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(54) **FIXED FOCUS PARABOLIC TROUGH COLLECTOR**

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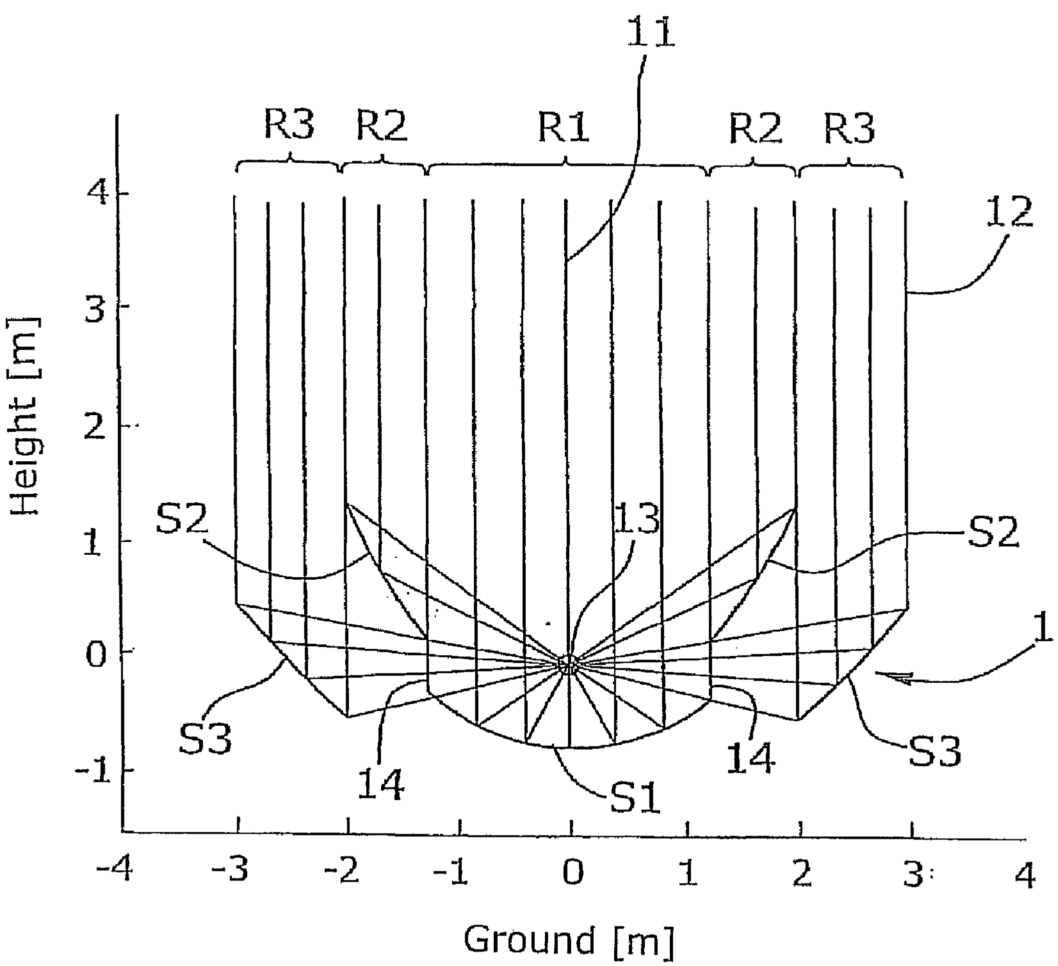
(57) **ABSTRACT**

The fixed focus parabolic trough collector comprises a mirror structure (**10**) with a plurality of mirror segments (S**1**, S**2**, S**3**, . . .). At least two adjacent mirror segments (S**1**, S**2**) form a gap (**14**) through which radiation (R**3**) reflected by a third mirror segment (S**3**) is incident on the absorber pipe (**13**) positioned at the focal point of all mirror segments. This minimizes the path of the reflected radiation. The mirror structure has compact dimensions relative to the aperture opening and is minimally affected by wind.



