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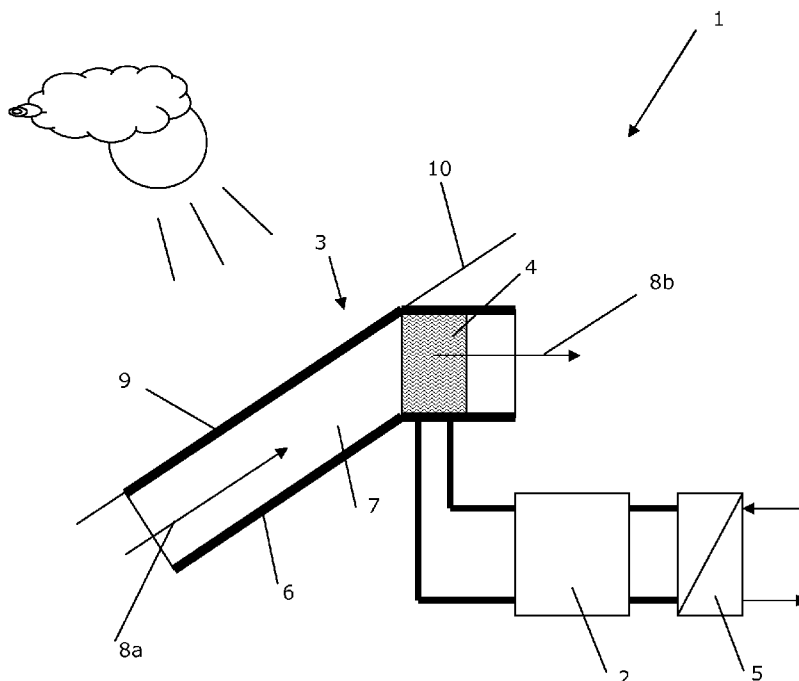
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(54) Title: A SOLAR AIR SYSTEM WITH A HEAT PUMP



(57) Abstract: The invention provides a system for collection of thermal energy. The system comprises a heat pump and an energy collector. The heat pump is adapted for transportation of thermal energy from a first heat exchanger to a second heat exchanger, and the energy collector comprises a wall forming a duct for conduction of an air-flow. Furthermore, the first heat exchanger is arranged in thermal communication with the duct.

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A SOLAR AIR SYSTEM WITH A HEAT PUMP

Technical field

The present invention relates to a system for collection of thermal energy. The system comprises a heat pump and a solar air collector.

5 Background of the invention

Traditionally, heat pumps may be used to convert low temperature energy from a cold surrounding air to usable hot air or hot water. The efficiency of a heat pump depends on the temperature difference at which it operates, i.e. the temperature of the air to be cooled, e.g. outdoor air, and the temperature at
10 which the heat pump delivers energy. The hot side of a heat pump is traditionally used for either heating of circulated indoor air or for delivering heat to the central heating system. In northern hemisphere this means that the efficiency is quite low when most energy is converted as most energy is consumed during wintertime, when outdoor temperature is low and the need of
15 heating is high. This leads to overall limited profitability of a heat pump for domestic usage.

The efficiency of a heat pump may be increased by improving the design of the heat pump itself, e.g. by increasing the surface area of the heat exchangers of the heat pump or by optimizing the flow through these. This, however, may
20 increase the costs and the size of a heat pump.

Summary of the invention

It is an object of embodiment of the invention to provide an improved system for collection of thermal energy.

Thus, in a first aspect, the invention provides a system for collection of thermal
25 energy, the system comprising a heat pump and an energy collector, the heat

pump being adapted for transportation of thermal energy from a first heat exchanger to a second heat exchanger, and the energy collector comprises a wall forming a duct for conduction of an air-flow, wherein the first heat exchanger is arranged in thermal communication with the duct.

- 5 By arranging the first heat exchanger in thermal communication with the duct, thermal energy contained in the air may be transferred to the first heat exchanger, thereby enabling transfer of the energy to the second heat exchanger and enabling usage thereof e.g. for heating of a building or heating of domestic water.
- 10 The energy collector may be a solar air collector which in this connection is an element in which air is heated by solar energy when air is conducted through the element. The energy collector may thus be a traditional solar air collector comprising e.g. a glass plate, an absorber and a duct through which the air may be conducted. Alternatively, the energy collector may comprise a simple duct
- 15 e.g. being dark coloured in order to improve absorption of solar heat. Other designs may also be applied.

In a further alternative, the energy collector may form part of a building's climate shield, e.g. form part of the roof in such a way that at least a part of the wall forms part of the roof. An energy collector in the form of a traditional solar

20 air collector may likewise be integrated in the shield, thus exchanging a part of the building shield with the energy collector.

It should be understood, that a building's climate shield in this connection comprises the roof, the outer walls, gables, and other building components which are at least partly in thermal communication with the space outside the

25 building.

The heat pump is adapted for transportation of thermal energy from a first heat exchanger to a second heat exchanger. By transportation of energy is in this connection understood, that the temperature of the first heat exchanger is decreased while the temperature of the second heat exchanger is increased.

If the energy collector comprises an absorber facilitating collection of thermal energy, the absorber may comprise a photovoltaic panel which may produce electricity based on incident solar radiation on the panel. The photovoltaic panel may be coupled to the heat pump in order to supply the heat pump with
5 electricity. The photovoltaic panel may be of a size which is large enough to fully cover the need for electricity of the heat pump.

In order to facilitate collection of energy, at least a first portion of the wall may form an outer surface of the system. The first portion forming an outer surface may be shaped and coloured to optimize collection of thermal energy.

