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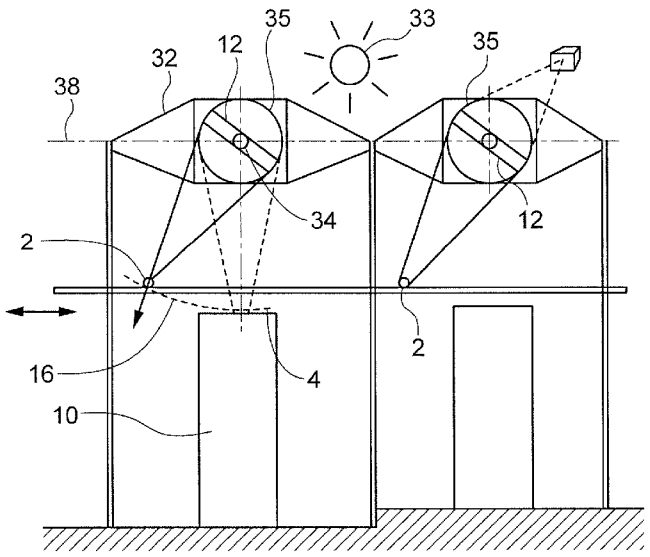

Fig. 2

(57) Abstract: Solar thermal heat exchange apparatus configured to receive solar radiation and then to concentrate the solar radiation to a solid body target and then to transfer heat energy from the solid body to a fluid medium in particular a gas phase medium such as air.

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Solar Thermal Heat Exchange Apparatus

Field of invention

The present invention relates to solar thermal apparatus and in particular, although not exclusively to solar thermal heat exchange apparatus configured to harness solar energy and transfer it to another medium for use in power generation.

Background art

Heat exchangers are well known and are designed to transfer heat from one medium to another. Heat exchangers have a wide variety of applications and are used in industry for cooling and heating large scale industrial processes. Double pipe heat exchangers are the simplest form used in industry and comprise a first working fluid flowing through a first pipe and a second working fluid flowing through a second pipe. The second pipe surrounds the first pipe in a concentric arrangement. The direction of the working fluid flow inside the double pipe heat exchanger may be parallel-flow or counter-flow. For efficiency, heat exchangers are designed to maximise the surface area of the pipe wall

which separates the two working fluids. The pipe wall should be thin and made of a high thermal conductive material. It is also important to minimize the resistance of the working fluid flowing through the exchanger. Heat from the higher temperature fluid passes through the pipe wall and heats the lower temperature fluid. However, double pipe heat exchangers often have low efficiency and occupy large areas of space due to their design.

There is a continued need for heat exchangers which are more energy efficient and less costly to manufacture and operate.

Solar energy collection devices are well established and may be categorised according to two types. Non-concentrating collectors receive the solar radiation directly, as parallel rays of radiation. Such devices typically comprise a solar panel, or array of photovoltaic cells that may be heated and configured to transmit and store the solar radiation. A further type of solar collector is referred to as a concentrating type which reflects or refracts the radiation using lenses or mirror assemblies so as to concentrate the rays onto a target as a more focused solar footprint.

There is a need for apparatus that will effectively harness the solar radiation throughout the day and year whilst being of a design sufficiently robust to withstand weathering by the elements whilst maximising the use of the incident radiation.

Conventional solar energy based power generation systems have a number of limitations including in particular, the efficiency of operation by which solar energy is captured and harnessed for power generation. Additionally, conventional systems often have insufficient capacity to store the captured solar energy. Their use is typically restricted to hot climates and there is a continual need to recharge the limited energy storage device. This may result in power or electricity being unavailable during poor or inclement weather conditions.

Summary of the Invention

It is an objective of the present invention to provide apparatus and method to collect solar energy and to make this energy available for subsequent storage, direct or indirect use. It is a further objective to provide a body that is capable of receiving solar energy from the sun either directly or indirectly and then to be capable of being transported, once heated to a location where the heat energy may be utilised, stored and/or converted to a different form such as electrical energy.

The objectives are achieved by providing apparatus and method in which a solid body is supported at a first location to receive solar energy and is then capable of being transported via a mechanism to a second location separated from and/or different to the first location. Accordingly, the body is capable of being heated by solar radiation via at least one lens or mirror and then transported in its heated state to a second location where the heat energy may be stored, used directly or indirectly or converted to electricity via one or a plurality of processes.

It is a further specific objective to power an engine such as a Brayton cycle engine or a Sterling engine directly via a mechanism of heating a volume of compressed air at or associated with the engine using a lens or mirror to direct solar energy onto a part or component provided directly or associated with the engine. The engine may then be coupled to a turbine or other suitable components to generate electricity.

According to one aspect of the present invention there is provided apparatus to receive and store energy comprising: a structure, vessel or housing defining an internal chamber; a body transfer inlet positioned at the internal chamber to allow a body to be introduced into the internal chamber; at least a first mechanism to allow the body to be transferred via the body transfer inlet from a first position where it may be heated by solar radiation to a second position within the internal chamber.

Optionally, a working fluid inlet and outlet may be provided at the internal chamber to allow a working fluid to flow into and from the internal chamber and exchange heat energy with the body.

Preferably, the body is rock or formed from rock. Optionally, the body comprises sand, stone, basalt, concrete, fly ash, slag, a naturally occurring material or a synthetic construction material, gravel, stones, pebbles, boulders or other granular mineral based material.

Optionally, the internal chamber comprises a body transfer outlet to allow the body to exit the internal chamber to a third position. Optionally, the body transfer inlet and outlet are the same or are at the same region of the internal chamber. Optionally, the body transfer inlet and outlet are provided at different regions of the internal chamber. Optionally, the apparatus comprises a second mechanism to transfer the body from the third position to the first position. Preferably the first and second mechanisms comprise at least one mechanical actuator. Optionally, the first mechanism may be a gravity feed mechanism wherein the body is capable of being transferred from the first to the second position at least in part by gravitational force. Optionally, the working fluid is a gas, such as air. Optionally the working fluid is a liquid such as water.

Optionally, the apparatus comprises a heat exchanger mounted within the internal chamber, the working fluid configured to flow through the heat exchanger into and from the internal chamber via the working fluid inlet and outlet.

According to a further aspect of the present invention there is provided solar energy and transfer apparatus comprising: the apparatus as claimed herein; and a lens or mirror to receive solar energy and to transfer or concentrate the solar energy onto the body when the body is in the first position.

Optionally, the apparatus comprises an actuating mechanism to move the lens or mirror to track the position of the sun. Optionally, the apparatus further comprises an automated

control to automate the movement of the lens or mirror to track the position of the sun and to transfer or concentrate solar energy to the body.

Preferably, the apparatus comprises at least one Fresnel lens. Preferably, the apparatus comprises a plurality of Fresnel lenses and bodies provided in communication with the internal chamber via at least one or a plurality of first mechanisms to allow the bodies to be transferred from respective first positions (outside of the internal chamber) to respective second positions within the internal chamber.

