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(54) **HEAT EXCHANGE ELEMENT AND SYSTEMS AND METHOD FOR EXCHANGING THERMAL ENERGY**

(57) A heat exchange element, comprising: an outer flow element, an inner flow element arranged within the outer flow element, an element flow path comprising forward flow path and a return flow path, wherein the forward flow path is arranged between the outer flow element and the inner flow element, the return flow path is arranged

within the inner flow element, the element flow path is configured to guide a working fluid from the forward flow path to the return flow path, a pressure control element, arranged fluidically between the forward flow path and the return flow path.

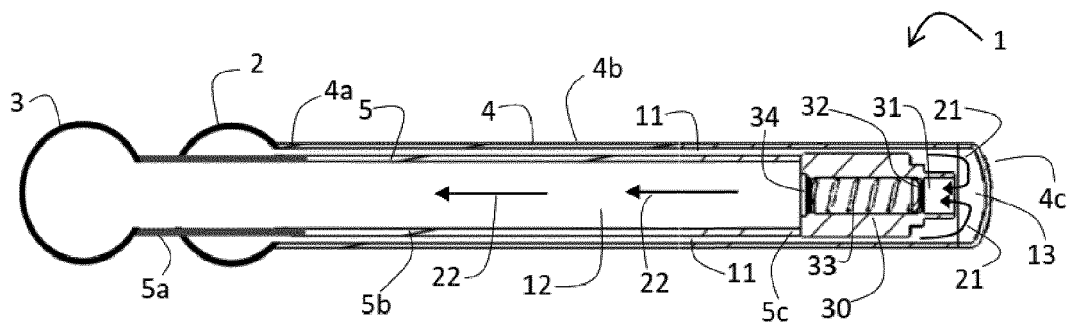


Fig. 1a

Description

[0001] The present invention relates to the field of heat exchangers, in particular for absorbing thermal energy, e.g. absorbing thermal energy with a liquid, e.g. thermal energy provided by a gas or the sun.

[0002] Heat exchanger systems for gas-liquid heat exchange are known. Often, the liquid is flowing through a plurality of parallel flow elements from an inlet to an outlet, and the gas is flowing around the flow elements.

[0003] Systems for absorbing thermal energy from the sun, or thermal energy, are also known. Often, a parabolic concentrator is used to concentrate the solar radiation on a flow element in which water or another liquid is arranged. The flow element can be arranged in a vacuum tube. The thermal energy converts the water into steam, which can be used for various applications.

[0004] The inventors have found that prior art systems are not optimal in view of efficiency and/or controllability.

[0005] It is an object of the invention to improve the controllability and/or efficiency of heat absorbing, or at least provide an alternative to the prior art.

[0006] This object is achieved with a heat exchange element, comprising

- an outer flow element,
- an inner flow element arranged within the outer flow element,
- an element flow path comprising forward flow path and a return flow path, wherein
 - the forward flow path is arranged between the outer flow element and the inner flow element,
 - the return flow path is arranged within the inner flow element,
 - the element flow path is configured to guide a working fluid from the forward flow path to the return flow path,
- a pressure control element, arranged fluidically between the forward flow path and the return flow path.

[0007] The invention thus relates to a heat exchange element. The heat exchange element can e.g. be a heat absorption element, e.g. configured to absorb thermal energy. The heat exchange element can e.g. be a heat expelling element, e.g. configured to expel thermal energy.

[0008] The heat exchange element comprises an outer flow element and an inner flow element. The inner and outer flow element can be any element configured to allow a fluid (gas or liquid) to flow, for example a tube, pipe, duct, conduit, or the like. The inner and outer flow element can be made of any material suitable for the intended application in terms of chemical resistance, pressure, and temperature. The outer flow element can for example have a diameter between DN15-DN150, e.g. between DN25-DN80. The inner flow element can e.g. have a di-

ameter that is 5-50 mm smaller, e.g. 8-25 mm smaller than the outer flow element. The outer flow element can for example be configured to withstand a pressure difference of at least 50 bar, e.g. at least 100 bar, e.g. at least 200 bar. The inner flow element can generally be embodied with lower wall thickness because the pressure difference between both sides of the inner flow element are smaller. The inner and outer flow element can be configured to be used up to at least 400 degrees Celsius, e.g. at least 650 degrees Celsius. For example, the temperature in the forward flow path may be 110-180 degrees Celsius. For example, the inner and/or outer can be made of steel. The inner flow element and the outer flow element may e.g. be tubular elements.

[0009] An element flow path is configured to guide a working fluid. The working fluid may e.g. be water, ammonia, acetone, an organic media suitable for an organic Rankine cycle, a thermal oil, an (inorganic) salt, or an organic paraffin. It is also possible to use a product commercialized under the trademark Downterm, which include several synthetic organic fluids with thermal stability which can be used at advantageous pressure ranges. Also hydrofluorocarbon such as the R245fa or other similar media are suitable to be used in advantageous flexible ranges of pressure and/or temperature. The heat exchange element is configured to absorb or expel thermal energy by means of the working fluid. The heat exchange element is configured for contactless heat exchange. That is, the working fluid within the heat exchange element does not come into direct contact with a fluid or radiation outside the heat exchange element which provides or absorbs the thermal energy. The thermal energy can e.g. be provided by a fluid arranged outside of the heat exchange element, for example a hot gas, which may e.g. include steam, hot air, or be an exhaust gas. Optionally the thermal energy can be provided by a gas or heat rejection steam from a process, e.g. an exhaust gas e.g. being created as waste product in an industrial process. The thermal energy can e.g. be provided by a hot liquid and/or a high viscosity liquid arranged outside the heat exchange element. The thermal energy can e.g. be provided a buffer material, e.g. an inorganic salt, an (organic) paraffin, a glycol, a thermal oil, metal spheres, or stones. The thermal energy can e.g. be provided by the sun, e.g. by solar radiation that is e.g. reflected towards the heat exchange element, e.g. by a parabolic concentrator. The thermal energy can e.g. be absorbed by a fluid arranged outside of the heat exchange element. The invention can e.g. be used in a metallurgical process, a dryer, the oil and gas sector, the energy sector, etc.

[0010] The element flow path comprises at least a forward flow path and a return flow path, and the working fluid is guided from the forward flow path to the return flow path. At least a part of the forward flow path is further defined between the outer flow element and the inner flow element, and at least a part of the return flow path within the inner flow element. For example, the element flow path is configured to guide the flow in a forward di-

rection in the forward flow path and in a return direction in the return flow path, wherein the forward direction is opposite of the return direction. For example, the element flow path is configured to guide the working fluid through the forward flow path from a proximate end to a distal end of the outer flow element, and then in the return flow path from a distal end of the inner flow element to a proximate end of the inner flow element. For example, the proximal end of the outer flow element may be an inlet of the heat exchange element and the proximal end of the inner flow element may be an outlet of the heat exchange element. For example, the outer flow element may at its proximal end be fluidly connected to an inlet pipe and the inner flow element may at its proximal end be fluidly connected to an outlet pipe. Optionally, when the heat exchange element is a heat absorption element, the working fluid is in a liquid state in the forward flow path and at least partially in a gaseous state in the return flow path.

[0011] The arrangement of the inner flow element being arranged within the outer flow element is advantageous, because reduces the cross section and volume of the forward flow path. This allows to maintain a high (linear) flow speed (e.g. measured in m/s) in the forward flow path, while keeping the flow rate (e.g. measured in kg/s) relatively low. The high flow speed is advantageous for heat transfer, while the low flow rate is advantageous because it allows the pumps etc. to be dimensioned smaller, as well as common inlet or outlet lines when multiple heat exchange elements are provided.

[0012] In embodiments, optionally a pressure control element is arranged fluidically between the forward flow path and the return flow path. For example, the pressure control element can be arranged at the distal end of the inner flow element. When the heat exchange element is a heat absorption element, the pressure control element can be configured to reduce the pressure of the working fluid as it flows from the outer flow element into the inner flow element. This allows to control the pressure of the working fluid both in the inner flow element as in the outer flow element. This improves the controllability of the heat absorbing on the one hand, and allows to improve efficiency on the other hand. The pressure control element can for example be controlled by a control unit or can e.g. be self-acting element, for example comprising one or more springs.

[0013] In embodiments wherein the heat exchange element is a heat absorption element, the pressure control element may be a flashing element configured to cause the working fluid to flash. For example, the flashing element may be configured to convert at least a part of the working fluid into a gaseous state when entering the return flow path. The return flow path within the inner flow element may be a flashing segment in this embodiment. Due to the flashing, the temperature of the working fluid is reduced in the return flow path. Working fluid that is still in the liquid state, may be further vaporized by absorbing thermal energy from the working fluid in the for-

ward flow path. This transfer of thermal energy happens via the wall of the inner flow element that is physically arranged between the forward flow path and the return flow path. This way, the working fluid in the return flow path can become saturated and/or superheated vapor (steam in the case of water). This allows for a large energy flow with a relatively low (mass) flow rate.

[0014] In embodiments wherein the heat exchange element is a heat absorption element, the pressure control element is configured to reduce the pressure of the working fluid for converting at least a part of the working fluid from a liquid to a gaseous state. For example, the pressure in the return flow path may be about 1-5 bar less than in the forward flow path, e.g. 2.5-3.5 bar less. For example, when water is used as working fluid, the working fluid in the return flow path may be a partial steam flow, or saturated steam, or (low) overheated steam.

[0015] In a liquid state the working fluid may be able to absorb thermal energy better. Therefore, it may be desired that the working fluid is in the liquid state in the forward flow path. In the gaseous state, however, it may be more efficient to transport the working fluid. By converting the working fluid with the pressure control element, heat absorption and transportation of the thermal energy can be improved. In addition, during the conversion to the gaseous state, the temperature of the working fluid may decrease. However, because the return flow path is arranged within the forward flow path, the working fluid in the return flow path further absorbs thermal energy from the working fluid in the forward flow path, further increasing efficiency.