- 10 In one embodiment, the first portion may form part of a climate shield of a building, which climate shield is arranged for thermal communication with a space outside the building. Consequently, at least a part of the duct may be built into the climate shield of the building and thus be in thermal communication with the space outside.
- 15 In order to ensure a sufficient level of absorption of incident solar radiation on the first portion being in thermal communication with the space outside the building, the first portion may have an emissivity being above 0.2. On the contrary, a surface having a too high reflection coefficient will not be able to utilize a significant part of the incident solar radiation.
- 20 It should be understood, that incident solar radiation on a surface comprises both diffuse radiation from the sky, direct radiation from the sun, and radiation reflected from adjacent surfaces.

Since the wall may collect thermal energy from a space surrounding the duct, the wall may be relatively large e.g. have a surface area being 100 pct or more
25 of the surface area of the first heat exchanger, e.g. in the range of 100-200 pct, 200-400 pct, even larger. The area of the wall may be increased without increasing the cross sectional area of the duct, e.g. by applying a non-planar surface. By increasing the area of the wall, a larger surface may be in thermal

communication with the surrounding air, thereby improving the energy collection.

Since the first portion may form part of the climate shield, it may be desired that the surface area hereof is large in order to facilitate incident solar radiation to this surface. Thus, the first portion may have a surface area being in the range 20-100 pct of a surface area of the first heat exchanger, e.g. in the range of 20-35 pct, 35-60 pct, or 60-100 pct.

A small surface area of the first portion may be particularly relevant, if it is desired that the heat pump is primarily running when the sun shines. It may however be desired to be able to utilize the diffuse solar radiation in order to be able to collect a larger amount of thermal energy during spring and autumn, where the amount of direct solar radiation is lower. In order to be able to collect a significant amount of thermal energy from the diffuse solar radiation it may be relevant to apply an energy collector in which the surface area of the first portion is larger.

In order to facilitate the conduction of an air-flow through the duct, the system may further comprise a ventilator being arranged to provide forced ventilation of the duct. The ventilator may be arranged inside the duct, e.g. close to an outlet of the duct and may thus draw the air through the duct. Dependent on the shape of the system and/or the shape of the duct other positions of the ventilation may also be applied.

In order to optimize the utilization of energy, it may be preferred that the air-flow experiences a certain temperature increase when being conducted through the duct. To ensure this, the air-flow through the duct may be controlled based on at least one temperature measurement. In order to control the air-flow, a damper may be inserted in the duct. The damper may control the air-flow dependent on the at least one temperature measurement.

In one embodiment, the air-flow may be controlled based on a temperature difference between air temperature at an inlet of the duct and air temperature

before the first heat exchanger in the direction of the air-flow. This temperature difference may be seen as an indication of the amount of thermal energy being collected by the air being conducted through the duct.

5 In embodiments comprising a ventilator, the ventilator may be controlled based on at least one temperature measurement. In particular, the ventilator may control the air-flow based on a temperature difference between air temperature at an inlet of the duct and air temperature before the first heat exchanger in the direction of the air-flow. As an example, the temperature difference may be 10 degrees C, thus ensuring a good coefficient of performance (COP) of the heat pump while keeping the use of energy for the ventilator at a reasonable level.

The air-flow may be controlled by a simple on/off control strategy. In another embodiment, the speed of the ventilator may be controlled, thus controlling the air-flow through the duct.

15 During hot and sunny periods where the temperature of the air may be very high, it may be desirable to prevent too much thermal energy from being collected by the first heat exchanger since this may overheat the system. Accordingly, the duct may comprise a second outlet through which at least a part of the air can escape the duct without passing the first heat exchanger.

20 The heat pump may comprise a refrigerant circulating between a compressor, a condenser, and an evaporator. In one embodiment, the evaporator may constitute at least a part of the first heat exchanger. In the evaporator the refrigerant is evaporated and consequently it absorbs thermal energy from the air which is heated in the duct, when the heated air reaches the first heat exchanger. The air may thus be cooled and the absorbed thermal energy may be 25 transported from the first heat exchanger to the second heat exchanger.

The heat pump may as an example include different types of cooling principles, such as Stirling or Scroll. Furthermore, the heat pump may comprise a gas, e.g. CO₂, Helium, Argon, or air.

Since cooling by evaporation may be highly efficient, ice may built up on the first heat exchanger during operation of the heat pump. This may particularly be the case if outdoor air is used for conducting the air-flow through the duct, since the temperature may be lower than if indoor air is used.

- 5 In order to facilitate de-icing of the first heat exchanger without having to stop the heat exchanger completely, the first heat exchanger may comprises two separate elements. Thus, the one of the elements may still be running while closing the other for de-icing, repair, maintenance or for other reasons.

10 The duct may form a unit with a cavity which houses the evaporator. The unit may form an inlet for the air-flow, an outlet for the airflow, an inlet for the refrigerant, and an outlet for the refrigerant. Thus, the energy collector and the first heat exchanger may be one unit which may be prepared for mounting on a loft. The inlet and outlet for the refrigerant may be adapted for connection to pipes e.g. for connection to a compressor. By one unit is e.g. meant that they
15 share the same mounting frame or that they constitute one single component for the user of the system.

In one embodiment, the condenser may constitute at least a part of the second heat exchanger. Furthermore, the condenser may form part of a heating system of a building. Thus, thermal energy transported from the first heat exchanger to
20 the second heat exchanger may be utilized in the heating system of a building.

As an example, the second heat exchanger may be arranged in thermal communication with a reservoir for a liquid medium such as water. Consequently, the thermal energy collected by the air-flow through the duct may be used to heat the reservoir.

- 25 The liquid medium may be domestic water, water for heating building, or water for both. Since the need for heating the building during summer time may be low and sometime non-existing, it may be preferred to heat the domestic water which normally is used almost constantly throughout the year.

In case the reservoir is fully heated, the excess heat from the second heat exchanger may be use to preheat the air of a traditional ventilation system, if such a system is present in the building.