Optionally, the internal chamber may be provided in fluid communication with a Brayton cycle engine and/or a Sterling engine.

According to a further aspect of the present invention there is provided a method of receiving and storing solar thermal energy comprising: concentrating or transferring solar energy onto a body using at least one lens or mirror; transferring the body into an internal chamber defined by a structure, vessel or housing; and transferring heat energy from the body to a working fluid configured to flow into and from the internal chamber.

According to a further aspect of the present invention there is provided apparatus for converting solar energy into electrical energy comprising: a turbine coupled to the apparatus as claimed herein; and an electric generator coupled to the turbine to generate electricity.

According to a further aspect of the present invention there is provided apparatus for converting solar energy into electrical energy comprising: the apparatus as claimed in herein wherein the electric generator is coupled to a Brayton cycle engine to generate electricity.

According to further aspect of the present invention there is provided a heat exchanger for transferring heat from one medium to another comprising: a body suitable to be heated, a housing having an inlet and an outlet for the temporary storage of the body, a working fluid provided within the housing to receive thermal energy from the body, and an

actuation mechanism to move the body from the inlet to the outlet, wherein in use, the body enters the housing via the inlet and the working fluid is in contact with the body as the body is moved by the actuation mechanism to the outlet of the housing.

The present apparatus is configured to form an assembly component within solar thermal apparatus to receive solar radiation and then to transfer, direct or concentrate the solar radiation to a solid body target and then to allow the transfer of heat energy from the solid body target to a receiving medium for storage or use in the generation of electricity. Optionally, the medium is a gas or liquid phase medium.

Optionally, the body comprises a plurality of sections which are stackable along an axis of the body. The sections are preferably disc-shaped and made from a material which has high thermal conductivity such as rock or steel. Optionally, the body comprises a metal gauze. Optionally, the body comprises at least one of: a metal, a metal alloy, steel, a ceramic or a rock.

Optionally, the actuation mechanism used to move the body from the inlet to the outlet of the housing comprises at least one or a plurality of hydraulic or pneumatic rams.

According to a further aspect of the present invention there is provided a solar energy collection and transfer apparatus comprising: a lens or mirror to receive and concentrate or transfer solar energy, optionally means to move the lens or mirror to track the position of the sun, a heat exchanger as claimed herein; wherein the body is capable of being heated by the solar energy received by the lens or mirror and transferring heat energy to the heat exchange.

Preferably, the body is heated by a solar energy concentrating apparatus via a heating channel before entering the inlet of the housing. The solar energy concentrating apparatus preferably comprises a lens or mirror to receive and concentrate solar radiation towards the body. Optionally, the apparatus comprises an actuation mechanism to move the lens or mirror to track the position of the sun, with such mechanism being automated.

Optionally, the housing comprises a window through which the solar energy received from the lens or mirror may enter the body. The heating channel preferably follows an arcuate path spaced apart from the lens by a distance equal to the focal length of the lens. The arcuate path is determined by the position of the lens as it tracks the sun.

Optionally, the housing of the heat exchanger may be in fluid communication with a heat store. The heat store is preferably made from a heat storage material.

Optionally, there is provided an assembly having a plurality of solar energy concentrating devises coupled and/or connected to at least one heat store or body transfer mechanism. Such an arrangement may be implemented as an array of lens and lens movement actuators arranged around a common heat store or a body transfer mechanism. Optionally the assembly comprises 2, 3, 4, 5, 6, 8, 10 lens and at least one lens actuation mechanism.

Optionally, the apparatus may further comprise at least one flow pump and/or fan unit coupled to the housing and/or heat store and configured to drive or assist the flow of the working fluid within/around the internal chamber.

Optionally, the internal chamber is in fluid communication with a Brayton cycle engine.

According to a further aspect of the present invention, there is provided an apparatus for converting solar energy into electrical energy comprising a turbine coupled to the apparatus or a heat exchanger as claimed herein and an electric generator coupled to the turbine to generate electricity.

According to a further aspect of the present invention there is provided solar thermal concentrating apparatus comprising: at least one lens to concentrate solar radiation; a mount assembly to support a lens at a position to receive solar energy from the sun; an engine or component of an engine mounted to receive the concentrated solar radiation from the lens.

The engine or component part to receive the solar radiation may be a chamber formed from a metal such as a steel chamber and in particular a compression chamber for air.

Preferably, the engine is a Brayton cycle engine. Preferably, the Brayton cycle engine comprises a compressor and a turbine and additional further components consistent with conventional arrangements of such engines.

Optionally, the apparatus comprises an actuating mechanism to move the lens to track the position of the sun such that he lens focuses continually the solar energy onto the engine or component of the engine. Optionally, the apparatus further comprises an automated control to automate the movement of the lens to track the position of the sun and to transfer or concentrate solar energy to the engine or component of an engine.

Preferably, the apparatus and optionally the Brayton cycle engine further comprises a chamber to receive and/or house compressed air, the chamber positioned to receive solar radiation from the lens such that the air in the chamber is capable of being heated. Preferably, the apparatus comprises a plurality of chambers movably mounted at the engine and/or the apparatus and provided in fluid communication with the compressor and/or the turbine.

Optionally, the engine is a Sterling engine. Optionally, the Sterling engine comprises a compressor and a turbine and additional further components consistent with conventional arrangements of such engines. Optionally, the apparatus and optionally the Sterling engine as may further comprise a chamber to receive and/or house compressed air, the chamber positioned to receive solar radiation from the lens such that the air in the chamber is capable of being heated. Optionally, the Sterling engine comprises a plurality of chambers movably mounted at the engine and/or the apparatus provided in fluid communication with the compressor and/or the turbine.

Preferably, the apparatus comprises a plurality of lens. Optionally, the lens may be arranged in groups at a single engine or power generation unit. Optionally, the lens may be arranged in groups or coupled individually with at a single engine or power generation

unit. Optionally, the apparatus may comprise a plurality engines and/or power generation units to receive concentrated solar radiation from a plurality of respective lens. Optionally, the apparatus comprises a greater number of lens than engines such that a plurality of lens are mounted to feed into a one or a respective lesser number of engine(s).

Brief description of drawings

A specific implementation of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a schematic illustration of the heat exchanger coupled to a heat store;

Figure 2 is a schematic illustration of the solar energy transfer and storage apparatus;

Figure 3 is a schematic illustration of the solar energy concentrating apparatus;

Figure 4 is a schematic illustration of the solid body being transported in the housing via heated body loading mechanisms;

Figure 5 is a schematic illustration of an engine unit mounted at the focal point of a lens to receive concentrated solar energy;

Figure 6 is a schematic illustration of apparatus to receive and store heat energy according to a further specific implementation of the present invention.

