(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 August 2012 (23.08.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/111008 A9

(51) International Patent Classification:
F24J 2/14 (2006.01) *F24J 2/52* (2006.01)
F24J 2/54 (2006.01)

(21) International Application Number:
PCT/IL2012/050044

(22) International Filing Date:
13 February 2012 (13.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/442,319 14 February 2011 (14.02.2011) US

(71) Applicant *(for all designated States except US)*: **SHIKUN & BINUI - RENEWABLE ENERGY LTD.** [IL/IL]; 1A HaYarden Street, Airport City, 70100 Lod (IL).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **COHEN, Gilbert** [US/US]; 115 White Bloom Lane, Cary, North Carolina 27519 (US).

(74) Agent: **EHRLICH, Gal**; G.E. EHRLICH (1995) LTD., 11 Menachem Begin Road, 52681 Ramat Gan (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

[Continued on next page]

(54) Title: SUPPORT STRUCTURE FOR SOLAR CONCENTRATOR

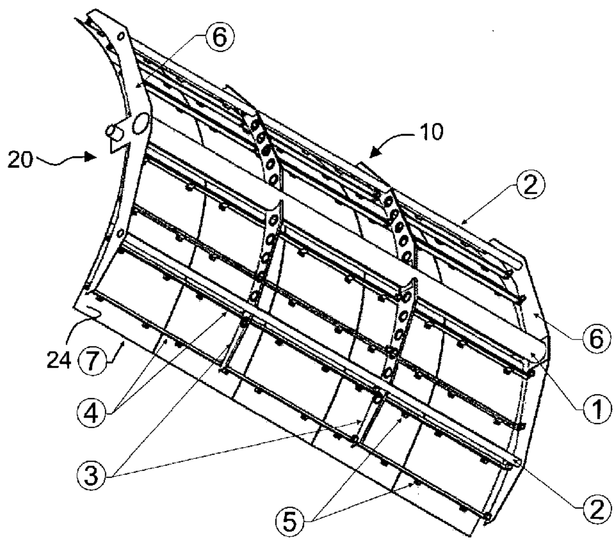

FIG. 4C

(57) Abstract: A supporting structure for a solar concentrating module having a parabolic trough surface mountable on the structure is disclosed. The parabolic trough surface is characterized by a focal line substantially parallel to a longitudinal axis of the surface. The structure comprises at least three torque rods which are substantially parallel to the longitudinal axis and are arranged such that a transverse distance between two adjacent torque rods is at least 1 meter. The supporting structure also comprises a plurality of generally parabolic ribs, mounted on the torque rods such that each rib engages a plane generally perpendicular to the torque rods.

WO 2012/111008 A9

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(48) Date of publication of this corrected version:
1 November 2012

(15) Information about Correction:
see Notice of 1 November 2012

SUPPORT STRUCTURE FOR SOLAR CONCENTRATOR

The contents of U.S. Provisional Patent Application No. 61/442,319, filed February 14, 2011, are incorporated by reference as if fully set forth herein.

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to renewable energy and, more particularly, but not exclusively, to a support structure for solar concentrator.

As the earth resources are wasted and the technology is developed, the shortage of the international energy resources is induced. In view of this, many countries in the world positively invest in the development of various renewable sources of energy. In the field of renewable energy, the use of trough-like concentrators for reflecting and focusing incident solar energy towards collectors located generally along the focal axes of the collectors is known. Typically, a solar concentrator includes a reflecting surface shaped as a linear parabolic trough for collecting and focusing sunlight onto an absorber tube at the focal line of the surface. The reflecting surface is moved along its horizontal axis to follow the movement of the sun during the day.

These solar concentrators have proved themselves over many years and are manufactured with different mirror support structures. Typically, solar concentrators of these types are used in large scale energy collection facilities that involve numerous unit systems spread over a wide area.

Numerous types of parabolic trough concentrators have been developed over the past few decades.

U.S. Patent No. 5,460,163, for example, discloses a trough shaped mirror extends in a longitudinal direction. The reflector has a focal zone in which is placed a linear heat pipe receiver. The receiver is fixed in relation to the reflector, and thus moves as the reflector tracks the sun's diurnal movement.

U.S. Patent No. 4,173,213 discloses a series of split linear parabolic reflectors in which the outer refectory is placed within the aperture of the inner reflector.

U.S. Patent No. 5,058,565 discloses a solar concentrating panel which includes a support structure for providing rigid torsional support for the panel. The support structure includes pairs of crossed, rigid structural support braces, each extending obliquely relative to the longitudinal axis of the panel between opposed longitudinal side edges of the parabolic surface.

U.S. Published Application No. 20040118395 discloses a solar concentrator module with a honeycomb structure which supports thin glass mirrors. The module is supported by a tubular element extending longitudinally, so as to support the panel honeycomb structure by means of suitable transverse fins and/or ribs.

U.S. Patent No. 6,668,820 discloses an arrangement of optical elements for the efficient collection of light while minimizing complexities of optics needed to achieve light collection and concentration. The arrangement includes a concave primary reflector, which receives the solar energy and sends it to a secondary convex reflector positioned in the focal zone of the first reflector. The secondary reflector sends the solar energy to a third non-imaging reflector positioned in the focal zone of the secondary reflector.

SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided a supporting structure for a solar concentrating module having a parabolic trough surface mountable on the structure. The parabolic trough surface is characterized by a focal line substantially parallel to a longitudinal axis of the surface. The structure comprises at least three torque rods substantially parallel to the longitudinal axis being arranged such that a transverse distance between two adjacent torque rods is at least 1 meter, and a plurality of generally parabolic ribs, mounted on the torque rods such that each rib engages a plane generally perpendicular to the torque rods.

According to an aspect of some embodiments of the present invention there is provided a solar concentrating module, comprising a parabolic trough surface mounted on the supporting structure.

According to an aspect of some embodiments of the present invention there is provided a solar system, comprising a plurality of solar concentrating modules, arranged in assemblies, wherein the modules of each assembly are connected to each other in a collinearly aligned manner.

According to an aspect of some embodiments of the present invention there is provided a method of converting solar radiation to heat. The method comprises using the solar system for concentrating the solar radiation onto a linear absorber tube having working liquid contained therein and being positioned generally at a focal line of the surface, so as to heat the liquid.

According to an aspect of some embodiments of the present invention there is provided a method of assembling a solar concentrating module. The method comprises mounting a parabolic trough surface onto the supporting structure.

According to some embodiments of the invention the structure further comprises a plurality of support bars mounted on the support ribs, and wherein the parabolic trough surface is mountable on the support bars.

According to some embodiments of the invention the support bars are characterized by yield strength of from about 200 MPa to about 250 MPa.

According to some embodiments of the invention the parabolic trough surface is mounted directly on the support bars so as to establish a generally rigid connection.

According to some embodiments of the invention there are exactly three torque rods.

According to some embodiments of the invention the three or more torque rods comprise a central rod and at least two secondary rods at both sides of the central rod, wherein a torsional load withstood by the central rod is larger than a torsional load withstood by each of the secondary rods.

According to some embodiments of the invention a ratio between the torsional load withstood by the central rod and the torsional load withstood by each of the secondary rods is from about 18 to about 198. According to some embodiments of the invention the ratio is from about 30 to about 100. According to some embodiments of the invention the ratio is from about 40 to about 100. According to some embodiments of the invention the ratio is from about 50 to about 100. According to some embodiments of the invention the ratio is from about 60 to about 100. According to some embodiments of the invention the ratio is from about 70 to about 100. According to some embodiments of the invention the ratio is about 78.

According to some embodiments of the invention at least one of the ribs is a shaped metal or metal alloy having a generally flat profile.

According to some embodiments of the invention the structure comprises a pair of torque plates, wherein each of the torque rods is mounted between the torque plates, such that the torque plates engage two generally parallel planes and the torque rod is generally perpendicular to the planes.

According to some embodiments of the invention at least one of the pair of torque plates has a linear profile in a cross-section perpendicular to the planes.

According to some embodiments of the invention at least one of the pair of torque plates has a planar a Y shape.

According to some embodiments of the invention at least one of the pair of torque plates has a planar C shape or the like.

According to some embodiments of the invention at least one of the pair of torque plates has a parabolic shape.

According to some embodiments of the invention the structure is characterized by a stiffness of at least at least 700 Nm/mrad. According to some embodiments of the invention the structure is characterized by a stiffness of at least 800 Nm/mrad. According to some embodiments of the invention the structure is characterized by a stiffness of at least 900 Nm/mrad. According to some embodiments of the invention the structure is characterized by a stiffness of about 1,000 Nm/mrad.

