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(54) **METHODS AND SYSTEMS FOR TEMPERATURE REGULATION OF ROOF MOUNTED AND SOLAR TRACKER MOUNTED PHOTOVOLTAIC MODULES**

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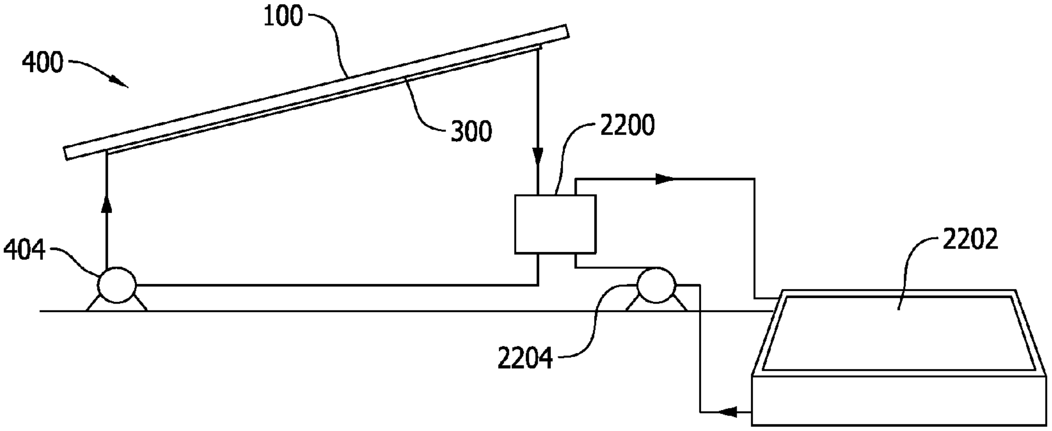
USPC **136/248**; 52/173.3; 165/47

(57) **ABSTRACT**

One example solar energy system includes a solar tracker, a plurality of photovoltaic modules mounted to the solar tracker, and a temperature regulation system. The PV modules are configured to generate an electrical power output from solar energy incident on the PV modules. The temperature regulation system includes a thermal transfer fluid, a fluid pump operable to pump the thermal transfer fluid, and a plurality of fluid heat exchangers in thermal communication with the plurality of PV modules and in fluid communication with the fluid pump. The fluid heat exchangers are configured to transfer heat from the PV modules to the thermal transfer fluid.



