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(54) LINEAR SOLAR ENERGY COLLECTION SYSTEM

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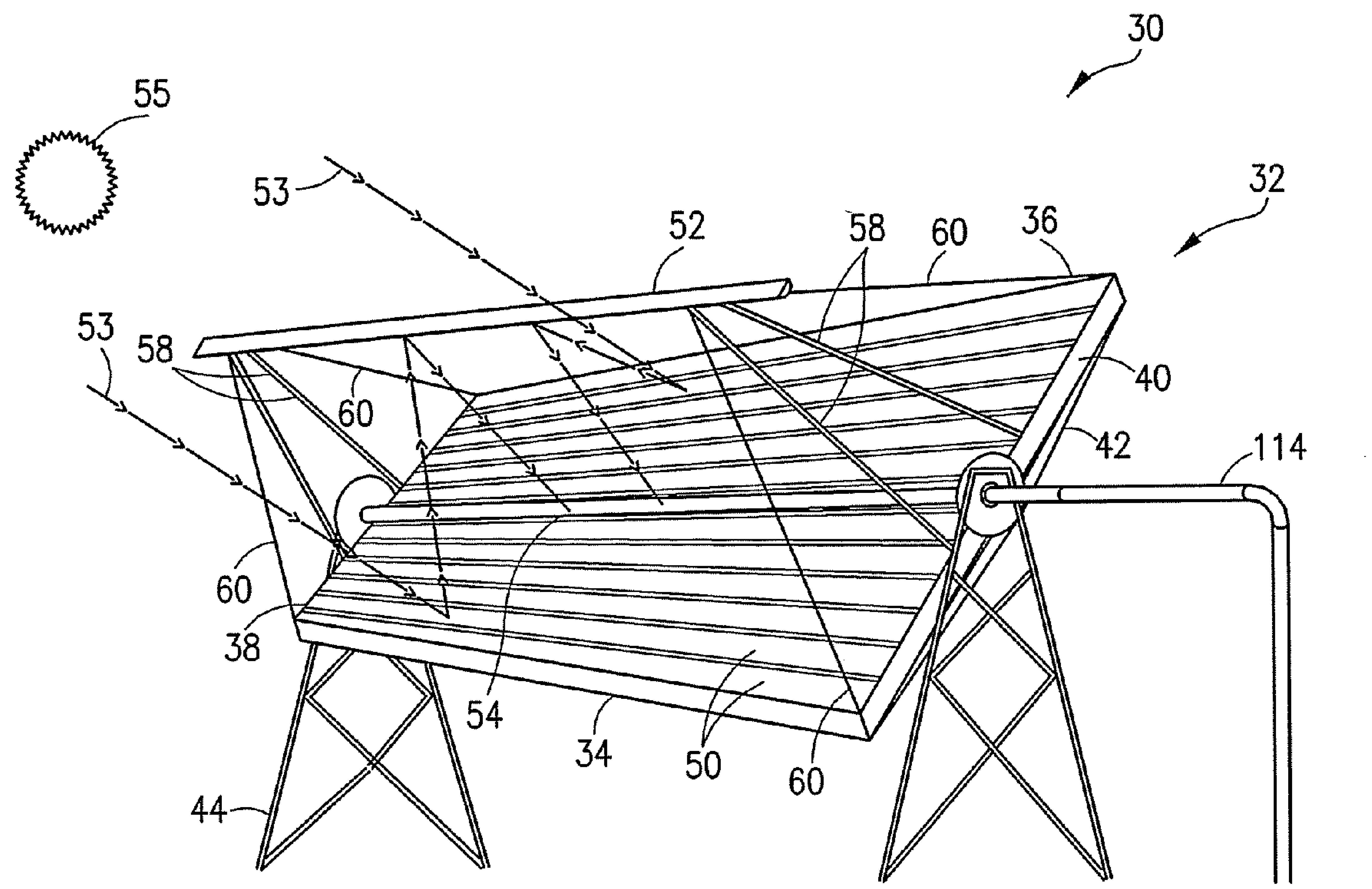
(57) ABSTRACT

A modular linear solar energy collection system comprises one or more reflector units each having a light-weight generally planar aluminum frame that mounts a number of solar panels in a fixed position at angles which progressively increase from the frame centerline outwardly to its perimeter so as to collectively form a surface having a shape approximating that of a parabola. The focal line of such parabola is coincident with a secondary reflector which receives sunlight incident on the solar panels and reflects such light onto a receiver tube mounted in a fixed position concentric to the centerline of the frame. The frame is connected to a drive mechanism operative to pivot the frame and solar panels in order to track the position of the sun during the course of a day.