Detailed description of preferred embodiment of the invention

Referring to Figure 1, a heat exchanger comprises a body 2 which is suitable for heating and a housing or conduit network 4 containing a working fluid. The housing 4 is designed to withstand high temperatures in the region of 500°C to 1000°C and may be made from a steel, a ceramic or a clay-based material. Housing comprises an inlet 31 and an outlet 32 to provide a chamber or region for the temporary storage and/or transport of body 2

between at least two positions. A working fluid is contained to circulate within the housing 4 optionally with the aid of a pump and/or fan. The working fluid is capable of being heated to high temperatures above 400°C and in particular up to around 1000°C. The working fluid may be air and in particular, atmospheric air. In addition, the housing 4 may be covered in an insulating material to ensure that heat energy is not lost to the environment. Insulation may comprise a mineral wool, a fibre based insulation, a partially evacuated region or a surrounding or encapsulating multilayer structure. Housing 4 comprises a first port 29 and a second port 36 provided in fluid communication with a heat store indicated generally by reference 10 via a plurality of fluid flow conduits 28, 37 respectively. Conduit 28 is configured to provide a supply flow of a working fluid to housing 4 and conduit 37 is configured to provide a return flow of the fluid (heated by body 2) to heat store 10 via respective ports 29, 36.

The body 2 comprises a series of discs 8 which are stacked together along a common axis. The discs comprise a gauze 6 or mesh to allow the working fluid to pass through a plurality internal apertures in a counter flow arrangement. This increases the surface area of the body 2 which is exposed to the working fluid. The discs 8 comprise a material having a high thermal conductivity such as steel or a ceramic.

Referring to Figures 2 and 3, in an embodiment of the present invention, a solar energy concentrating apparatus is used to heat the body 2. The solar energy concentrating apparatus comprises a lens 12 which concentrates solar energy towards the body 2.

Suitable mechanical movement means are connected to the lens 12 to change the position of the lens 12 to track the position of the sun 33. In particular, the lens 12 may be configured to mechanically pivot over two axes (East to West and North to South) so as to track the position of the sun 33 both annually and diurnally. This means that the solar radiation is continually focused onto the body 2. Accordingly, the centre of each lens 12 is capable of movement over an imaginary section of a surface of a sphere such that the centre of each lens 12 is continually orientated towards the body 2 with the separation distance between lens and body 2 being substantially equal to the focal length of the lens 12 using mounting and actuation apparatus described in WO 2011/089437 which is

incorporated by reference. Suitable means may also be provided to automate the movement of the lens 12 and the body 2 relative to the sun 33. The movement of the body 2 throughout the day follows an arcuate path 16 which is determined by the position of the lens 12 as it tracks the movement of the sun 33.

In particular, the apparatus to move a mount lens 12 comprises a plurality of cable structures 32 provide a primary support and are configured to rotate about axis 38. Each primary support 32 rotatably mounts internal a secondary support 35 formed from a cable structure configured to rotate about axis 34. Secondary structure 35 provides a direct mount for lens 12 configured to pivot about the two axes 38, 34 and to concentrate solar radiation onto target 2. The body 2 is positioned in an arcuate path 16 at the focal point of the lens 12. The body 2 sits on a suspension wire or other mechanism so as to move in a coordinated manner with the lens 12 to track the position of the sun 33 both daily and annually. The apparatus preferably comprises an actuating mechanism to move the target and a separate actuating mechanism to move the lenses 12. In particular, a suspension cable to mount the target 2 may be connected to a winch and stanchion (not shown) to move the cable and hence the target body 2. Housing 4 is provided with a window or a gate mechanism 5 to receive the body when heated by the lens 12. Mechanism 5 is mounted at a loading station 30 positioned adjacent housing inlet 31. Station 30 is configured to receive body 2 from a suitable loading mechanism that transfers body 2 from a heating position at the focal point of a respective lens 12. Gates 5 are configured to open and close via suitable pivot or slide mechanisms via automatic control that may also control the movement of lenses 12 and bodies 2 to track position of the sun 33. Further components of the subject invention are also controlled by suitable electronic control components to provide fully automated assembly.

According to a further specific implementation, station 30 may comprise a window formed from a suitable glass or other low absorption material configured to allow transmission of the concentrated solar energy received from the lens 12 onto the body 2. In particular, the window is configured to prevent or inhibit re-emission of solar energy in the form of long wavelength radiation resultant from the heated body 2 that receives the relative shorter wavelength solar energy.

The housing 4 may be formed as a conduit network 4 and includes a substantially elongate duct with inlet 31 and outlet 32 provided at each end. Housing 4 is configured to accommodate several bodies 2 simultaneously and to provide a means for transport of the bodies 2 from inlet 31 to outlet 32. In particular, an actuation mechanism comprising a hydraulic or pneumatic ram 3 is configured to advance bodies 2 from the initial loading station 30 through housing 4 via inlet 31. In particular, ram 3 is configured to contact a heated body 2 at station 30 and to force the body 2 into housing 4 via inlet 31 such that the heated body 2' within housing 4 is positioned in the fluid flow path that circulates to and from heat store 10 via conduits 28 and 37. Actuation mechanism 3 is then configured to actuate further heated bodies 2 through housing 4 as station 30 receives further bodies 2 heated by lens 12. The heated bodies 2' then transfer sequentially to outlet 32 of housing 4 to a final discharge position immediately adjacent outlet 32. Due to the continued flow of cool fluid from conduit 28, body 2'' is appreciably cooler than the heated body 2'. Cooled body 2'' is then deposited into a further loading station 7 ready to be collected by a suitable loading mechanism to transfer the cooled body 2'' to the mounting position at the focal point of lens 12. The present apparatus may comprise a series of temperature sensors, airflow sensors, position and motion sensors installed at various locations at for example the mounting position of body 2 at the focal point of lens 12, loading stations 30, 7 and housing 4 so as to fully automate the present apparatus and provide feedback control and analysis. In particular, and by way of example once the body 2 is heated to a predetermined temperature (at the lens focal point), a temperature sensor alerts the loading mechanism (not shown) to transfer the body 2 to the loading station 30.

As the body 2 moves from the inlet 31 to the outlet 32 of the housing 4, it transfers its heat energy to the working fluid in a counter-flow arrangement. The working fluid passes around and through the apertures in the series of discs 8 which are stacked together to form the body 2. This provides an increased surface area for the working fluid to be heated. The transfer of the heated body 2 from the loading station 30 to the discharge station 7is illustrated in figure 4A, B and C. Once the body 2 have been returned to the heating position at the focal point of lens 12, the process is repeated until the body 2 reaches the predetermined heated temperature at which time it is returned to the loading station 30 via

gates 5 to be transferred to housing 4 and its heat energy in turn transferred to heat store 10.