According to some embodiments of the invention a mass ratio between the supporting structure and the parabolic trough surface is less than 1.5. According to some embodiments of the invention the mass ratio is less than 1.4.. According to some embodiments of the invention the mass ratio is less than 1.3. According to some embodiments of the invention the mass ratio is less than 1.2. According to some embodiments of the invention the mass ratio is less than 1.1. According to some embodiments of the invention the mass ratio is less than 1.0.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIGs. 1A-C illustrate some support structures for parabolic trough reflective surfaces;

FIGs. 2A-D are schematic illustrations of a support structure in some exemplary embodiments of the invention;

FIGs. 3A-D are schematic illustrations of a support structure in additional exemplary embodiments of the invention;

FIGs. 4A-D are schematic illustrations of a support structure in further exemplary embodiments of the invention.

FIG. 5 is a schematic illustration showing an exemplary arrangement of mirrors or reflector panels and mounting elements of a support structure according to some embodiments of the present invention;

FIG. 6 is a schematic illustration of a solar assembly according to some embodiments of the present invention;

FIG. 7 is a schematic illustration of a solar system according to some embodiments of the present invention; and

FIGs. 8A and 8B are schematic illustrations exemplifying some notations used in calculations performed according to some embodiments of the present invention

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to renewable energy and, more particularly, but not exclusively, to a support structure for solar concentrator.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

For purposes of better understanding some embodiments of the present invention, as illustrated in FIGs. 2-8 of the drawings, reference is first made to the construction and operation of some supporting structures for parabolic trough reflective surfaces as illustrated in FIGs. 1A-C.

FIG. 1A illustrates a supporting structure which comprises a single central torque tube **100** and a plurality of support ribs **102** onto which the reflective surface (not shown) is mounted. The torsional load resulting from forces acting on the reflective surface is applied to torque tube **100** which transfers the forces from one rib to the other.

FIGs. 1B and 1C illustrate another type of supporting structure. In this type, the torsional load is applied, substantially equally, to a plurality of elements **104** instead of a single tube. Elements **104** are arranged in a dense arrangement forming a lattice like structure, which does not include a central element. The difference between the structures in FIGs. 1B and 1C is that in FIG. 1B elements **104** are mainly distributed far from the center, whereas in FIG. 1C they form a single unit which supports the center of the reflective surface.

It was found by the inventor of the present invention that the structures described above are costly, heavy and technologically difficult to employ. In a research made by the present inventor it was found that a significant improvement to the properties of a supporting structure can be achieved using three or more three torque rods.

FIG. 2A-D are schematic illustrations of a supporting structure **10** in various exemplary embodiments of the invention. Structure **10** is particularly useful in a solar concentrating module with a parabolic trough surface (not shown in FIG. 2A-D see, *e.g.*, FIGs. 3A-4D).

Structure **10** preferably comprises three or more torque rods generally shown at **1** and **2**.

As used herein, the term "rod" refers to a generally straight elongated structure of any cross-section which can be either hollow or non-hollow. In some embodiments of the present invention one or more of the torque rods is hollow. In some embodiments of the present invention one or more of the torque rods has a circular cross-section. Other types of rods are not excluded from the scope of the present invention.

Torque rods **1** and **2** serve for withstanding the torsional load resulting from moments pairs acting thereupon. When the parabolic trough surface is mounted on structure **10** torque rods **1** and **2** are aligned generally parallel (*e.g.*, with a deviation from parallelism of less than 5^o) to a longitudinal axis of the trough surface.

The longitudinal axis of a parabolic trough surface is defined as an axis which is parallel to the focal line of the surface. Apart for some small deviations due to manufacturing imperfection, a parabolic trough surface generally does not exhibit a curvature along its longitudinal direction. Thus, a cross-section of the surface along the longitudinal axis is linear, while a cross-section of the surface perpendicularly to the longitudinal axis is parabolic. In use as a solar concentrator, the parabolic trough surface is positioned outdoors such that its longitudinal axis is generally along the North/South direction.

Optionally and preferably, torque rods **1** and **2** are arranged such that a transverse distance, namely a distance as measured perpendicularly to the rodes, between two adjacent torque rods is at least 1 meter, or at least 1.1 meter, or at least 1.2 meter, or at least 1.3 meter, or at least 1.4 meter, or at least 1.5 meter, or at least 1.6 meter *e.g.*, about 1.7 meter or more.

In various exemplary embodiments of the invention structure **10** comprises a central rod **1** and two or more secondary rods **2** at both sides of central rod **1**. It was found by the present inventor that such configuration is advantageous from the standpoint of manufacturing simplicity and the mechanical properties of the supporting structure. The torsional load withstood by central rod **1** is optionally and preferably larger than the torsional load withstood by each of secondary rods. Typically, the ratio between the torsional loads withstood by central rod **1** and each of secondary rods **2** is from about 18 to about 198, or from about 30 to about 100, or from about 40 to about 100, or from about 50 to about 100, or from about 60 to about 100, or from about 70 to about 100, *e.g.*, about 78. Such ratios between the torsional loads can be obtained by a judicious selection of the relations between the diameters or rods **1** and **2**. Specifically, the diameter of rod **1** is preferably substantially larger (*e.g.*, at least two times larger or three times larger) than the diameter of each of rods **2**. In a representative example, which is not intended to be limited, structure **10** comprises two secondary rods **2**, each designed to withstand about 1.25 % of the torsional load on structure **10**, and one central rod 1 designed to withstand about 97.5 % of the torsional load. It was found by the present inventors that such torsional load distribution can be obtained by providing a central rod having a diameter which is about three times larger than the diameter of each of the two secondary rods. A typical structure can thus include a central rod, about 12" in diameter, and two central rods, each having a diameter of about 4".

Structure **10** can also comprise a plurality of generally parabolic ribs **3**, mounted on torque rods **1**, **2** such that each rib engages a plane generally perpendicular to torque rods **1**, **2**. In the illustration of FIG. 2A ribs **3** are mounted such that torque rods **1**, **2** are at the convex side of the ribs. However, this need not necessarily be the case, since, for some applications, it may not be necessary for all the rods to be at the convex side of the ribs. For example, one or more of the rods can pass through the ribs or be at their concave side. Such configurations are illustrated in FIGs. 3A, 3C, 3D, 4A and 4C.

Central rod **1** and secondary rods **2** are preferably non-coplanar, albeit two of the rods can define an imaginary plane. For example, when there structure **10** comprises one central rod and two secondary rods, the central rod can at a distance from the plane defined by the two secondary rods. In the schematic illustration of FIG. 2B, central rod **1** is between the plane defined by secondary rods **2** and the support ribs **3**, and in the schematic illustration of FIG. 3B, central rod **1** and support ribs **3** are at opposite sides of the plane defined by rods **2**. Also contemplated, are embodiments in which the torque rods are arranged such that when the parabolic trough surface is mounted on structure **10**, all the torque rods are generally at the same distance from the trough surface. A representative example of these embodiments is illustrated in FIG. 4A.

Optionally and preferably ribs **3** are made flat, namely they have a linear profile in a cross-section perpendicularly to the plane engaged by the respective rib (see FIG. 2C). It was found by the present inventor that such profile is advantageous for supporting parabolic trough surfaces since the main moments act at the plane of the ribs, where the shape of the rib is parabolic.

In some embodiments of the present invention structure **10** comprises a plurality of support bars **4** mounted on support ribs **3**. Support bars **4** serve as connecting elements to the parabolic trough surface and are therefore mounted at the concave side of ribs **3**. Support bars **4** are preferably made from a rigid material. A preferred yield strength of bars **4** is from about 200 MPa to about 250 MPa. Suitable material for bars **4** is steel, but other materials such as aluminum are not excluded from the scope of the present invention. In these embodiments, support bars **4** have a dual function: they support the parabolic trough surface and also add rigidity to the solar concentrating module. When the parabolic trough surface is mounted onto structure **10** it is preferably mounted directly on support bars **4** so as to establish a generally rigid connection. This is unlike conventional systems in which flexible support for the reflective surface is used. The present inventor discovered that glass breakage can be significantly reduced or eliminated by providing a rigid connection between the support structure and the parabolic trough surface. Preferably, the connection is rigid along both the axial direction and the radial direction.

The torque rods are preferably supported by a pair of torque plates **6**, mounted on opposite sides of the torque rods. In some embodiments of the invention torque plates **6** support torque rods **1** and **2**, but not bars **4** which are mounted on ribs **3**. This embodiment is illustrated in FIGs. 2C, 3B and 3C which show that bars **4** are shorter than the distance between plates **6** such that bars **4** and plates **6** are devoid of contact thereamongst. Alternatively, at least some of bars **4** are mounted on plates **6**, as illustrated in FIGs. 4A-C.

Plates **6** can have any shape. Preferably plates **6** are made flat, namely they have a linear profile in a cross-section perpendicularly to the plane engaged by the respective plate (see FIGs. 3B, 4B and 4D). In a front view, the planar shape of plates **6** can be any geometrical figure which allows holding the torque rods. Representative examples of planar shapes suitable for the present embodiments include, without limitation, a Y shape, a parabolic or generally parabolic shape, C shape, flattened C shape, and the like. In the embodiments illustrated in FIGs. 2B, 2D, 3A and 3C, plates **6** have Y shapes, and in the embodiments illustrated in FIGs. 4A and 4C, plates **6** have generally parabolic shapes.

