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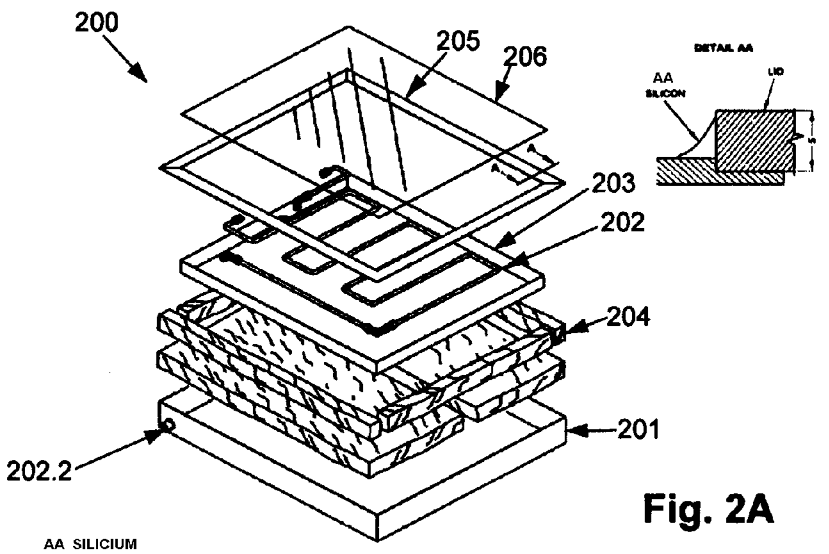


Fig. 2A

(57) Abstract: A solar thermal power apparatus including at least one heat trap including an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer medium being at least partially heated by solar radiation transmitted through the optically transparent portion, a steam generator for generating steam using heat from the heated heat transfer medium and a steam turbine coupled to a generator for generating electricity from the steam.

SOLAR THERMAL POWER APPARATUS

Background of the Invention

[0001] The present invention relates to a solar thermal power apparatus, and in particular to a solar thermal power apparatus for generating electricity.

Description of the Prior Art

[0002] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

[0003] The traditional arrangement for solar thermal power generation is to have a large field of reflectors focusing sunlight upon either tubes containing water or tubes containing a thermal medium. The heat harvested by the collectors is then converted to electricity or used as a heat source for other applications.

[0004] The traditional arrangement is not easily scalable and once assembled cannot be transported to other locations. Accordingly, whilst traditional arrangements may be suitable for large scale use, they typically have many limitations when used for small-scale facilities such as individual buildings or when used as a mobile facility in support of emergency services or the construction industries, or the like.

Summary of the Present Invention

[0005] In a first broad form the present invention seeks to provide a solar thermal power apparatus including:

a) at least one heat trap including an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer medium being at least partially heated by solar radiation transmitted through the optically transparent portion;

b) a steam generator for generating steam using heat from the heated heat transfer medium; and
c) a steam turbine coupled to a generator for generating electricity from the steam.

[0006] Typically the apparatus includes heat transfer medium transport pipes and a heat transfer medium pump for circulating heat transfer medium through the at least one heat trap and the steam generator.

[0007] Typically the apparatus includes at least one steam pipe for transferring steam from the steam generator to the steam turbine.

[0008] Typically the apparatus includes a condenser for condensing steam from the steam turbine and at least one water pipe for returning water to the steam generator.

[0009] Typically the housing includes:
a) an outer casing;
b) an inner casing;
c) insulation provided between the inner and outer casings; and,
d) a glass cover.

[0010] Typically each heat trap includes heat transfer medium transfer pipes extending along a floor of the inner casing for circulating heat transfer medium through the evacuated tubes.

[0011] Typically the heat transfer medium transfer pipes are coupled to the evacuated tubes via a manifold.

[0012] Typically the heat transfer medium transfer pipes are coupled to an inlet and an outlet respectively, the inlet and outlet being coupled to heat transfer medium pipes for circulating heat transfer medium through the steam generator.

[0013] Typically at least one heat transfer medium transfer pipe supports the evacuated tubes so that incoming heat transfer medium is warmed prior to entering the evacuated tubes.

[0014] Typically the steam generator includes a steam generator body having:
a) a water inlet for receiving water;
b) a steam outlet for supplying steam;

c) a heat transfer medium inlet for receiving heat transfer medium from the at least one heat trap; and,
d) an outlet for supplying heat transfer medium to the at least one heat trap.

[0015] Typically the steam generator includes a number of elongate heating pipes extending substantially along a length of the steam generator body.

[0016] Typically the heating pipes are interconnected using joining pipes.

[0017] Typically the heating pipes include a plurality of fins to thereby increase the effective surface area of the heating pipes.

[0018] Typically the heating pipes are arranged in first and second groups, the second group of heating pipes being immersed in water to thereby generate steam and the first group of heating pipes heating the steam.

[0019] Typically the apparatus includes a controller for controlling a heat transfer medium pump to thereby selectively circulate heat transfer medium through the at least one heat trap and the steam generator.

[0020] Typically the controller is coupled to at least one of:

a) at least one heat trap air temperature sensor for sensing a heat trap air temperature;
b) a heat trap inlet temperature sensor for sensing a heat transfer medium temperature at a heat trap inlet;
c) a heat trap outlet temperature sensor for sensing a heat transfer medium temperature at a heat trap outlet;
d) a heat transfer pump temperature sensor for sensing a heat transfer medium temperature at the heat transfer medium pump;
e) a steam generator inlet temperature sensor for sensing a heat transfer medium temperature at a steam generator inlet;
f) a steam generator outlet temperature sensor for sensing a heat transfer medium temperature at a steam generator outlet;
g) a steam temperature sensor for sensing a steam temperature in the steam generator;
h) a steam pressure sensor for sensing a steam pressure in the steam generator; and

i) a water level sensor for sensing a water level in the steam generator.

[0021] Typically the controller compares signals from at least one sensor to desired operating range and selectively controls the heat transfer medium pump in accordance with results of the comparison.

[0022] Typically the controller selectively controls the heat transfer medium pump in accordance with signals from at least one heat trap air temperature sensor.

[0023] Typically the controller selectively controls an external water supply for supplying water to the steam generator in accordance with signals from a water level sensor.

[0024] Typically the controller is for selectively storing signals from at least one sensor.

[0025] Typically the controller includes an electronic processing device.

[0026] Typically the electronic processing device includes a microprocessor, a memory, a input/output device, and an external interface.

[0027] Typically the steam turbine includes a turbine controller that controls a gate valve in accordance with signals from a turbine pressure sensor and turbine speed sensor to thereby selectively supply steam to the steam turbine.

[0028] Typically the apparatus includes heat transfer medium reservoir in fluid communication with a heat trap inlet.

[0029] Typically the apparatus includes a backflow prevention valve near a boiler heat transfer medium inlet.

[0030] In a second broad form the present invention seeks to provide a solar thermal generating apparatus including:

a) At least one heat trap including an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer material being heated by solar radiation;
b) A steam generator for generating steam using heat from the heated heat transfer medium; and

c) A steam turbine for generating electricity from the steam.

[0031] Typically the heat trap includes a double skinned insulated glass fronted box containing the evacuated tubes and pipes containing the heat transfer medium.

[0032] Typically the pipes runs along a floor of the heat trap and supports the evacuated tubes, thereby warming incoming heat transfer medium prior to entering the evacuated tubes.

[0033] Typically the apparatus includes:

a) A thermal collector array including a number of heat traps;
b) Heat transfer medium pipes for transporting heat transfer medium through the thermal collector array and the steam generator;
c) An electricity generator for generating electricity from rotation of the steam turbine;
d) A condenser for condensing steam output from the steam turbine;
e) Steam pipes for transporting steam from the steam generator to the steam turbine and then to the condenser;
f) Water pipes for transporting water from the condenser to the steam generator; and,

[0034] A frame for supporting the thermal collector array, the heat transfer medium pipes, the steam pipes, the water pipes, the steam turbine and the condenser.

Brief Description of the Drawings

[0035] An example of the present invention will now be described with reference to the accompanying drawings, in which: -

[0036] Figure 1 is a schematic diagram of an example of a solar thermal power apparatus;

[0037] Figure 2A is a schematic exploded view of an example of a heat box;

[0038] Figure 2B is a schematic plan view of an example of a heat box;

[0039] Figures 3A to 3C are schematic perspective, side and end views of an example of a steam generator;

[0040] Figure 4 is a schematic diagram of an example of a condenser;

[0041] Figures 5A and 5B are schematic front and rear views of an example of an assembly forming a scalable solar thermal power apparatus;

[0042] Figure 6A is a schematic perspective view of a second example of a steam generator;

[0043] Figure 6B is a schematic side view of the steam generator of Figure 6A;

[0044] Figure 6C is a schematic end view of the steam generator of Figure 6A;

[0045] Figure 7 is a schematic diagram of an example of a control system for a solar thermal power apparatus; and,

[0046] Figure 8 is a schematic diagram of a specific example solar thermal power apparatus.

Detailed Description of the Preferred Embodiments

[0047] An example solar thermal power apparatus will now be described with reference to Figure 1.

[0048] The solar thermal power generating apparatus includes at least one heat trap provided as part of a solar thermal collector array 111. The heat trap includes an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer medium being at least partially heated by solar radiation transmitted through the optically transparent portion. A steam generator 113 is provided for generating steam using heat from the heated heat transfer medium and a steam turbine 114 coupled to a generator 115 for generating electricity from the steam.

[0049] This provides a straightforward system for generating electrical power, allowing electricity to be generated at a low costs under a wide range of different ambient conditions. In particular, by providing the solar evacuated tubes in the housing of the heat trap, this maintains the tubes at a high ambient temperature, thereby helping further heat the heat transfer medium in addition to heating provided by incident sunlight.

[0050] In this regard, evacuated tubes typically consist of a copper or other similar pipe surrounded by an optically transparent tube (such as a glass tube), with a vacuum provided therein. An example of a commercially available evacuated tube collector is Product Code: CPC 1506/1512/1518 supplied by Genus Power SA.

[0051] The evacuated tubes act as a magnifying lens concentrating the heat of the sun onto a metal coating on the inside of the tube, with the coating then radiating heat into the copper pipe in the core of the evacuated tube. The metal coating is an array of layers of different metals and alloys which essentially reduces back radiation and directs the heat inwards. As the temperature increases the inner most layer of the metal coating becomes increasingly hot and radiates this heat to the copper pipe.

[0052] In the current arrangement, the heat trap includes an optically transparent portion, allowing solar radiation to be transmitted into the heat trap and onto the evacuated tubes, thereby heating the tubes. In one example, inner surfaces of the housing can be reflected to thereby increase the amount of solar radiation impinging on the tubes, thereby maximising heating.