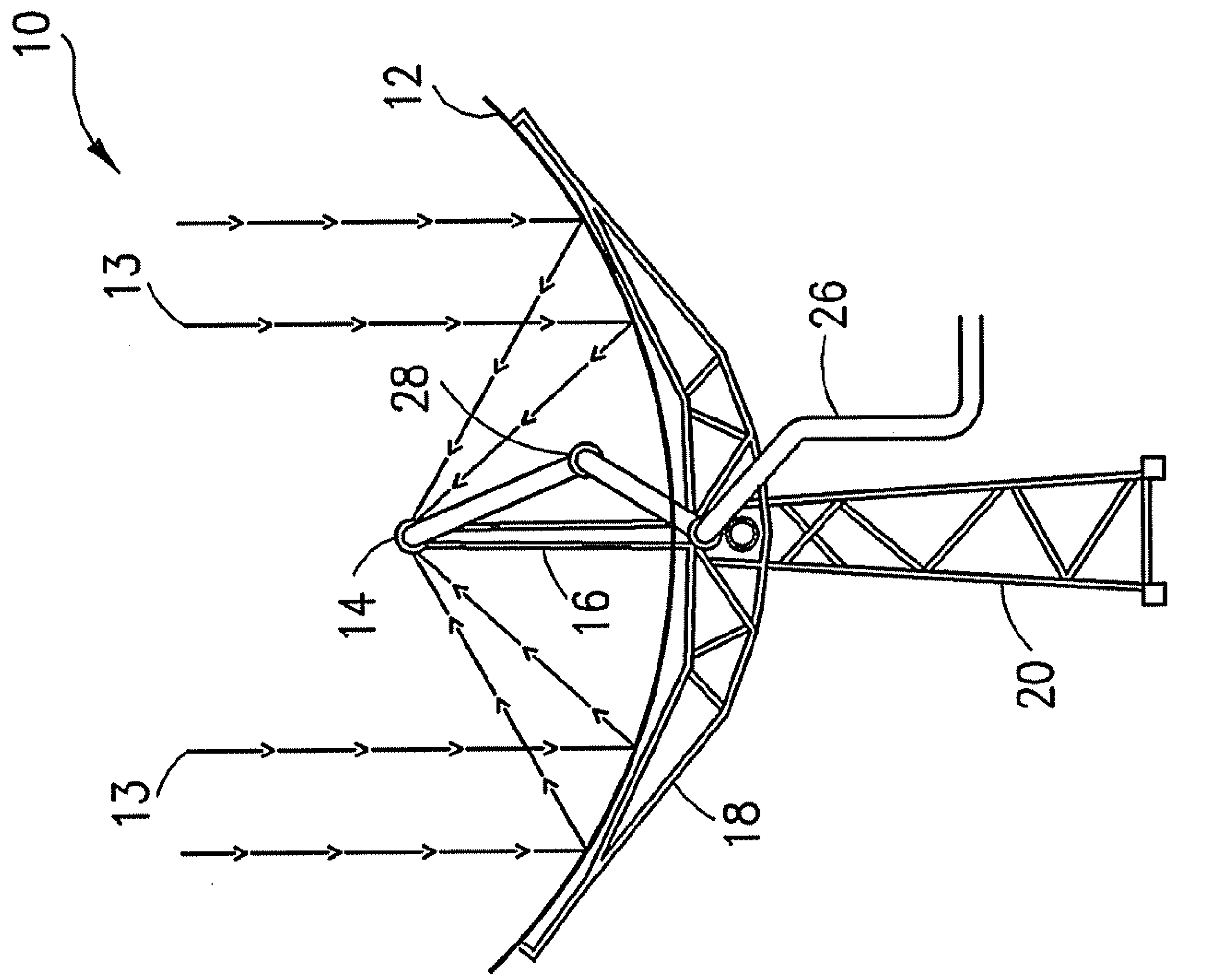


FIG. 2
PRIOR ART

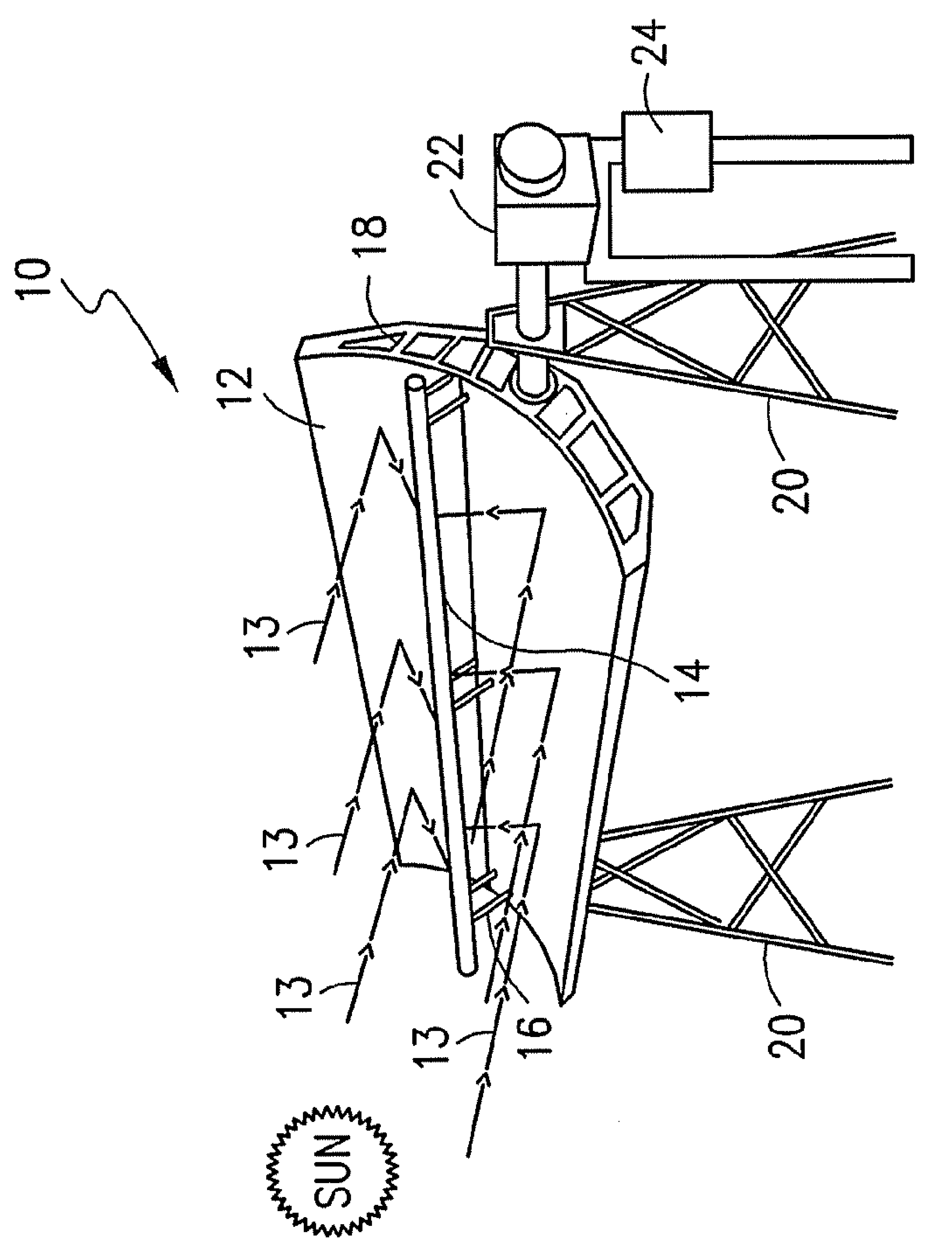


FIG. 1
PRIOR ART

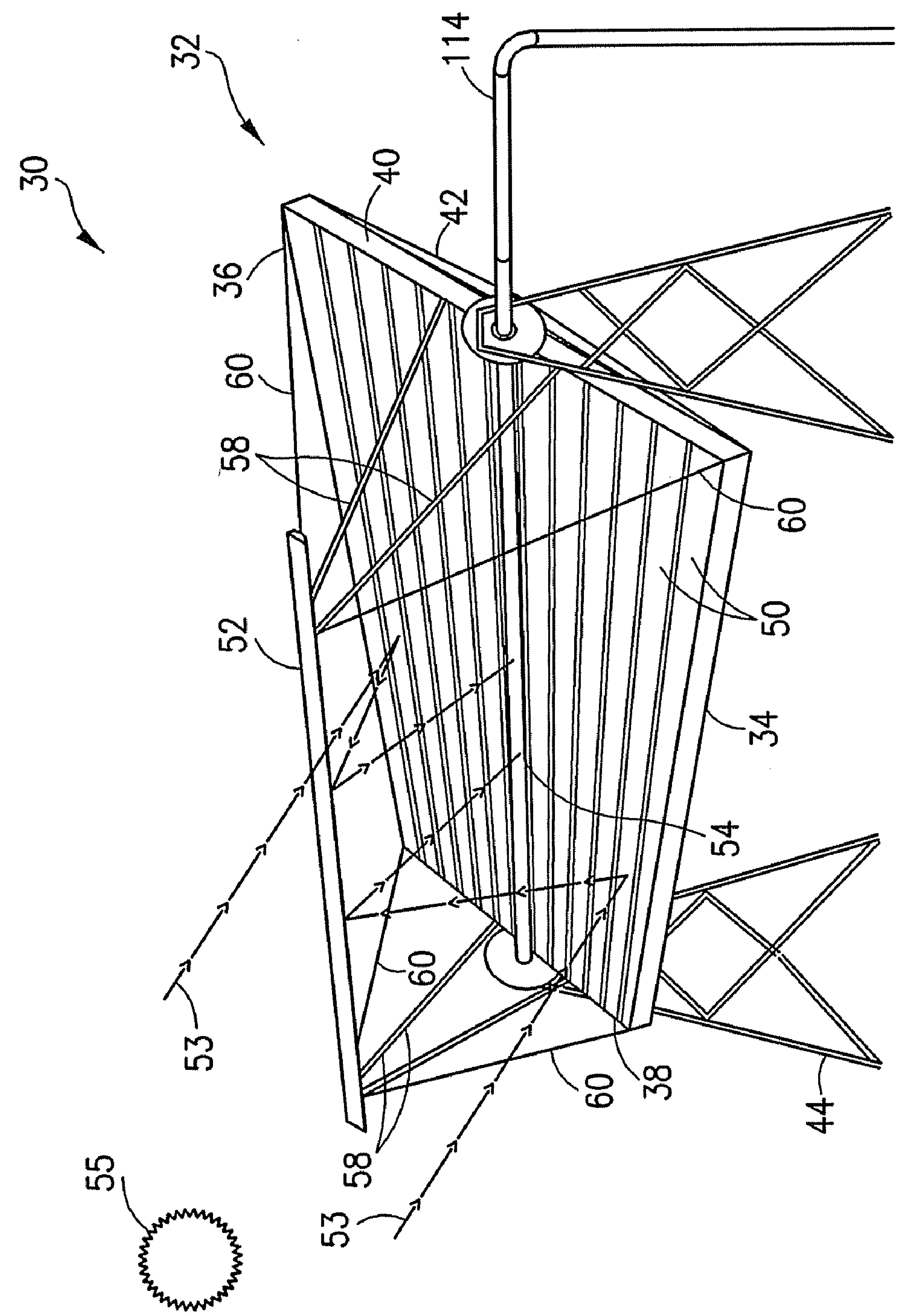


FIG. 3

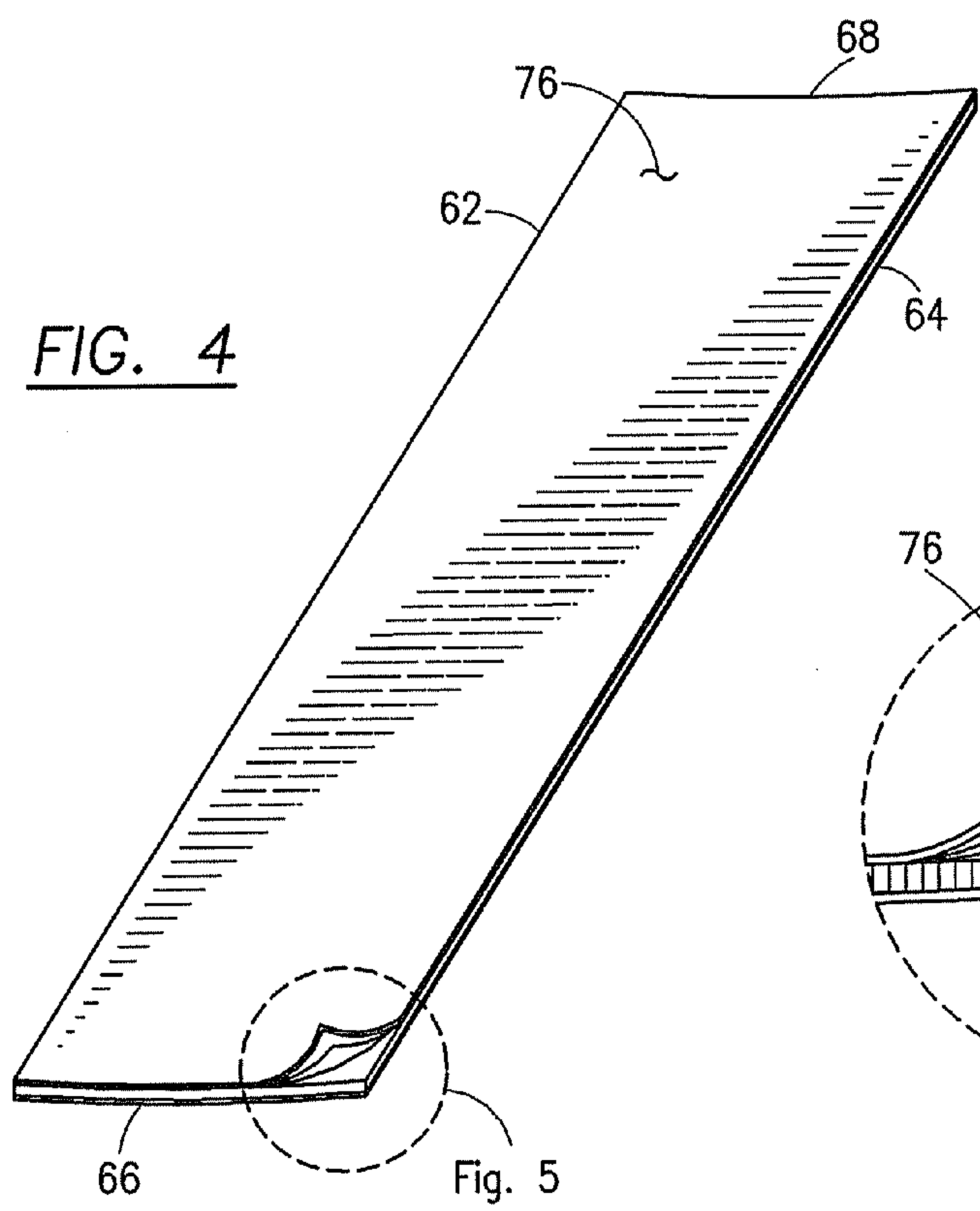