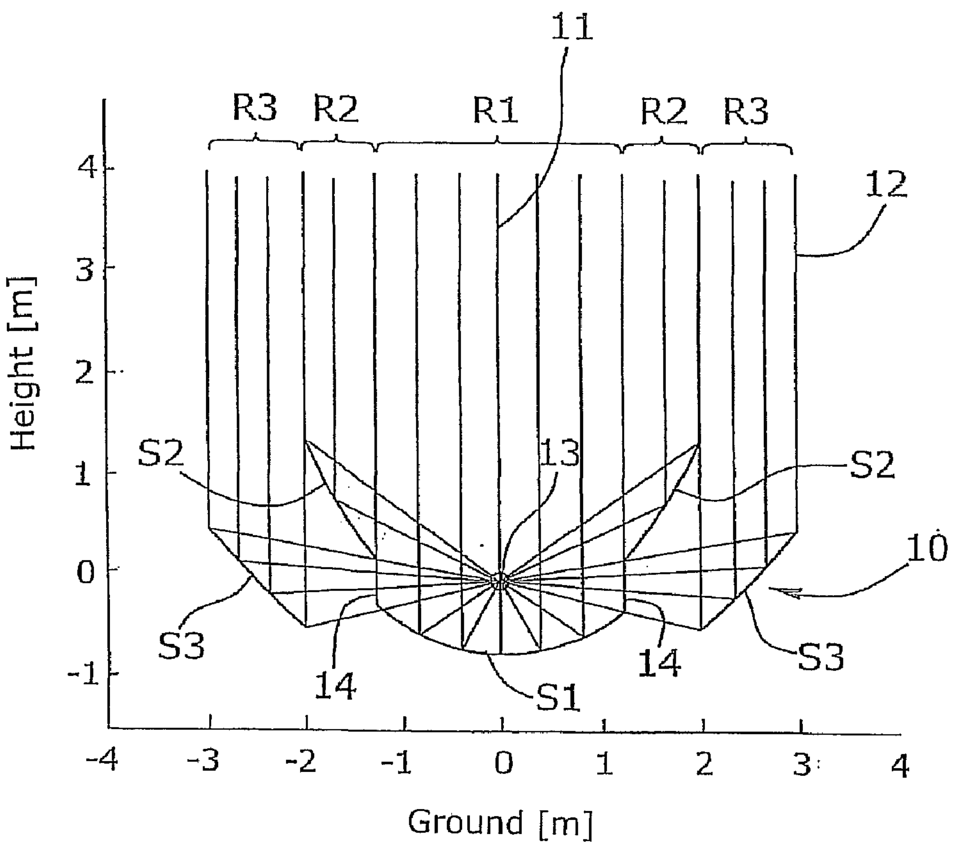

11
R3
R2
R1
R2
R3
12
Height [m]
S2
13
S2
10
S3
14
14
S3
S1
Ground [m]
-4
-3
-2
-1
0
1
2
3
4
-1
0
1
2
3
4

Fig.1

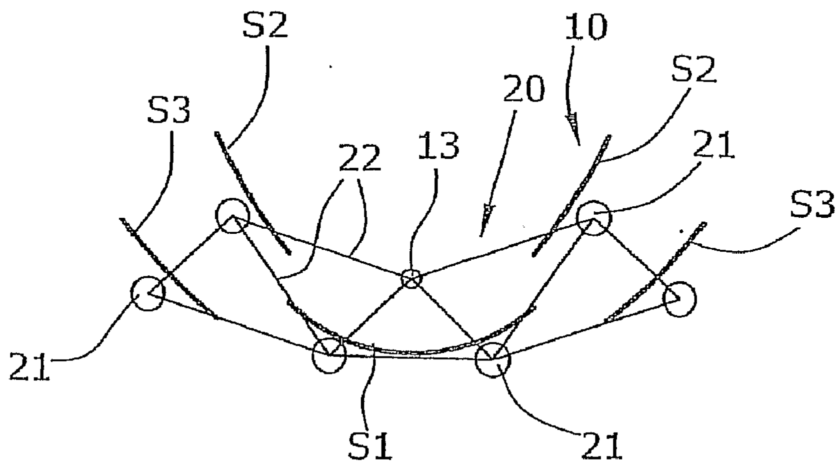

S2
10
S2
S3
20
22
13
21
S3
21
S1
21

Fig.2

FIXED FOCUS PARABOLIC TROUGH COLLECTOR

[0001] The invention relates to a fixed focus parabolic trough collector operative to collect solar radiation and provided for use in solar thermal power plants, said collector comprising an elongate mirror structure forming a focal line, and an absorber pipe extending along the focal line.

[0002] Solar thermal power plants are designed to utilize the energy of sunlight for generating electric current. By means of optical concentrators, the solar radiation will be focused onto an absorber having a heat carrier circulating in it. In solar thermal power plants, said optical concentrators represent the largest investment item and have a decisive influence on the efficiency of the plants. Various research projects are aimed at the development of new materials for the collectors. Important parameters for the energy yield and respectively for the efficiency are the shape and the construction of the collector, which have to meet high demands with regard to manufacturing tolerances and stability.

[0003] Already known are solar-thermal power plants with parabolic trough collector. A parabolic trough collector comprises an elongate mirror structure having a parabolic cross section. Typical aperture openings are dimensioned in the range of 5 m-7 m. Individual solar collector elements (SCE) having a length of about 12 m are assembled into units having a length of about 150 m and normally being oriented in north-south direction. Said units are coupled to a central drive unit. The center of gravity and, thus, the rotational axis of the mirror structure and respectively of the appertaining support structure are situated near the apex of the parabola, at a distance of about 1.80 m from the absorber pipe. Due to the tracking of the complete unit of mirror structure and absorber pipe, it is accomplished that no blocking or shading will occur and that the projected aperture opening will be nearly constant throughout the day. Thus, a high annual yield will be obtained. The concentration factor is about 50. Higher concentration factors will require larger aperture openings. This will entail stricter demands on the optical precision because, with increasing distance to the absorber pipe, possible mirror defects will have a stronger effect.

[0004] The wind load is the largest force among those forces acting on the collector which attain higher relevance along with an increase of the aperture and of the mirror surface. Therefore, larger-sized collectors will necessitate complex and heavy support structures. The absorber pipe, being moved along outside said rotational axis, will require flexible pipe connectors which must be designed to endure high temperatures and pressures. For this purpose, use is made of ball joints. Particularly in the case of direct evaporation, such joints are critical spots due to the high stresses involved.

[0005] A further known collector is that of the Fresnel type. A Fresnel collector is a line-concentrating system with fixed absorber pipe. Narrow rows of mirrors are individually rotated so as to focus the sunlight in the direction of the absorber pipe throughout the course of the day. The individual rows of mirrors can be produced from flat glass which can be bent to assume the required curvature. This construction is less vulnerable to wind. To keep the shading on the rows of mirrors at a minimum, the absorber pipe is installed at a height of about 8 m above the rows of mirrors. With growing distance between mirror and absorber, also the demands on the mirror accuracy and the tracking will increase. Due to blocking, shading and the relatively high cosine losses, the Fresnel collector will reach a lower annual wear in comparison to the parabolic trough collector.

[0006] It is an object of the invention to provide a parabolic trough collector which delivers a high annual yield, has a low sensitivity to wind and can be realized in a simple and inexpensive manner.

[0007] The fixed focus parabolic trough collector of the present invention is defined by claim **1**. It is characterized in that the mirror structure comprises a plurality of mirror segments and that at least two adjacent mirror segments form a gap through which radiation reflected by a third mirror segment or further mirror segments, will be incident on the absorber pipe. According to the invention, use is made of a plurality of mirror segments displaced relative to each other in the direction of the incident solar radiation (or in the opposite direction), with all of the mirror segments having the same focal point. The mirror segments are rigidly connected to each other and arranged to rotate together about the absorber pipe. As a result of the mutually displaced mirror segments, the fixed focus parabolic trough collector has a low collector depth. The collector surface is perforated, thus reducing the wind load acting on the collector. The length of the beam path of the reflected solar radiation is minimized. Thereby, and by the avoidance of shading, a high efficiency and a high power yield are obtained.

[0008] Preferably, the mirror segments are arranged symmetrically to a longitudinal central plane of the mirror structure, said longitudinal central plane including the absorber pipe (focal line) and the apex line of all parabola segments.

[0009] Preferably, the mirror segments are arranged to be free of overlap in the projection of radiation incident parallel to said longitudinal central plane. In this manner, shading effects on mirror areas are avoided. The mirror segments are preferably arranged in such a manner that radiation incident parallel to the longitudinal central plane cannot pass through the gap. This means that the mirror element which is situated at a forward position exactly covers the gap between two adjacent mirror segments. Thereby, it is achieved that no radiation incident in the area of the mirror elements will be lost.

[0010] According to a preferred embodiment of the invention, it is provided that two lateral mirror segments arranged symmetrically to the longitudinal central plane are situated forward in the direction of the incidence of radiation relative to a central mirror segment, and that two outer mirror segments are situated backward relative to said lateral mirror segments. Obtained thereby is a compact mirror structure of low depth.

[0011] It is of particular advantage if the mirror segments are fastened to a common support structure which is pivotable about the absorber pipe. In such an arrangement, the supporting structure and the mirror segments are situated to the effect that their common center of gravity coincides with the focal point of the mirror structure. Thereby, the axis of rotation and the absorber pipe are coaxial with each other. The need for complex flexible pipe connectors is obviated, and the absorber pipes can be fastened to each other via the shortest possible path.

[0012] The fixed focus parabolic trough collector can be divided along its length into individual modules, which are driven individually. This eliminates the need for a heavy torque box which would have to transmit the moment of rotation along the whole collector length. Further, it is not necessary that the terrain along the whole collector length is plane. Since the collector is freely rotatable about the absorber pipe, the structure can be brought into a safe stow position wherein the mirror surface is facing toward the ground.

[0013] An embodiment of the invention will be explained in greater detail hereunder with reference to the drawings.

[0014] In the drawings, the following is shown:

[0015] FIG. **1** is a schematic view of a mirror structure comprising a plurality of mirror segments, with plotted lines representing incident and reflected light beams, and

[0016] FIG. **2** is a view of the mirror structure according to FIG. **1** in connection with a load-bearing support structure, wherein the main axis of inertia coincides with the absorber pipe.

[0017] FIG. **1** illustrates a possible arrangement of a plurality of mirror segments in a fixed focus parabolic trough collector. In this arrangement, mirror segments which correspond to parabolic segments with different focal lengths, are arranged around a common focal point in a manner allowing the reflected rays to reach the absorber pipe unhindered.

[0018] The mirror structure, generally designated by **10**, comprises a plurality of parabolically curved mirror segments. In the present embodiment, a central mirror segment S**1** is provided which is flanked by two lateral mirror segments S**2**. On each outer side, an outer mirror segment S**3** is arranged.

[0019] Said mirror structure **10** will be adjusted to track the position of the sun so that the longitudinal central plane **11** of the mirror structure will be oriented to extend parallel to the direction **12** of the incident solar radiation. Arranged in the focus of mirror structure **10** is the absorber pipe **13** which is operative to receive the sunlight on its surface and to heat the heat carrier circulating in the absorber pipe. Mirror structure **10** and absorber pipe **13** form an elongate collector, herein referred to as a fixed focus parabolic trough collector, although said mirror segments S**1**, S**2**, S**3** do not form a closed parabolic trough. The central radiation area R**1** is assigned to the central mirror segment S**1**, the lateral radiation areas R**2** are assigned to the lateral mirror segments S**2**, and the outer radiation areas R**3** are assigned to the outer mirror segments S**3**. Between the mirror segment S**1** and each of the two adjacent mirror segments S**2**, a gap **14** exists, extending parallel to the longitudinal central plane **11**. Via this gap **14**, the radiation reflected from outer mirror segment S**3** will be incident on absorber pipe **13**. All mirror segments are focused on absorber pipe **13**. By the staggered arrangement of the mirror segments, with the lateral mirror segments S**2** situated forward relative to the central mirror segment S**1** and with the outer mirror segments S**3** situated backward, the length of the reflected rays is minimized. Thereby, the optical efficiency will be less affected by possible mirror defects, which in turn makes it easier to enlarge the aperture and reduces the demands on the optical quality, especially that of the central mirror segment S**1**.

[0020] FIG. **2** illustrates the arrangement of the mirror segments S**1**,S**2**,S**3** on a common support structure **20**. One possible realization of the support structure resides in a framework structure comprising longitudinal support bars **21**, herein formed as tubes, and transverse beams **22**. Said support structure **20** together with mirror structure **10** has a main axis of inertia which coincides with absorber pipe **13**. Preferably, said main axis of inertia is coaxial with the absorber pipe. Slight deviations up to five times the diameter of the absorber pipe are allowable. Since the center of gravity of the parabolic trough collector is in the close vicinity of the axis of rotation, the weight of the support structure is reduced. The connection of the absorber pipes to each other is realized by struts which also include the required bearings and the drive unit. In the central area of the collector, possibly required stiffening elements can be provided. The invention offers the advantage of a subdivision of the mirror surface into mutually offset mirror segments so that the path length of the reflected radiation will be minimized. Further, the wind load is reduced. The main axis of inertia and the focal line coincide with each other, with resultant reduction of constructional complexity. For each of the collector elements arranged in line behind each other, a respective individual decentralized drive can be provided in the form of a stepped motor. Also a common drive in the form of a central hydraulic unit is possible. The decentralized drive does however offer the advantage that, by rotating individual SCEs, the captured light quantity can be adapted to the energy generation process in a flexible manner.

1. A fixed focus parabolic trough collector comprising an elongated mirror structure forming a focal line, and comprising an absorber pipe extending along the focal line,

wherein the mirror structure further comprises a plurality of mirror segments, whereby at least two adjacent mirror segments form a gap through which radiation reflected by a mirror segment is incident onto the absorber pipe.

2. The fixed focus parabolic trough collector of claim **1**, wherein the mirror segments are arranged symmetrically to a longitudinal central plane including the absorber pipe.

3. The fixed focus parabolic trough collector of claim **2**, wherein the mirror segments are arranged free of overlap in the projection of radiation which is incident parallel to the longitudinal central plane.

4. The fixed focus parabolic trough collector of claim **1**, wherein two lateral mirror segments, arranged symmetrically to the longitudinal central plane, are situated forward in the direction of the incidence of radiation relative to a central mirror segment, and that two outer mirror segments are situated backward relative to said lateral minor segments.

5. The fixed focus parabolic trough collector of claim **1**, wherein each of the minor segments is pivotable about the absorber pipe as an axis of rotation.

6. The fixed focus parabolic trough collector of claim **1**, wherein the mirror segments are fastened to a common support structure which is pivotable about the absorber pipe.

7. The fixed focus parabolic trough collector of claim **6**, wherein the support structure has a main axis of inertia which substantially coincides with the absorber pipe.

8. The fixed focus parabolic trough collector of claim **1**, wherein the length of the parabolic trough collector is divided into a plurality of solar collector elements and that each of said elements is driven individually.

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