[0016] In embodiments wherein the heat exchange element is a heat absorption element, the pressure control element is configured to maintain the pressure in the forward flow path at a pressure at which the working fluid is in the liquid state. While the working fluid is absorbing thermal energy in the forward flow path, it could occur at some pressures that part of the working fluid is converted to a gaseous state. However, the thermal conductivity of gasses is generally lower than that of liquids, resulting in a lower efficiency of heat absorption. The pressure control element can be configured to maintain a sufficient high pressure in the forward flow path, thereby maintaining the liquid state and increasing the efficiency of the absorption of thermal energy. For example, the pressure in the forward flow path may be up to 200 bar, e.g. 25-200 bar, e.g. 50-100 bar.

[0017] In embodiments, the pressure control element is configured to prevent working fluid from backflowing from the return flow path into the forward flow path. Thus, the pressure control element is configured to only allow flow of the working fluid in one direction. This further improves the controllability and efficiency.

[0018] In embodiments, the pressure control element has at least a first position having a first fluid return opening and second position having a second fluid return opening, wherein the second fluid return opening is greater than the first fluid return opening. The first and second

fluid return opening define a passage for the working fluid to flow through. The larger the fluid return opening, the more fluid can flow through it, and the smaller the pressure drop over the pressure control element. By controlling the position of the pressure control unit, the flow rate and/or the pressure in forward flow path and/or the return flow path can be controlled. Optionally, the pressure control element is closed in the first position, such that no working fluid can flow into the return flow path. Optionally, the pressure control element has a third position having a third fluid return opening, a fourth position having a fourth fluid return opening. Optionally, the pressure control element can be arranged in a plurality of positions between a minimal position and a maximal position, e.g. in predetermined increments or continuously.

[0019] In embodiments, the pressure control element is configured to be arranged in the first or the second position (or third position) by a pressure difference between the working fluid in the forward flow path and the working fluid in the return flow path. For example, as the pressure in the forward flow path increases relative to the pressure in the return flow path, the fluid return opening may be increased, e.g. by arranging the pressure control element in the second position. For example, the pressure control element may comprise a moveable element configured to be moved by the working fluid.

[0020] In embodiments, the heat exchange element further comprises a control unit configured to control the pressure control element. The control unit can e.g. be configured to control the position of the pressure control element, e.g. between the first and second position (and third position). The control unit can e.g. receive process information based on which the control unit is configured to control the pressure control element. Said process information can e.g. relates to a pressure, temperature, or flow rate, e.g. in the forward flow path, the return flow path, an inlet pipe, and/or an outlet pipe, or of a fluid other than the thermal working fluid. When a system comprises multiple heat exchange elements, it is possible that the control unit is configured to control multiple pressure control elements.

[0021] In embodiments, the pressure control element is a self-acting element. For example, the pressure control element may comprise at least one spring configured to exert a spring force onto a moveable element of the pressure control element. The moveable element may further be configured to be moved by the working fluid, wherein the working fluid exerts a fluid force onto the moveable element. Said fluid force being dependent of the pressure of the working fluid, e.g. on the forward flow path side of the pressure control element. The position of the moveable element depends on the difference between the spring force and the fluid force. The moveable element may further define, at least partially, a fluid return opening of the pressure control element. The fluid return opening thus depends on the pressure of the working fluid.

[0022] In embodiments, the pressure control element

is a self-acting element. For example, the pressure control element may comprise at least one diaphragm configured to receive a pneumatic force and configured to exert a diaphragm force onto a moveable element of the pressure control element. The moveable element may further be configured to be moved by the working fluid, wherein the working fluid exerts a fluid force onto the moveable element. The diaphragm force is dependent on the pneumatic force. Optionally, the pneumatic force is controllable, e.g. by an operator. As such, the pressure control element (in particular the relation between fluid return opening and pressure of the working fluid) can be adapted.

[0023] In embodiments, the pressure control element is a check valve. The check valve may e.g. comprise a spring e.g. for providing a minimal pressure drop. The check valve may e.g. be a ball type check valve. In embodiments, the pressure control element is a pressure regulation valve, e.g. having a spring and/or having an annular close gap. In embodiments, the pressure control element is ball type pressure sustain valve. In embodiments, the pressure control element is a diaphragm type pressure regulation configuration, e.g. with gas or spring operation, which may e.g. be an upstream regulation mode.

[0024] In embodiments, the pressure control element is a pressure control valve. Optionally, the pressure control valve is controlled by a control unit. The pressure control valve is configured to be arranged in a plurality of positions having different fluid return openings. Advantageously, the pressure control valve allows precise control of the pressure. The pressure control valve can e.g. be a globe valve, a butterfly valve, a gate valve, a plug valve, or a ball valve.

[0025] In embodiments, the pressure control element is a pressure sustaining valve. Optionally, the pressure sustaining valve is controlled by a control unit. Optionally, the pressure control element further comprises a diaphragm pressure control which is controlled with analogue pressure and arranged upstream of the pressure sustaining valve.

[0026] In embodiments, the pressure control element can be pipe section with a small pipe diameter. For example, the pipe section can be a capillary section. For example, the pipe section can have a nozzle, spray, jet, or similar. For example, the pipe section can have a small orifice. For example, the small pipe diameter can be less than 20% of a diameter of the outer flow element, e.g. less than 10%, e.g. less than 5%, e.g. less than 2%. For example, the small pipe diameter can be less than 20% of a diameter of the inner flow element, e.g. less than 10%, e.g. less than 5%, e.g. less than 2%. For example, the small pipe diameter can be 10 mm or smaller, e.g. 5 mm or smaller, e.g. 2 mm or smaller. The pipe section with small pipe diameter will cause a pressure drop.

[0027] In embodiments, the forward flow path has an annular cross section and the return flow path as a circular cross section. The forward flow path surrounds the

return flow path. Advantageously, while the working fluid is in the return flow path, it is further heated by the working fluid in the forward flow path. In addition, the forward flow path has a relatively large surface to volume ratio, improving the heating of the working fluid flowing therein on the one hand, and allowing a relatively high linear speed of the working fluid in the forward flow path at relatively small flow rate. The design of the heat exchange element is further compact.

[0028] In embodiments, the outer flow element and the inner flow element are coaxial. This allows for a practical and compact design. In addition, this embodiment is advantageous in view of thermal expansion of the inner and outer flow element, which occurs in similar direction with relatively little thermal stresses.

[0029] In embodiments, the outer flow element can have a diameter between DN15-DN150, e.g. between DN25-DN80. The inner flow element can e.g. have a diameter that is 5-50 mm smaller, e.g. 8-25 mm smaller than the diameter of the outer flow element.

[0030] In embodiments, the length of heat exchange element can advantageously be very long, e.g. 2 m or more, e.g. 5 m or more, e.g. 10 m or more, e.g. 30 m or more. Because the outer and inner flow element can be annular, and the heat exchange element only has mechanical connection at the proximate end of the inner and outer flow elements, thermal expansion is not a limitation for the length of the heat exchange element. Also for this reason, it is possible that the heat exchange element does not comprise expansion joints.

[0031] The invention further relates to a modular heat exchange element, comprising a heat exchange element according to any of the embodiments described herein, wherein the inner flow element has an inner flow element diameter. The modular heat exchange element further comprises at least one further inner flow element having a further inner flow element diameter which is different from the inner flow element diameter. The modular heat absorbing is configured for arranging either one of the inner flow element and the further inner flow element modularly inside the outer flow element. This allows e.g. to modify the forward flow path and the return flow path.

[0032] The modular heat exchange element thus relates to a system having at least two, optionally more than two, inner flow elements with different inner flow element diameters. The diameter of the inner flow element determines the cross section of the return flow path (arranged within the inner flow element) and the cross section of the forward flow path (arranged between the inner flow element and the outer flow element). For a given flow rate, also the velocity and the pressure in the forward and return flow path are therefore dependent on the inner flow element diameter. Depending on the application, the most appropriate inner flow element can be selected and arranged within the outer flow element. The modular heat exchange element thus provides a modular system that can be applied for a wide variety of applications. Moreover, an existing heat exchange element can

easily be adapted to another application without requiring a complete redesign and maintaining the same spatial footprint.

[0033] The invention further relates to a system for exchanging thermal energy, e.g. for absorbing or expelling thermal energy, comprising: an inlet pipe, optionally configured to receive a working fluid in liquid state; an outlet pipe, optionally configured to guide the working fluid in an at least partially gaseous state; and a plurality of heat exchange elements according to any embodiments described herein, wherein optionally the heat exchange elements are arranged fluidically in parallel between the inlet pipe and the outlet pipe.

[0034] It is noted that the term "pipe" can be any element configured to allow a fluid (gas or liquid) to flow, and is considered equivalent to for example a tube, duct, conduit, or the like

[0035] The system for exchanging thermal energy can thus comprise a plurality of heat exchange elements fluidically arranged in parallel. Each of the heat exchange elements may e.g. be connected to the inlet pipe with a proximate end of the outer flow element and be connected to the outlet pipe with a proximate end of the inner flow element. By providing a plurality of heat exchange elements, more thermal energy can be absorbed. The arrangement with the inner and outer flow element is particularly advantageous, because it allows for a relatively high flow speed in the outer flow element at relatively low flow rate. The inlet pipe can therefore be relatively small while allowing sufficient working fluid to flow for all heat exchange elements, and pumps for causing the flow of working fluid need not be large.