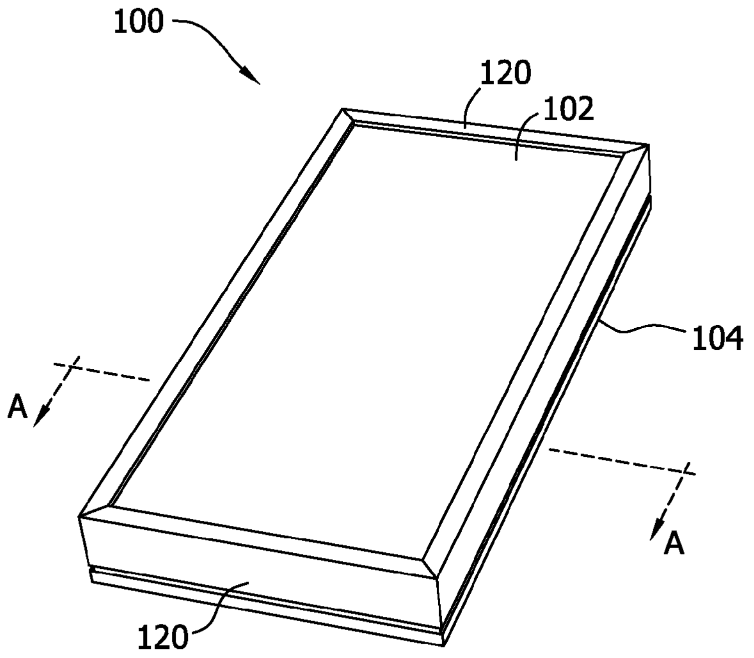

100
120
102
104
A
A
120

FIG. 1

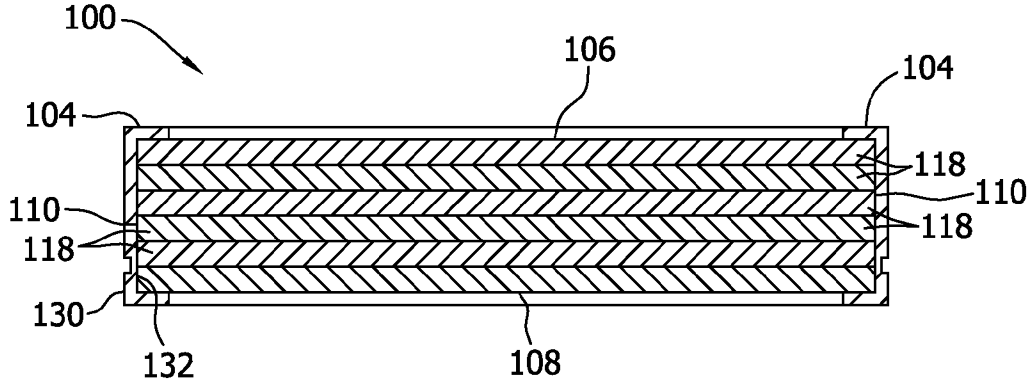

100
106
104
104
118
110
110
118
118
118
130
132
108

FIG. 2

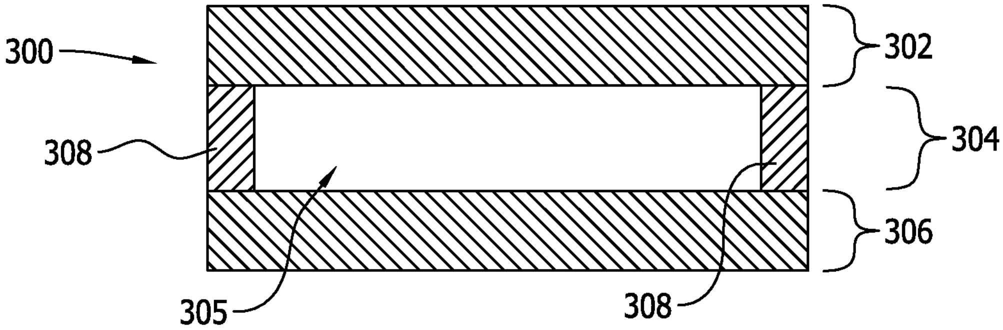


FIG. 3

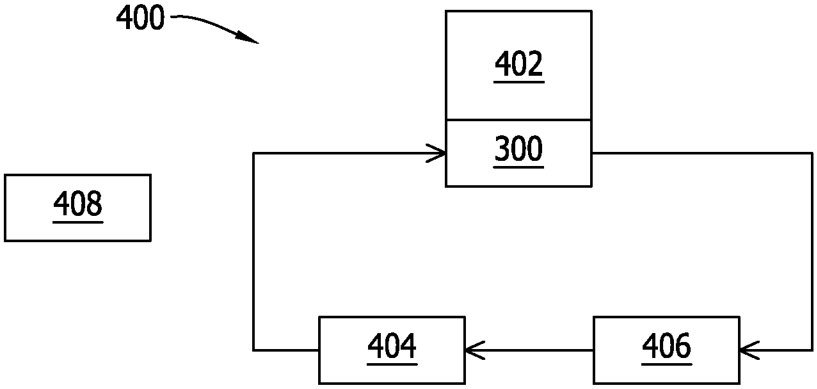


FIG. 4

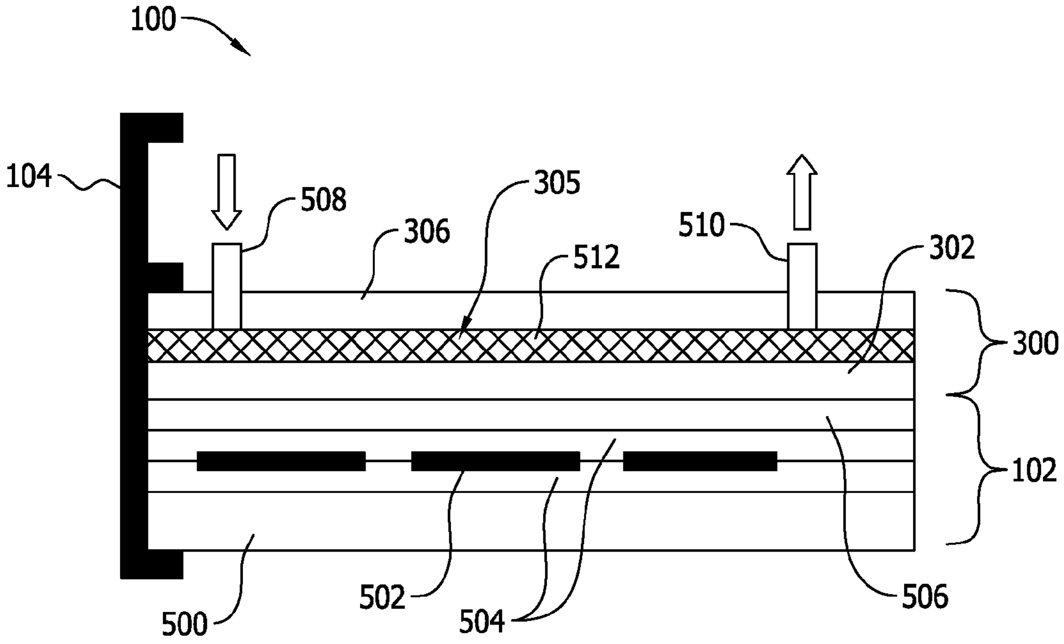


FIG. 5

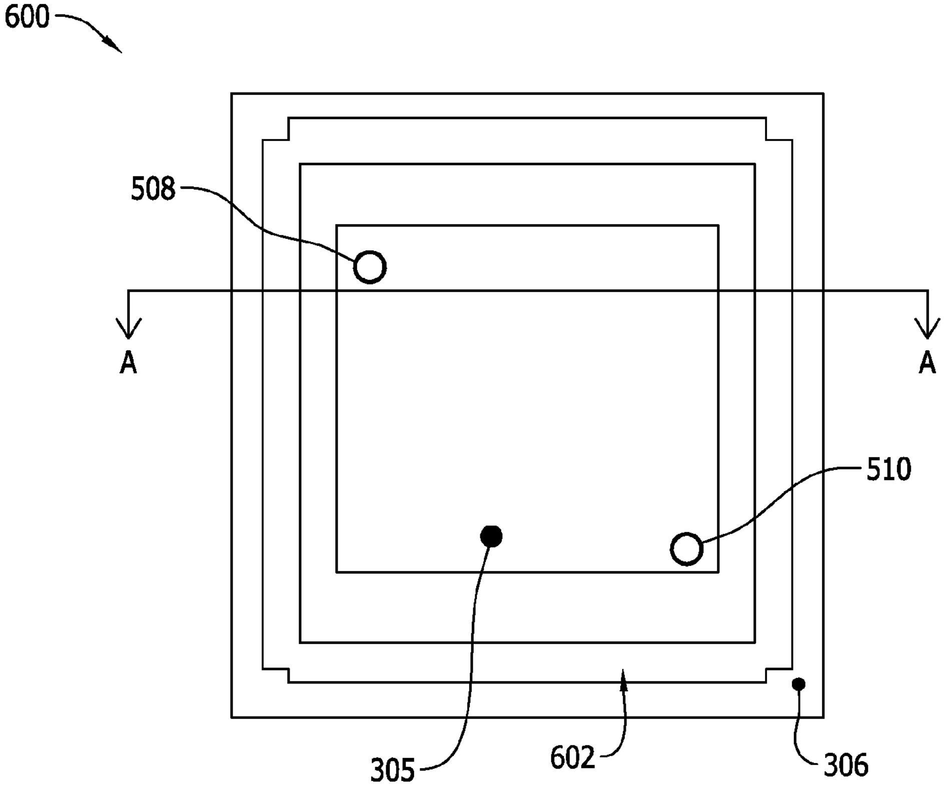


FIG. 6

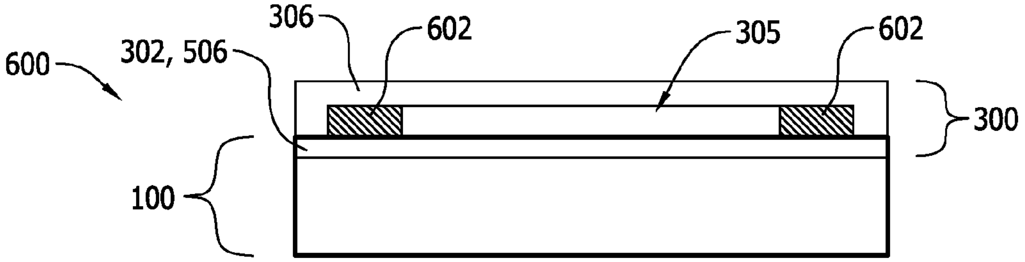


FIG. 7

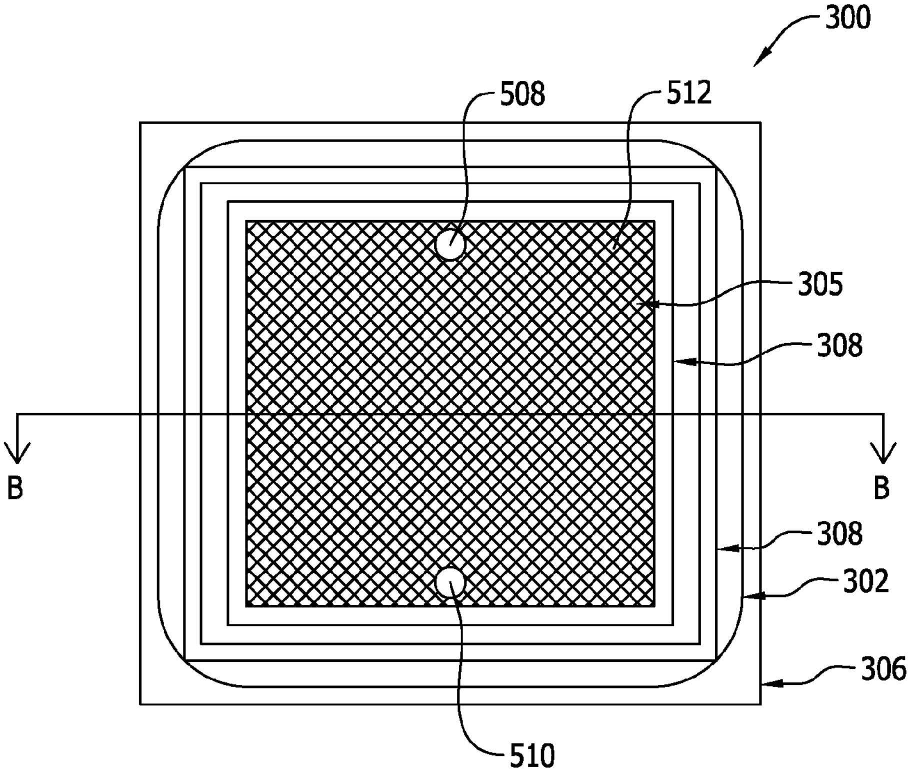

300
508
512
305
308
B
B
308
302
306
510

FIG. 8

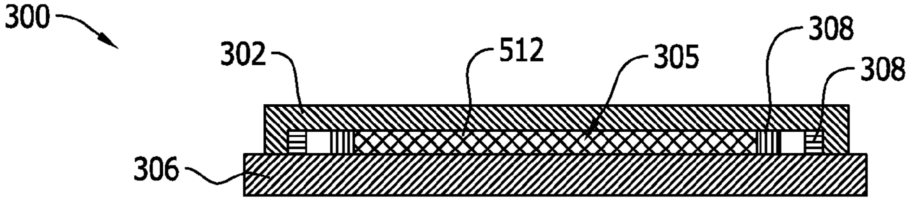

300
302
512
305
308
308
306

FIG. 9

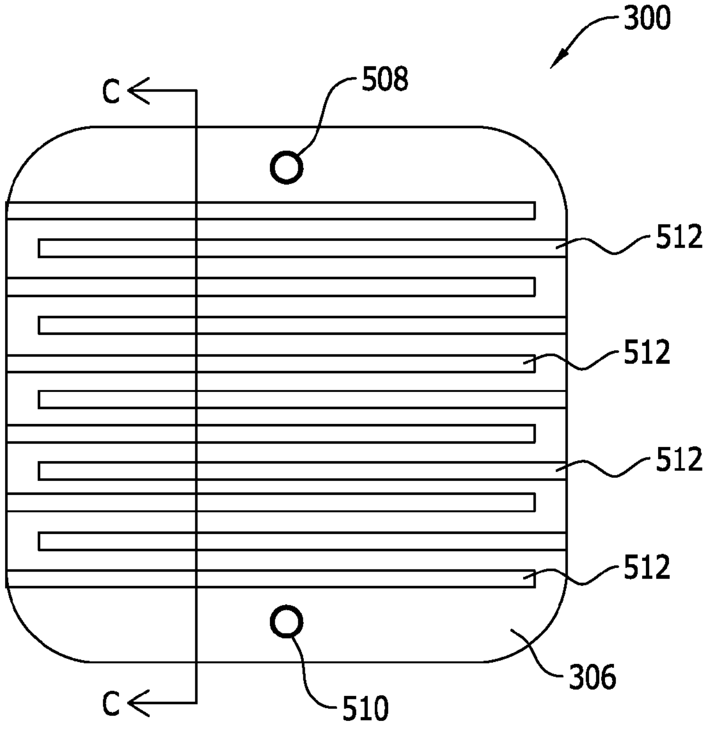


FIG. 10

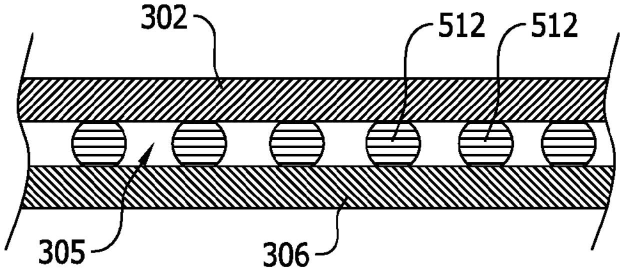


FIG. 11

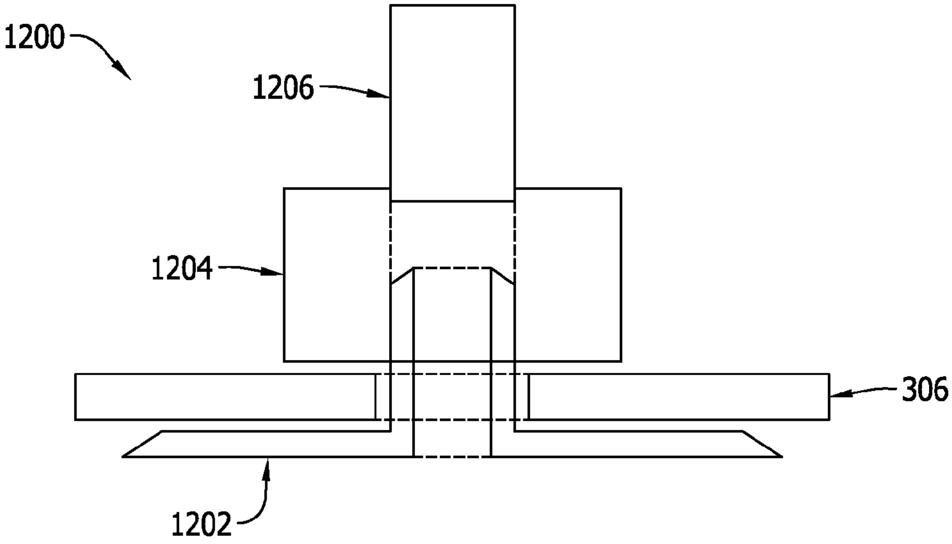


FIG. 12