When an air-flow is conducted through the duct, it may be exhausted via an outlet being positioned after the first heat exchanger. Dependent on the temperature of the air before the first heat exchanger and of the efficiency of the first heat exchanger, the exhaust air may have a temperature which is higher than the temperature of the outdoor air. The exhaust air may thus be used as preheated air for a traditional ventilation system.

The heat pump may comprise one or more Peltier elements. The use of Peltier elements may be particularly relevant if the temperature difference between the first and second heat exchanger during the majority of hours of operation is relatively low, since operation of a Peltier element at a high temperature difference may decrease the efficiency of the element. Running Peltier elements at maximum capacity may lower the efficiency, and it may therefore be an advantage to apply a plurality of Peltier elements, and thus operate them at around medium capacity.

It may even be an advantage to combine Peltier elements with a more traditional compressor based heat pump and to shift between the two principles based on the temperature difference across the heat exchanger so that the Peltier elements works at temperature differences which are low and the compressor based heat pump works when the temperature difference becomes above a specific level, e.g. above 10 degrees in difference between the hot and the cold site of the heat pump. In that case, the user may benefit from silent operation whenever the Peltier elements are active.

In order to conduct an air-flow through the duct, the duct may comprise a first inlet for the air, as mentioned above. To allow for conduction of air from different spaces or from a space and from the outdoor, the duct may comprise at least a first and a second inlet. As an example, the first inlet may be for conduction of air from a loft, e.g. an un-insulated constructional space, whereas

the other inlet may be for conduction of air from a room, e.g. from an insulated habitable area.

Depending on the amount of incident solar radiation, the outdoor and indoor temperature, the level of insulation of the building, the use of the building, etc., it may be an advantage to be able to shift between conduction of air through the first and second inlet. Thus, the system may comprise means for controlling an amount of air which may enter the duct via the first and second inlets based on a sensed temperature or based on solar radiation. As an example, the temperature may be measured in the vicinity of the first inlet, whereas the solar radiation may be measured by a sensor positioned on the roof of the building, at a gable, or at another position in the vicinity of the building in which the system is positioned.

In a second aspect, the invention provides a method of collecting thermal energy in a building which comprises an insulated habitable area, and an un-insulated constructional space which is at least partly shielded from an ambient space by a climate shield, the method comprising the steps of:

- providing a duct with an inlet arranged in the constructional space,
- providing a heat pump which can be operated to transport thermal energy from a first heat exchanger to a second heat exchanger;
- arranging the first heat exchanger in thermal communication with the duct; and
- conducting an air-flow through the duct while operating the heat pump.

By insulated habitable area is in this connection understood insulated rooms of a building, in which rooms people are supposed to stay, such as kitchens, living rooms, bedrooms, nurseries, bathrooms, offices, production facilities, etc. It should be understood, that the insulated habitable areas both comprises rooms of houses, flats, office buildings, etc.

On the contrary, an un-insulated constructional space is understood to comprise a loft, a roof space, a cellar, a greenhouse, a stable and other farm building, etc.

The space may be shielded from an ambient space, e.g. the outdoor by a

climate shield. The space is un-insulated, and may thus be in closer thermal communication with the outdoor, than the insulated rooms.

As an example, a loft may be shielded by an un-insulated roof, since the insulation may be positioned between the loft and the habitable area.

- 5 Consequently, the loft may be heavily heated by incident solar radiation and by the high temperature of the surrounding outdoor air.

In another example, it may be possible to provide the duct with an inlet arranged in a stable or a cowshed, and thus utilize the heat in the farmhouse for heating of the building or for heating of domestic water.

- 10 As an example, the duct may be an energy collector arranged in the climate shield and thus being in direct thermal communication with the outdoor, both incident solar radiation and the outdoor air. Another example of a duct may be a simple duct being formed by a wall.

- 15 The duct comprises an inlet being arranged in the un-insulated constructional space, and thus being able to conduct an air-flow through the duct by use of air from the constructional space.

The heat pump and thus the heat exchangers may be of the kind disclosed in connection with the first aspect of the invention.

- 20 By arranging the first heat exchanger in thermal communication with the duct, thermal energy contained in the air from the un-insulated constructional space may be transferred to the first heat exchanger, thereby enabling transfer of the energy to the second heat exchanger and enabling use thereof for. As an example, the energy may be used to heat a building or for heating of domestic water. This may be an advantage on a sunny day, e.g. during summertime
25 where the temperature under the roof may climb high above the temperature of the habitable area.

It should be understood, that the features of the first aspect of the invention may also be applicable in connection with the method of the second aspect of the invention.

5 The method may further comprise a step of providing an additional inlet into the duct, the additional inlet being arranged in the habitable area. This allows for conduction of air from difference spaces, and thus for conduction of air of different temperatures. This may be an advantage, e.g. during wintertime when the temperature under the roof is low. In this case, the heated air from the habitable area is exhausted through the duct, and the system thus ventilates the
10 building.

In order to benefit further from the possibility of having two different air-flows, the method may comprise a step of controlling an amount of air which enters the duct via the inlet and the additional inlet based on a sensed temperature or based on solar radiation. The temperature may be sensed in the constructional
15 area or in the ambient space, whereas solar radiation e.g. may be measured on top of the building.

In a third aspect, the invention provides a building comprising a system for collection of thermal energy, the building comprising an insulated habitable area; an un-insulated constructional space which is at least partly shielded from
20 an ambient space by a climate shield; and a duct for conduction of an air-flow, the duct comprising an inlet arranged in the constructional space, the system comprising a heat pump which can be operated to transport thermal energy from a first heat exchanger to a second heat exchanger, wherein the first heat exchanger is arranged in thermal communication with the duct.

25 It should be understood, that the above-mentioned features of the first and second aspects of the invention may also be applicable to the building of the third aspect of the invention.

Brief description of the drawings

Embodiments of the invention will now be further described with reference to the drawings, in which:

Fig. 1 illustrates an embodiment of a system for collection of thermal energy,

5 Figs. 2a and 2b illustrate an embodiment of an energy collector, and

Figs. 3-5 illustrate different embodiments of a system for collection of thermal energy.

Detailed description of the drawings

Fig. 1 illustrates an embodiment of a system 1 for collection of thermal energy.

10 The system 1 comprises a heat pump 2 and an energy collector 3. The heat pump 2 is adapted for transportation of thermal energy from a first heat exchanger 4 to a second heat exchanger 5. The energy collector 3 comprises a wall 6 forming a duct 7 for conduction of an air-flow. Furthermore, the first heat exchanger 4 is arranged in thermal communication with the duct 7. The air-flow
15 is illustrated by the arrows 8a, 8b.

In the illustrated embodiment, a first portion 9 of the wall 6 forms part of a climate shield of a building, in this case the roof 10 (only partly shown). The roof 10 is arranged for thermal communication with a space outside the building.

The air-flow is conducted through the duct 7 by natural ventilation utilizing the
20 chimney effect in the duct 7. In an alternative embodiment, forced ventilation of the duct 7 may be provided by a ventilator arranged in the duct 7.

By arranging the first heat exchanger 4 in thermal communication with the duct 7, thermal energy contained in the air is transferred to the first heat exchanger 4, thereby enabling transfer of the energy to the second heat exchanger 5 and

enabling usage thereof, e.g. for heating of the building in which the system 1 is positioned or for heating of domestic water.

Furthermore, the exhaust air illustrated by the arrow 8b may be used as pre-heated air for a ventilation system, dependent on the temperature hereof.

- 5 Fig. 2 illustrates an energy collector 3 according to the invention. The illustrated energy collector 3 is a traditional solar air collector comprising a glass plate 11, an absorber 12, insulation 13 and a duct 7 through which the air may be conducted. The arrows 14a, 14b illustrate the flow through the duct 7. The air enters the duct 7 at one end and flows as indicated by arrow 14a between the
10 glass plate 11 and the absorber 12 which may also act as a heat sink. At the other end, the energy collector 3 is closed and the duct 7 turns and thereby allows the air to flow back towards the inlet end in the direction indicated by arrow 14b. The return flow is between the absorber/heat sink 12 and the insulation 13 allowing for further heating of the air.
- 15 The illustrated energy collector may be built into a roof of a building, in which case the glass plate 11 may be part of the first portion 9 of the wall 6. But the energy collector 3 may also be a stand-alone unit, in which the duct 7 is arranged in thermal communication with the first heat exchanger 4 of a heat pump 2, i.e. as illustrated in Fig. 1 if the roof 10 is omitted.
- 20 Fig. 3 illustrates another embodiment of a system 1' for collection of thermal energy. The system 1' comprises three energy collectors 3, 3' for conduction of an air-flow. The air-flow is indicated by the arrows 15. The energy collectors 3, 3' are coupled in series, and in the last energy collector 3' the duct 7 is arranged in thermal communication with a first heat exchanger 4.
- 25 A ventilator 16 is arranged after the first heat exchanger 4 in the duct 7 of the last energy collector 3' in order to provide forced ventilation of the duct 7.

Fig. 4 illustrates yet another embodiment of a system 1'' for collection of thermal energy. The system comprises a heat pump 2 and an energy collector 3,

the energy collector 3 forming part of the roof 10 of the building 17. The heat pump 2 is adapted for transportation of thermal energy from a first heat exchanger 4 to a second heat exchanger 5. As illustrated, the energy collector 3 comprises a wall 6 forming a duct 7 for conduction of an air-flow. The first heat exchanger 4 is arranged in thermal communication with the duct 7 via a second duct 7' leading the air from an un-insulated loft to an insulated room of the building 17.

A ventilator 16 is arranged after the first heat exchanger 4 in the duct 7' in order to provide forced ventilation of the ducts 7, 7'.

- 10 By arranging the first heat exchanger 4 in thermal communication with the duct 7', thermal energy contained in the air is transferred to the first heat exchanger 4, thereby enabling transfer of the energy to the second heat exchanger 5 and enabling use thereof, e.g. for heating of the building in which the system 1'' is positioned or for heating of domestic water.
- 15 In the present embodiment, it is possible to control the transfer of thermal energy from the air to the first heat exchanger 4 in such a way that the air is not cooled below a predefined set-point, such as 20 degrees C. The exhaust air from the first heat exchanger 4 can thus be used for changing the air in building, the air thus being pre-heated.
- 20 By the control it is possible to switch between the at least two ways of operating the system, and it may thus during some running hours be possible to transfer at larger amount of energy from the air to the first heat exchanger 4 and cool the air further, e.g. to 8 degrees C or even further.

Fig. 5 illustrates a fourth embodiment of a system 1''' for collection of thermal energy. The system 1''' comprises a heat pump 2 and an energy collector 3'''. In this embodiment the energy collector 3''' is constituted by a simple duct for conduction of an air-flow, the air entering the duct 3''' via the inlet 18. The heat pump 2 is adapted for transportation of thermal energy from a first heat

exchanger 4 to a second heat exchanger 5. The first heat exchanger 4 is arranged in thermal communication with the duct 3'''.

By arranging the first heat exchanger 4 in thermal communication with the duct 3''', thermal energy contained in the air from the un-insulated loft 19 is

5 transferred to the first heat exchanger 4, thereby enabling transfer of the energy to the second heat exchanger 4 and enabling used thereof for. As illustrated, the energy is used for heating of domestic water contained in the reservoir 20.

The system 1''' further comprises additional inlet 21 into the duct 3''', the additional inlet 21 being arranged in the habitable area 22. This allows for
10 conduction of air from difference spaces, and thus for conduction of air of different temperatures.

In order to benefit further from the possibility of having two different air-flows, the system 1''' comprises a control unit (not shown) enabling control of an amount of air which enters the duct 3''' via the inlet 18 and the additional inlet
15 21 based on temperature measurements at the loft 19.

One way of controlling the shift between the inlets 18, 21 is to compare the temperature at the loft 19 with the temperature of the habitable area 22, and only open the first inlet 18, when the temperature at the loft 19 is higher than the temperature of the habitable area 22.

20 In the illustrated embodiment, a slide gate 23 controlled by a slide mechanism 24 shifts between the two configurations.

CLAIMS

1. A system for collection of thermal energy, the system comprising a heat pump and an energy collector, the heat pump being adapted for transportation of thermal energy from a first heat exchanger to a second heat exchanger, and
5 the energy collector comprises a wall forming a duct for conduction of an air-flow, wherein the first heat exchanger is arranged in thermal communication with the duct.
2. A system according to claim 1, wherein at least a first portion of the wall forms an outer surface of the system.
- 10 3. A system according to claim 2, wherein the first portion forms part of a climate shield of a building, which climate shield is arranged for thermal communication with a space outside the building.
4. A system according to claim 3, wherein the first portion has an emissivity being above 0.2.
- 15 5. A system according to any of the preceding claims, wherein the wall has a surface area being 100 pct or more of the surface area of the first heat exchanger.
6. A system according to any of claims 1-4, wherein the first portion has a surface area being in the range 20-100 pct of the surface area of the first heat
20 exchanger.
7. A system according to any of the preceding claims, further comprising a ventilator arranged to provide forced ventilation of the duct.
8. A system according to any of the preceding claims, wherein the air-flow is controlled based on at least one temperature measurement.

9. A system according to claim 8, wherein the air-flow is controlled based on a temperature difference between air temperature at an inlet of the duct and air temperature before the first heat exchanger in the direction of the air-flow.

5 10. A system according to any of claims 7-9, wherein the ventilator is controlled based on at least one temperature measurement.

11. A system according to any of the preceding claims, wherein the heat pump comprises a refrigerant circulating between a compressor, a condenser and an evaporator.

10 12. A system according to claim 11, wherein the evaporator constitutes at least a part of the first heat exchanger.

13. A system according to claim 12, wherein the duct forms a unit with a cavity which houses the evaporator, the unit forming an inlet for the air-flow, an outlet for the airflow, an inlet for the refrigerant, and an outlet for the refrigerant.

15 14. A system according to any of claims 11-13, wherein the condenser forms part of a heating system of a building.

15. A system according to any of claims 1-10, wherein the heat pump comprises one or more Peltier elements.

16. A system according to any of the preceding claims, wherein the duct comprises at least a first and a second inlet.

20 17. A system according to claim 16, further comprising means for controlling an amount of air which may enter the duct via the first and second inlets based on a sensed temperature or based on solar radiation.

25 18. A method of collecting thermal energy in a building which comprises an insulated habitable area, and an un-insulated constructional space which is at least partly shielded from an ambient space by a climate shield, the method

comprising the steps of:

- providing a duct with an inlet arranged in the constructional space,
- providing a heat pump which can be operated to transport thermal energy from a first heat exchanger to a second heat exchanger;
- 5 - arranging the first heat exchanger in thermal communication with the duct; and
- conducting an air-flow through the duct while operating the heat pump.

10 19. A method according to claim 18, further comprising a step of providing an additional inlet into the duct, the additional inlet being arranged in the habitable area.

20. A method according to claim 19, further comprising a step of controlling an amount of air which enters the duct via the inlet and the additional inlet based on a sensed temperature or based on solar radiation.

15 21. A method according to claim 20, wherein the temperature is sensed in the constructional area or in the ambient space.

22. A method according to any of claims 18-21, wherein the second heat exchanger is arranged in thermal communication with a reservoir for a liquid medium.

20 23. A method according to claim 22, wherein the liquid medium is domestic water.

25 24. A building comprising a system for collection of thermal energy, the building comprising an insulated habitable area; an un-insulated constructional space which is at least partly shielded from an ambient space by a climate shield; and a duct for conduction of an air-flow, the duct comprising an inlet arranged in the constructional space, the system comprising a heat pump which can be operated to transport thermal energy from a first heat exchanger to a second heat exchanger, wherein the first heat exchanger is arranged in thermal communication with the duct.