[0036] In embodiments, the plurality of heat exchange elements are arranged physically parallel to each other. For example, each heat exchange element may have a longitudinal axis, wherein the longitudinal axes of the plurality of heat exchange elements are parallel.

[0037] In embodiments, the inlet pipe and/or the outlet pipe extend perpendicular to the heat exchange elements. For example, the longitudinal axes of the plurality of heat exchange elements can extend perpendicular to a longitudinal axis of the inlet pipe and/or a longitudinal axis of the outlet pipe. Optionally, the inlet pipe and outlet pipe extend parallel to each other.

[0038] In embodiments, the system further comprises: a further inlet pipe configured to receive the working fluid or a further working fluid in liquid state; a further outlet pipe configured to guide the working fluid or the further working fluid, respectively, in an at least partially gaseous state; and; and a plurality of further heat exchange elements according to any embodiments described herein, wherein the further heat exchange elements are arranged fluidically in parallel between the inlet pipe and the outlet pipe. For example, the further inlet pipe may be fluidically connected to the inlet pipe, and the further outlet pipe may be fluidically connected to the further outlet pipe. Optionally, the heat exchange elements and the further heat exchange elements extend in opposite

directions, are arranged physically parallel to each other, and are arranged in an alternating arrangement. For example, the longitudinal axes of the heat exchange elements and the longitudinal axes of the further heat exchange elements may extend parallel to each other, but the forward flow paths of the heat exchange elements may be configured to guide the working fluid in an opposite direction compared to forward flow paths of the further heat exchange elements. Being arranged in an alternating arrangement means that when seen in a given direction, first a heat exchange element is provided, then a further heat exchange element, then again a heat exchange element, again a further heat exchange element, and so on. This allows for a compact arrangement. This may in particular be advantageous when the thermal energy is provided by a gas that is provided to be in contact with the outer flow elements.

[0039] Optionally, the system comprises an inlet pipe manifold to which a plurality of inlet pipes are connected, a further inlet pipe manifold to which a plurality of further inlet pipes are connected, an outlet pipe manifold to which a plurality of outlet pipe manifolds are connected, and a further outlet pipe manifold to which a plurality of further outlet pipes are connected. This allows to arrange heat exchange elements and further heat exchange elements to be arranged in alternating direction when seen in both a first direction and in a second direction, wherein the first and second direction extend perpendicular to each other, and both extend perpendicular to the longitudinal axes of the heat exchange elements and the further heat exchange elements.

[0040] The invention further relates to a thermal buffer system, e.g. a molten salt buffer system, comprising a housing configured to receive a buffer material, e.g. an inorganic salt, and a system for absorbing thermal energy according to any of the embodiments described herein, wherein the heat exchange elements are arranged in the housing. The thermal buffer system further comprises a system for expelling thermal energy, comprising a plurality of heat expelling elements, which optionally are according to any of the embodiments described herein. The thermal buffer system is configured to provide thermal energy to the buffer material with the system for expelling thermal energy, and absorb thermal energy from the buffer material with the system for absorbing thermal energy. The thermal buffer system may e.g. be a molten salt buffer system, wherein the buffer material is an inorganic salt. Other possible buffer materials include (organic) paraffins, glycols, thermal oils (which can e.g. be used without phase transition), metal spheres, or stones.

[0041] Advantageously, the thermal energy can be provided to the buffer material when there is an excess of (thermal) energy, which can e.g. cause the buffer material to convert from a solid state to a liquid state, depending on the buffer material. Generally, the buffer material is suitable for long-term accumulation of thermal energy. The buffer material is maintained in the liquid state as long as this energy is not required. When desired,

the thermal energy can be extracted by the system for absorbing thermal energy. As such, the thermal buffer system can store thermal energy and can function as a thermal battery. By using a system for absorbing thermal energy according to the invention, there is a large contact surface between the buffer material and the heat absorption elements, and the thermal energy can efficiently be absorbed.

[0042] The housing may e.g. be cylindrical. The housing may e.g. be insulated. The housing may e.g. comprise one or more buffer material inlets. The housing may comprise one or more buffer material outlets.

[0043] In embodiments, the system for absorbing thermal energy comprises a plurality of inlet pipes each with an associated outlet pipe, and a plurality of heat absorption elements fluidically in parallel between each inlet pipe and the associated outlet pipe, wherein the heat absorption elements extend in parallel to each other. Optionally, the system for expelling thermal energy comprises a plurality of heat expelling inlet pipes each with an associated heat expelling outlet pipe, and a plurality of heat expelling elements fluidically in parallel between each heat expelling inlet pipe and the associated heat expelling outlet pipe, wherein the heat expelling elements extend in parallel to each other. The heat absorption elements and heat expelling elements may extend in opposite directions, are arranged physically parallel to each other within the housing, and are arranged in an alternating arrangement. Advantageously, this allows for a compact configuration with a large contact surface to the buffer material.

[0044] In embodiments, the system comprises a heat absorption flange being physically connected to the heat absorption elements, and configured to be attached to the housing. In embodiments, the system comprises a heat expelling flange being physically connected to the heat expelling elements, and configured to be attached to the housing.

[0045] The invention further relates to a system for generating electricity, comprising the system for absorbing thermal energy according to any of the embodiments described herein. The system further comprises a gas turbine fluidly connected to the outlet pipe and configured to be convert thermal energy from the working fluid in gaseous state into electric energy. Advantageously, the efficient heat absorption is used to power the gas turbine and generate electricity. Using the pressure control element can further allow to convert the working fluid to the gaseous state, which allows to efficiently transport the working fluid over relatively long distances. The system may e.g. be used in an organic Rankine cycle. Optionally, the system further comprises an evaporator, and/or a condenser, and/or a recompression system (e.g. including a pump).

[0046] In embodiments, the heat exchange elements are configured to receive solar heat, e.g. solar radiation. Advantageously, renewable solar energy is used to heat the working fluid. For example, the system may comprise

parabolic concentrator configured to reflect solar radiation onto the heat exchange element. For example, each heat absorption element may have a longitudinal length of at least 15m, e.g. at least 20m, e.g. at least 30m, e.g. at least 50m, e.g. at least 100m. Advantageously, the system allows to only have mechanical connections at the proximate ends of the inner and outer flow elements, such that the risk of leakages is limited to a small area in comparison to the length of the heat absorption elements. In addition, the effects of thermal expansion are less harmful, such that longer heat absorption elements can be provided.

[0047] The invention further relates to several methods. Although the methods can be performed with the heat exchange element and/or a system according to the invention; neither the heat exchange element and/or the systems, nor the methods are limited thereto. Features explained herein with reference to the heat exchange elements and/or the systems have the same meaning with respect to the methods unless explicitly defined otherwise. Features explained with reference to the heat exchange element and/or the system can be applied mutatis mutandis to the method to achieve the similar advantages.

[0048] The object of the invention can e.g. be achieved with a method for absorbing thermal energy, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein. For example, a fluid, e.g. water, can be arranged to flow in the heat exchange element and absorb thermal energy.

[0049] The object of the invention can e.g. be achieved with a method for expelling thermal energy, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein. For example, a fluid, e.g. water, can be arranged to flow in the heat exchange element and expel thermal energy.

[0050] The object of the invention can e.g. be achieved with a method for exchanging thermal energy between a gas and a liquid, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein. For example, the liquid can flow through the heat exchange element while the gas is provided outside of the heat exchange element. It is noted that although liquid is mentioned, it is envisaged that possibly during and/or because of the exchanging of thermal energy, at least a part of the liquid may undergo a state change to the gas state.

[0051] The object of the invention can e.g. be achieved with a method for exchanging thermal energy between a first gas and a second gas, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein. For example, a first gas can flow through the heat exchange element while the second gas is provided outside of the heat exchange element. It is noted that although gas is mentioned, it is envisaged that possibly during and/or because of the exchanging of thermal energy, at least a part of the gas may undergo

a state change to the liquid state.

[0052] The object of the invention can e.g. be achieved with a method for generating electricity, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein, for example the system for generating electricity. For example, the heat exchange element may be used for absorbing thermal energy and/or generating a gas, e.g. steam, wherein said thermal energy, e.g. the gas, may be used to rotate a generator.

[0053] The object of the invention can e.g. be achieved with a method for buffering thermal energy, comprising a step of using a heat exchange element or a system according to any to any embodiments described herein, for example the molten salt buffer system.

[0054] The object of the invention can e.g. be achieved with a method for absorbing thermal energy, comprising the following steps: guiding a working fluid in liquid state through a forward flow path, wherein the forward flow path is arranged between an outer flow element and an inner flow element of a heat exchange element; and guiding the working fluid through a return flow path, wherein the return flow path is arranged within the inner flow element, wherein the working fluid flows through a pressure control element before flowing into the return flow path.

[0055] In embodiments, the method comprises a step of reducing the pressure of working fluid when the working fluid flows through the pressure control element, optionally thereby converting at least a part of the working fluid from a liquid to a gaseous state.

[0056] In embodiments, the method comprises maintaining the pressure in the forward flow path at a pressure at which the working fluid is in the liquid state, e.g. by means of the pressure control element.

[0057] In embodiments, the method comprises preventing working fluid from backflowing from the return flow path into the forward flow path, e.g. by means of the pressure control element.

[0058] Exemplary embodiments of the invention are described using the figures. It is to be understood that these figures merely serve as example of how the invention can be implemented and are in no way intended to be construed as limiting for the scope of the invention and the claims. Like features are indicated by like reference numerals along the figures. In the figures:

Fig 1a: schematically illustrates a heat exchange element;

Fig. 1b-1c: schematically illustrate cross-sections of heat exchange elements;

Fig. 2a: schematically illustrate an embodiment of a pressure control element comprising a spring;

Fig. 2b: schematically illustrate an embodiment of a pressure control element comprising a spring;

Fig. 2c: schematically illustrate an embodiment of a pressure control element being controlled by a control unit;

Fig. 2d-2e: schematically illustrate an embodiment of a pressure control element comprising a diaphragm;

Fig. 3a-3c: schematically illustrate a system for exchanging thermal energy comprising a plurality of heat exchange elements;

Fig. 4a-4b: schematically illustrate a system comprising a plurality of heat exchange elements and a plurality of further heat exchange elements, being arranged in alternating arrangement;

Fig. 5a-5c: schematically illustrate a molten salt buffer;

Fig. 6a-6c: schematically illustrate a system for generating electricity.

[0059] Fig. 1a schematically illustrates a heat exchange element 1, which comprises an outer flow element 4 and an inner flow element 5. The outer flow element 4 is at a proximate end 4a connected to an inlet pipe 2. A working fluid, e.g. water, is arranged to flow through the inlet pipe 2 and into the heat exchange element 1. The inlet pipe 2 may upstream be fluidly connected (not shown) to a working fluid reservoir and a pump for pumping the working fluid to the heat exchange element 1.

[0060] The inner flow element 5 is arranged within the outer flow element 4, wherein said arrangement defines an element flow path. Said element flow path comprises a forward flow path 11 between the outer flow element 4 and the inner flow element 5 and a return flow path 12 within the inner flow element 5. The cross-section illustrated in fig. 1b shows that in this example, the outer flow element 4 and the inner flow element 5 are both circular, such that the forward flow path 11 has an annular cross-section and the return flow path 12 has a circular cross-section. In addition, the outer flow element 4 and the inner flow element 5 are coaxial, having a coinciding longitudinal axis 13.

[0061] The inner flow element 5 is at a proximate end 5a fluidly connected to an outlet pipe 3. The element flow path is as such configured to guide the working fluid from the inlet pipe 2 into the forward flow path 12. At a distal end 4c of the outer flow element 4 the working fluid is reversed in a flow reverse path 13 as indicated by arrows 21, and guided towards the return flow path 12. In the return flow path 12 the working fluid flows in a direction as indicated by arrows 22, which is in an opposite direction compared to the forward flow path 11. The working fluid is guided towards the outlet pipe 3. The outlet pipe 3 may further be connected to any suitable component.

[0062] The heat exchange element 1 can be used for absorbing thermal energy. In particular, the working fluid can absorb said thermal energy. The thermal energy may be provided to the working fluid via the outer flow element 4. For example, a hot gas such as an exhaust gas from an industrial process or chemical reaction may be provided around outer flow element 4. For example, solar radiation can be concentrated onto the outer flow element 4. The heat transfer is performed contactless, as the working fluid does not come into direct contact with the gas or the solar radiation.

[0063] The arrangement of the outer flow element 4 and inner flow element 5 has several advantages. Firstly, the fact that the return flow path is arranged within the forward flow path, reduces the volume of the return flow path. This increases the contact surface (by means of the outer flow element) to volume ratio of the forward flow path, which makes the heating of the working fluid more efficient. In addition, the flow speed of the working fluid is increased, which improves heat transfer, and this is achieved without requiring larger pumps, as the flow rate can remain relatively low. Another advantage is of the heat exchange element 1 is that it only requires physical connections on one side, in fig. 1a being the left-hand side. This is advantageous in view of thermal expansion.

[0064] It may be preferred that the working fluid is a liquid state when absorbing the thermal energy, because this improves the heat transfer. Therefore, the inlet pipe 2 may provide the working fluid in the liquid state when entering the forward flow path 11.

[0065] The heat exchange element 1 further comprises a pressure control element 30, which is arranged at a distal end 5c of the inner flow element 5. The pressure control element 30 is arranged fluidically between the forward flow path 11 and the return flow path 12, such that the working fluid has to pass the pressure control element 30 before entering the return flow path 12. The pressure control element 30 subjects the working fluid to a pressure drop when flowing therethrough, which can be implemented to achieve several advantages. Firstly, the pressure in the forward flow path 11 can be maintained relatively high. Advantageously, this allows to maintain the working fluid in a liquid state, thereby improving the heat transfer. Secondly, as the pressure downstream of the pressure control element 30 is reduced, at least a part of the working fluid can be converted to a gaseous state. In said the gaseous state it may be more efficient to transfer the thermal energy, and in some cases, it may even be the objective of the heat absorption to convert the working fluid to a gaseous state.

[0066] Fig. 1a further illustrates that the forward flow path 11 partially encompasses the return flow path 12, at least in the region of a middle section 4b of the outer flow element 4 and a middle section 5b of the inner flow element 5. Advantageously, the working fluid the forward flow path 11 may provide thermal energy to the working fluid in the return flow path 12. During the flashing to the gaseous state, the temperature of the working fluid within

the inner flow element 5 may decrease, and become lower than the temperature of the working fluid withing the forward flow path 11. Advantageously, a further heat transfer can occur between the working fluid at different location, further heating the working fluid withing the return flow path 12. This may e.g. cause working fluid that is still in the liquid state to convert to a gaseous state.

[0067] In the example shown in fig. 1a, the pressure control element 30 is self-acting. A moveable member 32 is biased to a first position by a resilient member 33, comprising a plurality of springs. In the first position, which is shown in fig. 1a, the pressure control element has a first fluid return opening, which in this example is closed. That is, no working fluid can flow through the pressure control element 30 in the closed position. The pressure control element 30 has an inlet opening 31 in which the working fluid can accumulate. The working fluid arranged in said inlet opening 31 exerts a force onto the moveable member 32. Said force is dependent on the pressure difference between both sides of the moveable member 32, and thus the pressure difference between the forward flow path 11 and the return flow path 12. As the pressure of the working fluid in the inlet opening 31 builds up, said force increases. When said force exceeds the biasing force provided by the resilient member 33, the moveable member 32 is moved towards a second position. In said second position the pressure control element 30 has a second fluid return opening, which is greater than the first fluid return opening. Working fluid can now flow via a fluid outlet 34 of the pressure control element 30 into the return flow path 12.

[0068] It will be understood that for the shown example, in practice the movable member 31 can be arranged in a plurality of positions. At any time the exact position where the moveable member 31 is arranged depends on the pressure difference between the forward flow path 11 and the return flow path 12 on the one hand, and the biasing force provided by the resilient member 33 on the other hand. Optionally, said biasing force is adjustable, e.g. manually by an operator.

[0069] The pressure control element 30 as illustrated in fig. 1a also prevents the working fluid from backflowing from the return flow path 12 in the forward flow path 11. This is achieved by the fact that the moveable member 31 would be arranged in the first position wherein the fluid return opening is closed, when the pressure in the return flow path 12 exceeds the pressure in the forward flow path 11.

[0070] The heat exchange element 1 can be (part of) a modular heat exchange element 1, as schematically illustrated by fig. 1b and fig. 1c. In particular, a further inner flow element 5a is provided, having a further inner flow element diameter D2 being smaller than an inner flow element diameter D1 of the inner flow element 5. The inner flow element 5 and the further inner flow element 5a are modularly interchangeable. This allows to adapt the heat exchange element based on the application, as the flow speed and pressure in the forward flow

path 11 and the return flow path 12 can be adapted. The modularity advantageously only requires changing the inner flow element 5, requiring relatively few components while being suitable for many applications. Moreover, since the outer flow element 4 need not be replaced, the spatial footprint of the system remains the same, which provides the flexibility to easily adapt existing installations. For example, the inner flow element diameter D1 can be DN65, the further inner flow element diameter D2 can be DN50, and an outer flow element diameter D3 can be DN80.

[0071] The pressure control element can be implemented in various embodiments. For example, fig. 2a shows an embodiment of a pressure control element 300 that is self-acting, having a moveable member 302 and a resilient member 303. In this example, the resilient member 303 biases the moveable member 302 towards an outer end of the inner flow element 5 for the first position. In said first position, the fluid return opening is closed. As the pressure of working fluid in the forward flow path 11 increases, a pressure force is exerted on the moveable element 302 to move it towards what in fig. 2a is the right-hand side. This positions the moveable element 302 in a second position, allowing working fluid to flow into the return flow path 12.

[0072] Fig. 2b shows an embodiment of a pressure control element 310 that is self-acting, having a moveable member 312 and a resilient member 313. In this example, the moveable member 312 is a ball-shaped element that is biased by the resilient member 313 to close a fluid opening 314 for the first position. In said first position, the fluid return opening is closed. As the pressure of working fluid in the flow reverse path 13 increases, a pressure force is exerted on the moveable element 312 to move it towards what in fig. 2b is the left-hand side. This positions the moveable element 312 in a second position, allowing working fluid to flow into the return flow path 12.

[0073] The pressure control element can also be implemented as a valve, as is e.g. schematically illustrated in fig. 2c. In this example a pressure control element 320 comprises a pressure control valve 321. An actuator 322 is configured to arrange the pressure control valve 321 in a plurality of positions, thereby controlling the pressure drop over the pressure control valve 321. The pressure control valve 321 can be any type of suitable valve, e.g. a globe valve, a butterfly valve, a gate valve, a plug valve, or a ball valve. The actuator 322 can be any type of actuator, e.g. electric, pneumatic, or hydraulic.

[0074] A control unit 323 controls the actuator 322, e.g. with a control signal 322a that is emitted via a communication terminal 323.1. The control unit 323 may be configured to control a plurality of actuators 322 of a plurality of pressure control valves 321 arranged in plurality of heat exchange elements, e.g. arranged in the same system. The control unit 323 may e.g. be operatively connected to or be part of a control unit for controlling a process system in which the heat exchange element is incorporated. The control unit 323 may e.g. be configured to

receive one or more sensor signals and control the actuator based on said one or more sensor signals. Said sensor signals may e.g. be generated by temperature and/or pressure sensors measuring properties of the working fluid, e.g. arranged in the inlet pipe, outlet pipe, forward flow path, return flow path. It is also possible that the sensor signals are generated by e.g. temperature sensors measuring properties related to a secondary fluid, e.g. a hot gas arranged outside the heat exchange element and configured to provide thermal energy to the working fluid.

[0075] It is also possible that the pressure control element is embodied as a self-acting valve, e.g. a check valve.

[0076] Fig. 2d and fig. 2e illustrate an embodiment wherein the pressure control element 330 is embodied as an element comprising a diaphragm 333 that is subjected to a pneumatic force, wherein said pneumatic force is adaptable by an operator. The pressure control element 330 comprises a moveable member 332 which is connected to the diaphragm 333. A pressure chamber 334 is provided with a pressurized gas which exerts a pressure force onto the diaphragm 333. An operator can modify the pressure in the pressure chamber 334 by means of a valve 335.

[0077] In this example the outer flow element 4 diverges at the distal end 4c. This increases the cross section of the forward flow path 11 at distal end 11c, to increase the surface of the diaphragm 333 with which the working fluid can come into contact. Fig. 2d illustrates a situation wherein the pressure control element 330 is in a first position having a first fluid return opening 336 which is closed.

[0078] As the pressure of the working fluid in the distal end 11c of the forward flow path 11 increases, it will become larger than the pressure in the pressure chamber 334. This will cause the diaphragm 333 to deform, which decreases the size of the pressure chamber 334, until the pressure in the pressure chamber 334 is equal to the pressure in the distal end 11c of the forward flow path 11. Since the moveable member 334 is attached to the diaphragm 333, the deformation of the diaphragm 333 will cause the moveable member 333 to move to the second position as illustrated in fig. 2e. In this second position has a second fluid return opening 336, which is larger and allows fluid to flow into return flow path 12.

[0079] Fig. 3a-3c schematically illustrate a system 100 for absorbing thermal energy, wherein fig. 3a shows a front view; fig. 3b shows an enlarged view of the encircled part of fig. 3a; and fig. 3c shows an isometric view. It can be seen that the system 1 comprises the inlet pipe 2, the outlet pipe 3, and a plurality of heat exchange elements 1 (it will be appreciated that only a few are indicated with reference numeral 1 in fig. 3a and 3c to enhance the clarity of these figures). Although not visible in fig. 3a-3c, each of the heat exchange elements 1 can comprise a pressure control element according to any of the embodiments described herein.

[0080] The heat exchange elements 1 are arranged fluidically in parallel to each other. This is schematically illustrated in fig. 3b, which shows that the proximate end 5a of the inner flow element 5 of each heat exchange element 1 is connected to the outlet pipe 3. In addition, the outer flow element 4 of each heat exchange element 1 is connected to the inlet pipe 3. The working fluid flow towards the system 100 in the inlet pipe 2, and is then divided between the forward flow paths of the plurality of heat exchange elements 1. Then, the working fluid is returned via the return flow paths of the plurality of heat exchange elements 1 to the outlet pipe 3.

[0081] Although not shown, it will be appreciated that the inlet pipe 2 may at a first end 2a be connected to an inlet piping circuit, e.g. including a pump and e.g. being connected to a working fluid reservoir. The outlet pipe 3 is closed at a first end 3a. At its second end 2b the inlet pipe 2 is closed, while the outlet pipe 3 is at its second end 3b connected to an outlet piping circuit.

[0082] The heat exchange elements 1 are also physically arranged in parallel to each other. That is, their respective longitudinal axes extend parallel to each other. The shown arrangement allows for an efficient system having a large heat exchange surface while maintaining a relatively small spatial footprint.

[0083] Fig. 4a and fig. 4b illustrate another system 200 for exchanging (e.g. absorbing) thermal energy, again comprising a plurality of heat exchange elements 1 fluidically arranged in parallel between the inlet pipe 2, the outlet pipe 3. In addition, the system 200 comprises a further inlet pipe 202 which is fluidically connected to the inlet pipe 2 by means of an inlet pipe connector 212. The system 200 also comprises a further outlet pipe 203 which is fluidically connected to the outlet pipe 3 by a further outlet pipe connector 213. A plurality of further heat exchange elements 201 are arranged fluidically in parallel between the further inlet pipe 202 and the further outlet pipe 203.

[0084] In the shown example, the inlet pipe 2 and outlet pipe 3 are arranged below the heat exchange elements 1, such that the heat exchange elements 1 extend upwards. The further inlet pipe 202 and the further outlet pipe 203 are arranged above the further heat exchange elements 201, such that the further heat exchange elements 201 extend downwards. The longitudinal axes of the heat exchange elements 1 and the longitudinal axes of the further heat exchange elements 201 extend parallel to each other, but the forward flow paths of the heat exchange elements 1 are configured to guide the working fluid in an opposite direction compared to forward flow paths of the further heat exchange elements 201.

[0085] The heat exchange elements 1 and the further heat exchange elements 201 are further arranged physically parallel of each other. Moreover, the heat exchange elements 1 and the further heat exchange elements 201 are arranged in an alternating arrangement. For example, when seen in fig. 4a from left to right, a heat exchange element 1 is first arranged, then a further heat exchange

element 201, then again a heat exchange element 1, then again a further heat exchange element, and so on. This allows for a compact arrangement, which is in particular advantageous for gas/liquid heat exchanges, wherein the gas can be provided to flow between the heat exchange elements 1, 201.

[0086] Fig. 4b further illustrates that the heat exchange elements 1 and further heat exchange elements 201 are not only arranged in an alternating arrangement in a first direction from left to right, but also in a second direction from front to back. Both said first and second direction extend perpendicular to the longitudinal axes of the heat exchange elements 1 and the further heat exchange elements 201.

[0087] To achieve this, the system 200 comprises a plurality of inlet pipes 2 and a plurality of outlet pipes 3, and between each associated inlet pipe 2 and outlet pipe 3 a plurality of heat exchange elements 1. Similarly the system 200 comprises a plurality of further inlet pipes 202 and a plurality of further outlet pipes 203, and between each associated further inlet pipe 202 and further outlet pipe 203 a plurality of further heat exchange elements 201. The inlet pipes 2 can be connected to each other via a manifold, and similarly the outlet pipes 3, further inlet pipes 202, and further outlet pipes 203 as well.

[0088] Fig. 5a-5c schematically illustrate a thermal buffer system 500, which can e.g. be used as a molten salt buffer system. Fig. 5a shows a partially exploded view, fig. 5b shows a see-through top view, fig. 5c shows a cross section.

[0089] Fig. 5a illustrates that the system 500 comprises a housing 510, in this case a cylinder. The housing 510 comprises three inlets 511, 512, 513, and one outlet 514. A system 520 for expelling thermal energy and a system 530 for absorbing thermal energy each comprise a plurality of inlet pipes (not shown), a plurality of heat expelling outlet pipes 523 or outlet pipes 533, and a plurality of heat expelling elements 521 or heat absorbing elements 531. The heat expelling elements 521 can be embodied as described herein, although this is not required. For example, they may merely have a forward flow path and a return flow path without a pressure control element being arranged fluidically between them. The heat absorbing elements 531 can be embodied as shown in fig. 1a-2c, or according to any other embodiment described herein.

[0090] The heat expelling elements 521 can be arranged into the housing 510 via a cylinder opening 517. A heat expelling flange 529 is connected to the heat expelling elements 521 and can be connected to a cylinder connection flange 518 for providing a fixed connection and closing the cylinder opening 517. Similarly, the heat absorbing elements 531 can be arranged into the housing 510 via a further cylinder opening 515. A heat absorption flange 539 is connected to the heat absorption elements 531 and can be connected to a further cylinder connection flange 516.

[0091] Fig. 5b illustrates that when arranged in the

housing 510, the heat expelling elements 521 and the heat absorbing elements 531 extend in opposite directions. In addition, the heat expelling elements 521 and the heat absorbing elements 531 are arranged physically in parallel to each other and in an alternating arrangement. The alternating arrangement is also visible in fig. 5c, when seen from the left to the right.

[0092] The thermal buffer system 500 functions as a thermal battery. A buffer material, such as an inorganic salt, can be arranged in the housing 510 via the inlets 511, 512, 513 after the systems 520, 530 are provided therein. After installation and providing of the buffer material, the housing 510 can remain closed for multiple cycles.

[0093] When an excess of thermal energy occurs, e.g. when the supply of thermal energy is larger than the demand, said thermal energy can be provided to the buffer material by means of the system 520 for expelling thermal energy. It can e.g. also be the case that electricity or other energy, e.g. renewable energy, is produced in excess and converted to thermal energy for this purpose. The thermal energy that is provided to the buffer material may convert the buffer material from a solid state to a liquid state. When the thermal energy is required, e.g. when the demand is smaller than the supply the system 530 for absorbing thermal energy can be used to extract the thermal energy from the buffer material, which may again be converted to a solid state.

[0094] The arrangement as shown in fig. 5a-5c is particularly advantageous for this applications. The heat exchange can be achieved efficiently due to the pressure control element. In addition, the physical arrangement of the heat expelling elements 521 and heat absorption elements 531 efficiently provides a large contact surface with relatively little open space for the buffer material.

[0095] Fig. 6a and 6b schematically illustrate a system 400 for absorbing solar heat. The system 400 comprises the inlet pipe 2 and the outlet pipe 3, and a plurality of heat exchange elements 1, in this case heat absorption elements 1. The system 400 further comprises a plurality of parabolic concentrators 410 which direct solar radiation towards the heat absorption elements 1. The solar radiation radiates directly on the outer flow element of the heat absorption elements 1; that is, the heat absorption elements 1 are not arranged in a vacuum tube or the like. In the shown example, three parabolic concentrators 410 are provided for each heat absorption element 1; however, it will be understood that this can be implemented in various ways.