A solar concentrating module **20** according to some embodiments of the present invention is illustrated in FIGs. 3A-D and 4A-D. Module **20** comprises supporting structure **10** and a parabolic trough surface **7**. Surface **7** can be made of any reflective material, as known in the art. For example, in some embodiments, a glass surface is employed. The length of surface **7** along its longitudinal axis generally matches the length of structure **10** which approximately equals the length of rods **3**. The width of surface **7** along a transverse axis perpendicular to the longitudinal axis and to the vertex line of surface **7** (normal to surface **7** at its central line **22**), generally matches the distance between the two farthest support bars **4**.

Surface 7 is preferably mounted on bars **4** of structure **10**. Typically, surface **7** comprises a plurality of reflector panels or mirrors **24** (*e.g.*, glass mirrors, or aluminum panels) which are tiled onto bars **4** to form surface **7**. A typical separation distance between adjacent mirrors or reflector panels along the longitudinal direction is from about 7 mm to about 10 mm, and typical separation distance between adjacent mirrors or reflector panels along a direction perpendicular to the longitudinal is from about 5 mm to about 8 mm. In various exemplary embodiments of the invention each reflector panel or mirror **24** is attached to bars **4** using mounting elements **5**, such as pads or the like, at the rear side of the mirror or reflector panel. Mounting elements **5** can be made, for example, from a ceramic material. Mirrors or reflector panels **24** are preferably attached to bars **4** so as to establish a generally rigid connection between mirrors or reflector panels **24** and structure **10**.

Typically, each mirror or reflector panel is attached to two bars via four mounting elements, but use of a different number of mounting elements is excluded. Typical dimensions of a mirror or reflector panel are, without limitation, from about 1.4 m to about 1.7 m along the longitudinal direction and from about 1.0 m to about 1.5 m along the transverse direction. Mirrors or reflector panels **24** are typically arranged in a rectangular arrangement. The mirrors or reflector panels on each row (along the longitudinal direction) are optionally and preferably identical in their dimensions. Mirrors or reflector panels on adjacent rows can have different dimensions, particularly along the transverse dimension so as to account for the parabolic curvature of surface **7**. For example, in some embodiments of the present invention the mirrors or reflector panels on a row closer to the central line **22** are larger in their transverse dimension than the mirrors or reflector panels on an adjacent row farther from central line **22**. In the schematic illustration of FIGs. 3A-D and 4A-D, module **20** comprises a rectangular arrangement of 20 mirrors or reflector panels with four rows of five mirrors or reflector panels. A module with more or less than 20 mirrors or reflector panels, and/or other arrangements is also contemplated.

A typical length of surface **7** and structure **10** is from about 5 meters to about 12 meters, *e.g.*, about 8 meters, and typical width of surface **7** and structure **10** is from about 4 to about 8 meters, *e.g.*, about 5 meters. A typical focal length of surface **7** is from about 1 meter to about 2 meters, *e.g.*, about 1.5 meters. Other dimensions are not excluded from the scope of the present invention. An exemplary arrangement of mirrors or reflector panels **24** and mounting elements **5** is schematically illustrated in the diagram of FIG. 5. The dimensions shown in FIG. 5 are not intended to limit the scope of the present invention in any way.

In various exemplary embodiments of the invention the mass ratio between the supporting structure **10** and parabolic trough surface **7** is less than 1.5 or less than 1.4 or less than 1.3 or less than 1.2 or less than 1.1 or less than 1.0.

The structure of the present embodiments is preferably capable to sustain winds and rotational loads on surface **7** while keeping the integrity of surface **7**. The structure of the present embodiments is characterized by small torsional deflection. The torsional deflection is small when the overall stiffness of the support structure is high. Stiffness is typically expressed in units of torque per unit angle. In various exemplary embodiments of the invention the overall stiffness of the support structure is at least 700 Nm/mrad or at least 800 Nm/mrad or at least 900 Nm/mrad, *e.g.*, 1,000 Nm/mrad.

FIG. 6 is a schematic illustration of a solar assembly **60** according to some embodiments of the present invention. Solar assembly **60** comprises a plurality of solar concentrating modules **20** connected to each other in a collinearly aligned manner. Solar assembly **60** can further comprise a rotational drive unit **62** configured for rotating mirrors or reflector panels, preferably collectively, along a longitudinal axis **64**. Typically, there are equal numbers of solar concentrating modules at both sides of drive unit **62**. For clarity of presentation, FIG. 6 only shows modules at one side of unit **62** but the skilled person provided with the details described herein would know how to adjust the drawing to include solar concentrating modules at both sides of unit **62**.

The number of solar concentrating modules in assembly **60** is selected depending on the amount of radiation it is desired to collect, and the load sustainable by unit **62**. In some embodiments of the present invention assembly **60** comprises 10 modules (preferably 5 modules at each side of unit **62**), 12 modules (preferably 6 modules at each side of unit **62**), or 14 modules (preferably 7 modules at each side of unit **62**), or 16 modules (preferably 8 modules at each side of unit **62**), or 18 modules (preferably 9 modules at each side of unit **62**), or 20 (preferably 10 modules at each side of unit **62**). In some embodiments of the present invention the cumulative peak torsional torque on assembly **60** is on the order of at least 75,000 Nm.

Drive unit **62** can be of any type known in the art for rotating solar assemblies. For example, unit **62** can include a drive motor (*e.g.*, electric motor), a drum and cable device, a rack or worm gear drive, a hydraulic device or the like. Optionally and preferably drive unit **62** is of the self-tracking type which is capable of tracking the sun path automatically, *e.g.*, using a computer implemented algorithm as known in the art. In various exemplary embodiments of the invention unit **62** has a sufficiently shallow profile and narrow width so as to cast a minimal shadow on modules **20**. Unit **60** can comprise a heat collection element (not shown) for transfer of the solar energy reflected and focused by the reflector panels to the plant heat exchangers. Unit **62** provides modules with various orientations within a range of motion which includes a solar-tracking operational range (substantially between an east horizon-facing position and a west horizon-facing position). Optionally and preferably the range of motion also includes a stowed position and a maintenance position. The maintenance position can be at one end of that range of motion and one of the horizon-facing positions can be at the other end of that range.

Unit **62** can be configured to rotate modules **20** throughout a day to track the position of the sun during the day. Optionally, unit **62** is also configured to rotate modules **20** throughout the year to track a position of the sun throughout the seasons. That is, unit **62** according to the present embodiments may function as an elevation drive or as an azimuth drive, or both when two mechanisms are provided as a dual acting drive.

FIG. 7 is a schematic illustration of a solar system **70**, according to some embodiments of the present invention. System **70** comprises a plurality of assemblies, such as assembly **60** described above. For simplicity only two assemblies **60** are illustrated but more than two assemblies are also contemplated. A receiver tube **72** is positioned along the focal line of each assembly **60**. The tube is filled with a working liquid which flows through and out of the field of assemblies **60**. The working liquid which is heated by solar energy at the focal line is transferred via a forward conduit **80** to a turbine **76** which generate electricity as known in the art. In some embodiments of the present invention system **70** comprises a thermal storage unit **74**. In these embodiments, conduit **80** delivers the working liquid from the focal line also to unit **74**. The size and/or number of assemblies **60** can be selected to allow both generation of electricity and heat storage during the day, such that in the evening or during cloudy weather the stored heat can be utilized for further generation of electricity. From turbine **76** the working liquid, which now has a lower temperature, can be transferred via a return conduit **78** to tube **72**, optionally via a steam condenser **82**, as known in the art. It is expected that during the life of a patent maturing from this application many relevant solar systems based on parabolic trough surfaces will be developed and the scope of the term solar system is intended to include all such new technologies *a priori*.

As used herein the term “about” refers to ± 10 %.

The word "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word "optionally" is used herein to mean "is provided in some embodiments and not provided in other embodiments." Any particular embodiment of the invention may include a plurality of "optional" features unless such features conflict.

The terms "comprises", "comprising", "includes", "including", “having” and their conjugates mean "including but not limited to".

The term “consisting of means “including and limited to”.

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases “ranging/ranges between” a first indicate number and a second indicate number and “ranging/ranges from” a first indicate number “to” a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below find experimental support in the following examples.

EXAMPLES

Reference is now made to the following examples, which together with the above descriptions illustrate some embodiments of the invention in a non limiting fashion.

An estimation of the expected twist on the structure of the present embodiments has been performed. In this example an estimated twist of a structure which includes a central rod **1** and two secondary rods **2** (see FIG. 4A-C) was compared to an estimated twist of the same structure but without secondary rods **2**.