[0053] However, in addition to this, further heating is achieved by thermal heating of ambient air in the heat traps.

[0054] In this regard, the optically transparent portion of the housing permits heating of the heat trap. As heat continues to enter the box but can not escape it increases in intensity. This increase is radiated to all the components within the heat trap, including the evacuated tubes. As such evacuated tubes are typically designed for use in hot water systems, they are purposefully designed to shed heat into the surrounding air so as to minimize the potential of injuring someone with very hot water. The shedding only works if the surrounding air temperature is significantly lower than the internal air temperature of the tubes. Should the air temperature be equal or slightly higher outside of the tube air spaces then this heat shedding can't occur. Accordingly, by providing the evacuated tubes in a heat trap, this ensures the tubes are surrounded by hot air, preventing heat shedding, and maximising the temperature of the heat transfer medium therein.

[0055] Additionally heat transfers into the medium via conduction through the walls of the copper pipe of the evacuated tubes, and any other connections, such as a manifold and connecting pipes, as will be described in more detail below. It will be appreciated that providing the tubes and connecting pipes in the heat trap ensures that the pipes reach equilibrium with the air temperature in the heat trap, so that the heat trap prevents heat loss from the tubes and the copper pipe and additionally contributes to the heating that would be obtained based on incident solar radiation alone.

[0056] Furthermore, as, the heat trap can be formed from robust materials, and can avoid the need for mirrors, this means the heat trap can be left exposed to the environment without risk from damage, and further protects the solar evacuated tubes, for example from hail or the like. Despite this, the heat traps can be cheap to manufacture, allowing a cheap energy solution to be provided.

[0057] The apparatus typically includes heat transfer medium transport pipes 121, 122 and a heat transfer medium pump 112 for circulating heat transfer medium through the at least one heat trap and the steam generator 113, thereby heating the heat transfer medium and transferring the heated heat transfer medium to the steam generator 113. At least one steam pipe 123 is used for transferring steam from the steam generator 113 to the steam turbine 114, with a condenser 116 being provided for condensing steam from the steam turbine 114 and at least one water pipe for returning water to the steam generator.

[0058] In one particular example, the solar thermal power apparatus includes of the solar thermal collector array 111, steam generator 113, steam turbine 114, and electricity generator 115, as described above. In addition a condenser 116, heat transfer medium, heat transfer medium transport pipes 121 and 122, steam pipes 123 and 124, liquid water pipes 125, an oil pump 112 and a water pump 117 are also provided.

[0059] In use, the solar thermal collector array 111 is connected via the heat transfer medium transport pipes 121 and 122, to the steam generator 113, allowing a heat transfer medium, such as a thermal oil, to be circulated through the solar thermal collector array 111 and the steam generator 113 under control of the heat transfer medium pump 112. The steam pipes 123, 124 are used to transfer steam to the steam turbine 114 and subsequently to the condenser 116, allowing liquid water to be return to the steam generator 113 via the liquid water pipes 125, optionally using a water pump 117. The steam turbine 114 is coupled to a generator 115, via an optional gearbox (not shown), allowing electricity to be generated.

[0060] In one example, each component can be modular in order to allow ease of replacement and to add additional components as and when required. Examples of the components will now be described in more detail.

[0061] The thermal collector array 111 typically includes of a two heat traps in the form of glass fronted insulated heat boxes containing from a number (such as twelve to twenty four) solar evacuated tubes and their associated plumbing. The thermal collection arrays' purpose is to collect heat and transfer it to the heat transfer medium contained in the solar evacuated tubes. The number of tubes selected and thermal collector arrays used will vary dependent on the installation and may depend on parameters such as the environment, and in particular the available solar radiation, the amount of electricity to be generated, or the like. A specific example heat box will be described in more detail below.

[0062] In one example, the heat transfer medium is a class C1 (Combustible Liquid) low viscosity mineral oil, such as transformer oil (BSI Caltex product code 1692), or Shell heat transfer oil s2 (product code: 001d8388). It will be appreciated that other heat transfer mediums, such as water or the like, could be used. However, the use of mineral oils is particularly beneficial as these typically have a high specific heat capacity, allowing a large amount of heat to be transferred. Additionally, such oils typically have a high boiling point, around 900°c, allowing the heat transfer medium to remain unpressurised within the thermal collector array 111 and the steam generator 113, without the risk of the heat transfer medium evaporating.

[0063] The heat transfer medium is contained within the plumbing of the thermal collector array 111 and the heat transfer medium transport pipes 121 and 122. The heat transfer medium is circulated using a suitable heat transfer medium pump 112, such as an oil pump. The speed of the heat transfer medium pump 112 can be controlled by an electronic controller, as will be described in more detail below, thereby allowing the flow rate of the heat transfer medium to be adjusted. The heat transfer mediums' purpose is to transfer heat from the thermal collector array to the steam generator 113, allowing steam to be generated for driving the steam turbine 114. In use, alteration of the flow rate of the heat transfer medium can be used to control the amount of heat energy transferred to the steam generator, and hence the amount of steam and hence electricity generated.

[0064] The heat transfer medium transport pipes 121 and 122 can include 15 mm diameter copper pipes. The heat transfer medium transport pipes' purpose is to act as a conduit for the heat transfer medium.

[0065] In one example, the steam generator 113 is a 13-chambered water boiler including of a length of coiled heat transfer medium transport pipes, a gate valve (for steam egress) and a swing check valve (for water ingress). However, a number of different configurations can be used as will be described in more detail below. The steam generators' purpose is to produce steam to power the steam turbine 114.

[0066] The steam turbine 114 can be any suitable back pressure steam turbine generator and typically includes the steam turbine, an optional gear box, generator 115, and electrical control panels. The steam turbines' purpose is the generation of electricity.

[0067] The condenser 116, typically includes a small tank of water with a connection from the exhaust steam pipe 124 steam turbine, and a water pipe 125 and water pump 117 connected to the steam generator. The purpose of the condenser is to capture exhaust steam, liquefy it and feed it back into the steam generator.

[0068] In one specific example, the steam turbine 114, the generator 115 and condenser 116 are formed as part of an integrated unit, such as a Green Turbine™ produced by Green Turbine BV, and similar to that described in International Patent Application no. PCT/NL2008/050631, although other arrangements can be used.

[0069] The fittings for the heat transfer medium transport pipes and water pipes can be any suitable 5 mm and 15 mm flare compression fittings or similar.

[0070] The thermal collector array includes one or more heat boxes containing a number of, typically twelve or twenty-four, solar evacuated tubes. The heat box typically includes a housing formed from inner and outer casings, with insulation provided between the inner and outer casings and a glass cover enclosing the housing. The heat trap includes heat transfer medium transfer pipes extending along a floor of the inner casing for circulating heat transfer medium through the evacuated tubes. The heat transfer medium transfer pipes are coupled to an inlet and outlet, as well as to the evacuated tubes via a manifold, allowing heat transfer medium to be circulated therethrough. At least one heat transfer medium transfer pipe can also be used to support the evacuated tubes so that incoming heat transfer medium is warmed prior to entering the evacuated tubes.

[0071] The structure of an example heat box is illustrated in Figures 2A and 2B and will now be described in further detail.

[0072] In this example, the heat box 200 includes an outer casing 201, which may be formed from an open topped folded and spot welded metal box with two diagonally separated circular 15 mm diameter holes for providing an inlet 202.1 and outlet 202.2 for the heat transfer medium transport pipes 122, 121, respectively. The outer casing provides structural integrity, a container to hold glass fibre insulation, and a surface mounting for an assembly frame.

[0073] The glass fibre insulation 204 is typically a bed of glass fibre insulation positioned on the floor and against the walls of the outer casing to reduce heat loss and to provide for the secure placement of an inner casing 203. It will be appreciated however that alternative forms of insulation can be used.

[0074] In this example, the inner casing 203 is an open topped folded and spot welded metal box with a circular 15mm diameter entry hole opposite the circular re-entry hole of the outer casing and an exit hole 15 mm diameter opposite the exit hole of the outer casing.

[0075] The inner casing 203 contains heat transfer medium transport pipes 202 and solar evacuated tubes 207, which in this example are connected to the heat transfer medium transport pipes 202 via a manifold 208. Five solar evacuated tubes 207 are shown in this example, but it will be appreciated that this is for the purpose of illustration only and that in practice any number of solar evacuated tubes 207 can be used.

[0076] The heat transfer medium transport pipes 202 are connected to the heat transfer medium pipes 122, 121 coming from outside of the thermal collector array 200, via the inlet and outlet 202.1, 202.2, allowing the flow of heat transfer medium to the solar evacuated tubes 207. The heat transfer medium transport pipe 202 is positioned on the floor of the inner casing in a series of loops that supports the weight of the solar evacuated tubes 207. Heat loss from the heat transfer medium transport pipe 202 within the inner casing 203 is absorbed by the solar evacuated tubes 207.

[0077] A bridging cover 205 is provided, which in one example is a square of welded metal, which connects the wall of the inner casing to those of the outer casing thus closing the metal box. The bridging cover 205 is welded to the walls of the two casings 201, 203, with detail

A-A' illustrating a 1mm bevelled inner edge of the bridging cover. The purpose of the bevelled edge is the support a glass cover 206 to the thermal collector array.

[0078] The glass cover 206 can be a 5mm thick glass cover sits on the 1mm bevel cut into the upper surface of the bridging cover 205 and is held in place by silicon sealant. The purpose the glass cover is to seal the thermal array, protect the solar evacuated tubes 207 and minimize heat loss back to the atmosphere.

[0079] In one example, the glass is a low reflective glass, such as Suntex™ low iron solar glass, to thereby maximise transmission of solar radiation into the heat box. Whilst a glass cover is described, it will be appreciated that this is for the purpose of example only and that in practice any optically transparent material can be used for any portion of the housing, such as a wall, cover, or the like, to thereby permit solar radiation to enter the casing.

[0080] Accordingly, in use solar radiation is able to enter the heat box 200 via the glass cover 206. The resulting heat is retained within the housing by a combination of the insulated housing and reflective surfaces, which prevent transmission of radiation through the housing. This allows the heat box to act like a green house, so that inside of the heat box has a significantly higher temperature than the surrounding environment. In one example, temperatures of 300°C are easily maintained under conditions of normal sunlight levels, thereby heating the heat transfer medium to a suitably high temperature for steam generation. It will be appreciated that in addition, the use of evacuated tubes also means that incident solar radiation also contributes to heating of the heat transfer medium.