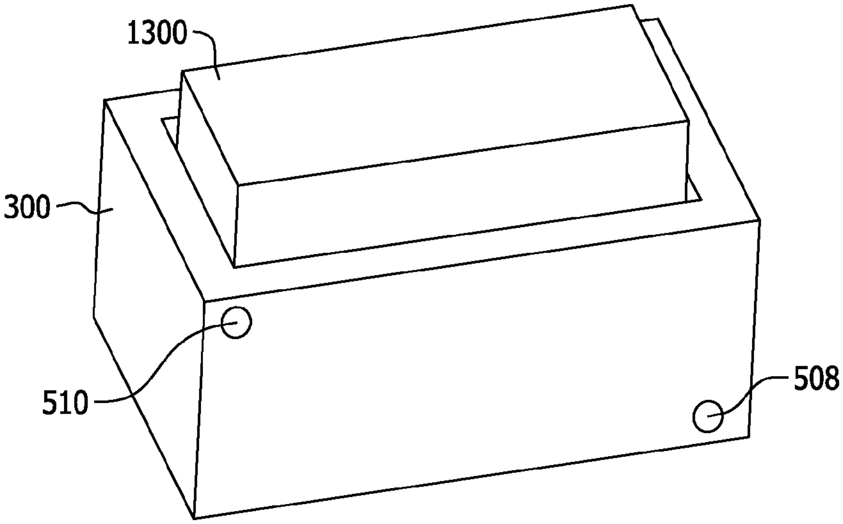


FIG. 13

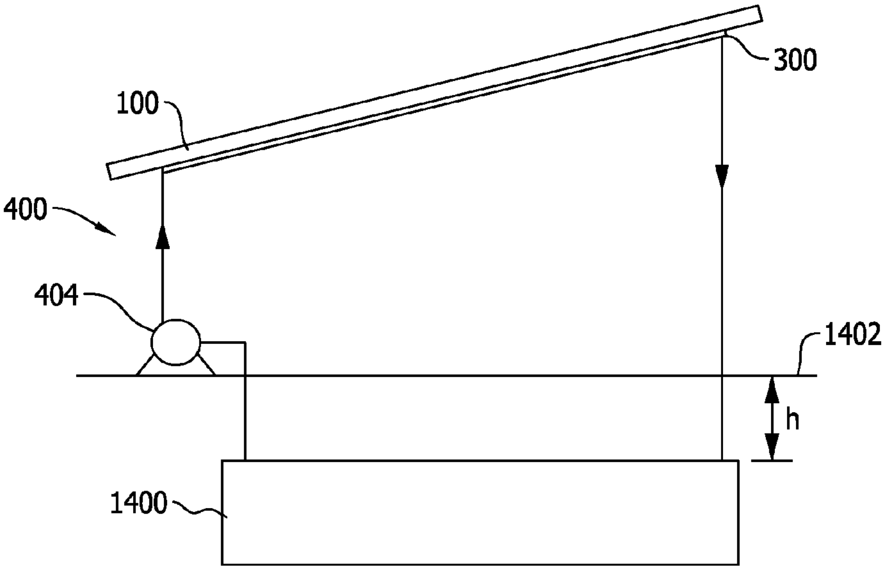


FIG. 14

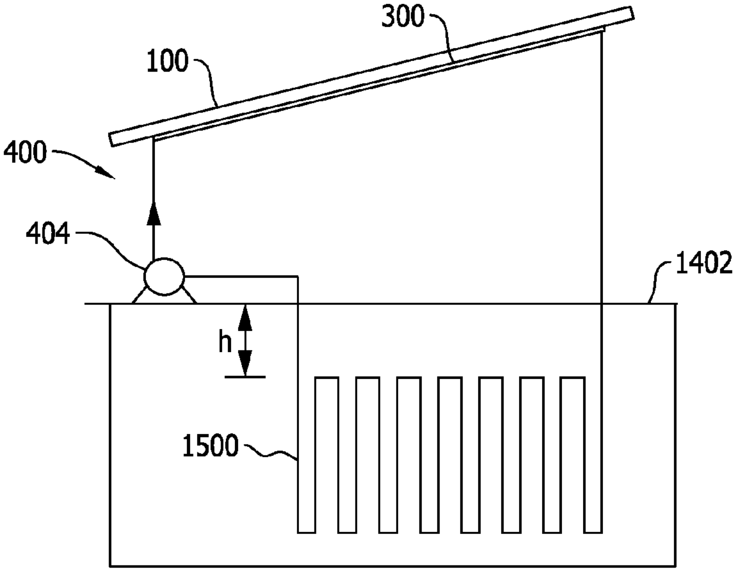


FIG. 15

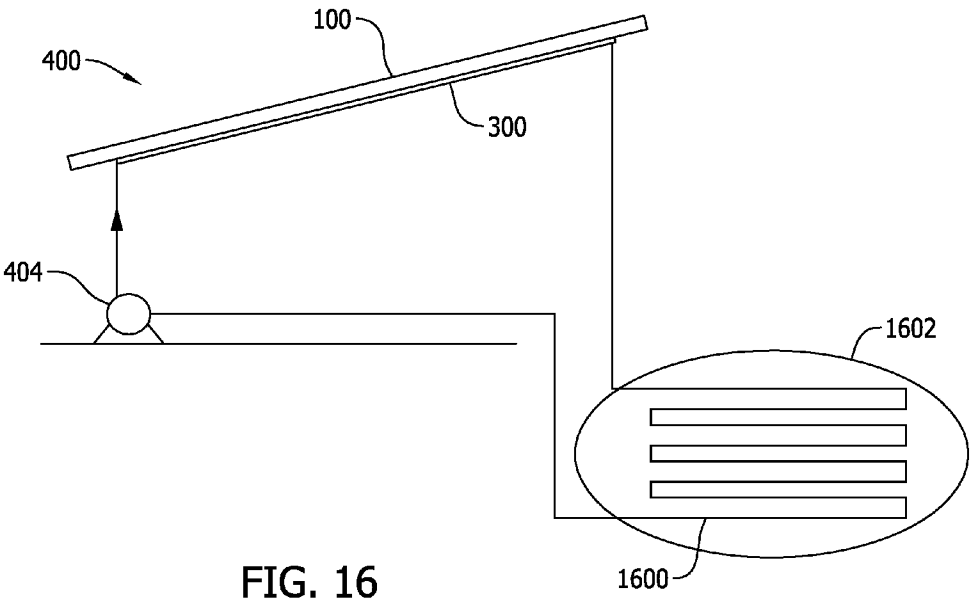


FIG. 16

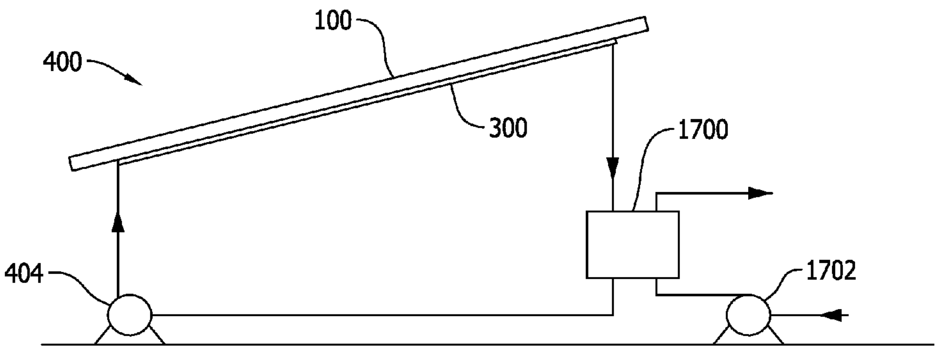


FIG. 17

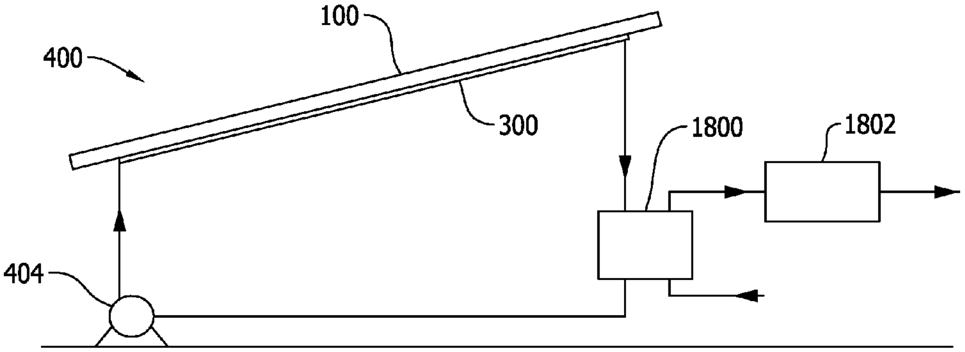


FIG. 18

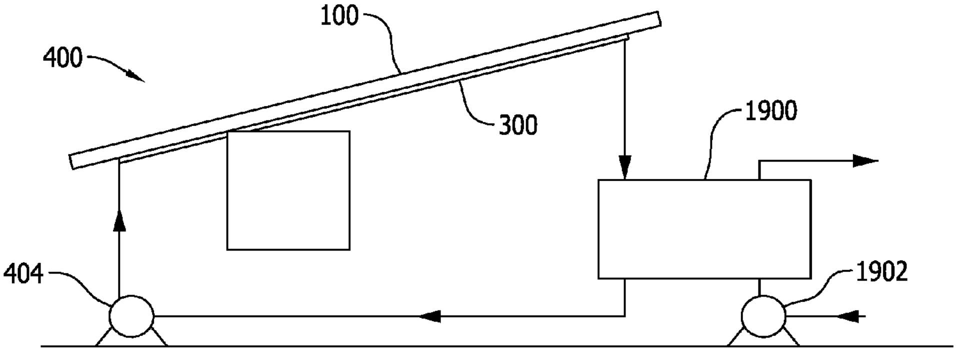


FIG. 19

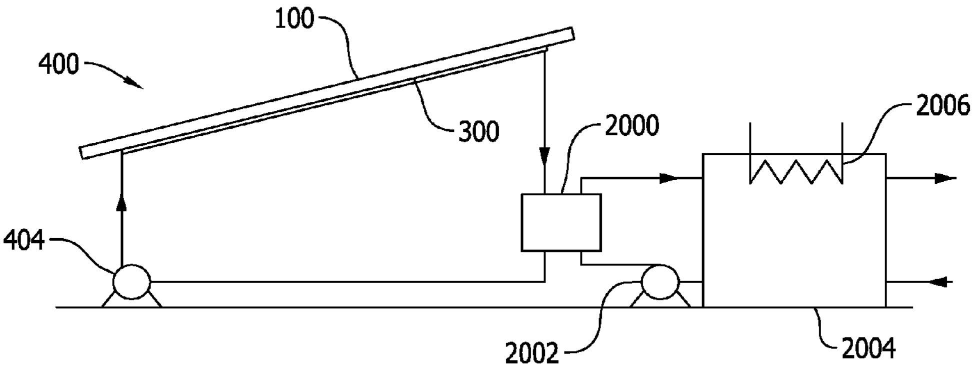


FIG. 20

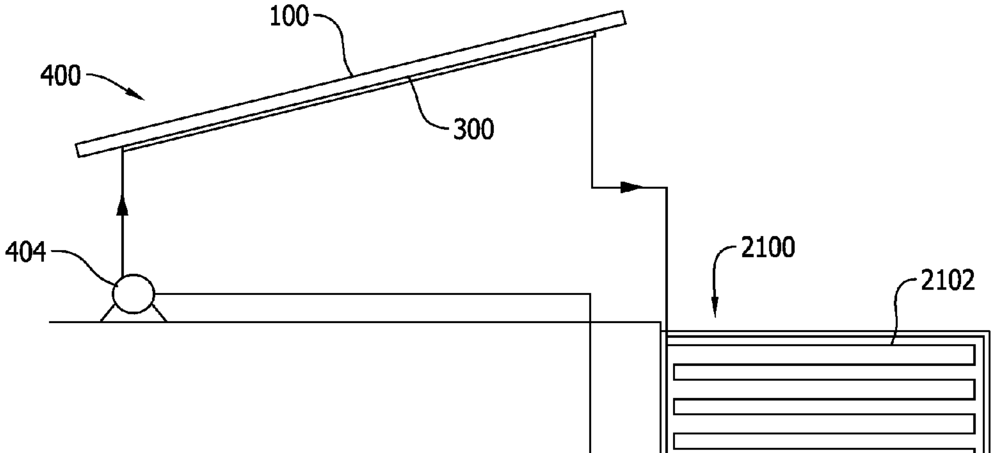


FIG. 21

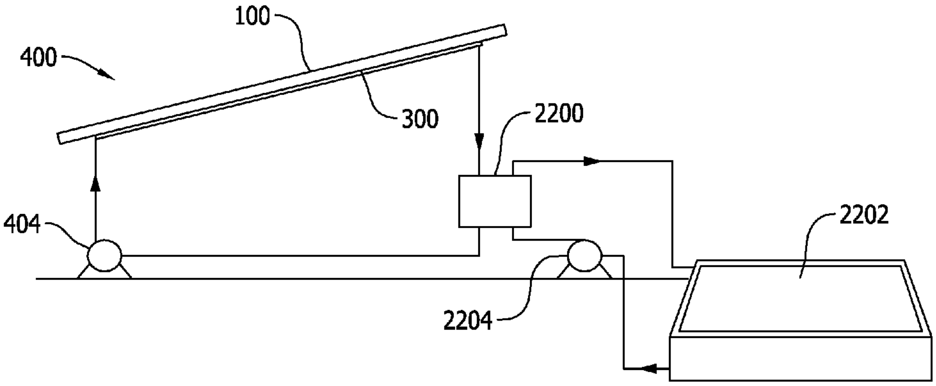


FIG. 22

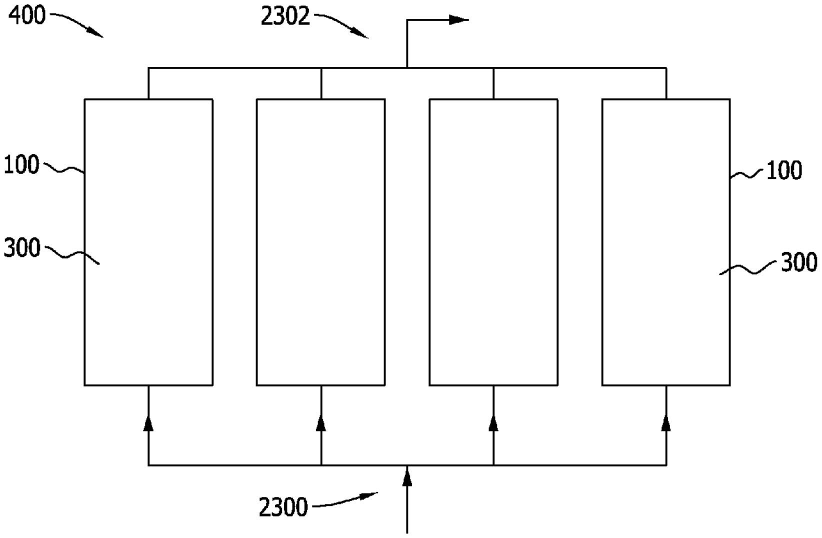


FIG. 23

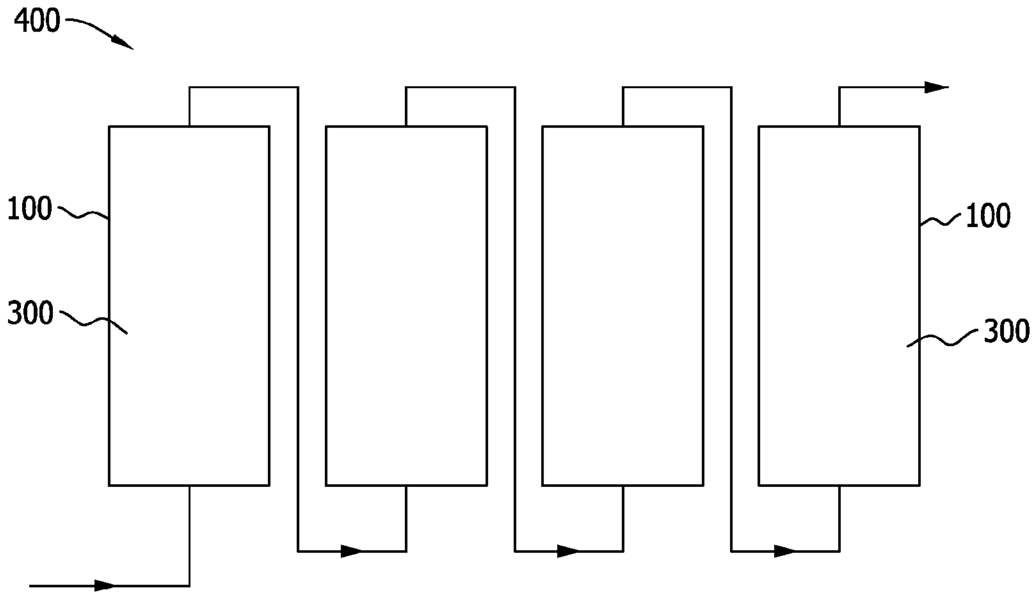


FIG. 24

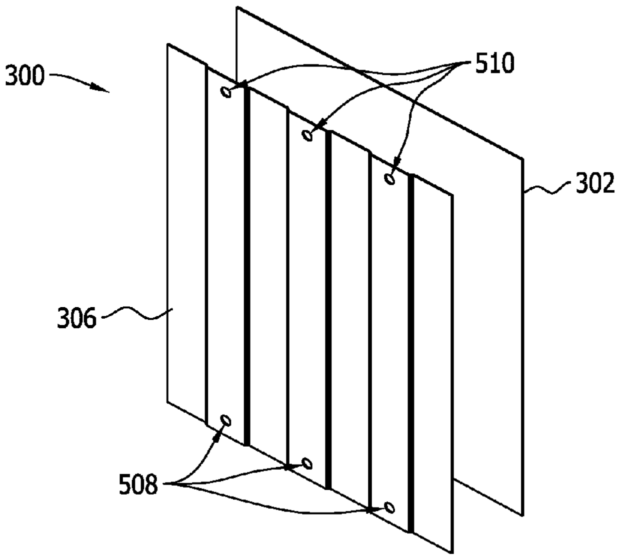


FIG. 25

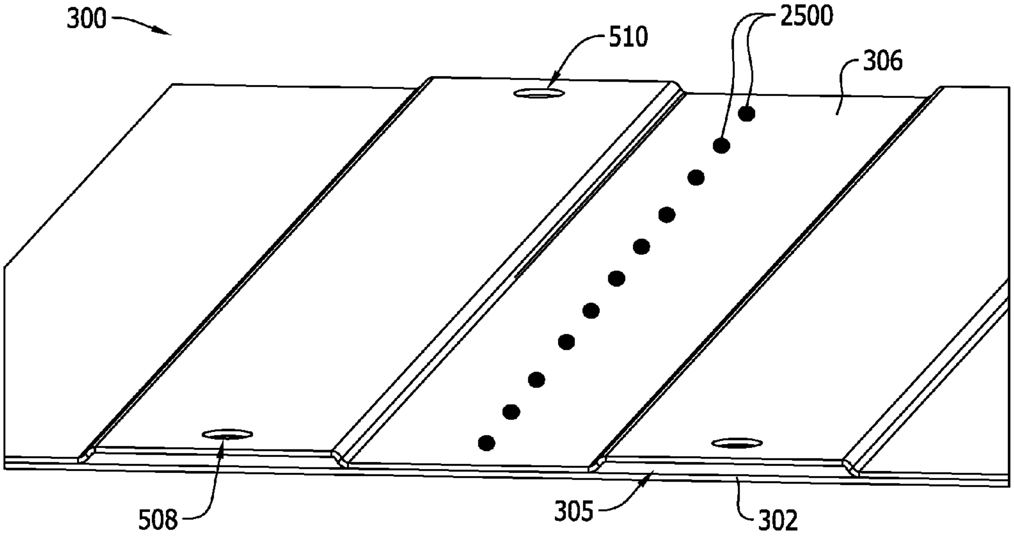


FIG. 26

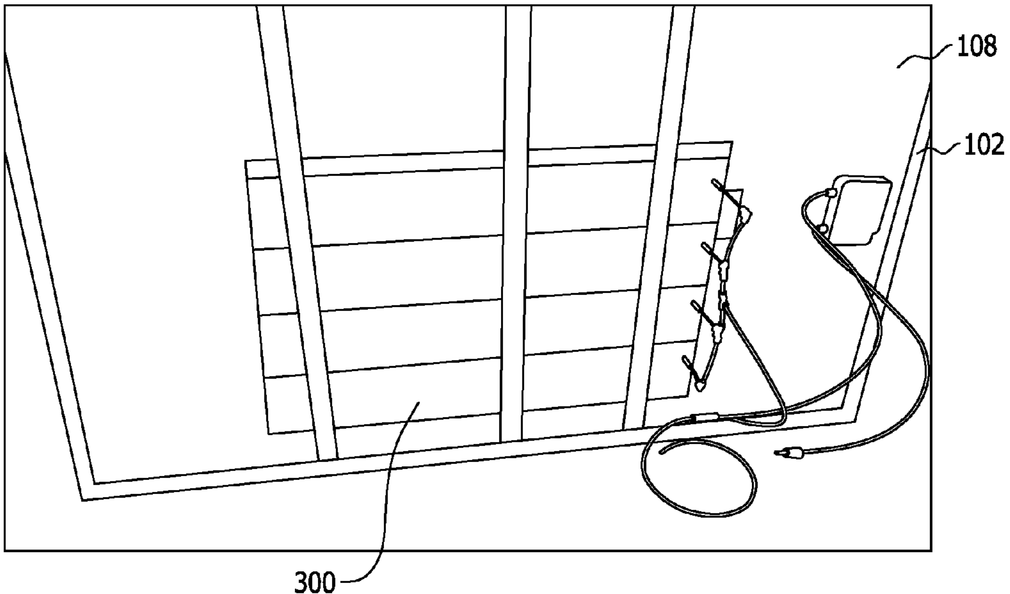

108
102
300