A structure with a central rod and two secondary rods

Notations

The following notations will be used, with reference to FIG. 8A

φ - angle of twist [°]

θ - relative angle of twist [°]

R - center of mass [m]

x_R - distance of the secondary rod from the center of mass R [m] in the x direction.[m]

y_R - distance of the secondary rod from the center of mass R [m] in the y direction.[m]

ℓ - length of the rods [m]

D_o - outer diameter of the central rod [m]

D_i - inner diameter of the central rod [m]

d_o - outer diameter of the secondary rod [m]

d_i - inner diameter of the secondary rod [m]

G - shear modulus

J_p - polar moment of inertia

T - torque, given by $T = \theta \cdot G \cdot J_p$

Twist calculations

The relative angle of the twist is given by the derivative $\theta = d\varphi/dx$, and the torque T is given by $T = \theta \cdot G \cdot J_p$. Thus $T = d\varphi/dx \cdot G \cdot J_p$. The angle of the twist, φ, can therefore be extracted from the torque:

$$d\varphi = \frac{T}{G \cdot J_p} dx$$

$$\varphi = \int_0^{\ell} \frac{T}{G \cdot J_p} dx$$

$$\varphi = \frac{T\ell}{G \cdot J_p}$$

The definition of J_p is $J_p = J_x + J_y$, where $J_x = \int_A y^2 dA$, and $J_y = \int_A x^2 dA$. Thus:

$$J_x = \left(\frac{\pi(D_o^4 - D_i^4)}{64}\right) + \left(\frac{\pi(d_o^4 - d_i^4)}{64}\right) + 2(y_R^2 \frac{\pi}{4}(d_o^2 - d_i^2))$$

$$Jy = \left(\frac{\pi(D_o^4 - D_i^4)}{64}\right) + \left(\frac{\pi(d_o^4 - d_i^4)}{64}\right) + 2(x_R^2 \frac{\pi}{4}(d_o^2 - d_i^2))$$

Substituting the typical values: D_o=0.3239m, D_i=0.3175m, d_o=0.1143m, d_i=0.1085, y_R = 1.7 m and x_R = 0,2514m, one obtains, J_x=0.0059 m^4, J_y=0.00017 m^4 and therefore J_p=0.00608 m^4.

A structure with a central rod and without secondary rods

Notations

The notations will be the same as above, with the following exceptions (see also FIG. 8B):

φ_1 - angle of twist [°]

θ_1 - relative angle of twist [°]

J_{p1} - polar moment of inertia

T_1 - torque, given by $T = \theta \cdot G \cdot J_p$

Twist calculations

Similarly to the above calculations, the angle of the twist, φ_1, can be extracted from the torque:

$$d\varphi_1 = \frac{T_1}{G \cdot J_{p_1}} dx$$

$$\varphi_1 = \int_0^{\ell} \frac{T_1}{G \cdot J_{p_1}} dx$$

$$\varphi_1 = \frac{T_1 \cdot \ell}{G \cdot J_{p_1}}$$

The value of J_{p1} can be calculated as follows:

$$J_{p_1} = \left(\frac{\pi (D_o^4 - D_i^4)}{32} \right)$$

Substituting the values used above (D_o=0.3239m, D_i=0.3175m) one obtains J_{p1}=0.0000829 m^4, which is almost 70 times lower than J_p.

Assuming that $T=T_1$ (same torque for both cases), the ratio between φ and φ_1 is given by J_{p1}/J_p. Substituting the calculated values of J_p and than J_{p1}, one concludes that the twist φ for a structure with a central rod and two secondary rods is almost two orders of magnitude lower than the twist φ_1 of a structure with a central rod but without secondary rods.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. A supporting structure for a solar concentrating module having a parabolic trough surface characterized by a focal line substantially parallel to a longitudinal axis of the surface, the parabolic trough surface being mountable on the structure, the structure comprising:

at least three torque rods substantially parallel to said longitudinal axis being arranged such that a transverse distance between two adjacent torque rods is at least 1 meter; and

a plurality of generally parabolic ribs, mounted on said torque rods such that each rib engages a plane generally perpendicular to said torque rods.

2. A solar concentrating module, comprising a parabolic trough surface mounted on the supporting structure of claim 1.

3. A solar system, comprising a plurality of solar concentrating modules, arranged in assemblies, wherein the modules of each assembly are connected to each other in a collinearly aligned manner.

4. A method of converting solar radiation to heat, comprising using the solar system of claim 3 for concentrating the solar radiation onto a linear absorber tube having working liquid contained therein and being positioned generally at a focal line of said surface, so as to heat the liquid.

5. A method of assembling a solar concentrating module, comprising mounting a parabolic trough surface onto the structure of claim 1.

6. The structure, module, system or method according to any of claims 1-3, wherein the structure further comprises a plurality of support bars mounted on said support ribs, and wherein the parabolic trough surface is mountable on said support bars.

7. The structure, module, system or method according to claim 6, wherein said support bars are characterized by yield strength of from about 200 MPa to about 250 MPa.

8. The module or system according to claim 7, wherein said parabolic trough surface is mounted directly on said support bars so as to establish a generally rigid connection.

9. The structure, module, system or method according to any of claims 1-8, wherein said at least three torque rods are three torque rods.

10. The structure, module, system or method according to any of claims 1-9, wherein said at least three torque rods comprise a central rod and at least two secondary rods at both sides of said central rod, wherein a torsional load withstood by said central rod is larger than a torsional load withstood by each of said secondary rods.

11. The structure, module, system or method according to claim 10, wherein a ratio between said torsional load withstood by said central rod and said torsional load withstood by each of said secondary rods is from about 18 to about 198.

12. The structure, module, system or method according to claim 10, wherein a ratio between said torsional load withstood by said central rod and said torsional load withstood by each of said secondary rods is from about 30 to about 100.

13. The structure, module, system or method according to any of claims 1-10, wherein at least one of said ribs is a shaped metal or metal alloy having a generally flat profile.

14. The structure, module, system or method according to any of claims 1-13, wherein the structure further comprises a pair of torque plates wherein each of said torque rods is mounted between said torque plates, such that said torque plates engage

two generally parallel planes and said torque rod is generally perpendicular to said planes.

15. The structure, module, system or method according to claim 14, wherein at least one of said pair of torque plates has a linear profile in a cross-section perpendicular to said planes.

16. The structure, module, system or method according to any of claims 14 and 15, wherein at least one of said pair of torque plates has a planar a Y shape.

17. The structure, module, system or method according to any of claims 14 and 15, wherein at least one of said pair of torque plates has a planar C shape.

18. The structure, module, system or method according to any of claims 14 and 15, wherein at least one of said pair of torque plates has a parabolic shape.

19. The structure, module, system or method according to any of claims 1-17, wherein the structure is characterized by a stiffness of at least at least 700 Nm/mrad.

20. The structure, module, system or method according to any of claims 1-19, wherein a mass ratio between the supporting structure and the parabolic trough surface is less than 1.5.