[0096] The heat exchange elements according to the present invention are particularly advantageous for the system 400 for receiving solar heat. Firstly, the arrangement of the forward flow path and the return flow path allow to provide the inlet pipe 2 and outlet pipe 3 centrally while covering a wide area with the heat exchange elements. This has practical advantages with respect to installation and maintenance, e.g. because the main connections are provided centrally at the inlet pipe 2 and

outlet pipe 3, and relatively few mechanical connections are required. The length of the heat absorption elements 1 can e.g. be 30m.

[0097] Another advantage is provided by the pressure control element. This allows on the one hand to maintain the fluid in liquid state in the forward flow path, thereby improving heat transfer. On the other hand, the fluid is converted to gas in the return flow path, making it more efficient to transport the thermal energy over long distances.

[0098] In addition, the gas generated in the system 400 can be used to generate renewable electricity, as e.g. schematically illustrated in fig. 6c showing a system 499 for generating electricity. In this example, an organic Rankine cycle is applied, wherein the generated gas is provided to a generator 451 for converting the thermal energy to electricity 452. The generator 451 may e.g. be a (steam) turbine having blades that are put into rotation by the gas. The generator 451 functions as expander. The working fluid is then provided to a regenerator 453, configured to exchange thermal energy between a hot side 453a and a cold side 453b. The working fluid is then converted to the liquid state by flowing through a hot side of a condenser 454a, further having a hot side 454b for recovering some of the thermal energy with a cooling fluid 460. A pump 455 increases the pressure of the working fluid, which is preheated in the regenerator before being provided to the system 400. In the system 400, the working fluid is converted to gas by the solar energy.

[0099] As required, detailed embodiments of the present invention are described herein; however, it is to be understood that the disclosed embodiments are merely examples of the invention, which may be embodied in various ways. Therefore, specific structural and functional details disclosed herein are not to be construed as limiting, but merely as a basis for the claims and as a representative basis for teaching those skilled in the art to practice the present invention in various ways in virtually any suitable detailed structure. Not all of the objectives described need be achieved with particular embodiments.

[0100] Furthermore, the terms and expressions used herein are not intended to limit the invention, but to provide an understandable description of the invention. The words "a", "an", or "one" used herein mean one or more than one, unless otherwise indicated. The terms "a multiple of", "a plurality" or "several" mean two or more than two. The words "comprise", "include", "contain" and "have" have an open meaning and do not exclude the presence of additional elements. Reference numerals in the claims should not be construed as limiting the invention.

[0101] The mere fact that certain technical features are described in different dependent claims still allows the possibility that a combination of these technical measures can be used advantageously.

[0102] A single processor or other unit can perform the functions of various components mentioned in the de-

scription and claims, e.g. of processing units or control units, or the functionality of a single processing unit or control unit described herein can in practice be distributed over multiple components, optionally physically separated of each other. Any communication between components can be wired or wireless by known methods.

[0103] The actions performed by the control unit can be implemented as a program, for example computer program, software application, or the like. The program can be executed using computer readable instructions. The program may include a subroutine, a function, a procedure, an object method, an object implementation, an executable application, a source code, an object code, a shared library / dynamic load library and / or other set of instructions designed for execution on a computer system.

[0104] A computer program or computer-readable instructions can be stored and / or distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied with or as part of other hardware, but can also be distributed in other forms, such as via internet or other wired or wireless telecommunication systems.

Claims

1. A heat exchange element, comprising

- an outer flow element,
- an inner flow element arranged within the outer flow element,
- an element flow path comprising forward flow path and a return flow path, wherein
 - the forward flow path is arranged between the outer flow element and the inner flow element,
 - the return flow path is arranged within the inner flow element,
 - the element flow path is configured to guide a working fluid from the forward flow path to the return flow path,
- a pressure control element, arranged fluidically between the forward flow path and the return flow path.

2. The heat exchange element according to claim 1, wherein the heat exchange element is a heat absorption element, wherein the pressure control element is configured to reduce the pressure of the working fluid for converting at least a part of the working fluid from a liquid to a gaseous state, wherein the pressure control element is configured to maintain the pressure in the forward flow path at a pressure at which the working fluid is in the liquid state.

3. The heat exchange element according to any of the preceding claims, wherein the pressure control element has at least a first position having a first fluid return opening and second position having a second fluid return opening, wherein the second fluid return opening is greater than the first fluid return opening. 5
4. The heat exchange element according to claim 3, wherein the pressure control element is configured to be arranged in the first or the second position by a pressure difference between the working fluid in the forward flow path and the working fluid in the return flow path. 10
5. The heat exchange element according to any of the preceding claims, further comprising a control unit configured to control the pressure control element. 15
6. The heat exchange element according to claim 1 or claim 2, wherein the pressure control element is a pipe section with a small pipe diameter, for example having a capillary section or a pipe section having a small orifice. 20
7. The heat exchange element according to any of the preceding claims, wherein the forward flow path has an annular cross section and the return flow path as a circular cross section. 25
8. The heat exchange element according to any of the preceding claims, wherein the pressure control element is arranged at a distal outer end of the inner flow element. 30
9. A modular heat exchange element, comprising a heat exchange element according to any of the previous claims, wherein the inner flow element has an inner flow element diameter, further comprising at least one further inner flow element having a further inner flow element diameter which is different from the inner flow element diameter, wherein modular heat absorbing is configured for arranging either one of the inner flow element and the further inner flow element modularly inside the outer flow element, thereby allowing to modify the forward flow path and the return flow path. 35 40
10. A system for exchanging thermal energy, comprising
- an inlet pipe configured to receive a working fluid in liquid state; 50
 - an outlet pipe configured to guide the working fluid in an at least partially gaseous state; and
 - a plurality of heat exchange elements according to any of the preceding claims, wherein the heat exchange elements are arranged fluidically in parallel between the inlet pipe and the outlet pipe. 55
11. The system according to claim 10, comprising
- a further inlet pipe configured to receive the working fluid or a further working fluid in liquid state;
 - a further outlet pipe configured to guide the working fluid or the further working fluid, respectively, in an at least partially gaseous state; and
 - a plurality of further heat exchange elements according to any of the claims 1-8, wherein the further heat exchange elements are arranged fluidically in parallel between the further inlet pipe and the further outlet pipe;
- wherein the heat exchange elements and the further heat exchange elements extend in opposite directions, are arranged physically parallel to each other, and are arranged in an alternating arrangement.
12. A thermal buffer system, e.g. a molten salt buffer system, comprising
- a housing configured to receive a buffer material, e.g. an inorganic salt,
 - a system for absorbing thermal energy according to claim 10 or claim 11, wherein the heat exchange elements are arranged in the housing,
 - a system for expelling thermal energy, comprising a plurality of heat expelling elements,
- wherein the thermal buffer system is configured to provide thermal energy to the buffer material with the system for expelling thermal energy, and absorb thermal energy from the buffer material with the system for absorbing thermal energy.
13. A system for generating electricity, comprising the system according to claim 10 or claim 11, wherein the heat exchange elements are configured to receive solar heat, further comprising a gas turbine fluidly connected to the outlet pipe and configured to be convert thermal energy from the working fluid in gaseous state into electric energy..
14. A method for absorbing or expelling thermal energy, and/or for exchanging thermal energy between a gas and a liquid, and/or for buffering thermal energy, and/or for generating electricity, wherein the method comprises a step of using a heat exchange element or a system according to any of the preceding claims.
15. A method for absorbing thermal energy, comprising the following steps:
- guiding a working fluid in liquid state through a forward flow path, wherein the forward flow path is arranged between an outer flow element and an inner flow element of a heat exchange

element;

- guiding the working fluid through a return flow path, wherein the return flow path is arranged within the inner flow element, wherein the working fluid flows through a pressure control element before flowing into the return flow path,

further comprising a step of reducing the pressure of working fluid when the working fluid flows through the pressure control element, thereby converting at least a part of the working fluid from a liquid to a gaseous state.

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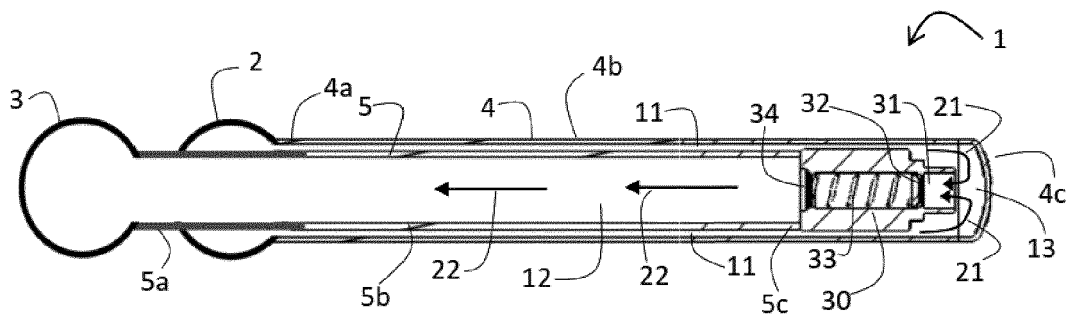