FIG. 4

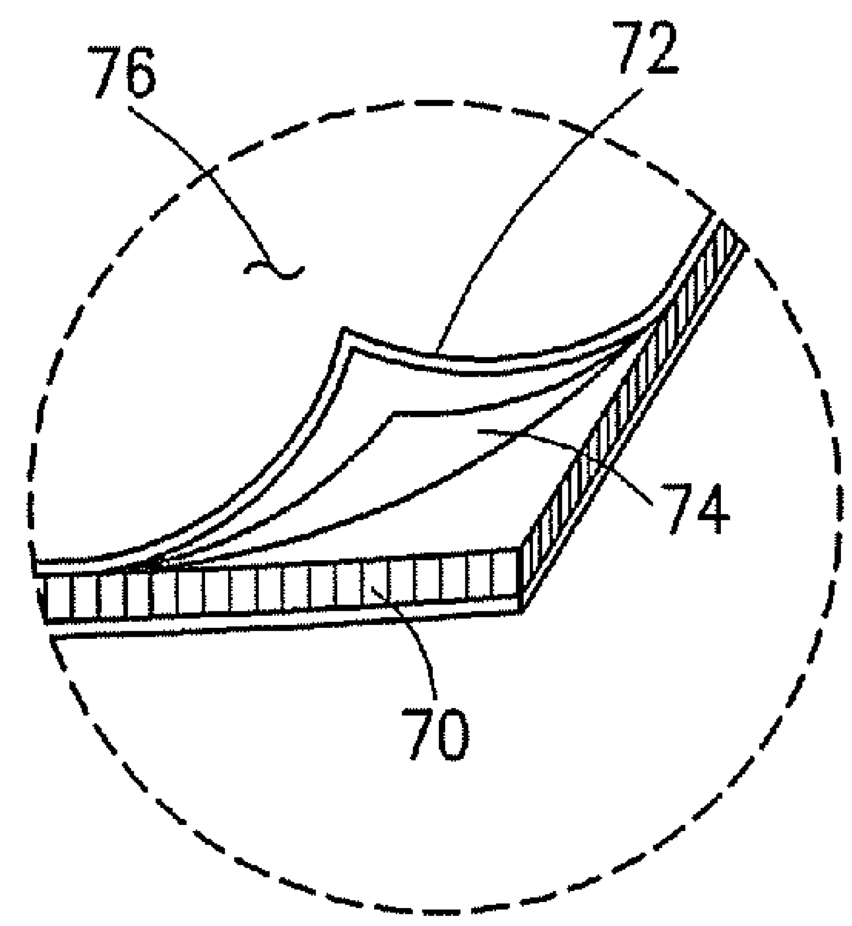


FIG. 5

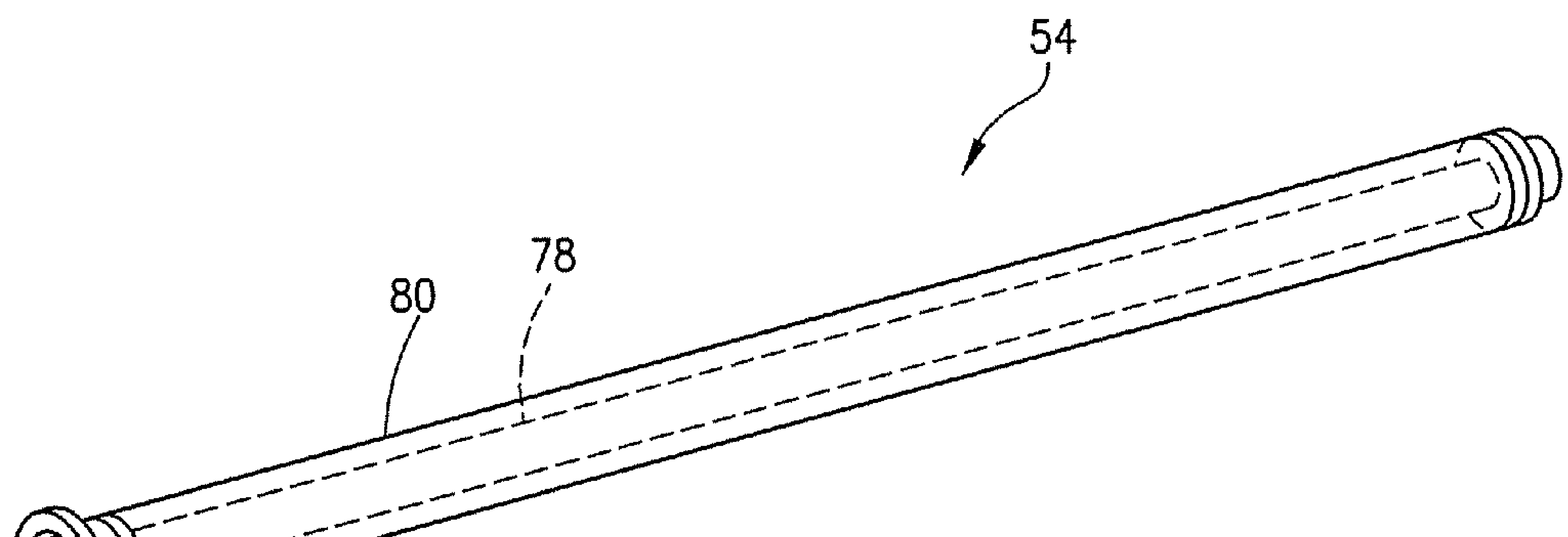


FIG. 6

FIG. 7

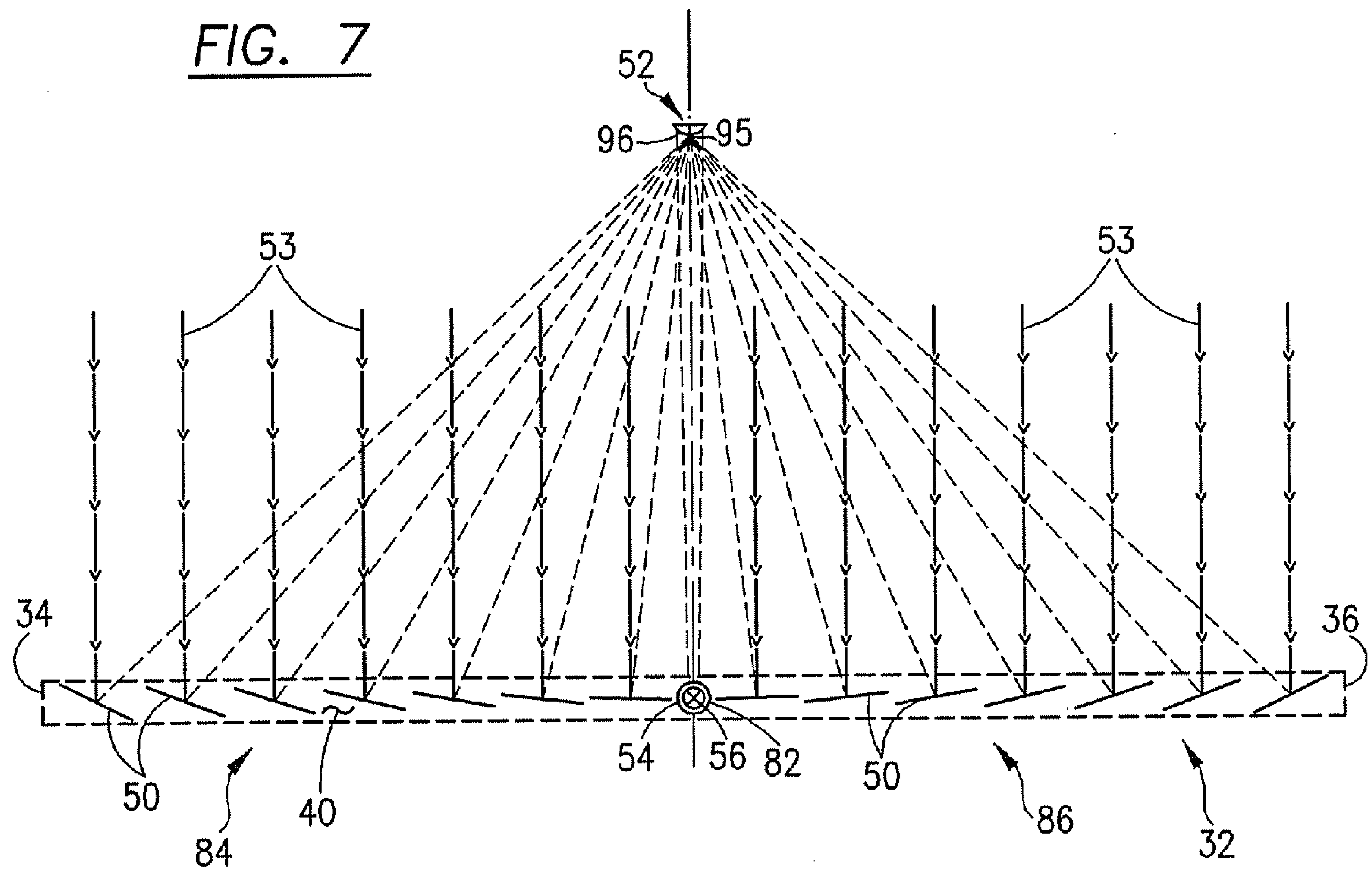
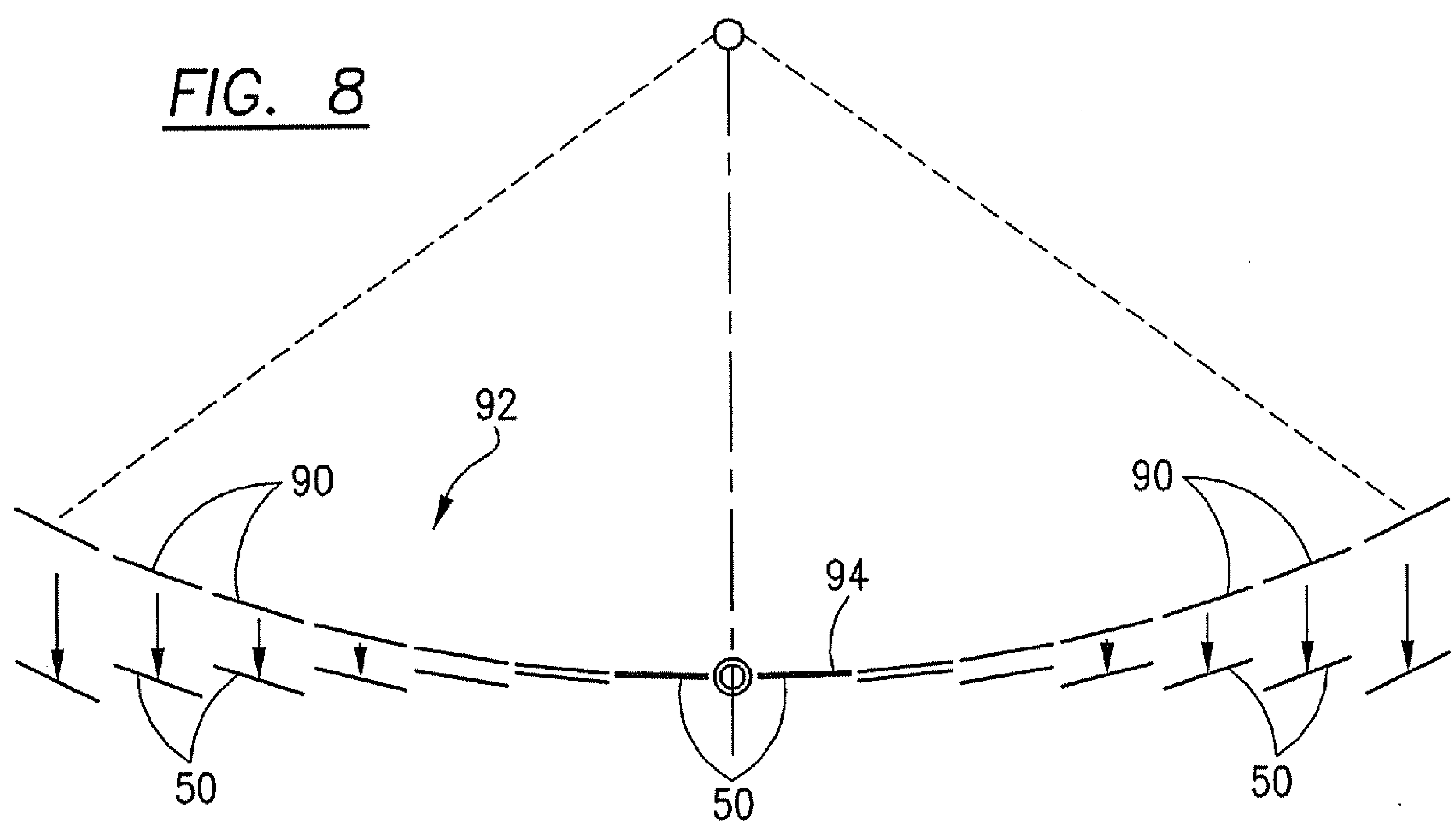


