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(54) **SOLAR HEATER AND METHOD**

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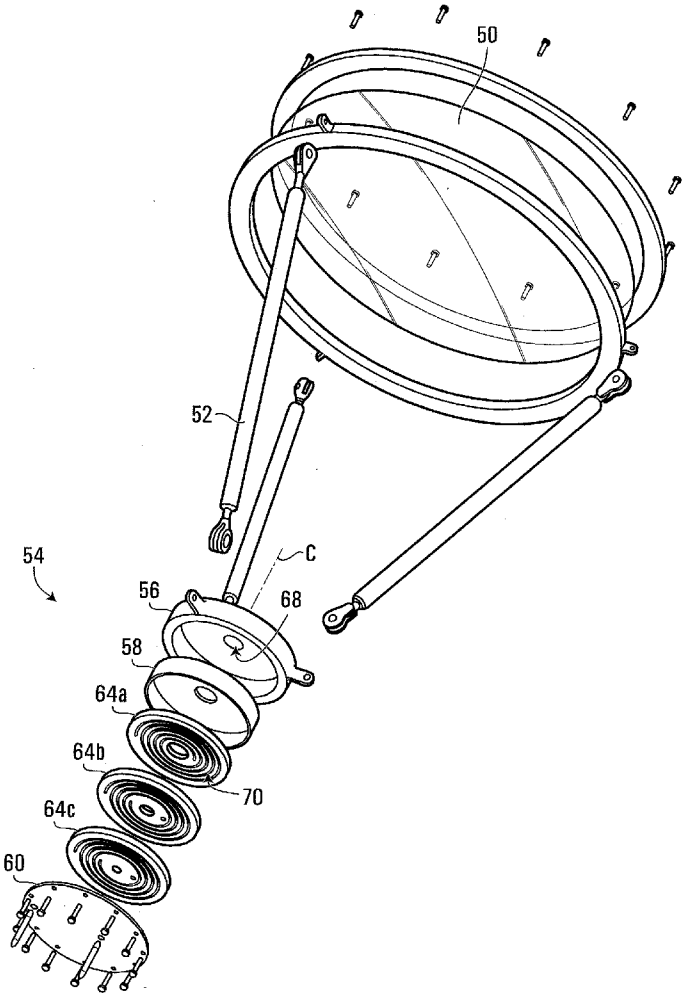
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USPC **126/601**; 126/699; 126/674

(57) **ABSTRACT**

A solar heater has a light collector which collects light incident on the light collector into a beam that extends along a beam axis. A plurality of thermally conductive plates is arranged along the beam axis, each of the plates having an aperture on the beam axis. For each plate, the aperture of the plate is smaller than apertures of all plates disposed between each plate and the light collector along said beam axis. A fluid pathway is associated with one or more of the plates for transferring heat to a fluid in the fluid pathway. In a related method of heating a fluid, light rays are collected into a beam and passed through progressively smaller apertures in a plurality of serially arranged plates such that a portion of the beam is incident on each one of said plates. The fluid is thermally contacted with the plates.