Fig. 1a

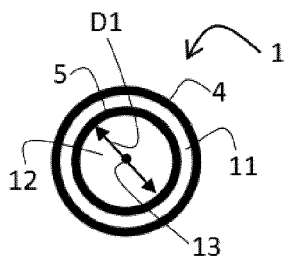


Fig. 1b

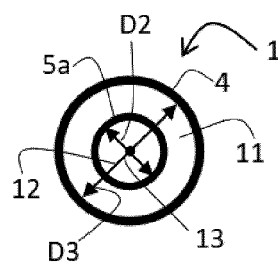


Fig. 1c

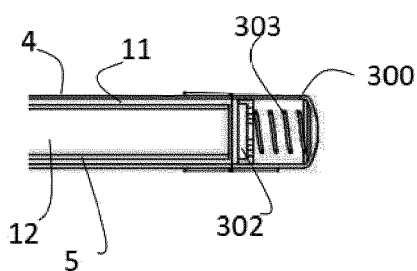


Fig. 2a

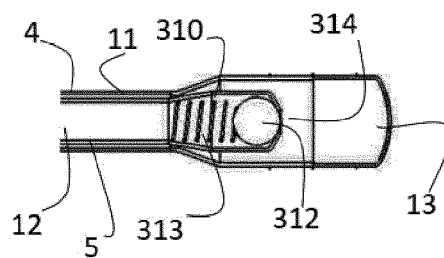


Fig. 2b

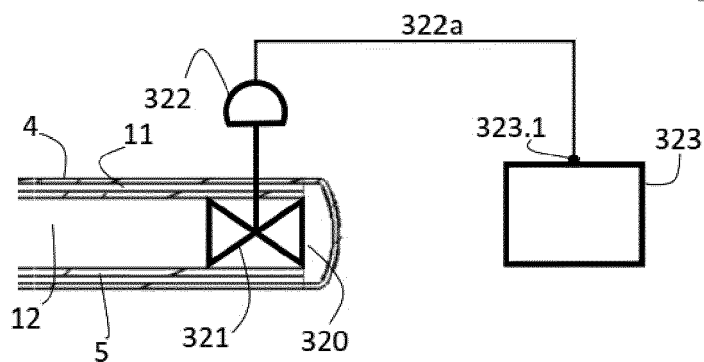


Fig. 2c

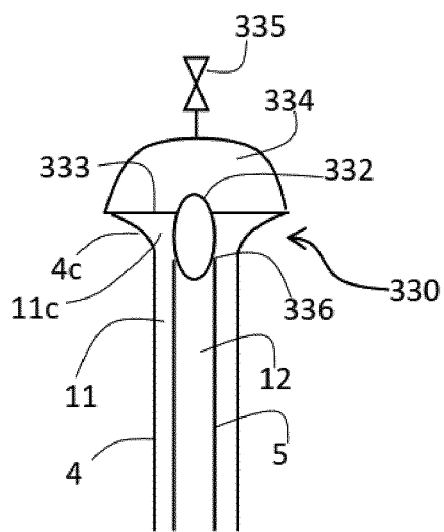


Fig. 2d

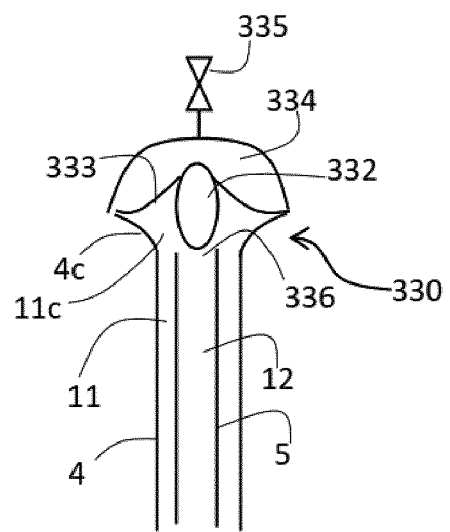


Fig. 2e

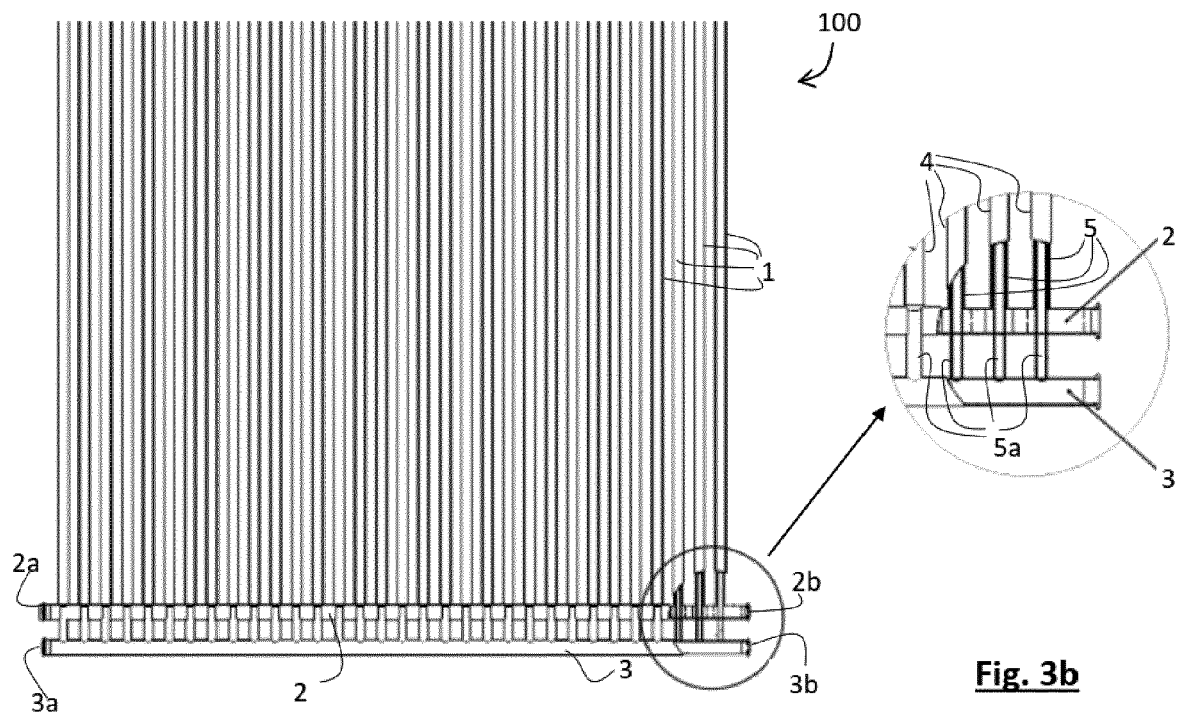


Fig. 3a

Fig. 3b

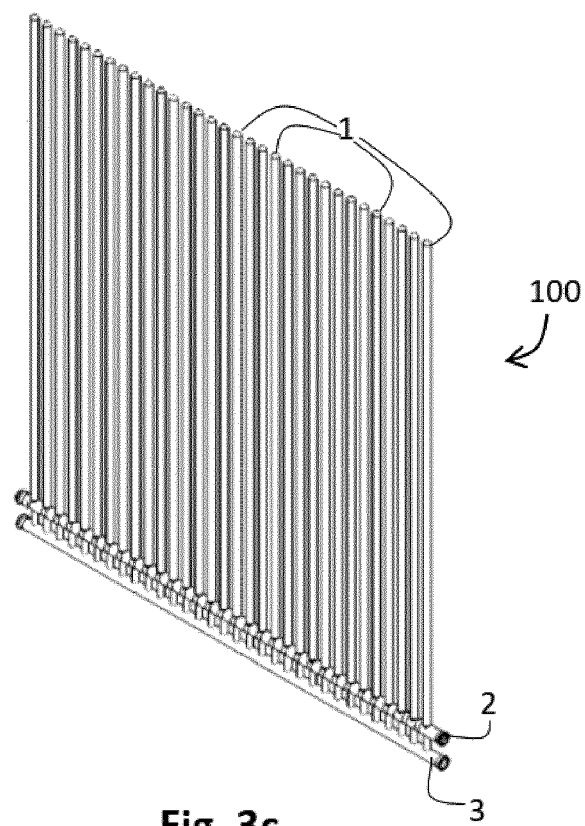
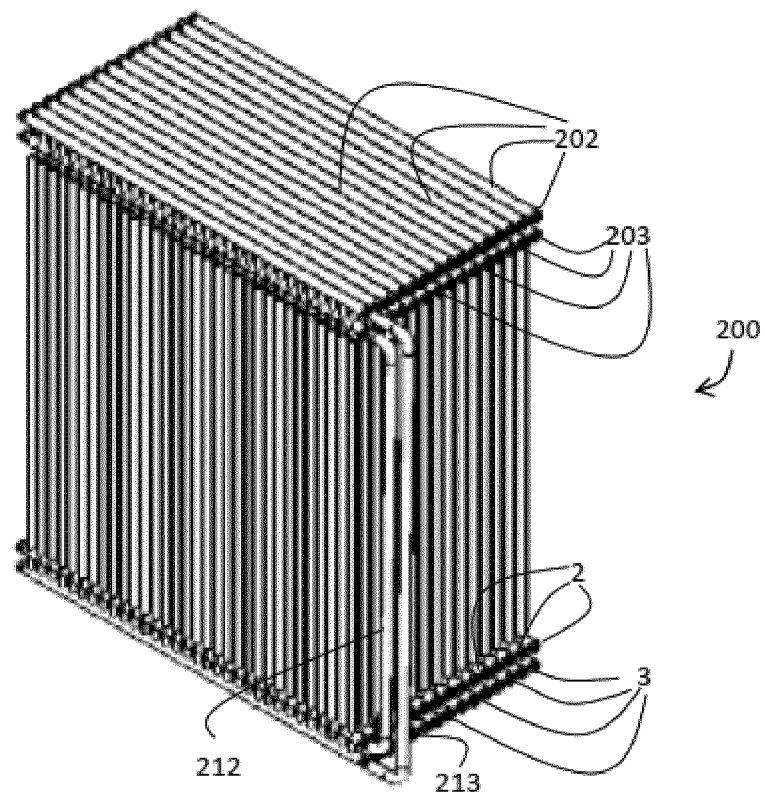
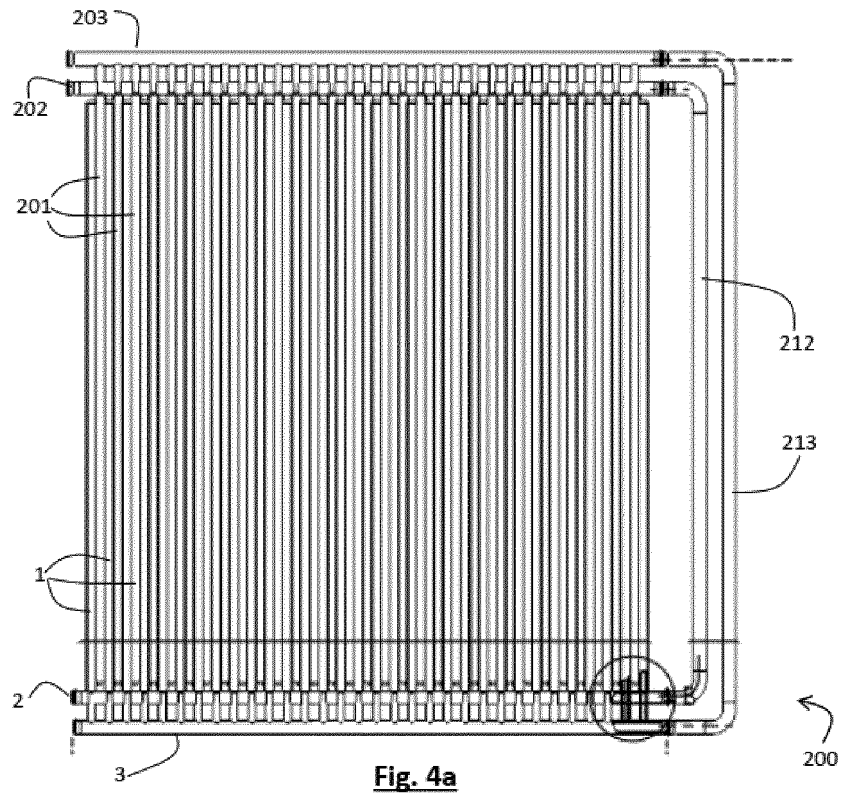