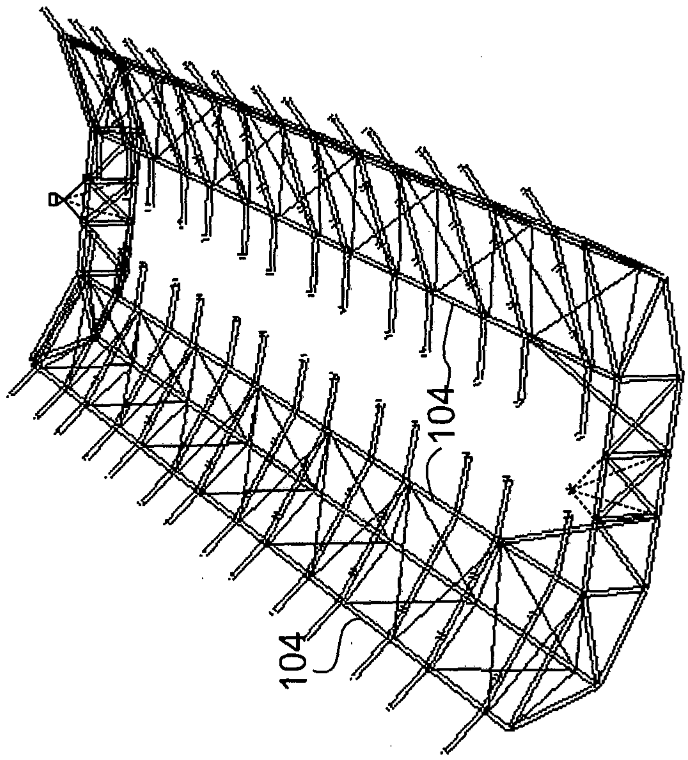

FIG. 1B

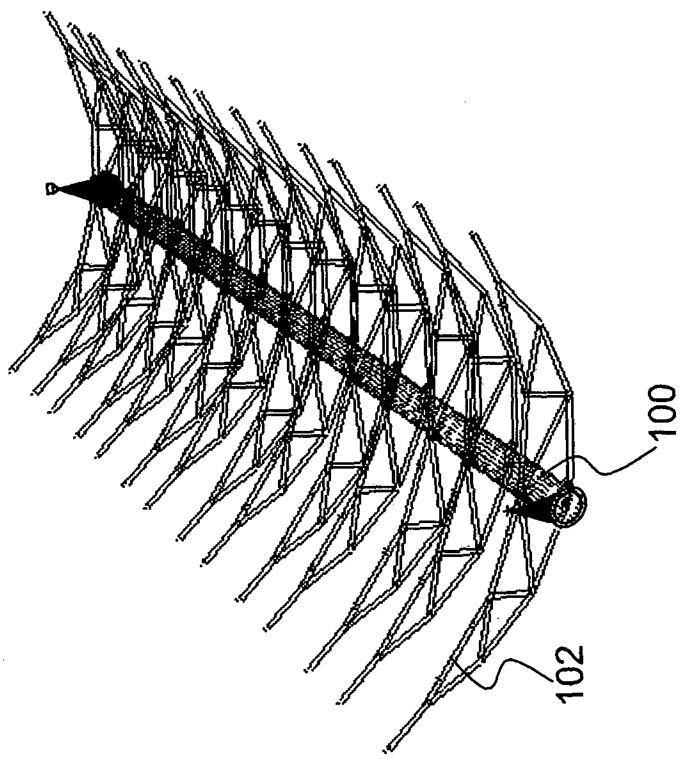

FIG. 1A

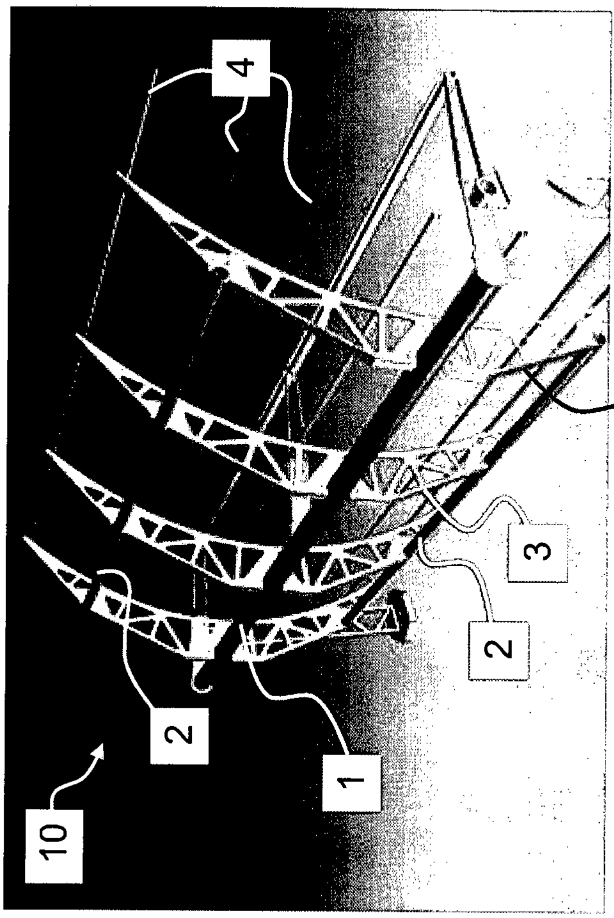

FIG. 2A

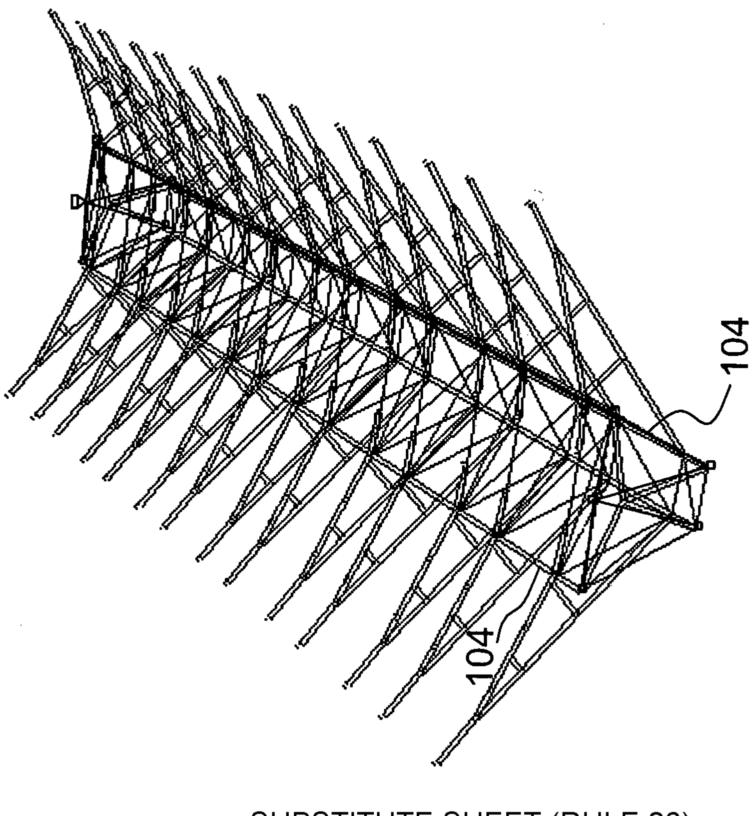

FIG. 1C

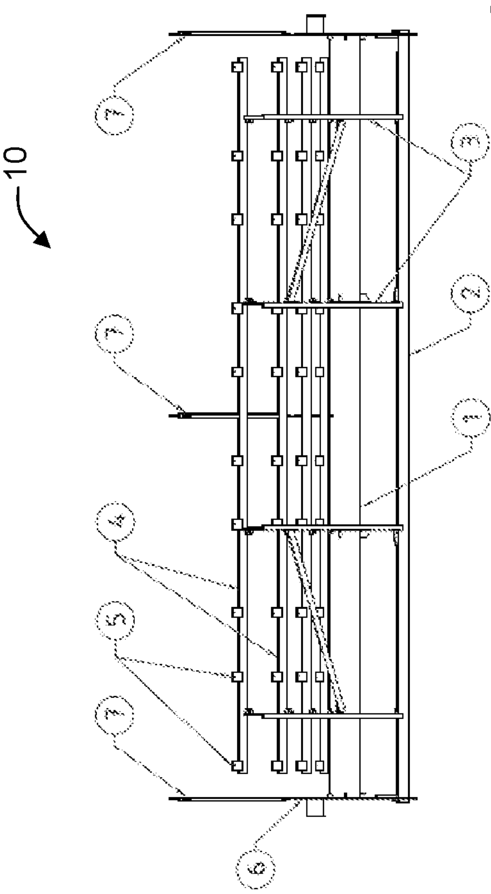

FIG. 2C

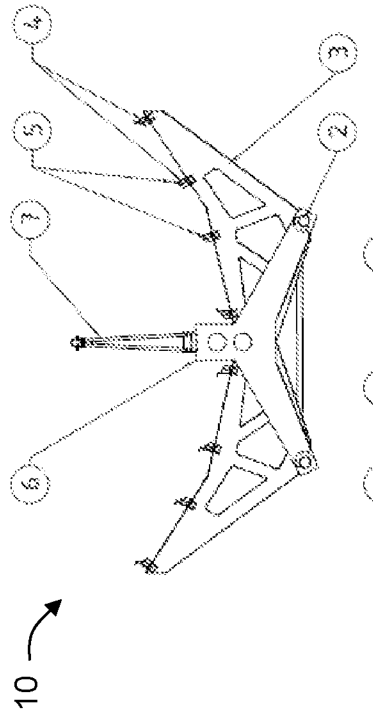