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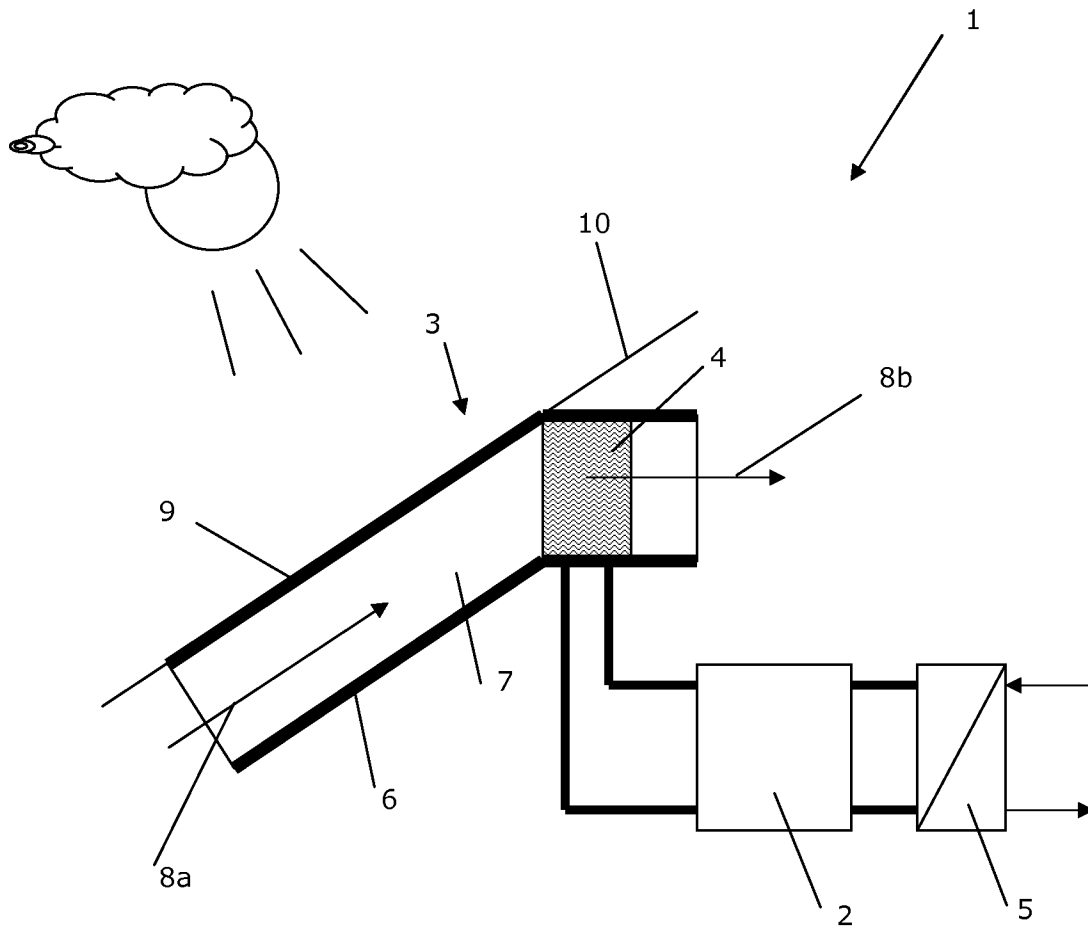


Fig. 1

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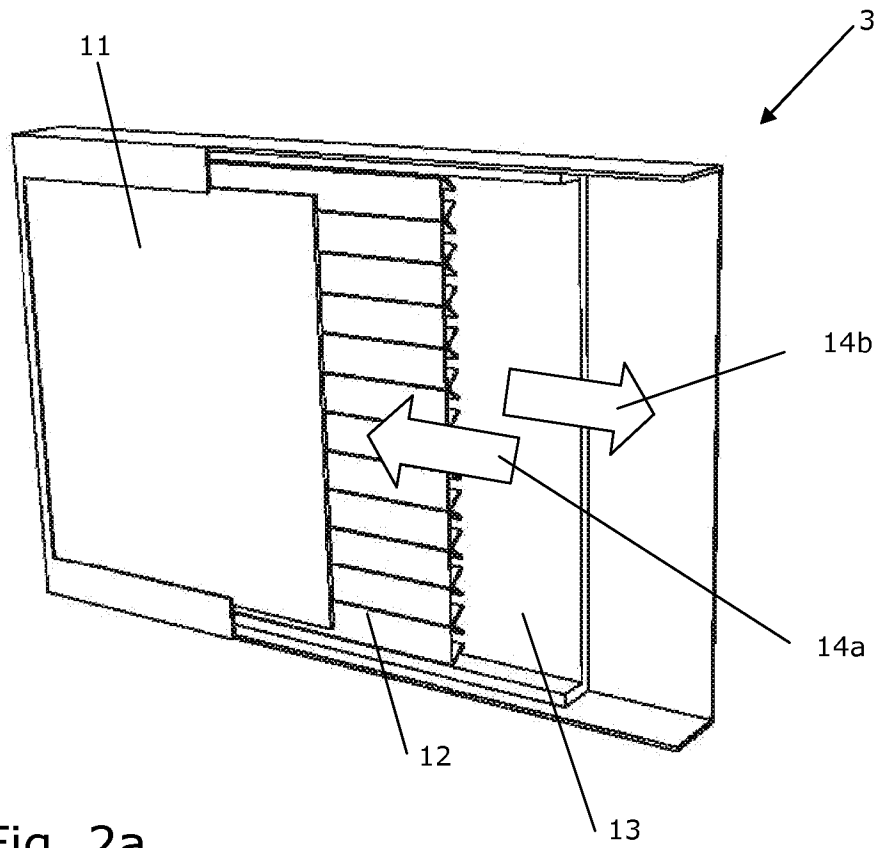