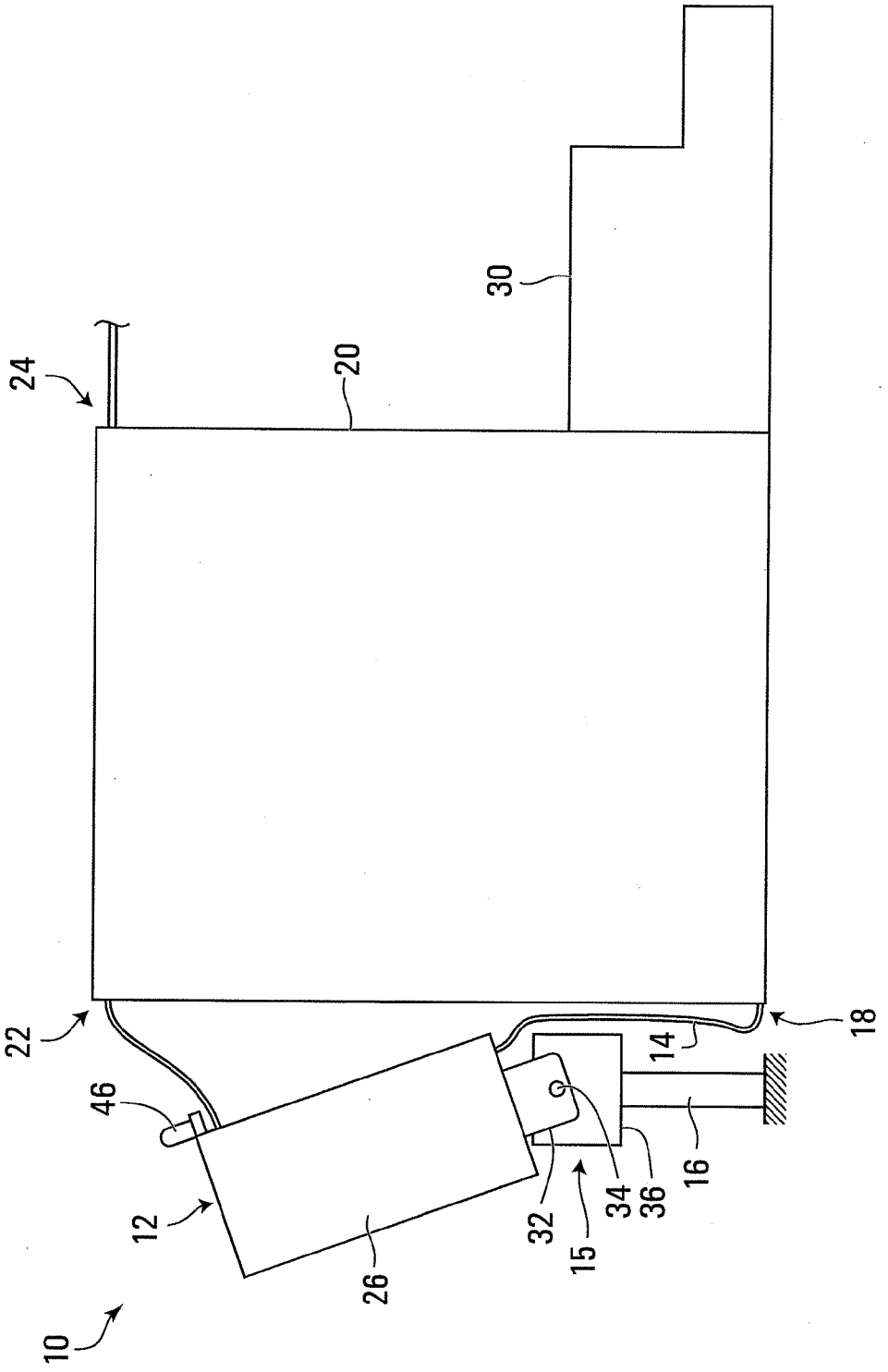


FIG. 1

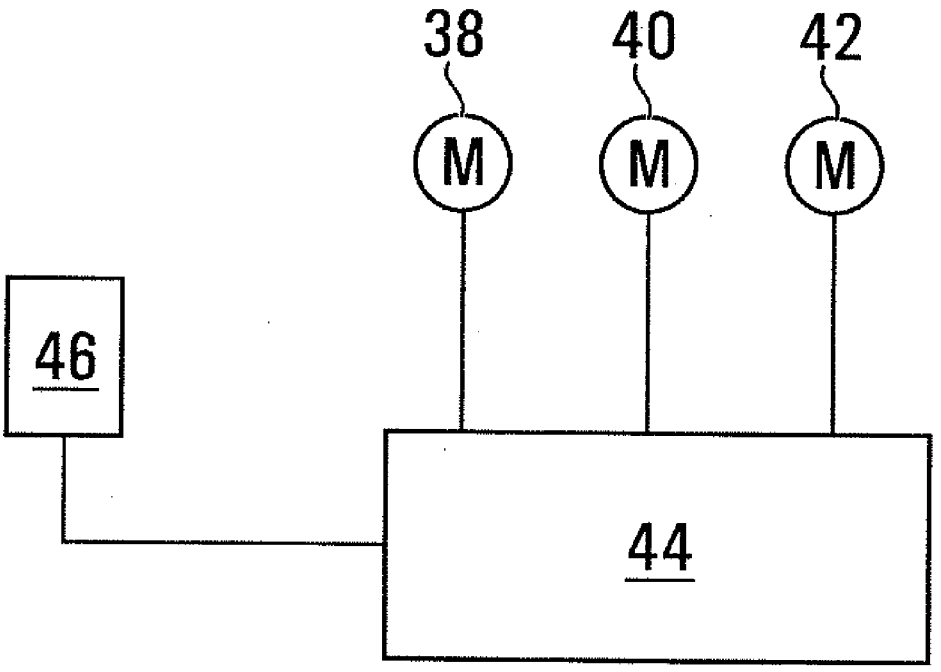


FIG. 2

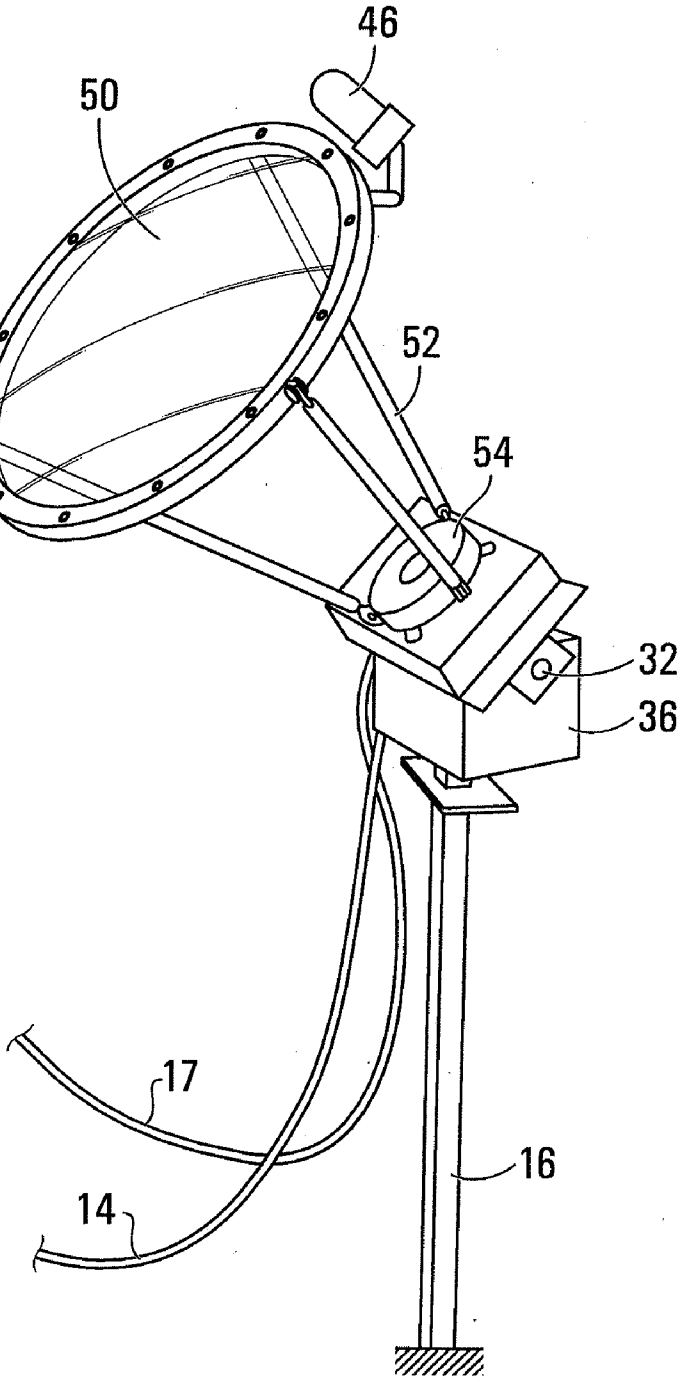


FIG. 3

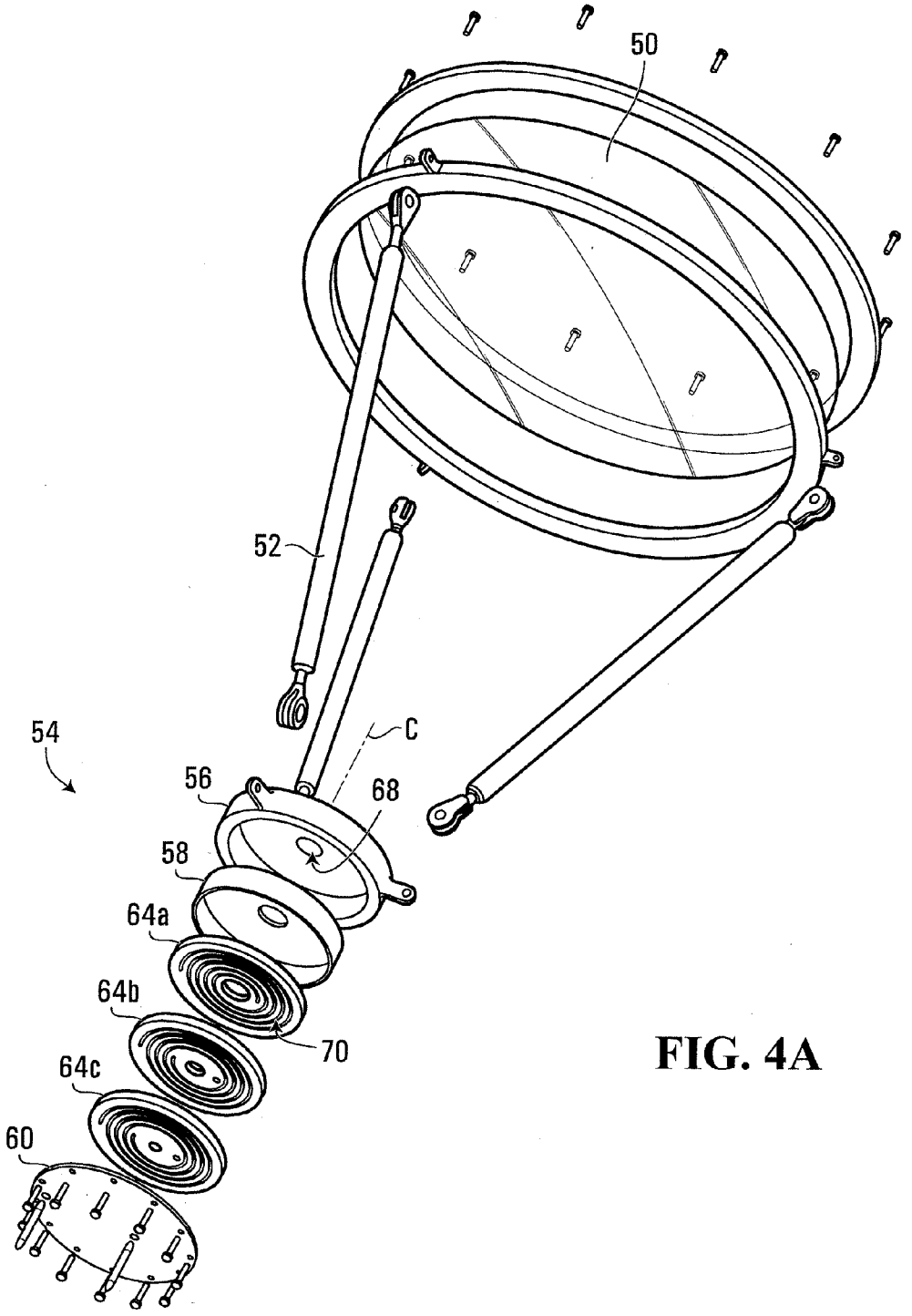


FIG. 4A

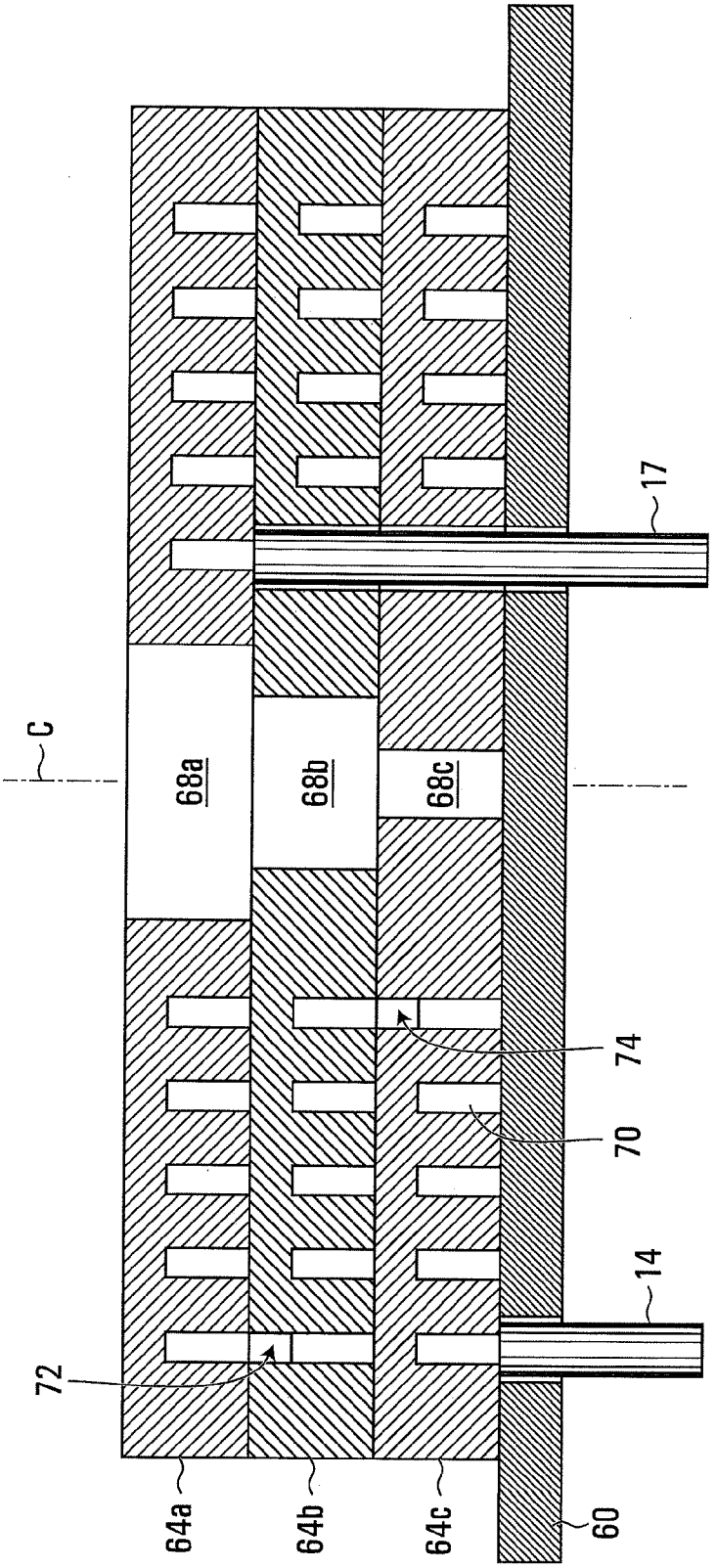


FIG. 4B

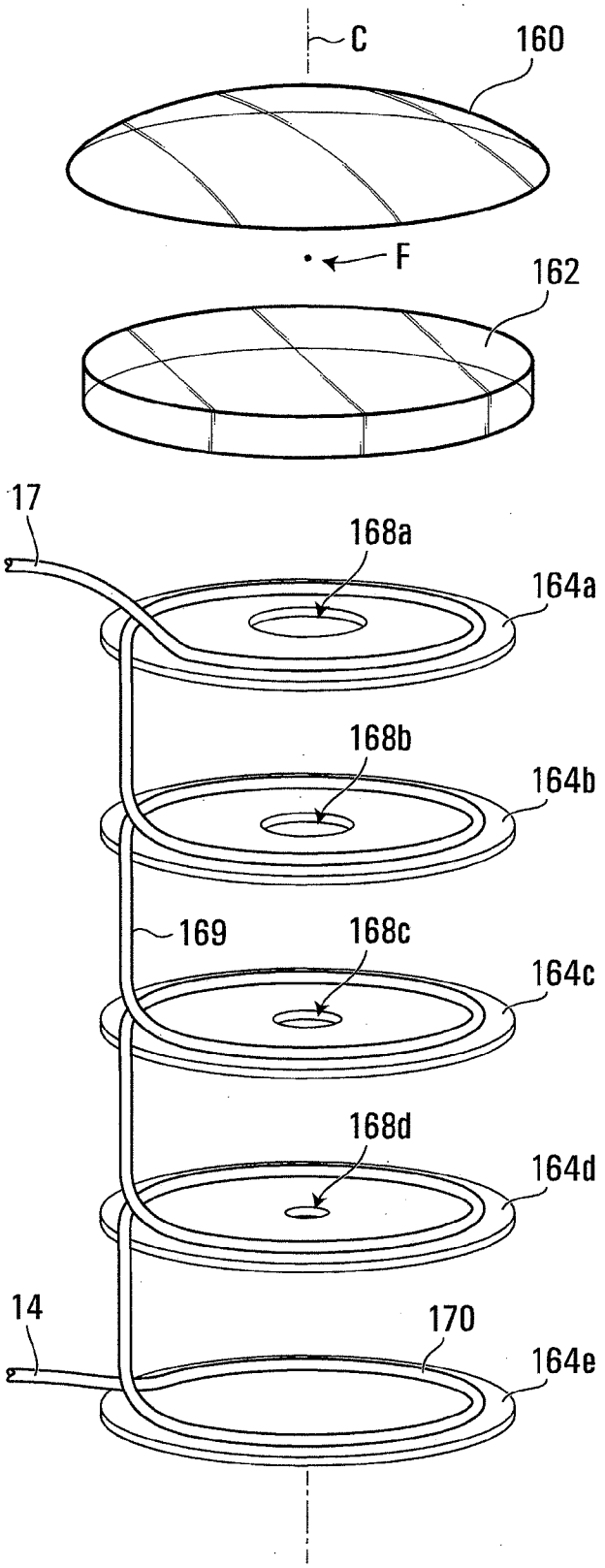

C
160
112
F
162
17
168a
164a
168b
154
164b
169
168c
164c
168d
164d
14
170
164e

FIG. 5

SOLAR HEATER AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority under 35 USC 119 (e) from provisional application No. 61/537,728.

BACKGROUND

[0002] The present invention relates to solar heaters and to methods of solar heating.