FIG. 27

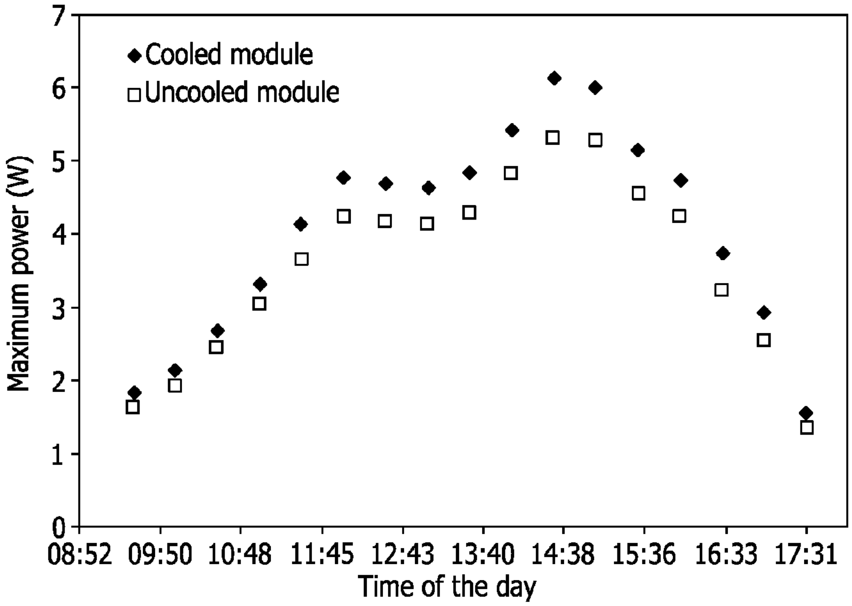

◆Cooled module
□Uncooled module
Maximum power (W)
0
1
2
3
4
5
6
7
08:52
09:50
10:48
11:45
12:43
13:40
14:38
15:36
16:33
17:31
Time of the day

FIG. 28

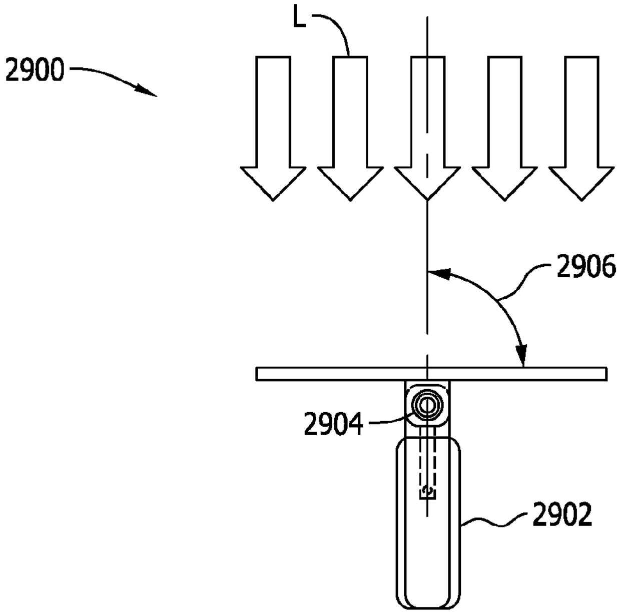


FIG. 29

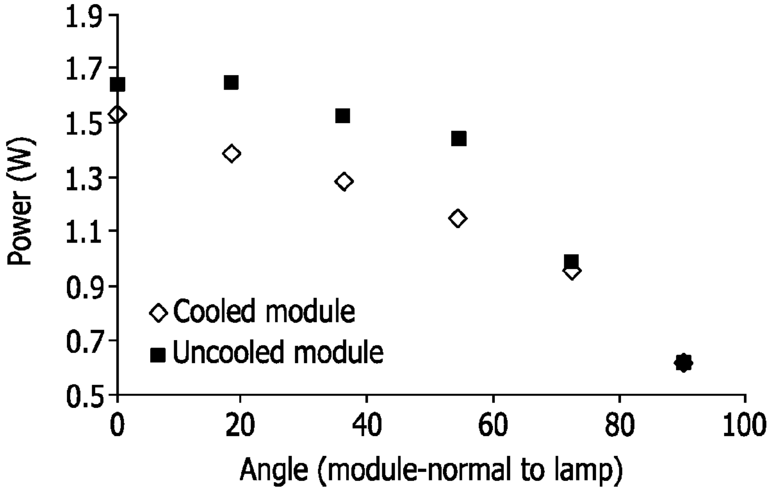


FIG. 30A

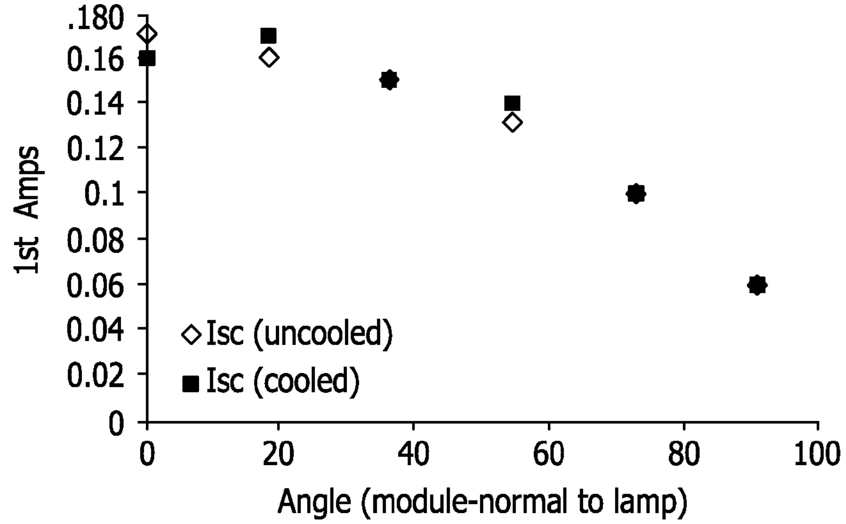


FIG. 30B

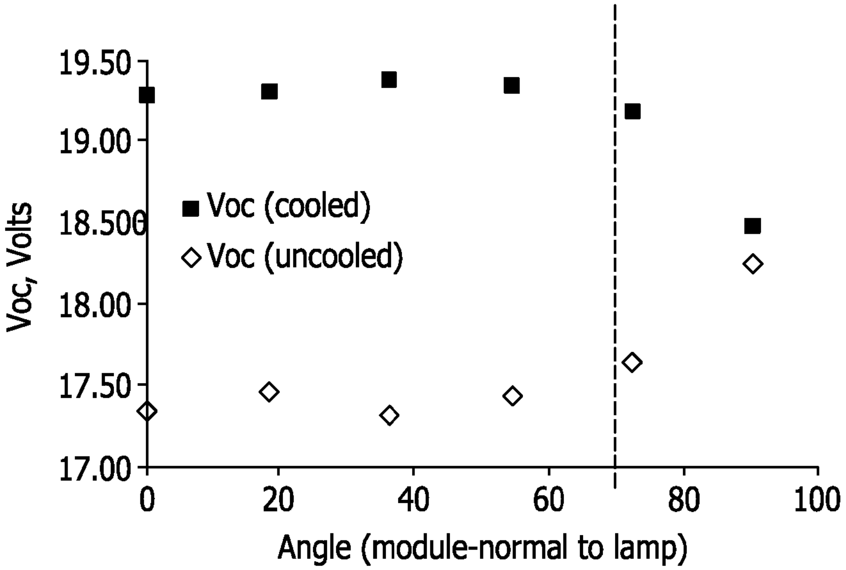


FIG. 30C

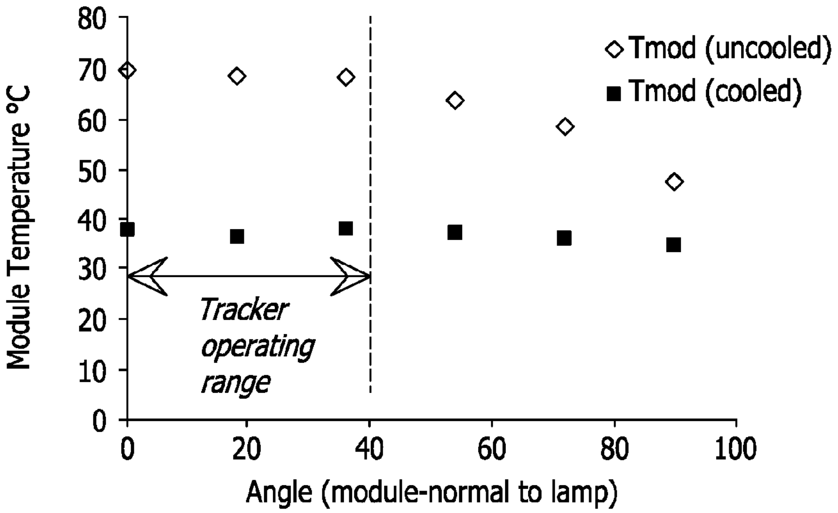


FIG. 30D

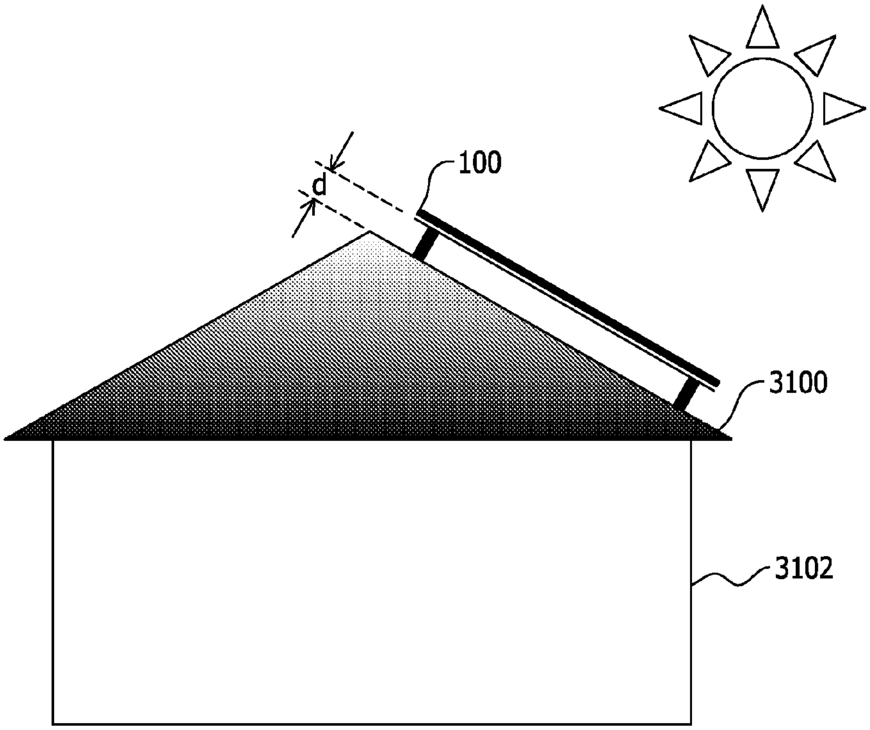


FIG. 31

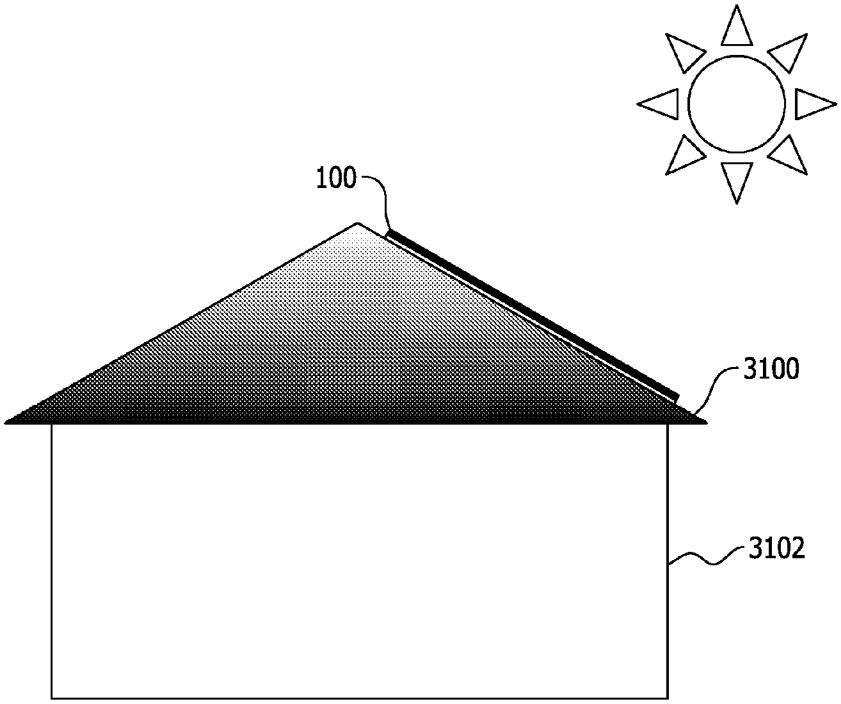


FIG. 32

		Measured temperature [°C]		
Height [mm]	Module cooling	Roof under module	Module	Open roof
0	No	45.9	62	58
0	Yes	41.8	40	59
10	No	41.5	58	58
10	Yes	40.1	38	57
20	No	39.8	52.3	58
20	Yes	37.2	35.4	57

