

[0107] A reflective layer is attached to the inner surface of structural fabric wall **62**. In one embodiment this is a layer of aluminized PET film. Mounted to the inner wall **62** is a refracting layer **64**. In one embodiment layer **64** is made of prismatic transparent reflecting film, as used in lighting system light tubes. One such commercially available material is **3**M optical lighting film TM. This film uses the principal of total internal reflection as taught by Whitehead in U.S. Pat. No. 4,260,220, "Prism light guide having surfaces which are in octature" and can be 99% efficient in reflecting light within the acceptance angle. A portion of the small amount of light that leaks through the prismatic film **64** is reflected by the metallic reflective film **62**, further enhancing overall reflection efficiency.

[0108] Another embodiment uses multiple layers of transparent film such as PET film for layer **64** and exploits the principle of multi layer reflectance as taught by Waymouth in U.S. Pat. No. 4,895,420, "High reflectance Light Guide". This approach also only works for a limited acceptance angle. These various techniques, exploiting both reflection from layer **62** and refraction within layer **64** can exceed 99.5% overall reflectivity.

[0109] Operation—FIGS. **1**, **2**, **3**, **4**, **5**, **6**, **7**

[0110] FIG. **1**A and FIG. **1**B shows two operational positions of a first embodiment. FIG. **1**A shows the solar concentrator assembly pointing at the horizon, or approximately 0 degrees of altitude as it is at dawn and dusk. The light pipe **20** is shown straight and vertical, as is the case when no wind is blowing.

[0111] As the sun rises, light is reflected from concentrator mirror **36** onto collimating mirror **38**, and then reflected from collimator mirror **38** to the entrance aperture of light pipe segment **21**. As the light reflects off mirror **36** and **38** and is concentrated, its dispersion half angle increases from the 4.653 mrad of the incident sunlight to a larger number approaching 60 mrad at the entrance to light pipe segment **21**. The light then travels down light pipe segment **21** reflecting occasionally off the reflective walls and around the bend in the pipe at the alt azimuth mount **44** that connects to the main light pipe **20**. Light then travels down light pipe **20** reflecting occasionally off the reflective wall which has gradual bends as the light pipe adjusts to the force of the wind it experiences in the troposphere.

[0112] At the bottom of light pipe **20** at ground level the light passes through the final optical concentrator element CPC **26**, exiting the optical system and entering the thermal system

[0113] In one embodiment of a solar energy conversion system shown in FIG. **7**A receiver **80** accepts the concentrated solar energy through input aperture **120**, absorbs it, and transfers it as thermal energy to the working fluid. The working fluid is used to transfer the thermal energy to thermal store **30** via a closed loop. A second closed loop transfers heat from thermal store **30** to a high pressure, high temperature working fluid. This gas is expanded through heat engine **84**, converting the heat to mechanical work. This work is used to drive electricity generator **86**, which converts the mechanical work to electricity.

[0114] Exhaust gas from heat engine **84** passes through regenerator **92**, transferring heat to the cooler high pressure gas output from compressor **90**. After exiting regenerator **92**, the low pressure, low temperature gas passes through ambient cooler heat exchanger **88**, where it is further cooled before entering compressor **90**. High pressure pre-heated gas from the regenerator **92** enters thermal store **30**, completing the thermal circuit.

[0115] In the combined cycle solar energy conversion system embodiment shown in FIG. **7**B, the exhaust gas from heat engine **84** is used to heat high pressure, low temperature water in boiler heat exchanger **94**. This superheated water then expands as steam through steam turbine **96**, converting the heat to mechanical work. This work is used to drive electricity generator **98**, which converts the mechanical work to electricity. Condensor heat exchanger **100** cools turbine **96** exhaust gas which is then pressurized by water pump **102**. Ambient heat exchanger **88** can be much simpler for this combined cycle system.

[0116] As the day progresses, the solar concentrator and collimator tracks the sun, rotating the entire mirror and alt-azimuth mount structure in azimuth and tilting the structural axis (which is parallel to beam **40**) in azimuth. The motion is driven by motors in the alt-azimuth mount **44** which are controlled by a sun tracking control system. As is shown in FIG. **1**B, the light pipe **20** bends in response to winds in the lower atmosphere. The upper approximately 5 km portion of light pipe **20** is always kept vertical. There are no significant winds acting on this section and it is filled with buoyancy gas. This minimizes the adjustments necessary to maintain sun tracking as the base of the alt-azimuth mount moves with light pipe **20**.

[0117] Advantages

[0118] Unlike prior art concentrating solar energy systems, the geographic location of these embodiments is not constrained to desert areas. This is of particular benefit to normally cloudy mid latitude locations where most large urban areas are located.

[0119] The combination of geographic flexibility and power generation without the need for any fuel provides a secure and clean energy system.

[0120] Power in the form of concentrated solar energy or electricity can be provided at any point on the earth's surface, where the definition of surface includes the entire surface, including all land and oceans. Offshore platforms could be a particularly convenient in some locations. Concentrated direct solar energy and or electricity could be provided near mines, allowing convenient high temperature processing without transportation of bulk ores.

[0121] The very small amount of land area needed means that systems can be located very near existing power plants, or existing transmission and distribution networks, which reduces or eliminates the need for new electricity transmission infrastructure.

[0122] With the thermal storage described in the embodiments a reliable and flexible power generation system that can continuously supply all energy requirements without augmentation with other power generation sources, as is required with prior art solar power and other alternative energy systems.

[0123] Energy systems that do not put carbon dioxide into the atmosphere are highly desirable. Currently all alternative energy systems suffer from major problems:

[0124] 1) They are very costly to build

[0125] 2) They are unreliable providers of electricity due to intermittent weather affects, and so need backup generation using alternate energy sources such as natural gas.

[0126] 3) They need large additional energy storage and transmission infrastructure investments.

[0127] 4) The energy is located far from users, again requiring large transmission infrastructure investments

[0128] This new system has the benefit of not producing carbon dioxide and has none of these problems. The bottom line is clean secure energy can be provided at much lower cost.

[0129] The benefits of suspending a collector in the stratosphere are the reliability of the energy source, the higher incident energy density, and the benign stable calm low wind weather free environment. These benefits come at the price of lower atmospheric density, which means less buoyant lift and a consequent need for a very lightweight structure. This complicates the use of heavy energy absorbing and/or power conversion equipment at the collector in the stratosphere, and explains the benefit of embodiments using a light pipe to transport the light energy directly to the earth's surface, without conversion.

[0130] It is envisaged that the large buoyant optical structures, particularly mirror structures **36** and **38** will be assembled at one or more centralized factory locations in a highly automated fashion. The assembled structures will then be raised by their own buoyancy into the stratosphere and "flown" to their destination anywhere on the planet. There they will be connected to the light pipe and ground based elements. This manufacturing method greatly reduces cost, improves quality, and speeds construction. It is envisaged that when production is mature, complete utility size electricity generating facilities could be operational in less than a year from breaking ground. This compares with current technologies which require three to five or more years to construct.

[0131] Although the present invention has been described in terms of a first embodiment, it will be appreciated that various modifications and alterations might be made by those skilled in the art without departing from the spirit and scope of the invention. Though the first embodiment is described using offset parabolic mirror arrays for the concentrator and collimator elements, other forms of concentrators and collimators using a myriad of different optical geometries are possible. Also refractive optics elements such as lightweight arrays of thin prismatic elements, or inflatable reflective or refractive optical elements are also possible.

[0132] All that is required of the light tube is a sound gas tight structure and a high inner surface reflective efficiency, both of which can be met with many alternative materials and structural approaches. As described in the specification, there are various structural techniques to stabilize the light pipe against atmospheric wind forces including:

[0133] a) pre-tensioned hanging cables using excess buoyancy to provide the tensioning force,

[0134] b) cable stays,

[0135] c) rigid light pipe walls.

[0136] Each of these techniques or a combination of some or all is possible.

[0137] The invention should therefore be measured in terms of the claims which follow.