FIG. 8



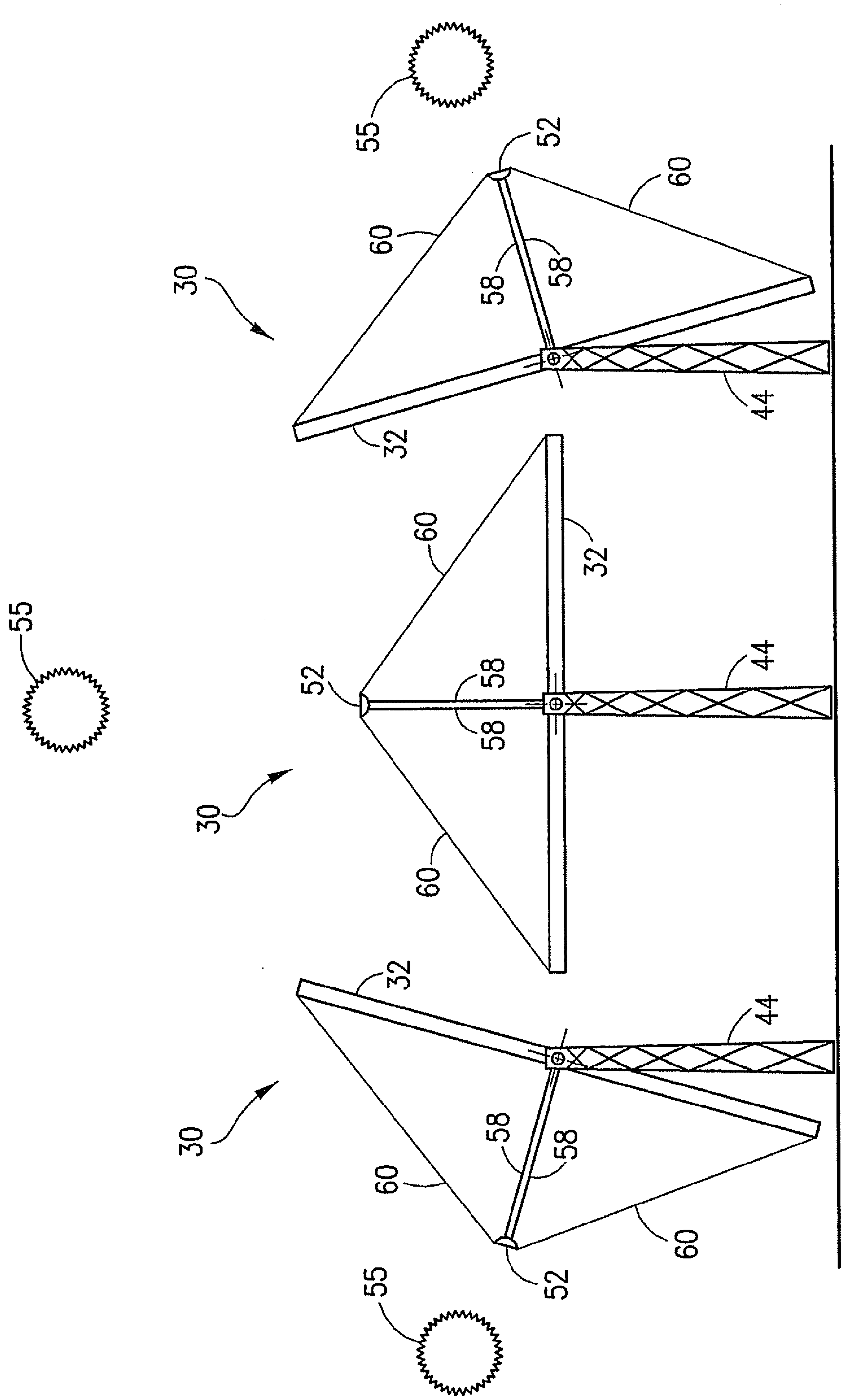


FIG. 9

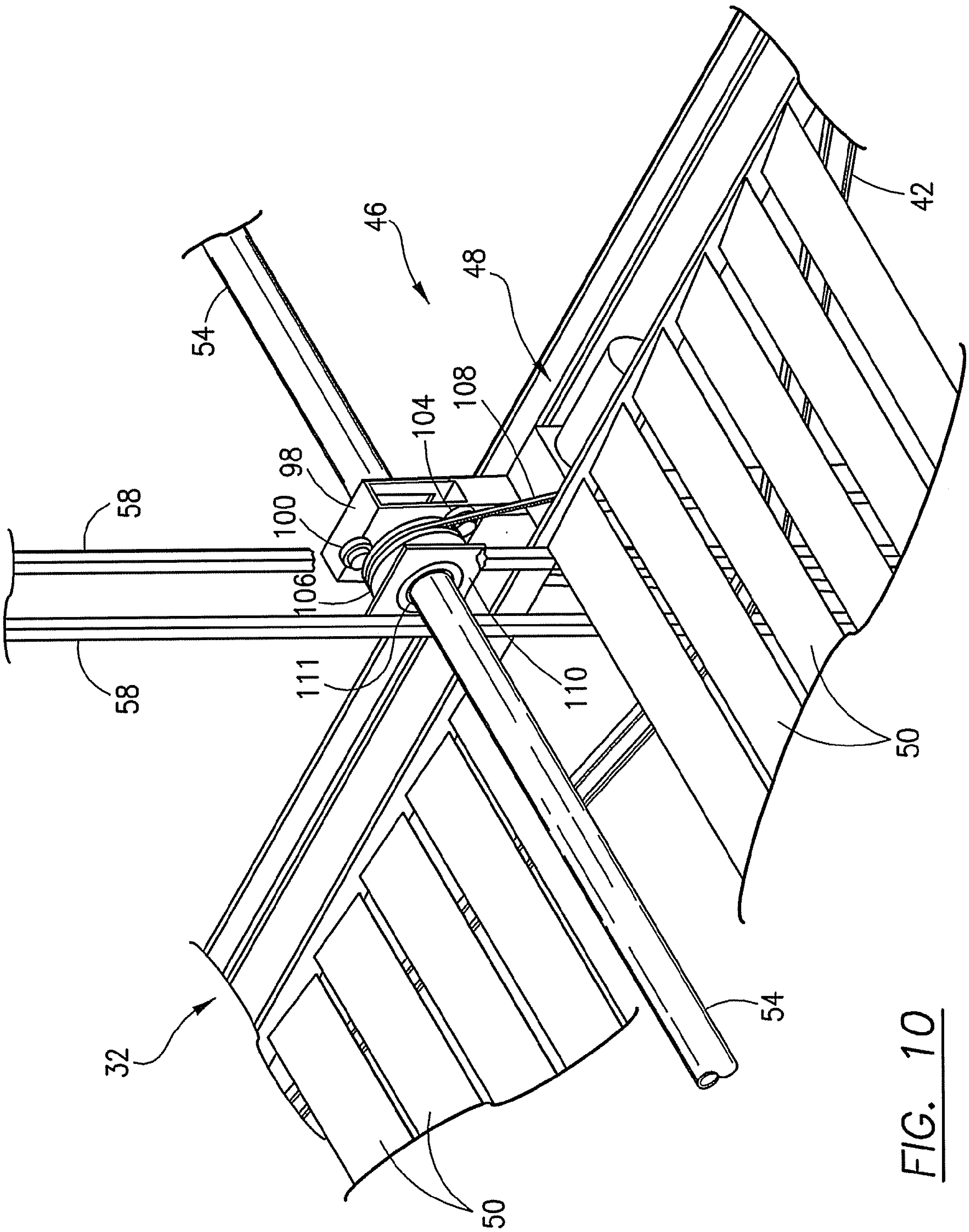


FIG. 10

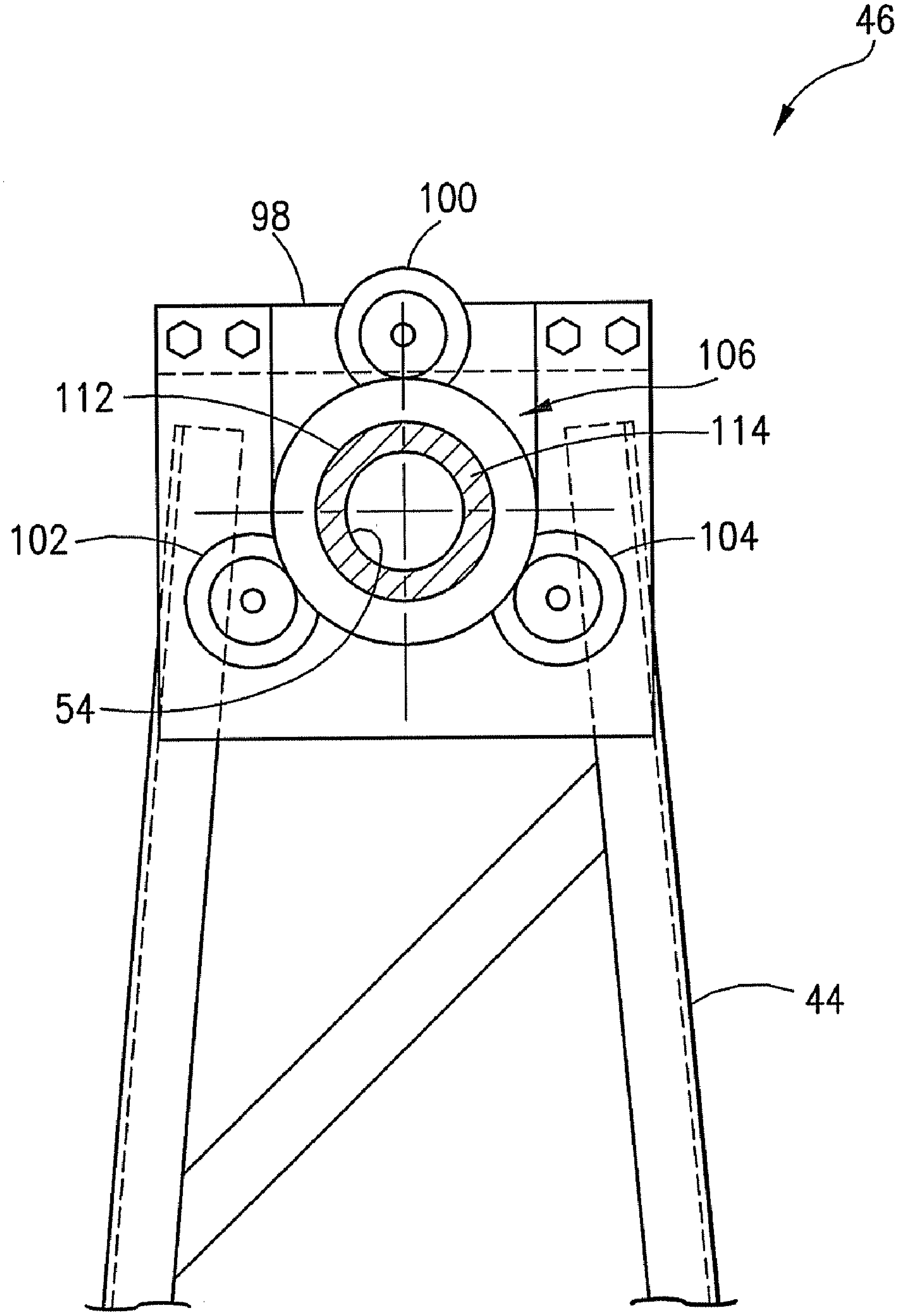


FIG. 11

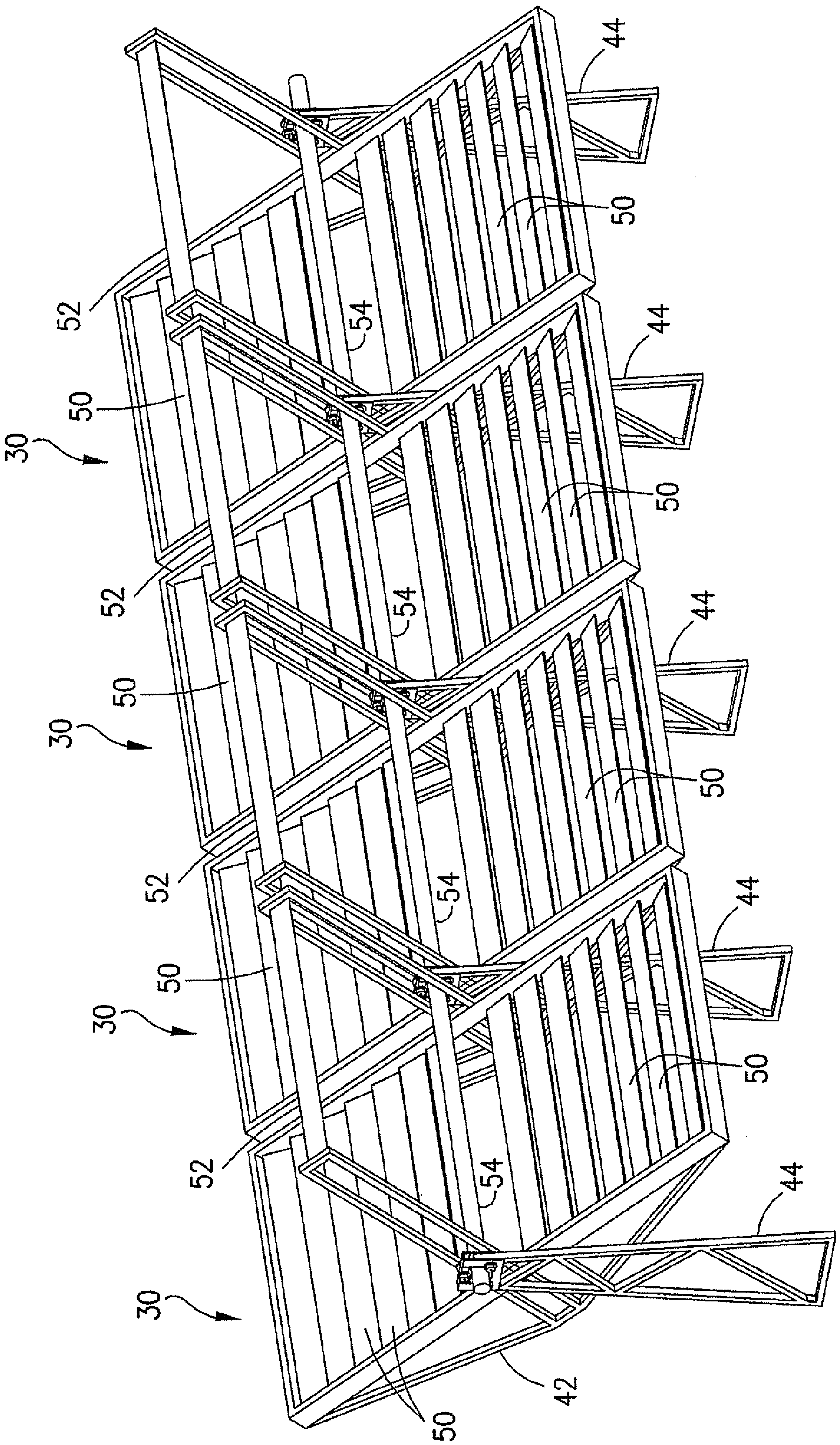


FIG. 12

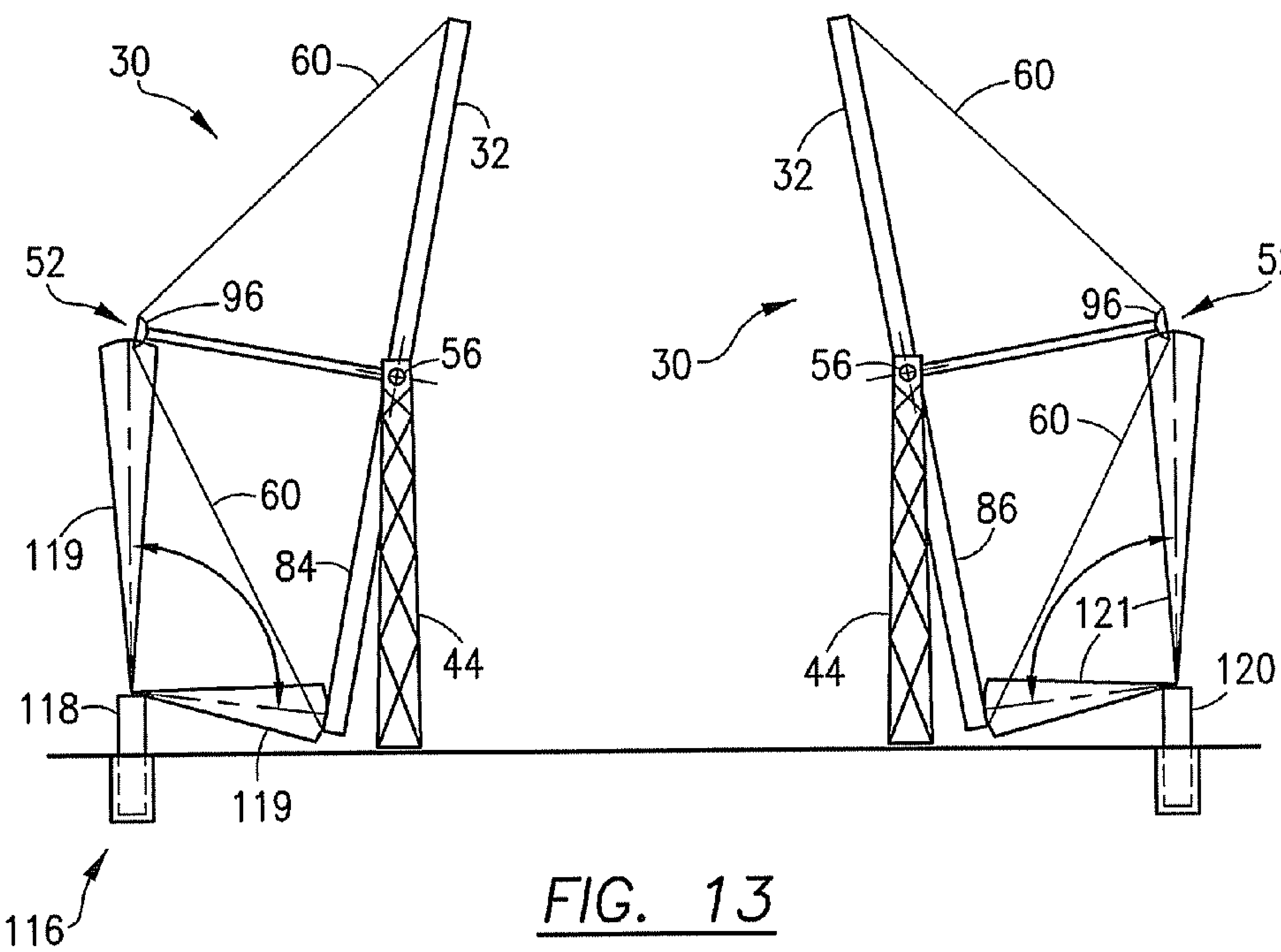

30
60
32
52
96
56
60
119
84
44
118
119
116
30
60
32
52
96
56
60
86
121
44
120

FIG. 13

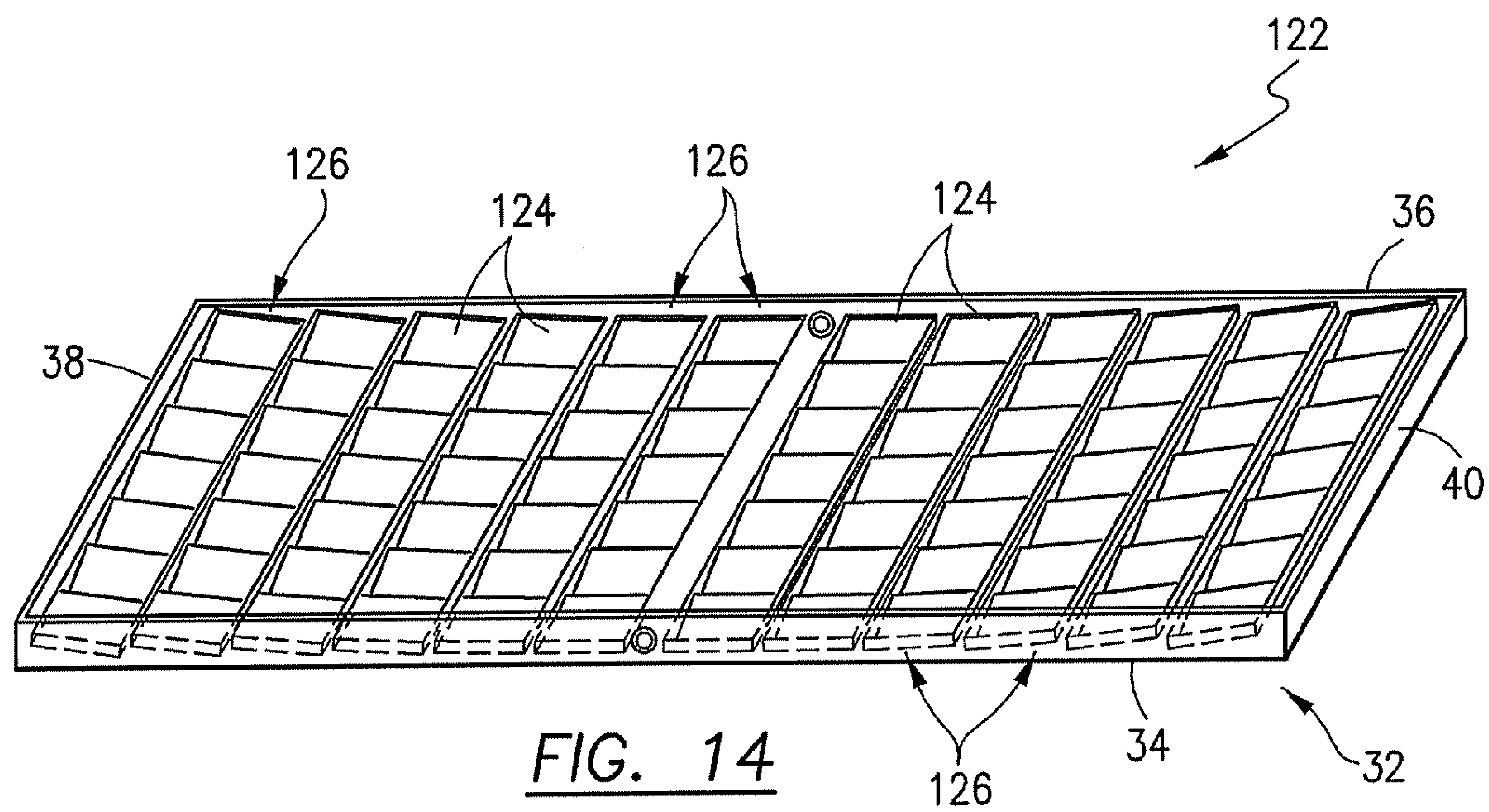

122
126
124
126
124
36
38
40
34
126
32

FIG. 14

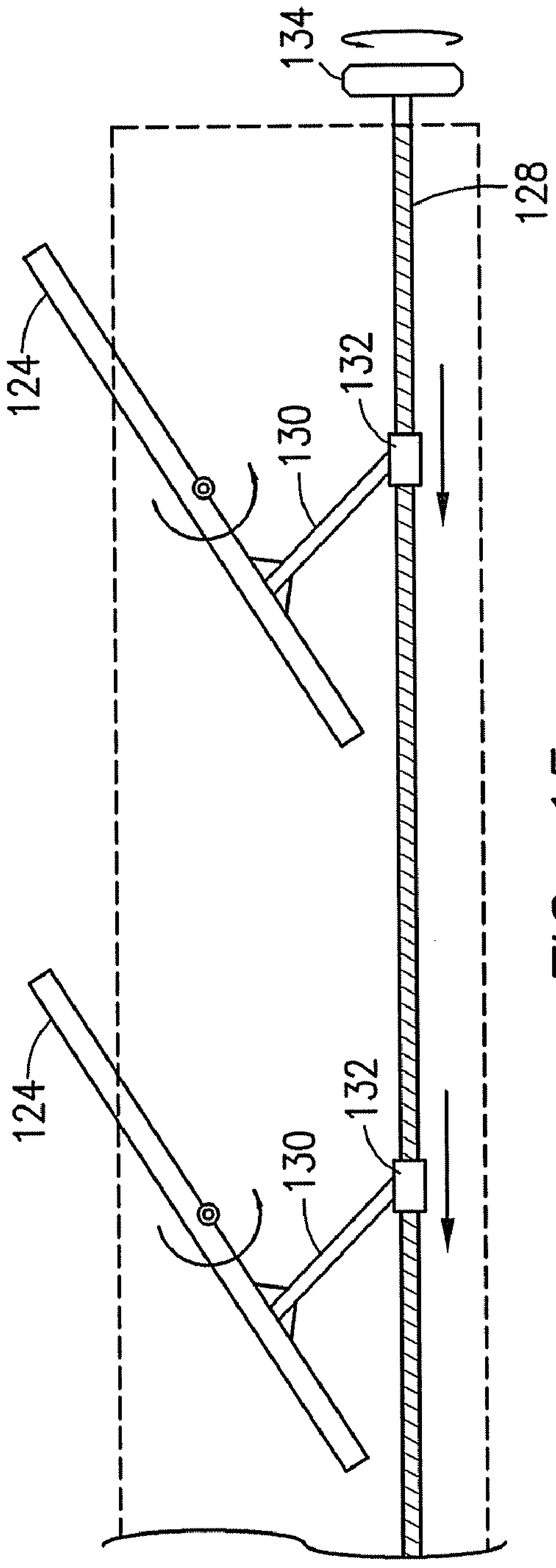


FIG. 15

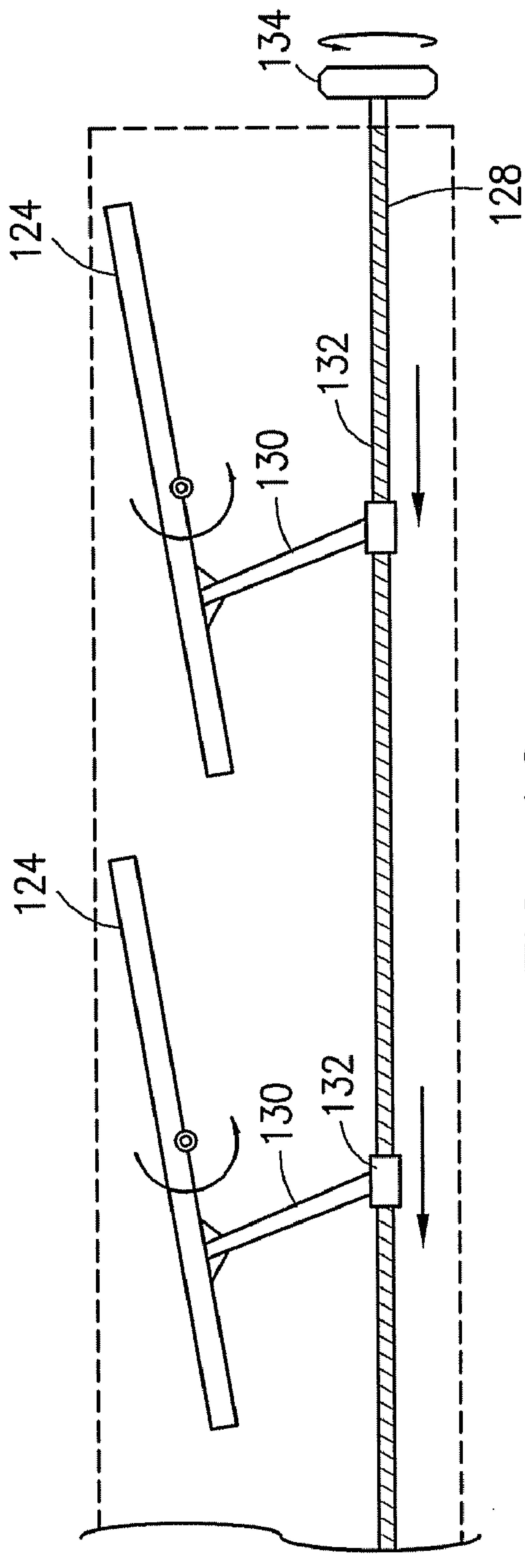


FIG. 16

LINEAR SOLAR ENERGY COLLECTION SYSTEM

FIELD OF THE INVENTION

[0001] This invention relates to the generation of electrical energy through solar thermal power collection, and, more particularly, to a linear solar energy collection system that employs a secondary reflector, light-weight solar panels and a fixed linear receiver tube in which a heat transfer fluid is circulated.

BACKGROUND OF THE INVENTION

[0002] Systems for the generation of electricity by collecting solar thermal radiation were first introduced in 1914, and have become increasingly popular with the rise in fossil fuel costs and concerns over global warming. The majority of solar energy collection systems currently in use are of the type depicted in FIGS. **1** and **2**. A generally parabolic-shaped trough **10** is provided having a curved, reflective surface **12** that is typically formed of a number of mirrors. The reflective surface **12** is effective to concentrate and reflect incident sunlight **13** at 30 to 80 times its normal intensity along a focal line that is coincident with a receiver tube **14** mounted by holding bars **16** in a position above the reflective surface **12**. The mirrors are carried by a support structure **18** which, in turn, is connected at each end to pylons **20** secured in the ground on a concrete foundation or the like. A motor **22** is drivingly connected to the support structure **12** to pivot it thus allowing the reflective surface **12** to track the progress of the sun across the sky. A local controller **24** may be provided to control the operation of the motor **22** as it pivots the support structure **18** and surface **12** throughout a day, and to monitor certain alarm conditions.

[0003] A heat transfer fluid is circulated through the receiver tube **14** which is heated by the sunlight reflected from surface **12**. This fluid is used to generate steam which powers a turbine that drives an electric generator. In order to transfer the heated fluid from the receiver tube **14** to a steam generator, a flexible hose **26** is coupled to the receiver tube **14**, typically via ball joints **28**, and moves with it as the support structure **18** is pivoted. The flexible hose **26** may be connected to a header pipe (not shown), which then connects to the steam generator.

[0004] Solar collection systems of the type described above suffer from a number of deficiencies. The mirrors forming the reflective surface **12** typically comprise 4 mm low-iron float glass mirrors thermally sagged during manufacturing into a parabolic shape. These mirrors are very heavy, and are available from only a few manufacturers. They are difficult to install and require robust mounting structure to support in order to provide for accurate positioning of the reflective surface **12** and to resist wind loads. While thinner glass mirrors have been suggested as an alternative, they are more fragile resulting in increased handling costs and breakage losses. Most support structures **18** for the mirrors are formed of galvanized steel which is also heavy, requires precise manufacturing and is expensive to build. Bridge trusses have been employed in more recent designs for the support structures **18**, but have proven to be nearly equally expensive to manufacture and often are lacking in torsional stiffness. In addition to these problems, the flexible hoses **26** and ball joints **28** employed to transfer heated fluid from the receiver tube **14** have high thermal losses, and exhibit high failure rates and leaks since they must move with the support structure **18** and reflective surface **12** as they pivot.

