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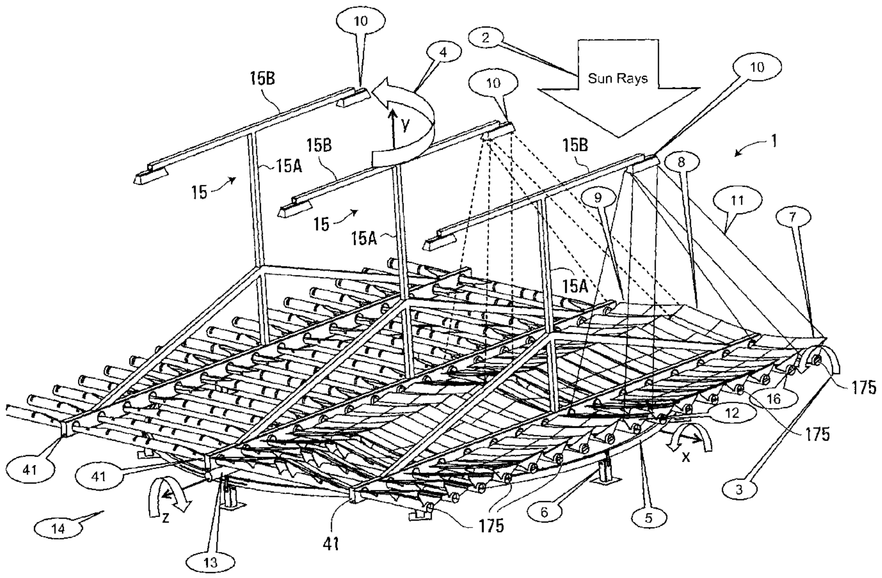


FIG. 1

(57) **Abstract**: A solar collector comprises a plurality of reflectors positioned in series along a first direction and a receiver for receiving solar radiation reflected by the reflectors. A rotary support supports each reflector for movement about a respective axis orthogonal to the first direction to enable the angle of elevation of each reflector to be varied to enable reflected solar radiation to be directed onto the receiver with changes in elevation of the sun. An azimuthal support is provided to enable the azimuthal direction of the reflectors to be varied with changes in the azimuthal direction of the sun. The reflectors are parabolic in a direction orthogonal to the first direction to concentrate reflected solar radiation onto the receiver.

SOLAR COLLECTOR

Field of the Invention

The present invention relates to solar collectors, and in particular, but not limited to solar collectors having a plurality of reflective elements for reflecting solar radiation onto a common receiver.

Background of the Invention

Solar collectors for collecting solar energy generally fall into one of two categories: concentrating and non-concentrating. Concentrating solar collectors typically comprise a reflector for reflecting and concentrating received solar radiation towards an absorber. The absorber may include a conduit for carrying a heat transfer fluid for absorbing solar thermal energy and/or an array of photovoltaic cells for converting solar energy into electrical energy. The reflector is either in the form of a circular dish with the focal position above the center of the dish, or a trough-like, parabolic reflector which produces a line focus along the length of the reflector. In the latter case, the absorber typically comprises a radiation absorbing tube positioned centrally above the reflector and extending along its length.

Focussing or concentrating solar collectors typically require some type of sun tracking mechanism and tracking control system to vary the orientation of the collector to maintain the focal position of the solar radiation of the absorber surface. Non-focusing solar collectors generally comprise flat, solar absorbing panels which are fixed in position and do not actively track the sun.

An example of a trough-like solar collector system is disclosed in WO 2005/090873. The solar collector comprises a parabolic trough-like reflector having a longitudinal absorber positioned above the reflector and mounted thereon by means of a central support upstanding from the reflector. The reflector includes spaced apart ribs fixed to the underside of the reflector panel to help maintain the shape of the reflective surface. The absorber comprises a longitudinal plate having a radiation absorbing surface which may include an array of solar cells mounted thereon. A conduit is positioned adjacent the back of the plate for transferring solar thermal energy into a heat transfer fluid. Transparent panels extend from each side of the absorber to opposed longitudinal edges of the reflector to protect the reflective surface from weathering and to provide additional structural rigidity.

An example of a parabolic trough solar thermal electric plant is shown in Figure 25.

Another known solar collector has a Fresnel-based reflector comprising a one-dimensional array of elongate reflector members all mounted in a fixed position frame just above the ground in a substantially horizontal plane. An elongate receiver is positioned above and between the ends of the reflector assembly and extends from one side to the other. The angle of elevation of a number of reflector elements can be varied in order to track the sun's elevational movement to maintain the direction of solar radiation towards the receiver. An example of a solar thermal electric plant which uses a Fresnel-based solar collector is shown in Figures 26 and 27.

Summary of the Invention

According to one aspect of the present invention, there is provided a solar collector comprising a receiver, reflector means for reflecting solar radiation towards said receiver and for concentrating the reflected radiation in a first direction, wherein said reflector means comprises a plurality of reflectors positioned in series along said first direction, support means for supporting each reflector for movement about an axis orthogonal to said first direction, to enable the angle of elevation of each reflector to be varied, each respective axis being spaced apart along said first direction, and wherein said support means is adapted to enable the azimuthal direction of said reflectors to be varied.

Advantageously, in this arrangement, with the support means adapted to enable the azimuthal direction of the reflectors to be varied, the azimuthal orientation of the reflectors can be changed depending on the position of the sun to enable the reflectors to reflect a greater proportion of the received solar energy onto the receiver. For example, the azimuthal orientation of the reflectors may be controlled so that the first direction in which the reflector means concentrates the reflected radiation by virtue of the angle of elevation of each reflector is substantially aligned with the direction of incident solar radiation. In some embodiments, the support means includes a support and bearing means for movably supporting said support to enable the azimuthal direction of the reflectors to be varied.

In some embodiments, one or more reflectors are adapted to concentrate reflected solar radiation in a second direction orthogonal to the first direction. Advantageously, this enables the solar radiation reflected from the reflector means to be concentrated over a smaller area, thereby increasing the concentration ratio and enabling the dimension of the receiver to be reduced, for both material savings and cost and also significantly reduced wind loading.

In some embodiments, each reflector has opposed side edges spaced apart in a direction along a respective rotational axis, and the receiver is positioned between the opposed side edges. Advantageously, this arrangement enables the receiver to receive reflected solar radiation from reflective surfaces on both sides of the receiver, thereby increasing the amount of solar radiation that the receiver can receive from the reflector and helping to reduce the angular range of reflected radiation at the receiver for more efficient energy capture. In some embodiments, the reflector may be symmetric on either side of the receiver in order to simplify and reduce production costs.

In some embodiments, one or more reflectors each comprises a first reflective surface on one side of the receiver and a second reflective surface on the other side of the receiver, and in which the first and second reflective surfaces are angled oppositely relative to a respective axis towards the receiver.

In some embodiments, at least one of the first and second surfaces is curved to concentrate the reflected solar radiation in the second direction.

In some embodiments, at least one of the first and second reflective surfaces comprises a plurality of discrete reflective surfaces arranged along the rotational axis, each angled relative to the axis to reflect radiation towards the receiver. In some embodiments, each discrete reflective surface has opposed side edges spaced apart along the axis, wherein adjacent side edges of at least two adjacent discrete reflective surfaces are at different heights. In some embodiments, the plurality of discrete surfaces may comprise first and second discrete surfaces, the first surface being closer to the receiver than the second discrete surface, and wherein the distal side edge of the first discrete surface is positioned above the proximal, adjacent side edge of the second discrete surface, thus forming a Fresnel-based reflective surface.

In some embodiments, the reflector means has opposed ends spaced apart in the first direction by a first dimension, the receiver has opposed ends spaced apart in the first direction by a second dimension, wherein the second dimension is shorter than the first dimension. In this embodiment, one or more reflectors may be positioned beyond one or both ends of the receiver. Reflectors spaced at different distances from the receiver may have different focal lengths for concentrating solar radiation in the second direction in order to control the area of concentrated solar radiation from each reflector at the receiver. For example, the focal length of the reflectors may increase with distance from the receiver (along the first direction).

In some embodiments, the reflector means comprises a plurality of reflector elements positioned along the first direction such that different reflector elements are spaced from the receiver by different distances. Reflector elements at different distances from the receiver may be tilted with respect to the second direction by different tilt angles to direct reflected solar rays from each reflector element onto the receiver.

In some embodiments, the receiver is positioned between the ends of the reflector means. For example, the receiver may be positioned at or approximately at a mid-point between the ends of the reflector means. Advantageously, in embodiments in which the reflectors concentrate solar radiation in the second direction (orthogonal to the first direction) and in which the focal length of the reflectors is different depending on their distance from the receiver, this arrangement enables the reflector means to be substantially symmetric in the length direction about the middle or mid-point so that the reflector means can comprise pairs of reflectors having the same focal length in the second direction (one on either side of the mid-point), thereby possibly saving production costs.

In some embodiments, the receiver includes a concentrator for concentrating in at least one of the first and second directions, solar radiation reflected from the reflector means. Advantageously, this arrangement enables the solar energy from the reflector to be concentrated even further.

In some embodiments, the concentrator means comprises a one or two-dimensional array of concentrators.

In some embodiments, the receiver comprises an absorber for absorbing solar energy and a light capturing element having an entrance aperture for receiving the solar radiation and an exit aperture for passing solar radiation to the absorber, wherein the light capturing element is structured to guide solar radiation entering the entrance aperture which is not directed towards the exit aperture towards the exit aperture. Advantageously, the light capturing element enables misaligned solar radiation from the reflector to be realigned or directed onto the absorber, thereby potentially increasing the amount of reflected solar radiation that can be received.

In some embodiments, the light capturing element comprises a horn having opposed reflective internal walls which taper inwardly in a direction from the entrance aperture to the exit aperture over at least part of a distance between the entrance and exit apertures.

In some embodiments, the receiver further comprises one or more optical elements between the light capturing element and the absorber, the optical element being structured to at least one of (1) concentrate light received by the optical element onto the absorber and (2) increase the homogeneity of solar energy over an area of the absorber.

In some embodiments, the receiver comprises a plurality of optical elements each having an input for receiving light from the light capturing element.

In some embodiments, the receiver comprises one or more converters for converting solar energy to electrical energy.

In some embodiments, the receiver comprises heat transfer means for carrying heat transfer fluid to absorb thermal energy.

In some embodiments, the solar collector further comprises means for rotatably mounting the support means for azimuthal rotation about an axis. The rotatable mounting means may include a circular member substantially centered on the axis of azimuthal rotation. The circular member may comprise a circular ring. The circular member or ring may be supported on bearings spaced apart about the azimuthal axis.

Some embodiments may further comprise drive means for driving rotation of one or more reflectors about a respective axis. The drive means may comprise a single drive means, for example, a rotatable shaft which is adapted to simultaneously drive rotation of a plurality of reflectors.

Some embodiments further comprise a controller for controlling the angle of elevation of one or more reflectors to maintain the direction of reflected solar radiation towards the receiver with changes in the elevation of the sun.

Some embodiments further include a controller for controlling the azimuthal direction of the reflectors. The controller may be adapted to control the azimuthal direction to maintain the first direction substantially aligned with the direction of solar rays as the azimuthal direction of the sun changes.

In some embodiments, adjacent reflectors have adjacent edges, and the minimum distance between adjacent edges is less than one inch, for example, half an inch or less. Advantageously, by positioning the reflectors close together, higher power densities can be achieved.

In some embodiments, the receiver is adapted for azimuthal movement with the support means. For example, the receiver may be supported on the support means, or on a different support which is also adapted for azimuthal movement with the reflectors.

According to another aspect of the present invention, there is provided a solar collector assembly comprising a plurality of solar collectors as described above, wherein the support means for each solar collector comprises a common support supporting the reflector means of each solar collector. In some embodiments, the receiver of each solar collector is mounted on the common support. In some embodiments, the common support may be adapted for azimuthal rotation about an axis.

In some embodiments of the solar collector assembly, the reflector means of the solar collectors are positioned substantially end to end and/or side by side in a one or two-dimensional array.

In some embodiments, the rotational axes of the reflectors may be positioned substantially within the same plane. In some embodiments, the plane in which the axes are contained may be substantially horizontal. Advantageously, this arrangement helps to minimize wind loading and enables all of the reflectors of the reflector means to remain relatively close to the ground or other support supporting the solar collector.

According to another aspect of the present invention, there is provided a solar collector system comprising a plurality of solar collectors each having a receiver and reflector means for reflecting solar radiation towards said receiver and support means for rotatably supporting the reflector means for azimuthal rotation about a respective axis, said axes being laterally spaced apart, and wherein at least a portion of the reflector means of one solar collector is adapted to overlap at least a portion of the reflector means of an adjacent solar collector for one or more positions of rotation about said azimuthal axis.

In some embodiments, the plurality of solar collectors have at least one angular position about the axis at which adjacent reflector means do not overlap or do not substantially overlap. Advantageously, this enables the ratio of the total area of the plurality of reflector means to the real estate area used for accommodating the plurality of reflector means to be substantially increased for one or more orientations of the reflector means. The geometrical shape of one or more reflector means may be such that at least one side or peripheral edge is substantially linear or has a shape which is complementary to or interlocks with an adjacent peripheral side or edge of an adjacent reflector means. In this orientation, the complementary contour of adjacent side edges allows any gaps between adjacent reflector means in this position to be minimized. In some embodiments, the plan view geometry of one or more reflector means is rectangular, e.g. square. At one orientation of each reflector means, adjacent sides of adjacent reflector means are substantially aligned. Adjacent reflector means may be positioned at different heights so that they do not interfere with one another when rotated. Arranging the adjacent reflector means at different heights also enables any gap between adjacent side edges to be reduced or eliminated altogether thereby enabling the density of reflector surface per unit area of real estate to be increased. The azimuthal orientation of the reflector means may be such that the total reflective area presented to the sun is at a maximum when the sun is at or near its maximum elevation.

In some embodiments, the solar collector system comprises a controller for controlling rotation of one or more solar collectors about the azimuthal axis. The controller may be adapted to control rotation such that there is substantially no overlap of the reflector means of adjacent solar collectors at a predetermined time of day or a predetermined range of times or a predetermined elevation of the sun or predetermined range of elevations of the sun.

In some embodiments, one or more solar collectors of the solar collector system may comprise a solar collector or solar collector assembly or any embodiment or variant thereof described herein.

According to another aspect of the present invention, there is provided a receiver for a solar collector comprising absorber means for absorbing solar energy, a light capturing element having an entrance aperture for receiving light and an exit aperture for passing light to said absorber, wherein said light capturing element is structured to guide light entering the entrance aperture which is not directed towards said exit aperture towards said exit aperture.

In some embodiments, the light capturing element comprises a horn having opposed reflective internal walls which taper inwardly in a direction from the entrance aperture to the exit aperture over at least part of the distance between the entrance and exit apertures.

In some embodiments, the receiver further comprises one or more optical elements between the light capturing element and the absorber, the optical element being structured to at least one of (1) concentrate light received by the optical element onto the absorber and

(2) increase the homogeneity of solar energy over an area of the absorber.

In some embodiments, the receiver comprises a plurality of optical elements each having an input for receiving light from the light capturing element. The optical elements may be arranged in a one or two-dimensional array over an area of the absorber.

In some embodiments, the absorber comprises a plurality of converters for converting solar energy to electrical energy. In some embodiments, each optical element is arranged to direct light onto at least one converter.

In some embodiments, the absorber comprises a plurality of converters for converting solar energy to electrical energy, each having conductive means (e.g. terminal means) for enabling one or both of electrical current from a respective converter and a voltage across a respective solar converter to be measured. Advantageously, this arrangement enables the performance of individual converters to be measured or monitored.

In some embodiments, the receiver comprises a number of groups, each group containing a plurality of converters for converting solar energy to electrical energy, and one or more groups comprises conductive means (e.g. terminal means) for enabling one or both of electrical current from a respective group and voltage across a respective group to be measured.

According to another aspect of the present invention, there is provided a solar collector comprising a receiver, a plurality of reflector elements for reflecting solar radiation towards said receiver, support means for supporting the reflector elements for movement relative to the receiver, so that the angle of elevation of each reflector element relative to a plane can be varied, and wherein said support means is adapted to enable movement of at least one of (1) said reflector elements and (2) said receiver in at least one of said plane and a direction orthogonal to the direction along which said angle of elevation can be varied, to enable said reflector elements to maintain the direction of reflected solar radiation onto said receiver as the direction of incident solar radiation changes in both elevation and azimuth.

For example, in some embodiments, the position of the receiver may be varied along the orthogonal direction to capture solar radiation reflected beyond the side edge of a reflector. For example, the receiver may be moved laterally and transverse to the side edge of the reflector to capture solar radiation that is reflected beyond the side edge.

In some embodiments, the support means includes a support for supporting the plurality of reflector elements and the support is adapted to rotate in the plane.

In some embodiments, the receiver is mounted for rotation about an axis transverse to the plane. For example, the receiver may be mounted on the support.

In some embodiments, each reflector has an area for reflecting solar radiation having a first dimension along a direction (e.g. x-direction in the drawings) orthogonal to the direction (e.g. z-direction in the drawings) along which the angle of elevation can be varied, and the reflector is adapted to reflect solar radiation in the orthogonal direction from said area over a second dimension at the receiver which is shorter than the first dimension. In some embodiments, the receiver has a shorter dimension in the orthogonal direction than the first dimension.

In some embodiments, each reflector is rotatably mounted for rotation about a respective axis, each axis being spaced apart in the direction along which the angle of elevation can be varied, each axis being orthogonal to the direction along which the angle of elevation can be varied.

In some embodiments, the solar collector comprises a plurality of rotatable members or shafts to rotatably mount a respective reflector thereon.

In some embodiments, mounting means are provided for mounting a reflector to a respective rotatable member or shaft, wherein the mounting means enables adjustment of the relative orientation between the member or shaft and the reflector about the longitudinal axis of the member or shaft. The mounting means may for example comprise a collar and locking means having a first state in which the collar is unlocked and capable of rotating relative to the member or shaft and a second state in which the collar is secured in a fixed orientation relative to the shaft or member.

In some embodiments, the receiver has an entrance aperture for receiving solar rays reflected from the reflector wherein the entrance aperture is oriented downwardly.

In some embodiments, the receiver is positioned at a sufficient height above the reflector that the maximum included angle of incident solar radiation from the reflector enables substantially all of the reflected light to be captured by the receiver.

According to another aspect of the present invention there is provided a solar reflector comprising a series of longitudinal members which provide a supporting means for simple two dimensional mirrors to be mounted on. The reflective mirrors may be concentrating mirrors, e.g. parabolic or Fresnel-type mirrors, and may provide an area concentration ratio of 18:1, for example, or any other desirable concentration ratio. The longitudinal members are arranged in an array to allow multiple mirrors, e.g. parabolic shapes to focus on the same area, in one embodiment 8 on either side of a central receiver, which is positioned above the array of e.g. 16 reflectors and in an optional gap between tilted mirrors so as to produce substantially no shading on the mirrors. The 16 reflectors focus on the same receiver providing a further concentration factor of 16 (or n, where n is the number of reflectors). The receiver may also include means to concentrate the solar radiation from the mirrors. The receiver may provide a further concentration ratio of 5:1, for example, or any other ratio. The combination of Fresnel concentration along one axis, plus parabolic or other concentration along an orthogonal axis, together with receiver concentration and two axis tracking, enables this embodiment to achieve 18*16*5 = 1440:1 concentration ratio.

In other embodiments, changing the number of mirrors and parabolic concentration ratio up to 80 and receiver (e.g. CPC) concentration ratio up to 7 could feasibly produce concentration ratios of 32 Fresnel mirrors* 80:1 Parabolic * receiver or CPC 7:1= 18,000:1 geometric.

In some embodiments, the receiver is fitted with a series of Compound Parabolic Curved shapes or other optical means to further focus and/or homogenize the light onto solar converters, e.g. small multi-junction solar cells, providing a further concentration ratio of up to 7 or more. This series of longitudinal members track the sun in elevation. Two or more, or all members may be actuated by a single motor and optional gear box, driven through a mechanical coupling, since identical elevation movement of the mirrors results in them all continuing to focus on the same area. In some embodiments, a drive shaft wrapped cable drive or mechanical gear box or series of levers, or other mechanism connects all the longitudinal mirror mounting tubes or members to a common motion actuating element. The entire assembly tracks the sun on Azimuth allowing a low profile structure to increase or maximize solar capture area, and reduce or minimize inter-array shading, thus providing increased power density and low cost, since the capture area per unit plan area can be 3 to 4 times conventional single axis parabolic or freznel reflector solar concentrators alone.

According to another aspect of the present invention, the primary reflector can be 0.08 to 0.25" thick aluminum (or other material, and/or other thickness), pre-laminated with reflective plastic film or other reflective film, that is formable into the two dimensional parabolic shape without losing its highly reflective optical properties.

According to another aspect of the present invention the arrays may be interleaved that is to say over lapped where every adjacent array sits higher or lower in elevation allowing near zero horizontal clearance between azimuth rotating adjacent arrays. This is one of the keys to providing high power density while only sacrificing a small, e.g. < 4% energy capture efficiency through inter-array shading.

According to another aspect of the present invention, the included angle of sun rays entering the receiver can be very small by raising the receiver higher above the plane of the parabolic reflectors. This is a very simple feature that will allow low included angles to effectively be further concentrated enabling the use of low numerical aspect ratio (highly efficient) optical fibers to capture the concentrated solar energy. Having a variable and/or small included angle in sun rays entering into the absorber, enables the use of a secondary reflector to guide mis-focused rays of sunlight into the receiver within the acceptance angle of the final stage CPC (Compound Parabolic Curve) concentrator, thus providing a very high acceptance angle or tolerance on errant azimuth and elevation tracking angles.

According to another aspect of the invention, and in some embodiments, the reflective parabolic mirrors can be elastically formed and may be made of glass, plastic and/or metal all having a reflectivity in excess of 80%, for example.

In some embodiments, the CPCs may be made of reflective or refractive glass-like material having a maximum light transmission in the 280 to 1550 nano meter light spectrum.

In some embodiments, the receiver may not require the use of a CPC as the concentration ratio from the Fresnel and parabolic or other concentrating mirror may be sufficient.

In some embodiments, a transparent diffusion plate may be incorporated in front of the absorber, e.g. solar cells to provide enhanced light mixing on the underlying solar cells to avoid hot spots.

Other aspects and embodiments of the present invention may provide or include any one or more of the following features.

A concentrating solar collector comprising an array of trough like reflectors that form a parabolic shape in the X-Y plane, each mounted on a longitudinal member (running on the x' axis) that provides rotational synchronization (about the x' axis) between longitudinally mounted reflectors and multiply arranged in a lateral array (along z' axis) to track the sun in elevation (about x' axis), where pairs of longitudinally mounted reflectors focus on common receiver areas, all mounted on a rotary turntable to track the sun in azimuth (about the y' axis).

A solar concentrator wherein pairs of parabolic reflectors are tilted toward a common receiver about the z axis by angle "a" and separated along x' axis by distance "b" so as to provide no shadowing of the receiver onto reflective parabolic surfaces.

A solar concentrator wherein the parabolic curve in the x-y plane is described by the equation:

$y=+/-mx^2$ where

$m = 1/(4fl)$

where fl is the parabola focal length

and/or where there are separate parabolas corresponding with the focal length distance from the mirror surface at x=0 to the receiver surface.

An arrangement where the mirrors are positioned symmetrically about one or more receivers in the y'-z' plane to as to reduce the number of different parabolic curves required to keep the light focused on the central receiver length in the x' direction.

A cable connected rotary drive system to activate a plurality of or all the parabolic mirrors in rotation about the x' axis by rotating a single drive shaft about the z' axis.

A longitudinal mirror mounting member that is contoured in arrays along the x' axis to provide support for the parabolic curve in the X-Y plane.

A longitudinal mirror mounting member that is fitted with a mirror support frame intermittently along the x' axis to maintain the parabolic shape.

A parabolic mirror that retains its parabolic shape substantially with minimum support.

A parabolic mirror formed from metal such as aluminum or steel formed by a stamping or rolling process.