FIG. 33

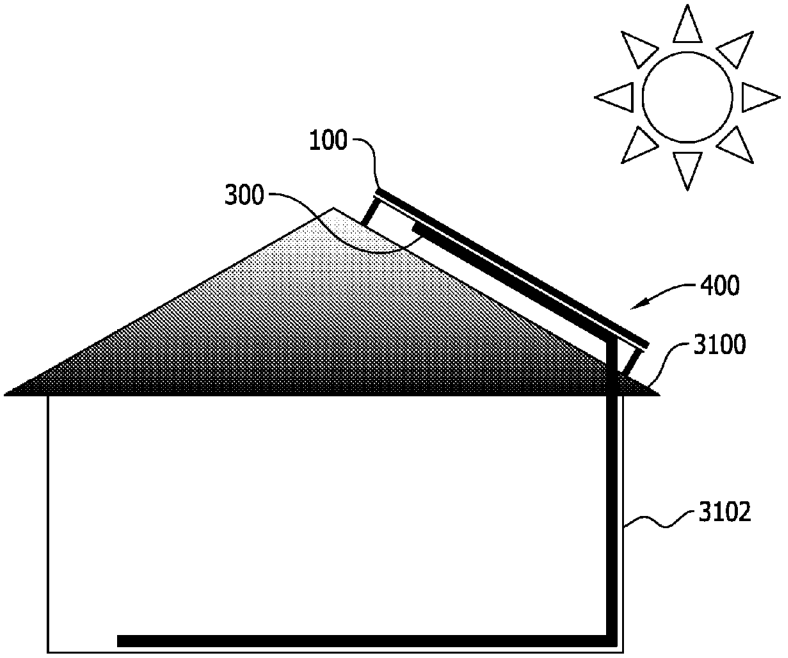

100
300
400
3100
3102

FIG. 34

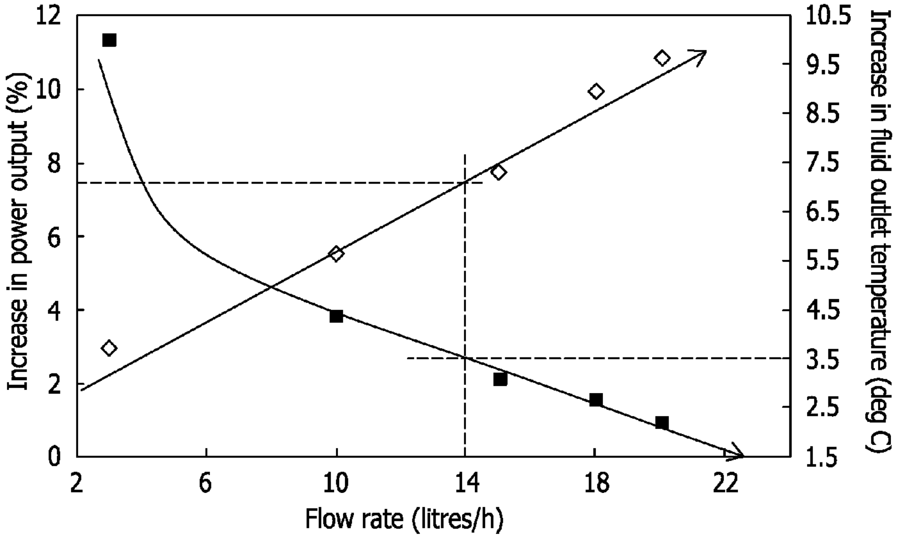

12
10
8
6
4
2
0
Increase in power output (%)
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
Increase in fluid outlet temperature (deg C)
2
6
10
14
18
22
Flow rate (litres/h)

FIG. 35

METHODS AND SYSTEMS FOR TEMPERATURE REGULATION OF ROOF MOUNTED AND SOLAR TRACKER MOUNTED PHOTOVOLTAIC MODULES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application Ser. No. 61/833,262, filed Jun. 10, 2013, which is hereby incorporated by reference in its entirety.

FIELD

[0002] This disclosure generally relates to temperature regulation and processing of thermal energy, and more specifically, to methods and systems for regulating the temperature of roof and/or solar tracker mounted photovoltaic modules and using the energy therefrom.

BACKGROUND

[0003] Various devices can benefit from temperature regulation. In particular, many electronic and/or electrical devices benefit from temperature control or regulation. For example, photovoltaic (PV) modules are devices which convert solar energy into electricity. Some known PV modules convert around 85% of incoming sunlight into heat. During peak conditions, this can result in a heat-generation of 850 W/m^2 and PV module temperatures as high as 70° C. The electrical power produced by PV modules decreases linearly with increase in module temperature. For example, in bright sunlight, crystalline silicon PV modules may heat up to 20-30° C. above ambient temperature, resulting in a 10-15% reduction in power output relative to the rated power output for the PV module. Moreover, higher PV module temperatures may increase material degradation, such as thermal fatigue failure of interconnections between PV cells in the PV module. Accordingly, PV modules may benefit from reduced temperatures and/or from reducing a rate of increase in temperature.

[0004] This Background section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

BRIEF SUMMARY

[0005] According to one aspect of this disclosure, a solar energy system includes a solar tracker, a plurality of photovoltaic (PV) modules mounted to the solar tracker, and a temperature regulation system. The PV modules are configured to generate an electrical power output from solar energy incident on the PV modules. The temperature regulation system includes a thermal transfer fluid, a fluid pump operable to pump the thermal transfer fluid, and a plurality of fluid heat exchangers in thermal communication with the plurality of PV modules and in fluid communication with the fluid pump. The fluid heat exchangers are configured to transfer heat from the PV modules to the thermal transfer fluid.

[0006] Another aspect of this disclosure is a solar energy system including a plurality of photovoltaic (PV) modules mounted to the roof of a structure, and a temperature regulation system. The PV modules are configured to generate an electrical power output from solar energy incident on the PV modules. The temperature regulation system includes a thermal transfer fluid, a fluid pump operable to pump the thermal transfer fluid, and a plurality of fluid heat exchangers in thermal communication with the plurality of PV modules and in fluid communication with the fluid pump. The fluid heat exchangers are configured to transfer heat from the PV modules to the thermal transfer fluid.

[0007] Various refinements exist of the features noted in relation to the above-mentioned aspects. Further features may also be incorporated in the above-mentioned aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to any of the illustrated embodiments may be incorporated into any of the above-described aspects, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a perspective view of an example PV module;

[0009] FIG. **2** is a cross-sectional view of the PV module shown in FIG. **1** taken along the line A--A;

[0010] FIG. **3** is a cross-sectional view of a heat exchanger;

[0011] FIG. **4** is a temperature regulation system including the heat exchanger shown in FIG. **3**;

[0012] FIG. **5** is a cross-sectional illustration of an assembly including a heat exchanger attached to a PV module;

[0013] FIG. **6** is a top view of an assembly including a heat exchanger integrated into a PV module;

[0014] FIG. **7** is a cross sectional view of the assembly shown in FIG. **6** taken along the line A-A in FIG. **6**;

[0015] FIG. **8** is a top view of a stand-alone heat exchanger;

[0016] FIG. **9** is a cross sectional view of heat exchanger shown in FIG. **8** taken along the line B-B in FIG. **8**;

[0017] FIG. **10** is a top view of a heat exchanger including a plurality of plastic spacers;

[0018] FIG. **11** is a cross sectional view of heat exchanger shown in FIG. **10** taken along the line C-C in FIG. **10**;

[0019] FIG. **12** is a cross sectional view of a connection assembly for use as an inlet and/or outlet for a heat exchanger;

[0020] FIG. **13** is a heat exchanger coupled to a device;

[0021] FIG. **14** is a temperature regulation system including an in-ground secondary heat exchanger;

[0022] FIG. **15** is another temperature regulation system including an in-ground secondary heat exchanger;

[0023] FIG. **16** is a temperature regulation system with a secondary heat exchanger in a body of water;

[0024] FIG. **17** is a temperature regulation system with a secondary heat exchanger to provide hot water;

[0025] FIG. **18** is a temperature regulation system with a secondary heat exchanger to provide hot air;

[0026] FIG. **19** is a temperature regulation system with a PCM based storage and heat exchanger to provide hot water;

[0027] FIG. **20** is a temperature regulation system with a secondary heat exchanger to provide hot water to a hot water storage tank;

[0028] FIG. **21** is a temperature regulation system configured to provide hot water to coils for underfloor heating;

[0029] FIG. **22** is a temperature regulation system with a secondary heat exchanger to provide hot water to a pool;

[0030] FIG. **23** is an assembly of PV modules including heat exchangers;

[0031] FIG. **24** is another exemplary assembly of PV modules including heat exchangers;

[0032] FIG. **25** is an exploded view of the inner and outer layers of an example heat exchanger;

[0033] FIG. **26** is a partial view of the assembled heat exchanger shown in FIG. **25**;

[0034] FIG. **27** is a view of the heat exchanger shown in FIG. **25** attached to the bottom surface of a solar panel;

[0035] FIG. **28** is a graph of output power of fixed tilt cooled and uncooled PV modules as a function of the time of day;

[0036] FIG. **29** is a side elevation view of an exemplary system including a PV module and heat exchanger mounted on a solar tracker;

[0037] FIG. **30**A is a graph of output power of cooled and uncooled PV modules as a function of the angle of incidence of light on the PV modules;

[0038] FIG. **30**B is a graph of short circuit current of cooled and uncooled PV modules as a function of the angle of incidence of light on the PV modules;

[0039] FIG. **30**C is a graph of open circuit voltage of cooled and uncooled PV modules as a function of the angle of incidence of light on the PV modules;

[0040] FIG. **30**D is a graph of the temperature of cooled and uncooled PV modules as a function of the angle of incidence of light on the PV modules;

[0041] FIG. **31** is a diagram of an example PV module mounted to a roof of a building;

[0042] FIG. **32** is a diagram of a PV module flush mounted on the roof of a building;

[0043] FIG. **33** presents temperature measurements obtained for an uncooled PV module and a cooled PV module installed various distances above a roof;

[0044] FIG. **34** is a temperature regulation system including a roof mounted PV module and heat exchanger; and

[0045] FIG. **35** is a graph of the increase in PV module power output and the increase in water temperature, both as a function of the flow rate of the water through a heat exchanger.

[0046] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0047] The embodiments described herein generally relate to temperature regulation and control. More specifically, embodiments described herein relate to methods and systems for regulating and controlling temperature using a heat exchanger. Specific embodiments are described herein with reference to photovoltaic (PV) modules. However, the teachings of the present disclosure may be applied to any device that may benefit from enhanced temperature regulation. Moreover, although various embodiments will be discussed with respect to cooling a device, it should be understood that the embodiments described herein may additionally, or alternatively, be used to heat a device with which they are used.

[0048] Referring initially to FIGS. **1** and **2**, a PV module is indicated generally at **100**. A perspective view of PV module **100** is shown in FIG. **1**. FIG. **2** is a cross sectional view of PV module **100** taken at line A-A shown in FIG. **1**. PV module **100** includes a solar panel **102** and a frame **104** circumscribing solar panel **102**.

[0049] Solar panel **102** includes a top surface **106** and a bottom surface **108** (shown in FIG. **2**). Edges **110** extend between top surface **106** and bottom surface **108**. In this embodiment, solar panel **102** is rectangular shaped. In other embodiments, solar panel **102** may have any suitable shape.