Fig. 2a

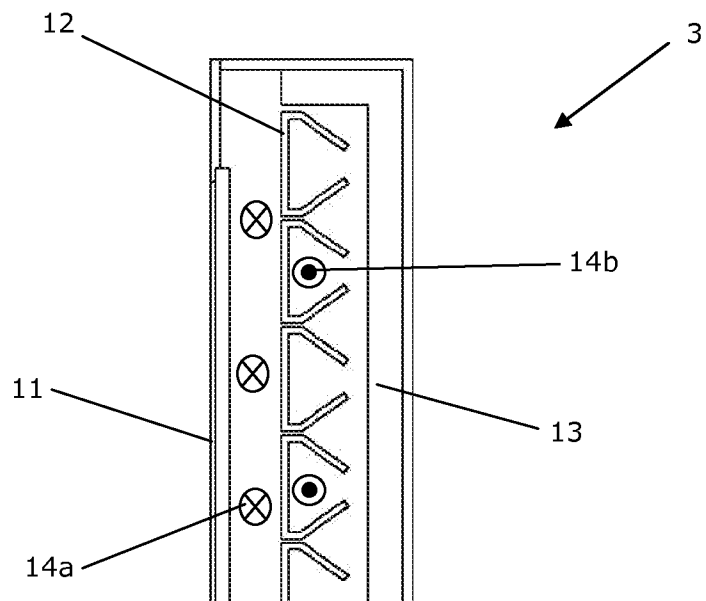


Fig. 2b

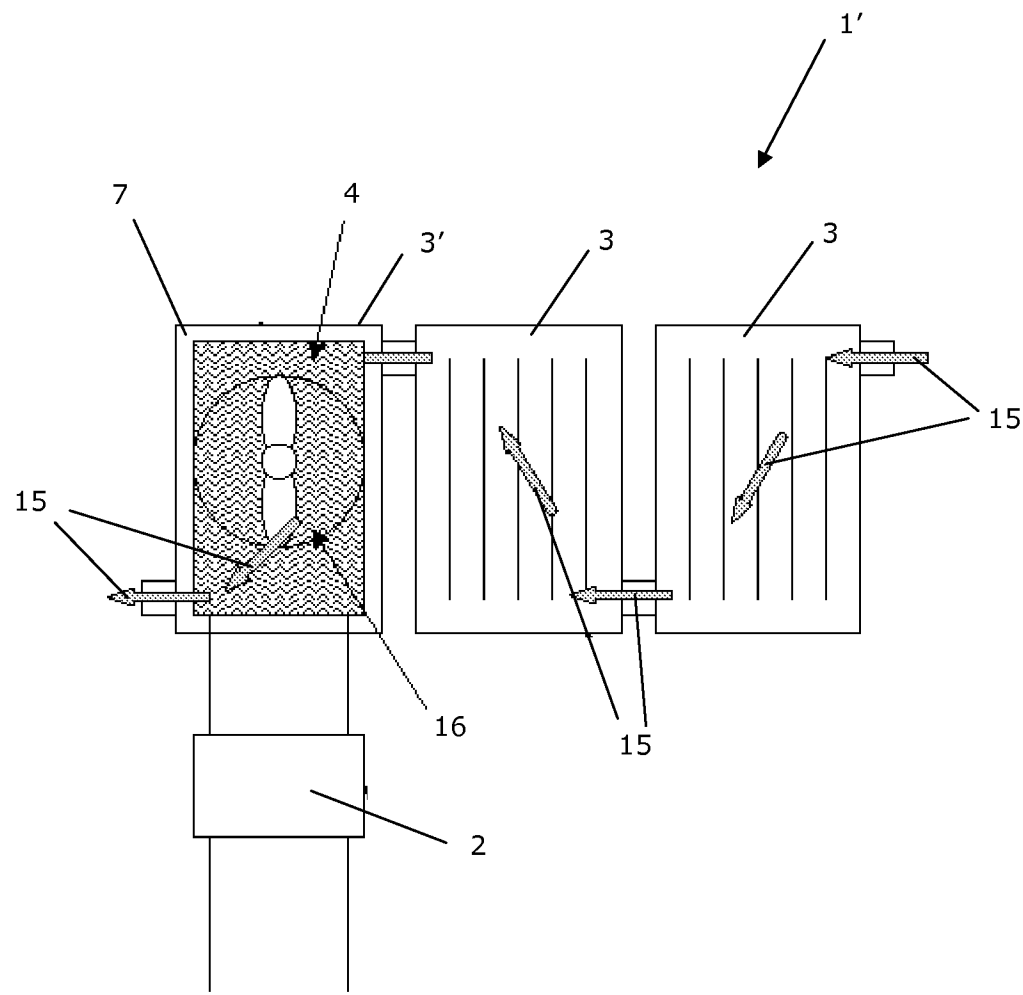


Fig. 3

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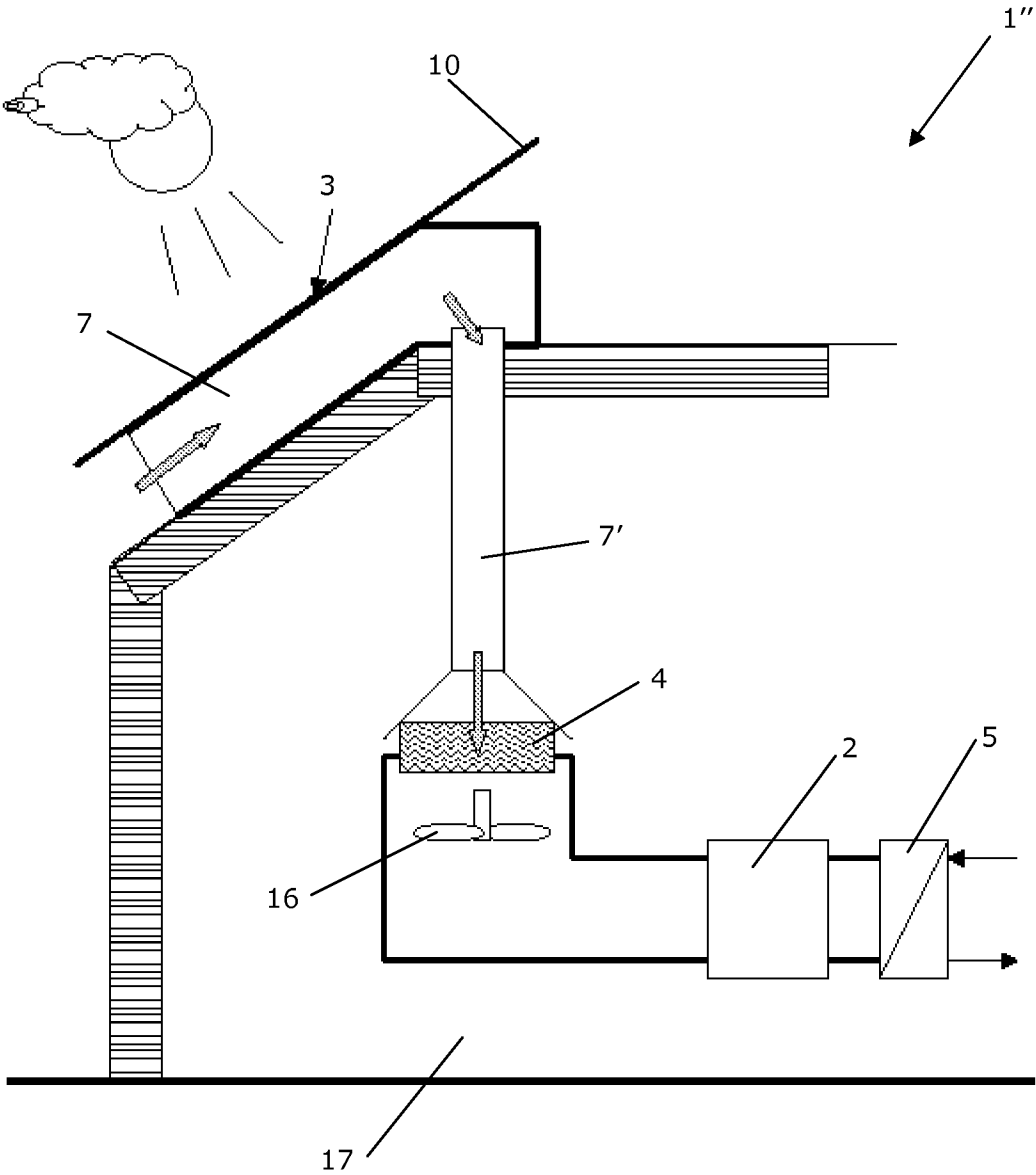