Heat store 10 is located downstream of the solar energy concentrating apparatus via conduits 28 and 37. The heat store 10 is formed from a suitable heat storage material such as rock, stone or a synthetic material designed to withstand high temperatures in the order of 1000°C. The stone walls and/or internal sections of the heat store 10 define internal fluid flow channels within which the fluid is capable of flowing. The heat store 10 may be optionally coupled to a turbine which is then connected to a generator to produce electricity as described in WO 2010/116162 which is incorporated by reference. When required to generate electricity, the heat energy within the heat store 10 is extracted by the flow of the working fluid. The heat energy is used to drive the turbine which in turn powers the generator. The lower temperature working fluid is then be recycled to the heat store 10 and/or housing 4 via control pumps or fans to be reheated by the bodies 2.

Referring to figure 3, in one embodiment the apparatus comprises a body loading mechanism 40 to transport body 2 from its '*in use*' position at the focal point of lens 12 to a carrier station 43. Carrier station 43 is provided in communication with housing inlet 31 and acts to transfer body 2 to housing 4 (via load mechanism 40). A corresponding carrier 43 is provided at housing outlet 32 and is provided in communication with a second loading mechanism 41 to transfer body 2 to the return position at the focal point of lens 12. Accordingly, when body 2 is heated by solar radiation from lens 12, loading mechanism 40 transports the heated body 2 via carrier 43 to housing inlet 31. The body 2 then transfers its heat energy to unit 42. The cooled body 2 is then returned to the '*in use*' position at the focal point of lens 12 via carrier 43 and second loading mechanism 41. According to specific embodiments, unit 42 may comprise a Brayton cycle engine or a Sterling engine configured to communicate with heated bodies 2. Unit 42 may be positioned in direct contact with housing 4 via suitable ports 29, 36 or may be connected via suitable conduits 28, 37. The unit 42 may accordingly be coupled to other downstream components for the generation of electricity as described in WO 2010/116162. In a further embodiment, the solar thermal collection and concentrating apparatus may comprise the heat exchanger as

described, a heat store, Brayton cycle engine and/or a Sterling engine coupled to or comprising a suitable turbine to produce electricity.

Referring to figure 5, and according to a further embodiment, the lens 12 and associated mounting and actuation apparatus 22, 35 may be positioned with respect to a target 20 so as to focus solar radiation directly onto target 20. Target 20 may be stationary or may be configured to move with the movement of lens 12 to track the position of sun 33. Figure 5 illustrates target 20 forming part of a Brayton cycle engine assembly. In particular, a turbine 21 is mounted in fluid communication with target 20 and comprises an exhaust 22 and a suitable work output drive (not shown). Target 20 is also coupled to a compressor 26 via conduit 25 to supply a flow of cold compressed air to target 20. Air is received at compressor 26 via conduit 27 attached to a pump system as will be appreciated. Alternatively, compressor 26 may be attached directly to target 20 and supplied with air via conduit 23. In one embodiment the Brayton engine may be open to the atmosphere and comprise an internal combustion chamber or may be a closed system comprise a heat exchanger. The present apparatus is compatible with both types of engine such that in use, target 20 is heated by the solar thermal energy received from lens 12 and the heated air then drives turbine 21 to output power and in particular drive electricity generation. Accordingly, lens 12 and apparatus 32, 35 is coupled directly to a Brayton cycle engine as illustrated in figure 5. According to further embodiments, the components of the Brayton cycle engine illustrated in figure 5 may be replaced by suitable components of a Sterling engine in which target 20 comprises a heating plate, heating conduit or chamber component formed directly or indirectly with the Sterling engine.

A further specific implementation of the present invention is described with reference to figure 6. According to the further embodiment, apparatus is provided to receive and store temporarily solar thermal energy received from a lens 12. The apparatus comprises a structure, vessel or housing 10 having housing walls 58 that define an internal chamber 57 that is capable of accommodating a plurality of bodies illustrated generally by reference 2. The bodies 2 are formed from rock of generally regular or irregular shape. The internal chamber 57 comprises a body transfer inlet 59 and a corresponding body transfer outlet 60. A first body transfer mechanism 52 is provided in communication with inlet 59 and a

second body transfer mechanism 53 is provided in communication with outlet 60. Each respective mechanism 52, 53 is capable of transferring body 2 between two different positions into and from internal chamber 57. In particular, first mechanism 52 is configured to transfer body from the first position 2a (outside of the internal chamber 57) to a second position 2c (within internal chamber 57). Second mechanism 53 is configured to transfer the body 2 from a corresponding position 2d within internal chamber 57 (adjacent outlet 60) to a third position 2b (outside of the internal chamber 57). A third mechanism 54 is configured to transfer body 2 from the third position 2b to the first position 2a via transfer pathway 55. Such mechanisms 52, 53, 54 may comprise conventional actuators such as mechanical actuators, belt conveyors, rollers, pulleys, chain or cable driven arrangements. Optionally, the mechanisms 52, 53, 54 may comprise fluid based transfer mechanisms such as conduits comprising air or water transfer fluids. Mechanisms 52, 53, 54 may be configured to work with gravity or against gravity. In particular, the first mechanism 52 is configured to allow body 2 to at least partially fall under gravity from position 2a to position 2c. The first mechanism 52 is configured to support the body at position 2a so as to receive concentrated solar energy from lens 12 that in turn receives solar energy from the sun 33 as described previously. Lens 12 is mounted at a suitable support structure 56. In one embodiment, lens 12 is static via mounting by structure 56 or structure 56 may be configured to move lens 12 so as to track the position of the sun. Optionally, structure 56 may be a static or generally rigid structure or support platform arrangement.

Housing 58 comprises a fluid inlet 51 and a fluid outlet 50. A working fluid is capable flowing into and from internal chamber 57 via the respective inlet and outlet 51, 50. In such an arrangement, the working fluid (typically air or a gas phase medium) is configured for direct contact with the body 2 within the internal chamber 57. Accordingly, heat energy from the body 2 is transferred to the working fluid and from the internal chamber 57 via fluid flow outlet 50.

According to further embodiments, a heat exchanger may be mounted within the internal chamber 57 such that the working fluid of the heat exchanger enters and leaves the internal chamber 57 via the inlet and outlet 51, 50. Accordingly, the fluid flow inlet and outlet 51,

50 may comprise the same port at the same location at the housing 58. In such an arrangement, the working fluid of the heat exchanger is not provided in direct contact with the body 2.

Depending upon the direct or indirect contact of the working fluid with body 2, internal chamber 57 or at least one conduit connected to fluid flow inlet 51 or outlet 50 may comprise a fan, jet or impeller type arrangement to provide circulation of the working fluid towards and from direct or indirect contact with body 2 within internal chamber 57.

Internal chamber 57 may be formed simply by providing a cavity below ground in the form or a cave or other similar subterranean chamber arrangement to contain one or a plurality of bodies 2 at and between the respective positions 2a, 2c, 2d and 2b. Optionally, the housing 58 may be a free standing structure mounted above ground and may be formed from a material such as concrete, steel, rock or similar to define internal chamber 57.