[0003] Given the environmental concerns arising from the use of fossil fuels and the environmental risks associated with the production of nuclear energy, there is an increasing interest in the use of "green" technologies for energy production. One green technology which has been subject of significant development is that of harnessing solar energy. There is therefore a continued need for improved approaches to harness solar energy.

SUMMARY

[0004] A solar heater and a solar heating method utilize a plurality of plates with apertures that decrease in size in a direction of propagation of a light beam.

[0005] According to an aspect, a solar heater has a light collector which collects light incident on the light collector into a beam that extends along a beam axis. A plurality of thermally conductive plates is arranged along the beam axis, each of the plates having an aperture on the beam axis. For each plate, the aperture of the plate is smaller than apertures of all plates disposed between each plate and the light collector along said beam axis. A fluid pathway is associated with one or more of the plates for transferring heat to a fluid in the fluid pathway.

[0006] According to another aspect, in a method of heating a fluid, light rays are collected into a beam and passed through progressively smaller apertures in a plurality of serially arranged plates such that a portion of the beam is incident on each one of said plates. The fluid is thermally contacted with the plates.

[0007] Other features and aspects of the invention will become apparent from the following description in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the figures which illustrate, by way of example only, embodiments of the present disclosure:

[0009] FIG. **1** is a schematic view of a solar heating system made in accordance with an embodiment;

[0010] FIG. **2** is a schematic view of a portion of the system of FIG. **1**;

[0011] FIG. **3** a perspective view of a portion of the solar heating system of FIG. **1**;

[0012] FIG. **4**A is an exploded view of a portion of FIG. **2**;

[0013] FIG. **4**B is a schematic cross-sectional view of a portion of FIG. **2**; and

[0014] FIG. **5** is an exploded view of a portion of a solar heating system made in accordance with another embodiment.