Fig. 4

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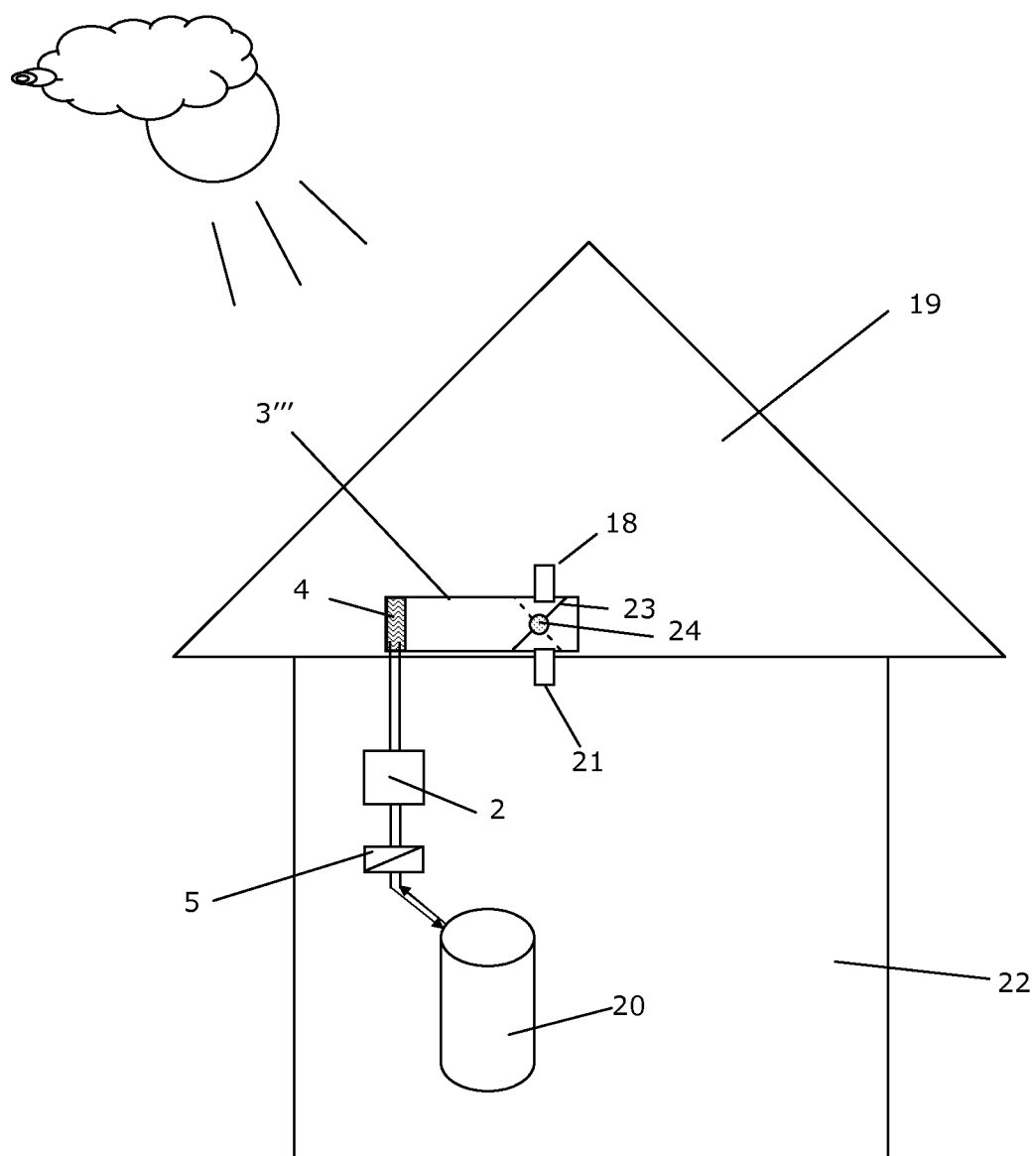


Fig. 5