According to some embodiments, a plurality of lenses 12 may be positioned around body 2 at position 2a. Optionally, a plurality of lenses 12 may be configured to concentrate solar thermal energy onto a plurality of bodies at position 2a, with each body 2 capable of being transferred into internal chamber 57 via a single or a plurality of mechanisms 52. The internal chamber 57, as illustrated in figure 6, is capable of accommodating a plurality of bodies 2 transferred sequentially and/or in parallel into internal chamber 57 from position 2a and subsequently from the internal chamber 57 from position 2d to position 2b.

According to a further embodiment, the arrangement described referring to figure 6 does not comprise the second and third mechanisms 53 and 54. In such an arrangement the first mechanism 52 is capable of transferring body 2 between positions 2a and 2c in a forward and reverse direction such that the body 2 is capable of shuttling back and forth between positions 2a and 2c as the body is heated by lens 12, transfers its heat energy to the working fluid (position 2c) and is then retransferred to the heating position (position 2a) so as to provide a cyclical movement of the bodies 2 between positon 2a (at the focal point of the lens 12) and the subsequent positions into, through and from the internal chamber 57 (positions 2c, 2d, 2b).

As will be appreciated, the arrangement described with reference to figure 6 may comprise the same or similar components described with reference to figures 1 to 5. In particular, the apparatus described with reference to figure 6 is compatible with the Brayton cycle engine or Sterling engine described with reference to figure 5.

Claims

1. Apparatus to receive and transfer energy comprising:

a support structure to support a body at a first location to receive solar energy from a lens or mirror;

a mechanism to transfer the body from the first location to a second location different to the first location.

2. The apparatus as claimed in claim 1 wherein the first location is at or towards a focal point of at least one lens.

3. The apparatus as claimed in claims 1 or 2 further comprising, at the second location, any one of:

- a heat storage body;
- a heat storage chamber;
- a heat storage vessel;
- a region of a conduit network to contain a fluid capable of transport within the network;
- a turbine;
- a heat exchanger;
- a structure, vessel or housing to allow passage or storage of the body at the second location.

4. The apparatus as claimed in any one of claims 1 or 2 wherein the second location comprises a Brayton cycle engine and/or a Sterling engine.

5. The apparatus as claimed in claims 1 or 2 further comprising at the second location a heat storage structure comprising any one or a combination of:

- stone
- rock
- basalt
- concrete

- fly ash
- slag
- a naturally occurring mineral
- a synthetic construction material
- sand
- gravel
- pebbles
- boulders; or
- other granular mineral based material.

6. The apparatus as claimed in any preceding claim wherein the mechanism comprises any one or a combination of the following:

- a mechanical mechanism
- an electronic mechanism
- an electromechanical mechanism
- an electromagnetic mechanism.

7. The apparatus as claimed in any preceding claim wherein the body is a solid body.

8. The apparatus as claimed in any preceding claim wherein the second location comprises an inlet at a structure, vessel or housing defining an internal chamber, the body capable of being positioned at the inlet and capable of being transferred into the structure, vessel or housing defining the internal chamber.

9. The apparatus as claimed in any preceding claim further comprising an actuating mechanism to move the lens or mirror to track a position of the sun.

10. The apparatus as claimed in any preceding claim further comprising an automated control to automate the movement of the lens or mirror to track the position of the sun and to transfer or concentrate solar energy to the body.

11. The apparatus as claimed in any preceding claim wherein the apparatus comprises at least one Fresnel lens.

12. A method of receiving and transferring solar thermal energy comprising:

supporting a body at a first location using a support structure, the body capable of receiving solar energy from a lens or mirror;

transferring the body from the first location to a second location different to the first location using a mechanism.

13. A method of generating electricity from heat energy transferred to the body by the apparatus according to any of the preceding claims.

14. Apparatus to receive and store energy comprising:

a structure, vessel or housing defining an internal chamber;

a body transfer inlet positioned at the internal chamber to allow a body to be introduced into the internal chamber;

at least a first mechanism to allow the body to be transferred via the body transfer inlet from a first position where it may be heated by solar radiation to a second position within the internal chamber.

15. The apparatus as claimed in claim 14 comprising:

a working fluid inlet and outlet provided at the internal chamber to allow a working fluid to flow into and from the internal chamber and exchange heat energy with the body.

16. The apparatus as claimed in claim 14 wherein the body is rock or formed from rock.

17. The apparatus as claimed in claim 14 wherein the body comprises sand, stone, basalt, concrete, fly ash, slag, a naturally occurring material or a synthetic construction material, gravel, stones, pebbles, boulders or other granular mineral based material.

18. The apparatus as claimed in any preceding claim wherein the internal chamber comprises a body transfer outlet to allow the body to exit the internal chamber to a third position.

19. The apparatus as claimed in claim 18 wherein the body transfer inlet and outlet are the same or are at the same region of the internal chamber.

20. The apparatus as claimed in claim 18 wherein the body transfer inlet and outlet are provided at different regions of the internal chamber.

21. The apparatus as claimed in any one of claims 18 to 20 comprising a second mechanism to transfer the body from the third position to the first position.

22. The apparatus as claimed in claim 21 wherein the first and second mechanisms comprise at least one mechanical actuator.

23. The apparatus as claimed in any preceding claim wherein the first mechanism is a gravity feed mechanism wherein the body is capable of being transferred from the first to the second position at least in part by gravitational force.

24. The apparatus as claimed in any preceding claim wherein the working fluid is a gas.

25. The apparatus as claimed in any preceding claim comprising a heat exchanger mounted within the internal chamber, the working fluid configured to flow through the heat exchanger into and from the internal chamber via the working fluid inlet and outlet.

26. Solar energy and transfer apparatus comprising:

the apparatus as claimed in any preceding claim; and

a lens or mirror to receive solar energy and to transfer or concentrate the solar energy onto the body when the body is in the first position.

27. The apparatus as claimed in claim 26 further comprising an actuating mechanism to move the lens or mirror to track the position of the sun.

28. The apparatus as claimed in claim 27 comprising an automated control to automate the movement of the lens or mirror to track the position of the sun and to transfer or concentrate solar energy to the body.

29. The apparatus as claimed in any one of claims 26 to 28 wherein the apparatus comprises at least one Fresnel lens.

30. The apparatus as claimed in claim 29 comprising a plurality of Fresnel lenses and bodies provided in communication with the internal chamber via at least one or a plurality of first mechanisms to allow the bodies to be transferred from respective first positions to respective second positions within the internal chamber.

31. The apparatus as claimed in any one of claims 26 to 30 wherein the internal chamber is provided in fluid communication with a Brayton cycle engine and/or a Sterling engine.

32. A method of receiving and storing solar thermal energy comprising:

concentrating or transferring solar energy onto a body using at least one lens or mirror;

transferring the body into an internal chamber defined by a structure, vessel or housing; and

transferring heat energy from the body to a working fluid configured to flow into and from the internal chamber.