DETAILED DESCRIPTION

[0015] With reference to FIG. **1**, an example solar heating system **10** for heating a working fluid has a solar heater **12** mounted through a positioning system **15** to support arm **16**. A fluid conduit **14** which is connected to a cold fluid outlet **18** of a storage tank **20**, runs to the solar heater **12**, and a second fluid conduit **17** exits the heater and terminates at a hot fluid inlet **22** of storage tank **20**. A back-up system **30** to solar heating system **10** is in heat exchange relationship with storage tank **20**. A hot fluid outlet **24** of tank **20** may connect to an external system (not shown), such as a domestic heating system. The storage tank holds a working fluid, such as water. Back-up system **30** could include a back-up boiler and a back-up burner, such as a conventional oil or gas fired or electric burner.

[0016] A clevis **32** extending from the solar heater **12** is pivotably mounted at pivot **34** to base **36**. The base **36** is in turn mounted to support arm **16** through a first pivot (not shown) so as to rotate about the longitudinal axis of the support arm and a second pivot (not shown) so as to tilt in a direction which is both perpendicular to the support axis and perpendicular to the axis of the pivot **34**. Turning to FIG. **2**, servo motor **38** of positioning system **15** acts to tilt the solar heater about pivot **34**; servo motor **40** acts to tilt the solar heater about a pivot which is both perpendicular to the support axis and perpendicular to the axis of the pivot **34**; and servo motor **42** acts to pivot the solar heater about the longitudinal axis of the support arm **16**. The servo motors input computer-controller **44**; the controller **44** also receives an input signal from solar intensity sensor **46**.

[0017] The controller **44** operates to control the servo motors of positioning system **15** so as to orient solar heater **12** to follow the path of the sun. Thus, controller **44** and positioning system **15** act as a solar tracking system. Since solar tracking systems are conventional, the solar tracking system is believed to be within the skill of one skilled in the art and is not further described. Optionally, a photovoltaic panel (not shown) may be used to provide power to the controller and the servo motors.

[0018] As seen in FIG. **1**, solar heater has a housing **26**. FIG. **3** illustrates the solar heater **12** without this housing. With reference to FIG. **3**, solar heater **12** includes a light collector in the nature of a focusing lens **50** supported by arms **52** at a stand-off from a heat exchanger **54**. When facing the sun, the lens **50** directs light along a beam axis coincident with a central axis C and focuses this light at a focal point at heat exchanger **54**. With reference to FIG. **4**A, the heat exchanger **54** has upper housing cups **56** and **58** and lower housing disc **60** encasing a stack of plates **64***a*, **64***b*, and **64***c* (collectively, plates **64**) extending transversely of, and aligned along, central axis C. The upper housing cups **56**, **58** and each plate **64** has a central aperture, collectively, apertures **68**, centered on central axis C. The plates **64** are made of a thermally conductive material, such as metal, as, for example, aluminum.

[0019] The central aperture in each of the upper housing cups **56**, **58** is larger than the aperture in top plate **64***a*. As is most easily seen in FIG. **4**B, each apertured plate **64** has a different sized aperture and the plates are arranged so that the apertures progressively decrease in size in a direction away from lens **50**. Thus, plate **64***a*, which is closest to lens **50**, has the largest aperture **68***a;* plate **64***b* next closest to lens **50** has the second largest aperture **68***b*, and plate **64***c* the smallest aperture **68***c*.

[0020] The underside of each plate **64** is etched to form a spiral pathway **70**; when the plates **64** are sandwiched together as shown in FIG. **4**B, the underside of each spiral

pathway is closed off. An opening **72** through the top of middle plate **64***b* communicates the outer end of the spiral pathway of the top plate with the outer end of the spiral pathway of the middle plate. An opening **74** through the top of the lower plate **64***c* communications the inner end of the spiral pathway of the middle plate **64***b* with the inner end of the spiral pathway of the lower plate **64***c*. Aligned openings in housing disc **60** and plates **64***b*, **64***c* receive the end of conduit **17** which terminates at the inner end of the spiral pathway of the top plate **64***a*. A further opening in the housing disc **60** receives conduit **14** which terminates at the outer end of the spiral pathway of the bottom plate **64***c*.

[0021] It will be apparent from FIG. **4**B that the stack of plates **64** extends a relatively short distance along the central axis C. Consequently, the lens **50** can have a focal plane somewhere within the heat exchanger and the light with be substantially in focus at each plate of the stack of plates. The characteristics of the lens are chosen such that sunlight focused by the lens **50** has, at each plate **64***a*, **64***b*, **64***c*, a beamwidth greater than the diameter of the aperture **68***a*, **68***b*, **68***c* through the plate.

[0022] In use, solar heater **12** is located in an area where it is exposed to sunlight. Controller **44** may then control servo motors **38**, **40**, and **42** in order to adjust the orientation of solar heater **12** through the day so that the lens **50** constantly faces the sun.