A parabolic mirror that is formed of a composite panel where a low cost core material such as Low density polyethylene, aluminum, plastic or kraft paper honey comb matrix forms the core where one reflective and one non reflective metal skin are structurally sandwiched or laminated to form a composite stiff structural panel.

A parabolic mirror where a highly reflective film is laminated to the surface of the structural skin forming the parabolic shape.

A solar collector where the reflective surface is a thin reflective film laminated to structural metal or plastic sheet prior to forming the two dimensional parabolic surface.

A solar collector where a structural surface supports a thin reflective surface that forms the two dimensional parabolic reflective surface.

A solar collector where said reflective surface is formed by vacuum thermal forming.

A solar collector where said reflective surface is formed by fiberglass layup or spray up.

A solar collector where said reflective surface is formed by reaction injection molding.

A solar collector where said reflective surface is formed by pre-preg sheets of carbon fiber, kevlar or glass fiber sheets.

Single or multiple receiver(s) for the solar collector where the solar cells contained at the focal area of the reflectors and are housed in an environmentally protective housing covered by a translucent glass or similar material and individual Concentrating Parabolic Curves (CPCs) guide, concentrate up to a concentration ratio of 7.5

and mix the light and said cells are fluid cooled with natural or forced fluid convection.

Single or multiple receiver(s) for the solar collector where the solar cells contained at the focal area of the reflectors and are housed in an environmentally protective housing covered by a translucent glass or similar material and individual Concentrating Parabolic Curves (CPCs) guide, concentrate up to a concentration ratio of 7.5 and mix the light and said cells are air cooled with natural or forced convection.

Single or multiple receiver(s) for the solar collector where the solar cells contained at the focal area of the reflectors and are housed in an environmentally protective housing covered by a translucent glass or similar material and individual Concentrating Parabolic Curves (CPCs) guide, concentrate up to a concentration ratio of 7.5 and mix the light and said cells are conduction cooled with the aid of heat pipes to transfer the heat to a large finned area for natural or forced convection cooling.

Single or multiple receivers where CPC is formed by a reflective surface.

Single or multiple receivers where CPC is formed by a refractive optical element using total internal reflection.

Cooling fins for a receiver, where said cooling fins are substantially shaded from the sun.

Single or multiple receivers where the receiver is fitted with a mis-aligned beam redirection horn that acts to redirect light rays back into the receiver CPCs and onto the solar cells or absorber.

Single or multiple receivers where there are no CPCs and the light is not further concentrated, but still have the housing, the translucent cover, the heat sink and the mis-aligned light ray horn.

Single or multiple receivers where solar cells are connected in arrays or series and parallel to match the voltage and current requirements of specific DC to AC inverters.

Single or multiple receivers where intermediate test points are provided to determine the voltage and/or current of each cell or a group of cells to aid in focusing and aligning mirrors and to maximize solar electric energy production when the receiver is fitted with multiple solar cells.

Single or multiple receivers where only the heat is captured by supplying heat absorbed by a receiver to a fluid heat sink which is thermally insulated from heat loss to the ambient air, and where the surface of the light receiver is coated with a material that has high absorptivity and low emittance.

Single or multiple receivers as described above where both the electricity and heat are captured for useful purposes.

A thermal receiver where the geometric surface of the light receiving area is arranged in such a way as to provide multiple opportunities for reflected energy to be re-absorbed by adjacent surfaces.

An optical receiver where glass plastic or other light transmitting fibers are positioned in the focal area of the receiver as described in U.S. Patent Application

No. 12/043,706, filed on 6th March, 2008, the entire content of which is incorporated herein by reference.

An embodiment in which a secondary dichroic mirror absorbs the infrared and ultraviolet wavelength of solar input light generating useful heat and transferring it to a fluid media, and where 400-700 nm of the solar spectrum is re-directed into optical fibers, as for example shown in Figure 11.

An optical receiver where the light is focused directly on glass or other UV and IR tolerant, preferably highly optically clear fibers with low transmission losses where said fibers are thermally connected to a heat transfer fluid to capture useful heat generated and transfer a wide spectrum of light (200-1500 nm) light into the fibers or any portion of the spectrum thereof depending on the glass filter cover of the receiver or lighting needs of the process to which the light will be transported via the fiber optic cable.

A receiver for receiving reflected solar radiation and including one or more optical fibres or waveguides for receiving and guiding the received solar radiation.

An RFP concentrating solar array where the arrays are interleaved, one positioned above or below in the plane of elevation (y'-z' plane) so as to allow intermittent overlapping of the reflective surfaces during off solar noon parts of the solar day.

A mirror aiming and support mechanism which allows simple micro and macro adjustment of individual longitudinal parabolic mirror support members by providing a split collar clamped to said member with a screw adjustment for rotary micro position and two mating annular surfaces for macro adjustment, that are concentrically located about the longitudinal mirror mounting member.

A mirror member rotary support mechanism that uses multiple bearings located in a radial pattern around a tube where said bearings ride on a sleeve centrically mounted to the longitudinal mirror support member that acts as a race for the small bearings supporting such member to ride on.

A drive support mechanism comprising a cable supporting the weight of the drive shaft and with bearings positioned in a radial pattern that counteract the cable tension to keep the drive shaft concentrically positioned.

According to another aspect of the present invention, there is provided a solar collector or solar reflector having any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided a solar collector comprising a receiver, reflector means for reflecting solar radiation towards said receiver and for concentrating the reflected radiation in a first direction, said reflector means comprising a plurality of reflectors positioned in series along said first direction, support means for supporting each reflector for movement about an axis orthogonal to said first direction, to enable the angle of elevation of each reflector to be varied, each respective axis being spaced apart along said first direction, and wherein one or more reflectors are adapted to concentrate reflected solar radiation in a second direction orthogonal to said first direction.

According to another aspect of the present invention, there is provided a receiver including a plurality of converters for converting solar energy into electrical energy and a gap between adjacent converters for accommodating a bypass diode and/or one or more electrical conductors and which are interconnected electrically with optionally flat electrical conductors either embedded in the receiver or with optionally flat electrical conductors connected (e.g. soldered) between the receivers or optionally interconnected with flat electrically conductive tabs, secured (e.g. glued) to each individual receiver using electrically conductive adhesive.

According to another aspect of the present invention, there is provided a receiver in which a plurality of rows and columns of reflective or refractive secondary concentrating optical elements, for example having concentration ratios between 1.5 and 8, allow gaps between multi-sun converters for electrical connections and cell to cell interconnecting conductors and optional bypass diodes.

According to another aspect of the present invention, there is provided a receiver having a plurality of converters for converting solar energy to electrical energy and a plurality of secondary concentrating optical elements, optionally encapsulated by an optically translucent cover on one side thereof and optionally a heat sink on the other side thereof.

According to another aspect of the present invention, there is provided a receiver including a heat sink having one or more heat pipes thermally coupled to the heat sink at at least a portion thereof (e.g. at one end), the heat sink having one or more heat transfer fin(s) at another portion thereof (for example the other end) for natural convection cooling with ambient air.

According to another aspect of the present invention, there is provided a receiver which is connected with one or more heat pipes to a fin and one or more fans for forced convection cooling, wherein the fan is powered by one or more converters for converting solar energy to electrical energy.

According to another aspect of the present invention, there is provided a receiver comprising any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided a solar collector comprising any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided a solar reflector comprising any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided an apparatus for driving angular movement of one or more reflectors of a solar collector comprising any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided an apparatus comprising any one or more features disclosed or claimed herein.

According to another aspect of the present invention, there is provided a method of collecting solar radiation comprising any one or more features disclosed or claimed herein.

Brief Description of the Drawings

Examples of embodiments of the present invention will now be described with reference to the drawings, in which:

Figure 1 shows a perspective view of a solar collector according to an embodiment of the present invention;

Figure 2 shows a plan view of the solar collector shown in Figure 1;

Figure 3 shows a side view of the solar collector of Figures 1 and 2;

Figure 4A shows an end view of the solar collector shown in Figures 1 to 3;

Figure 4B shows a view of a reflector panel in the x-y plane;

Figure 4C shows a view of a reflector panel in the x-y plane;

Figure 4D shows a view of the reflector panels of Figures 4B and 4C in the z-y plane;

Figure 5 shows two exploded perspective views of a receiver according to an embodiment of the present invention;

Figure 6 shows perspective upper and lower views of compound parabolic concentrators according to an embodiment of the present invention;

Figures 7A, 7B and 7C show front, side and bottom views of the embodiment of the receiver shown in Figure 5;

Figure 8 shows a cross-sectional view along a portion of the length of the receiver shown in Figure 7;

Figure 9 shows a perspective view of a solar cell according to an embodiment of the present invention;

Figure 10 shows a perspective side view of part of a support assembly for supporting a solar collector according to an embodiment of the present invention which includes a rotatable bearing supporting a circular support member;

Figure 11 shows a plan view of a group of four solar collectors having a geometry and positional relationship according to an embodiment of the present invention;

Figure 12 shows examples of different orientations of each solar collector of Figure 11 according to embodiments of the present invention;

Figure 13 shows tables of data which illustrate the effect of varying inclination angles on the amount of energy that can be captured by a solar collector according to embodiments of the present invention;

Figure 14 shows a perspective view and a number of different cross-sectional views of a drive shaft mechanism for rotatably supporting a reflector according to an embodiment of the present invention;

Figure 15 shows a perspective view of a drive mechanism for driving rotation and thereby changing the angle of elevation of a reflector according to an embodiment of the present invention;

Figure 16 shows a cross-sectional view through a drive shaft and reflector support shaft according to an embodiment of the present invention;

Figure 17 shows a perspective view of a mounting mechanism for mounting a reflector to a rotary support member according to an embodiment of the present invention;

Figure 18 shows a perspective view of a solar collector according to an embodiment of the present invention;

Figure 19 shows a plan or top view of the solar collector shown in Figure 18;

Figure 20 shows a side view of the solar collector shown in Figures 18 and 19;

Figure 21 shows a front view of the solar collector shown in Figures 18 to 20;

Figure 22 shows a perspective view of a solar collector according to another embodiment of the present invention;

Figure 23 shows a perspective view of a drive mechanism for changing the inclination or angle of elevation of a plurality of reflectors according to an embodiment of the present invention;

Figure 24 shows top, side and front views of a drive mechanism for changing the inclination or angle of elevation of a plurality of reflectors according to another embodiment of the present invention;

Figure 25 shows a perspective view of a parabolic trough solar collector thermal electric plant; and

Figures 26 and 27 show an example of a single axis tracking Fresnel reflector solar thermal electrical plant.

Description of Non-Limiting Embodiments

Figure 1 shows a three quarter view of a Reflective Fresnel Parabolic (RFP) two axis tracking Solar Collector or Concentrator 1, according to an embodiment of the invention. The solar collector comprises a receiver 10, and reflector means for reflecting solar radiation towards the receiver and for concentrating the reflected radiation in a first direction, e.g. along the z direction. The reflector means comprises a plurality of reflectors positioned in series along the first direction. The solar collector further comprises support means for supporting each reflector for movement about an axis, e.g. axis x, orthogonal to the first direction (e.g. z direction), to enable the angle of elevation of each reflector to be varied. Each respective axis is spaced apart along the first direction, and the support means is adapted to enable the azimuthal direction of the reflectors to be varied.

In this embodiment, each reflector of the reflector means comprises first and second reflector members 7, 8, although in other embodiments, one or more reflectors may be continuous between its opposed side edges. In this embodiment, each reflector is shaped to concentrate solar radiation reflected therefrom in a second direction (i.e. along the x direction in the embodiment shown in Figure 1) which is orthogonal to the first direction (i.e. z direction). In this embodiment, each reflector is curved, e.g. parabolic, in the x-y plane, in order to concentrate solar radiation reflected therefrom in the second, e.g. x-direction. In other embodiments, one or more reflectors may have a Fresnel type configuration to concentrate reflected radiation in the second (e.g. x) direction. In this case, the reflective surface of the reflector on one or both sides of the receiver may comprise a plurality of discrete reflective surfaces which may be planar or parabolic in the second direction and which are arranged in series along the rotational axis of the support means.

In the present embodiment, the reflector surfaces are substantially planar in the first (e.g. z) direction, although in other embodiments one or more may be curved to concentrate solar radiation along the first direction.

In this embodiment, the support means for supporting each reflector comprises a longitudinal member 175, e.g. rotary shaft, on which each reflector is mounted. The longitudinal, rotary support members are spaced apart along the first, e.g. z-direction, as shown in Figure 1. Each longitudinal member 175 is rotatable about its longitudinal axis to enable the elevation angle or inclination of each reflector to be varied. This enables each reflector to be controlled to maintain the direction of reflected radiation onto the receiver 10 as the elevation of the sun changes over time. In some embodiments, fewer than all of the reflectors of the reflector means may be capable of having the angle of elevation varied.

In this embodiment, the support means includes a longitudinal member or support beam 41 between the reflector members 7, 8 of each reflector and which extends along the first, e.g. z direction. The longitudinal member 41 may be adapted to rotatably support one or more rotatable longitudinal members 175 and/or support the receiver 10. The solar collector further includes a support 15 for supporting the receiver above the reflector means. In the embodiment of Figure 1, the support 15 includes an upright member or mast 15A extending from the longitudinal member 41 and an upper longitudinal member 15B extending laterally from the upright member 15A for supporting the receiver 10. Advantageously, the upright member 15A has a width in the z direction which is sufficiently small to substantially prevent the receiver support from shadowing the reflector means when the direction of solar rays is substantially parallel to the z-y plane.

In this embodiment, the support means for enabling the azimuthal direction of the reflectors to be varied comprises a circular support member, for example, support ring 5 which is rotatably supported on a plurality of bearing members 6 which are themselves supported by a suitable support, for example, the ground or a suitable structure or substrate, for example a building, foundation, pile or other support. The support ring 5 is supported for rotation about an azimuthal axis, e.g. y-axis shown in Figure 1. In other embodiments, the support means may include any other structure for enabling the azimuthal direction or orientation of the reflectors to be varied, and may comprise, for example, a track which may be curved but not necessarily circular. Further, optional and non-limiting features of embodiments of the solar collector are described below.

The azimuthal direction of the solar collector may be varied by a motor, and controlled by a controller in response to changes in the sun's position, as measured by a suitable sensor or tracked by any other means. The controller may be adapted to control the azimuthal direction of the solar collector to maximize the amount of solar energy received at the receiver as the sun's position changes, or to maintain the amount of solar energy received by the receiver above a predetermined value as the sun's position changes. For example, an azimuth tracking motor controlled by a hybrid tracking control system controls and may be adapted to maximize the current produced by solar cells of the receiver through the use of an algorithm, e.g. a perturbation algorithm, running simultaneously with a closed loop optical encoder feed back on solar position. In some embodiments, the azimuth rotational angle 4 aligns the solar cell support mast(s) 15 with the sun so that the shadow cast by the mast(s) falls between the parabolic mirrors 7, 8. An elevation tracking motor drives the drive shaft 13 through a gear box or similar or appropriate mechanical drive system. The drive shaft is rotationally coupled to the individual longitudinal mirror support members and rotates them in elevation so as to keep the reflected solar rays 11 contained within the receiver 10. All the rotary longitudinal mirror support members 175 may move at the same time and may be coupled to the same elevation drive motor through the common drive shaft 13. Pairs of parabolic mirrors positioned along the length of the longitudinal mirror support members are tilted toward the receiver closest to them symmetrically so that two mirrors e.g. 7, 8 on each row are focused on the same absorber, providing an additional concentration factor of two.

In some embodiments, the azimuth support ring 5 is supported on multiple roller wheel assemblies 6 located at equal intervals around the perimeter of the ring to provide adequate structural support. One or more of the roller support structures may be fitted with a clip or wheel or other feature to prevent uplift of the structure. One of the support wheel structures may be fitted with a capstan drive, where a cable (e.g. steel cable) is wrapped around a drive wheel attached to an optional gear box and motor and is also wrapped around the outside of the azimuth support ring 5 to enable azimuthal rotation. The azimuth ring may include a sensor, for example, an optical encoder, to enable the control system to know exactly what angle the azimuth angle is at with respect to the sun.

Figure 2 shows parabolic mirrors in groups 38 of 16 mirrors (numbered 20-27 and 28-35) all focusing on the same receiver 39 in plan view. In this embodiment there are 6 groups of 16 mirrors focusing on 6 receivers for a total number of parabolic mirrors of 16 rows * 6 mirrors per row = 96 mirrors. Other embodiments may have any other number of mirrors in each group and any other number of groups. The number of mirrors in one group may be different to the number in one or more other groups.

Figure 3 shows a side view of an example of the RFP array and how the individual angles of the longitudinal mirror support members need to be set up initially to insure that the incoming sun rays 2 are reflected into the receiver or absorber 39. Once the initial setup is complete, turning the drive shaft enables all mirrors to stay tracking their receiver throughout the day. A main post truss arrangement 40 may be provided to reduce deflection of the main support beam(s) 41. In this embodiment, the truss arrangement comprises first and second beams 40A, 40B, each having a first end coupled to the main support post 15A which supports the receiver(s), and a second end coupled to a main support beam 41.

Figure 4A shows an example of the RFP in end view and how the concentrated sun rays 42 and 43 from the reflective parabolic panels 7 and 8 respectively are individually reflected to a common receiver 39 to achieve a concentration ratio of 2 in addition to their maximum parabolic concentration, of for example, 80 times. Figure 4 also shows an example of the parabolic curve in mirrors 7 and 8 in end view (x-y plane). The formula for the curved surface may be:

$y=+/-mx^2$

where m = 1/(4fl)

where fl is the parabola focal length

The focal length is shown in Figure 3 for reference. In this embodiment there is a requirement for four different focal length parabolas due to the different distance of each reflector from the receiver.

As shown in Figure 4A, the reflective parabolic panels 7, 8 are also tilted in the x-y plane relative to the x-axis in order to direct the reflected solar rays 42, 43 onto the receiver. The tilt angle for each panel is provided by an appropriate mounting between the support shaft 175 and the panel. As the focal length between the reflector and receiver increases with distance away from the receiver along the z-axis, the tilt angle in the x-y plane for different reflectors spaced along the z-axis may vary so that solar rays from each reflector are directed towards the common receiver 39. Referring to Figures 4B, 4C and 4D, Figures 4B and 4C show views of respective reflector panels in the x-y plane and Figure 4D shows a view of the reflectors in the z-y plane. As shown in Figure 4B, the first reflector has a tilt angle, a_1 in the x-y plane, and the second reflector has a tilt angle, a_2 in the x-y plane. The tilt angle of each reflector will be different depending on its distance from the receiver along the z-axis. Generally, the required tilt angle will decrease as the distance between the reflector and receiver (and therefore the focal length between the two) increases. The required tilt angle will depend on the geometry of the system. In one non-limiting example, the tilt angle for the four differently spaced reflectors of the embodiment of Figures 1 to 4 varies from 4.75° for the furthest reflector to 6.01° for the nearest reflector to the receiver. Generally, the reflector panels are titled towards a common receiver about the z-axis by angles a_1, a_2... a_n, corresponding to reflector rows 1, 2... n, respectively.

Figure 5 shows an exploded view of an example of a receiver which includes solar-electric converters, e.g. photovoltaic cells 56 fitted in an array 60 of CPC (Compound Parabolic Curve) elements 52. The receiver is optionally covered with environmentally protecting and translucent glass or other translucent material 53, fitted in an optional frame 51, which is preferably weather tight, and may include an optional mis-aimed solar ray reflective capturing horn 54. As shown in Figure 5, the receiver may include an optional fluid heat exchanger 50 with fluid in/out connections 57. Optionally the back side of the solar cells can be cooled by natural convection with conductive metal fins replacing the fluid heat transfer plate 50. Optional enhanced cooling could be provided by one or more heat pipes thermally coupled or affixed to a heat conductive spreader plate in place of or in addition to the fluid heat exchanger 50.

Figure 6 shows a ¾ view of the CPC Array 60 and the array of solar cells 61. In one embodiment, the solar cells can be fixedly attached to the heat transfer plate by any suitable means, for example, with thermally conductive adhesive or solder. Each CPC can be adhered to the surface of the cell substrate with electrically insulative high temperature adhesive, a non-limiting example of which is an adhesive with a ceramic base.

Figures 7A, 7B and 7C show a front, side, and bottom view of the receiver fitted with a mis-aimed solar ray capture horn 54, the CPCs 52, the solar cells 56, the heat transfer plate 50, and the enclosure frame. The horn 54 redirects mis-aimed solar rays 75 towards the CPC array 52, as for example shown by redirected ray 76.

Figure 8 shows a close up cross sectional view of the receiver with fluid heat transfer plate 50, fluid internal pipe connection 81, solar cell environmental protection frame 51, solar cell 56, CPC concentrator and light homogenizer element 85, protective glass or other material 53 and mis-aimed light ray reflector horn 54. The cells mounted on their receiver 86 may be fixedly attached to the heat transfer plate 50, for example by a suitable adhesive, e.g. high temperature, high dielectric adhesive.

Figure 9 shows a ¾ view of the solar cell 56, by-pass diodes 90, 91 and current collector tab 93 mounted to the solar cell receiver. An electrical conductor 94, for example, an interconnecting high electrical conductivity flat ribbon cable made of copper or other high electrical conductivity material may be used to electrically connect the solar cells in series and may reduce or minimize the electrical resistance and stress cell to cell. This interconnection 94 may be soldered or optionally fixedly adhered to the cells current collector tabs using electrically conductive, e.g. high electrical conductivity, adhesive. Optional interconnecting conductors e.g. wiring may be placed in parallel and/or series with these conductors to enable measurement of the exact current and voltage on each cell, thereby enabling very accurate aiming and/or adjustment and/or control of the light beams from the parabolic surfaces into the receiver. The CPC 52, 95 is also shown in position over the cell, guiding, mixing and concentrating the light up to a further 7 times or more.

Figure 10 shows an embodiment of an azimuth ring support wheel assembly 100. The assembly includes a support roller 102 with one or more guide flanges to keep the ring in position, e.g. centered on the roller, a vertical lift prevention member 103 and an optional load spreading base plate 101. Optionally this support wheel assembly can be anchored to the ground with a helical anchor or other mechanism or supported by a piling, e.g. of concrete or other suitable material.

Figure 11 shows an example of four FRP arrays 110 aligned to the sun at solar noon with a small walkway gap 111 between each array for servicing. All dimensions are in inches and are in no way limiting.

The array configuration enables relatively efficient use of the plan area required to accommodate the collector arrays. By way of illustration only, the active area per array may equal (16x30/12x39) = 1560sqft or 145sqm. In this case, the active area per 4 arrays = 4x145 = 580sqm. Assuming the area used by 4 arrays =

(1022x1032/144/10.76) = 680sqm, then the ratio: Active Area/Plan Area = 580/680 = 85%.

Figure 12 shows the same four RFP arrays at different azimuth angles experienced thought a typical day and also shows the amount of inter-array shading 120 that occurs. Note that adjacent arrays are interleaved, that is to say, adjacent units are positioned one higher than the other in elevation to prevent collision of the outer edges of the arrays with each other during rotation.

Figure 13 shows the calculation table of inter-array azimuth shadowing to be less than 3.7% 140.

Figure 13 also shows the effect of varying inclination angles of the sum on the amount of energy able to be captured with the RFP array. It can be seen that the apparent aperture of the RFP 141, 142, 143 decreases with the sine of the solar inclination angle, in effect reducing the effective area of the array to zero at sunrise and sunset. This seemingly negative effect is reversed at and around solar noon when the maximum energy is able to be gathered from the sun since the aperture is maximum at the same time as the sun is delivering maximum energy. The calculation shows that for similar energy efficiency systems, some embodiments of the RFP can capture 2.5 times more energy per unit land area than a parabolic trough solar plant and produce 3.3 times more peak power than the same.

Figure 14 shows one embodiment of a drive system for the RFP concentrator using main beam extrusions 154, bearing support pins 153, bearing support extrusions 150, sealed bearings 152, a drive shaft 151 and drive cable 155.