FIG. 2B

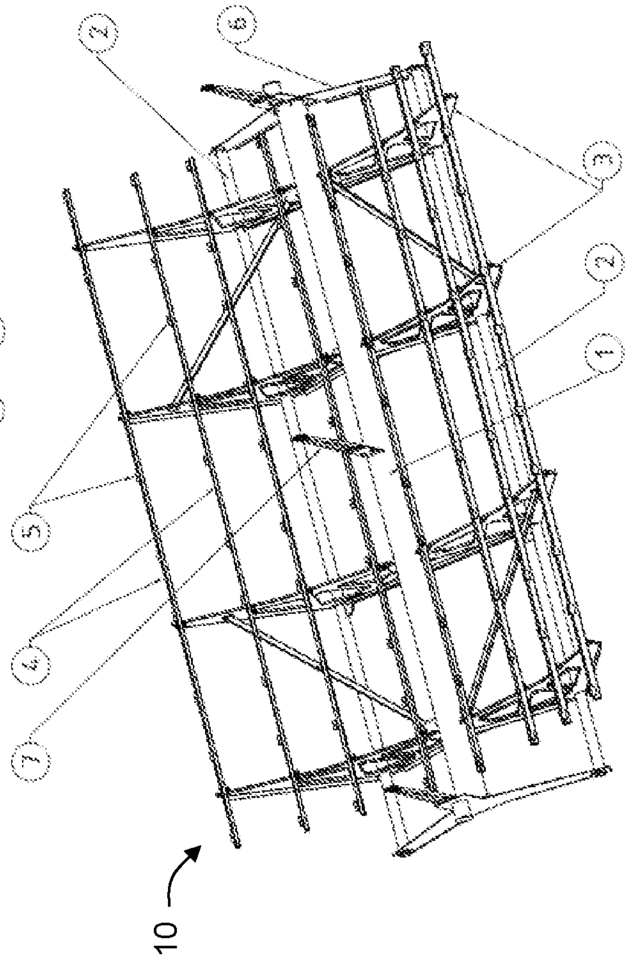

FIG. 2D

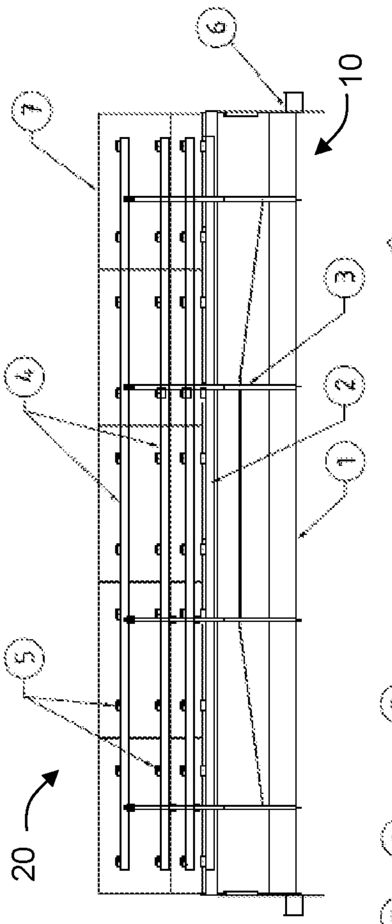

FIG. 3B

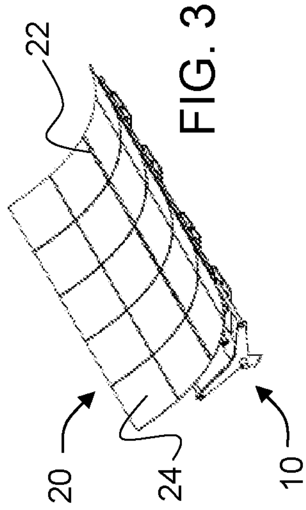

FIG. 3D

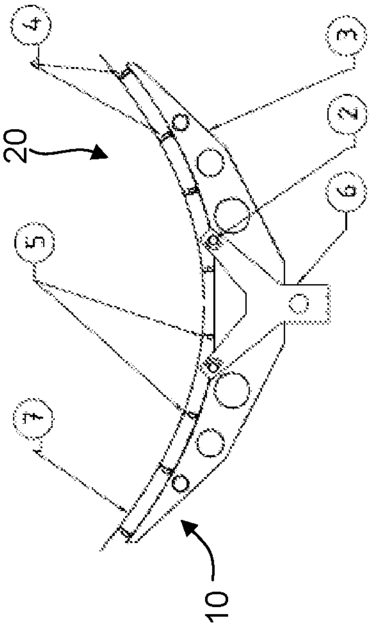

FIG. 3A

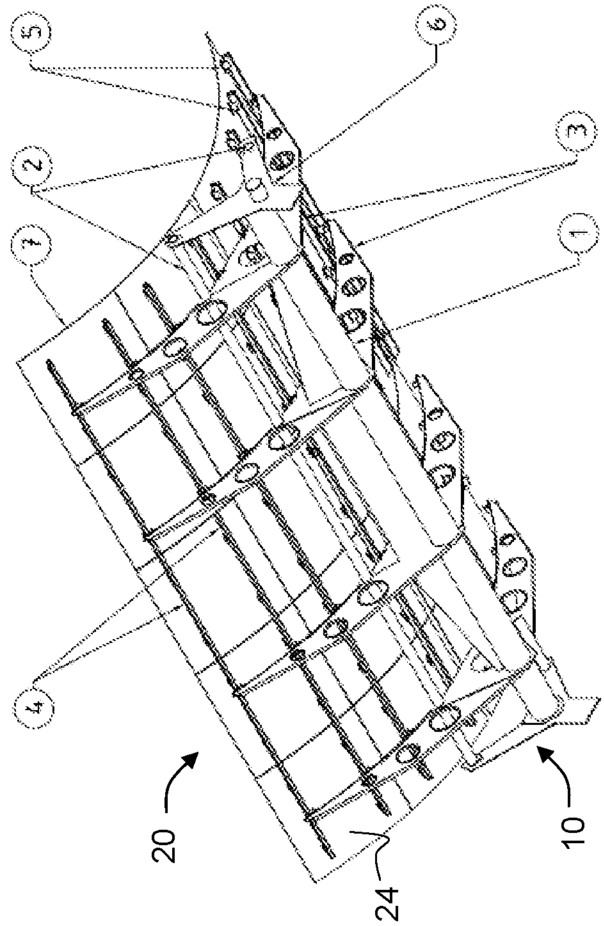

FIG. 3C