[0050] As shown in FIG. **2**, this solar panel **102** has a laminate structure that includes several layers **118**. Layers **118** may include for example glass layers, non-reflective layers, electrical connection layers, n-type silicon layers, p-type silicon layers, and/or backing layers. In other embodiments, solar panel **102** may have more or fewer, including one, layer **118**, may have different layers **118**, and/or may have different types of layers.

[0051] As shown in FIG. **1**, frame **104** circumscribes solar panel **102**. Frame **104** is coupled to solar panel **102**, as best seen in FIG. **2**. Frame **104** assists in protecting edges **110** of solar panel **102**. In this embodiment, frame **104** is constructed of four frame members **120**. In other embodiments frame **104** may include more or fewer frame members **120**.

[0052] Exemplary frame **104** includes an outer surface **130** spaced apart from solar panel **102** and an inner surface **132** adjacent solar panel **102**. Outer surface **130** is spaced apart from and substantially parallel to inner surface **132**. In this embodiment, frame **104** is made of aluminum. More particularly, in some embodiments frame **104** is made of 6000 series anodized aluminum. In other embodiments, frame **104** may be made of any other suitable material providing sufficient rigidity including, for example, rolled or stamped stainless steel, plastic, or carbon fiber.

[0053] FIG. **3** is a simplified cross-sectional view of a heat exchanger **300** according to one embodiment of the present disclosure. Heat exchanger **300** includes an inner layer **302**, a fluid layer **304**, and an outer layer **306**. In this embodiment, fluid layer **304** includes a chamber **305** and one or more spacers or spacing material (not shown in FIG. **3**) to maintain a substantially consistent separation between inner and outer layers **302** and **306**. The spacers are connected to inner layer **302** and outer layer **306** to, among other things, prevent bulging of inner or outer layer **302** or **306** when fluid is pumped into chamber **305** of fluid layer **304**. Seals **308** connect inner and outer layers **302** and **306** to provide a substantially water tight seal around fluid layer **304**, and more specifically around chamber **305**. Thus, a heat transfer fluid, such as water, oil, ethylene glycol, etc., may flow through fluid layer **304** to extract heat from a device with which heat exchanger **300** is used, without the fluid contacting the device. In some embodiments, seals **308** may be, additionally or alternatively, spacers or spacing material. Moreover, in some embodiments, seals **308** may be integrally formed with inner layer **302** and/or outer layer **306**.

[0054] Inner layer **302** is the portion of heat exchanger **300** that will be in contact with the device to be temperature regulated by heat exchanger **300**. Accordingly, inner layer **302** is made from a material having relatively high thermal conductivity, such as aluminum, copper, etc. Moreover, the material for inner layer **302** is selected to conform reasonably well to the surface of the device with which it will be used in order to provide sufficient thermal contact or thermal communication with the surface of the device. In this embodiment, inner layer **302** comprises a sheet that is suitably made of metal. In other embodiments, inner layer **302** may be an aluminum sheet.

[0055] The thickness of inner layer **302** may be varied, e.g., to suit different uses. Thicker sheets may be used to provide increased rigidity and thermal transfer, but with a corresponding decrease in flexibility and/or conformability. In some embodiments, inner layer **302** is a thin, metal foil. In one exemplary embodiment, inner layer **302** is a metal foil having a thickness of about 0.1 millimeter. In another embodiment, inner layer **302** is an aluminum foil having a thickness of about 300 micrometers. Other embodiments may use thicker or thinner metal foils. The use of thinner materials for inner layer **302** may increase the flexibility of heat exchanger **300**, reduce the weight of heat exchanger **300**, and/or permit it to conform to more irregular shaped devices. In general, inner layer **302** may be constructed from any thermally conductive material of sufficient strength and impermeability to retain a heat transfer fluid within heat exchanger **300**.

[0056] Outer layer **306** is the portion of heat exchanger **300** opposite the side of heat exchanger **300** that will be in contact with the device to be temperature regulated by heat exchanger **300** (i.e., opposite inner layer **302**). In some embodiments, outer layer **306** is made of a material having relatively high thermal conductivity, such as a metal sheet or a metal foil, to permit heat to radiate from fluid layer **304** through outer layer **306**. In other embodiments, outer layer is fabricated from a material that is not particularly thermally conductive, such as a plastic sheet or film. The thickness of outer layer **306** may be varied to suit different uses. Thicker sheets may be used to provide increased rigidity and thermal transfer, but with a corresponding decrease in flexibility and/or conformability. In some embodiments, outer layer **306** is a thin, metal foil. In other embodiments, outer layer **306** is a thin sheet that is suitably made of plastic. The use of thinner materials for outer layer **306** may increase the flexibility of heat exchanger **300**, reduce the weight of heat exchanger **300**, and/or permit it to conform to more irregular shaped devices. In general, outer layer **306** may be made of any material of sufficient strength and impermeability to retain a heat transfer fluid within heat exchanger **300**. In one example embodiment, outer layer **306** is a transparent acrylic sheet having a thickness of about three millimeters.

[0057] FIG. **4** is a simplified diagram of a closed loop temperature control or regulation system **400** including heat exchanger **300** (heat exchanger may alternatively be referred to as a meshplate). Heat exchanger **300** is coupled to a device **402** that may benefit from temperature regulation provided by heat exchanger. In this embodiment, device **402** is a device, such as PV module **100**, that generates heat and heat exchanger **300** is used to reduce the temperature and/or slow the rise in temperature of device **402**. In other embodiments, heat exchanger **300** may be used to increase the temperature of device **402** and/or slow the decrease in temperature of device.

[0058] In this embodiment, a pump **404** pumps a thermal transfer fluid (e.g., a coolant) to an inlet (not shown in FIG. **4**) of heat exchanger **300**. The transfer fluid passes into chamber **305** of fluid layer **304** through the inlet. Within chamber **305**, the thermal transfer fluid draws off heat from device **402**, via thermal conduction through connection of inner layer **302** to device **402**. The thermal transfer fluid exits heat exchanger **300** via an outlet (not shown in FIG. **4**) and is directed to a fluid heat exchanger **406** (also referred to herein as a secondary heat exchanger). As will be described in more detail below, fluid heat exchanger **406** may be any heat exchange device suitable for extracting the heat carried by the thermal transfer fluid. For example, fluid heat exchanger may be a radiator, an extended length of thermally conductive conduit, a condenser, etc. Moreover, in some embodiments fluid heat exchanger **406** may be part of another system, such that heat extracted from thermal transfer fluid may be used by the other system. In one example embodiment fluid heat exchanger **406** is a radiator used to warm the air inside a structure. In another embodiment fluid heat exchanger **406** is used to heat water.

[0059] As will be readily understood by those of ordinary skill in the art, system **400** may, additionally or alternatively, be used to heat device **402**. In such embodiments, thermal transfer fluid having a temperature greater than device **402** is pumped by pump **404** to heat exchanger **300**. Within chamber **305**, the thermal transfer fluid loses its heat to device **402**, via conduction through inner layer **302**. Fluid heat exchanger **406** then increases the temperature of the heat transfer fluid before pump **404** returns the fluid to heat exchange device **300**. A single system **400** may be used to selectively heat or cool device **402** through use of a dual purpose fluid heat exchanger **406** or separate, selectable, fluid heat exchangers **406**: one for heating the thermal fluid and another for cooling the thermal fluid. Thus, device **402** may be cooled by system **400** when temperatures are relatively high, and warmed by system **400** when temperatures are relatively cool.

[0060] A controller **408** controls operation of system **400**. More specifically, controller **408** controls operation of system **400** to obtain a desired amount of cooling and/or heating of device **402**. In some embodiments, controller **408** may monitor a temperature of device **402** with a sensor (not shown). Other embodiments do not include controller **408**. In this embodiment, controller **408** is configured to control operation of pump **404**. Controller **408** may operate pump **404** continuously, intermittently, and/or may pulse pump **404** to achieve a desired heating/cooling of device **402**. In some embodiments, controller **408** may additionally, or alternatively, control operation of fluid heat exchanger **406** and/or heat exchanger **300**. In still other embodiments, controller **408** may also control operation of device **402**. For example, controller **408** may be a PV system controller that controls operation of a direct current (DC) to alternating current (AC) power converter extracting power from a PV module device **402**.

[0061] In this embodiment, controller **408** is configured to operate pump **404** other than continuously. Controller **408** can operate pump **404** at a duty cycle of less than 100% in some embodiments because system **400** cools device **402** faster than the device **402** heats up when pump **404** is turned off (i.e., not pumping). In one example, device **402** is PV module **100** and system **400** is operable to cool down the PV module **100** twice as fast as the PV module **100** heats up due to the high heat capacity and low thermal conductivity of PV module **100**. In this example, controller **408** may operate pump **404** with a duty cycle between 30% and 50%. This may provide significant energy gain while reducing pumping costs and coolant usage.

[0062] Controller **408** may be any suitable controller, including any suitable analog controller, digital controller, or combination of analog and digital controllers. In some embodiments, controller **408** includes a processor (not shown) that executes instructions for software that may be loaded into a memory device. The processor may be a set of one or more processors or may include multiple processor cores, depending on the particular implementation. Further, the processor may be implemented using one or more heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. In another embodiment, the processor may be a homogeneous processor system containing multiple processors of the same type. In some embodiments, controller **408** includes a memory device (not shown). As used herein, a memory device is any tangible piece of hardware that is capable of storing information either on a temporary basis and/or a permanent basis. The memory device may be, for example, without limitation, a random access memory and/or any other suitable volatile or non-volatile storage device. The memory device may take various forms depending on the particular implementation, and may contain one or more components or devices. For example, the memory device may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, and/or some combination of the above. The media used by memory device also may be removable. For example, without limitation, a removable hard drive may be used for the memory device.

[0063] FIG. **5** is a cross-sectional illustration of an assembly including heat exchanger **300** attached to PV module **100**.

[0064] In this embodiment, solar panel **102** includes a front glass **500**, solar cells **502** surrounded by an encapsulant **504**, and a back sheet **506**. In this embodiment, the encapsulant **504** comprises ethylene vinyl acetate (EVA). In other embodiments, any other suitable encapsulant may be used. In this embodiment, back sheet **506** is a polyvinyl fluoride (PVF) material. In other embodiments, back sheet **506** may be any other suitable back sheet material or a laminate of materials, including, for example a laminate of PVF surrounding a polyester material.

[0065] Thermal transfer fluid enters heat exchanger **300** via inlet **508** and passes through chamber **305** to outlet **510**. A spacer **512** is contained within chamber **305**. Spacer **512** separates inner and outer layers **302** and **306** and slows the flow of the thermal transfer fluid through chamber **305** to permit the thermal transfer fluid to absorb heat from solar panel **102**. In this embodiment, spacer **512** includes a mesh. More specifically, mesh is a woven-plastic mesh. In other embodiments, spacer **512** may include a non-woven mesh, a metal mesh, a sponge, spacer strips, capillary tubes, or some combination of the above. In this embodiment, mesh **512** is attached to inner and outer layers **302** and **306** and substantially fills chamber **305**. In one exemplary embodiment, mesh **512** is approximately 300 micrometers thick.

[0066] Heat exchanger **300** may be permanently or semi-permanently integrated into solar panel **102**, or may be a standalone component that may be removably attached to a device. A standalone heat exchanger **300** may be coupled to device **402** by any suitable means to provide a thermally connection between inner layer **302** and a surface of device **402**. In some embodiments, heat exchanger **300** is connected to device **402** using a thermally conductive adhesive, including for example a double-sided, thermally conductive tape.

[0067] FIG. **6** is a top view of an assembly **600** including heat exchanger **300** integrated into PV module **100**. FIG. **7** is a cross sectional view of assembly **600** taken along the line A-A in FIG. **6**.

[0068] In assembly **600**, heat exchanger **300** is integrally formed with PV module **100** and does not need to be separately adhered to PV module **100**. Moreover, heat exchanger **300** uses backsheet **506** of PV module **100** as inner layer **302**. Spacer strips **602** extend between inner layer **302** (i.e., backsheet **506**) and outer layer **306** to define cavity **305**. Although not shown in FIGS. **6** and **7**, cavity **305** also includes spacer **512**. In this embodiment, spacer **512** is a metallic mesh **512** capable of withstanding the heat and pressure of lamination with PV module **100**. In other embodiments, cavity **305** may include any other suitable filler and/or spacer. Outer layer **306** extends around spacer strips **602** to adhere heat exchanger **300** to PV module **100** and facilitate sealing cavity **305**.

[0069] FIG. **8** is a top view of a stand-alone heat exchanger **300** of one embodiment. FIG. **9** is a cross sectional view of heat exchanger **300** taken along the line B-B in FIG. **8**. The embodiment of heat exchanger **300** shown in FIGS. **8** and **9** is not integrally formed with any device and may be attached to any device, such as PV module **100**, by any suitable type of attachment. In this embodiment, two sets of seals **308** are included around spacer **512**.

[0070] FIGS. **10** and **11** show an example heat exchanger **300** in which spacer **512** includes a parallel arrangement of plastic spacers. FIG. **10** is a top view, and FIG. **11** is a cross sectional view taken along the line C-C in FIG. **10**. The illustrated heat exchanger **300** provides a serpentine fluid flow through heat exchanger **300**. The serpentine fluid flow provides increased heat transfer as compared to non-serpentine fluid flows. Heat exchanger **300** shown in FIGS. **10** and **11** may be integrated into a device or may be a standalone heat exchanger **300**. The gap between adjacent spacers may be any suitable distance that ensures good fluid flow within the system to improve heat transfer and reduce bloating issues.