[0005] The goal of any solar collection system is to reduce the cost of electricity generated. There are fundamentally two ways to do this, namely, reduce the cost of the solar field and annual operating expenses, and, to increase system efficiency. Solar field optical efficiency is dependent upon a number of factors, including, without limitation, sunlight incident angle effects, collector tracking error, the geometric accuracy of the mirrors to focus light on the receiver tubes, mirror reflectivity, cleanliness of the mirrors, the creation of shadows across the mirrors, transmittance of solar energy into the receiver tubes, cleanliness of the receiver tubes, absorption of solar energy by the receiver tubes, end losses and the creation of shadows between rows of mirrors. While current systems produce electricity at a cost in the range of $0.12 to $0.18 per kilowatt-hour, it is desirable to achieve a cost level of about $0.05 per kilowatt-hour to be more competitive with present fossil-fuel based systems.

SUMMARY OF THE INVENTION

[0006] This invention is directed to a linear solar energy collection system that improves solar field efficiency, lowers operational and maintenance costs, and therefore reduces the overall cost of generating electricity per kilowatt-hour.

[0007] One aspect of this invention is predicated on the concept of providing a simple, modular linear solar energy collection system comprising one or more reflector units each fabricated using light-weight materials arranged in a construction that is highly accessible, easily maintained, and lower in initial cost. In one embodiment, each reflector unit includes a light-weight, generally planar aluminum frame that mounts a number of solar panels in a fixed position at angles progressively increasing from the frame centerline outwardly to its perimeter so as to collectively form a surface having a shape approximating that of a parabola. The focal line of such parabola is coincident with a secondary reflector which receives sunlight incident on the solar panels and reflects such light onto a receiver tube mounted in a fixed position substantially concentric to the centerline of the frame. The frame is supported by truss elements to add rigidity, and is connected to a drive mechanism operative to pivot the frame and truss elements in order to track the position of the sun during the course of a day. A number of individual reflector units may be arranged side-by-side to form a solar energy collection system having a collection field of desired size.

[0008] Preferably, each solar panel comprises a honeycomb aluminum section and a highly reflective silver-metallized surface connected together by an adhesive layer. The solar panels are strong, durable, light-weight and efficiently reflect incident sunlight many times its normal intensity onto the secondary reflector. The reflective surface of such panels may be washed to maintain cleanliness, which, in one presently preferred embodiment of this invention, is accomplished by the provision of an in-ground washing system operative to direct cleansing water against such surfaces.