Referring to Figure 15, which shows a perspective view of the assembly drive system, the drive shaft 160 is interfaced to longitudinal parabolic mirror support members 166 so that one drive shaft drives all the mirrors in elevation. The drive shaft support bearings include first and second spaced apart bearings 162 mounted below the support beam 41, and which engage the circumferential surface of the drive shaft 160. Longitudinal support member bearings 163 are provided for supporting the longitudinal support member 166. In this embodiment, the bearings 163 includes first and second spaced apart bearings which engage the circumferential surface of a bearing collar 165 surrounding the support member 166. In this example, each longitudinal mirror support member is driven by its own drive cable which is fixedly attached to the drive shaft and the member itself and may be pre-tensioned appropriately to provide minimum elastic backlash. A bearing support plate 164 may be provided to attach the bearings rigidly to the lateral central support beam 167. The support beam 167 may rest at either end on the azimuth support ring.

Figure 16 shows the drive shaft 171 in end view interconnected to one of the longitudinal mirror support members 175 supported by its sealed bearings 173 and a drive cable 172. The central support beam 151 has a clearance hole for a bearing race member, e.g. extrusion 181 which provides the bearings 179 with a race 177 in which to run that is thicker than the tube forming the longitudinal member to support the high contact stresses present there. The bearing race extrusion is fixedly attached to the longitudinal mirror support member by any suitable means, which, in this embodiment is provided by an outer clamp assembly 178 that allows macro and micro adjust of the mirrors in elevation relative to each other and to the main drive shaft.

Figure 17 is one embodiment of a drive system to interconnect the drive shaft with each of the longitudinal mirror support members 198. The drive cable 192 is tensioned to the collar 197. The support member 198 is allowed to freely slide inside the collar 197. A split collar 194 is clamped to the drive tube with bolts or other means, joining the two halves of the split collar once the macro adjust has been made. At that point a micro adjustment can be made by rotating a screw 195 (e.g. allen screw) to push/pull against a pin 191, once the desired mirror position is verified on the receiver. Bolts may be used to clamp the split collar fixedly to the cable anchor collar 197 using threaded holes in drive collar 193, for example.

In other embodiments, the reflector mounting means may comprise a rotary member on the shaft, engagement means coupled to the rotary member for engaging the shaft or a structure associated therewith, whereby movement of the engagement means causes movement of the rotary member at least one of about the shaft and along the shaft. The engagement means may include a thread or helical feature for converting rotational movement thereof into linear movement.

Figures 18, 19, 20 and 21 show perspective, top, side and end views of a solar collector according to another embodiment of the present invention. In this embodiment, the solar collector comprises eight receivers, each having a respective associated array of eight concentrating reflectors, all mounted for azimuthal movement on a common support assembly. In this embodiment, each mirror of a respective array is rotatably supported by a respective rotatable member 206 to allow the angle of elevation to be changed, with the axes being spaced apart along the transverse direction (z). The reflective surface of the reflectors along the transverse direction is substantially planar as shown in Figure 20, for example, and concave in a direction along the rotational axis to concentrate light onto the receiver. In the particular orientation shown, the receivers are substantially laterally aligned along the z direction, i.e. their angle of elevation is substantially zero. One of the main differences between this embodiment and that shown in Figures 1 to 4, is that the reflector of each array is substantially continuous, rather than being formed of two separate elements with a gap between their adjacent edges for receiving a support beam. In the embodiment of Figures 18 to 20, the rotary support members are supported at a position adjacent the edge of a respective reflector, rather than supported in the middle. In other embodiments, the rotary members may be supported at any other position in the axial direction. Each reflector may comprise a single sheet or a plurality of sheets each making up part of the reflective area of a reflector.

In this embodiment, the reflectors of each array are positioned symmetrically with respect to the receiver as particularly shown in the plan view of Figure 19. In this embodiment, a common upright member 205 supports a pair of receivers spaced apart in the axial (x) direction. Optionally, the axial lateral receiver support extending from one upright member may be connected to the axial, lateral support extending from an adjacent upright member for increased rigidity, as for example, shown in Figure 18, in which adjacent receivers supported by different upright members are interconnected by an intermediate axial member 502, which may comprise a separate member from the axial support members or a portion of a single axial member to which all of the receivers are mounted. One or more optional guy wires extending from one or more upright members or masts 205 may be provided to geometrically stabilize one or more receiver(s), for example, in high winds.

Although in the embodiments of Figures 18 to 21, there is a shadow cast by the receiver 200 onto the mirror 207, the shadow is relatively small and may for example be less than 2% of the reflective area. In this embodiment, the reflectors may also be closer to the surface of the longitudinal mirror elevation rotational members 206 than indicated in the embodiment of Figures 1 to 4. As each reflector of each array may comprise an essentially single reflector, the embodiment of Figures 18 to 20 effectively has about 30% fewer individual members than the embodiment of Figures 1 to 4.

Figure 19, which shows a top view of the solar collector, illustrates the receiver 221, showing the outer limits of the concentrating light cone 220 with eight parabolic mirrors 222 focussed on each receiver 221. Also shown is a rotatory azimuth support ring 223.

Figure 20 shows the solar collector in side view, depicting eight concentrating (e.g. parabolic) mirrors 242 and the outer light rays 240 of the concentrating light cone focussed on a single receiver 241. This view also shows examples of guy wires 243, the rotary mirror support members (e.g. tubes) 246, support beams 233 and rotary azimuth drive ring 245.

Figure 21 shows a front view of the solar collector of Figures 18 to 20, depicting four mirrors 262 mounted to the rotary mirror support members 267, the support beams 265 in end view, which, in this embodiment have an "I" shaped cross section (although in other embodiments, the support members may have any other cross sectional geometry), and rotary azimuth drive ring 245, 266. Figure 21 also shows examples of the upright members or masts 264 supporting the receivers 261, guy wires 263, focussing light cone 260, and incoming light rays 2. As for the embodiment of Figures 1 to 4, the azimuth direction of the solar collector may be controlled so that the sun's rays are substantially parallel to the z direction (i.e. transverse to the rotational axis of the reflectors) as the azimuthal direction of the sun changes with time.

In other embodiments, each reflector array may have any number of reflectors and the receiver may be disposed symmetrically or asymmetrically with respect to the reflectors. The solar collector may have any other number of receivers and arrays of reflectors and the number of reflectors of one array may be different from that of one or more other arrays. The receiver support for supporting the receivers may have any other configuration from that shown in Figures 18 to 21, and each receiver may be supported by an individual mast or a number of receivers may be supported by the same mast. The guy wires may have any other suitable configuration than that shown in Figures 18 to 21 and guy wires may be added or removed or omitted altogether, as desired.

Figure 22 shows another embodiment of a solar collector, which is essentially one quarter of the embodiment shown in Figures 18 to 21. In this embodiment, the solar collector comprises two sets of eight reflectors or mirrors 282, each set of eight focussing on a single receiver 281, so that the mirrors collectively form an array of sixteen mirrors. Corresponding mirrors of each set are mounted on a respective rotary support (e.g. elevation drive tubes) 284, and the rotary drive members are supported on a support which allows the azimuthal direction of the reflectors to be varied. In this particular embodiment, the elevation rotary drive members 284 are supported by one or more (e.g. three) structural beams. The support includes an azimuth drive ring 285 for enabling the azimuthal direction of the reflectors to be varied. In this embodiment, the two receivers are supported on a common mast, although in other embodiments, each receiver may be supported by a separate mast. The mast or upright member is mounted at a position between the two reflector arrays. Also depicted in Figure 22 are reflected sunrays 280, showing the outer limits of the light concentrating cone and the Fresnel reflector concentrating effect.

In other embodiments, the solar collector may comprise a single array having any number of reflectors and a single receiver in which the reflectors are mounted on a dedicated support which enables the azimuthal direction of the reflector array to be varied.

Figure 23 shows another embodiment of a drive mechanism for variable inclination or elevation of the reflectors. Only a truncated portion of each rotary support member 301 is shown for clarity. In this embodiment, each rotary support member 301 is mounted on a support beam 306 which for example may be the central support beam 208 in Figure 18 or another support beam, e.g. 207 or 209. The drive mechanism comprises a linear actuator 305 which may be electrically driven or hydraulically or pneumatically driven, and a drive beam 308 which is slidably supported on the support beam 306, for example by one or more rotary bearings 310. Each rotary support member is provided with a pulley 300 and a flexible cable 313 for coupling the drive beam to the rotary member, so that linear movement of the drive beam along the support beam is translated into rotational movement of the rotary support member. The cable which may comprise a wire cable, may be fixedly attached to the pulley 300, and the pulley may have a relatively large diameter, i.e. larger than the diameter of the rotary support member. The drive beam 308 may include a cable anchor 311 for anchoring the cable thereto. The cable anchor may be adjustably mounted to the drive beam 308, and may include a micro or fine adjust mechanism 311 for adjusting the angular position of each reflector relative to the drive beam 308 to focus the mirror on the receiver during system setup. Thus, each rotary support member which is coupled to the same drive beam will be rotated in a fixed relationship on movement of the drive beam.

In this embodiment, two bearings 303 are provided for rotatably supporting each rotary support member on each beam 306, so that, for example, with reference to the embodiment of Figure 18, which includes three support beams 208, 209, each support member is supported by a total of six bearings. The bearings 303 are supported by a bearing mount 304 which is fixedly mounted to the main support beam 306, 208 and 209, in Figure 18. The bearings 303 ride on a race 302 which is fixedly attached to the rotary support members. The rotary support members 301 may be held down by gravity during normal operation and by other means, such as a strap 307 in the event of uplifting winds. In the embodiment of Figure 23, first and second drive beam assemblies are provided for driving alternate rotary support members 301. The drive beams may be conveniently positioned on opposite sides of the same support beam 306. In other embodiments, the drive beams may be mounted on the same side of the same support beam or one drive beam may be mounted on one support beam and another drive beam may be supported on another support beam. In other embodiments, a single drive beam may be coupled to two or more adjacent rotary members or all rotary members in a single array.

Embodiments of the solar collector in which the elevation of one or more reflectors of an array are driven by a separate drive mechanism to one or more other reflectors of the array allows the reflectors to be directed or focused on a different area of the receiver. It has been found that for some solar elevation angles, for example when the sun is low on the horizon at sunrise or sunset, solar rays may be concentrated or biased towards one end of the receiver. Under such conditions, enabling different reflectors to direct reflected solar rays on different areas of the receiver, allows the solar radiation to be distributed over the receiver more evenly. The arrangement of Figure 23 allows every second row of reflectors to be focussed on a different area of the receiver.

Figure 24 shows another embodiment of a drive mechanism for the rotary adjustment of the reflectors. In particular, Figure 24 shows the drive cable 322, the drive pulley 321, the rotary support members 320, the fine or micro adjust mechanism 327, the rotary support member support bearings 324, the drive beam 326 and the drive beam guide bearings 325. Figure 24 also shows a recessed rotary support beam bearing race or seat 328, that provides lateral support for the rotary drive member. Figure 24 also shows the linear actuator 323 for driving movement of the drive beam 326. Figure 24 also shows a plurality of grooves, e.g. for dual cables, in the drive pulley 326 and cables 322, 329 attached to the drive pulley 321 and anchored to it at positions 330. Each cable may be pre-tensioned to reduce or remove backlash of the drive system.

In other embodiments, any other drive mechanism may be used to drive elevational changes in one or more reflectors. In some embodiments, each reflector may be separately driven by a drive means which can individually control, for at least part of the time or all of the time, the elevation angle of the individual reflector, or the drive mechanism may be used to drive two or more reflectors. Other aspects and embodiments of a solar collector may provide any one or more of the following features:

A concentrating solar collector comprising an array of trough like reflectors that form a parabolic shape in the X-Y plane (figures 18-22) mounted on a longitudinal member (running on the x axis) that provides a single, dual or quad rotational synchronization between mirror mounting tubes 284 (about the x axis) between longitudinally mounted reflectors and multiply arranged in a lateral array (along the z axis) to track the sun in elevation (about x axis).

An RFP solar concentrator that tracks the sun on two axes (elevation and azimuth) using a combination of either multiple reflective Fresnel flat mirrors, multiple Fresnel positioned parabolic reflectors to achieve concentration ratios of 50 to 18000 times.

An RFP solar concentrator that uses an additional Compound Parabolic Concentrator (CPC) secondary concentration or homogenizing lens or reflector to achieve concentration ratios of 50 to 18000 times.

A dual actuator drive system as depicted in Figures 23 and 24 (mirror image of drive not shown) that allows alternate rows of mirrors to focus on different areas of the receiver to provide uniform illumination of the receiver during late afternoon and early morning when the sun is low in the sky.

A drive system, where there are 3, 4 or more drive systems for elevation tracking of the rotary mirrors and providing uniform illumination of the receiver area.

A solar concentrator, where the parabolic curve in the x-y plane is described by the equation:

$y=+/-mx^2$ where

$m = 1/(4fl)$

where fl is the parabola focal length

and where there are separate parabolas corresponding with the focal length distance from the mirror surface at x=0 to the receiver surface.

A cable connected linear drive system to activate all or pairs of the parabolic mirrors in rotation about the x axis by actuating a single or multiple drive rods 326 with either a linear actuator 323 or a rotary actuator shaft about the z′ axis.

A linear micro position adjustment feature 327 to allow accurate manual adjustment of parabolic mirror support tube elevation angles about the "x" axis and subsequent focus on the receiver with a single rotary adjustment point for each mirror support member.

An RFP concentrator where the receiver is geometrically stabilized by a support mast 264 and guy wires 263.

A receiver as in Figures 5-9 where multi-sun solar cells are spaced with gaps to allow room for bypass diodes 90, 91 and wiring 94, but are interconnected electrically with flat electrical conductors 94, typically made of copper, either imbedded in the receiver (solder ready copper/ceramic substrate) or with flat electrical conductors soldered between the receivers or interconnected with flat electrically conductive tabs glued to each individual receiver using electrically conductive adhesive.

A receiver where multiple rows and columns of reflective or refractive secondary concentrating optical elements 95 having concentration ratios between 1.5 and 8 allow gaps between the multi-sun solar cells for solar cell electrical connections and cell to cell interconnecting wiring and bypass diodes.

A receiver where the cells and secondary concentrating optical elements are encapsulated by an optically translucent cover on one side and a heat sink on the other side.

A receiver where the heat sink is cooled by a series of heat pipes attached to the heat sink at one end and to large area heat transfer fins at the other for a natural convection cooling solution with ambient air.

A receiver connected with heat pipes to large area fins fitted with a fan or fans for a forced convection solution, where the fan is powered by a solar cell or cells.

Some, non-limiting embodiments of the solar collector may provide any one or more of the following features or benefits:

- Low Profile;
- Reduced Wind Load;
- Ease to erect;
- Reduced cost on labor and materials to erect due to higher power density;
- Large Solar Noon Area (e.g. 85% of plan area) vs: 50% for typical reflective fresnel and 26% for a typical trough based solar thermal plant;
- High Solar Power Density, e.g. 0.85*1000 w/sqm*27% Efficient Module: e.g. 230 W/sqm versus 170 W/sqm for best flat panel PV today and 60 W/sqm for thin film PV;
- Efficient use of land, e.g. enables 2.5 times more energy per acre of land and 3.25 times more peak power than typical parabolic troughs given the same efficiency levels, or 5 times more energy and 6.5 times the peak power given solar thermal electric efficiencies of 13.5% versus CPV 27%;
- Tracking on a 2nd axis ;
- High concentration ratios, e.g. enables Concentration ratios 1000-18000 x with small included optical angles for maximum efficiency optics;

- Eliminates Incidence Angle Modifier (IAM) optical losses in the transverse direction;
- Reduced Array to Array shadowing e.g. to 7.5% maximum at 85% active/plan area ratio;
- Ability to invert Reflector Panels to Wash and protect from Hail & Snow
- Higher concentration, e.g. 50 times more concentration than 1 axis tracking Fresnel reflective alone;
- Enables a CPV and CSP combination solution on the same platform.

Other aspects and embodiments of the present invention may comprise any one or more features disclosed herein in combination with any one or more other features disclosed herein.

In any aspect or embodiment of the invention, any one or more features disclosed or claimed herein may be omitted altogether or replaced by another feature which may or may not be an equivalent or variant thereof.

Numerous modifications to embodiments disclosed herein will be apparent to those skilled in the art.

CLAIMS:

1. A solar collector comprising a receiver,

reflector means for reflecting solar radiation towards said receiver and for concentrating the reflected radiation in a first direction, said reflector means comprising a plurality of reflectors positioned in series along said first direction,

support means for supporting each reflector for movement about an axis orthogonal to said first direction, to enable the angle of elevation of each reflector to be varied, each respective axis being spaced apart along said first direction, and

wherein said support means is adapted to enable the azimuthal direction of said reflectors to be varied.

2. A solar collector as claimed in claim 1, further comprising mounting means for mounting said support means to enable the azimuthal direction of said reflectors to be varied.

3. A solar collector as claimed in claim 1 or 2, wherein one or more reflectors are adapted to concentrate reflected solar radiation in a second direction orthogonal to said first direction.

4. A solar collector as claimed in claim 3, wherein each reflector has opposed side edges spaced apart in a direction along a respective said axis and said receiver is positioned between said opposed side edges.

5. A solar collector as claimed in claim 4, wherein the opposed side edges of a reflector are spaced apart by a

first dimension, and the receiver has opposed side edges spaced apart in the direction of said axis by a second dimension shorter than said first dimension.

6. A solar collector as claimed in claim 5, wherein one or more reflectors each comprises a first reflective surface on one side of said receiver and a second reflective surface on the other side of said receiver and in which said first and second reflective surfaces are angled oppositely relative to a respective axis towards said receiver.

7. A solar collector as claimed in claim 6, wherein at least one of said first and second surfaces is curved to concentrate the reflected solar radiation in said second direction.

8. A solar collector as claimed in claim 6 or 7, wherein at least one of said first and second reflective surfaces comprises a plurality of discrete reflective surfaces arranged along said axis each angled relative to said axis to reflect radiation towards said receiver.

9. A solar collector as claimed in claim 8, wherein each discrete reflective surface has opposed side edges spaced apart along said axis wherein adjacent side edges of at least two adjacent discrete reflective surfaces are at different heights.

10. A solar collector as claimed in claim 9, wherein said plurality of discrete surfaces comprises first and second discrete surfaces, said first surface being closer to the middle of the reflector than the second discrete surface, and wherein the distal side edge of the first discrete surface is above the proximal, adjacent side edge of the second discrete surface.

11. A solar collector as claimed in any one of claims 1 to 10, wherein said reflector means has opposed ends spaced apart in said first direction by a first dimension, said receiver has opposed ends spaced apart in said first direction by a second dimension, wherein said second dimension is shorter than said first dimension.

12. A solar collector as claimed in claim 11, wherein said receiver is positioned between the ends of said reflector means.

13. A solar collector as claimed in any one of claims 1 to 12, wherein said receiver includes a concentrator for concentrating in at least one of said first and second directions solar radiation reflected from said reflector means.

14. A solar collector as claimed in claim 13, wherein said concentrator means comprises a one or two-dimensional array of concentrators.

15. A solar collector as claimed in any one of claims 1 to 14, wherein said receiver comprises an absorber for absorbing solar energy, a light capturing element having an entrance aperture for receiving the solar radiation and an exit aperture for passing solar radiation to said absorber, wherein said light capturing element is structured to guide solar radiation entering the entrance aperture which is not directed towards said exit aperture towards said exit aperture.

16. A solar collector as claimed in claim 15, wherein said light capturing element comprises a horn having opposed reflective internal walls which taper inwardly in a direction from said entrance aperture to said exit aperture

over at least part of a distance between said entrance and exit apertures.

17. A solar collector as claimed in claim 15 or 16, further comprising one or more optical elements between said light capturing element and said absorber, said optical element being structured to at least one of (1) concentrate light received by said optical element onto said absorber and (2) increase the homogeneity of solar energy over an area of said absorber.

18. A solar collector as claimed in claim 17, comprising a plurality of optical elements each having an input for receiving light from said light capturing element.

19. A solar collector as claimed in any one of claims 1 to 18, wherein said receiver comprises one or more converters for converting solar energy to electrical energy.

20. A receiver as claimed in any one of claims 1 to 19, wherein said receiver comprises heat transfer means for carrying heat transfer fluid to absorb solar thermal energy.

21. A solar collector as claimed in any one of claims 1 to 20, further comprising means for rotatably mounting said support means for azimuthal rotation about an axis.

22. A solar collector as claimed in claim 21, wherein said rotatable mounting means includes a circular member substantially centered on said axis of azimuthal rotation.

23. A solar collector as claimed in any one of claims 1 to 22, further comprising drive means for driving rotation of one or more reflectors about a respective axis.

24. A solar collector as claimed in any one of claims 1 to 23, further comprising a controller for controlling the angle of elevation of one or more reflectors to maintain the direction of reflected solar radiation towards said receiver with changes in the elevation of the sun.

25. A solar collector as claimed in any one of claims 1 to 24, further comprising a controller for controlling the azimuthal direction of said reflectors.

26. A solar collector as claimed in claim 25, wherein said controller is adapted to control the azimuthal direction to maintain said first direction substantially aligned with the direction of solar rays as the azimuthal direction of the sun changes.

27. A solar collector as claimed in any one of claims 1 to 26, wherein adjacent reflectors have adjacent edges, and the minimum distance between adjacent edges is less than one inch.

28. A solar collector as claimed in any one of claims 1 to 27, wherein said plurality of reflectors are adapted to concentrate solar radiation in a second direction orthogonal to said first direction and wherein at least one of (1) the effective focal length of each reflector is different from the focal length of at least one other reflector of said plurality of reflectors, and (2) each reflector is tilted along said second direction, wherein the tilt angle of each reflector is different to that of at least one other reflector of said plurality of reflectors.

29. A solar collector as claimed in any one of claims 1 to 28, wherein said receiver is adapted for azimuthal movement with said support means.

30. A solar collector as claimed in claim 29, wherein said receiver is supported on said support means.

31. A solar collector assembly comprising a plurality of solar collectors as claimed in any one of claims 1 to 30, and wherein said support means for each solar collector comprises a common support supporting the reflector means of each solar collector.

32. A solar collector assembly as claimed in claim 31, wherein the receiver of each solar collector is mounted on said common support.

33. A solar collector assembly as claimed in claim 31 or 32, wherein said common support is adapted for azimuthal rotation about an axis.

34. A solar collector assembly as claimed in any one of claims 31 to 33, wherein the reflector means of the solar collectors are positioned substantially end to end and/or side by side in a one or two-dimensional array.

35. A solar collector system comprising a plurality of solar collectors each having a receiver and reflector means for reflecting solar radiation towards said receiver and support means for rotatably supporting the reflector means for azimuthal rotation about a respective axis, said axes being laterally spaced apart, and wherein at least a portion of the reflector means of one solar collector is adapted to overlap at least a portion of the reflector means of an adjacent solar collector for one or more positions of rotation about said azimuthal axis.

36. A solar collector system as claimed in claim 34, wherein said plurality of solar collectors have at least one angular position about said axis at which said reflector means do not overlap or do not substantially overlap.

37. A solar collector system as claimed in claim 36, comprising a controller for controlling rotation of one or more solar collectors about said azimuthal axis.

38. A solar collector system as claimed in claim 36, wherein said controller is adapted to control rotation such that there is substantially no overlap of the reflector means of adjacent solar collectors at a predetermined time of day or a predetermined range of times or a predetermined elevation of the sun or predetermined range of elevations of the sun.

39. A solar collector system as claimed in any one of claims 34 to 38, wherein one or more solar collectors comprises a solar collector or solar collector assembly as claimed in any preceding claim.

40. A solar collector as claimed in any preceding claim, wherein adjacent edges of adjacent reflectors has substantially the same contour or complementary contours.

41. A solar collector as claimed in any preceding claim, wherein the reflective surface of one or more reflectors is substantially planar in the first direction or shaped to concentrate solar radiation in the first direction or dimension.