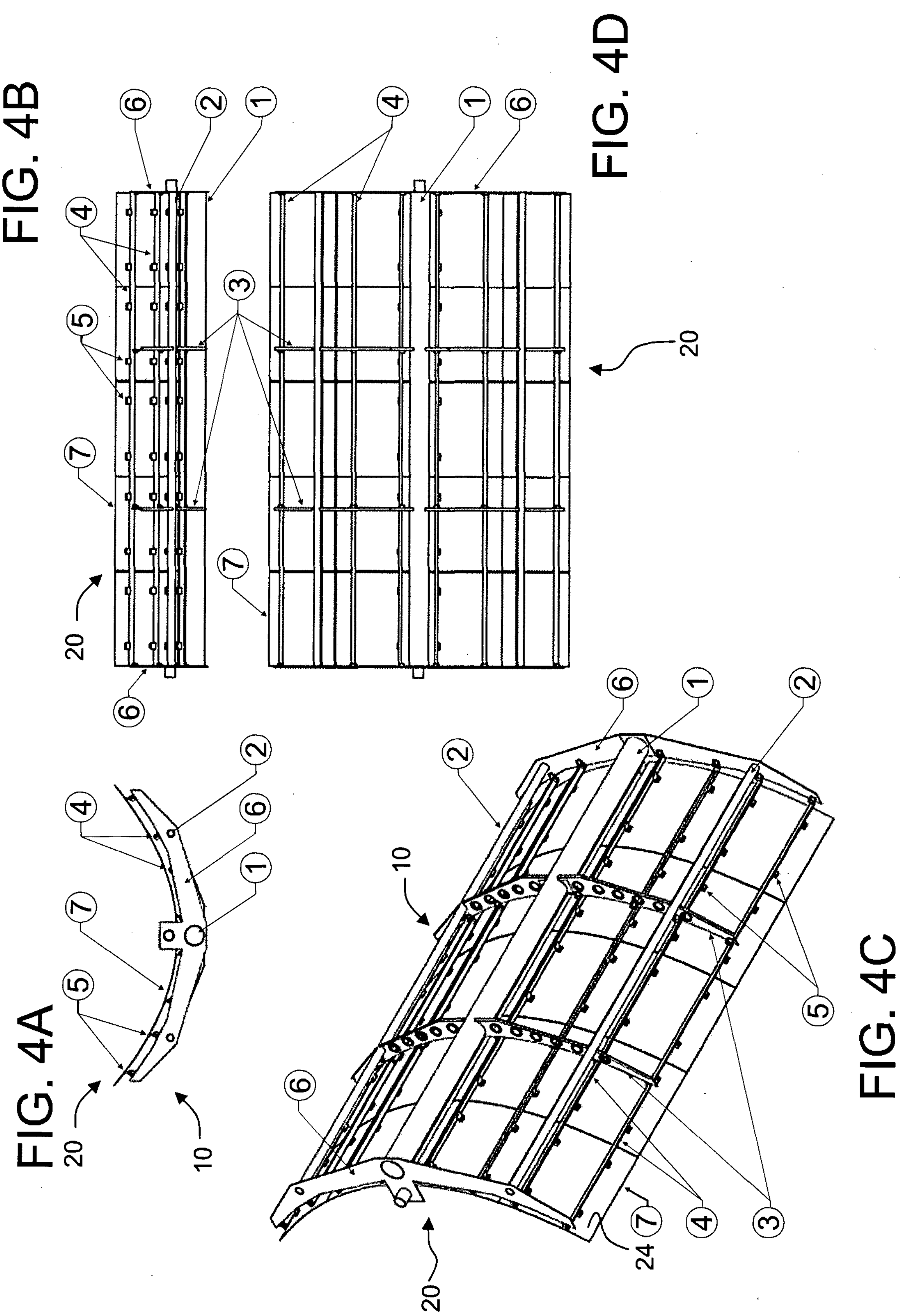

FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

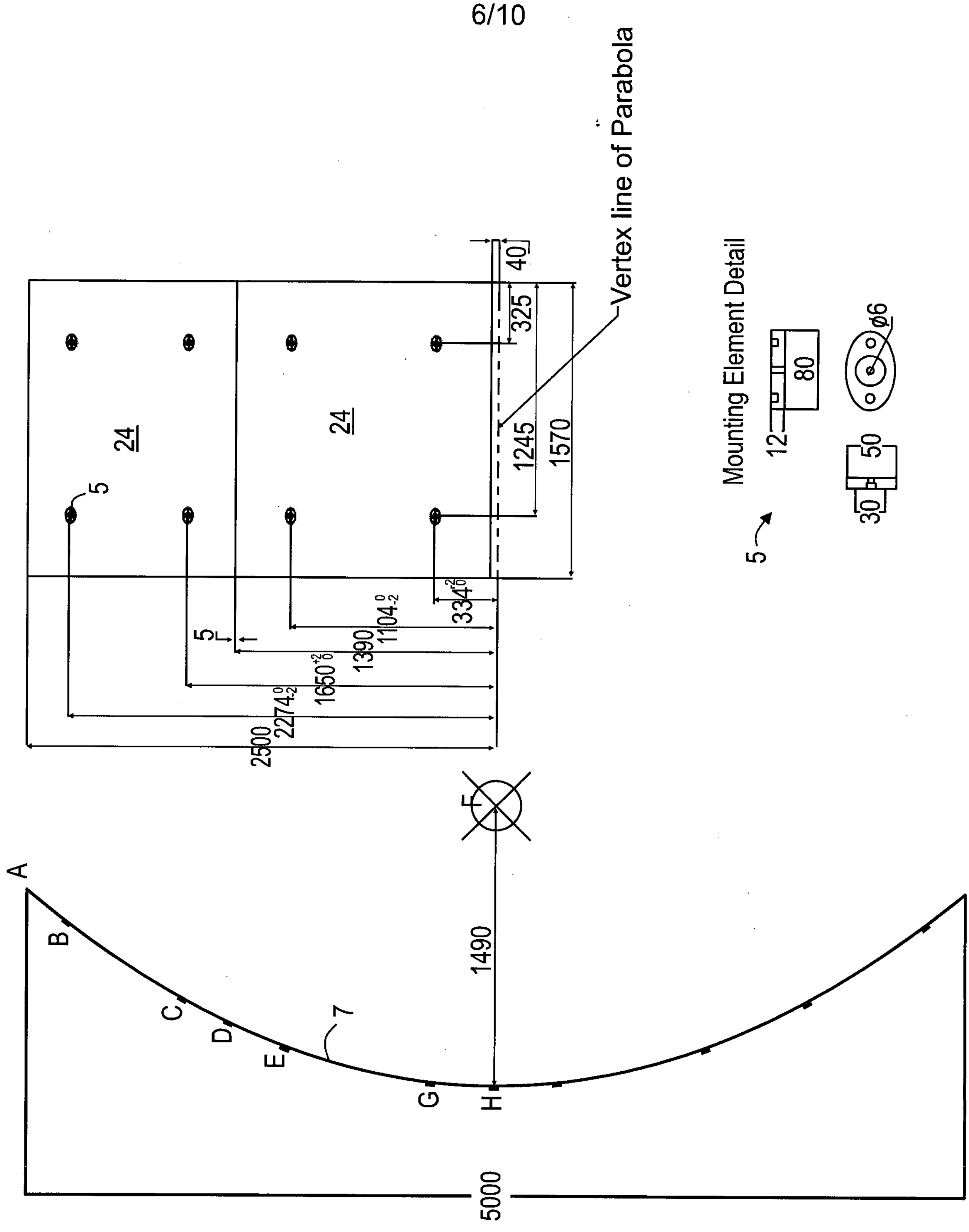
Vertex line of Parabola
40
325
1245
1570
24
24
5
334
1104
1390
1650
2274
2500
F
1490
A
B
C
D
E
7
G
H
5000
Mounting Element Detail
12
80
50
30
ϕ6
5