Fig. 3c



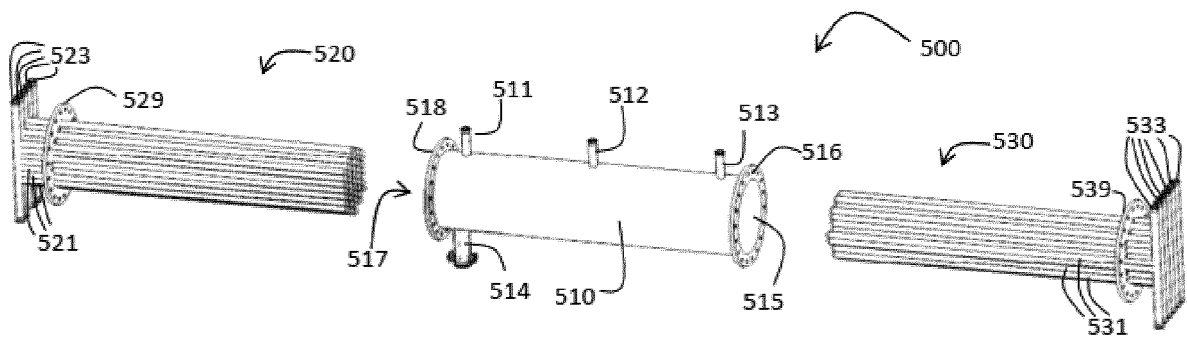


Fig. 5a

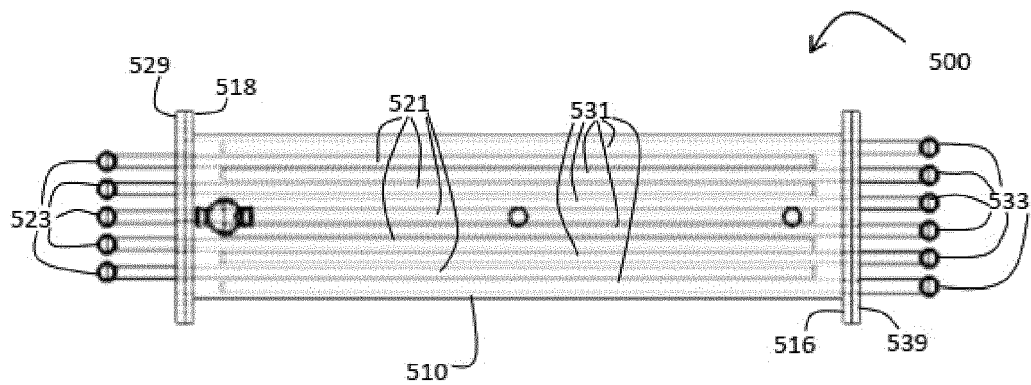


Fig. 5b

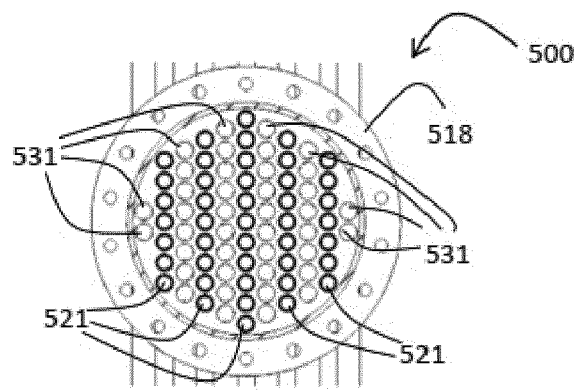


Fig. 5c

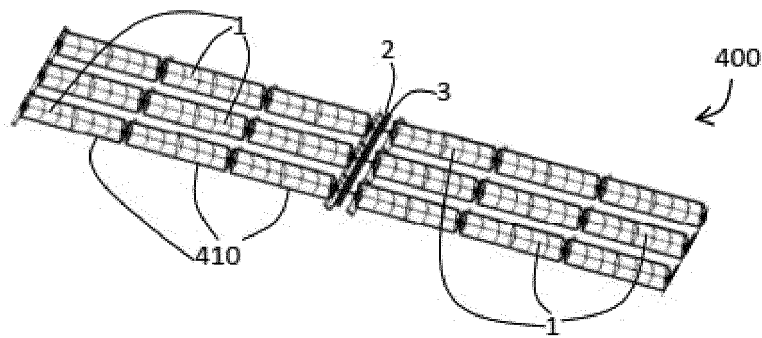


Fig. 6a

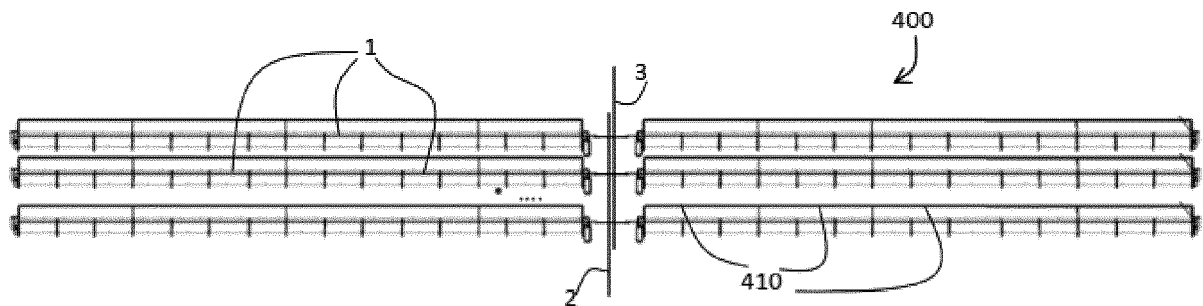


Fig. 6b

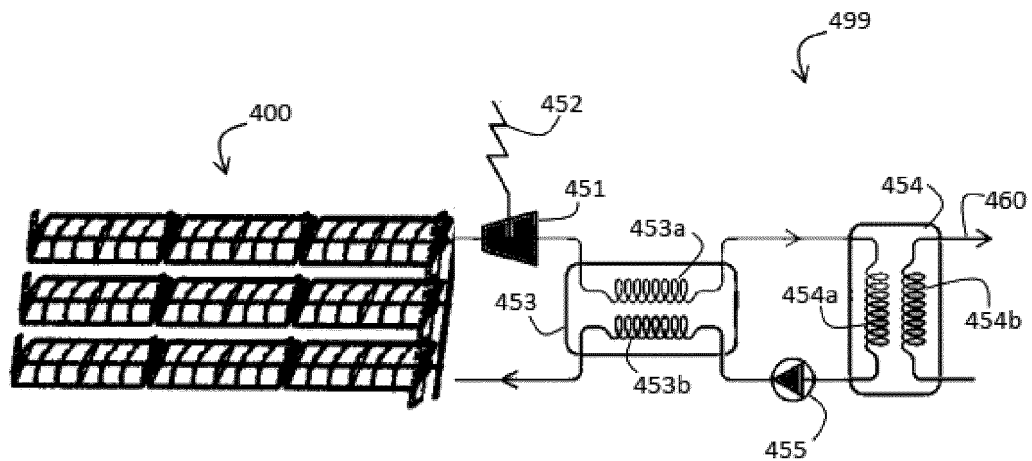


Fig. 6c



EUROPEAN SEARCH REPORT

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			F28D F28F
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Place of search Munich		Date of completion of the search 12 December 2022	Examiner Vassoille, Bruno
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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