[0071] FIGS. **25**, **26** and **27** show an example heat exchanger **300** including parallel chambers **305** through which heat transfer fluid passes. FIG. **25** is an exploded view of the inner and outer layers **302** and **306**. FIG. **26** is a partial view of assembled inner and outer layers **302** and **306**. FIG. **27** is a view of the example heat exchanger **300** attached to the bottom surface **108** of a solar panel **102**. Although three and four chambers **305** are shown in FIGS. **25-27**, heat exchanger **300** may include any suitable number of chambers **305**, whether more or fewer.

[0072] In this embodiment, inner layer **302** is a substantially flat sheet, outer layer **306** is a corrugated sheet, and both inner layer **302** and outer layer **306** are aluminum. Alternatively, inner and outer layers **302**, **306** may be any other suitable thermally conductive material. Moreover, inner layer **302** and outer layer **306** may be made of different materials. Inner layer **302** is attached to outer layer **306** by spot welds **2500** between chambers **305**. Alternatively or additionally, inner layer **302** may be attached to outer layer **306** by any suitable connector(s), including rivets, nuts and bolts, adhesives, etc. Heat exchanger **300** shown in FIGS. **25-27** may be integrated into a device or may be a standalone heat exchanger **300**.

[0073] In one example, a heat exchanger **300** shown in FIGS. **25-27** was used to cool PV module **100** positioned in a fixed position (i.e., without solar tracking). A twenty liter per hour (LPH) flow rate of water fluid through heat exchanger **300** produced a 12% power gain and output water that was 2° C. hotter than the input water. A 2.5 LPH flow produced a 3% power gain in PV module **100** and output water that was 11° C. hotter than the input water. Thus, by varying the rate of flow of water, or other thermal transfer fluid, through heat exchanger **300**, the amount of cooling (and accordingly, the power gain) and the temperature gain of the water may be varied. FIG. **28** is a graph comparing the maximum power output of PV module **100** with the heat exchanger **300** (the "cooled module") to the maximum power output of an uncooled PV module **100** as a function of the time of day. FIG. **35** graphs the increase in power output of the PV module **100** and the increase in temperature of the water used for cooling (i.e., outlet temperature minus inlet temperature) both as a function of the flow rate of water through the heat exchanger **300**.

[0074] FIG. **12** is a partially schematic cross section of a suitable connection assembly **1200** for use at inlet **508** and/or outlet **510** of any embodiment of heat exchanger **300**. Assembly **1200** includes a male component **1202** positioned inside exchanger **300** and extending through outer layer **306**. A female component **1204** is positioned outside of heat exchanger **300** adjacent outer layer **306**. Female component **1204** receives and surrounds the portion of male component **1202** that extends outside of heat exchanger **300**. A portion of outer layer **306** is trapped between female component **1204** and male component **1202**. Tubing **1206**, used to transport thermal transfer fluid to and from heat exchanger **300**, is inserted into female component **1204** to couple tubing **1206** to male component **1202**. Assembly **1200** forms a liquid tight connection to heat exchanger **300**. Thermal transfer fluid (e.g., a suitable coolant) may be transferred, via tubing **1206** and assembly **1200**, from outside of heat exchanger **300** to the interior of heat exchanger **300**, and vice versa.

[0075] FIG. **13** is a partially schematic view of heat exchanger **300** coupled to a device **1300**. The device may be any suitable device that may benefit from temperature regulation provided by heat exchanger **300**.

[0076] FIGS. **14-22** illustrate various embodiments of closed loop temperature control or regulation system **400** including heat exchanger **300**. It should be understood that any of the embodiments of heat exchanger **300** described above may be used in the temperature regulation systems **400** shown in FIGS. **14-22**. At least some of the temperature regulation systems **400** described herein utilize thermal energy produced by the PV modules **100** for other useful purposes and thus are sometimes referred to herein as solar energy systems.

[0077] FIG. **14** is a simplified diagram of a temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and an in-ground secondary heat exchanger **1400**. The secondary heat exchanger **1400** is a fluid retaining tank positioned underground. The secondary heat exchanger **1400** may be made of metal, plastic, or any other suitable material or combination of materials. Fluid from the secondary heat exchanger **1400** is pumped through heat exchanger **300** by pump **404**. The heated fluid exiting the heat exchanger **300** flows back to the secondary heat exchanger **1400**. The heat stored in the fluid in secondary heat exchanger **1400** is dissipated through the secondary heat exchange **1400** into the ground. The dissipation of heat into the ground occurs particularly at times when the fluid is not being used to cool the PV module **100**, such as a night. The secondary heat exchanger **1400** is buried a depth "h" below the ground level **1402**. In some embodiments, h is a depth below ground level **1402** at which the annual ground temperature is relatively constant. Alternatively, the depth h may be any other suitable depth. In some embodiments, additives (e.g., charcoal, metal dust, etc.) may be added to the soil surrounding the secondary heat exchanger **1400** to enhance the heat transfer between the secondary heat exchanger **1400** and the ground. In still other embodiments secondary heat exchanger **1400** may be positioned on or above ground level.

[0078] FIG. **15** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and an in-ground secondary heat exchanger **1500**. The secondary heat exchanger **1500** is a serpentine array of tubes positioned underground. The secondary heat exchanger **1500** may be made of metal, plastic, or any other suitable material or combination of materials. The heated fluid exiting the heat exchanger **300** flows through the secondary heat exchanger **1500** before returning to the heat exchanger **300**. At least some of the heat stored in the fluid is dissipated through the secondary heat exchange **1500** into the ground. The secondary heat exchanger **1500** is buried a depth "h" below the ground level **1402**. In some embodiments, h is a depth below ground level **1402** at which the annual ground temperature is relatively constant. Alternatively, the depth h may be any other suitable depth. In some embodiments, additives may be added to the soil surrounding the secondary heat exchanger **1500** to enhance the heat transfer between the secondary heat exchanger **1500** and the ground. Although shown as a vertical array of tubes, secondary heat exchanger **1500** may be a vertical array of tubes, a horizontal array of tubes, an array of coils, an array of vertical and horizontal tubes, an array of arbitrary angled tubes, and/or any suitable combination of horizontal tubes, vertical tubes, arbitrary angled tubes, and coils.

[0079] FIG. **16** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **1600**. The secondary heat exchanger **1600** is a serpentine array of tubes disposed in a body of water **1602**. The secondary heat exchanger **1600** may be made of metal, plastic, or any other suitable material or combination of materials. The heated fluid exiting the heat exchanger **300** flows through the secondary heat exchanger **1600** before being returned by pump **404** to the heat exchanger **300**. At least some of the heat stored in the fluid is dissipated through the secondary heat exchange **1600** into the body of water **1602**. In the illustrated embodiment, the body of water is an open body of water, such as a lake or pond. Alternatively, the body of water **1602** may be an underground body of water, including a reservoir, an underground lake, an underground river, etc. Although shown as a horizontal array of tubes, secondary heat exchanger **1600** may be a vertical array of tubes, a horizontal array of tubes, an array of coils, an array of vertical and horizontal tubes, an array of arbitrary angled tubes, and/or any suitable combination of horizontal tubes, vertical tubes, arbitrary angled tubes, and coils.

[0080] FIG. **17** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **1700**. The cooling fluid flows through heat exchanger **300** in a first fluid loop. The secondary heat exchanger **1700** is configured to transfer at least some of the heat contained in fluid exiting the heat exchanger **300** to a secondary fluid loop. In the illustrated embodiment, the secondary fluid loop provides heated water for residential, commercial, industrial, or any other suitable application. More particularly, the secondary heat exchanger **1700** receives the heated fluid from the heat exchanger **300** and cooler water from a water supply (not shown). A second pump **1702** pumps the water to secondary heat exchanger **1700**. The heat contained in the fluid exiting the heat exchanger **300** is transferred to the water pumped into the secondary heat exchanger **1700**. The reduced temperature cooling fluid is returned to the heat exchanger **300** by pump **404**. The heated water exits the secondary heat exchanger **1700** and is delivered for use.

[0081] FIG. **18** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300**

coupled to PV module **100** and a secondary heat exchanger **1800**. The cooling fluid flows through heat exchanger **300** in a first fluid loop. The secondary heat exchanger **1800** is configured to transfer at least some of the heat contained in fluid exiting the heat exchanger **300** to a secondary fluid loop. In the illustrated embodiment, the secondary fluid loop provides heated air for residential, commercial, industrial, or any other suitable application. More particularly, the secondary heat exchanger **1800** receives the heated fluid from the heat exchanger **300** and a cooler air input. A pump, fan, blower, or other suitable motivator (not shown) forces the cooler air into secondary heat exchanger **1800**. The heat contained in the fluid exiting the heat exchanger **300** is transferred to the air in secondary heat exchanger **1800**. The reduced temperature cooling fluid is returned to the heat exchanger **300** by pump **404**. The heated air exits the secondary heat exchanger **1700** and is input to an auxiliary heater **1802** to provide additional heat to the air. Alternatively, the heated air exiting the secondary heat exchanger **1800** is delivered for use without heating by an auxiliary heater **1802**.

[0082] FIG. **19** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **1900**. The cooling fluid flows through heat exchanger **300** in a first fluid loop. The secondary heat exchanger **1900** is a phase change material (PCM) combined heat storage and heat exchanger configured to transfer at least some of the heat contained in fluid exiting the heat exchanger **300** to a secondary fluid loop. In the illustrated embodiment, the secondary fluid loop provides heated water for residential, commercial, industrial, or any other suitable application. More particularly, the secondary heat exchanger **1900** receives the heated fluid from the heat exchanger **300** and cooler water from a water supply (not shown). A second pump **1902** pumps the water to secondary heat exchanger **1900**. The heat contained in the fluid exiting the heat exchanger **300** is transferred, via a phase change material, to the water pumped into the secondary heat exchanger **1900**. The reduced temperature cooling fluid is returned to the heat exchanger **300** by pump **404**. The heated water exits the secondary heat exchanger **1900** and is delivered for processing and/or use.

[0083] FIG. **20** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **2000**. The cooling fluid flows through heat exchanger **300** in a first fluid loop. The secondary heat exchanger **2000** is configured to transfer at least some of the heat contained in fluid exiting the heat exchanger **300** to a secondary fluid loop. In the illustrated embodiment, the secondary fluid loop provides heated water for residential, commercial, industrial, or any other suitable application. More particularly, the secondary heat exchanger **2000** receives the heated fluid from the heat exchanger **300** and cooler water from a water supply (not shown). A second pump **2002** pumps the water to secondary heat exchanger **2000**. The heat contained in the fluid exiting the heat exchanger **300** is transferred to the water pumped into the secondary heat exchanger **2000**. The reduced temperature cooling fluid is returned to the heat exchanger **300** by pump **404**. The heated water exits the secondary heat exchanger **2000** and is delivered to an insulated hot water storage tank **2004**. The storage tank **2004** includes an auxiliary heater **2006** to provide additional heat to the water stored in the storage tank **2004**. Alternatively, the auxiliary heater **2006** may be omitted. The heated water stored in storage tank **2004** is delivered from the hot water storage tank **2004** for processing and/or use. In the illustrated embodiment, pump **2002** pumps water from storage tank **2004** to secondary heat exchanger **2000**, while the water supply provide water into storage tank **2004** as needed. Alternatively, water may be provided to secondary heat exchanger **2000** from the water supply directly.

[0084] FIG. **21** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **2100**. The secondary heat exchanger **2100** is an array of coils **2102** for underfloor heating or in-wall heating. The coils **2102** are disposed underneath the surface of a floor and/or within the walls (not shown) in a home, office, warehouse, etc. In some embodiments, the coils **2102** are disposed within a floor, such as by being embedded in a concrete foundation. The secondary heat exchanger **2100** may be made of metal, plastic, or any other suitable material or combination of materials. The heated fluid exiting the heat exchanger **300** flows through the secondary heat exchanger **2100** before being returned by pump **404** to the heat exchanger **300**. At least some of the heat stored in the fluid is dissipated through the secondary heat exchange **2100** into the floor and/or through the walls. Secondary heat exchanger **2100** may be include a vertical array of tubes, a horizontal array of tubes, an array of coils, an array of vertical and horizontal tubes, an array of arbitrary angled tubes, and/or any suitable combination of horizontal tubes, vertical tubes, arbitrary angled tubes, and coils.

[0085] FIG. **22** is a simplified diagram of another temperature regulation system **400** including heat exchanger **300** coupled to PV module **100** and a secondary heat exchanger **2200**. The cooling fluid flows through heat exchanger **300** in a first fluid loop. The secondary heat exchanger **2200** is configured to transfer at least some of the heat contained in fluid exiting the heat exchanger **300** to a secondary fluid loop. The secondary fluid loop provides heated water for heating a body of water. In the illustrated embodiment, the body of water is a pool **2202**. Alternatively, the body of water may be a pond, a lake, a tub, or any other body of water that may benefit from heating. The secondary heat exchanger **2200** receives the heated fluid from the heat exchanger **300** and cooler water from the pool **2202**. A second pump **2204** pumps the water to secondary heat exchanger **2200**. The heat contained in the fluid exiting the heat exchanger **300** is transferred to the water pumped into the secondary heat exchanger **2200**. The reduced temperature cooling fluid is returned to the heat exchanger **300** by pump **404**. The heated water exits the secondary heat exchanger **2200** and is delivered to the pool **2202**.