42. A receiver for a solar collector comprising absorber means for absorbing solar energy, a light capturing element having an entrance aperture for receiving light and an exit aperture for passing light to said absorber, wherein

said light capturing element is structured to guide light entering the entrance aperture which is not directed towards said exit aperture towards said exit aperture.

43. A receiver as claimed in claim 42, wherein said light capturing element comprises a horn having opposed reflective internal walls which taper inwardly in a direction from said entrance aperture to said exit aperture over at least part of the distance between said entrance and exit apertures.

44. A receiver as claimed in claim 42 or 43, further comprising one or more optical elements between said light capturing element and said absorber, said optical element being structured to at least one of (1) concentrate light received by said optical element onto said absorber and (2) increase the homogeneity of solar energy over an area of said absorber.

45. A receiver as claimed in claim 44, comprising a plurality of optical elements each having an input for receiving light from said light capturing element.

46. A receiver as claimed in claim 45, wherein said optical elements are arranged in a two-dimensional array over an area of said absorber.

47. A receiver as claimed in claim 45 or 46, wherein said absorber comprises a plurality of converters for converting solar energy to electrical energy.

48. A receiver as claimed in claim 47, wherein each optical element is arranged to direct light onto at least one converter.

49. A solar collector as claimed in any one of claims 42 to 48, wherein said absorber comprises one or more converters for converting solar energy to electrical energy.

50. A receiver as claimed in claim 49, wherein two or more converters each have terminal means for enabling one or both of electrical current from a respective converter and voltage across a respective solar converter to be measured.

51. A solar collector comprising a receiver, a plurality of reflectors for reflecting solar radiation towards said receiver,

support means for supporting the reflector elements for movement relative to the receiver, so that the angle of elevation of each reflector element relative to a plane can be varied, and wherein said support means is adapted to enable movement of at least one of (1) said reflector elements and (2) said receiver in at least one of said plane and a direction orthogonal to the direction along which said angle of elevation can be varied, to enable said reflector elements to maintain the direction of reflected solar radiation onto said receiver as the direction of incident solar radiation changes in both elevation and azimuth.

52. A solar collector as claimed in claim 51, wherein said support means includes a support for supporting said plurality of reflector elements, and said support is adapted to rotate in said plane.

53. A solar collector as claimed in claim 52, wherein said receiver is mounted for rotation about an axis transverse to said plane.

54. A solar collector as claimed in claim 52 or 53, wherein said receiver is mounted on said support.

55. A solar collector as claimed in any one of claims 51 to 54, wherein each reflector has an area for reflecting solar radiation having a first dimension along a direction orthogonal to the direction along which said angle of elevation can be varied, and said reflector is adapted to reflect solar radiation from said area over a second dimension in said orthogonal direction at the receiver shorter than said first dimension.

56. A solar collector as claimed in claim 55, wherein said receiver has a shorter dimension in said orthogonal direction than said first dimension.

57. A solar collector as claimed in claim 55 or 56, wherein said reflector extends either side of said receiver along said orthogonal direction.

58. A solar collector as claimed in claim 57, wherein said reflector includes a first reflective surface on one side of said receiver and a second reflective surface on the opposite side of said receiver.

59. A solar collector as claimed in claim 58, wherein said first and second reflective surfaces are angled relative to said plane towards said receiver.

60. A solar collector as claimed in claim 58 or 59, wherein at least one of said first and second reflective surfaces are curved to concentrate solar radiation reflected from said surface towards said receiver.

61. A solar collector as claimed in any one of claims 51 to 60, wherein said plurality of reflectors are

positioned next to one another in a direction along which said angle of elevation can be varied.

62. A solar collector as claimed in claim 61, wherein said reflectors collectively extend over a first dimension along said direction and the receiver extends over a second dimension along said direction, wherein said second dimension is shorter than said first dimension.

63. A solar collector as claimed in claim 61 or 62, wherein said receiver has opposed ends spaced apart along said direction and wherein one or more reflectors are positioned beyond one end and one or more other reflectors are positioned beyond the other end of said receiver.

64. A solar collector as claimed in any one of claims 61 to 63, wherein each reflector is rotatably mounted for rotation about a respective axis, each axis being spaced apart in the direction along which the angle of elevation can be varied, each axis being orthogonal to the direction along which the angle of elevation can be varied.

65. A solar collector as claimed in claim 64, comprising a plurality of rotatable shafts to rotatably mount a respective reflector thereon.

66. A solar collector as claimed in claim 65, further comprising drive means for driving rotation of each shaft.

67. A solar collector as claimed in claim 66, wherein said drive means comprises a single driver for driving rotation of two or more shafts.

68. A solar collector as claimed in claim 67, wherein said drive means includes a drive shaft extending transversely across said rotatable shafts and coupling means

for rotatably coupling said drive shaft to each rotatable shaft.

69. A solar collector as claimed in claim 68, wherein said coupling means comprises a cable.

70. A solar collector as claimed in claim 69, wherein said cable at least partially supports said drive shaft.

71. A solar collector as claimed in any one of claims 68 to 70, further comprising a plurality of bearings spaced apart along the axis of the drive shaft for guiding said drive shaft to rotate about the drive shaft axis.

72. A solar collector as claimed in any one of claims 51 to 71, wherein said support means comprises a circular support member having a central axis and bearing means for rotatably supporting said circular support member for rotation in said plane and about said central axis.

73. A solar collector as claimed in claim 72, wherein said bearing means comprises a plurality of bearings spaced apart about said central axis.

74. A solar collector as claimed in any one of claims 51 to 73, wherein each reflector is adapted to rotate about a respective axis to enable the angle of elevation of each reflector to be varied relative to said plane wherein each axis spaced apart and lies in substantially the same plane.

75. A solar collector as claimed in any one of claims 51 to 74, wherein each reflector has an edge and the reflectors are arranged adjacent one another, wherein the minimum distance between edges of adjacent reflectors is one inch or less.

76. A solar collector as claimed in any one of claims 51 to 75, wherein said plurality of reflectors constitute a first group of reflectors for said receiver, and further comprising a second receiver and a second group comprising a plurality of reflectors, wherein said support means supports the reflectors of the second group for movement relative to the second receiver so that the angle of elevation of each reflector relative to said plane can be varied, and wherein said support means is adapted to enable movement of at least one of (1) said second group of reflectors and (2) said second receiver in at least one of said plane and a direction orthogonal to the direction along which said angle of elevation can be varied to enable the second group of reflectors to direct reflected solar radiation onto the second receiver as the direction of incident solar radiation changes in both elevation and azimuth.

77. A solar collector as claimed in claim 76, wherein said support means comprises a support for supporting the reflector elements of both the first and second groups.

78. A solar collector as claimed in claim 77, wherein said support is adapted to rotate in said plane.

79. A solar collector as claimed in claim 77 or 78, wherein said second receiver is adapted to rotate about an axis transverse to said plane.

80. A solar collector as claimed in claim 79, wherein said second receiver is mounted on said support.

81. A solar collector as claimed in claim 80, wherein said support comprises an upright member and said first and second receivers are both mounted on said upright member.

82. A solar collector as claimed in claim 79, 80 or 81, wherein the reflectors of the first and second groups are mounted for rotation about a respective axis, each axis of the first and second groups being spaced apart along a first direction.

83. A solar collector as claimed in claim 82, further comprising a third receiver and a third group of reflectors for reflecting solar radiation towards said third receiver and wherein said support means supports the reflector elements of the third group for movement relative to the third receiver so that the angle of elevation of the third group of reflectors relative to said plane can be varied, and wherein said support means is adapted to enable movement of at least one of (1) said third group of reflectors and (2) said third receiver in at least one of said plane and a direction orthogonal to the direction along which the angle of elevation of said third group of reflectors can be varied to enable said third group of reflectors to direct reflected solar radiation onto said receiver as the direction of incident solar radiation changes in both elevation and azimuth.

84. A solar collector as claimed in claim 83, wherein the reflectors of the third group are spaced from the first and second group of reflectors in the direction orthogonal to the direction along which the angle of elevation can be varied.

85. A solar collector as claimed in claim 83 or 84, wherein said support means comprises a support for supporting the reflectors of each of said first, second and third groups and the support is adapted to rotate in said plane.

86. A solar collector as claimed in any one of claims 83 to 85, wherein said third receiver is adapted to rotate with said support.

87. A solar collector as claimed in claim 86, wherein said third receiver is mounted on said support.

88. A group of solar collectors, each solar collector comprising one or more feature(s) of any preceding claim, wherein the support means of each solar collector comprises a support for supporting the reflectors, the support being adapted to rotate in a respective plane about a respective axis, each axis being spaced apart, and wherein the reflectors of a solar collector are positioned at a different height to the reflectors of another adjacent solar collector and are positioned relative to one another so that at one or more positions of rotation, a portion of the reflectors of one solar collector overlap a portion of the reflectors of another solar collector.

89. A solar collector as claimed in any preceding claim, wherein one or more reflectors are arranged to direct solar rays onto a different part of the receiver to a part of the receiver to which one or more other reflectors direct solar radiation, for one or more values of elevation of the sun.

90. A solar collector as claimed in claim 89, wherein said value includes one or more values when the sun is at a relatively low elevation, for example, one or more values in a range between when the sun is at the horizon to an elevational angle of 45° or more.

91. A solar collector as claimed in claim 89 or 90, comprising a plurality of separate drivers each for changing

the angular elevation of one or more reflectors, at least one reflector, driven by one driver, directing solar radiation onto a different part of the receiver than another reflector driven by another driver for one or more values of elevation of the sun.

92. A solar collector as claimed in any preceding claim, including a driver for changing the inclination of one or more reflectors, wherein the driver comprises a linear actuator operatively coupled to a pulley, wherein the pulley is adapted to change the angle of inclination of a reflector on linear actuation of the linear actuator.

93. A solar collector as claimed in claim 92, comprising one or more cables for coupling the pulley to the linear actuator.

94. A solar collector as claimed in claim 92 or 93, comprising a plurality of drivers each for changing the inclination of one or more reflectors.

95. A solar concentrator as claimed in any preceding claim, comprising control means for controlling the reflectors to provide a substantially uniform distribution of solar energy over the area of the receiver.

96. A solar collector as claimed in any preceding claim, further comprising a driver for changing the inclination of one or more reflectors comprising one or more of a linear actuator and a rotary actuator.

97. A solar collector as claimed in any one of claims 1 to 96, further comprising one or more support masts and/or one or more guy wires/cables for supporting and/or stabilizing the receiver.

98. A solar collector comprising a receiver,

reflector means for reflecting solar radiation towards said receiver and for concentrating the reflected radiation in a first direction, said reflector means comprising a plurality of reflectors positioned in series along said first direction,

support means for supporting each reflector for movement about an axis orthogonal to said first direction, to enable the angle of elevation of each reflector to be varied, each respective axis being spaced apart along said first direction, and

wherein one or more reflectors are adapted to concentrate reflected solar radiation in a second direction orthogonal to said first direction.

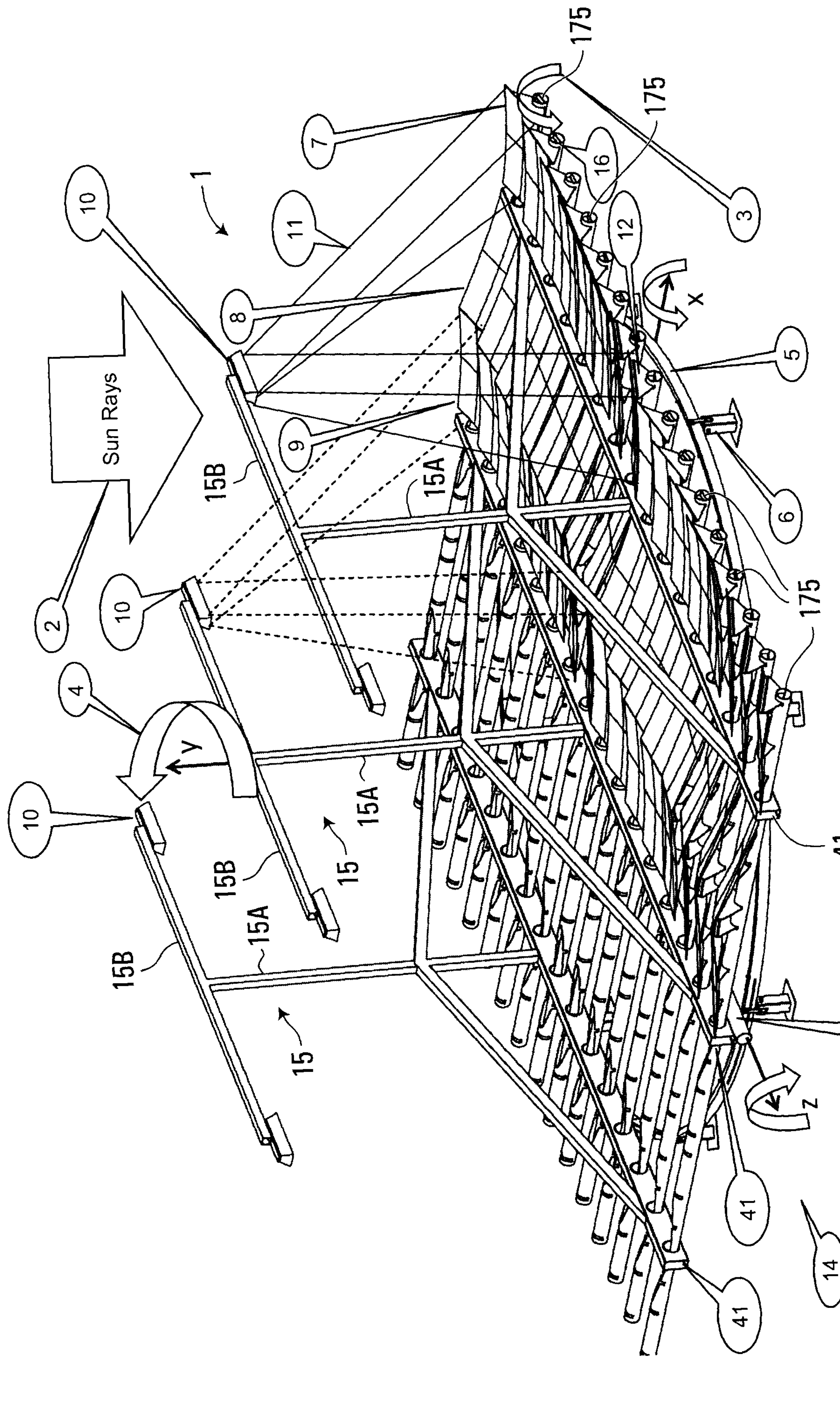

Sun Rays
1
2
3
4
5
6
7
8
9
10
10
10
11
12
13
14
15
15
15A
15A
15A
15B
15B
15B
16
41
41
41
175
175
175
175
x
y
z

FIG. 1

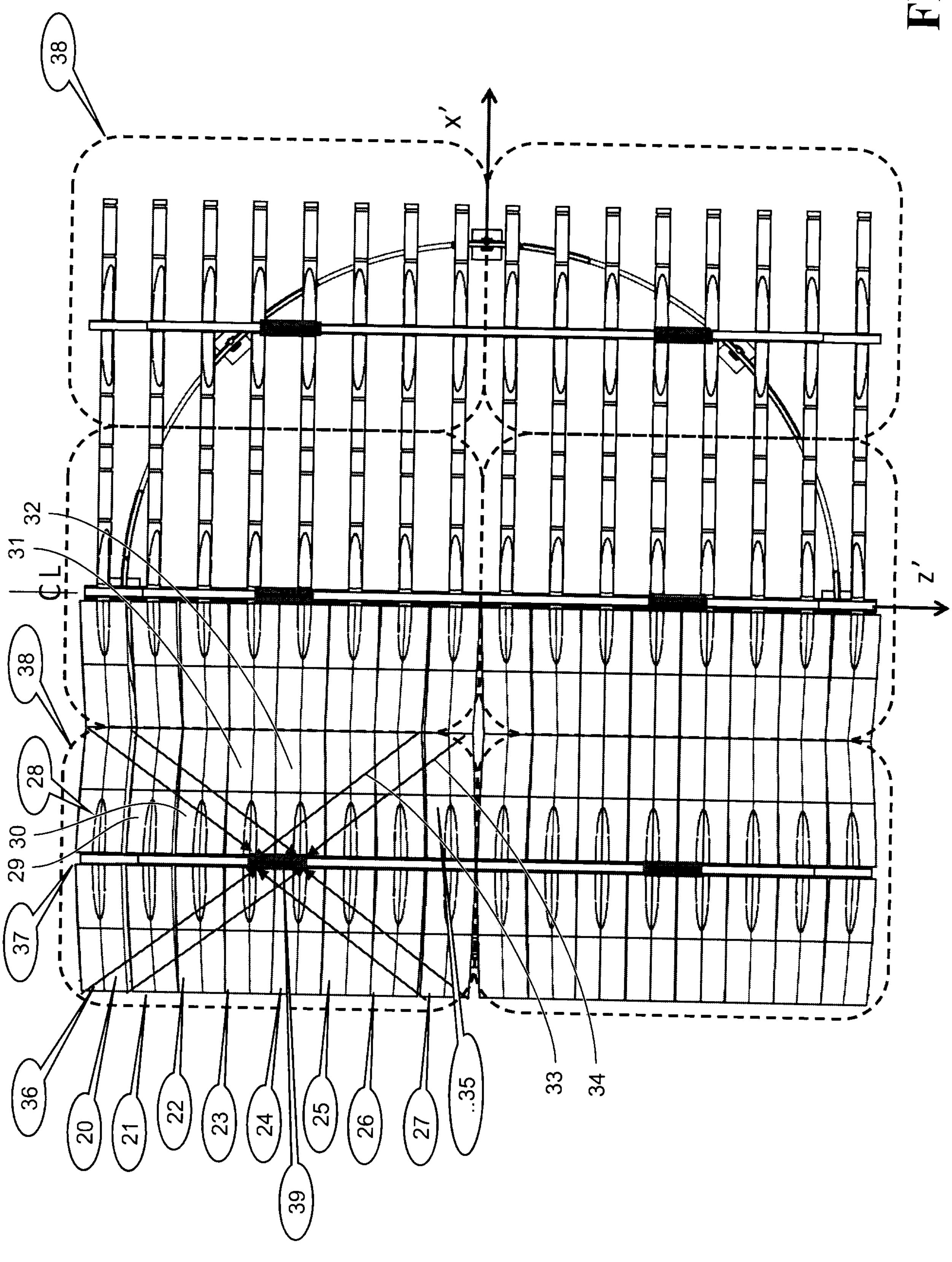


FIG. 2

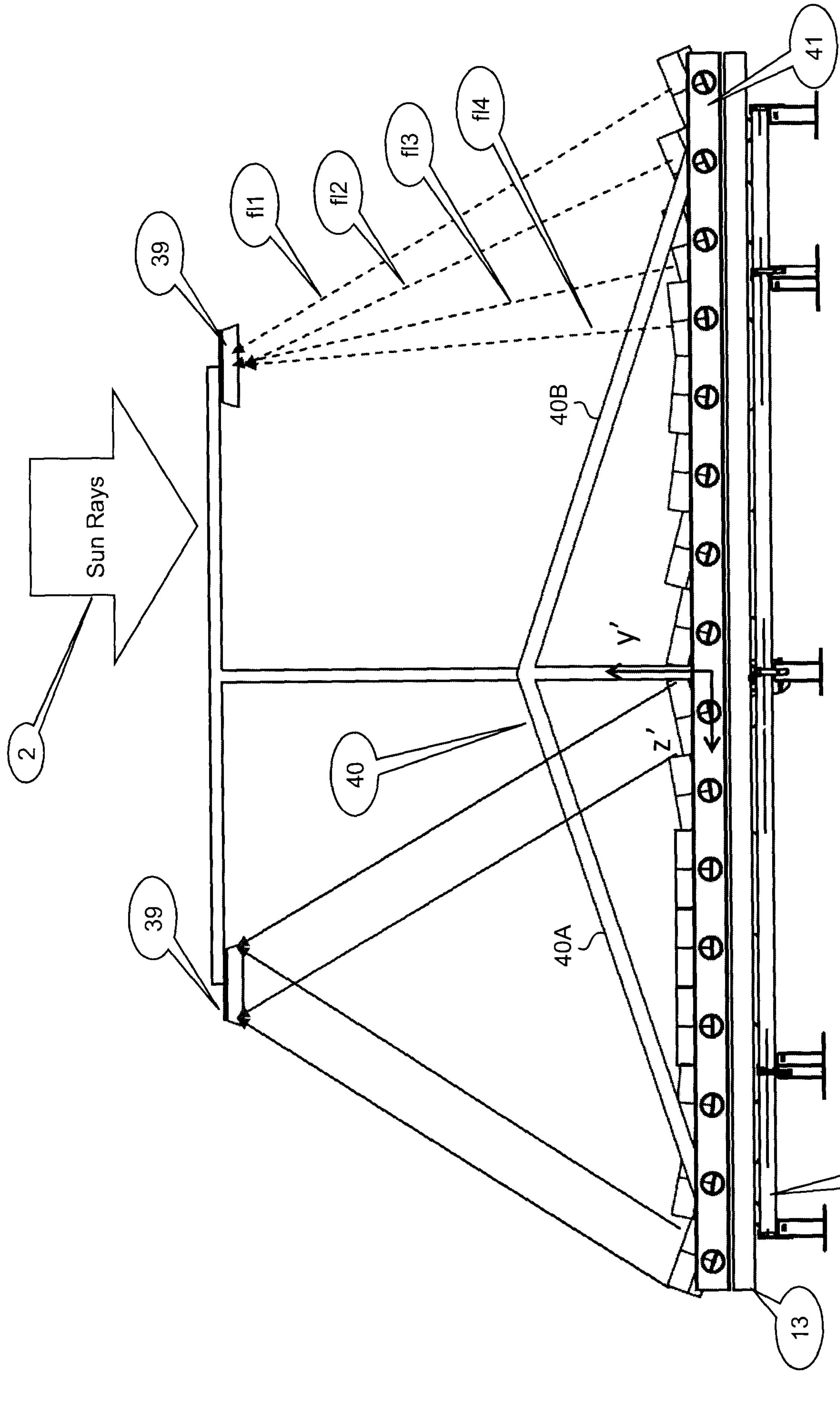


FIG. 3

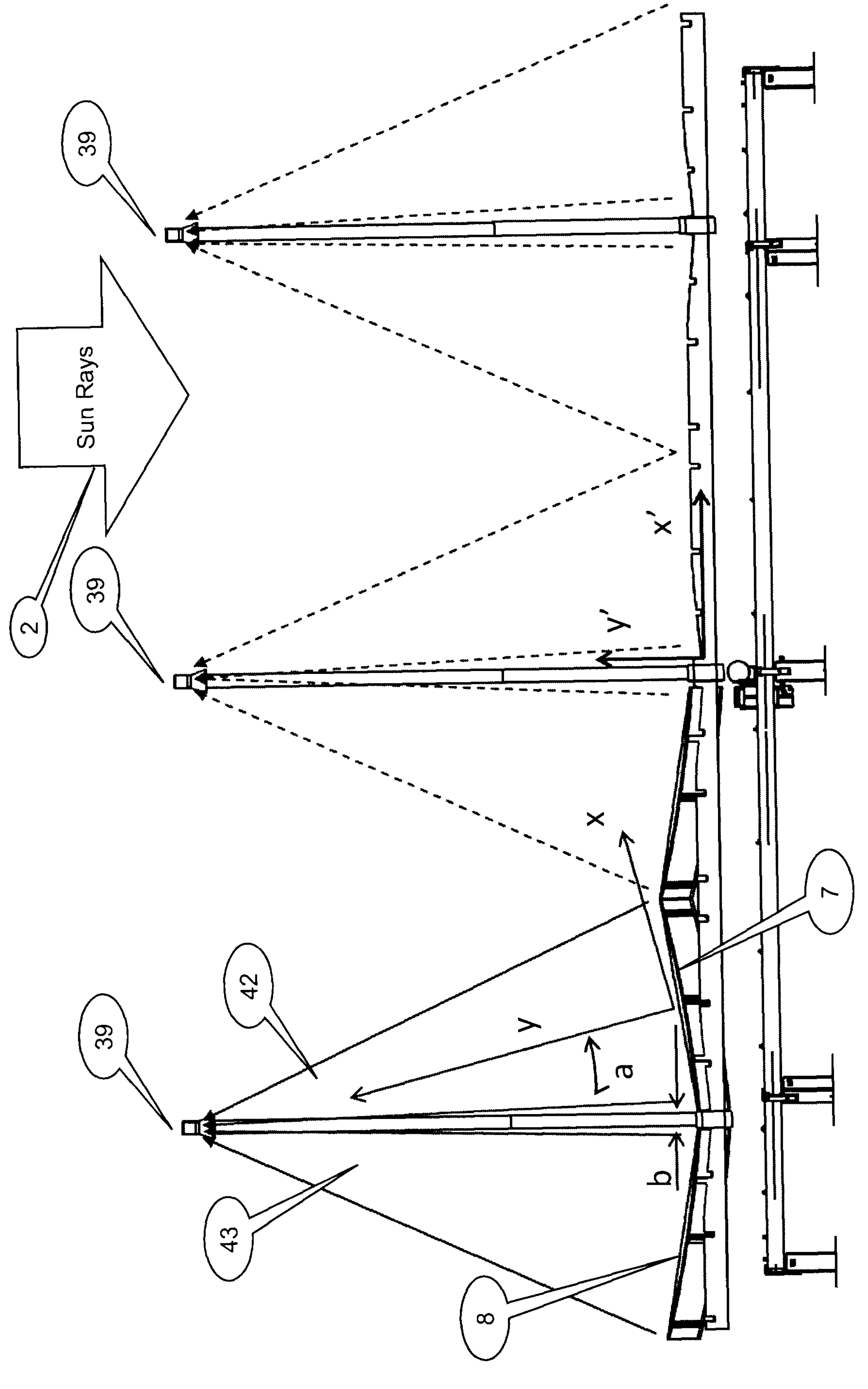


FIG. 4A

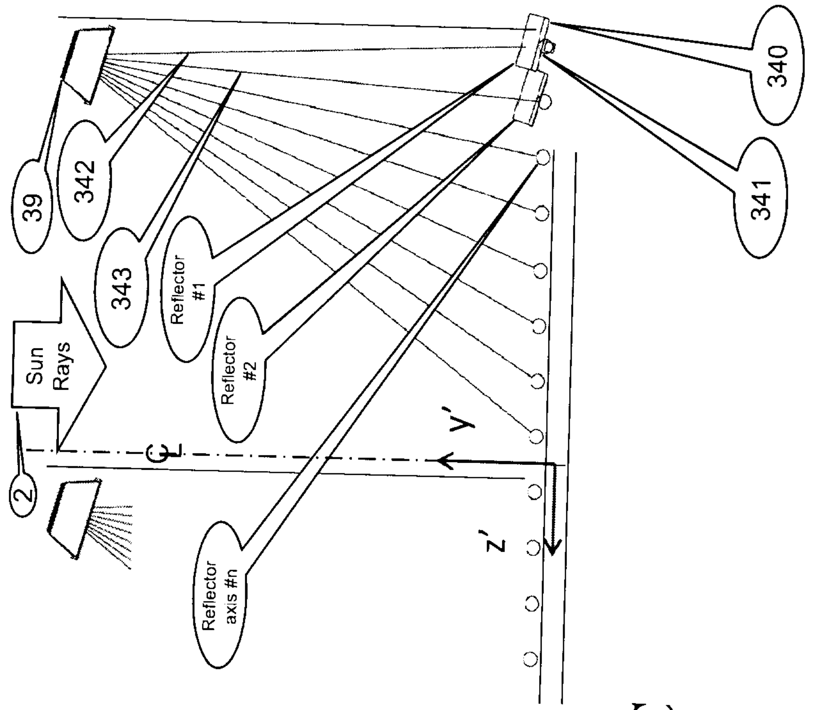


FIG. 4D

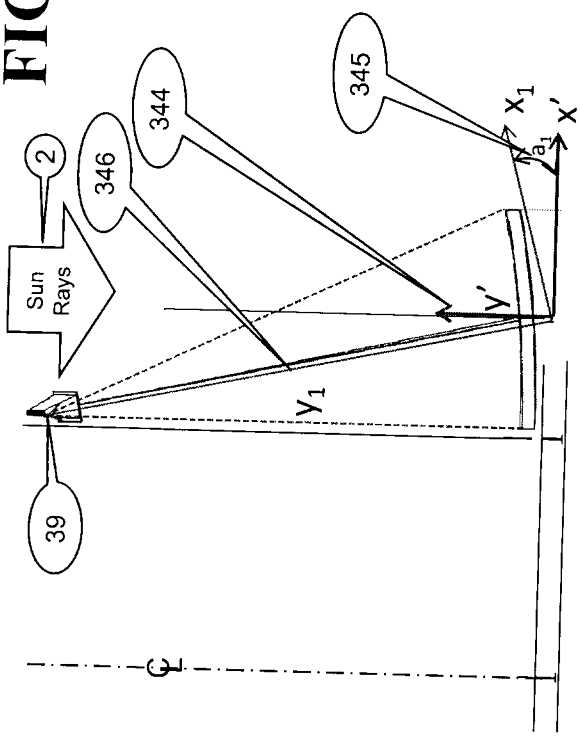


FIG. 4B

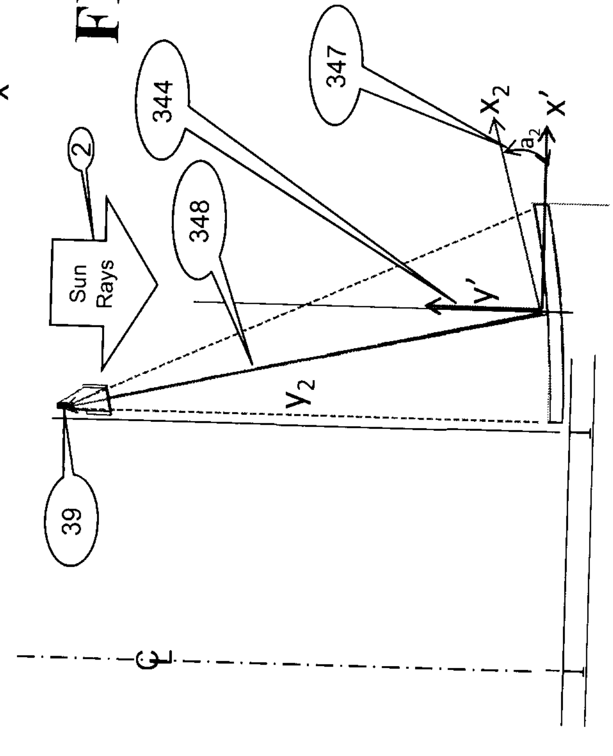
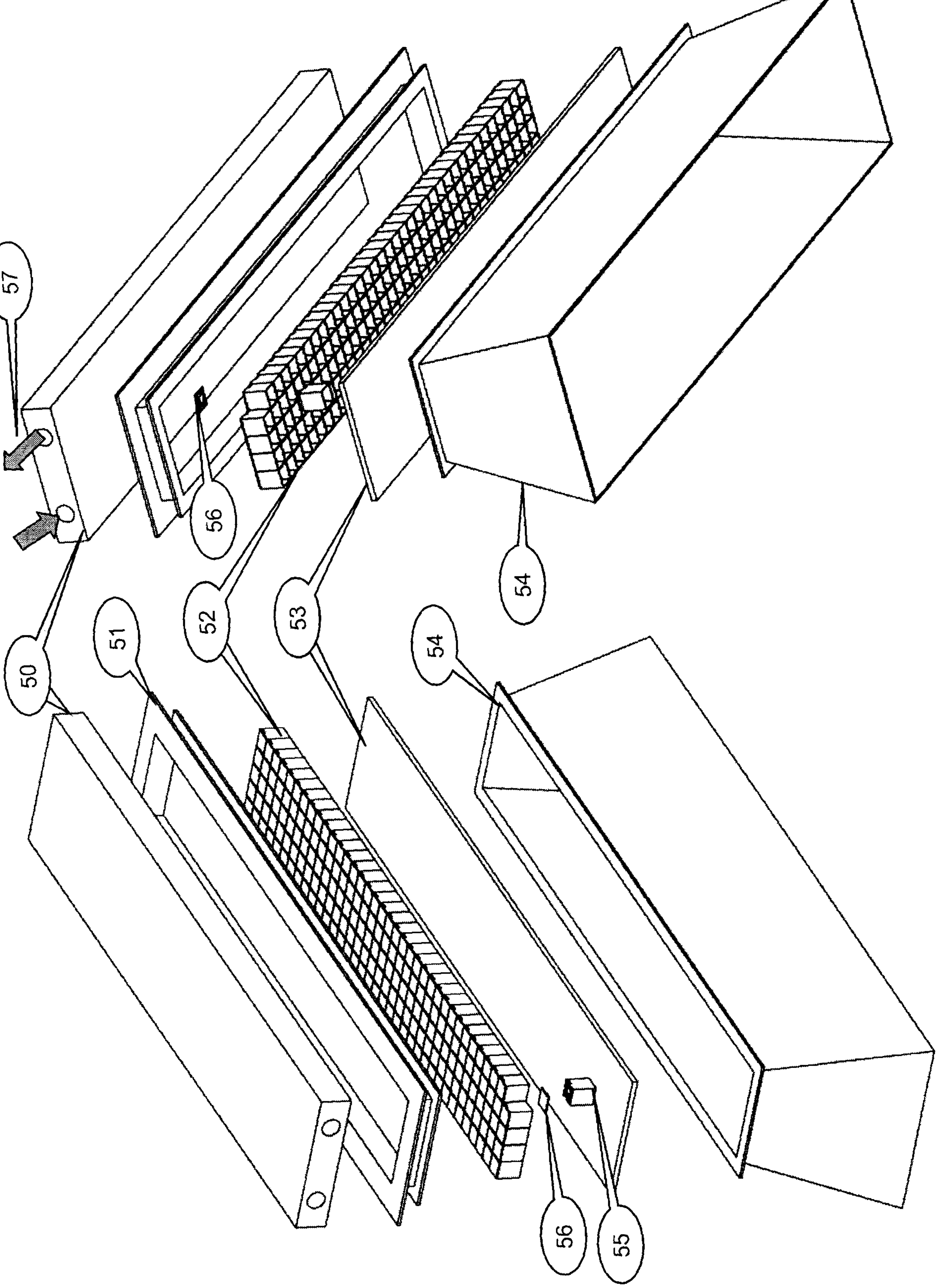


FIG. 4C

FIG. 5



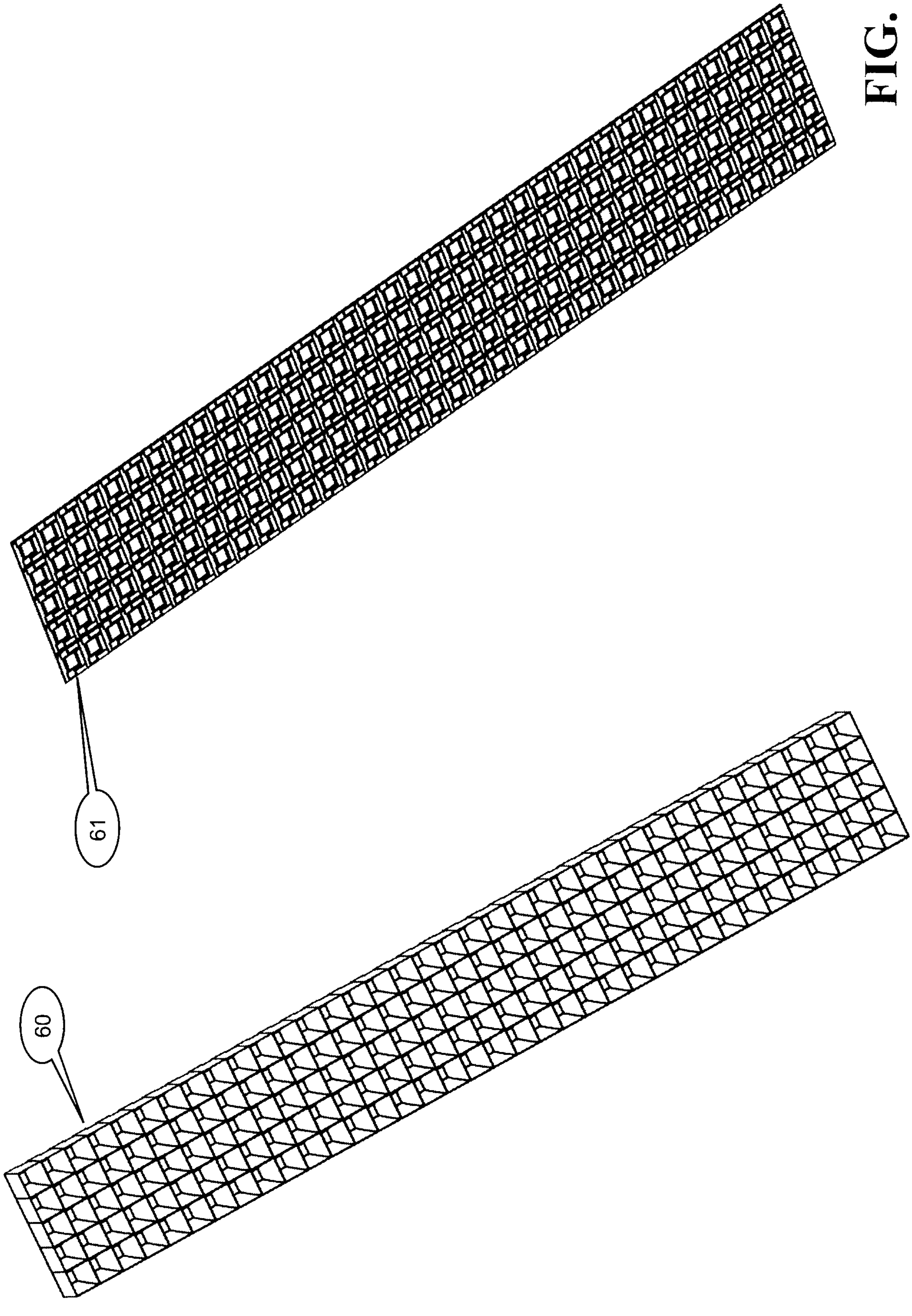


FIG. 6

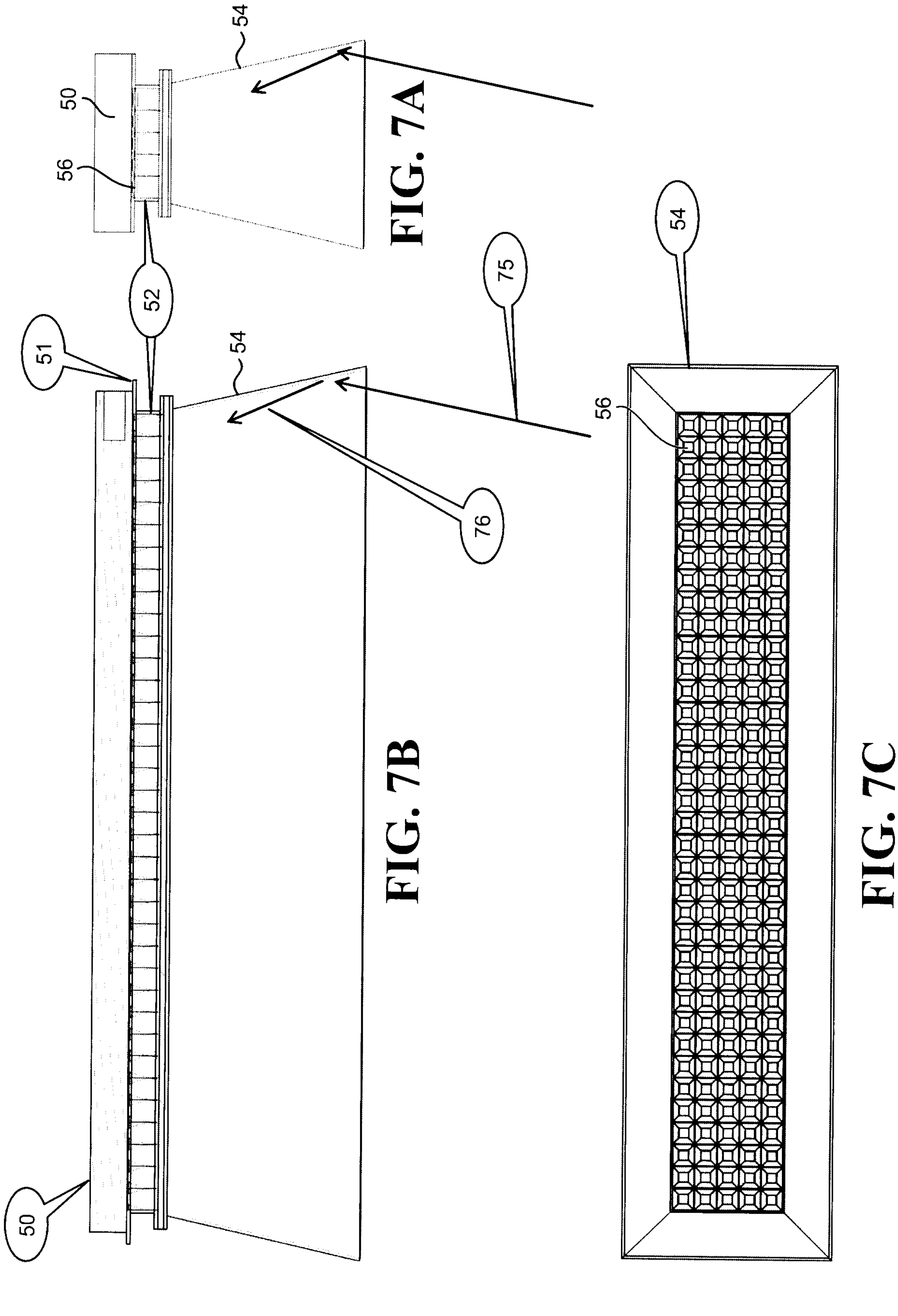
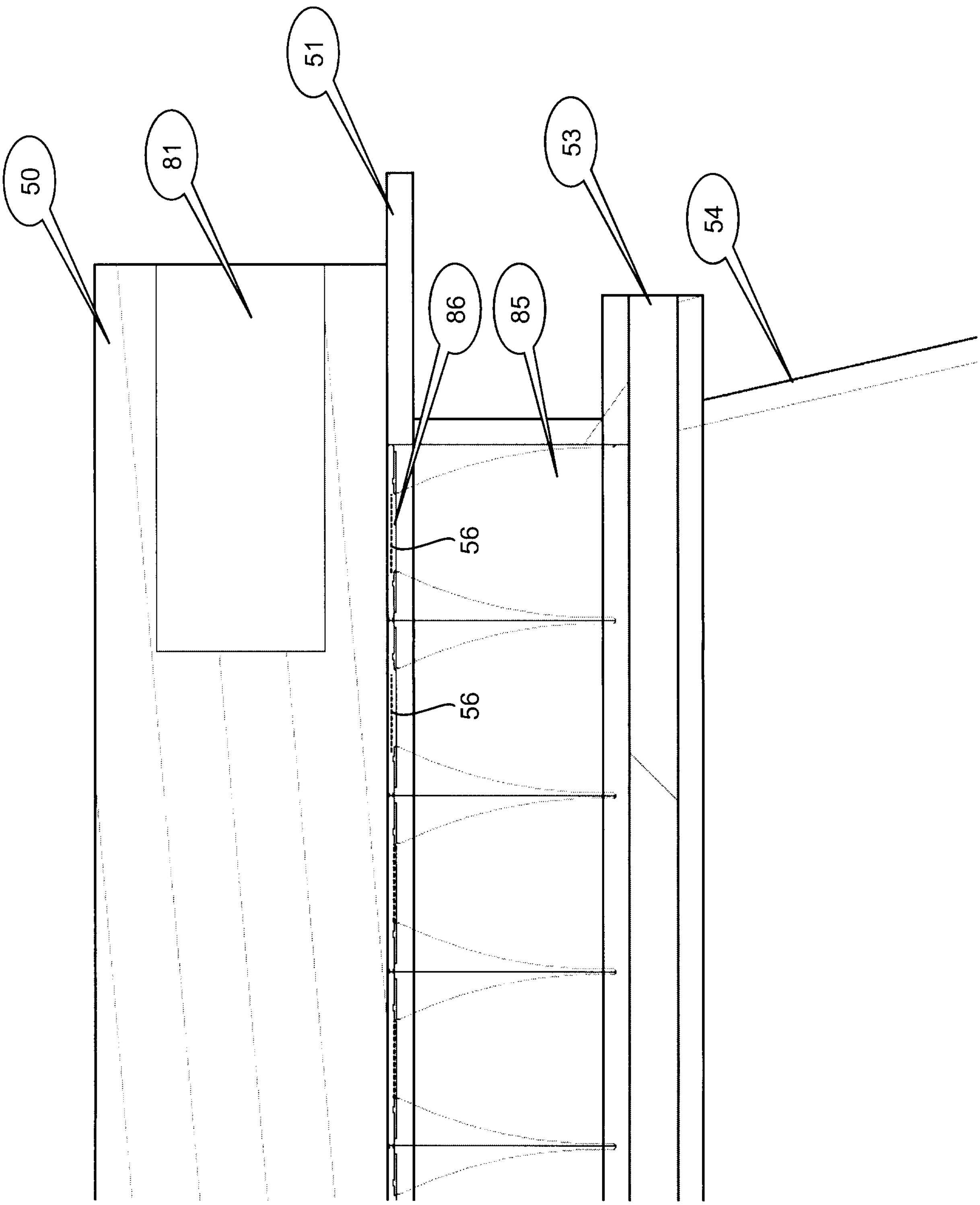


FIG. 7A

FIG. 7B

FIG. 7C

FIG. 8



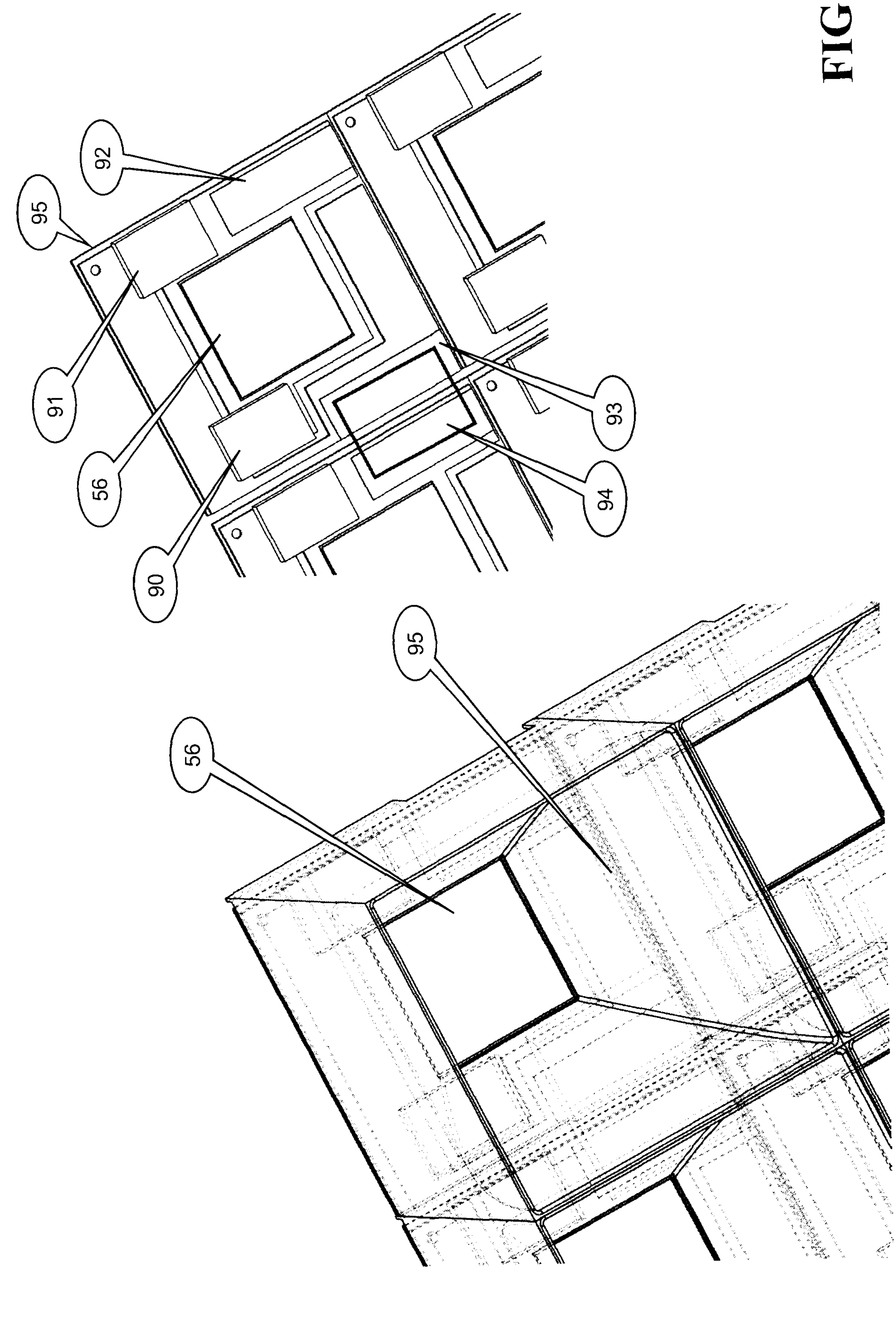
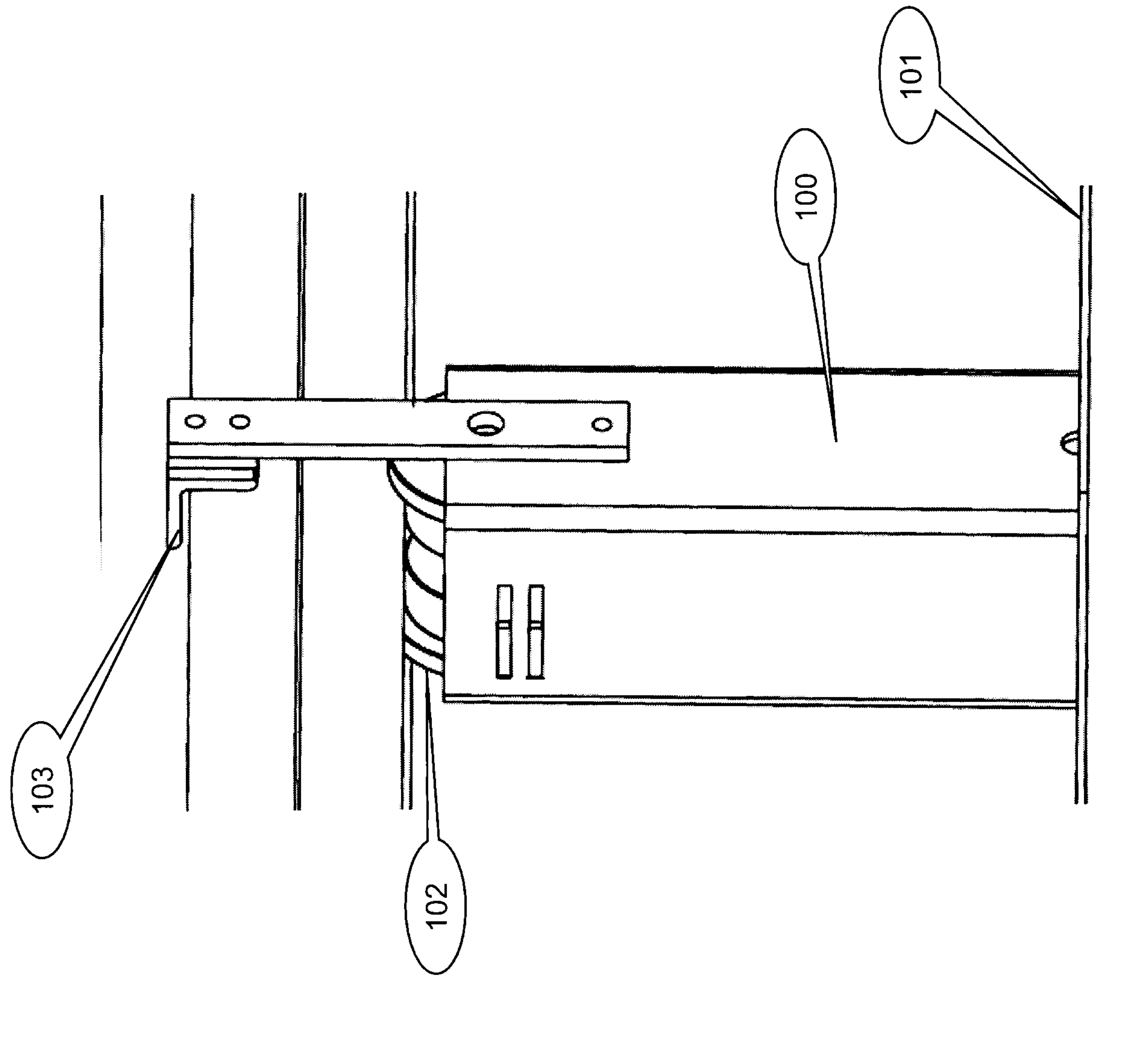
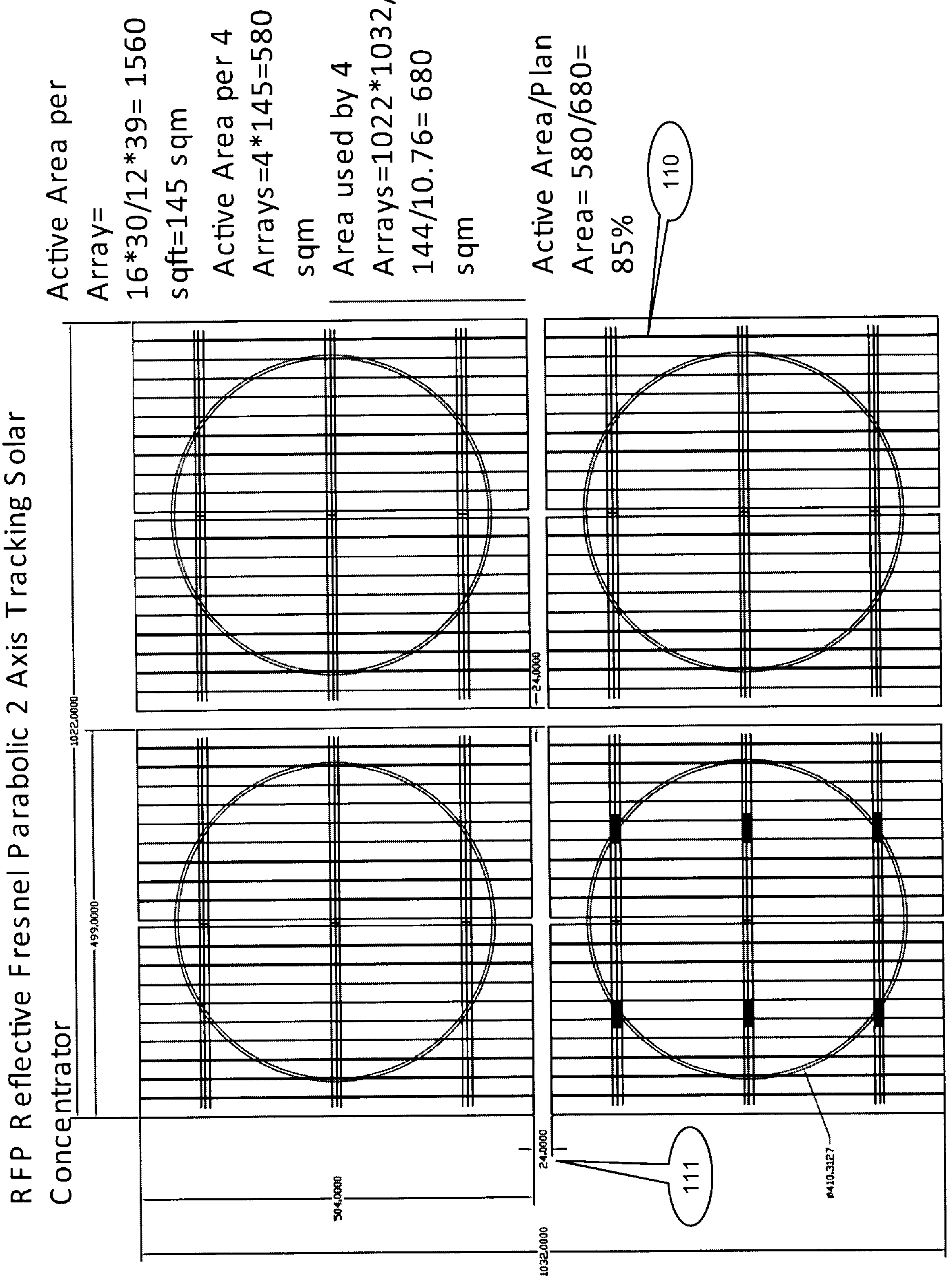


FIG. 9

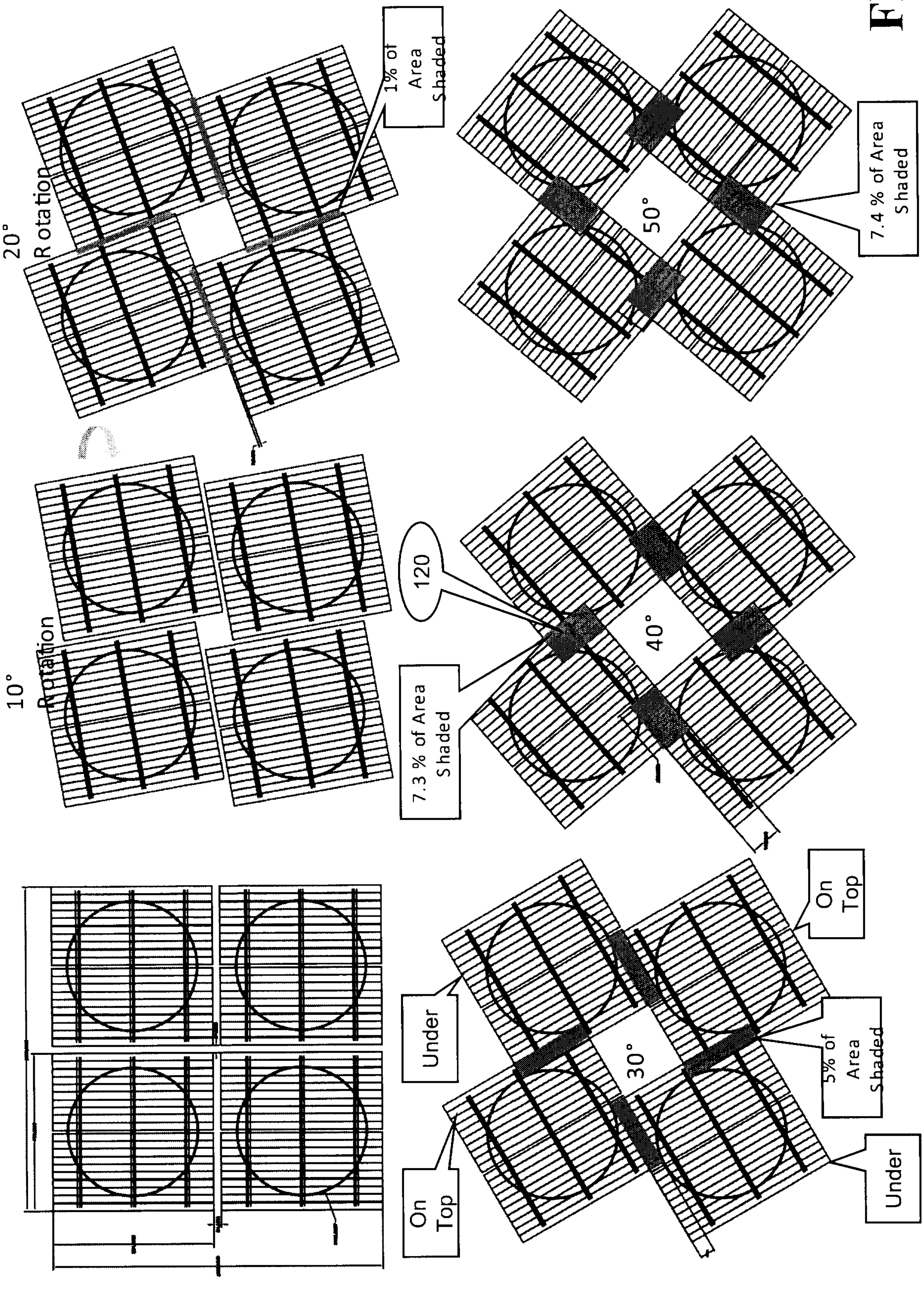
FIG. 10





RFP Reflective Fresnel Parabolic 2 Axis Tracking Solar Concentrator
Active Area per Array= 16*30/12*39= 1560 sqft=145 sqm
Active Area per 4 Arrays=4*145=580 sqm
Area used by 4 Arrays=1022*1032/ 144/10.76= 680 sqm
Active Area/Plan Area= 580/680= 85%
110
111
1022.0000
499.0000
504.0000
24.0000
24.0000
1032.0000
ø410.3127

FIG. 11



20° Rotation
1% of Area Shaded
50°
7.4 % of Area Shaded
10° Rotation
120
40°
7.3 % of Area Shaded
30°
On Top
Under
5% of Area Shaded
Under
On Top

FIG. 12

RFP Array Azimuth Shadowing Analysis

Metric Description				Value	Unit	% of 4 Arrays Shaded	% of Energy Incoming During Interval	Net Loss of Energy Due to Overlapping
Active Area for one Array				145.00	sqm			
Walkway Width				0.62	m			
Plan Area for 4 Arrays				680.70	sqm			
Active/Plan Area Ratio				85%				
0-20 Deg Azimuth				0	sqm	0	25%	0.00%
20-30 Deg Azimuth				6.40	sqm	1.1%	22%	0.24%
30-40 Deg Azimuth				29.12	sqm	5.0%	20%	1.00%
40-50 Deg Azimuth				42.60	sqm	7.3%	17%	1.25%
50-60 Deg Azimuth				43.18	sqm	7.4%	16%	1.19%
Summation of Total Energy Lost							100%	3.69%

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RFP Array Inclination Shadowing Analysis

	North Winter	North Summer		Inclination Angle of Sun in Sky 0 Deg Solar Noon	% of Full Active Area	Active Appeture (C*B) sqm	% of Solar Energy in Interval (Summer)	% of Solar Energy in Interval (Winter)	Effective Energy versus Trough (%) Summer	Energy versus Trough (%) Winter
Width of Array A			11.88662	m						
Depth of Array into Page B			11.88662							
Energy and Appeture				0-10	9%	12.3	3%	0.05	0.26%	0.44%
				10-20	26%	36.6	4%	0.15	1.04%	3.88%
				20-30	42%	59.7	8%	0.2	3.38%	8.45%
				30-40	57%	81.0	9%	0.25	5.16%	14.34%
				40-50	71%	99.9	11%	0.35	7.78%	24.75%
				50-60	82%	115.7	13%		10.65%	0.00%
				60-70	91%	128.1	15%		13.59%	0.00%
				70-80	97%	136.5	17%		16.42%	0.00%
				80-90	100%	140.8	20%		19.92%	0.00%
Totals							100%	100%	78.21%	51.86%
Including Azimuth Shading									75.3%	49.9%

RFP/trough Area Ratio in Same Plan Area 1.88 this compares on a cost of hardware basis

Effective Energy Production Ratio RFP/Trough for same Plan Area 1.42 0.94

So on Average the RFP will be about 28% more energetic given 70% of our energy falls in summer months 1.28

This system gets much better in southerly climates where the sun is high in the sky for more of the day

If we consider the plan area use the energy production ratios are much higher

Typical active area as a % of land Area for a trough plant is 26.00%

Active Area ratio for RFP 85%

RFP/Trough plan areas 3.27 *times better than trough on peak output per acre*

Energy Production ratio in southerly climates is 2.46 *times as much energy for a given patch of land!*

144

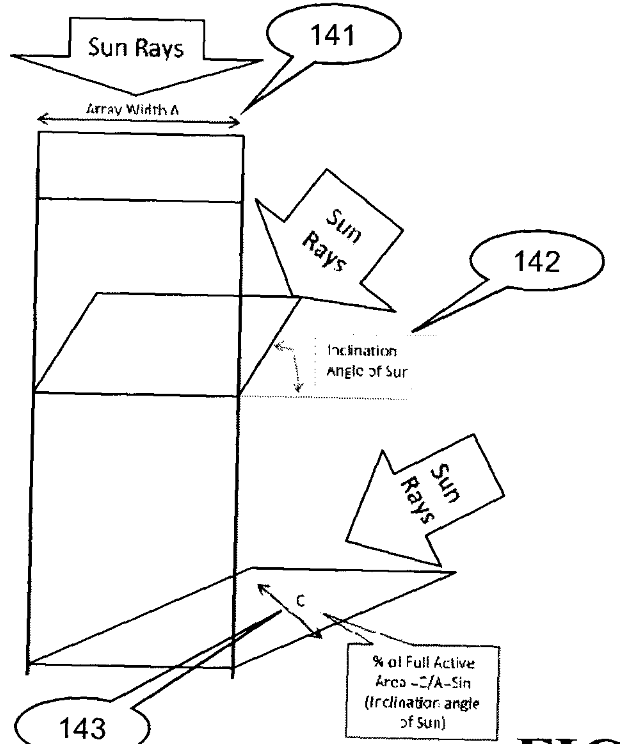
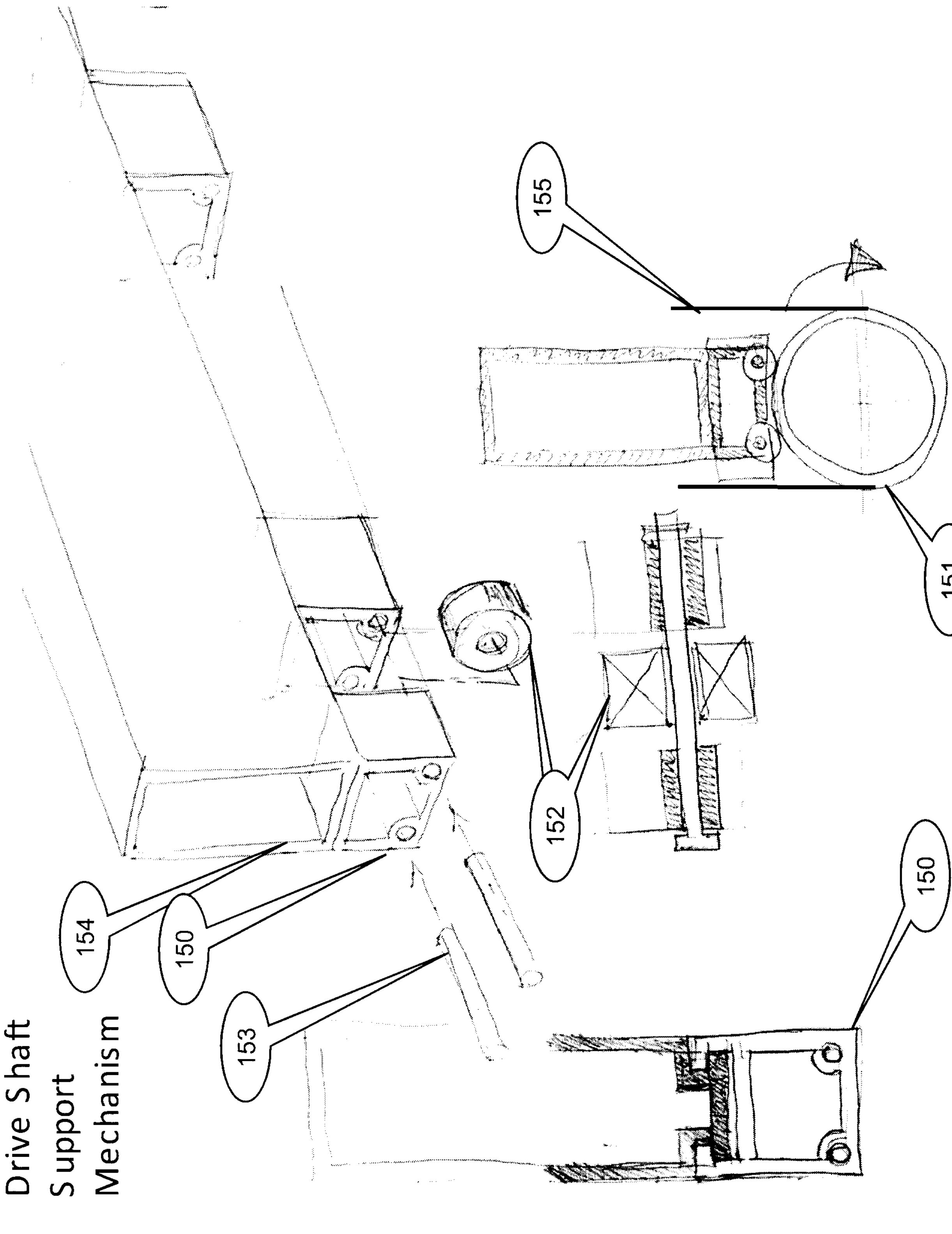


FIG. 13

FIG. 14



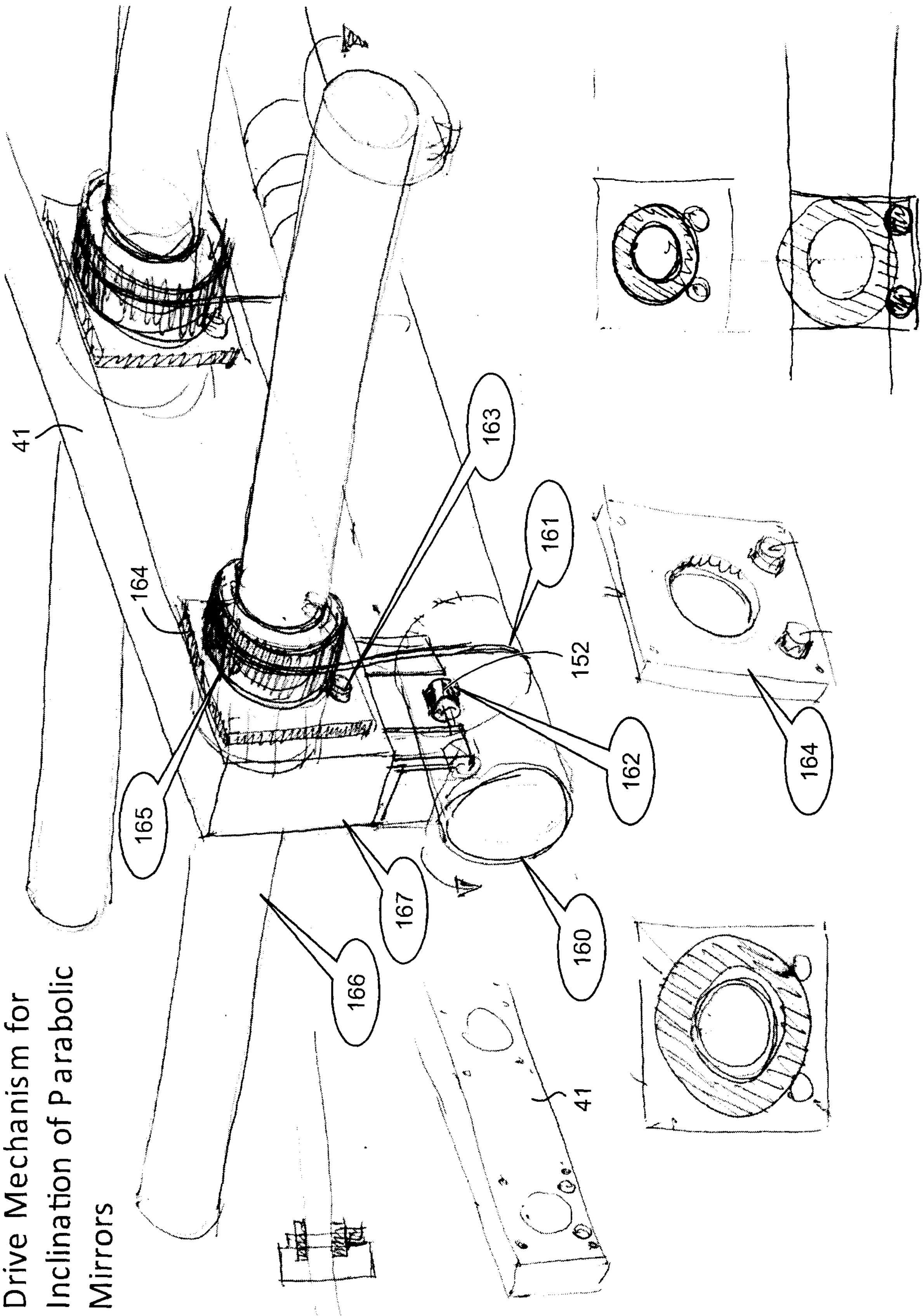

Drive Mechanism for Inclination of Parabolic Mirrors
41
164
163
161
152
162
165
167
166
160
164
41

FIG. 15

FIG. 16

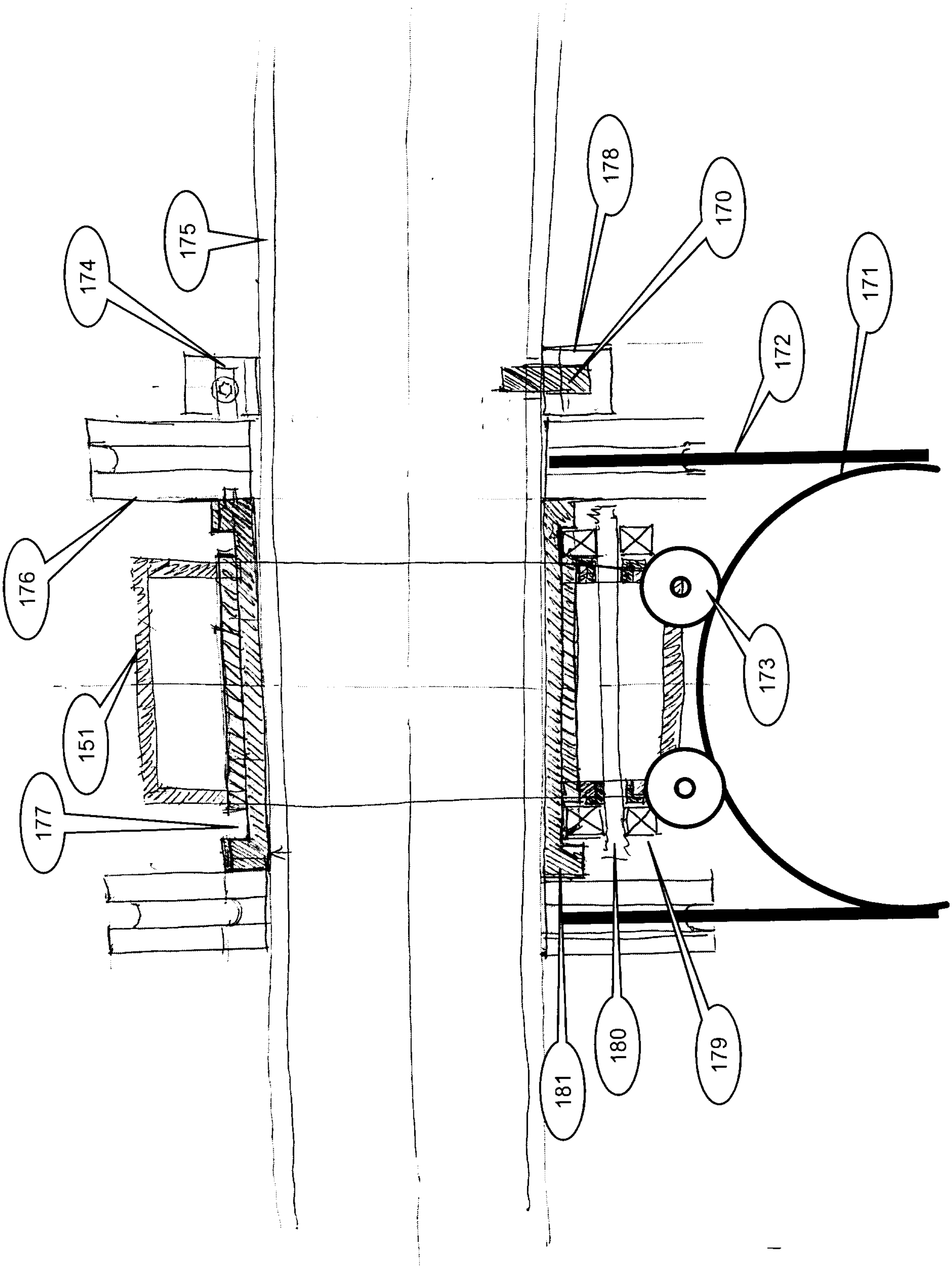
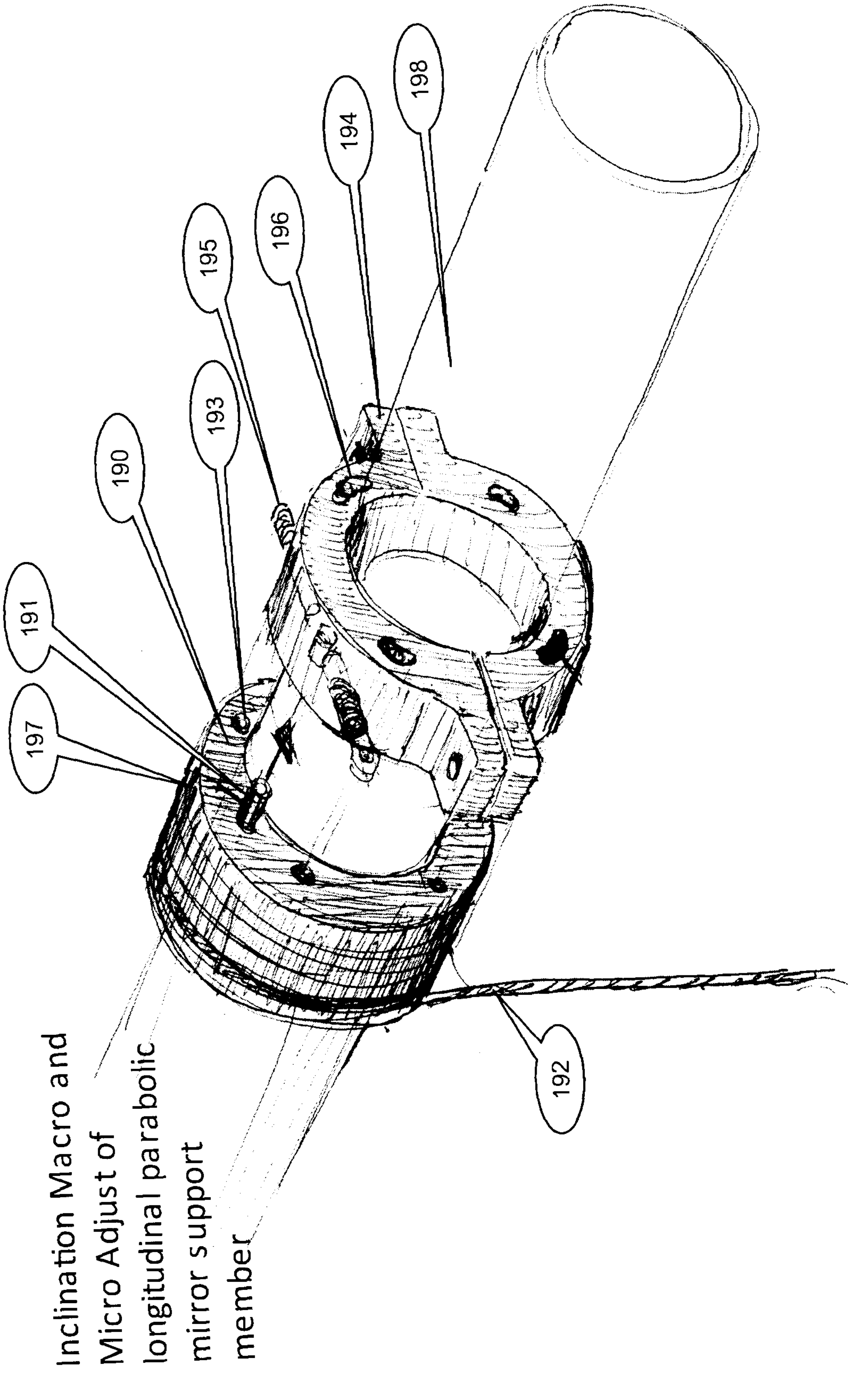


FIG. 17


197
191
190
193
195
196
194
198
192
Inclination Macro and
Micro Adjust of
longitudinal parabolic
mirror support
member

Reflective Fresnel Parabolic
Solar Concentrator Variant #2
– 8 Heads 64 Mirrors

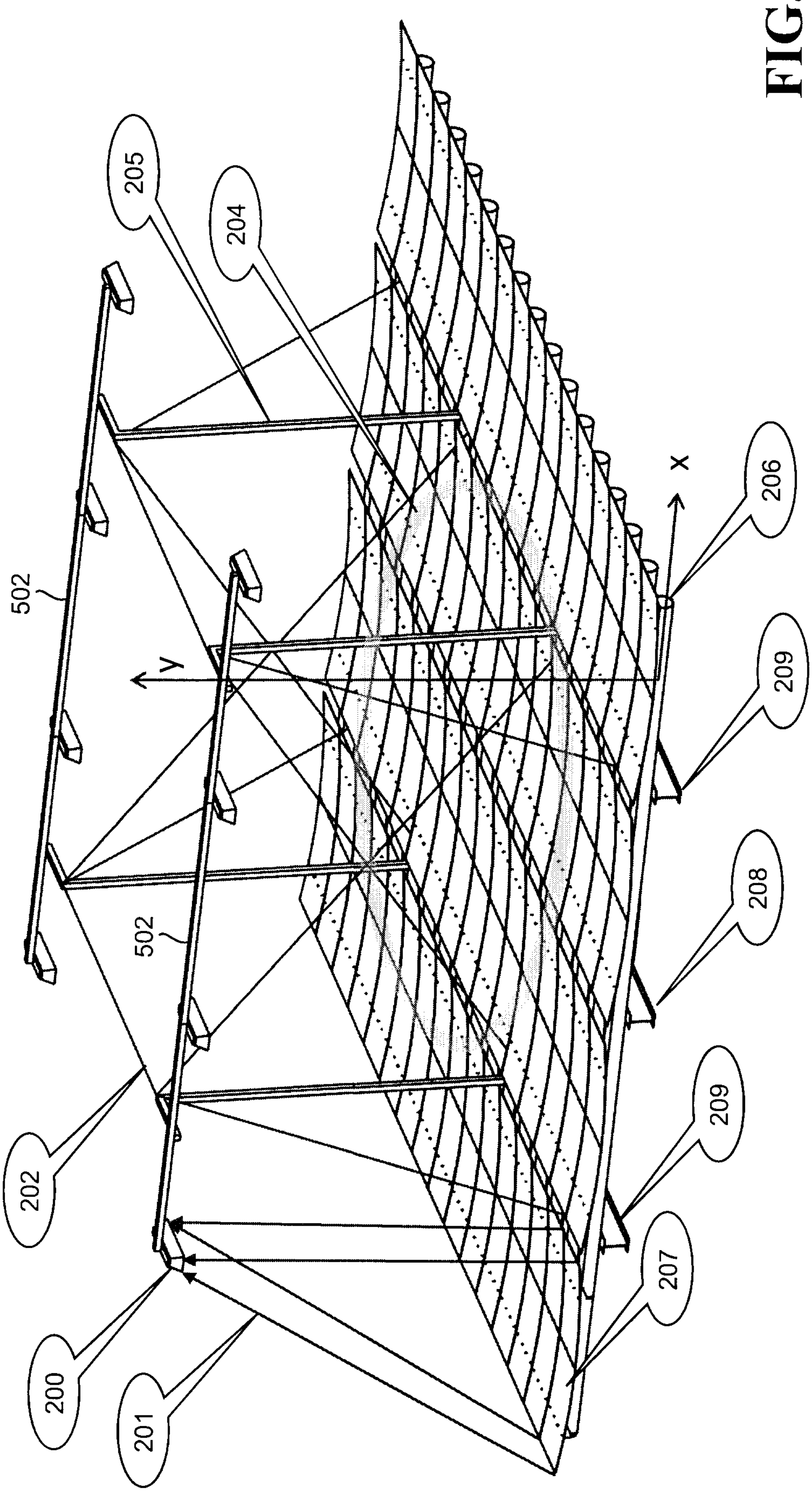


FIG. 18

Reflective Fresnel Parabolic Solar Concentrator Variant #2 – 8 Heads 64 Mirrors – Top View

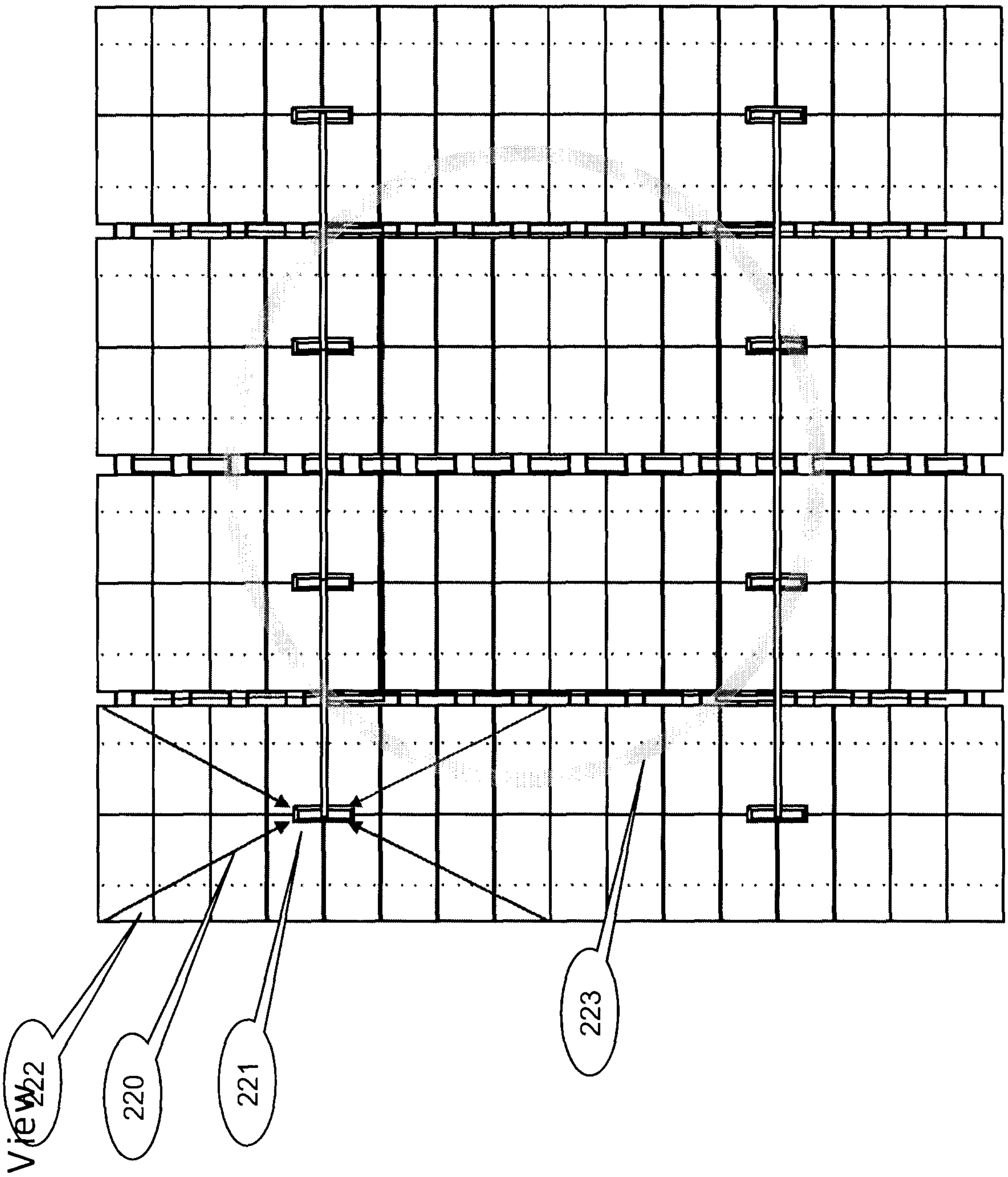


FIG. 19

Reflective Fresnel Parabolic Solar Concentrator Variant #2 – 8 Heads 64 Mirrors – Side View

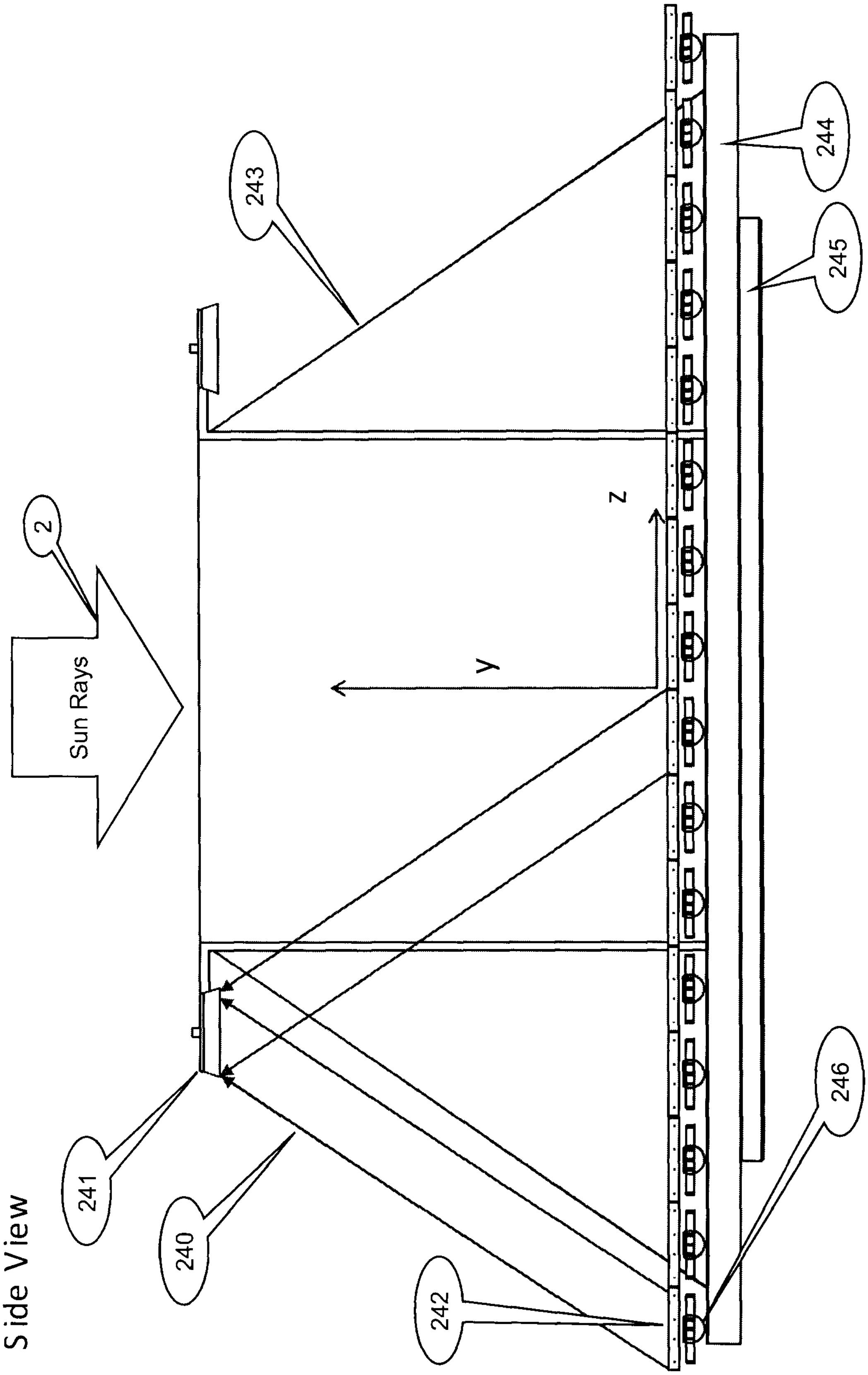


FIG. 20

Reflective Fresnel Parabolic Solar Concentrator Variant #2 – 8 Heads 64 Mirrors – Front View