[0023] Since the apertures **68** of each successive plate **64** in a downstream direction decrease in size, for any given apertured plate downstream of plate **64***a*, a peripheral portion of the part of the beam that passes through the aperture of the plate immediately upstream of the given plate will be incident on the given plate **64** while a central portion of the beam will pass through the aperture of this given plate. The portion of the beam passing through aperture **68***c* of the last apertured plate **64***c* is incident upon solid plate **60**. Thus, it will be apparent that a portion of the light from the beam is incident on each one of plates **64**.

[0024] The portion of the beam striking a plate **64** transfers energy to the plate, and therefore heats the plate. While the beam strikes only the more central region of a plate, since the plates are made of a thermally conductive material, this heat will diffuse across the plate.

[0025] As plates **64** are heated, working fluid within the spiral pathway **70** of each plate is heated. This reduces the density of the working fluid and will result in a convective flow through the conduit **14** from cold fluid outlet **18** of tank **20** to the hot fluid inlet **22** of the tank, given a judicious choice for the height of the cold fluid outlet **18** relative to the plates **64**. Flow may be more readily assured if, as shown, the conduit **14** is connected so that fluid flowing from the cold fluid outlet **18** flows first through the spiral path **70** of the bottom plate **64***c*. Alternatively, and especially if the conduit is connected so that fluid flowing from the cold fluid outlet **18** flows first through the spiral pathway **70** of the top plate **64***c*, a pump (not shown) may be placed in fluid conduit **14** to pump fluid through the conduit **14** to hot fluid inlet **22**.

[0026] The temperature at which working fluid is discharged from fluid conduit **14** depends on the quantity of solar energy collected by solar heater **12**, the efficiency of heat transfer to the working fluid, and the flow rate of the working fluid, among other factors. The quantity of solar energy collected by solar heater **12** is directly proportional to the area of lens **50** and the intensity of the incident solar radiation.

[0027] Heated working fluid in tank **20** may be drawn off for use at the tank's hot fluid outlet **24**.

[0028] In some circumstances, it may be desirable to supplement the supply of heated working fluid from the solar heater **12**. For example, on a cloudy day, solar heater **12** may not heat the working fluid to the desired temperature. If this occurs, additional heating may be provided by back-up system **30**. Back-up system **30** may be operated in parallel with solar heater **12**, supplementing its output. The back-up system may also be operated when solar heater **12** inactive, such as at night.

[0029] The heated fluid produced by solar heating system **10** can be used for a variety of purposes. For example, heated fluid may be circulated through pipes and radiators in a building to provide heating for the building. Also, if the working fluid is water, solar heating system **10** may be used to provide a supply of warm or hot water for domestic use.

[0030] Optionally, lens **50** could be replaced with a different light collector, such as a reflector.

[0031] In another embodiment, with reference to FIG. **4**, the solar heater **112** includes a collector **160**, a collimator **162**, and a heat exchanger **154** with a stack of plates **164***a*, **164***b*, **164***c*, **164***d*, and **164***e* (collectively, plates **164**) extending transversely of, and aligned along, a central axis C. Each plate, except plate **164***e*, has a central aperture **168***a*, **168***b*, **168***c*, and **168***d* (collectively, apertures **168**) centered on central axis C. In the example embodiment, collector **160** and collimator **162** are lenses positioned so that the collector lens has a focal point, F, located between the collector lens and the collimator lens and so that focal point F is also a focal point of the collimator lens. The heating power of solar heater **112** is proportional to the amount of solar radiation incident on collector **160**, i.e., to the area of collector **160**. Accordingly, collector **160** may be as large as available space permits.

[0032] Each apertured plate **164** has a different sized aperture and the plates are arranged so that the apertures progressively decrease in size in a direction away from collimator **162**. Thus, plate **164***a*, which is closest to collimator **162**, has the largest aperture; plate **164***b* next closest to collimator **162** has the second largest aperture, plate **164***c* the next largest aperture, and plate **164***d* the smallest aperture.

[0033] Fluid conduit **14** terminates at a coil **169** with a looped portion **170** lying on each plate **164**; each looped portion may be soldered, or otherwise affixed, to the underlying plate. The coil, or at least each looped portion **170** of the coil, is formed of a thermally conductive material so as to permit heat transfer from the plates **164**.

[0034] In use, collector lens **160** concentrates light by focusing it at focal point F and the light then diverges from this point and is collimated by the collimator lens. Collimator **162** collimates light into a beam having a beam axis coincident with central axis C. Collimator **162** is configured so that this beam has a diameter greater than that of the aperture **168***a* in the topmost plate **164***a*, such that a peripheral portion of the beam is incident on plate **164***a* while the central portion of the beam passes through aperture **168***a*.