33. Apparatus for converting solar energy into electrical energy comprising:

a turbine coupled to the apparatus as claimed in any one of claims 1 to 21; and

an electric generator coupled to the turbine to generate electricity.

34. Apparatus for converting solar energy into electrical energy comprising:

the apparatus as claimed in claim 33 wherein the electric generator is coupled to a Brayton cycle engine to generate electricity.

35. A heat exchanger for transferring heat from one medium to another comprising:
a body suitable to be heated,
a housing having an inlet and an outlet for the temporary storage of the body,
a working fluid provided within the housing to receive thermal energy from the body, and
an actuation mechanism to move the body from the inlet to the outlet,
wherein in use, the body enters the housing via the inlet and the working fluid is in contact with the body as the body is moved by the actuation mechanism to the outlet of the housing.

36. The heat exchanger as claimed in claim 35, wherein the body comprises a plurality of apertures or an open structure.

37. The heat exchanger as claimed in claims 35 to 36, wherein the body comprises a plurality of sections which are stackable along an axis of the body.

38. The heat exchanger as claimed in claim 37, wherein the sections are disc-shaped.

39. The heat exchanger as claimed in any preceding claim, wherein the body comprise a gauze, mesh or rock.

40. The heat exchanger as claimed in any preceding claim, wherein the body comprises at least one of: a metal, a metal alloy, steel, a ceramic or a rock.

41. The heat exchanger as claimed in any preceding claim, wherein the actuation mechanism comprises a hydraulic or pneumatic ram.

42. A solar energy collection and transfer apparatus comprising:
a lens or mirror to receive and concentrate or transfer solar energy,

optionally means to move the lens or mirror to track the position of the sun,

a heat exchanger as claimed in any one of claims 35 to 41;

wherein the body is capable of being heated by the solar energy received by the lens or mirror and transferring heat energy to the heat exchange.

43. The solar energy collection and transfer apparatus as claimed in claim 42, wherein the housing comprises a window through which the concentrated solar energy received from the lens or mirror may be received by the body.

44. The solar energy collection and transfer apparatus as claimed in claims 42 to 43, comprising an actuation mechanism to automate movement of the lens or mirror to track the position of the sun.

45. The solar energy collection and transfer apparatus as claimed in claims 42 to 44, wherein the lens comprises a Fresnel lens.

46. The solar energy collection and transfer apparatus as claimed in claims 42 to 45, wherein the body is mounted to follow an arcuate path spaced apart from the lens by a distance equal to the focal length of the lens.

47. The solar energy collection and transfer apparatus as claimed in claims 42 to 46, wherein the housing is in fluid communication with a heat store.

48. The solar energy collection and transfer apparatus as claimed in claim 47, wherein the heat store comprises a heat storage material to store the heat energy received from the working fluid.

49. The solar energy collection and transfer apparatus as claimed in claims 47 to 48, comprising a plurality of lenses and bodies provided in communication with the heat store.

50. The solar energy collection and transfer apparatus as claimed in claims 42 to 49, further comprising at least one flow pump and/or fan unit coupled to the housing and/or the

heat store and configured to drive or assist the flow of the working fluid around the housing and/or the heat store.

51. The solar energy collection and transfer apparatus as claimed in claims 42 to 46, wherein the housing is provided in fluid communication with a Brayton cycle engine or Sterling engine.

52. Apparatus for converting solar energy into electrical energy comprising:
a turbine coupled to the apparatus as claimed in claims 42 to 51 and
an electric generator coupled to the turbine to generate electricity.

53. Apparatus for converting solar energy into electrical energy comprising:
the apparatus as claimed in claim 51 comprising an electricity generator coupled to the Brayton engine to generate electricity.

54. Solar thermal concentrating apparatus comprising:
at least one lens to concentrate solar radiation;
a mount assembly to support the lens at a position to receive solar energy from the sun; and
an engine or component of an engine mounted to receive concentrated solar radiation from the lens.

55. The apparatus as claimed in claim 54 wherein the engine is a Brayton cycle engine.

56. The apparatus as claimed in claim 55 wherein the Brayton cycle engine comprises a compressor and a turbine.

57. The apparatus as claimed in claim 56 further comprises a chamber to receive and/or house compressed air, the chamber positioned to receive solar radiation from the lens such that the air in the chamber is capable of being heated.

58. The apparatus as claimed in claim 57 comprises a plurality of chambers movably mounted at the engine and/or the apparatus and provided in fluid communication with the compressor and/or the turbine.

59. The apparatus as claimed in claim 54 wherein the engine is a Sterling engine.

60. The apparatus as claimed in claim 59 wherein the Sterling engine comprises a compressor and a turbine.

61. The apparatus as claimed in claim 60 further comprises a chamber to receive and/or house compressed air, the chamber positioned to receive solar radiation from the lens such that the air in the chamber is capable of being heated.

62. The apparatus as claimed in claim 61 comprises a plurality of chambers movably mounted at the engine and/or the apparatus provided in fluid communication with the compressor and/or the turbine.