[0081] By using a combination of trapped heat and solar radiation to heat the heat transfer medium, this ensures that a certain degree of heating occurs even in the event that incident solar radiation levels fall, for example due to cloud or the like, thereby maximising the amount of energy that can be recovered. Additionally , this means that cleaning of the glass cover is less important than cleaning the mirrors of traditional solar thermal power systems, allowing cleaning to be performed less frequently, if at all.

[0082] Furthermore, the heat traps can therefore be robust, protecting the evacuated tubes. In the event that the glass covers become damaged, for example from hail, these can easily be replaced.

[0083] Depending on the expected power output the environmental and geographical characteristics of the site the scalable solar thermal power system can have 2 or more groupings of thermal collector arrays i.e. 2 x thermal collector arrays, 4 x thermal collector arrays, 6 x thermal collector array ... Etc, each including one or more heat traps. It will be appreciated however that any suitable configuration used, depending on the preferred implementation, and a more detailed example will be described in more detail below.

[0084] An example steam generator will now be described in more detail with reference to Figures 3A to 3C.

[0085] In this example, the steam generator 113 includes a multiple chambered water boiler 300 including a length of coiled heat transfer medium transport pipes, a gate valve for steam egress, a swing check valve for water ingress. The role of the steam generator is to produce steam at sufficient temperature and pressure in order to drive a steam turbine.

[0086] The steam generator 113 typically includes an external case 310 made from steel in the shape of a cylinder with end plates, which in one example has a length 1000mm, width 500mm and height 500mm.

[0087] As shown in Figure 3B, external connections to the steam generator can include a steam outlet pipe 311 which is connected to a gate valve, a heat transfer medium transport pipe inlet 312, a heat transfer medium transport pipe outlet 313, and a water ingress pipe 314. The water ingress pipe 314 can include a 30mm diameter copper pipe providing a continuous feed of water into the boiler via a swing check valve.

[0088] In one example, the heat transfer medium transport pipe inlet 213 connects to a series of coiled 15mm copper pipes 316 within heat chambers 315 of the steam generator. The flow of the heat transfer medium along the coiled copper pipes 316 follows the arrows in Figure 3B.

[0089] Heat is transferred to the first heat chamber as the heat transfer medium moves through the coils, gradually depositing heat in successive heat chambers 315 until the heat transfer medium transport pipe outlet 313 is reached. This establishes a thermal cycle within the steam generator 113, as shown by the arrows in Figure 3C, which permits continuous mixing of hot and warm water. This gradually increases the temperature and the pressure with each successive movement of heat transfer medium through the coils of the copper pipe 316.

[0090] When steam of sufficient temperature and pressure 180°C / 0.8 MPa is attained steam is released into the steam pipe 123 and enters the steam turbine.

[0091] Two cool water/steam entry chambers 320 flank each central heating chamber 315. The cool water/steam entry chambers sit flush with the lower internal sides of the steam generator and allow cool water/steam to enter the central heating chamber via the cool water/steam vents.

[0092] A vortex generating chamber is formed by the space above the central heating chambers and cool water/steam entry chambers 317. This chamber has no internal structures and is the central water storage and mixing chamber within the steam generator. Vortexes are generated by hot water/steam rising out of the central heating chambers and striking the ceiling of the vortex generating chamber. This causes the stream of hot water/steam to split and travel down along the walls of the chamber until it enters the cool water/steam entry chambers. During this passage down the chamber wall the water/steam will mix with water/steam from the other chambers. This mixing will initially cause vortexes due to differing thermal characteristics of the fluid.

[0093] In one example, the steam turbine 114 is a back pressure steam turbine generator, such as a Shandong Zerchen Group Model B0.005-0.8/0.11. The steam turbine accepts steam from the steam generator via its steam inlet valve. Steam temperature / pressure at the steam inlet valve are no less than the minimum temperature and pressure to propel the turbine and therefore generate power within the specific steam turbine generator installed. The design is capable of accepting a range of Zerchen back pressure steam turbine generators from the 5kw to 500kw.

[0094] Used steam is exhausted via the steam outlet valve. The used steam travels along a steam pipe 124 to the condenser 116, an example of which will now be described in more detail with reference to Figure 4.

[0095] The condenser 400 is a single chamber device intended to convert the exhaust steam from the steam turbine generator into hot water suitable for re-ingestion into the steam generator. The condenser includes of a water tank 420 with the exhaust pipe 410 from the turbine terminating above the floor of the tank. This allows steam to directly enter the water as shown by the red arrow thereby heating the water and condensing the steam. The condenser outlet pipe 440, returns hot water as shown by the blue arrow to the steam generator via the hot water inlet pipe. When required additional water can be transported to the steam generator via the condenser. The condenser is un-pressurized and is progressively toped up via a water pipe connection to an external water supply 430.

[0096] However, alternatively the steam turbine 114, the generator 115 and condenser 116 are formed as part of an integrated unit, such as a Green Turbine™ produced by Green Turbine BV, and similar to that described in International Patent Application no. PCT/NL2008/050631. Such units can range in power from 1 kW to 15kW. However, it will be appreciated that a generator of any suitable power can be used depending on the configuration of the system. For example, in the event that additional power is required, the number of heat boxes 200 used can be increased, and used in conjunction with a larger steam generator 113, allowing additional steam, and hence additional power to be generated.

[0097] An example of an assembly in the form of a scalable solar thermal power system will now be described with reference to Figures 5A and 5B.

[0098] In this example, a frame, which supports the assembled structure, is made from metal tubing and metal sheets. The arrangement of the frame is dependent of the installation, and will vary from facility to facility.

[0099] The scalable solar thermal power generator includes the thermal collector array 510, containing the solar evacuated tubes, the heat transfer medium transport pipe 520 connecting the thermal collector array pipe exit point to the steam generator pipe entry point, and the heat transfer medium transport pipe 530 connecting the thermal collector array pipe entry point to the steam generator pipe exit point.

[0100] The scalable solar thermal power generator also includes the steam generator 540, the steam turbine generator 550, the condenser 560 and the assembly frame 570.

[0101] In one example, the electrical supplied by the steam generator 550 can be connected directly to a load, such as equipment to be powered. However, alternatively the electrical power may be provided to a storage system 580, such as batteries or the like, allowing electrical power to be drawn by a load from the storage system as required. This is particularly beneficial as this allows electrical power to be stored until it is required. Thus, during the day the solar power system can be used to charge the storage system, with electrical power being used throughout the day or night, as required. This can be used to ensure a continuous supply of power even in the absence of sunlight.

[0102] In one particular example, the storage system includes one or more Zinc-Bromine Flowing Electrolyte Batteries, such as those produced by RedFlow Limited. These are particularly beneficial due to their high storage capacity and high number of charge cycles. Additionally and/or alternatively, the generator could be used to supply electrical power directly into the mains electrical power grid, as will be appreciated by persons skilled in the art.

[0103] A second example of a steam generator that can be utilised with the above described solar thermal power station will now be described with reference to Figures 6A to 6B.

[0104] In this example, the steam generator 600 includes a substantially cylindrical steam generator body 610. In one example, the steam generator body is 1.4 m in length with a 0.76 m diameter, although it will be appreciated that alternative sizes can be used and this is not intended to be limited.

[0105] The steam generator body 610 includes a water inlet 621 for receiving water, and a steam outlet 622 for supplying steam to the generator 114 via the steam pipe 123. In use, water may be supplied to the water inlet 621 from the condenser 116, via the liquid water pipes 125, as well as from an external source, to top up water levels as may be required. This is generally performed to maintain a roughly constant water level, as shown generally at 616.

[0106] The steam generator body 610 also includes a heat transfer medium inlet 611 coupled to the heat transfer medium transport pipe 121 for receiving heat transfer medium from the at least one heat trap, and a heat transfer medium outlet 612 coupled to the heat transfer medium transport pipe 122, for supplying heat transfer medium to the at least one heat trap.

[0107] The heat transfer medium inlet and outlet 611, 612 are interconnected by a number of elongate heating pipes 613 extending substantially along a length of the cylindrical steam generator body 610. The heating pipes are interconnected via joining pipes 614 (shown in Figure 6A only) to provide a continuous fluid path between the heat transfer medium inlet and outlet 611, 612.

[0108] The heating pipes 613 are typically formed from a nickel-copper alloy and include a plurality of fins 615 extending radially outwardly from the heating pipes 613 to thereby increase the effective surface area of the heating pipes 613, and hence maximise transfer of heat from the heat transfer medium to water and/or steam in the steam generator body 600.

[0109] In the current example, the heating pipes 613 are arranged into first and second groups 613.1, 613.2. The second group of heating pipes 613.2 are positioned below the water level 616 so they are immersed in the water to thereby heat the water and generate steam. Steam collects in an upper region of the steam generator body 610 above the water level, where it is further heated by the first group of heat transfer pipes 613.1, to thereby generate super heated steam which is supplied via the steam outlet 622.

[0110] It will be appreciated from the above described arrangement that the heated heat transfer medium received from the heat boxes 111 is supplied via the inlet 611 to the first group of heating pipes 613.1, thereby providing maximum heat transfer to the steam, with slightly cooler heat transfer medium being supplied to the second group of heating pipes 613.2 to heat the water, and thereby generate steam. This maximises the resulting temperature and pressure of the steam, allowing for the production of super heated steam having a temperature of 200°C to 220°C at pressures of 10-12 bar. However, it will be appreciated that these parameters are for the purpose of example only, and in practice the temperature and pressure of the steam will depend on factors such as the temperature of the heat transfer medium, as well as the particular configuration of heating tubes 613.

[0111] In use, operation of the system is typically controlled using a controller that controls at least the heat transfer medium pump 112 to thereby selectively circulate heat transfer medium through the at least one heat trap and the steam generator 113. An example controller will now be described with reference to Figure 7.

[0112] In this example the controller 700 is in the form of an electronic processing device typically including a microprocessor 701, a memory 702 and optional input/output device

703, such as a keypad and display, and an external interface 704 interconnected by a bus 705. In use the external interface 704 is used to connect the controller 700 to a number of sensors.

[0113] The sensors can include at least one heat trap air temperature sensor 711, 712 for sensing a heat trap air temperature, a heat trap inlet temperature sensor 713 for sensing a heat transfer medium temperature at a heat trap inlet 201.1, and a heat trap outlet temperature sensor 714 for sensing a heat transfer medium temperature at a heat trap outlet 201.2. A heat transfer pump temperature sensor 721 may be provided for sensing a heat transfer medium temperature at the heat transfer medium pump 112.