[0086] PV modules **100** including heat exchangers **300** may be mounted to any suitable support structure. For example, a PV module **100** with heat exchanger **300** may be mounted to a ground based rack, a roof (whether directly or via a rack), a solar tracker, etc.

[0087] FIG. **29** is a side elevation view of a system **2900** including PV module **100** and heat exchanger **300** (not visible) mounted to a solar tracker **2902**. Tracker **2902** is a horizontal single axis tracker configured to rotate the PV module **100** about an axis of rotation (going into the page) at point **2904**. Alternatively, the tracker **2902** may be a multi-axis tracker, a single axis tracker rotating about a different axis of rotation, or any other suitable solar tracker. Moreover, although a single PV module **100** is shown in FIG. **29**, system **2900** may include more than one PV module **100**.

[0088] Solar trackers (sometimes referred to herein as trackers or tracking devices) are used to alter the position of one or more PV modules **100** mounted to the tracker to attempt to control an angle of incidence **2906** of sunlight on the PV modules. Typically, the desired angle of incidence **2906** is normal (i.e. ninety degrees) to the PV module **100**. This substantially maximizes the solar energy that is received by the PV modules **100** throughout the day. The increased light intensity on the PV module increases the output current of the PV module **100**, thereby leading to increased power output. The introduction of trackers can boost the output power of a solar power plant by, for example, 10%-35%. The increased light intensity on the PV module **100** also increases the temperature of the PV module **100**. PV modules **100** mounted on solar trackers will often be 10° C.-15° C. hotter than a similar module **100** mounted in a fixed position. Heat exchanger **300** reduces the temperature of the PV module **100** and offsets at least a portion of the increased temperature of the PV module **100**.

[0089] FIGS. **30**A-**30**D compare the characteristics of an uncooled PV module **100** (i.e., without a heat exchanger **300**) and a cooled PV module **100** (i.e., with a heat exchanger **300**) for various angles of incidence of light on the PV module. In this example, the light was generated using a lamp and the indicated angle of incidence is relative to normal. Thus, at an angle of 0 degrees, the PV module **100** faces the lamp directly and receives the most incident light from the lamp. FIG. **30**A presents the output power of the modules **100** as a function of the angle of incidence. FIGS. **30**B and **30**C show the short circuit current and the open circuit voltage, respectively, of the PV modules **100**. The temperature of the PV modules **100** is shown as a function of the angle of incidence in FIG. **30**D. As can be seen, the cooled module remained significantly cooler than the uncooled module. The cooled module **100** provided higher open circuit voltages at substantially the same short circuit current as the uncooled module **100**, thereby generating more output power.

[0090] As mentioned above, PV modules **100** may be mounted to a roof of a building. As is well known, a significant amount of heat enters a building through the roof from sunlight shining on the roof. Placing PV modules on a roof shades the portion of the roof under the PV module from the sun, thereby reducing the temperature of the roof and potentially reducing the amount of heat entering the building through the roof. FIG. **31** is a diagram of a PV module **100** mounted to a roof **3100** of a building **3102**. In FIG. **31**, PV module **100** is mounted such that it is spaced a distance d from the surface of roof **3100**. The distance d is selected to provide clearance to permit air (e.g., wind) to pass between the roof **3100** and the PV module **100** to facilitate cooling the PV module **100**. Reducing the distance d reduces the wind loading that the PV module **100** applies to the roof **3100**, at the cost of reduced cooling of the PV module (because less air can flow between the PV module **100** and the roof **3100**). When the PV module **100** is flush mounted on roof **3100**, as shown in FIG. **32**, the distance d is reduced substantially to zero and the PV module's contribution to wind loading of the roof **3100** is substantially minimized. However, the cooling produced by air passing between the PV module **100** and the roof **3100** is nearly eliminated. Use of heat exchanger **300** with roof mounted PV modules reduces the temperature of the module **100** without reliance on the airflow between the PV module **100** and the roof **3100**.

[0091] FIG. **33** presents temperature measurements obtained for installation with various distances d (referred to in FIG. **33** as "Height") for an uncooled PV module **100** and a cooled PV module **100** (i.e., PV module **100** with heat exchanger **300**). As can be seen, the temperature of the PV module **100** (whether cooled or uncooled) increased as the distance d decreased. The cooled module **100**, however, was significantly cooler than the uncooled module **100** at all heights and had a smaller temperature change than the uncooled module **100** as the distance d changed. Moreover, when distance d was reduced to zero (i.e., the modules **100** were flush mounted), the temperature of the cooled module **100** was still less than the temperature of the uncooled module at any distance. Similarly, the temperature of the roof under the PV modules **100** increased as the distance d decreased. The roof temperature under the cooled PV module **100** remained cooler than the roof under the uncooled PV module **100** at all distances d. Thus, a cooled PV module **100** (i.e., including heat exchanger **300**) may be installed spaced apart from the roof **3100**, flush with the roof **3100**, or anywhere in between to achieve a desired wind loading on the roof **3100**, reduction in roof temperature, and/or aesthetic appearance of the installed system.

[0092] Moreover, as shown in FIG. **34**, a roof mounted PV module **100** and heat exchanger **300** may be used as part of any of the example temperature regulation systems **400** described above. The cooling fluid passed through the heat exchanger may be used for additional purposes as described above (for example with respect to FIGS. **17**-**22**). Thus, a temperature regulation system **400** may include roof mounted PV modules **100** that reduce the temperature of the roof, thereby reducing the temperature in the building and reducing the cost to cool the building. The system **400** also provides hot water (or other thermal transfer fluid) that may be used to heat drinking water, heat non-potable water, heat an environment, etc., thereby further reducing electrical usage (and costs) for the building.

[0093] Additionally, a roof mounted PV module **100**, may be recess mounted into the roof. The amount of recess into the roof may be varied to vary the distance between the top surface **106** of the PV module **100** and the surface of the roof. In some embodiments, the PV module may be recessed to position the top surface **106** of the PV module **100** level or below the surface of the roof. Recessing the PV module **100** into the roof reduces the wind loading on the PV module **100** (and thereby reduces the wind loading on the roof). The reduced wind loading may permit fewer structural components to be used to mount the PV module **100** to the roof, thereby reducing costs.

[0094] It should be recognized that the temperature regulation systems described above may be combined without departing from the scope of this disclosure. For example, a temperature regulation system may include the secondary heat exchanger **1700** and the secondary heat exchanger **1400**. Cooling fluid exiting the secondary heat exchanger **1700** may be delivered to secondary heat exchanger **1400** for further heat dissipation. Moreover, the systems described herein are not limited to the uses described above. For example, systems of this disclosure may be used to provide a low grade energy input to vapor absorption systems for cooling applications. Other uses include a wide range of heating applications in the food product industry, dairies, breweries, distilleries, automobile industry, machine industry, chemical industries, paper and pulp industries, timber processing, etc.

[0095] Although the exemplary embodiments were described above with reference to a single device **402** and/or a single PV module **100**, the apparatus, methods, and systems described herein are not so limited. A temperature regulation system **400** may include more than one heat exchanger **300** coupled to one or more devices **402**. FIGS. **23** and **24** illustrate two exemplary configurations of such systems. In FIG. **23**, the system **400** includes four heat exchangers **300**. PV modules **100** are coupled to each heat exchanger **300**. The fluid flows through the heat exchangers **300** in parallel. Cooling fluid branches off from an input **2300**, e.g. the output of pump **404**, to provide cooling fluid to each heat exchanger **300**. The cooling fluid exiting each heat exchanger **300** is provided to an output **2302** to be delivered to a secondary heat exchanger. In FIG. **24**, the cooling fluid flows through four heat exchangers **300** in series. The cooling fluid output from one heat exchanger **300** is input to the next heat exchanger **300** in the series. The cooling fluid from the last heat exchanger in the series or delivered to a secondary heat exchanger for extraction of the heat in the cooling fluid. The parallel configuration shown in FIG. **23** provides for a greater cooling fluid flow rate than the series configuration shown in FIG. **24**. The series configuration of FIG. **24** provides a higher output temperature for the cooling fluid than the parallel configuration shown in FIG. **23**. Moreover, the parallel configuration of FIG. **23** may provide more even cooling of the PV modules **100** than the series connection of FIG. **24**.

[0096] The heat exchangers and systems described herein generally provide inexpensive and effective ways to regulate temperature of a device, such as a PV module. Moreover, the temperature regulation provided by the exemplary heat exchangers and systems may permit PV modules to be mounted without the significant gap typically needed between the back of the PV module and an underlying support (such as a roof) to permit natural convective cooling of the PV module. Such flush mounting of PV modules may decrease wind loading on support structures and reduce installation costs. Moreover, experiments have shown that the temperature of the surface beneath PV modules including the exemplary temperature regulation systems may be lower than the surface beneath a PV module without the exemplary temperature regulation systems. This can reduce conductive and/or convective heating of space below the mounting surface. In roof mounted installations, the space beneath the mounting surface may be the interior of a building. Accordingly, the exemplary systems may facilitate reducing the cooling costs of a building to which PV modules are attached.

[0097] Some embodiments of the heat exchangers disclosed herein can be integrated into the backsheet structure of a PV module using only an encapsulant and can thereby capitalize on existing manufacturing infrastructure and corresponding economy of scale. Some embodiments of the heat exchangers can be used with a simple attachment mechanism to be affixed to nearly any PV modules, thereby making it field-retrofittable and easy to clean and/or replace. These heat exchangers are thus usable to convert a conventional PV system or module into a PV-thermal system.

[0098] Moreover, coolant losses in the exemplary heat exchangers and systems will be negligible in a properly constructed system because coolant is retained within the system, i.e., it is a closed loop system, and there is no provision to allow coolant to intentionally escape. When used to cool PV modules, some heat exchangers of this disclosure have produced a decrease in PV module temperature of 18-20° C., and increased power output of the PV modules by about 10% at peak operating conditions. Other implementations may result in greater or lesser temperature reductions and/or greater or lesser increases in PV module efficiency. Furthermore, some embodiments provide useful dissipation of the heat extracted from a device. For example, the extracted heat may be used to provide heated water, to heat a pool or other body of water or liquid, and/or to heat air.

[0099] When introducing elements of the present invention or the embodiment(s) thereof, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of the elements. The terms "comprising", "including" and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0100] As various changes could be made in the above without departing from the scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

1-20. (canceled)

21. A solar energy system comprising:

a plurality of photovoltaic (PV) modules mounted to the roof of a structure, the PV modules configured to generate an electrical power output from solar energy incident on the PV modules; and

a temperature regulation system comprising:

a thermal transfer fluid;

a fluid pump operable to pump the thermal transfer fluid; and

a plurality of fluid heat exchangers in thermal communication with the plurality of PV modules and in fluid communication with the fluid pump, the fluid heat exchangers configured to transfer heat from the PV modules to the thermal transfer fluid.

22. The solar energy system of claim **21**, wherein the PV modules are mounted to the roof of the structure spaced a distance from the roof.

23. The solar energy system of claim **21**, wherein the PV modules are mounted to the roof of the structure with substantially no distance between the PV modules and the roof.

24. The solar energy system of claim **21** further comprising a secondary heat exchanger in fluid communication with the fluid pump and the fluid heat exchanger, the secondary heat exchanger configured to dissipate at least some of the heat contained in the thermal transfer fluid.

25. The solar energy system of claim **24**, wherein the secondary heat exchanger comprises an array of tubes or coils.

26. The solar energy system of claim **21**, wherein the array of tubes or coils is configured to be buried underground.

27. The solar energy system of claim **21**, wherein the array of tubes or coils is configured for disposition under a floor to provide underfloor heating.

28. The solar energy system of claim **21**, wherein the array of tubes or coils is configured for disposition in a body of water.

29. The solar energy system of claim **21**, wherein the array of tubes or coils is configured for disposition within walls of a structure to provide room heating in the structure.

30. The solar energy system of claim **21**, wherein the array of tubes or coils is configured for disposition within walls of a structure to provide room heating in the structure.

31. The solar energy system of claim **24**, wherein the secondary heat exchanger is configured to indirectly dissipate at least some of the heat contained in the thermal transfer fluid to a second fluid.

32. The solar energy system of claim **31**, wherein the second fluid is air.

33. The solar energy system of claim **31**, wherein the second fluid is water.

34. The solar energy system of claim **33**, wherein the secondary heat exchanger is coupled to a water storage tank to provide the water to the water storage tank after dissipating at least some of the heat contained in the thermal transfer fluid to the water.

35. The solar energy system of claim **33**, wherein the secondary heat exchanger is coupled to a body of water to provide the water to the body of water after dissipating at least some of the heat contained in the thermal transfer fluid to the water.

36. The solar energy system of claim **35**, wherein the body of water is a pool.

37. The solar energy system of claim **31**, wherein the secondary heat exchanger comprises a phase change material based heat exchanger.

38. The solar energy system of claim **31**, wherein the second fluid is ethylene glycol.

39. The solar energy system of claim **31**, wherein the second fluid is a thermal transfer fluid.

40. The solar energy system of claim **21**, wherein the PV modules are mounted to the roof of the structure recessed into the roof.

41. The solar energy system of claim **22**, wherein the PV modules are configured to reduce a temperature of the roof below the PV modules.

42. The solar energy system of claim **22**, wherein the plurality of PV modules are operable to generate a greater electrical power output than similar PV modules that are not in coupled to the temperature regulation system.

43. The solar energy system of claim **22**, wherein the temperature regulation system is configured to provide at least some of the heat transferred from the PV modules for use in one of a residential application, a commercial application, and an industrial application.

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