What is claimed is:

1. A method of providing concentrated solar energy for use at any location on the earth irrespective of weather, comprising:

a) providing a light weight solar concentrator,
b) providing a rigid buoyant structure supporting the solar concentrator,
c) suspending the buoyant structure high in the earth's atmosphere,
d) pointing the concentrator continuously at the sun, collecting solar energy,
e) concentrating solar energy,

whereby concentrated solar energy can be provided for use at high altitude at any location on the earth, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

2. The method of claim **1**, further comprising:

a) providing a collimator coupled to the solar concentrator of claim **1**,
b) providing a light pipe coupled to said collimator high in the earth's atmosphere at one end and connected to the earths surface at the other end,
c) transmitting the concentrated solar energy from the solar concentrator, through said collimator, and then through said light pipe to the earth's surface,

whereby concentrated solar energy can be provided for use at any location on the earth's surface, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

3. The method of claim **2**, further comprising:

a) providing a second concentrator at earth's surface coupled to said light pipe,
b) concentrating solar energy with said second concentrator,
c) providing a solar receiver optically coupled to said second concentrator,
d) receiving said concentrated solar energy,
e) heating a first working fluid in said receiver,
f) providing a thermal storage element thermally coupled to said receiver,
g) storing heat in said thermal storage element by transferring heat from said first working fluid,
h) heating a second working fluid from heat stored in said thermal element when needed to generate electricity,
i) providing a heat engine thermally coupled to said thermal storage element,
j) expanding said second working fluid to drive said heat engine,
k) providing a generator mechanically coupled to said heat engine,
l) driving said generator to produce electricity,

whereby electricity can be continuously provided at any location on the earth's surface.

4. The method of claim 2, further comprising:
a) providing a second concentrator at earths surface coupled to said light pipe,
b) concentrating solar energy with said second concentrator,
c) providing a solar receiver optically coupled to said second concentrator,
d) receiving said concentrated solar energy,
e) heating a working fluid in said receiver,
f) expanding said working fluid to drive said heat engine,
g) providing a generator mechanically coupled to said heat engine,
h) driving said generator to produce electricity,
whereby electricity can be provided during daylight at any location on the earth's surface.

5. The method of claim 2, wherein:
the light pipe is a buoyant, pressurized, thin walled tube structure with an air tight structural skin and a highly reflective inner wall surface.

6. The method of claim 1, further comprising:
a) providing a light pipe coupled to said concentrator high in the earth's atmosphere at one end and connected to the earths surface at the other end,
b) transmitting the concentrated solar energy from the solar concentrator, through said light pipe to the earth's surface,
whereby concentrated solar energy can be provided for use at any location on the earth's surface, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

7. The method of claim 6, further comprising:
a) providing a solar receiver optically coupled to said light pipe,
b) receiving said concentrated solar energy,
c) heating a first working fluid in said receiver,
d) providing a thermal storage element thermally coupled to said receiver,
e) storing heat in said thermal storage element by transferring heat from said first working fluid,
f) heating a second working fluid from heat stored in said thermal element when needed to generate electricity,
g) providing a heat engine thermally coupled to said thermal storage element,
h) expanding said second working fluid to drive said heat engine,
i) providing a generator mechanically coupled to said heat engine,
j) driving said generator to produce electricity,
whereby electricity can be continuously provided at any location on the earth's surface.

8. The method of claim 6, further comprising:
a) providing a solar receiver optically coupled to said light pipe,
b) receiving said concentrated solar energy,
c) heating a working fluid in said receiver,
d) providing a heat engine thermally coupled to said thermal storage element,
e) expanding said second working fluid to drive said heat engine,
f) providing a generator mechanically coupled to said heat engine,
g) driving said generator to produce electricity,
whereby electricity can be provided during daylight at any location on the earth's surface.

9. The method of claim 1, further comprising:
a) providing energy conversion means to convert the concentrated solar energy to high voltage electricity,
b) Providing buoyant high voltage transmission lines connected from the high altitude high voltage convertor to the earths surface,
c) Transmitting high voltage electricity from said high altitude high voltage convertor to the earths surface,
whereby high voltage electricity can be provided during daylight at any location on the earth's surface.