[0114] Sensors may also be provided on the steam generator 113 including a steam generator inlet temperature sensor 731 for sensing a heat transfer medium temperature at a steam generator inlet 611, a steam generator outlet temperature sensor 732 for sensing a heat transfer medium temperature at a steam generator outlet 612, a steam temperature sensor 713 for sensing a steam temperature in the steam generator, a steam pressure sensor 714 for sensing a steam pressure in the steam generator, and a water level sensor 715 for sensing a water level in the steam generator 113.

[0115] The controller 700 is also adapted to provide control signals to the heat transfer medium pump 112, as well as an optional external water supply 730, allowing operation of the heat transfer medium pump 112 to be controlled, as well as to allow additional water to be supplied to steam generator 113.

[0116] The steam turbine 114 typically includes an internal turbine controller having a steam pressure sensor and speed sensor which form part of the turbine controller. In one example the turbine is a green turbine similar to that described in the international patent application no. PCT/NL2008/050631 which incorporates a turbine controller as mentioned above.

[0117] In use the controller 700 is adapted to receive signals from the sensors, interpret the signals to determine the current operating parameters of the solar thermal apparatus and then control operation of the heat transfer medium pump 112 and, optionally the water supply 730, accordingly. In particular, the controller 700 can compare signals from at least one sensor to desired operating range and selectively controls the heat transfer medium pump in accordance with results of the comparison.

[0118] For example, the controller can selectively control the heat transfer medium pump in accordance with signals from at least one heat trap air temperature sensor, and selectively control an external water supply for supplying water to the steam generator in accordance with signals from a water level sensor.

[0119] To achieve this, the microprocessor 701 typically executes instructions stored in the memory 702, for example as applications software. It will be appreciated from this that the controller 700 can be any form of electronic processing device such as a microprocessor, microchip processor, logic gate configuration, firmware optionally associated with implementing logic such as an FPGA field programmable gate array, or any other electronic device, system or arrangement, and that the example of Figure 7 is for the purpose of illustration only.

[0120] Operation of the controller 700 to control the solar thermal system will now be described.

[0121] Typically, the start-up process for the solar thermal system is completely automated and will only commence when the parameters required for operation of the heat boxes 111, the steam generator 113 and steam turbine 114 are met.

[0122] In particular, the controller 700 uses signals from the temperature sensors 711, 712 associated with each heat box to determine an air temperature averaged across all heat boxes 111. When the temperature reaches a predetermined temperature threshold stored in memory 702, which is sufficient to heat the steam generator 113, the controller 700 activates the heat transfer medium pump 112. This causes heat transfer medium to be circulated through the heat boxes 111 and steam generator 113, thereby heating the water in the steam generator 113.

[0123] At this time the controller 700 uses signals from the water level sensor 715 to ensure that the water level is at the required level when the heat transfer medium pump 112 is activated. Should the water level be below the required level, then external water is automatically added from the external supply 730, until the required water level is attained.

[0124] Following activation of the heat transfer medium pump 112, heat transfer medium will be heated and thereby cause the temperature in the steam generator 113 to increase, thereby generating steam, which is supplied to the steam turbine 114.

[0125] In one example, the steam turbine includes an in-built turbine controller (not shown) that controls a gate valve (not shown) in accordance with signals from a turbine pressure sensor (not shown) and turbine speed sensor (not shown) to thereby selectively supply steam to the steam turbine. In particular, the turbine controller monitors the temperature and pressure of the steam supplied to the turbine, and the steam temperature and pressure reach predetermined levels then the gate valve to the steam turbine is opened and the turbine begins operation.

[0126] During normal operation, the controller 700 monitors the heat transfer medium temperature, and uses this to control the heat transfer medium pump 112, and hence the amount of heat supplied to the steam generator 113. In this regard, if the heat transfer medium pump 112 speed is increased, this will increase the amount of heat supplied to the steam generator 113. This can therefore be used to maintain required operating parameters even if the temperature within the heat box alters, for example depending on the amount of ambient sunlight.

[0127] The controller 700 will typically control the heat transfer medium pump 112 depending on whether the parameters fall within normal operating ranges. For example, if the steam temperature and/or pressure rise above safe limits, the heat transfer pump 112 can be deactivated or reduced in speed, to reduce the transfer of heat to the steam generator, thereby allowing the temperature and/or pressure to fall back within normal limits.

[0128] The controller 700 can also control a shut-down process, which is implemented when the parameters required for non-operation or un-safe operation of the heat boxes 111, steam generator 113 or steam turbine 114 are met. This can be determined by comparing signals from any one of the sensors to desired operating ranges, for example stored in the memory 702, and selectively controls the heat transfer medium pump in accordance with results of the comparison. For example, if signals from the sensors indicate any temperatures or pressures are outside the defined operating ranges, the controller 700 can stop operation of the apparatus by stopping the heat transfer medium pump.

[0129] Thus, if the temperature averaged across all heat box temperature sensors 711, 712, 713, 714 drops below a predetermined average temperature, the controller deactivates the heat transfer medium pump 112. This stops circulation of the heat transfer medium and allows the steam generator 113 to cool. Similarly, if the steam temperature and pressure or fall below or above predetermined limits, then the turbine controller similarly deactivates the heat transfer medium pump 112.

[0130] In either case, when the heat transfer medium pump is deactivated a turbine steam valve can also be automatically shut (for example under control of the steam turbine controller), causing the turbine to stop generating electricity.

[0131] In use, information from each of the sensors 711, 712, 713, 714, 721, 731, 732, 733, 734, 735 can be stored, for example in memory 702, or in an external store, allowing operation of the system to be reviewed. This information can be stored with a unique code designating the equipment item type and its unique identifier, the date the information was gathered and the number start/stop time of the diurnal operating cycle in which it was operating, allowing operation of the system to be subsequently analysed and any problems diagnosed.

[0132] Typically the solar thermal system needs to be taken off line and the systems shut down, so that the heat transfer medium level and condition can be examined, and topped up or replaced. During this process, the steam turbine condition can be ascertained and any remedial action taken if required, and the condition of the boiler and its ancillary equipment determined.

[0133] A specific example of a particular solar thermal apparatus will now be described with reference to Figure 8. In this example, like reference numerals are used to refer to the components described above.

[0134] In this example, the apparatus 800 includes two heat boxes 200, connected via heat transfer medium pipes 821, 822, to the steam generator 600, with a heat transfer pump 812 being used to circulate heat transfer medium therethrough. The steam generator 600 is coupled to a steam turbine 814, in this example, the Green Turbine™ described above, via steam pipes 823, 824. The steam turbine 814 is coupled to an energy store, such as Zinc-

Bromine Flowing Electrolyte Batteries 834, allowing regulated power to be supplied as required, including at night when the apparatus is no longer generating power. A controller 700 is provided for controlling the heat transfer medium pump 812 and a water supply 833 for supplying water to the steam generator 600.

[0135] In this example, the solar thermal power apparatus 800 further includes a heat transfer medium reservoir 831, for containing heat transfer medium. The reservoir 831 is typically coupled to the heat transfer medium pipe 822, at or near the inlet 202.1 of the heat trap, which generally corresponds to the coolest point in the heat transfer medium circuit defined by the heat traps 200, steam generator 600 and the heat transfer medium pipes 821, 822. The heat transfer medium reservoir 831 allows for expansion of the heat transfer medium, and also allows the heat transfer medium to be drained from the system, for example if the system is being transported.

[0136] The solar thermal power apparatus also includes a back flow prevention valve provided in the heat transfer pipe 821, near the inlet 612 of the steam generator. This prevents back flow of the heat transfer medium in the event of turbulence in the team generator, as may occur for example during heating up or cooling down of the heat transfer medium.

[0137] In use, the solar thermal power apparatus 800 can be used in a modular fashion, with each module 800 including the components shown in Figure 8, although in some examples common energy storage 834 can be used for different modules.

[0138] The modules 800 can be mounted on respective frames, similar to that described above with respect to Figure 5, to provide a fully self-contained compact unit capable of operating away from fixed infrastructure sites. The size and weight of each module 800 means that it can be mounted on an off-road trailer or the back of a four-wheel drive. The modules 800 are also air portable, and can be flown as a slung load under a helicopter or in the cargo bay of a fixed wing transport aircraft.

[0139] In use, each module 800 can generate between 5kW and 15kW of electricity, depending on ambient conditions, and the number of heat boxes and solar tubes used in each heat box. By combining a number of modules 800 larger power generation capabilities can be achieved. For example, an array of 420 15 kW modules 800 to generate 3.15MW for daytime use and to store 3.15MW for night-time use.

[0140] When forming an array, the modules 800 may be provided in a triangular arrangement so as to reduce shadows from adjacent modules. The heat boxes 200 can also be provided orientated towards the sun, and may optionally be provided on a tracking platform, allowing the glass cover to face towards the sun and maximise the solar radiation incident on the solar evacuated tubes. However, it will be appreciated that this is not essential and static arrangements can be used.

[0141] In one example, the array includes modules divided into two groups, one for generating electricity for daily electricity consumption and another for charging a battery farm for night-time electricity consumption, although this is not essential and other arrangements can be used.

[0142] In one example, each module 800 is interconnected by a medium voltage (usually 34.5 kV) power collection system and a communications network. The medium voltage power collection system then terminates at an electricity substation, where medium-voltage electrical current can be increased in voltage via a step-up transformer for connection to the high voltage transmission system.

[0143] Even when provided as an interconnected array, each module 800 can operate independently of its neighbours, allowing it to be brought on line and off line without affecting the performance of the array as a whole.

[0144] The array described above, including the transmission cables and electricity substation covers an acre of land. This compares favourably with traditional solar thermal power plants, which require 20 acres for a similar sized facility, (Sierra Sun Tower, in California).

[0145] It will be appreciated however that the arrangement can be scaled to any size, and for any power generating requirements. For example, a 40 MW combined array would extend over a 14.23-acre block of land, whilst a traditional solar thermal power station generating the equivalent amount of electricity would require 247 acres (Alvarado 1 facility in Spain). Despite this, economies of scale mean the power plant could be manufactured for up to 60%

less than a traditional solar thermal power plant (based on internationally averaged manufacture costs per watt).

[0146] Additionally, unlike traditional solar thermal power plants combined arrays and are not limited to flat ground, allowing individual modules to be arranged on any terrain type that allows the module 800 to face the sun. This includes, mountainous, industrial, semi-urban and urban environments.

[0147] Additionally modules 800 do not need to be adjacent to other modules 800 in order to form an array, for example if used in built up areas or regions having severe land use restrictions. Accordingly, this allows the above described arrangement to allow a solar thermal power plant with sufficient generating capacity to be established in areas where traditional solar thermal power plants cannot.