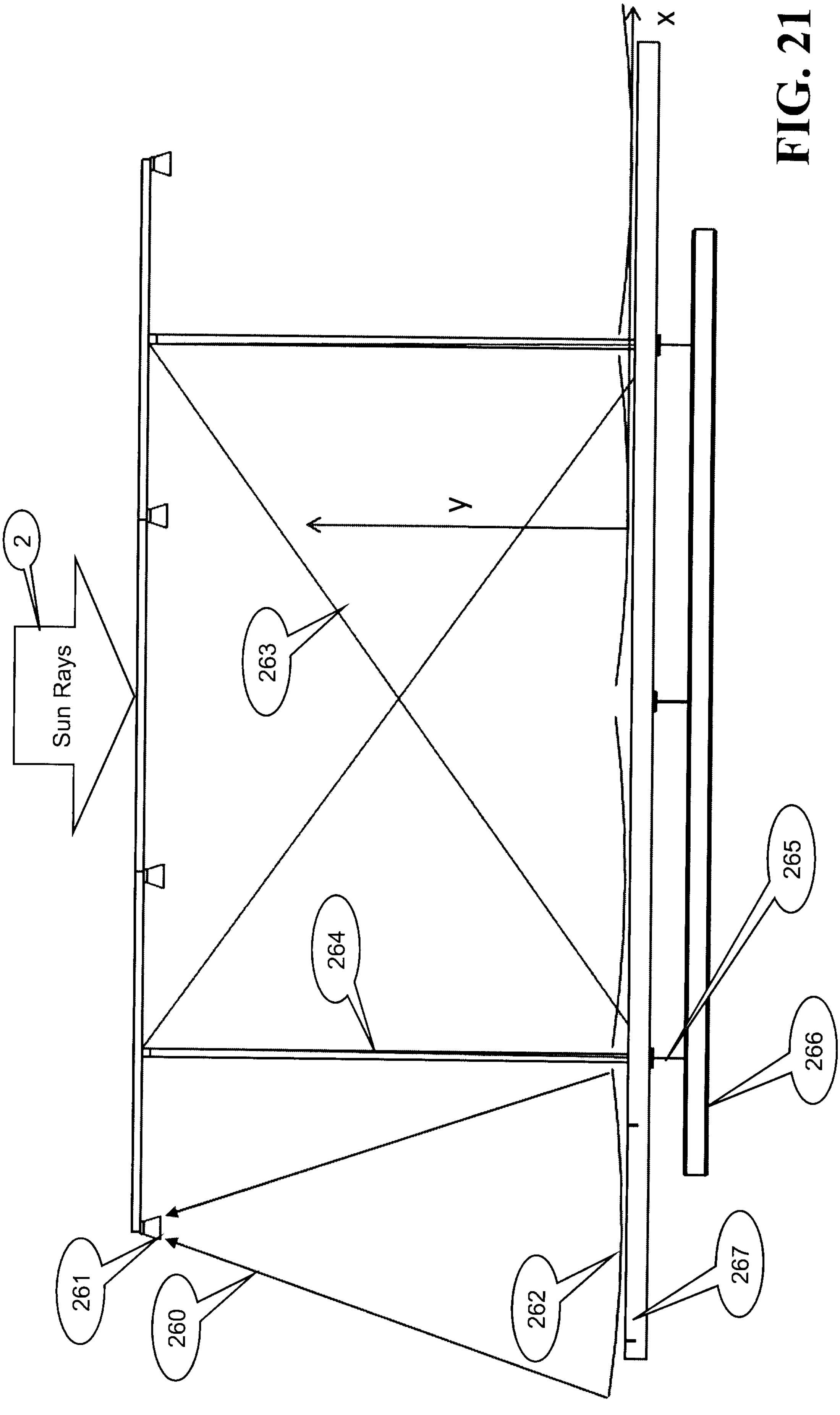


FIG. 21

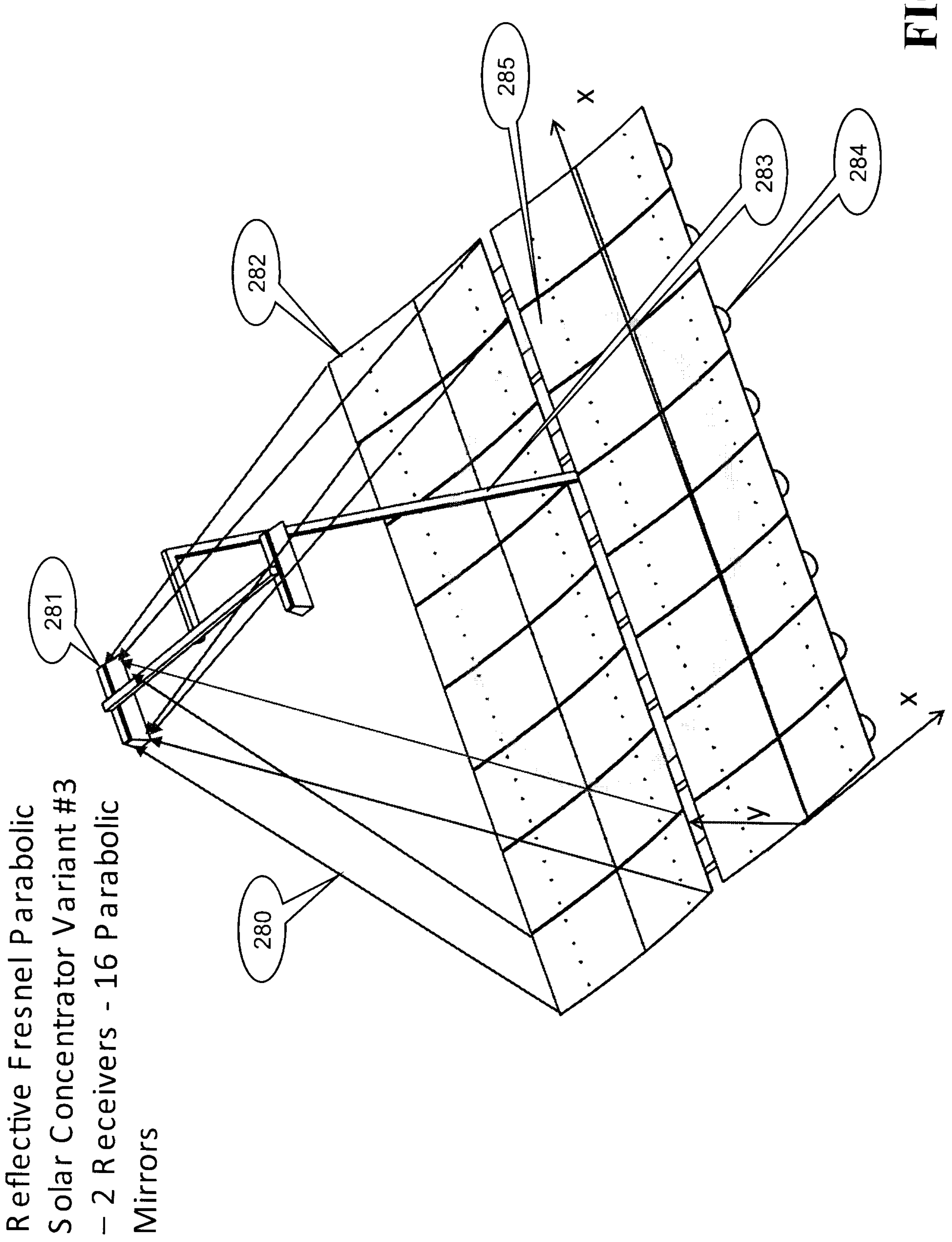
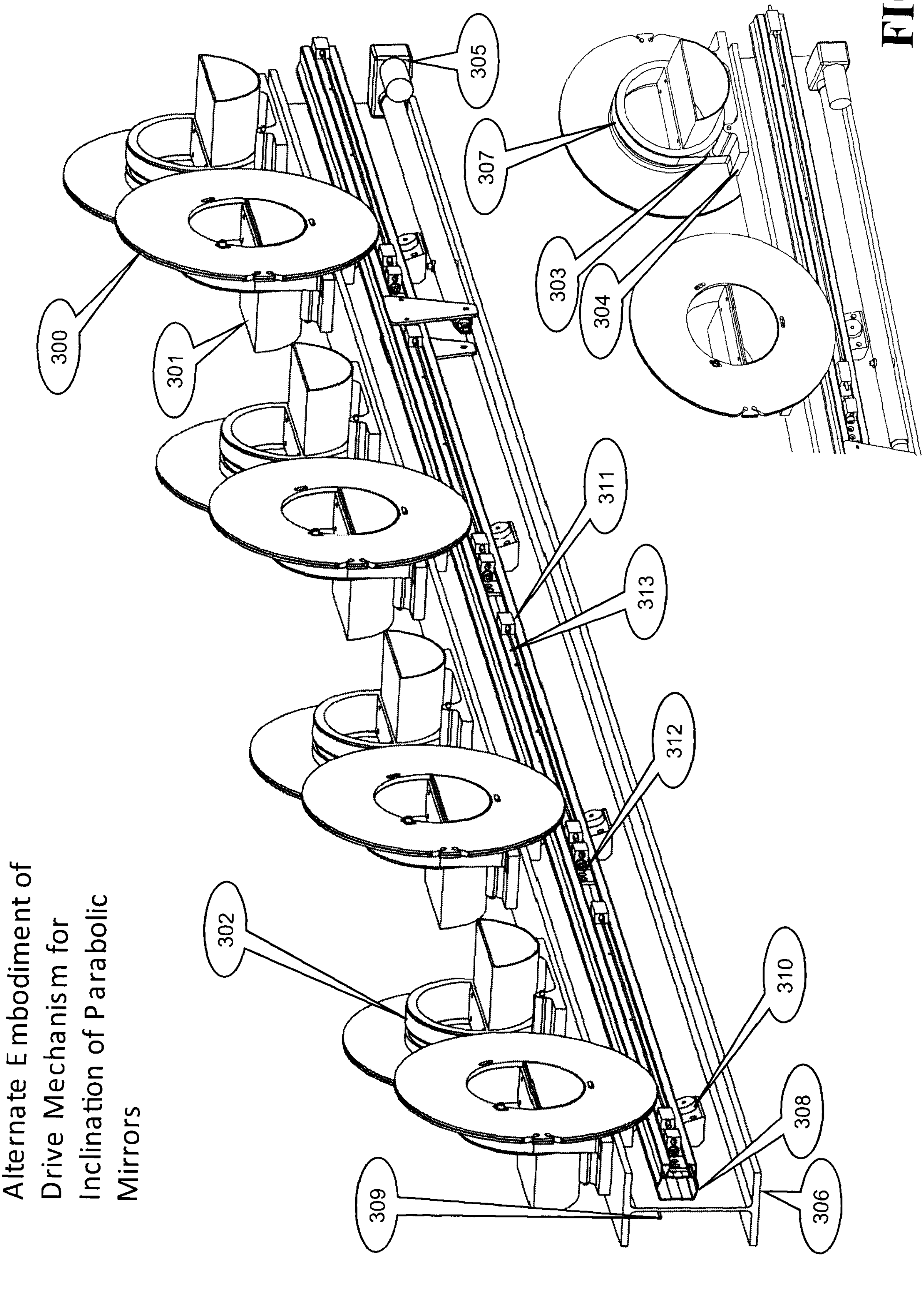

Reflective Fresnel Parabolic Solar Concentrator Variant #3 – 2 Receivers - 16 Parabolic Mirrors
280
281
282
283
284
285
x
x
y

FIG. 22

FIG. 23



Alternate Embodiment of Drive Mechanism for Inclination of Parabolic Mirrors
300
301
302
303
304
305
306
307
308
309
310
311
312
313

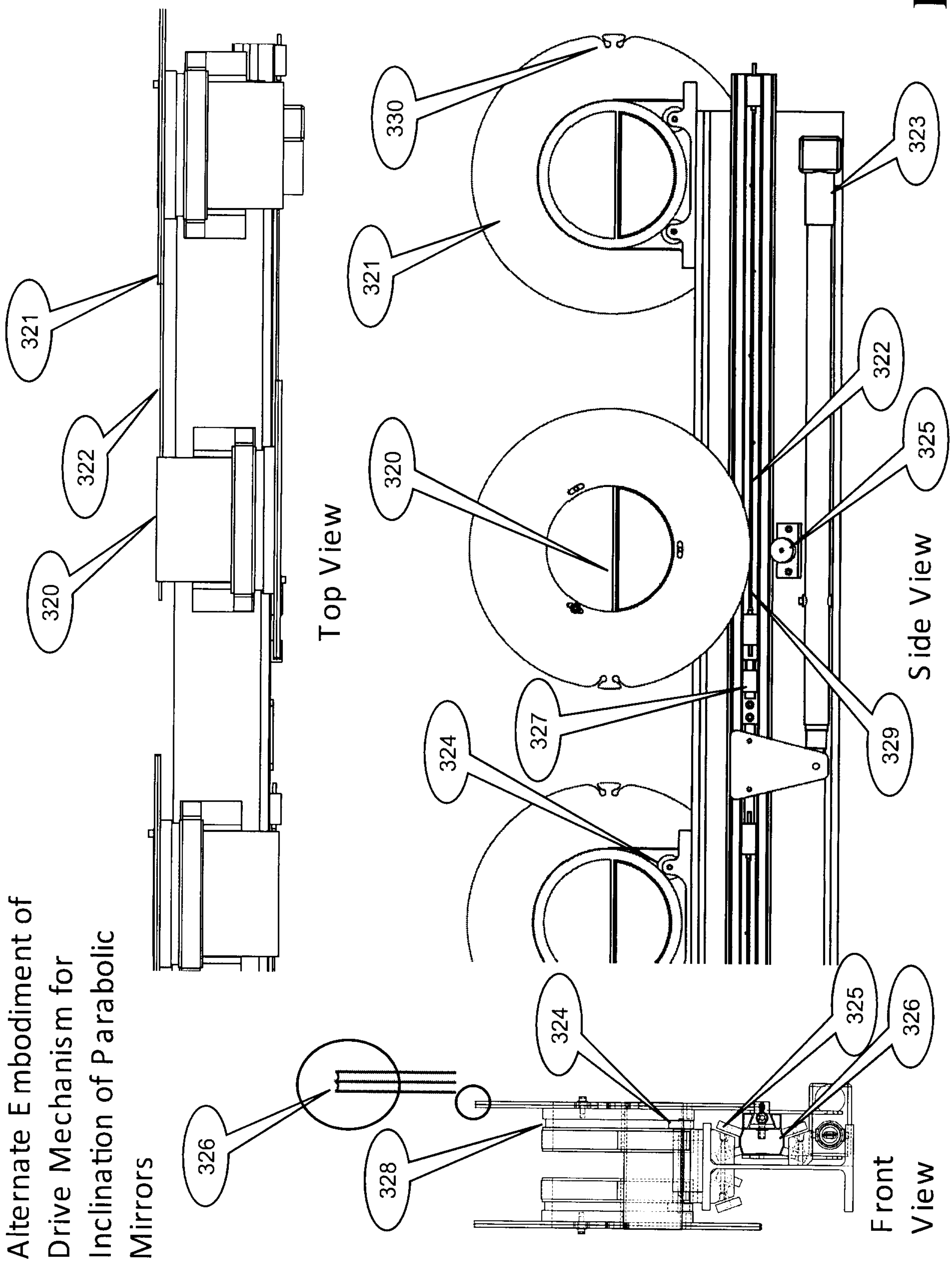
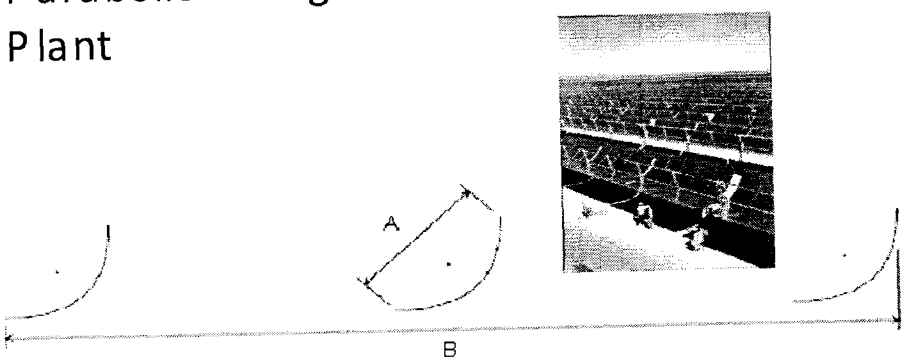

Alternate Embodiment of Drive Mechanism for Inclination of Parabolic Mirrors
Top View
Side View
Front View
320
321
322
323
324
325
326
327
328
329
330

FIG. 24

Parabolic Trough Solar Thermal Electric Plant



Active Area (A)/Land Use Area (B)= 10340/40000 = 26%

1MW/40,000 sqm= 25 w/sqm

Table 1. APS Plant Characteristics

Plant Location:	Saguaro, AZ	
Direct Normal Solar	2636 kW/m²-yr	
Plant Size (nominal)	1.0 MWe	
ORC Turbine gross output	1.16 MWe	
Solar Field Heat Transfer Fluid	Xceltherm 600	
Inlet Temperature	120°C	
Outlet Temperature	300°C	
ORC Working Fluid	n-pentane	
ORC Inlet Temperature	204°C	
ORC Inlet Pressure	22.3 Bara	
ORC Design Point Efficiency	20.7%	
	Base	Expanded
Solar Field Size	10,340 m²	17,233 m²
Land Area	40,000 m²	64,000 m²
Thermal Energy Storage Design Capacity	 none 0 hrs	 thermocline 6 hrs
Annual Capacity Factor	23%	40%
Solar to Electric Efficiency Design Point Annual	 12.1% 7.5%	 12.1% 7.9%

Parabolic Trough Organic Rankine Cycle Power Plant

S. Canada, Arizona Public Service, Phoenix, Arizona (Scott.Canada@aps.com)
G. Cohen and R. Cable, Solargenix Energy, Raleigh, North Carolina
D. Brosseau, Sandia National Laboratories, Albuquerque, New Mexico
H. Price, National Renewable Energy Laboratory, Golden, Colorado

FIG. 25

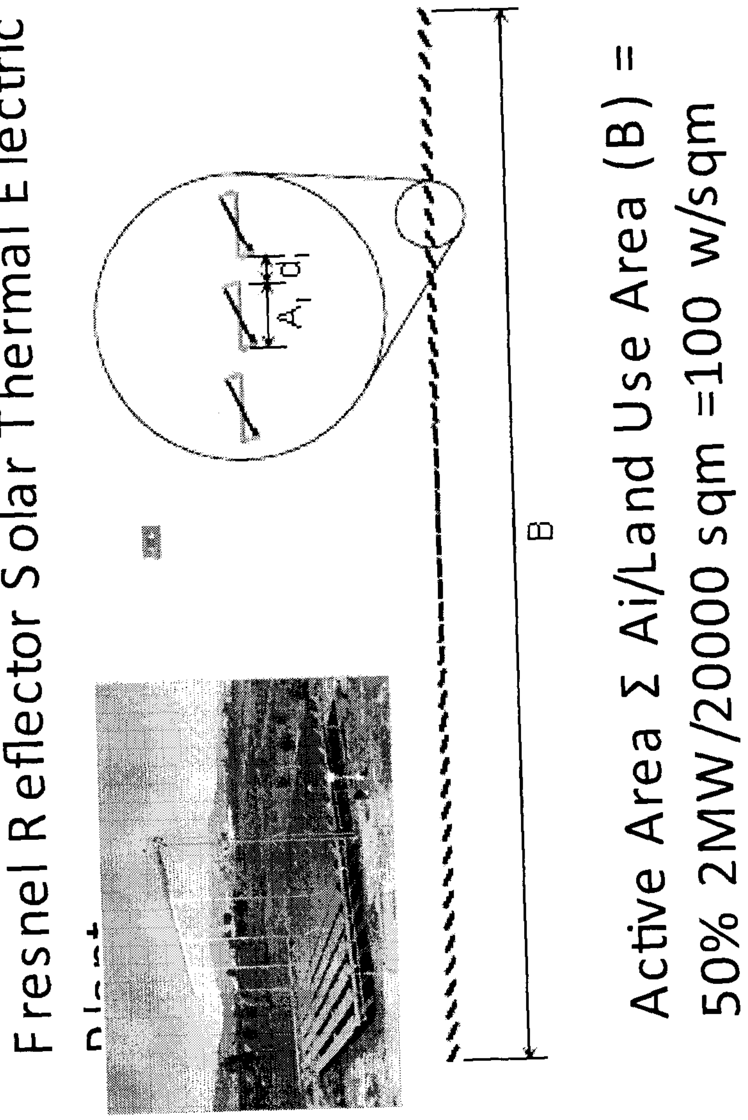
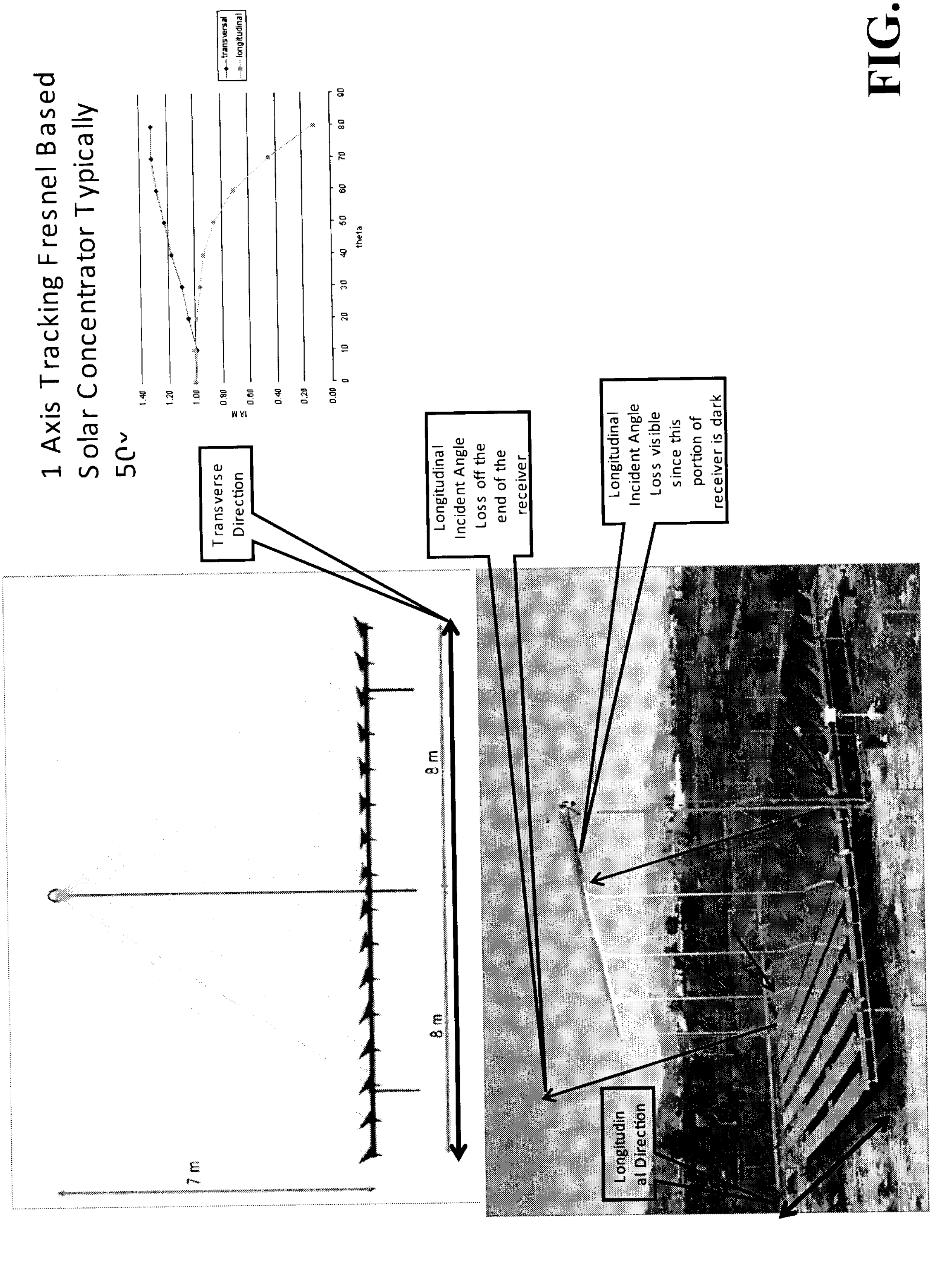

Fresnel Reflector Solar Thermal Electric Plant
A_i
d
B
Active Area Σ Ai/Land Use Area (B) =
50% 2MW/20000 sqm =100 w/sqm

FIG. 26



1 Axis Tracking Fresnel Based Solar Concentrator Typically 50˅
transversal
longitudinal
IAM
theta
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
Transverse Direction
Longitudinal Incident Angle Loss off the end of the receiver
Longitudinal Incident Angle Loss visible since this portion of receiver is dark
8 m
8 m
7 m
Longitudin al Direction

FIG. 27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2009/000404

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F24J 2/06*** (2006.01) , ***F24J 2/16*** (2006.01) , ***F24J 2/38*** (2006.01) , ***F24J 2/54*** (2006.01) , ***H01L 31/052*** (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2006.01): F24J, H01L 31/xx

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
QPat, Delphion, Internet and Canadian Patent Database
Keywords: solar, azimuth, multi-faceted, multi-axis, compound curve, double curve,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2007/109901 A1 (GERWING, D.) 4 October 2007 (04-10-2007) *see page 10, line 11 to page 15, line 29; figures 1, 5, 8, 9, 12 and 13*	1, 2, 19-27, 29-54, 61-97 3-18, 28, 55-60, 98
X Y	WO 2002/097341 A1 (LAWHEED, P.) 5 December 2002 (05-12-2002) *see page 9, paragraph 5 to page 12, paragraph 2; figure 1*	1, 2, 19-27, 29-54, 61-97 3-18, 28, 55-60, 98
Y	WO 2005/124245 A2 (VALSECHI, A.) 29 December 2005 (29-12-2005) *see whole document*	3-14, 55-60, 98
Y	US 4,463,749 A1 (SOBCZAK et al.) 7 August 1984 (07-08-1984) *see whole document*	3-14, 55-60, 98
Y	WO 2005/078360 A1 (LE LIEVRE, P.) 25 August 2005 (25-08-2005) *see abstract; figure 1*	28
A, P	US 2008/0276929 A1 (GERWING et al.) 13 November 2008 (13-11-2008) *see paragraphs [0039] to [0043]; figures 4-9*	15-18, 42-50

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 June 2009 (23-06-2009)	14 July 2009 (14-07-2009)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
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Authorized officer
Kristian MacKenzie 819- 934-4267

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2009/000404

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		EP 1728030A1	06-12-2006
		MX PA06009182A	26-01-2007
		US 2007157923A1	12-07-2007
US 2008276929A1	13-11-2008	None	