[0009] A heat transfer fluid is circulated through the receiver tube for heating by the sunlight directed thereto from the secondary reflector. Because the receiver tube is fixed relative to the pivoting frame, it may be connected to a fixed transfer conduit that communicates with a steam generator and turbine. Since both the receiver tube and transfer conduit are mounted in a fixed position, heat losses resulting from the transfer of fluid out of the receiver tube are minimized and maintenance problems with the moving connections between the receiver tube and transfer conduit that were required in prior art systems, as described above, are substantially eliminated.

[0010] In an alternative embodiment, a reflector unit includes solar panels formed in smaller segments mounted to a number of shafts, which, in turn, are pivotally connected to the frame. The solar panels collectively form a generally parabolic surface as in the previously described embodiment, but may also be tilted by rotation of the shafts in a generally northerly and southerly direction to more directly face the sun as its incidence angle varies with the changing of the seasons.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The structure, operation and advantages of the presently preferred embodiment of this invention will become further apparent upon consideration of the following description, taken in conjunction with the accompanying drawings, wherein:

[0012] FIG. **1** is perspective view of a prior art solar energy collection system;

[0013] FIG. **2** is an end view of the system shown in FIG. **1**;

[0014] FIG. **3** is a perspective view of one embodiment of a reflector unit for the solar energy collection system of this invention;

[0015] FIG. **4** is a perspective view of a solar panel of this invention;

[0016] FIG. **5** is an enlarged view of the encircled portion of FIG. **4** showing the solar panel partially disassembled;

[0017] FIG. **6** is a perspective view of the receiver tube employed herein;

[0018] FIG. **7** is a schematic, end view of the solar panels and secondary reflector of the unit depicted in FIG. **3**, illustrating the orientation of the solar panels from the centerline of the frame outwardly;

[0019] FIG. **8** is a schematic view of the relationship between the solar panels and secondary reflector of the unit of FIG. **3**;

[0020] FIG. **9** is a schematic view depicting how the unit herein tracks the position of the sun during the course of a day;

[0021] FIG. **10** is a perspective view of the drive mechanism for pivoting the frame and solar panels;

[0022] FIG. **11** is an end view of the drive mechanism illustrated in FIG. **10**;

[0023] FIG. **12** is a perspective view of a solar collection system according to this invention in which a number of reflector units shown in FIG. **3** are oriented side-by-side;

[0024] FIG. **13** is a perspective view of the sprinkler system of this invention operating with the solar panels and secondary reflector in a first position before sunrise and a second position after sunset;

[0025] FIG. **14** is a perspective view of the frame and solar panel portion of an alternative embodiment of a solar energy collection system according to this invention;

[0026] FIG. **15** is an enlarged, side view of a portion of FIG. **14** illustrating the manner in which the solar panels are mounted for tilting movement relative to the frame; and

[0027] FIG. **16** is a view similar to FIG. **15** showing the solar panels tilted after rotation of the mounting shaft.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Referring now to FIGS. **3-12**, one embodiment of a solar energy collection system according to this invention is illustrated which may comprise several individual reflector units **30** oriented side-by-side, as discussed below with reference to FIG. **12**. The reflector unit **30** is initially generally described, followed by a discussion of individual aspects of the design.

[0029] The reflector unit **30** includes a frame **32** having opposed side walls **34**, **36**, and opposed end walls **38**, **40** connected together in a generally rectangular shape as depicted in FIG. **3**. The walls **34-40** are preferably formed of aluminum or other light-weight, weather resistant and durable material. The frame **32** is reinforced by a truss structure **42**, a portion of which is shown in FIGS. **3** and **12**, which is also preferably formed of aluminum or similar material. The truss structure **42** and frame **32** may be supported above ground level by pylons **44** secured on a foundation such as concrete footers (not shown) that can support the weight of the unit **30** and wind loading applied to it. As described in detail below with reference to FIGS. **10** and **11**, the frame **32** and truss structure **42** are pivotally mounted to the pylons **44** and may be tilted by operation of a drive mechanism **46** including a drive motor **48**.

[0030] The frame **32** mounts a number of solar panels **50** and a secondary reflector **52** which collectively form the structure for receiving incident sunlight **53** from the sun **55** and reflecting it onto a receiver tube **54** located in a fixed position at the centerline **56** (See FIG. **7**) of the frame **32**. The solar panels **50** extend between the end walls **38**, **40** and are spaced from one another on either side of the receiver tube **54** in a direction toward the side walls **34**, **36**. The secondary reflector **52** is located above the solar panels **50**, as discussed below, and is supported in that position at each end by rods **58** and tension wires **60** extending from the frame **32**.

[0031] Referring now to FIGS. **4** and **5**, a solar panel **50** according to this invention is shown in greater detail. Each solar panel **50** is generally rectangular in shape having opposed side edges **62**, **64** and opposed end edges **66**, **68**. The panels **50** have a slight concave curvature in a direction from one side edge **62** to the other side edge **64**, which may be slightly different from one panel **50** to another as described below. Each panel **50** comprises a base section **70**, a top section **72** and an intermediate section **74** sandwiched between the sections **70**, **72**. The base section **70** is preferably formed of a honeycomb aluminum, or similar light-weight, weather resistant and durable material that may be bent in the slight curvature noted above and shown in FIG. **4**. The top section **72** is preferably a highly-reflective, silver-metallized film comprising multiple layers of polymer film with an inner layer of pure silver to provide a reflective surface **76** having high specular reflectance. One suitable material for top section **72** is commercially available from ReflecTech, Inc. of Wheat Ridge, Colo. under the trademark "ReflecTech" solar film. The intermediate layer **74** is preferably a layer of pressure sensitive adhesive. Layer **74** may be affixed on one side to the top section **72** and provided with a peel-off backing (not shown) which is removed prior to attachment to the base section **70**.

[0032] The receiver tube **54** is a component employed in prior art solar collection systems and is readily commercially available. As shown in FIG. **6**, it comprises a hollow, stainless steel housing **78** having a solar-selective absorber surface surrounded by an anti-reflective, evacuated glass sleeve **80**. Typically, the housing **78** has a length of 4 meters and a diameter of 70 mm, and the glass sleeve is 115 mm in diameter. A heat transfer fluid such as oil or water is circulated through the housing **78** where it is heated by reflected sunlight, as discussed below. The receiver tube **54** has glass-to-metal seals and metal bellows (not shown) to accommodate differing rates of thermal expansion between the stainless steel housing **78** and glass sleeve **80**, and to help maintain the vacuum-tight enclosure. This reduces heat losses at high operating temperatures and protects the solar-select absorber surface of the housing **78** from oxidation.

[0033] The solar panels **50** and secondary reflector **52** collectively function to direct incident sunlight **53** onto the receiver tube **54** to elevate the temperature of heat transfer fluid circulating within the receiver tube **54** to a level sufficient to operate a steam generator (not shown) for the production of electricity. The positioning of the solar panels **50** with respect to the secondary reflector **52**, and the configuration of the secondary reflector **52**, are both important in maximizing the efficiency of the reflector unit **30**. The discussion that follows concerns this aspect of the present invention.

[0034] A parabola is a geometric shape defined by the locus of points that are equidistant from a point (the focus) and a focal line (directrix) that lie in the same plane. Reflective surfaces having the shape of a parabola have been commonly used in solar power collection systems because incident sunlight may be reflected to collection device located at the focus or directrix of the parabola. The unit **30** of the present invention is designed to take advantage of this property of a parabola, but in a much more efficient, less expensive and practical manner than taught in the prior art.

[0035] Referring now to FIG. **7**, an end view of the frame **32** and its end wall **40** is shown with the receiver tube **54** depicted within an opening **82** formed in the frame end wall **40**, substantially concentric to the frame centerline **56**, and the secondary reflector **52** located at a position spaced from the receiver tube **54**. A first array **84** of solar panels **50** extends from the receiver tube **54** to the side wall **34** of frame **32**, and a second array **86** of solar panels **50** is mounted between the receiver tube **54** and side wall **36**. The end edges **66** and **68** of each panel **50** are secured in a fixed position to an end wall **38** and **40**, respectively, of the frame **32** by fasteners or other suitable means such as the provision of recesses in the end walls **38**, **40** (not shown). The solar panels **50** in each array **84**, **86** are oriented at an angle with respect to the secondary reflector **52** so as to direct incident sunlight **53** to a focal line or directrix that is coincident with the surface **96** of secondary reflector **52**. As seen in FIG. **7**, the angle of the solar panels **50** increases from the centerline **56** of frame **32** outwardly to its side walls **34**, **36**. In the presently preferred embodiment, the angle of each panel **50** relative to the secondary reflector **52** is chosen to closely approximate the orientation of each of a number of discrete segments **90** "sliced" from a continuous parabola **92**, as schematically depicted in FIG. **8**. In essence, the solar panels **50** in each array **84**, **86** comprise segments of the parabola **92** which are separated from one another, and then individually affixed to the frame **32**. Consequently, the solar panels **50** collectively form a reflective, substantially parabolic-shaped surface **94** whose focus and directrix **95** are substantially coincident with the secondary reflector **52**.

[0036] It should be understood that in a true parabola the distance from every point along its surface to the focal point of the parabola is the same. When a parabola is "cut" into segments **90**, e.g. discrete solar panels **50**, and then individually mounted to the frame **32** as contemplated in this invention, there must be at least some spacing between the side edges **62**, **64** of adjacent solar panels **50** to facilitate mounting and to avoid shadowing or overlap between them. See FIG. **7**. The spacing between panels **50**, and their linear orientation along the frame **32**, both contribute to a change in the distance from the center of each panel **50** to the focus and directrix. Consequently, a slight concave curvature is required in each panel **50**, which differs from one panel **50** to another depending on its angulation relative to the secondary reflector **52**, in order to ensure that the individual focal point of each panel **50** is substantially the same. Such curvature may be calculated using the standard mathematical equation defining a parabola, namely:

$$y=x^2/4f$$

[0037] Where: f=the focal point

[0038] x=horizontal distance from the center

[0039] y=vertical distance

[0040] As noted above, the first and second arrays **84**, **86** of solar panels **50** collectively form a parabolic surface **94** that reflects incident light to a focus or directrix. The secondary reflector **52** is located along the directrix or focal line of surface **94** and is constructed to reflect the light from surface **94** onto the receiver tube **54** to elevate the temperature of heat transfer fluid circulating therein. In one presently preferred embodiment, the secondary reflector **52** is approximately 200 mm to 250 mm in width with a reflective surface **96** in the shape of a hyperbola. The exact geometry of the reflective surface **96** is derived from the Cassegrain Equations for a primary parabolic-shaped reflective surface, which, in this instance, is the parabolic surface **94** collectively formed by the solar panels **50**, and a secondary hyperboloid reflective surface. The secondary reflector **52** may be constructed of a honeycomb panel having the appropriate shape noted above connected by an adhesive layer to the same material that forms the top section **74** of solar panels **50**.

[0041] Referring now to FIGS. **9-11**, it is advantageous for the solar panels **50** to be oriented substantially perpendicular to the position of the sun **55** throughout the course of a day in order to maximize the efficiency with which the sunlight is reflected to the secondary reflector **52**, and, in turn, to the receiver tube **54**. FIG. **9** illustrates this pivotal movement of frame **32**, and, in turn, the solar panels **50** and secondary reflector **52**, during daylight hours. Such pivotal movement is about an axis which is generally coincident with the centerline **56** of the frame **32**.

[0042] With reference to FIGS. **10** and **1**, and as noted briefly above, the frame **32** is pivoted by a drive mechanism **46** including a motor **48**. In the presently preferred embodiment, a support frame **98** is connected to a pylon **44** which rotatably mounts three rollers **100**, **102** and **104** spaced approximately 120° apart. These rollers **100-104** receive and support a drive wheel **106** which is connected by a link chain **108**, or other suitable drive means such as a belt, to the output shaft of motor **48**. The drive wheel **106** is connected by a plate **110** to the rods **58** which support the secondary reflector **52** at one end, and connect to the frame **32** at the opposite end. In response to operation of the motor **48**, the drive wheel **106** rotates with respect to the rollers **100-104**. The rods **58** and frame **32** rotate with the drive wheel **106**, thus pivoting relative to the pylons **44** to assume the positions shown in FIG. **9**.

[0043] In the presently preferred embodiment, the receiver tube **54** remains in a fixed position with respect to the frame **32** and drive wheel **106** throughout the pivotal motion of the frame **32**. As described above, the receiver tube **54** extends through an opening **82** formed in each end wall **38**, **40** of frame **32**. The protruding end of receiver tube **54** enters a bore **111** formed in the plate **110**, and a central bore **112** formed in the drive wheel **106** where it is received and supported by a bearing **114** that allows the receiver tube **54** to remain in a fixed position during rotation of the drive wheel **106**. This construction has the advantage of allowing the receiver tube **54** to be connected to a fixed transfer conduit **114**, shown in FIG. **3**, coupled to a steam generator (not shown). Consequently, the expensive and leak-prone connections between the moving receiver tubes and transfer conduits employed in the prior art, and shown, for example, in FIG. **2**, are eliminated in this invention.