[0148] Despite this, the modules 800 can also be used separately, for example for domestic purposes, allowing heat boxes to be roof mounted or provided in other suitable locations. Again, the heat boxes 200 can also be provided orientated towards the sun, and may optionally be provided on a tracking platform.

[0149] It will be appreciated that the above described arrangement can be used to provide a scalable solar thermal power plant capable of generating electricity. The system utilises heat boxes containing evacuated tubes, used to transport a heat transfer medium, such as a thermal oil, to a steam generator. The generated steam can then be used to generate electricity, for example using a steam turbine. The heat boxes are cheap and easy to construct, whilst being robust and capable of protecting the evacuated tubes from the environment. Furthermore, by increasing the number of heat boxes and/or evacuated tubes per heat box, the amount of heat energy available to heat the thermal oil can be increased, thereby increasing the steam generating capacity of the steam generator, and hence the amount of electricity produced. It will therefore be appreciated that this allows the capacity of the system to be adjusted to suit a wide range of applications.

[0150] The traditional arrangement for solar thermal power generation is to have a large field of reflectors focusing sunlight upon either tubes containing water or a boiler, which then uses the heat to produce steam and drive a turbine generator. The traditional arrangement is good for large-scale applications such as a town, but is not easily scalable and cannot be transported. In contrast to this, the above described system provides a scalable and transportable solar thermal power system, which can be used in a traditional field array arrangement capable of powering a small town, domestically as a single unit providing electricity to a family, or as a transportable unit to provide electricity to remote sites for mining, construction and other activities.

[0151] This allows a scalable and portable solar thermal electricity generating system to be deployed using commercial off the shelf components, and can provide enough electricity and capacity to power various domestic, industrial and urban installations.

[0152] In one particular example, the scalable solar thermal power system includes of a thermal collector array, for light and heat conversion, pipes for heat collection and transportation using a heat transfer medium, a steam generator, and a commercially available steam turbine generator, to generate electricity.

[0153] The thermal collector array is composed of solar evacuated tubes contained within one or more insulated glass fronted heat traps and linked by an array of copper pipes. The copper pipes contain a heat transfer medium, which is exposed to solar thermal heating within the solar evacuated tubes.

[0154] The heat traps, containing the solar evacuated tubes and copper pipes with its internal heat transfer medium include double skinned insulated glass fronted boxes. Copper pipes run along the floor of the heat trap and supports the solar evacuated tubes. The purpose of the heat trap is to ensure that only minimal thermal loss occurs and that incoming heat transfer medium is warmed prior to entering the solar evacuated tubes.

[0155] The solar evacuated tubes can be an array of commercially sourced solar thermal tubes connected via copper pipes to a spine including of copper pipes. The solar evacuated tubes have an internal carriage system for the heat transfer medium. The solar evacuated tube arrays are contained within the heat traps and connected directly to the copper pipes supporting them. The heat transfer medium moves from the cooler side of the array to the hotter side within the heat trap. The hot heat transfer medium temperature is further boosted in any supplemental thermal collector arrays, should they be required.

[0156] The number of solar evacuated tubes within each heat trap and the number of thermal collector arrays used depends on the latitude of the installation. In tropical climates less tubes and heat traps are required than in temperate and polar climates.

[0157] Providing a closed circuit from the thermal collector arrays to the steam generator and back into the solar thermal arrays. The movement of the heat transfer medium is achieved via a pressure differentiation established by the thermal difference across the system. Hot heat transfer medium travels towards the cold heat transfer medium generating current within the heat transfer system. Alternatively a pump can be used to ensure heat transfer medium flow.

[0158] The heat transfer medium exits the solar thermal array and enters the steam generator via an insulated copper pipe. The steam generator is a boiler based on the fire box boiler design. The heat transfer medium is maintained within copper pipes inside the steam generator. The steam is produced by the exposure of the water to the surface area of the hot copper pipes within the barrel of the boiler.

[0159] The heat transfer medium becomes cooler as it travels through the steam generator and exits at a lower temperature. The heat transfer medium is then fed back into the thermal collector array, thus completing the cycle. Each time the heat transfer medium travels through the steam generator more heat is deposited into the water contained within. As the water boils steam is generated and the pressure within the boiler increases. When the steam reaches the desired temperature and pressure it is released into a commercially available small steam turbine generator. The commercially available small steam turbine generator uses the steam from the steam generator to power an electric generator. The used steam is fed into a condenser and returned to the steam generator.

[0160] Accordingly, a scalable solar thermal power system can be constructed which uses solar evacuated tubes as the heat source. The scalable solar thermal power system can be a single unit construction with all components making up an integral package, which can be moved as a single unit. The scalable solar thermal power system can be scaled up by simply connecting additional scalable solar thermal power systems up to a single distribution system to meet any power demands for any facility or urban area, or operated individually for small-scale electricity requirements. The scalable solar thermal power system can be mounted on a trailer or flat bed vehicles and operated in remote locations or areas where electricity supply has been disrupted. The scalable solar thermal power system does not need to be permanently fixed in a single geographical location in order to function.

[0161] The scalable solar thermal power system can be assembled using a mixture of commercially available solar evacuated tubes and a back pressure steam turbine generator and a bespoke steam generator and heat box. Typically the thermal collector array can generate sufficient heat and can transfer that heat to a heat transfer medium, which can deliver sufficient heat to a steam generator to produce steam at the appropriate temperature and pressure to drive a back pressure steam turbine generator.

[0162] The design of the scalable solar thermal power system can be modular to allow the installation of additional thermal collector arrays or there removal, and larger or smaller steam turbine generators depending on need of the installation. There is no set design for the assembly frame, and the arrangement can depend on the geographic, environmental and power requirements of each installation.

[0163] Accordingly, this allows the solar thermal apparatus to be configured for small or large scale applications and to be either installed in a permanent location or configured for mobile use.

[0164] It is to be appreciated that reference to "one example" or "an example" of the invention is not made in an exclusive sense. Accordingly, one example may exemplify certain aspects of the invention, whilst other aspects are exemplified in a different example. These examples are intended to assist the skilled person in performing the invention and are not intended to limit the overall scope of the invention in any way unless the context clearly indicates otherwise.

[0165] Features that are common to the art are not explained in any detail as they are deemed to be easily understood by the skilled person. Similarly, throughout this specification, the term "comprising" and its grammatical equivalents shall be taken to have an inclusive meaning, unless the context of use clearly indicates otherwise.

[0166] Persons skilled in the art will appreciate that numerous variations and modifications will become apparent. All such variations and modifications which become apparent to persons skilled in the art should be considered to fall within the spirit and scope of the invention broadly appearing and described in more detail herein.

[0167] The examples presented within this document are intended to give an impression of the components and overall structure of the invention. Some installations, as a result of climate or geographic conditions may result in a modification of the number of components or a modification of the arrangement of components. The purpose of the examples is to illustrate the key components in an ideal arrangement for climatic conditions likely to be found in South East Queensland.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1) A solar thermal power apparatus including:
   a) at least one heat trap including an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer medium being at least partially heated by solar radiation transmitted through the optically transparent portion;
   b) a steam generator for generating steam using heat from the heated heat transfer medium; and
   c) a steam turbine coupled to a generator for generating electricity from the steam.
2) Apparatus according to claim 1, wherein the apparatus includes heat transfer medium transport pipes and a heat transfer medium pump for circulating heat transfer medium through the at least one heat trap and the steam generator.
3) Apparatus according to claim 1 or claim 2, wherein the apparatus includes at least one steam pipe for transferring steam from the steam generator to the steam turbine.
4) Apparatus according to any one of the claims 1 to 3, wherein the apparatus includes a condenser for condensing steam from the steam turbine and at least one water pipe for returning water to the steam generator.
5) Apparatus according to any one of the claims 1 to 4, wherein the housing includes:
   a) an outer casing;
   b) an inner casing;
   c) insulation provided between the inner and outer casings; and,
   d) a glass cover.
6) Apparatus according to claim 5, wherein each heat trap includes heat transfer medium transfer pipes extending along a floor of the inner casing for circulating heat transfer medium through the evacuated tubes.
7) Apparatus according to claim 6, wherein the heat transfer medium transfer pipes are coupled to the evacuated tubes via a manifold.
8) Apparatus according to claim 6 or claim 7, wherein the heat transfer medium transfer pipes are coupled to an inlet and an outlet respectively, the inlet and outlet being coupled to heat transfer medium pipes for circulating heat transfer medium through the steam generator.

9) Apparatus according to any one of the claims 6 to 8, wherein at least one heat transfer medium transfer pipe supports the evacuated tubes so that incoming heat transfer medium is warmed prior to entering the evacuated tubes.

10) Apparatus according to any one of the claims 1 to 9, wherein the steam generator includes a steam generator body having:

   a) a water inlet for receiving water;
   b) a steam outlet for supplying steam;
   c) a heat transfer medium inlet for receiving heat transfer medium from the at least one heat trap; and,
   d) an outlet for supplying heat transfer medium to the at least one heat trap.

11) Apparatus according to claim 10, wherein the steam generator includes a number of elongate heating pipes extending substantially along a length of the steam generator body.

12) Apparatus according to claim 11, wherein the heating pipes are interconnected using joining pipes.

13) Apparatus according to claim 11 or claim 12, wherein the heating pipes include a plurality of fins to thereby increase the effective surface area of the heating pipes.

14) Apparatus according to any one of the claims 11 to 13, wherein the heating pipes are arranged in first and second groups, the second group of heating pipes being immersed in water to thereby generate steam and the first group of heating pipes heating the steam.

15) Apparatus according to any one of the claims 1 to 15, wherein the apparatus includes a controller for controlling a heat transfer medium pump to thereby selectively circulate heat transfer medium through the at least one heat trap and the steam generator.

16) Apparatus according to claim 15, wherein the controller is coupled to at least one of:

   a) at least one heat trap air temperature sensor for sensing a heat trap air temperature;
   b) a heat trap inlet temperature sensor for sensing a heat transfer medium temperature at a heat trap inlet;
   c) a heat trap outlet temperature sensor for sensing a heat transfer medium temperature at a heat trap outlet;
   d) a heat transfer pump temperature sensor for sensing a heat transfer medium temperature at the heat transfer medium pump;
   e) a steam generator inlet temperature sensor for sensing a heat transfer medium temperature at a steam generator inlet;

f) a steam generator outlet temperature sensor for sensing a heat transfer medium temperature at a steam generator outlet;
g) a steam temperature sensor for sensing a steam temperature in the steam generator;
h) a steam pressure sensor for sensing a steam pressure in the steam generator; and
i) a water level sensor for sensing a water level in the steam generator.