FIG. 5

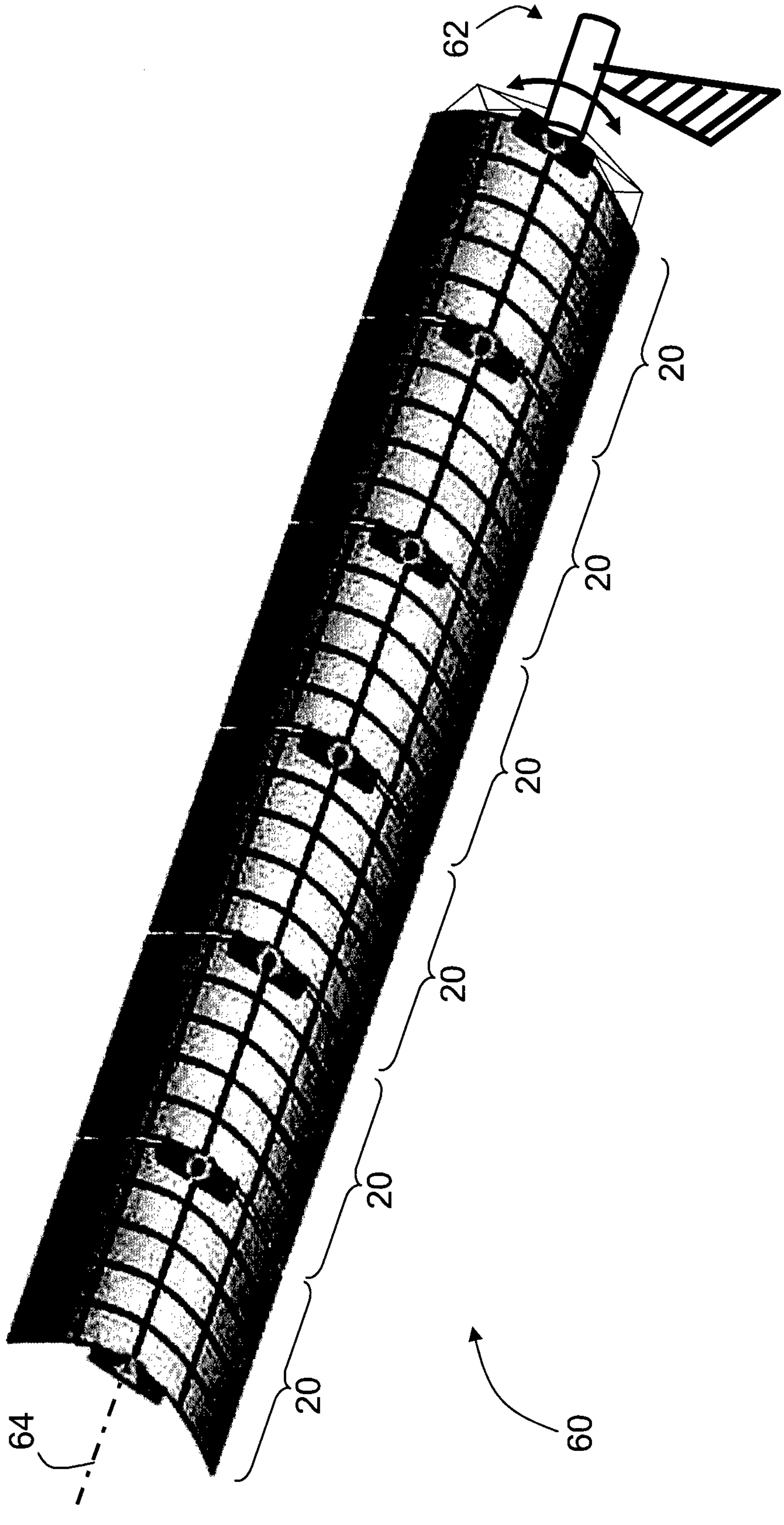

FIG. 6

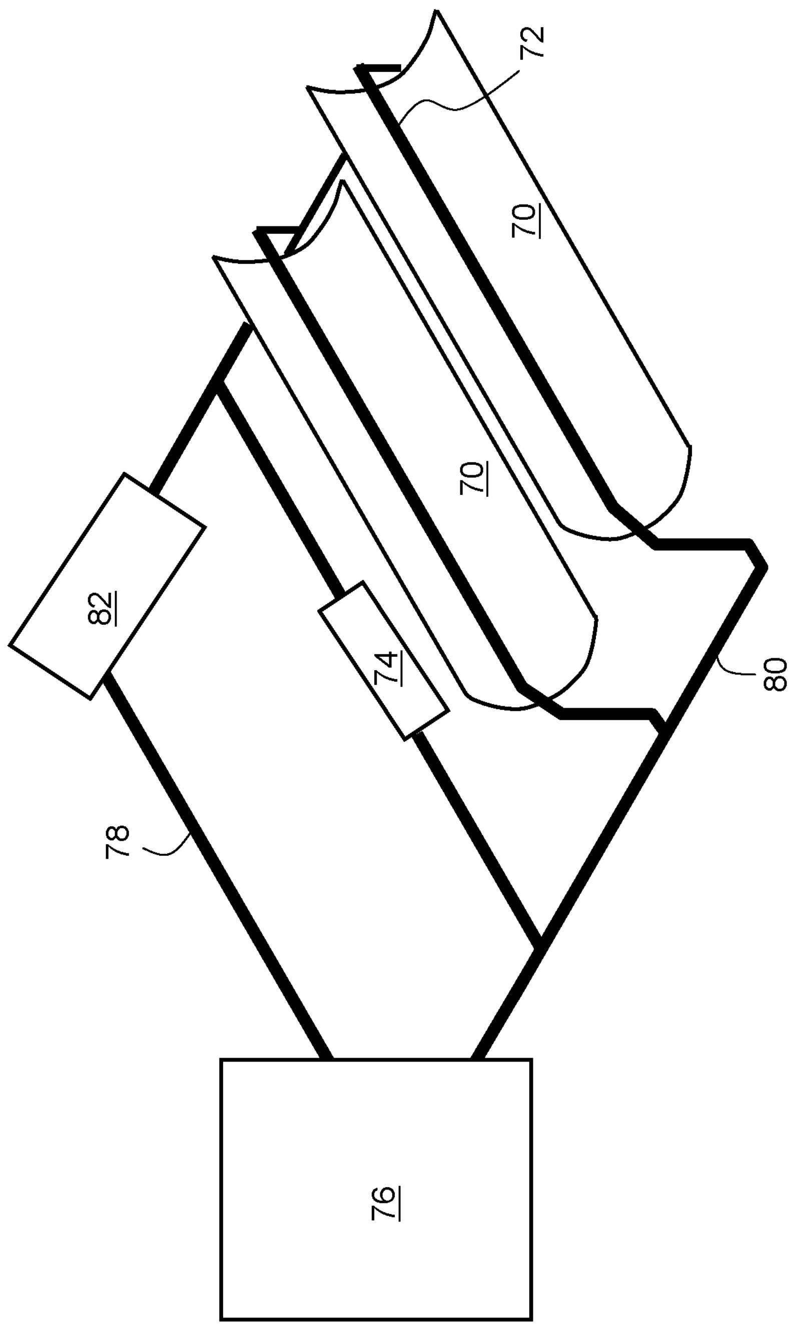

FIG. 7

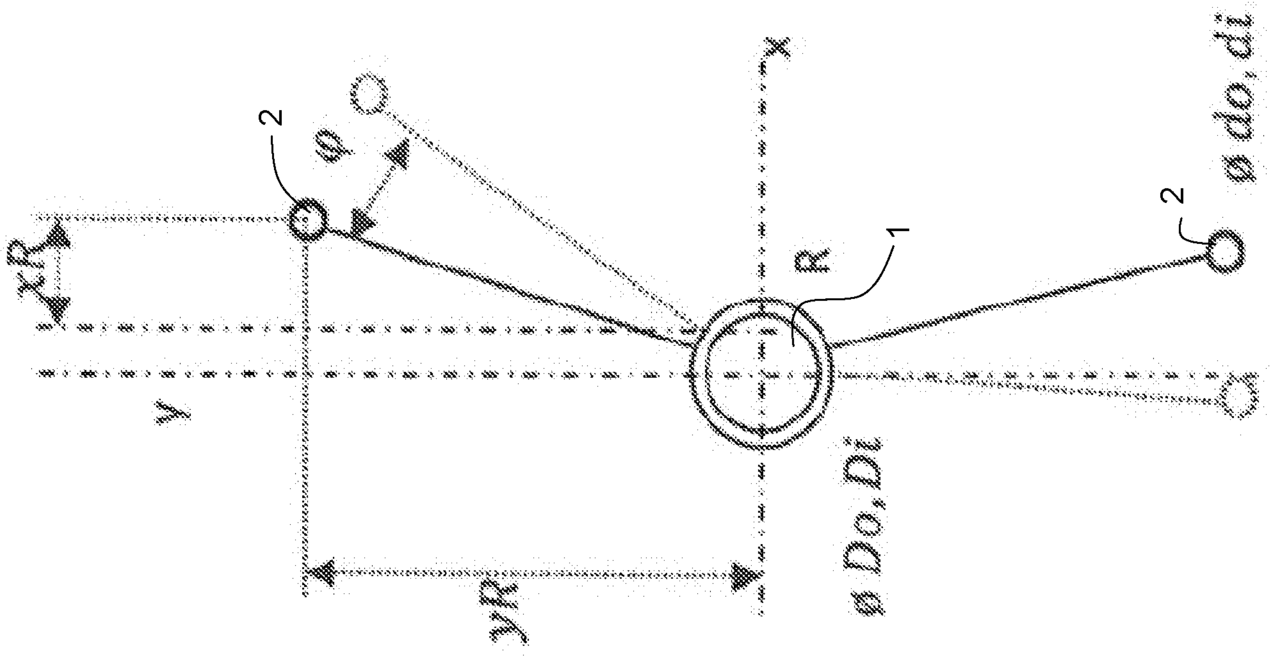

FIG. 8A

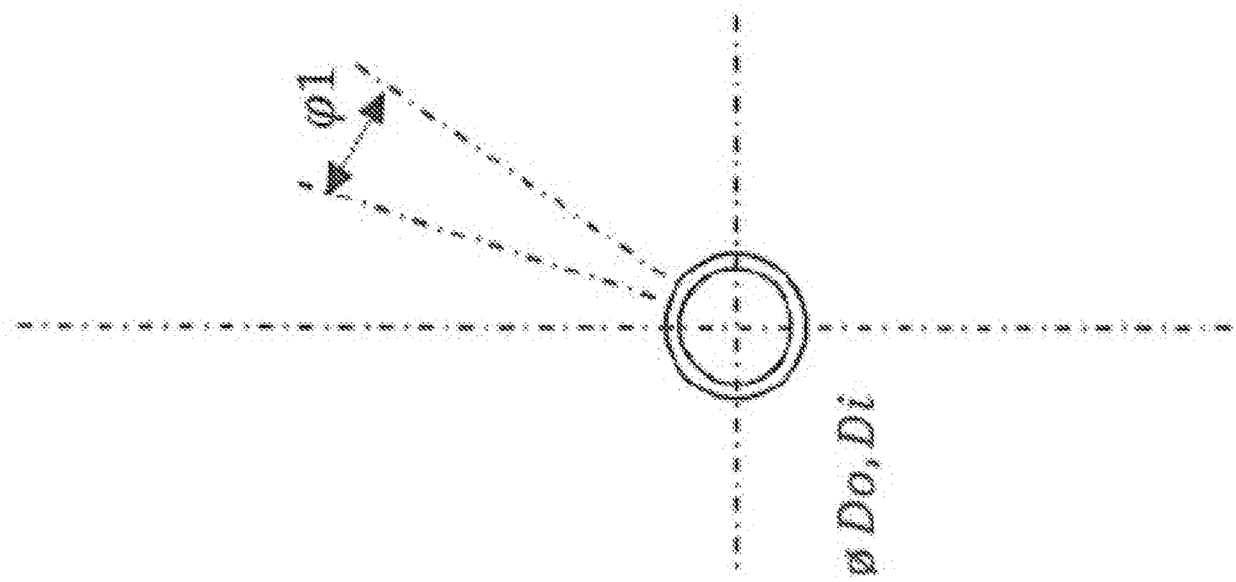

FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2012/050044

A. CLASSIFICATION OF SUBJECT MATTER
INV. F24J2/14 F24J2/54 F24J2/52
ADD.

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)
F24J

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/146215 A2 (SOPOGY INC [US]; DOPP KIP H [US]; KIMURA DARREN T [US]) 3 December 2009 (2009-12-03) figures 1, 2, 17	1-20
X	CN 201 318 827 Y (CHINA HUADIAN ENGINEERING GROU [CN]) 30 September 2009 (2009-09-30) figure 2	1-15,17, 19,20
X	WO 2010/016934 A2 (SOPOGY INC [US]; MARGANKUNTE NAVEEN N [US]; SIKORA JOSEF A [US]; KIMUR) 11 February 2010 (2010-02-11) figures 1, 2, 5	1-15, 17-20
X	US 4 678 292 A (MIYATANI KAZUO [JP] ET AL) 7 July 1987 (1987-07-07) figures 1, 2	1-15, 17-20

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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
19 July 2012	01/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Louchet, Nicolas

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2012/050044

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CH 637 202 A5 (ATLANTIS ENERGIE AG [CH]) 15 July 1983 (1983-07-15) figures 7, 8 -----	1-15,19, 20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2012/050044

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2009146215 A2	03-12-2009	AU 2009251510 A1	03-12-2009
		EP 2304333 A2	06-04-2011
		US 2011073104 A1	31-03-2011
		WO 2009146215 A2	03-12-2009
CN 201318827 Y	30-09-2009	NONE	
WO 2010016934 A2	11-02-2010	AU 2009280011 A1	11-02-2010
		EP 2321586 A2	18-05-2011
		MA 32606 B1	01-09-2011
		US 2011220096 A1	15-09-2011
		WO 2010016934 A2	11-02-2010
US 4678292 A	07-07-1987	NONE	
CH 637202 A5	15-07-1983	NONE	