[0044] The solar energy collection system of this invention is modular in construction. As shown in FIG. **12**, a number of individual reflector units **30** depicted in FIG. **3** and described above may be located side-by-side to increase capacity and overall efficiency of the solar field. In such arrangements, a drive mechanism **46** may be located in between adjacent units **30** such that each end of the output shaft of motor **48** may be coupled to the drive wheel **106** of one of the units **30** in the manner described above in connection with a discussion of FIGS. **10** and **11**. Further, the receiver tube **54** of one unit **30** may be coupled to the receiver tube **54** of an adjacent unit **30** to transmit heat transfer fluid to one or more conduits (not shown) for the combined collection system.

[0045] In another aspect of this invention, an in-ground sprinkler system **116** is provided to help clean the reflective surface **94** of the solar panels **50** and the surface **96** of the secondary reflector **52**. As schematically depicted in FIG. **13**, one or more first sprinkler heads **118** connected to a source of water (not shown) are positioned to direct streams **119** of water onto the first array **84** of solar panels **50** and a portion of the secondary reflector **52** with the unit **30** in position prior to sunrise, and one or more second sprinkler heads **120** direct streams **121** of water onto the second array **86** of solar panels **50** and the remainder of the secondary reflector **52** when the reflector unit **30** moves to its position at the end of a day. Maintaining the collective reflective surface **94** of the solar panels **50**, and the surface **96** of the secondary reflector **52**, clean significantly increases the overall efficiency of the reflector unit **30**.

[0046] An alternative embodiment of a solar energy collection system having one or more reflector units **122** according to this invention is illustrated in FIGS. **14-17**. The reflector unit **122** is similar to reflector unit **30** in many respects except for the addition of structure that permits adjustment of the position of solar panels about a second axis. As discussed above, the frame **32** and solar panels **50** of the unit **30** are pivoted as illustrated in FIG. **9** about an axis generally coincident with the centerline **56** of the frame **32**. Such motion is in an easterly to westerly direction consistent with the apparent movement of the sun **55** across the sky during the daylight hours. As is well known, the earth tilts on its axis during the course of a year causing the change of seasons and altering the angle of inclination of the sun's rays. The unit **122** of this embodiment of the present invention is designed to not only track the sun's daily path but its annual inclination.

[0047] The same frame **32** described above is employed in unit **122**, but instead of elongated solar panels **50** extending between the frame side walls **34**, **36**, a plurality of shorter, segmented solar panels **124** are provided. The solar panels **124** are divided into groups, and each group of panels **124** essentially takes the place of a single solar panel **50** in the embodiment of FIGS. **3-13**. As best seen in FIG. **14**, one group of several panels **124** is mounted within each of a number of sub-frames **126**, e.g. a generally rectangular-shaped structure having opposed ends and opposed sides. These sub-frames **126** are secured in the same fixed positions to the side walls **34** and **36** of frame **32**, and at the same angles, as solar panels **50** described above. In one embodiment, the panels **124** within each group may be coupled to a threaded shaft **128**, which, in turn, is rotatably mounted to the end walls of a sub-frame **126**. A lever arm **130** may extend from each panel **124** and connect to an internally threaded sleeve **132** which threads onto the shaft **128**. In response to rotation of a shaft **128**, either manually by turning a knob **134** or by operation of a motor (not shown), the sleeves **132** move axially along the shafts **128** causing the panels **124** to tilt. See FIGS. **15** and **16**. The direction of rotation of the shaft **128** determines the direction of tilting of the panels **124**. In this manner, the panels **124** may be tilted in a northerly direction or in a southerly direction according the angle of inclination of the sun **55**. The remainder of the structure and operation of the system **122** is essentially the same as that described above in connection with a discussion of reflector unit **30**.

[0048] While the invention has been described with reference to a preferred embodiment, it should be understood by those skilled in the art that various changes may be made and equivalents substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof.

[0049] For example, the receiver tube **54** is depicted in FIGS. **7**, **9**, **13** and **14** as being positioned at the center of frame **32** and substantially concentric to its centerline **56**. As shown in FIGS. **3**, **10** and **12**, the receiver tube **54** may also be located slightly above the center of frame **32**. In both instances, the receiver tube **54** is located at substantially the center of rotation of the frame **32** and generally at the center of gravity of the reflector unit **30**.

[0050] Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A solar energy collector system, comprising:

at least one frame;

a number of solar panels each having a reflective surface, said solar panels being mounted to said at least one frame in position to reflect sunlight incident on said reflective surface thereof;

a receiver tube within which a heat transfer fluid is circulated;

a secondary reflector positioned so as to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein.

2. The system of claim **1** in which said at least one frame comprises opposed end walls and opposed side walls interconnected to form a substantially planar structure having a centerline, said receiver tube being concentrically disposed about said centerline.

3. The system of claim **2** in which said solar panels are arranged in a first array extending from said receiver tube to one of said side walls, and a second array extending from said receiver tube to the other of said side walls, each of said solar panels in both said first and second arrays having a first end fixed to one of said end walls and a second end fixed to the other of said end walls.

4. The system of claim **3** in which said solar panels in said first array and said second array each have opposed side edges extending between said first and second ends thereof, said solar panels in each of said first array and said second array being oriented side-by-side with a space between the side edge of adjacent solar panels.

5. The system of claim **3** in which said solar panels in each of said first array and said second array are oriented at an angle with respect to said secondary reflector, the angle of each solar panel within said first and second arrays progressively increasing from said centerline of said frame to said opposed side walls thereof.

6. The system of claim **5** in which said angulation of said solar panels in said first array and in said second array collectively form a surface having a shape approximating that of a parabola with a focal line substantially coincident with said secondary reflector.

7. The system of claim **1** in which each of said at least one frame comprises a number of frames located side-by-side, each of said frames mounting a number of said solar panels.

8. The system of claim **1** in which each of said solar panels comprises a first section formed of honeycomb aluminum, a second section having said reflective surface and a third section connecting said first section to said second section.

9. The system of claim **8** in which said first section of honeycomb aluminum has opposed ends and opposed sides, said first section being formed in a concave shape between said opposed sides.

10. The system of claim **1** in which said at least one frame is pivoted to track the movement of the sun during the course of a day, said frame being pivoted relative to said receiver tube which is mounted in a fixed position.

11. The system of claim **10** further including a conduit connected to said receiver tube, said conduit being mounted in a fixed position relative to said frame.

12. The system of claim **1** in which said frame has opposed end walls and opposed side walls interconnected to one another, said receiver tube and said secondary reflector extending between said opposed end walls of said frame.

13. The system of claim **12** in which said secondary reflector directs reflected sunlight along substantially the entire extent of said receiver tube.

14. A solar energy collector system, comprising:

at least one frame;

a number of solar panels, each of said solar panels including a first section formed of a light-weight honeycomb structure, a second section having a reflective surface and a third section connecting said first and second sections, said solar panels being mounted to said at least one frame in position to reflect sunlight incident on said reflective surfaces thereof;

a receiver tube within which a heat transfer fluid is circulated;

a secondary reflector positioned so as to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein.

15. The system of claim **14** in which said light-weight honeycomb structure is honeycomb aluminum.

16. The system of claim **14** in which said first section has opposed ends and opposed sides, said first section being formed in a concave shape between said opposed sides.

17. A solar energy collector device, comprising:

at least one frame;

a number of solar panels each having a reflective surface, said solar panels being mounted to said at least one frame in position to reflect sunlight incident on said reflective surface thereof;

a receiver tube within which a heat transfer fluid is circulated;

a secondary reflector supported by said frame in position to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein;

a drive mechanism operative to pivot said at least one frame between a first position in which said solar panels face in a substantially easterly direction, and a second position in which said solar panels face in a substantially westerly direction;

a washing system operative to apply water onto a first array of said solar panels and onto at least a portion of said secondary reflector when said at least one frame is in said first position, and to apply water onto a second array of said solar panels and onto at least one other portion of said secondary reflector when said at least one frame is in said second position.

18. The system of claim **17** in which said washing system is an in-ground sprinkler system having sprinkler heads effective to direct water onto said solar panels and onto said secondary reflector.

19. A solar energy collector device, comprising:

at least one frame including opposed side walls and opposed end walls interconnected to one another, said frame being pivotal between a first position and a second position;

a receiver tube within which a heat transfer fluid is circulated, said at least one frame being pivotal relative to said receiver tube;

a number of solar panels each having a reflective surface, said solar panels being mounted to said at least one frame in position to reflect sunlight incident on said reflective surface thereof;

a secondary reflector positioned so as to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein.

20. The system of claim **19** further including a conduit coupled to said receiver tube, said conduit being mounted in a fixed position relative to said frame.

21. The system of claim **19** in which said at least one frame comprises a number of frames oriented end-to-end, said receiver tube associated with each frame being coupled to said receiver tube associated with an adjacent frame.

22. The system of claim **19** in which each of said end walls of said at least one frame is formed with a bore, said receiver tube extending between said end walls and within said bore therein.

23. A solar energy collector system, comprising:

at least one frame including opposed end walls and opposed side walls interconnected to one another;

a number of shafts pivotally supported by said at least one frame, said shafts being spaced from one another in a direction from one end wall to the other end wall of said at least one frame;

a number of solar panels fixed to each of said shafts in position to reflect sunlight incident on a reflective surface of said solar panels;

a receiver tube within which a heat transfer fluid is circulated;

a secondary reflector positioned so as to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein;

a first drive mechanism operative to pivot said at least one frame between a first position in which said solar panels face in a substantially easterly direction, and a second position in which said solar panels face in a substantially westerly direction;

a second drive mechanism coupled to said shafts, said second drive mechanism being effective to pivot said shafts to orient said solar panels at different positions in a generally northerly direction and in a generally southerly direction according to the angle of incidence of the sun.

24. The system of claim **23** in which each of said solar panels collectively form a surface having a shape approximating that of a parabola with a focal line substantially coincident with said secondary reflector.

25. The system of claim **23** in which each of said solar panels comprises a first section formed of honeycomb aluminum, a second section having said reflective surface and a third section connecting said first section to said second section.

26. The system of claim **23** in which said first section of honeycomb aluminum has opposed ends and opposed sides, said first section being formed in a concave shape between said opposed sides.

27. A solar energy collector system, comprising:

a number of reflector units oriented side-by-side, each of said reflector units comprising:

(i) a frame;

(ii) a number of solar panels each having a reflective surface, said solar panels being mounted to said frame in position to reflect sunlight incident on said reflective surface thereof;

(iii) a receiver tube within which a heat transfer fluid is circulated;

(iv) a secondary reflector positioned so as to receive sunlight reflected from said solar panels and to reflect said sunlight onto said receiver tube to heat the heat transfer fluid therein.

28. The system of claim **27** in which said frame of each of said reflector units comprises opposed end walls and opposed side walls interconnected to form a substantially planar structure having a centerline, said receiver tube being concentrically disposed about said centerline.

29. The system of claim **27** in which said solar panels of each of said reflector units collectively form a surface having a shape approximating that of a parabola with a focal line substantially coincident with said secondary reflector.

30. The system of claim **27** in which each of said solar panels comprises a first section formed of a honeycomb aluminum, a second section having said reflective surface and a third section connecting said first layer to said second layer.

31. The system of claim **30** in which said first section of honeycomb aluminum has opposed ends and opposed sides, said first section being formed in a concave shape between said opposed sides.

32. The system of claim **1** in which said frame is pivoted to track the movement of the sun during the course of a day, said frame being pivotal relative to said receiver tube which is mounted in a fixed position.

33. The system of claim **27** in which said receiver tube of each of said reflector units is coupled to said receiver tube of at least one adjacent reflector unit.

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