17) Apparatus according to claim 16, wherein the controller compares signals from at least one sensor to desired operating range and selectively controls the heat transfer medium pump in accordance with results of the comparison.

18) Apparatus according to claim 16 or claim 17, wherein the controller selectively controls the heat transfer medium pump in accordance with signals from at least one heat trap air temperature sensor.

19) Apparatus according to any one of the claims 16 to 18, wherein the controller selectively controls an external water supply for supplying water to the steam generator in accordance with signals from a water level sensor.

20) Apparatus according to any one of the claims 16 to 19, wherein the controller is for selectively storing signals from at least one sensor.

21) Apparatus according to any one of the claims 16 to 20, wherein the controller includes an electronic processing device.

22) Apparatus according to claim 21, wherein the electronic processing device includes a microprocessor, a memory, a input/output device, and an external interface.

23) Apparatus according to any one of the claims 1 to 22, wherein the steam turbine includes a turbine controller that controls a gate valve in accordance with signals from a turbine pressure sensor and turbine speed sensor to thereby selectively supply steam to the steam turbine.

24) Apparatus according to any one of the claims 1 to 23, wherein the apparatus includes heat transfer medium reservoir in fluid communication with a heat trap inlet.

25) Apparatus according to any one of the claims 1 to 24, wherein the apparatus includes a backflow prevention valve near a boiler heat transfer medium inlet.

26) A solar thermal generating apparatus including:

a) At least one heat trap including an housing having an optically transparent portion and containing one or more evacuated tubes containing a heat transfer medium, the heat transfer material being heated by solar radiation;

b) A steam generator for generating steam using heat from the heated heat transfer medium; and

c) A steam turbine for generating electricity from the steam.

27) Apparatus according to claim 26, wherein the heat trap includes a double skinned insulated glass fronted box containing the evacuated tubes and pipes containing the heat transfer medium.

28) Apparatus according to claim 27, wherein the pipes runs along a floor of the heat trap and supports the evacuated tubes, thereby warming incoming heat transfer medium prior to entering the evacuated tubes.

29) A solar thermal generating apparatus according to any one of the claims 24 to 26, wherein the apparatus includes:

a) A thermal collector array including a number of heat traps;

b) Heat transfer medium pipes for transporting heat transfer medium through the thermal collector array and the steam generator;

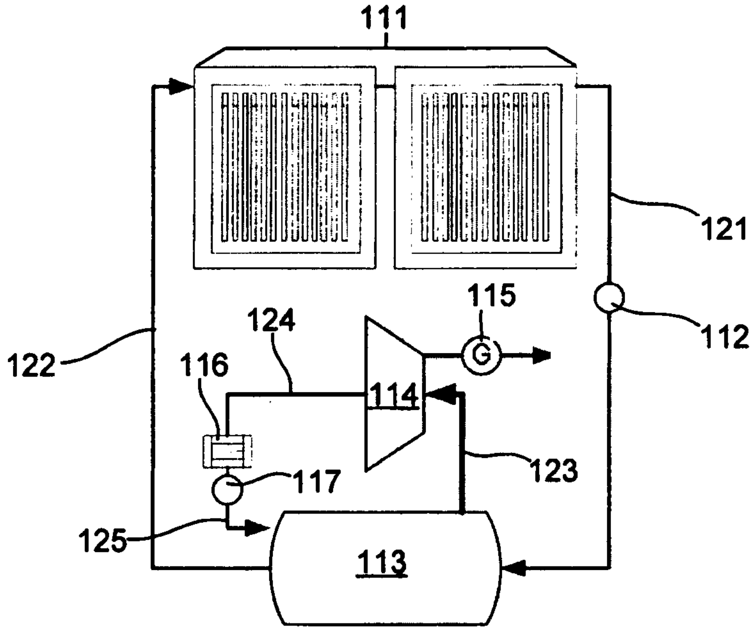
c) An electricity generator for generating electricity from rotation of the steam turbine;

d) A condenser for condensing steam output from the steam turbine;

e) Steam pipes for transporting steam from the steam generator to the steam turbine and then to the condenser;

f) Water pipes for transporting water from the condenser to the steam generator; and,

g) A frame for supporting the thermal collector array, the heat transfer medium pipes, the steam pipes, the water pipes, the steam turbine and the condenser.


111
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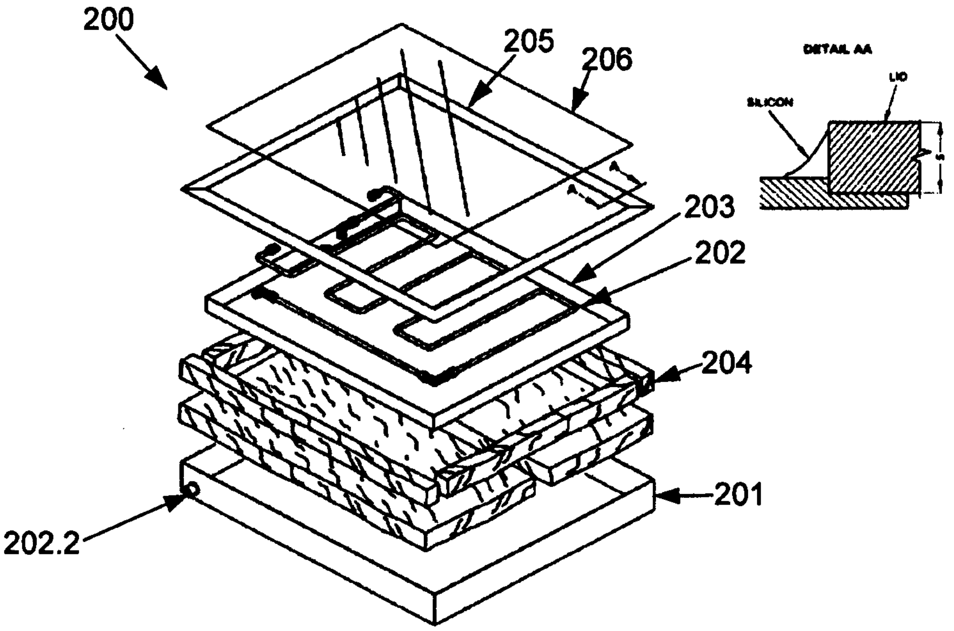
113

Fig. 1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205
206
203
202
204
201
202.2
DETAIL AA
SILICON
LID

Fig. 2A

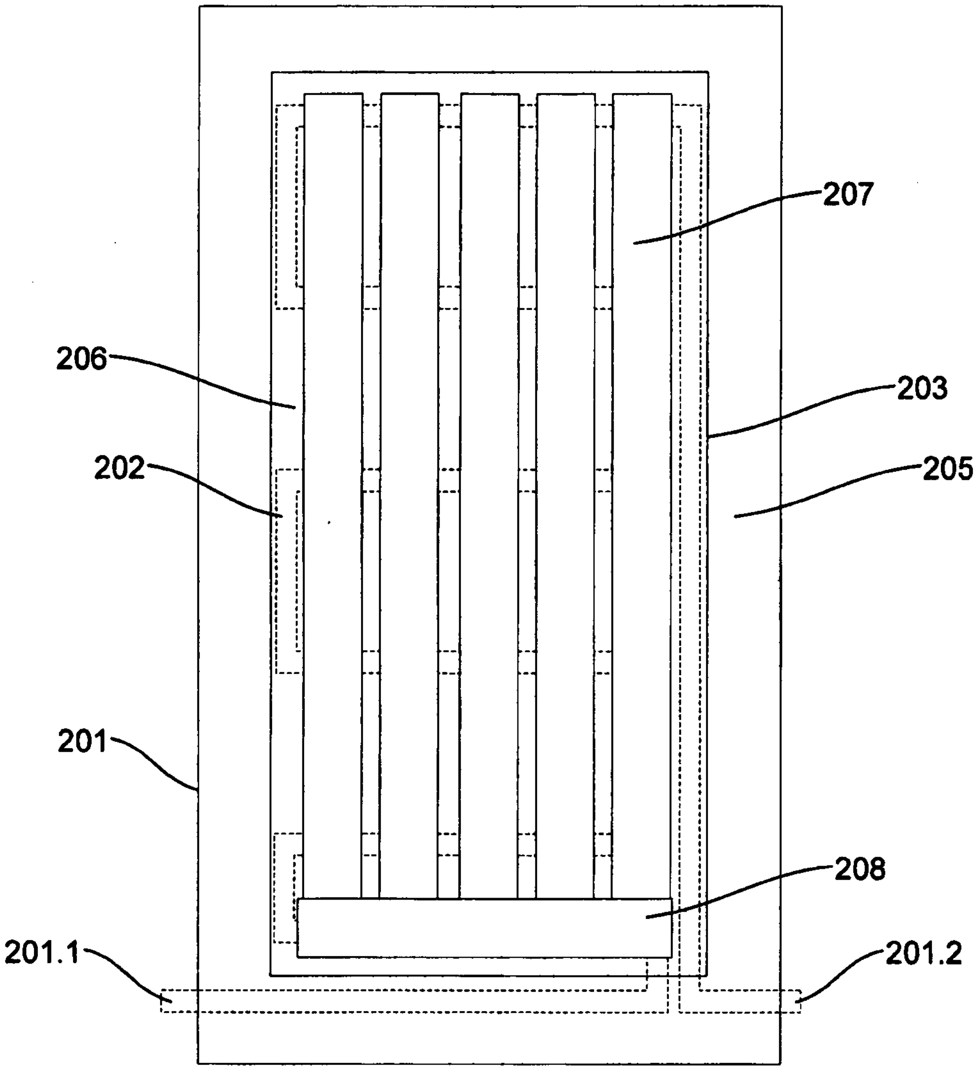


Fig. 2B

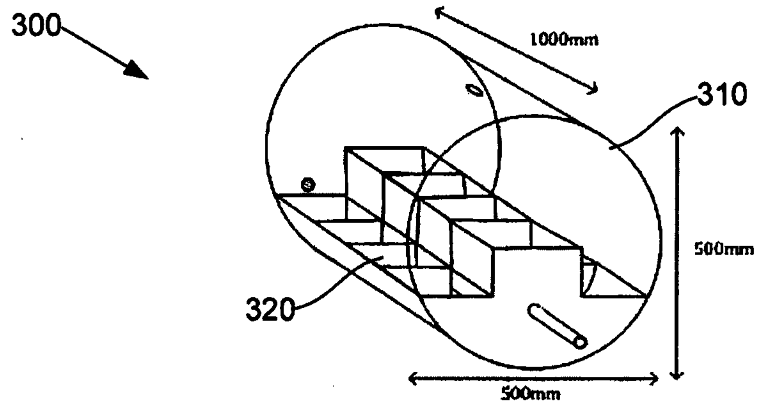
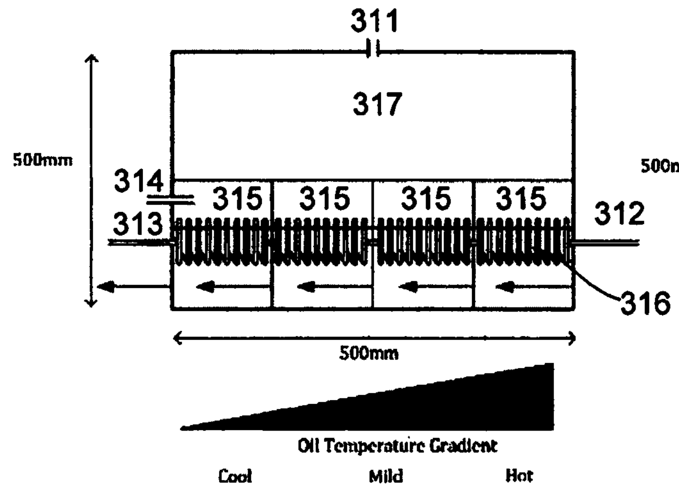