63. The apparatus as claimed in any one of claims 54 to 62 comprising a plurality of lens.

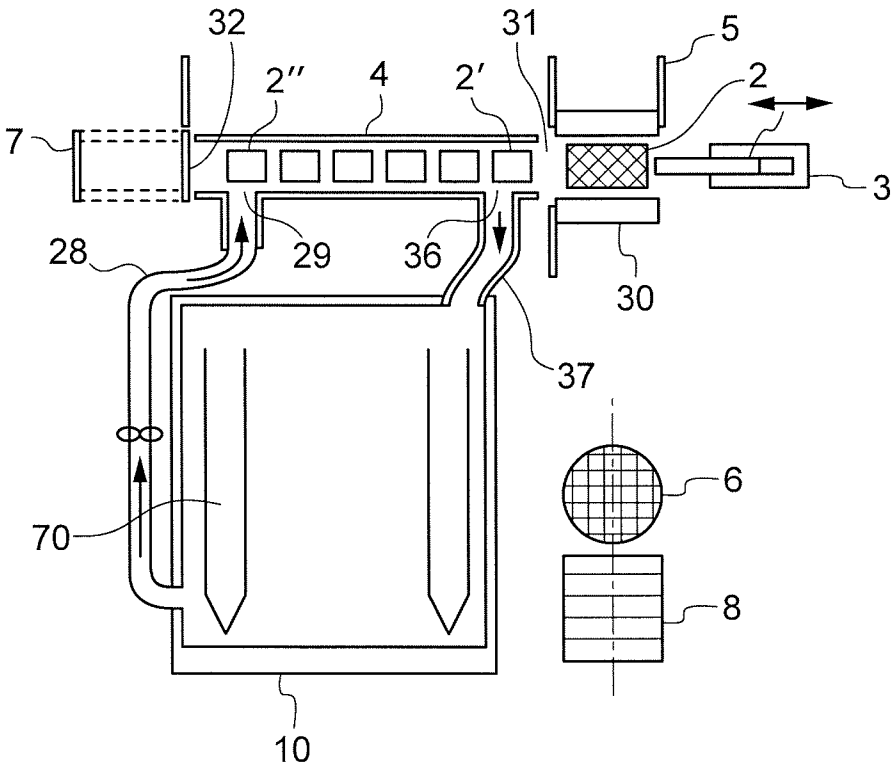

Fig. 1

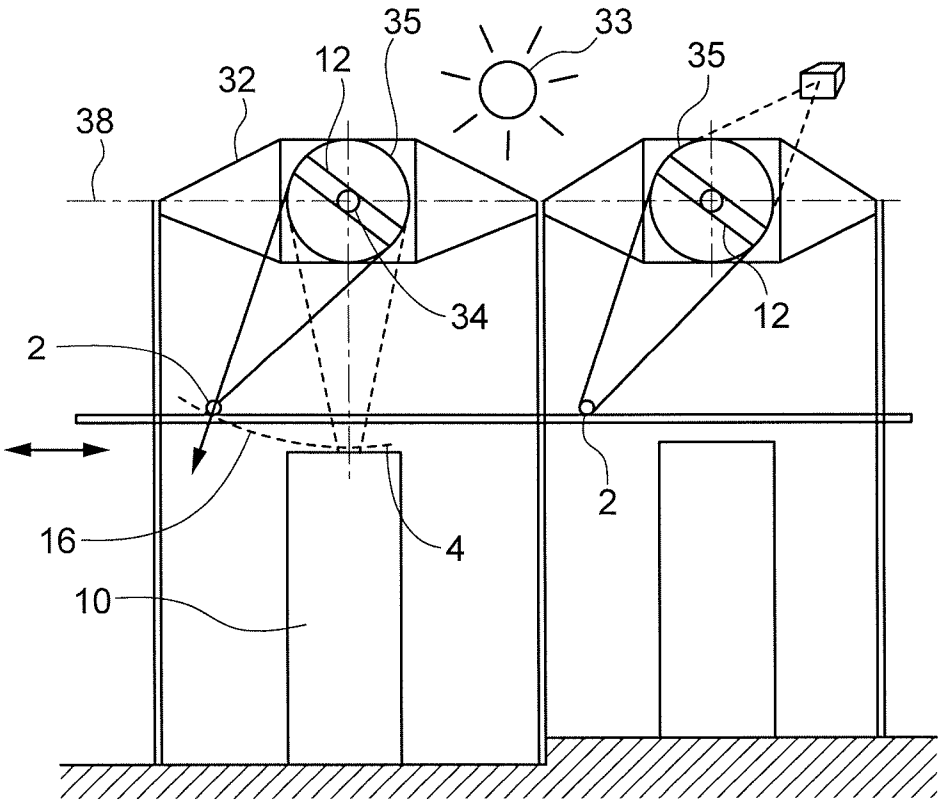

Fig. 2

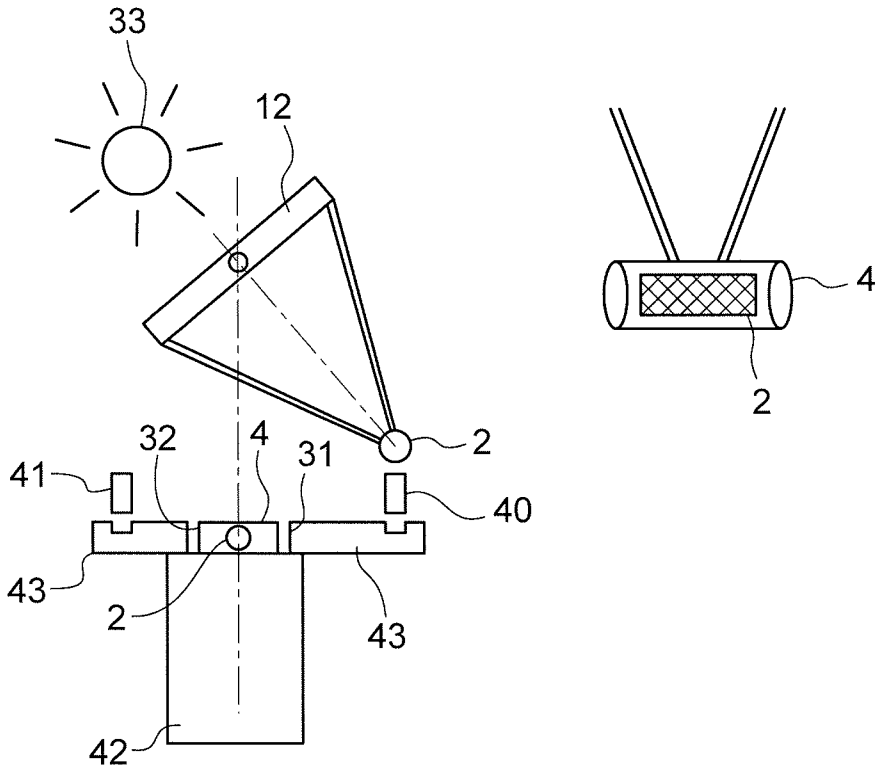

Fig. 3

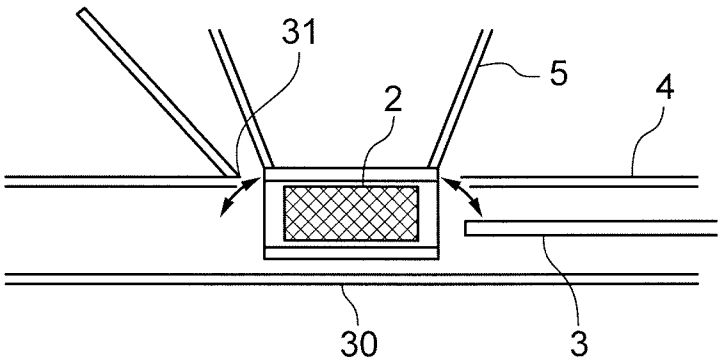

Fig. 4A

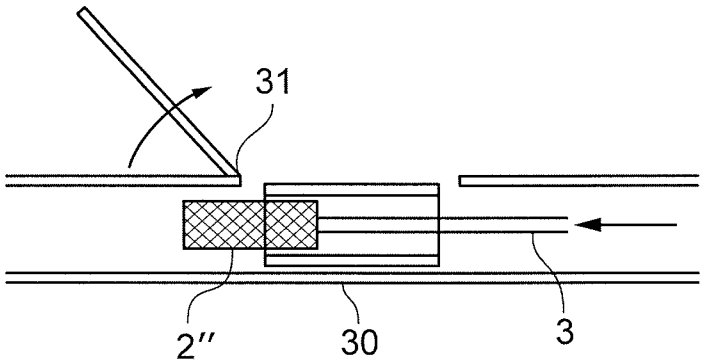

Fig. 4B

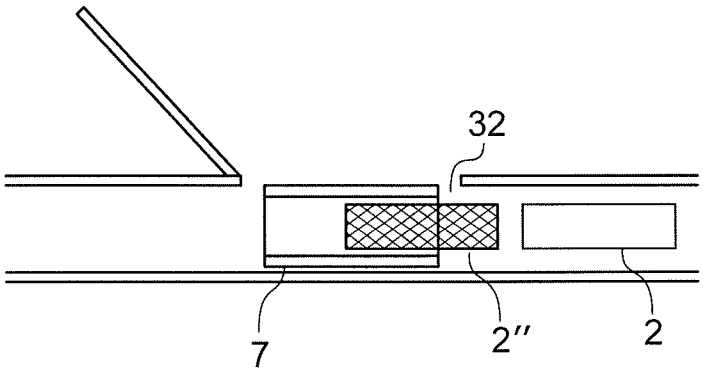

Fig. 4C

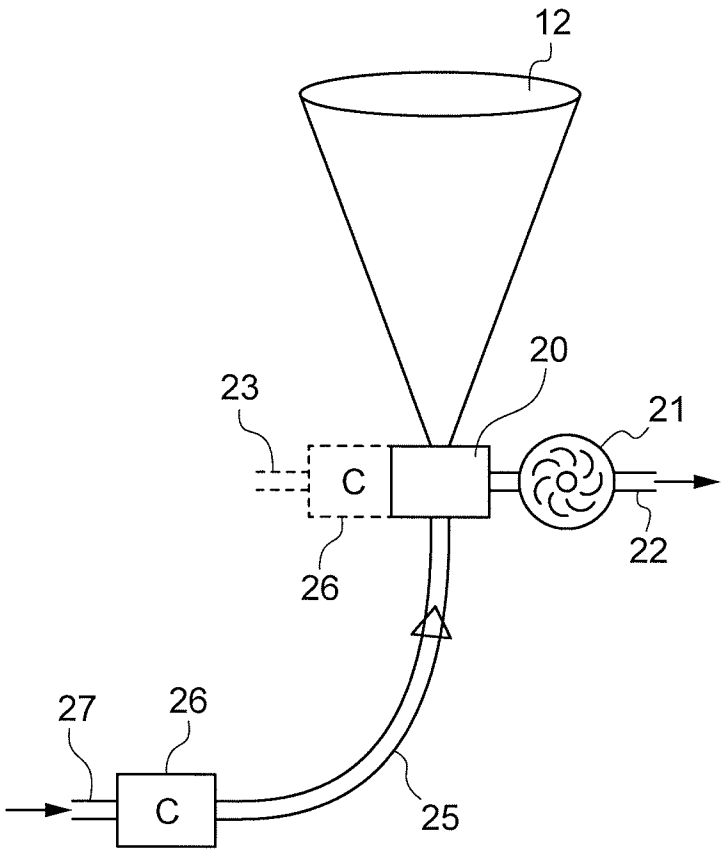

Fig. 5

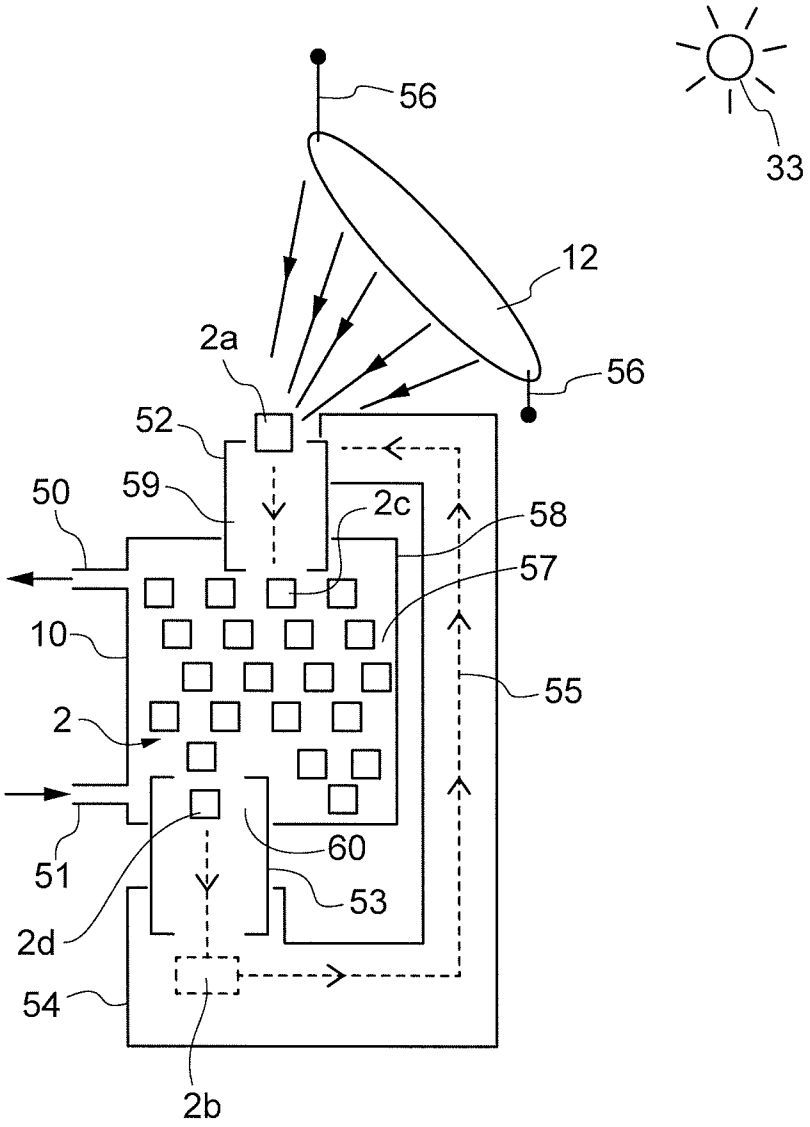

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/052682

A. CLASSIFICATION OF SUBJECT MATTER
INV. F28D20/00 F24S20/25
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D F24S

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/084586 A1 (THAKKAR DHAVAL VASANTKUMAR [IN]) 24 March 2016 (2016-03-24) paragraphs [0021], [0022] - [0028], [0033] - [0039] -----	1-63
X	US 6 640 580 B1 (STRASSER ROLAND [DE]) 4 November 2003 (2003-11-04) the whole document -----	1-63

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 2018	03/01/2019

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2018/052682

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016084586 A1	24-03-2016	CN 105393076 A	09-03-2016
		EP 3004776 A2	13-04-2016
		US 2016084586 A1	24-03-2016
		WO 2014192019 A2	04-12-2014
US 6640580 B1	04-11-2003	AU 1964400 A	05-12-2000
		DE 19922696 A1	28-10-1999
		EP 1179161 A1	13-02-2002
		PL 352322 A1	11-08-2003
		US 6640580 B1	04-11-2003
		WO 0070269 A1	23-11-2000