10. The method of claim 1, wherein the concentrator is a large multi element mirror array.

11. A system capable of concentrating solar energy at any location on the earth irrespective of weather, the system comprising:
a) a light weight solar concentrator,
b) a light weight rigid buoyant structure connected to and supporting the solar concentrator suspended high in the earth's atmosphere,
c) means for said concentrator to track the sun, such means including steerable mirrors, and a steerable structure,
whereby uninterrupted concentrated solar energy can be provided for use at any location at high altitude on the earth, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

12. The system of claim 11 further comprising:
a) a collimator optically coupled to the solar concentrator of claim 11,
b) a light pipe optically coupled to said collimator high in the earth's atmosphere at one end and connected to the earths surface at the other end, said light pipe capable of transmitting the concentrated solar energy received from said solar concentrator, through said light pipe to the earth's surface,
whereby concentrated solar energy can be provided for use at any location on the earth's surface, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

13. The system of claim 12 further comprising:
h) a second concentrator at earth's surface optically coupled to said light pipe, said second concentrator further concentrating said solar energy,
i) a receiver, optically coupled to said second concentrator, receiving said concentrated solar energy, said receiver heating a first working fluid,
j) a heat storage element in fluid communication with said receiver, storing heat transferred from said first working fluid, said heat storage element heating a second working fluid when needed to generate electricity,
k) a heat engine in fluid communication with said heat storage element, expanding said second working fluid generating work,
l) a generator, mechanically connected to said heat engine, generating electricity from said work,
whereby electricity can be continuously provided at any location on the earth's surface.

14. The system of claim 12 further comprising:
a) a second concentrator at earth's surface optically coupled to said light pipe, said second concentrator further concentrating said solar energy,
b) a receiver optically coupled to said second concentrator, receiving said concentrated solar energy, said receiver heating a working fluid,

c) a heat engine in fluid communication with said receiver expanding said working fluid, generating work,

d) a generator, mechanically connected to said heat engine, generating electricity from said work,

whereby electricity can be provided during daylight at any location on the earth's surface.

15. The system of claim **12** wherein said light pipe is a buoyant, pressurized, thin walled tube structure with an air tight structural skin and a highly reflective inner wall surface.

16. The system of claim **11** further comprising:

a light pipe coupled to said concentrator high in the earth's atmosphere at one end and connected to the earths surface at the other end, said light pipe capable of transmitting the concentrated solar energy received from said solar concentrator, through said light pipe to the earth's surface,

whereby concentrated solar energy can be provided for use at any location on the earth's surface, such use including generation of electricity via thermal or photovoltaic means and, direct and indirect process heat.

17. The system of claim **16** further comprising:

a) a solar receiver at earth's surface optically coupled to said light pipe, receiving said concentrated solar energy, said receiver heating a first working fluid,

b) a heat storage element in fluid communication with said receiver, storing heat transferred from said first working fluid, said heat storage element heating a second working fluid when needed to generate electricity,

c) a heat engine in fluid communication with said heat storage element, expanding said second working fluid generating work,

d) a generator, mechanically connected to said heat engine, generating electricity from said work,

whereby electricity can be continuously provided at any location on the earth's surface.

18. The system of claim **16** further comprising:

a) a receiver optically coupled to said light pipe, receiving said concentrated solar energy, said receiver heating a working fluid,

b) a heat engine in fluid communication with said receiver expanding said working fluid, generating work,

c) a generator mechanically connected to said heat engine, generating electricity from said work,

whereby electricity can be provided during daylight at any location on the earth's surface.

19. The system of claim **11** further comprising:

a) power conversion means to convert the concentrated solar energy to high voltage electricity,

b) buoyant high voltage transmission lines connected from the high altitude high voltage power convertor to the earths surface, said transmission lines transmitting high voltage electricity from said high altitude high voltage power convertor to the earths surface,

whereby high voltage electricity can be provided during daylight at any location on the earth's surface.

20. The system of claim **11** wherein said concentrator is a large multi element mirror array.

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