Fig. 3A



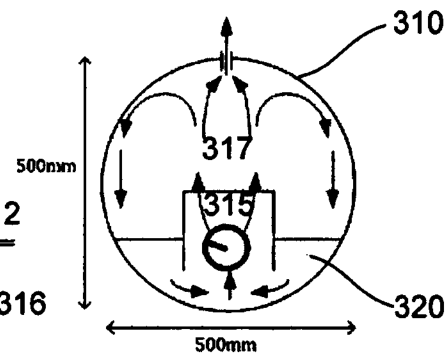


Fig. 3B **Fig. 3C**

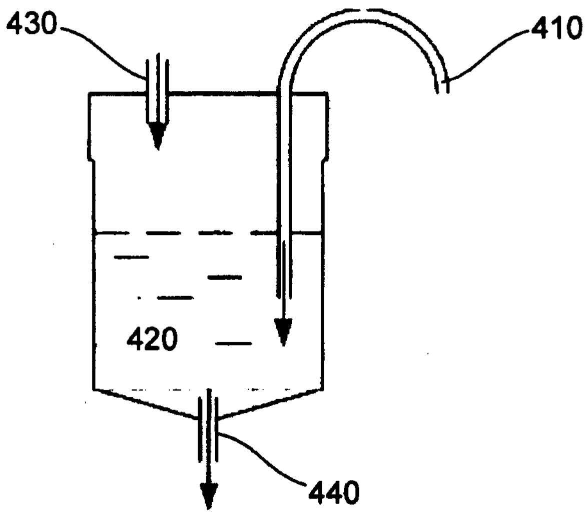


Fig. 4

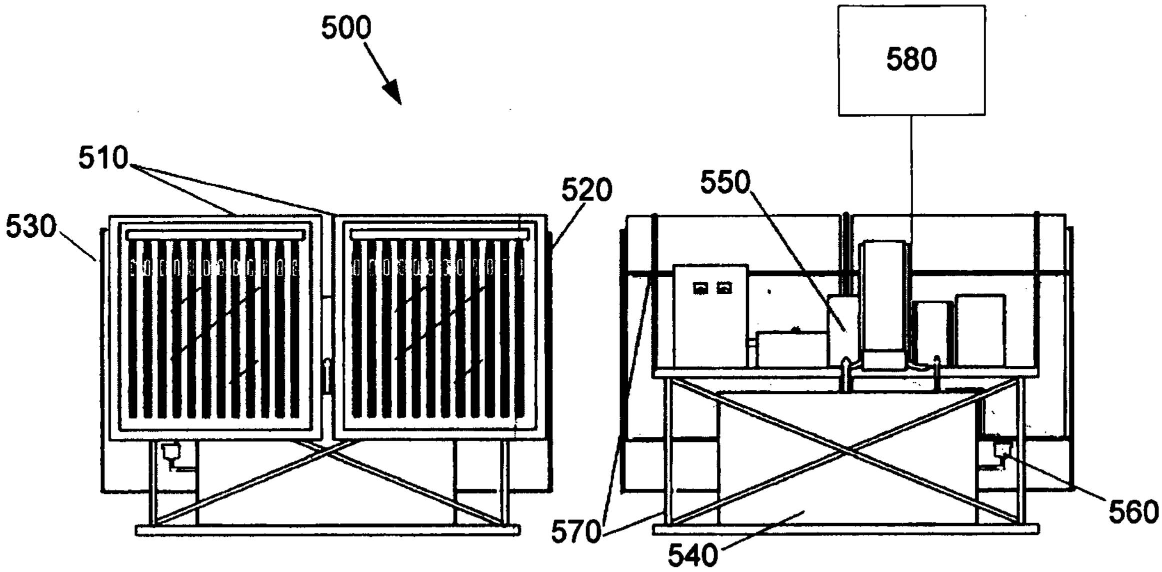


Fig. 5A **Fig. 5B**

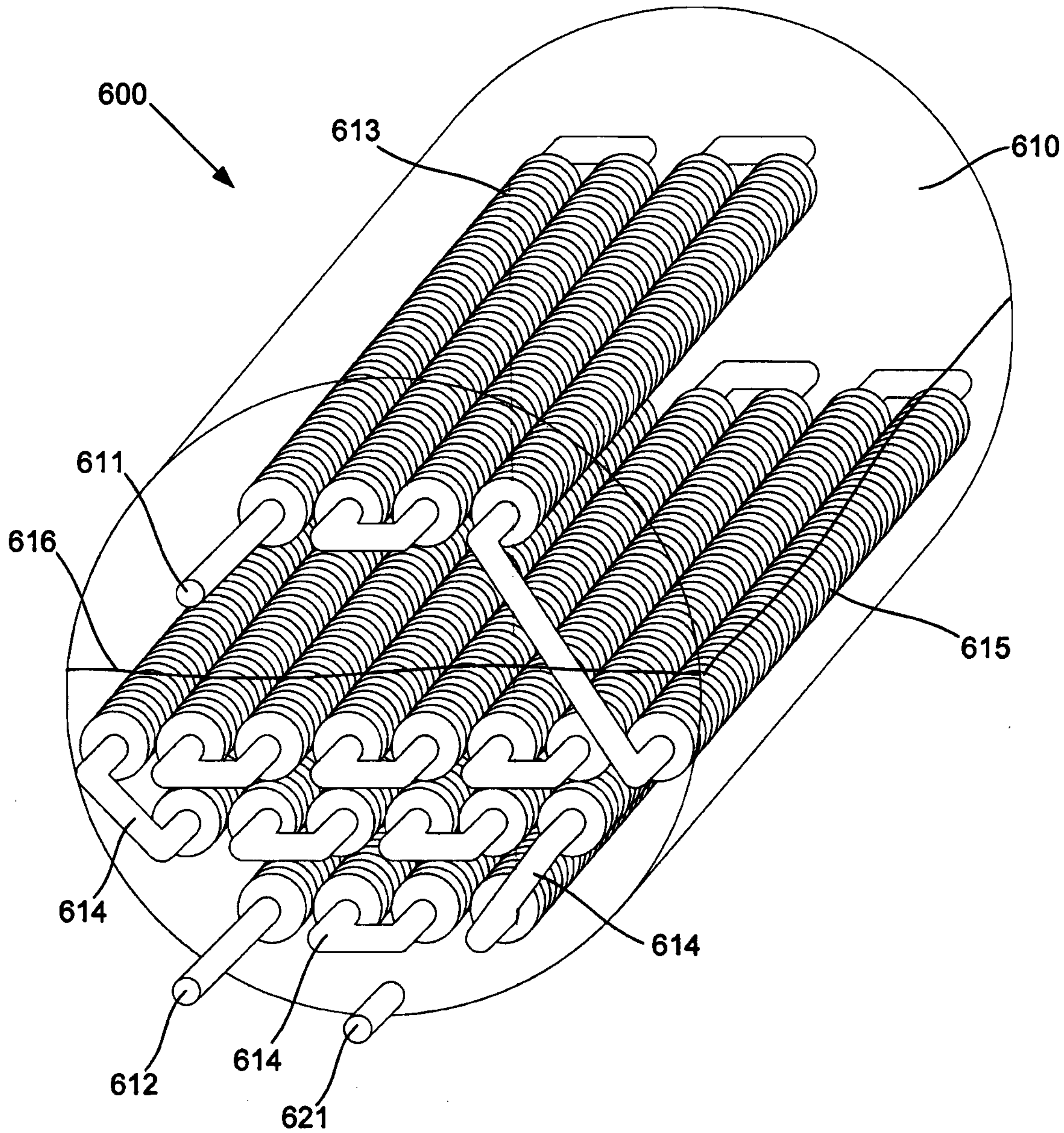


Fig. 6A

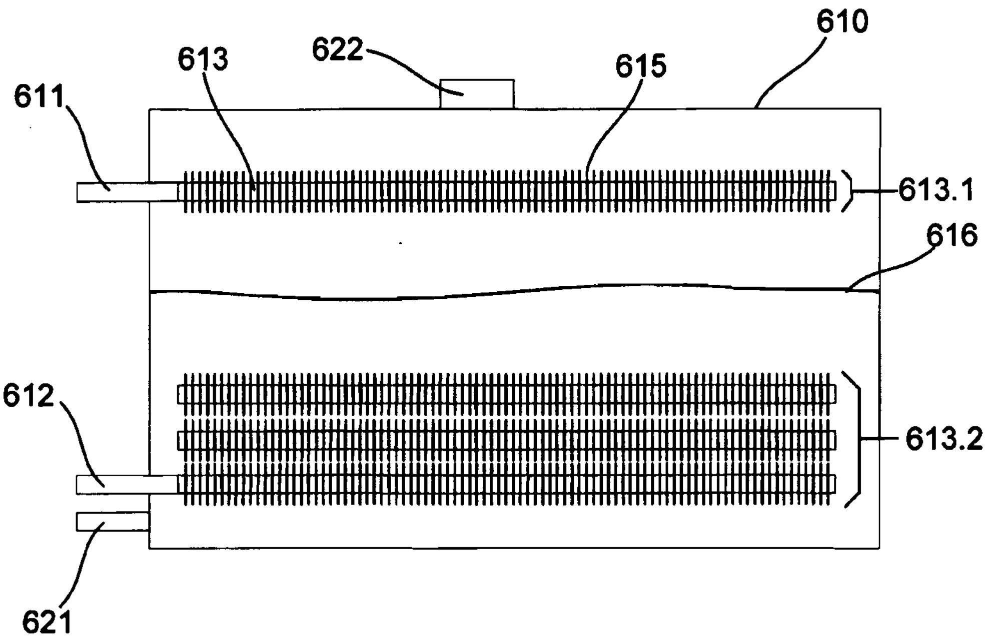


Fig. 6B

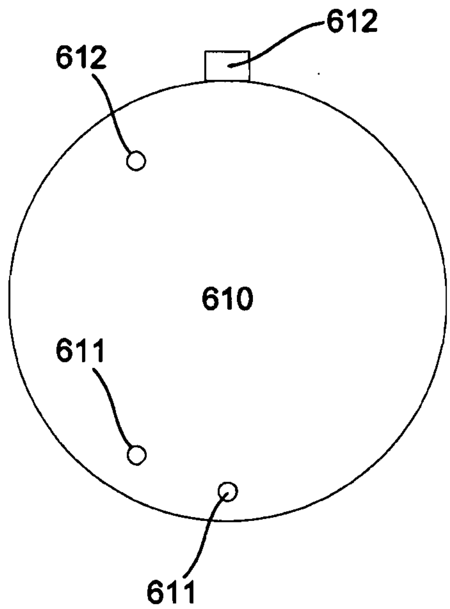


Fig. 6C

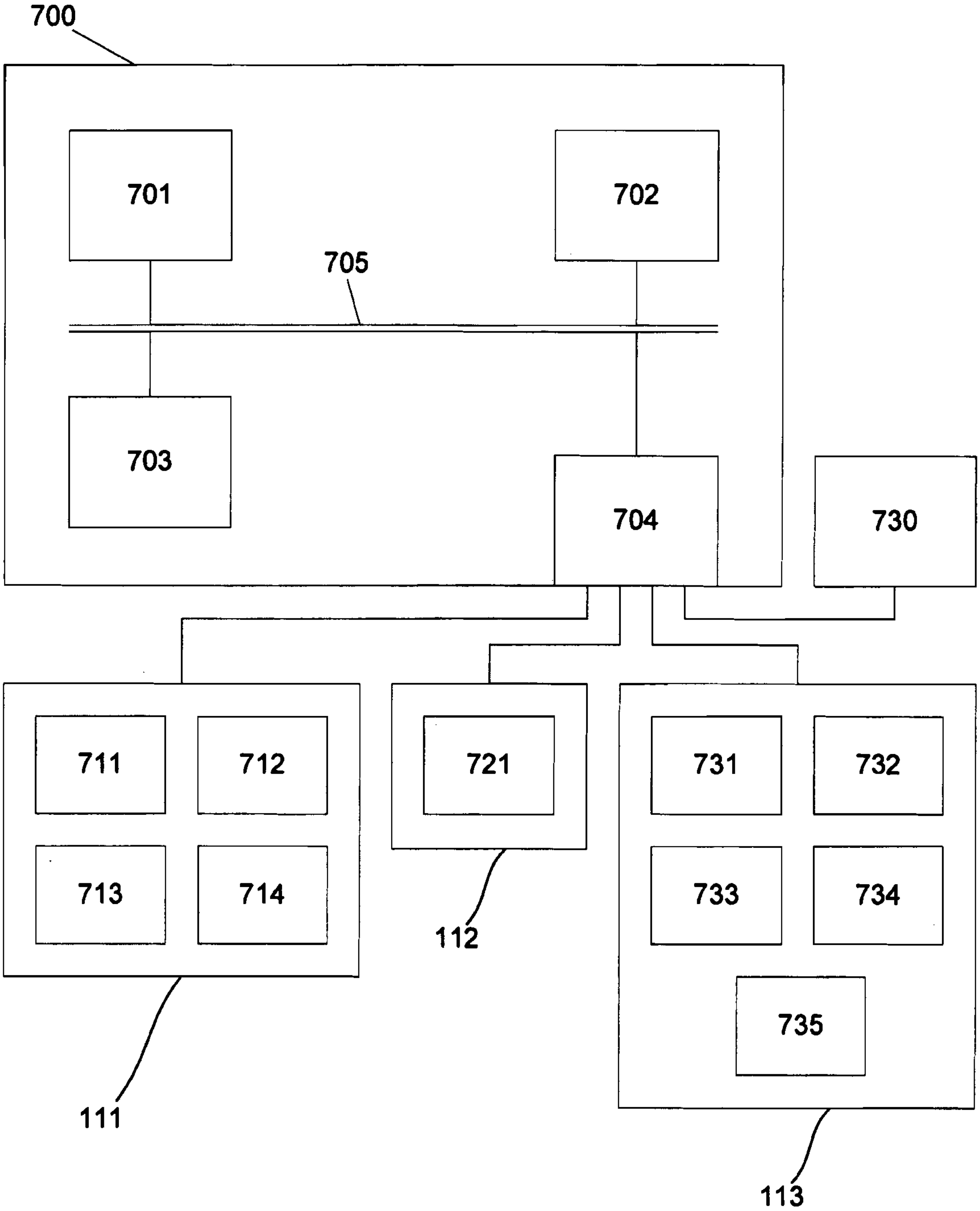

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Fig. 7

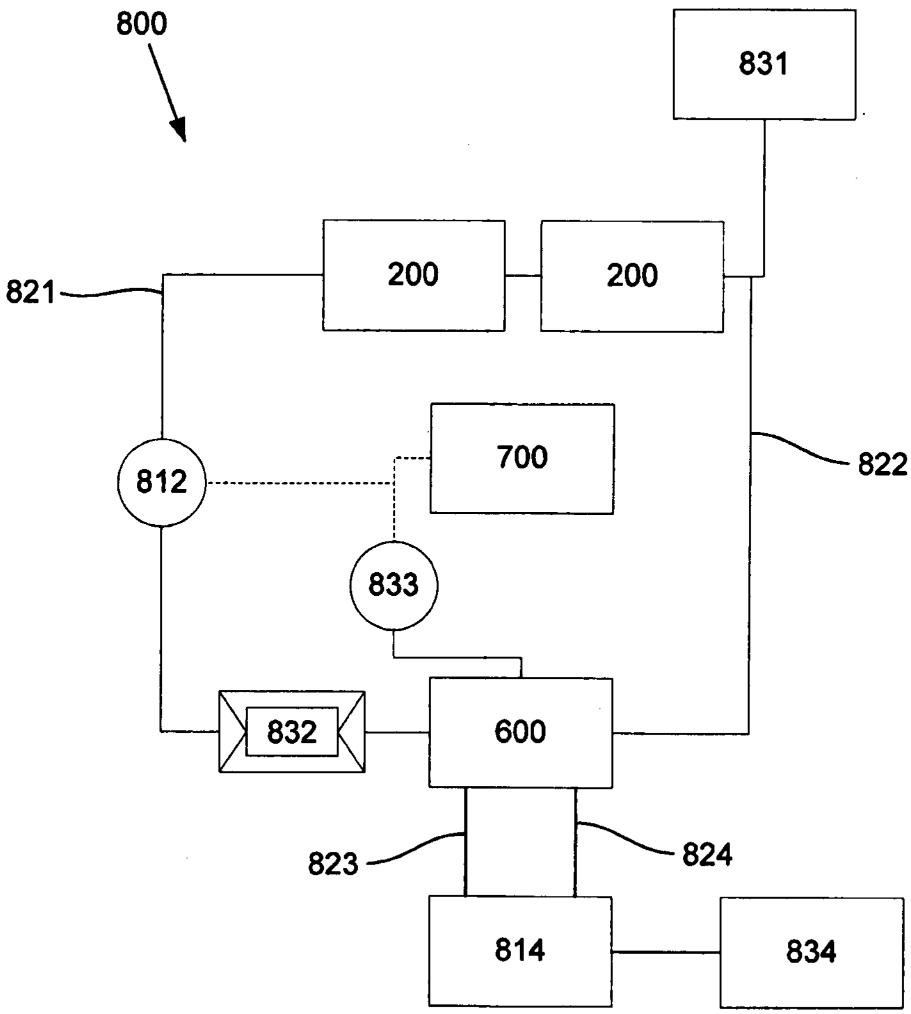

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/001670

A. CLASSIFICATION OF SUBJECT MATTER	
Int. Cl.	
F24J 2/07 (2006.01) *F24J 2/04* (2006.01) *F24J 2/42* (2006.01)	
According to International Patent Classification (IPC) or to both national classification and IPC	
B. FIELDS SEARCHED	
Minimum documentation searched (classification system followed by classification symbols)	
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC; WPI: Keywords: solar, evacuated tube, generator, turbine	

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4249083 A (BITTERLY) 03 February 1981 Abstract; Figs. 8, 10; col. 5, line 49 –col. 6, line 26.	1-29
X	CN 101893327 A (SHANGHAI SHENGHE NEW ENERGY RESOURCES SCIENCE & TECHNOLOGY CO LTD) 24 November 2010 English abstract retrieved from EPODOC.	1-29