[0035] Since the aperture **168** of each successive plate in a downstream direction decreases in size, for any given apertured plate downstream of plate **164***a*, a peripheral portion of the part of the beam that passes through the aperture of the plate immediately upstream of the given plate will be incident on the given plate **164** while a central portion of the beam will pass through the aperture of this given plate. The portion of the beam passing through aperture **168***d* of the last apertured

plate **164***d* is incident upon solid plate **164***e*. Thus, it will be apparent that a portion of the light from the beam is incident on each one of plates **164**.

[0036] The portion of the beam striking a plate **164** transfers energy to the plate, and therefore heats the plate. While the beam strikes only the more central region of a plate, since the plates are made of a thermally conductive material, this heat will diffuse across the plate and heat the working fluid in the loops **170** of coil **169**.

[0037] In an alternate embodiment, the collecting lens could be replaced with a parabolic reflector disposed below a stack of plates and reflecting light back up through a lens-type collimator and through the stack of plates. With such an embodiment, the plate with the largest aperture would be at the bottom of the stack. In a further alternate embodiment, collimator **162** could be a reflector.

[0038] While in the illustrated embodiment the loops **170** of the coil lie on each plate, they could obviously instead be associated with the underside of each plate. While the loops **170** are depicted near the periphery of each plate, they could instead be located near the center of each plate, where the plate temperature is highest. In another embodiment, there could be multiple loops **170** on each plate.

[0039] For a given collector size, the quantity of solar energy transferred to a particular plate **164** is proportional to the size of the annular portion of the plate which is exposed to the beam. The relative sizes of successive apertures **168** can therefore be adjusted to control the peak temperature of each plate during operation in order to maximize the heat transfer to working fluid in the conduit **14**.

[0040] While in the illustrated example embodiment of FIGS. **1** to **4** there are three plates and in the illustrated embodiment of FIG. **5** there are five plates, obviously a different number of plates may be used. Where, for example, the FIG. **5** embodiment were modified so that there are eleven plates, the plate closest to the collimator could have an aperture with a diameter of 1.1" and each successive plate could have an aperture 0.1" smaller such that the tenth plate has an aperture with a diameter of 0.2". As with the embodiment of FIG. **5**, the eleventh plate could be a solid plate (lacking an aperture).

[0041] While the apertures of the illustrated embodiments are circular, they could also have other shapes. Further, the apertures of the plates do not need to have identical shapes provided they are progressively smaller so as to permit a portion of the beam to strike each plate.

[0042] While the illustrated embodiment shows a single tank, optionally, there could be a cold fluid reservoir and a separate hot fluid reservoir. Moreover, if the working fluid is water, the cold fluid reservoir may be a naturally occurring reservoir such as a lake or other body of water. As a further option, there may be no hot fluid reservoir and instead heated fluid may simply be discharged to where it is to be used.

[0043] The solar tracking system of the example embodiment may be replaced with any suitable solar tracking system, Indeed, while not as efficient, for some applications, solar heater may be used without a solar tracking system.

[0044] An advantage of the present solar heating system is its compact horizontal extent, allowing the solar heater **12** or **112** to be placed in a number of constrained spaces.

[0045] Other modifications will be apparent to those skilled in the art; therefore, the invention is defined in the claims.

What is claimed is:

1. A solar heater comprising:

a light collector which collects light incident on said light collector into a beam that extends along a beam axis;

a plurality of thermally conductive plates arranged along said beam axis, each of said plates having an aperture on said beam axis, for each plate, said aperture of said each plate being smaller than apertures of all plates disposed between said each plate and said light collector along said beam axis;

a fluid pathway associated with one or more of said plates for transferring heat to a fluid in said fluid pathway.

2. The solar heater of claim **1**, wherein each of said plates extend transversely of said beam axis.

3. The solar heater of claim **2**, further comprising a tracking system for orienting at least said collector relative to the position of the sun in the sky.

4. The solar heater of claim **3**, wherein said tracking system comprises a computer-controller.

5. The solar heater of claim **1** further comprising an additional plate arranged along said beam axis adjacent a one of said plurality of plates having a smallest aperture of said apertures, said additional plate being a solid plate.

7. The solar heater of claim **1** wherein said fluid pathway is a spiral pathway formed in at least one of said plurality of plates.

8. The solar heater of claim **7** wherein one said spiral pathway is formed on an underside of each of said plurality of plates.

9. The solar heater of claim **8** further comprising an opening from one end of said spiral pathway of one plate to one end of said spiral pathway of an adjacent plate.

10. The solar heater of claim **1** wherein said fluid pathway is a looped conduit lying on at least one of said plurality of plates.

11. The solar heater of claim **1** wherein said plates are metal.

12. A method of heating a fluid, said method comprising:

collecting light rays into a beam;

passing said beam through progressively smaller apertures in a plurality of serially arranged plates such that a portion of said beam is incident on each one of said plates;

thermally contacting said fluid with said plates.

13. The method of claim **12** wherein said apertures progressively decrease in size in the direction of propagation of said beam.

14. The method of claim **13**, wherein said thermally contacting comprises providing a spiral pathway on each of said plates.

* * * * *