X	US 7296410 B2 (LITWIN) 20 November 2007 Abstract; col. 5, lines 22-46; fig. 3; col. 4, lines 4-25; col. 6, lines 40-43.	1-29
Y	US 2010/0295306 A1 (RIDNIK ET AL) 25 November 2010 Abstract; figures; paragraphs 0008, 0012.	1-29

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
14 February 2012	20 February 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **SERINEL SAMUEL** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2382

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0162700 A1 (BIRNBAUM ET AL) 01 July 2010 Abstract; figures; paragraph 0021.	1-29
Y	US 7246492 B2 (HENDRIX ET AL) 24 July 2007 Abstract; figures; col. 3, line 67 – col. 4, line 2 ; col. 4, lines 17-36; claims 2, 4.	1-29
Y	US 2007/0193872 A1 (GARCIA ET AL) 23 August 2007 Abstract; figures; paragraph 0049.	1-29
Y	WO 1999/030089 A1 (PARK H R (KR)) 17 June 1999 Abstract; figures.	1-29

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4249083	NONE					
CN	101893327	NONE					
US	7296410	US	2005126170				
US	2010295306	US	8039984				
US	2010162700	AU	2008228211	AU	2008228596	CN	101680648
		CN	101680649	EP	2126467	EP	2126468
		WO	2008113482	WO	2008113798	ZA	200906293
		ZA	200906294				
US	7246492	US	2004182080				
US	2007193872	NONE					
WO	9930089	AU	15096/99				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX