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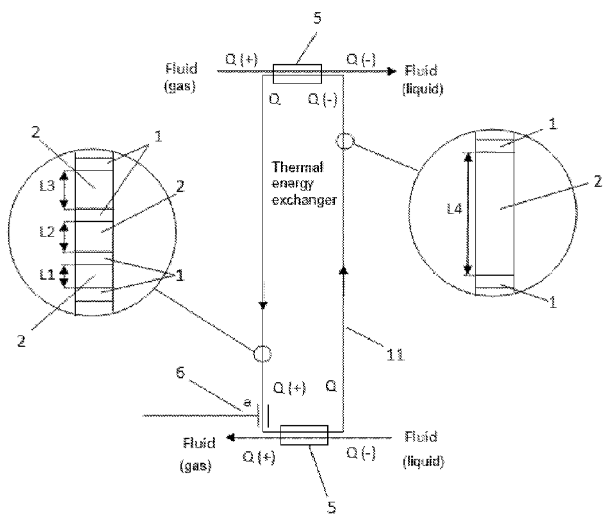

Fig. 1

(57) Abstract: The present invention comprise a thermal energy exchanger comprising a closed loop with a level differential between top and bottom of more than 400 meters, and where the contents of the loop is circulating by means of applied energy. By circulating gas that is sent downwards in the loop will become compressed as a result of the increasing pressure in the loop at increasing depth Since gas has a small specific gravity the larger part of the pressure increase can be from piston devices which sections the contents in the loop, and that with its specific gravity and accompanying mass contributes to a pressure increase in the underlying gas sections. Compression of gases will lead to heat development and a temperature development in the gas sections. In order to limit the temperature development liquid particles will be part of the gas section in order to collect heat. The amount of liquid particles will influence the temperature development, and by regulating how many fluid particles which, in spray or droplet phase, takes up heat, the temperature development can be regulated to the desired level. The piston devices which functions as plugs that are circulating in the loop can gather heated liquid and transfer heat to the pipe walls of the loop when desired with heat exchange from the thermal energy exchanger to the accompanying energy system. In the same manner gas that is moving upwards in the loop will expand and develop cold as a result of the reduced pressure. Liquid particles will then be added in order to collect cold and reduce the negative temperature development, and then become transferred to the pipe walls by thermal heat exchange to an external medium outside of the loop. The present invention also concern a system comprising of a thermal energy exchanger and energy loop, which directly or indirectly receive thermal energy and converts this to power production, and which in addition has a level difference between the top and bottom of the loop of at least 800 meters. A heat loop can receive heat from the thermal energy exchanger, or from a system connected thereto, and transfer it to the lower part of the energy loop. In addition, a cold loop can receive cold and exchange thermal energy in the upper part of the energy loop. Thermal energy that is added to a medium in the energy loop can change the density

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of the medium, such that the medium has a low density when moving upwards and higher density when moving downwards in the energy loop. The density difference will result in a pressure difference in the energy loop that can be used for power production. In addition, a marine construction comprising a liquid filled heat loop in the lower part and a thermal energy exchanger in the upper part may be able to provide a stable construction with uplift at the top and ballast at the bottom.

Thermal energy exchanger

The present invention relates to a thermal energy exchanger comprising one or more mediums circulating in a closed loop, where the level difference between the top and bottom of the loop is at least 400 meters. Such a thermal energy exchanger can be used in relation to power production, or for enabling an increase in energy in an energy system.

In addition, the invention also relates to the construction of an energy system with an energy loop for power production or energy storage, which comprises a thermal energy exchanger. Thus, the invention also relates to use of the thermal energy exchanger in an energy system for power production or energy storage.

In addition, the invention also relates to uses of the thermal energy exchanger in an energy system for power production of energy storage.

The present invention provides for a thermal energy exchanger that may be used in an energy system for renewable power production with possibilities for energy storage where it may also be used for other purposes where there is a need for thermal energy.

The distinguishing feature of the thermal energy exchanger is that it is comprised of a closed loop with a large height differential between the top and bottom of said loop, and that it can regulate the heat generation with gas compression by providing liquid in spray or droplet form, and thus achieve a compression which is close to an isomeric compression, as well as a decompression that is close to an isomeric decompression.

Another distinguishing feature is that it can be combined with other renewable energy sources, and constitute part of a system that can deliver a lot of energy from a small area. By utilizing for example thermal energy from cold water at large depths with warmer surface water, the thermic energy amount in the system may be increased in order to provide an improved effect. In addition, other renewable energy can be stored as thermal energy and be used as a stable and adjustable power on the power grid.

Known art

If renewable energy is to replace conventional energy it must be able to be supplied in large amounts, and be cost effective. With an increased focus on climate and environment, there is now an increased interest for renewable energy, especially relating to ocean energy where with time there are many companies that have developed and patented their solutions. For now few installations are up and running.

Existing solutions in ocean energy are mainly based on offshore windmills and wave power generation. Offshore windmills have been developed the furthest, and have the most planned projects. Within wave power generation there are many solutions, but not so many of them have been built. Another energy type is tidal currents and ocean currents. Presently this is a energy source that has not been used much, but there does exist operational installations.

OTEC (Ocean Thermal Energy Converter) is a technology that is known, but has few or no operational installations. The method is based upon thermal energy, and utilizes the temperature difference between warmer surface water and colder water at deeper levels, and is suitable at locations where the temperature differential mostly is as much as 20 degrees Celsius.

OTEC functions by transferring heat from the surface water by a heat exchanger to a medium which, by added heat, changes it phase from liquid to gas. The expanding gas is used to drive a gas turbine before it is lead through a condenser in order to change phase back to liquid. This occurs by addition of cold from a cold exchanger connected to the cold water. A pump provides for circulating the medium through the heat and cold exchangers. In addition, there will be present pumps that provide addition and circulation of the cold and warm water. The cold water is provided from depths of 500 meters or more. The challenge OTEC installations face is related to the costs of the heat and cold exchangers. In order to reduce the extent of the exchangers only about 20 % of the thermal energy of the cold and warm water is utilized. For the present OTEC installations a heat exchanger for a 1 MW system may be of the size order of a 20 feet container. For an installation of 200 MW the heat exchangers will comprise both a large volume and a high cost.

An OTEC installation has the potential to deliver effects in the size order of gigawatts, and also has the advantage of being able to deliver continual energy. In addition to electric power production, an OTEC installation may also be combined with other technologies where one may utilize the cold and nutrient rich water that is transported to the surface.

An OTEC installation is presently not competitive in relation to other renewable energy sources due to too high costs. A thermal energy exchanger combined with for example an OTEC solution may provide a prize competitive solution, which in addition provides an installation that may provide approximately continuous energy production. With an increased amount of energy and higher temperature differences the heat and cold exchange can become more effective. In addition, a system based on a thermal energy exchanger with a large height differential between top and bottom may be able to utilize the gravitational potential energy instead of the expansion force energy for energy production. An installation with a large fall height will provide an improved effect when compared with an OTEC installation based on expansion force. That the system may utilize pipe in pipe heat exchange by circulation of the mediums constitutes an additional improvement.

The thermal energy exchanger has many possibilities of use and may also be combined with other renewable energy sources for effective conversion of thermal energy to electrical energy. In addition, the thermal energy exchanger may also be used for other purposes than only energy production. One possibility is to provide a better adaption between consumption and production of energy for example during a 24 hour period, by storing energy as thermal energy and return the thermal energy to the energy system when the need for power production arises.

In existing patents discussing power production with thermal energy we have found several within OTEC, ref. WO2013/013231A2, WO2013/025797A2, WO2013/025807A2, and WO2013/031903A1. US3945218A describes an energy system for power production or for energy enhancement in the system, where it for example between a mountain top and wally bottom with large temperature differences is provided a closed loop with a medium, for example R-12. A heat exchanger 26 in the valley bottom may be connected to a geothermal source. Heat exchange with the surrounding air happens at the top and bottom of the loop. A height differential is described between top and bottom of 11326 feet (corresponding to about 3400 meters), and a temperature difference of 40 degrees Fahrenheit, and a pressure differential in the medium of 6292 Psi due to the height differential. The pressure differential is used for controlling and optimizing the fluid current of the medium.

Object of the invention

The present invention aims at providing a new type of thermal energy exchanger that may integral in an energy system, with the goal of providing a steady and stabile power delivery with renewable and environmentally sound energy. The energy system shall also have a high effect per area, and be able to provide a considerable effect as well as being able to be installed without disfiguring or harm the surrounding environment.

Short description of the invention

The thermal energy exchanger in accordance with the present invention is thus characterized by that when the loop contents are circulated, heat is generated when the content is moved downwards and cold when the content is moved upwards, where said heat and cold is transferred to one or more separate mediums where the separated thermal energy amount indirectly or directly is used for power production or to an energy increase in an energy system.

In accordance with a preferred embodiment of the present invention the pressure differential between the top and bottom of the loop is minimum 10 bar, preferably it is 15 bar or more.

In accordance with a preferred embodiment of the present invention the liquid particles absorb heat by compression and cold by decompression, and thus the temperature generation in the system is limited by circulation of the contents.

In accordance with a preferred embodiment of the present invention the loop comprises in addition to the internal medium in said loop piston devices which circulates in the loop and sections the medium in the loop into smaller volumes. The piston devices preferably function as plugs, that by their specific gravity and accompanying mass constitutes a pressure onto the underlying sections, where the pressure in each section mainly is a function of the number of plugs laying above.

The content of the loop is thus sectioned into smaller volumes of piston devices that functions as plugs, where specific gravity and accompanying mass contributes to provide an increased pressure on the underlying sections. In accordance with a more preferred embodiment of the present invention the plugs gather and distribute the liquid particles in each section. In accordance with another more preferred embodiment of the invention the liquid particles will be distributed in spray or droplet phase. Thus, the liquid particles in spray or droplet phase will limit the temperature development by compression and decompression of the sections when the contents of the loop are circulating. In accordance with a preferred embodiment the loop comprises a device for exchanging plugs at need.

In accordance with a preferred embodiment of the present invention thermal energy form other energy sources may be added in order to contribute to increasing the total thermal energy amount transferred to the separated medium.

Use of the thermal energy exchanger in accordance with the present invention is thus characterized by the thermal energy exchanger delivering thermal energy directly or indirectly to an energy loop 4, which has a level difference between top and bottom of above 800 meters, where one or more power converters for power production is directly or indirectly connected to the energy loop.

In addition the present invention comprises the construction of an energy system with a thermal energy exchanger that delivers thermal energy either directly or indirectly to an energy loop 4, which has a level differential between the top and bottom of above 800 meters, and which is connected to a power converter for power production.

In accordance with a preferred embodiment of the present invention the energy system comprises a heat loop that transfers hear from the thermal energy exchanger to the energy loop, and where the heat loops lower part extends down a minimum of 400 meters below the closed loop of the thermal energy exchanger.

In accordance with another preferred embodiment the construction is such that the lower part of the heat loop provides the construction with a negative uplift by placement in a maritime environment, and will, together with the thermal energy exchangers positive uplift in the upper part, impair the construction with an advantageous stability with a low center of gravity and a high uplift point.

In accordance with another preferred embodiment the construction may also comprise a tower, which extends the level difference between top and bottom of the energy loop, and where the cold loop transfers cold from the thermal energy exchanger to the energy loop.

In accordance with yet another preferred embodiment the thermal energy exchanger produce thermal energy by circulating the contents, where heat is generated by an increasing pressure at increasing depth, and cold is generated by a decreasing pressure at a decreasing depth. Thermal energy may also be added from other energy sources, and can contribute to increase the total energy amount in the energy system.

In accordance with another preferred embodiment the liquid particles in spray or droplet phase will contribute to reduce the temperature development by pressure variations internally in the thermal energy exchanger.

The present invention is to be explained in more detail by reference to the following figures, where:

Figure 1 shows a thermal energy exchanger 3 with plugs 2
Figure 2 shows temperature reduction and pressure increase of CO_2 in supercritical phase.
Figure 3 shows pressure reduction and temperature increase of CO_2 in supercritical phase.
Figure 4 shows an energy system with a thermal energy exchanger 3 collecting thermal energy from the surrounding water.
Figure 5 shows an energy system with a thermal energy exchanger 3 collecting thermal energy from renewable energy sources via a heat reservoir.
Figure 6 shows an energy system including heat- 8 and cold loops 9
Figure 7 shows a floating construction with a thermal energy exchanger and heat- 8 and cold loops 9.
Figure 8 shows a bottom anchored construction with a thermal energy exchanger and heat- 8 and cold loops 9

Detailed description

The thermal energy exchanger comprises a closed loop with a large height differential between top and bottom, which produces thermal energy when the contents of said loop circulate by means of added energy. The thermal energy is generated by compression and decompression of one or more gasses, optionally a fluid in a gas like phase (supercritical phase or similar). When the content of the loop is circulating the gas will be compressed when it is moved downwards as a result of the pressure in the loop increasing with increasing depth. In order to achieve compression close to an isothermal compression, the liquid particles in spray or droplet phase will collect thermal energy and contribute to keep the temperature down. By regulating the amount of liquid particles the temperature will also be able to be adjusted to the desired level. The amount of heat developed as a consequence of the compression may be transferred to a medium outside the loop, for example a pipe in pipe heat exchange. In the same manner the thermal energy exchanger will generate cold when the gas is moved upwards, and the pressure is reduced by increasing height. The liquid particles will then collect cold, and reduce the negative temperature development in the gas, so that the decompression is close to an isothermal decompression, and aid with the transferal of the thermal energy to an external medium outside the loop.

The pressure build up in each section in the loop will be generated by the specific gravity of the content in the loop. Since the specific gravity of gases is very low, the pressure build up will mainly occur via the specific gravity of the piston devices sectioning the contents of the loop, and from liquids and other mass connected to the piston devices. The piston devices with their mass will function as plugs that circulates in the loop, and where the in each section will be a function of the number of plugs applying a pressure on the underlying sections. The pressure will thus be the lowest in the top of the loop, and increase as the section is moved downwards to the bottom of the loop where the pressure is highest. When the gas section has passed the bottom and is moving upwards in the loop the pressure will decrease as the number of above laying plugs is decreasing.

The temperature development in each section will be a function of the gas compression/decompression, thermal energy exchange with the surrounding, as well as the amount of liquid particles absorbing thermal energy. By regulating the amount of liquid particles in each section in accordance with thermal energy development and to thermal energy exchange with the surroundings, the temperature in each section will be able to be controlled. The regulation of the amount of liquid particles may occur by liquid particles that have collected thermal energy and transferred this to the pipe walls of the loop for thermal energy exchange being gathered in a container in connection to the plug. The liquid particles will them be in liquid phase, and can be pumped back into the gas section as liquid particles for a new cycle of thermal energy collection and thermal energy exchanger. By regulating how much liquid that is added to the gas section in spray or droplet phase, the temperature development for each section may also be controlled.

The temperature variations in the loop will influence the volume in each section as the section is moved around in the loop. By movement downwards the temperature will increase to a maximal level, but is reduced back to the starting temperature after thermal energy exchange in the lower part. By downwards movement the temperature will decrease to a minimal level before returning to the starting temperature after thermal energy exchange in the upper part. Since gases expand with increasing temperature a gas section will have a larger volume during the downwards motion than during rising where the temperate is lower. This volume difference will lead to that the number of plugs may be higher on the raising side than on the descending side, and thus result in a higher pressure that must be overcome in order for the contents to circulate. By substantially isothermal compression and decompression the temperature development will be limited and thus also result in a limited pressure difference between the descending side and the ascending side.

The thermal energy exchanger will be connected to a pump device or an accelerator device that can drive the circulation of the contents in the loop. In addition to overcoming the pressure differentials that results from the temperature variation the pump/accelerator device must overcome the friction in the system, both from the plugs and the gas sections. With compression and decompression of the gas sections the velocity of the plugs will vary during a cycle in the loop. In the lower part the velocity will be low since the gas sections are compressed. During the rise the gas section will expand, and the velocity of the plugs will increase and reach a maximum velocity at the top of the loop. The relationship between the velocity in the bottom and the velocity at the top will be a function of the degree of compression in the system.

The thermal energy exchange to an external medium will be adapted to the energy system that the thermal energy exchanger is part of. In some installations it will be an advantage to have energy exchange that is concentrated around the top and bottom of the loop. In other installations thermal energy exchange will be preferably in shorter or longer parts of the ascent and decent. The thermal energy exchanger will be able to adjust the transferal of thermal energy to the external medium by collecting thermal energy in the plugs and regulating when the thermal energy is to be transferred to the pipe walls. Each installation will have pipe walls with heat conducting abilities adapted to the energy system the installation is designed for. Thus, there will be areas where the pipe walls will be fitted with thermal insulation in order to avoid loss of thermal energy, as well as areas with thermal energy exchange where the pipe walls has good heat conduction ability to the external medium in order to avoid thermal energy loss to the surroundings the hole thermal energy exchanger will be heat insulated in order to reduce the loss of effect in the system.

Figure 1 shows a thermal energy exchanger comprising of a closed loop 11 with plugs 2 that are circulating. The specific gravity to each plug 2 results in an increased pressure in the underlying gas section 1, and the distances between each plug 2 will therefore decrease with increasing dept. A pump in connection with each plug 2 distributes liquid in particle phase out to the associated gas section 1, while a liquid container collects liquid with increased thermal energy. At the top and bottom of the figure there is show thermal energy exchange 3 with an external medium where heat is released at the lower level, and cold is released at the higher level, by adding liquid with thermal energy to the pipe wall. For driving the circulation of the contents in the thermal energy exchanger 3 there is shown an accelerator where spools with electric conductors connected to the pipe wall produce a magnetic field that pulls on the plugs 2 as they pass by.

An energy system may comprise of a closed loop 4 which, by means of heat exchangers 5, is connected to a thermal energy exchanger 3, and where the contents in the loop 4 comprises a medium that by the addition of thermal energy changes its density. With the addition of thermal energy heated medium with reduced density will rise up in one end of the loop 4 while cooled medium with an increased density will sink down at the opposite of loop 4. The density difference will result in a circulation in loop 4 and a pressure differential that may be used for energy production. By leading the medium through a turbine in the lower part of the loop, energy may be drawn from the system and be converted to electrical energy with a generator 7 connected to the turbine.

The medium in the energy loop 4 connected to the thermal energy exchanger 3 may be a medium which changes phase by the addition of thermal energy. In the same manner as in an OTEC system the medium can shift between being in a liquid phase and in a gas phase. By the addition of cold in the energy loops 4 upper part the medium will be able to change phase from gas to liquid prior to the decent and thus attain an increased pressure as the depth increases in the liquid column. After passing by the turbine/generator device in the lower part, the pressure will be reduced, and the medium may be lead through the heat exchanger in order to change phase from liquid to gas phase. During the ascent in gas phase the medium will be able to be raised to the upper level by means of very little energy, while them medium in liquid phase during the decent will make up an energy that can be drawn from the system. The distance between the upper part and the lower part will thus be important for the energy amount the system can deliver.

The amount of energy that must be supplied in order to turn a medium from liquid to gas is different for every medium. Water is a medium that requires a lot of energy in order to change phase from liquid to steam, while mediums like propane and butane requires a lot less energy. Table 1 shows a collection of mediums with values for the necessary amount of energy in order to change phase from liquid to gas, where propane and butane are the mediums requiring the least amounts of energy with respectively 356 KJ/Kg and 320 KJ/Kg medium. Even if propane and butane is given as requiring the least amount of energy there may be other mediums better suited that also require a smaller amount of energy in order to change phase. In order to change the phase of the medium back from gaseous phase to liquid there is required an equally large amount energy as from liquid to gas. By combining a thermal energy exchanger with an energy loop, the energy loop is supplied with both heat and cold by continual circulation of the contents in the thermal energy exchanger.

Table 1; Necessary energy amount in order to change the phase from liquid to gas

Compound	Heat of vaporization (kJ mol^{-1})	Heat of vaporization (kJ kg^{-1})
Ammonia	23.35	1371
Butane	21.0	320
Ethanol	38.6	841
Hydrogen	0.46	451.9
Methane	8.19	760
Methanol	35.3	1104
Propane	15.7	356
Phosphine	14.6	429.4
Water	40.65	2257
Aluminium	294.0	10897

In addition to the necessary amounts of energy in order to phase change the medium, the mediums density in liquid condition is also important for how much energy can be drawn. A liquid column comprising of water with a density of 1000 kg/m^3, will result in a static pressure of about 40 % more than butane and propane, which has a density of about 600 kg/m^3. On the other hand, water requires an energy amount that is about 7 times higher than butane, in order to change phase between liquid and gas, and thus butane will be a better choice of medium.

A medium does not necessarily need to change phase between gas and liquid. Instead a medium like for example CO_2 be in a supercritical phase at the correct pressure and temperature in the energy loop. In figure 2 there is shown a temperature reduction of around 50 degrees Celsius at the top of the energy loop where the density changes from abound 200 kg/m^3 to around 750 kg/ m^3, resulting in a change of density of about 550 kg/ m^3. When the CO_2 medium is sent downwards in the loop the pressure increases while the temperature does not increase noticeably. After passing by the turbine the pressure is reduced to a level that is high enough to keep the circulation of the CO_2 medium going. In the heat exchanger in the lower part the temperature is increased by 50 degrees Celsius and the medium can be raised to the upper part with reduced density. During the ascent the pressure drops back to the starting point of around 75 bars as shown in figure 3.

By not changing the phase all the added energy will be used in order to increase the temperature of the medium. The different mediums will have different capacities and the energy amount that is required in order to change the temperature is therefore different for the different mediums. With CO_2 as a medium instead of propane or butane the energy system will be able to produce more energy per energy amount delivered from the thermal energy exchanger. Propane and butane still has the advantage of being able to operate at a lower pressure in the energy loop, and a lower temperature that is easier to adjust by thermal energy collection from the surrounding water, in addition to that a lower temperature also will result in a lower energy loss to the surrounding water. What medium is better suited for the energy loop may vary with different types of energy systems. Instead of CO_2 there is also other medium that may change the density without changing phase, and that may operate at lower temperatures and pressures, and thus be a better alternative as a medium in the energy loop than CO_2.

Figure 4 shows an energy system for energy production, which consists of a thermal energy exchanger 3 that in addition to its own thermal energy production also gathers thermal energy from the surrounding water. The thermal energy is transferred between the thermal energy exchanger 3 and the energy loop 4 on the upper and lower levels via the heat exchanger 5. The heat exchange enables the contents of the energy loop to circulate, and results in a pressure difference in the system that is used for energy production by means of a turbine/generator device 7 in the bottom of the energy loop 4. The effect 6 and the power efficiency of such an energy system will increase with increasing level difference between the top and bottom of the system, both for the thermal energy exchanger 3 and for the energy column 4.

A different solution may be a system that combines the thermal energy exchanger 3 with solar energy or other energy sources. In figure 5, a system is shown where thermal energy both from warm surface water and from sun catchers is collected by the thermal energy exchanger 3 on the upper level. During the decent the thermal energy amount increases as the gas becomes decompressed before it is transferred to the energy loop 4 on the lower level by means of direct heat exchanger between the loops. After the heat exchange at the lower level, the thermal energy exchanger collects cold from the surrounding water, which during the ascent has added more cold.

An energy system that is to have a large level difference between the top and bottom, may advantageously be placed in deep water. A construction that for example shall be at more than 1000 meters will be able to be constructed by modules and is immersed as they are connected. Such a construction will have to be balanced in order for there to be enough mass in order to sink the construction as it is put together, and at the same time the construction must have enough buoyancy to keep itself afloat. An energy system with a thermal energy exchanger will contain a lot of uplift and this must therefore be compensated for by adding mass in the lower part of the energy system. By exchanging the energy loop in order for it to extend down deeper than the thermal energy exchanger 3, as well as transferring heat by means of a liquid filled heat loop 9 from the thermal energy exchanger 3 and down to the lower part of the energy loop 4, the lower part of the construction will have less buoyancy and thus it will be easier to build in a negative buoyancy in the lower part of the construction. The energy system will thus comprise of a stabile construction with a center of buoyancy that is situated far above the center of mass for the construction. In addition to the heat loop 9 the energy system may also comprise a cold loop 8 in the top of the construction, which draws heat out of the upper most part of the energy loop 4 and exchange this for cold form the thermal energy exchanger 3. An extended energy loop 4 with an increased level differential between top and bottom of the loop will in addition to providing a stabile construction also give a higher effect 6 out of the energy system.

Figure 6 shows a system comprised of both a thermal energy exchanger 3 and a heat loop 9 at the bottom and a cold loop 8 at the top. Both the heat loop 9 and the cold loop 8 are provided with pumps to drive the circulation in the loops. Thermal energy transferal may with such a solution occur by “pipe in pipe” heat exchange over a great extent of the thermal energy exchanger, before it is transferred to the energy loop 4. In figure 7, there is shown a floating construction of an energy system as described in figure 6. The thermal energy exchanger consists of many systems delivering heat to a common heat loop 9 in the lower part, as well as cold to a common cold loop 8 in the upper part. The heat loop 9 is in this case considerably longer than the cold loop 8, in order to ensure a stabile construction with a low point of gravity and a buoyancy point that is located considerably higher. The turbine/generator devices 7 in the lower part will typically be exchangeable units that are adapted to be able to be raised to the surface for maintenance and repairs. By having several turbine/generator devices 7 each unit will be simpler to handle, at the same time as a disconnection of a unit may occur without stopping all energy production. Figure 8 shows the same energy system as in figures 6 and 7, but as a bottom anchored construction with anchoring 10, with three energy systems, instead of one floating construction with one energy system.

An energy system with thermal energy exchangers can be constructed in many variants, and can also be adapted to energy storages, for example thermal energy storage or pneumatic storage. With energy collection from several energy sources the installation will be an effective energy system that can deliver predictable power that is competitive with other power sources. Since the energy systems gives the best effect with energy loops that has a large distance between the top and bottom, it will be most advantageous with field development at large depths, with a common power cable to land or to offshore installations nearby. In the same manner as an OTEC-installation or a wind power installation the effect from such an installation may be from a couple hundred megawatt to several gigawatt. An advantage of this type of energy system is that they have a high effect per area, and can deliver a considerable effect. In addition they can be constructed without marring or depreciating the surrounding environment. Another advantage is that they have few movable parts, where exchange of plugs comprises the most considerable maintenance work in addition to the turbine/generator part and other maintenance.

CLAIMS

1. Thermal energy exchanger (3) comprising one or more mediums circulating in a closed loop (11), where the level difference between top and bottom of said loop (11) is at least 400 meters, characterized by that when the content of said loop (11) circulate, heat is generated when the content is moving downwards, and cold is generated when the content is moving upwards, where said heat and cold is transferred to one or more separate mediums, where the separate thermal energy amount indirectly or directly is used for power production or for energy increase in an energy system.

2. Thermal energy exchanger in accordance with claim 1, characterized by that the pressure differential between the top and bottom of said loop is at least 10 bar, preferably 15 bar or more.

3. Thermal energy exchanger in accordance with claim 1, characterized by that liquid particles collect heat by compression and cold by decompression , and thus the temperature development in the system is limited by circulation of the content.

4. Thermal energy exchanger in accordance with claim 1, characterized by that in addition to the internal medium in the loop, the loop comprises piston devices circulating in said loop and sectioning the medium in said loop into smaller volumes.

5. Thermal energy exchanger in accordance with claim 4, characterized by that the piston devices function as plugs (2) which with their specific gravity and accompanying mass constitutes a pressure on the underlying sections, where the pressure in each section is mainly a function of the number of above laying plugs.

6. Thermal energy exchanger in accordance with claim 5, characterized by that the plugs (2) gather and disperse liquid particles to each section.

7. Thermal energy exchanger in accordance with claim 6, characterized by that the liquid particles are dispersed in a spray or liquid phase.

8. Thermal energy exchanger in accordance with claim 5, characterized by that the loop is arranged with a device for exchanging plugs as needed.

9. Thermal energy exchanger in accordance with claim 1, characterized by that thermal energy is added from other energy sources and contributes to increase the total thermal energy amount transferred to the separate medium.

10. Energy system for power production or energy storage comprising a thermal energy exchanger, characterized by that the thermal energy exchanger supply thermal energy directly or indirectly to an energy loop with a level difference between top and bottom of at least 800 meters, where one or more power converters for power production is directly or indirectly connected to said energy loop.

11. Energy system for power production or energy storage comprising a thermal energy exchanger in accordance with one or more of claims 1-9, characterized by that the thermal energy exchanger (3) supplies thermal energy directly or indirectly to an energy loop (4) with a level difference between top and bottom of at least 800 meters, where one or more power converters for power production is directly or indirectly connected to said energy loop (4).

12. Energy system in accordance with claim 10, characterized by that a heat loop (9) transfers heat from the thermal energy exchanger (3) to the energy loop (4), where the lower part of the heat loop extends down under the thermal energy exchangers closed loop by at least 400 meters.

13. Energy system in accordance with claim 11, characterized by that the loops (9) lower part provides the lower part of the construction with a negative buoyancy by placement in a maritime environment, and will together with the positive buoyancy of the thermal energy exchanger in the upper part impair the construction with an advantageous stability, with a low center of gravity and a high buoyancy point.

14. Energy system in accordance with claim 11, characterized by that the energy system comprises a tower which extends the level differential between the top and bottom in the energy loop, and a cold loop transfers the cold form the thermal energy exchanges (3) to the energy loop (4).

15. Energy system in accordance with claim 11, characterized by that the thermal energy exchanger (3) produces thermal energy by circulation of the content, where heat is generated by increasing pressure at increasing depth, and cold is generated by decreasing pressure at decreasing depth.

16. Energy system in accordance with claim 10, characterized by that liquid particles in spray or droplet phase contribute to reduce the temperature development by pressure variations internally in the thermal energy exchanger.

17. Use of the thermal energy exchanger in accordance with one or more of claims 1-9 in an energy system for power production or energy storage, where the thermal energy exchanger (3) supply thermal energy directly or indirectly to an energy loop (4) with a level differential between top and bottom of more than 800 meters, where one or more power converters for power production are directly or indirectly connected to the energy loop (4).

AMENDED CLAIMS
received by the International Bureau on 25 August 2014

1. Thermal energy exchanger (3) comprising one or more mediums circulating in a closed loop (11), where the level difference between top and bottom of said loop (11) is at least 400 meters, characterized by that a pump device or an accelerator device drive said circulation in said loop, and when the content of said loop (11) circulate, heat is generated by compression when the content is moving downwards, and cold is generated by decompression when the content is moving upwards, where said heat and cold is transferred to one or more separate mediums, where the separate thermal energy amount indirectly or directly is used for power production or for energy increase in an energy system.

2. Thermal energy exchanger in accordance with claim 1, characterized by that the pressure differential between the top and bottom of said loop is at least 10 bar, preferably 15 bar or more.

3. Thermal energy exchanger in accordance with claim 1, characterized by that liquid particles collect heat by compression and cold by decompression, and thus the temperature development in the system is limited by circulation of the content.

4. Thermal energy exchanger in accordance with claim 1, characterized by that in addition to the internal medium in the loop, the loop comprises piston devices circulating in said loop and sectioning the medium in said loop into smaller volumes.

5. Thermal energy exchanger in accordance with claim 4, characterized by that the piston devices function as plugs (2) which with their specific gravity and accompanying mass constitutes a pressure on the underlying sections, where the pressure in each section is mainly a function of the number of above laying plugs.

6. Thermal energy exchanger in accordance with claim 5, characterized by that the plugs (2) gather and disperse liquid particles to each section.

7. Thermal energy exchanger in accordance with claim 6, characterized by that the liquid particles are dispersed in a spray or liquid phase.

8. Thermal energy exchanger in accordance with claim 5, characterized by that the loop is arranged with a device for exchanging plugs as needed.

9. Thermal energy exchanger in accordance with claim 1, characterized by that thermal energy is added from other energy sources and contributes to increase the total thermal energy amount transferred to the separate medium.

10. Energy system for power production or energy storage comprising a thermal energy exchanger in accordance with one or more of claims 1-9, characterized by that the thermal energy exchanger (3) supplies thermal energy directly or indirectly to an energy loop (4) with a level difference between top and bottom of at least 800 meters, where one or more power converters for power production is directly or indirectly connected to said energy loop (4).

11. Energy system in accordance with claim 10, characterized by that a heat loop (9) transfers heat from the thermal energy exchanger (3) to the energy loop (4), where the lower part of the heat loop extends down under the thermal energy exchangers closed loop by at least 400 meters.

12. Energy system in accordance with claim 10, characterized by that the loops (9) lower part provides the lower part of the construction with a negative buoyancy by placement in a maritime environment, and will together with the positive buoyancy of the thermal energy exchanger in the upper part impair the construction with an advantageous stability, with a low center of gravity and a high buoyancy point.

13. Energy system in accordance with claim 10, characterized by that the energy system comprises a tower which extends the level differential between the top and bottom in the energy loop, and a cold loop transfers the cold form the thermal energy exchanges (3) to the energy loop (4).

14. Energy system in accordance with claim 10, characterized by that the thermal energy exchanger (3) produces thermal energy by circulation of the content, where heat is generated by increasing pressure at increasing depth, and cold is generated by decreasing pressure at decreasing depth.

15. Energy system in accordance with claim 10, characterized by that liquid particles in spray or droplet phase contribute to reduce the temperature development by pressure variations internally in the thermal energy exchanger.

16. Use of the thermal energy exchanger in accordance with one or more of claims 1-9 in an energy system for power production or energy storage, where the thermal energy exchanger (3) supply thermal energy directly or indirectly to an energy loop (4) with a level differential between top and bottom of more than 800 meters, where one or more power converters for power production are directly or indirectly connected to the energy loop (4).

STATEMENT UNDER ARTICLE 19 (1)

Claim 1 was found to be novel and inventive, but unclear, as it did not state specifically how the circulation in the loop was achieved. This is now amended; the claim now specifically states that this is done by a pump device or an accelerator device. Claim 1 was also found to be unclear because it did not specifically state that heat is developed by the downwards movement and cold by the upwards movement. This has also been corrected, so claim 1 should now be clear.

Claim 10 was found not novel above D1, while claim 10 and 12 were found not inventive based on D1 and D2-D4. Claim 10 is now deleted. Claim 12 is now dependent on new claim 10/earlier claim 11, and therefore should be considered inventive as well.

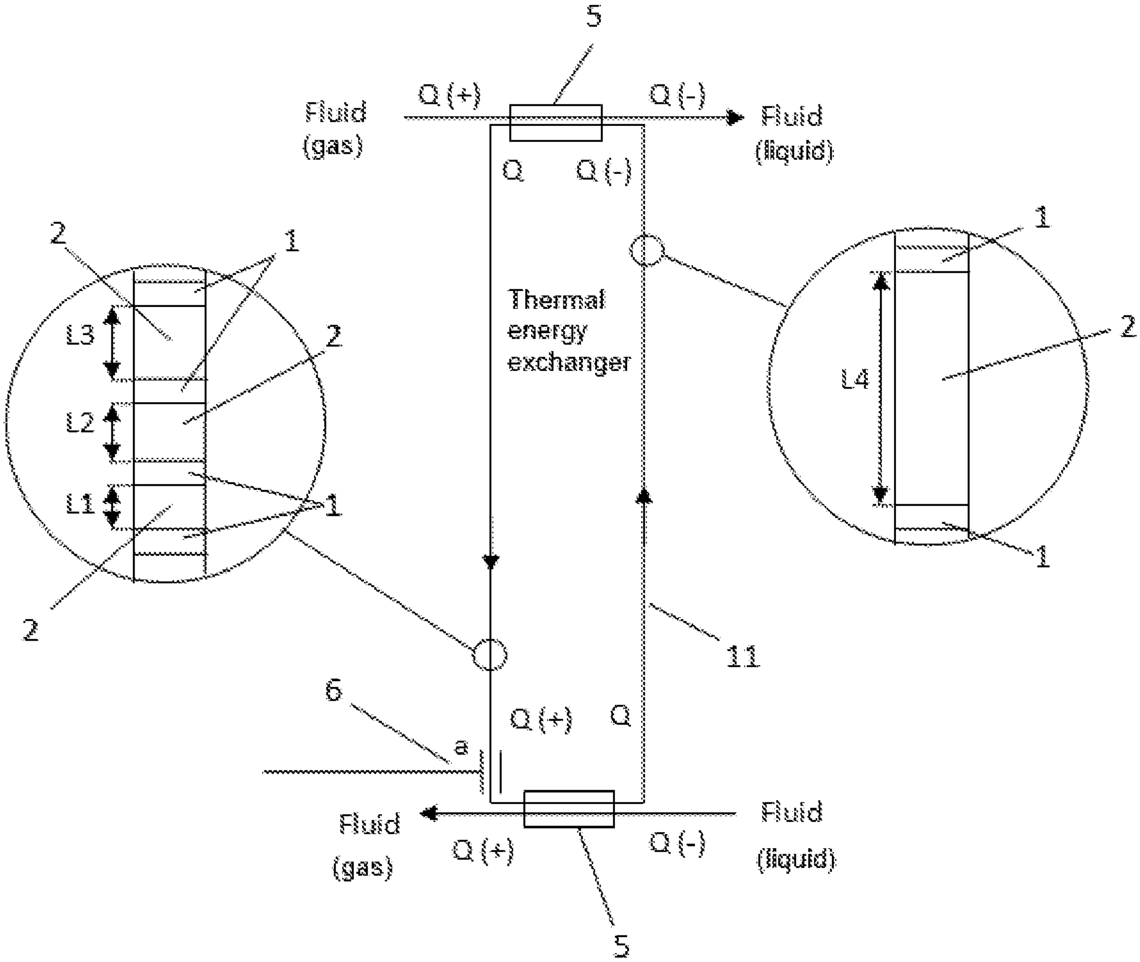
5
Fluid
(gas)
Q (+)
Q (-)
Fluid
(liquid)
Q
Q (-)
2
1
1
L3
2
L2
L1
1
2
Thermal
energy
exchanger
2
L4
1
11
6
a
Q (+)
Q
Fluid
(gas)
Q (+)
Q (-)
Fluid
(liquid)
5

Fig. 1

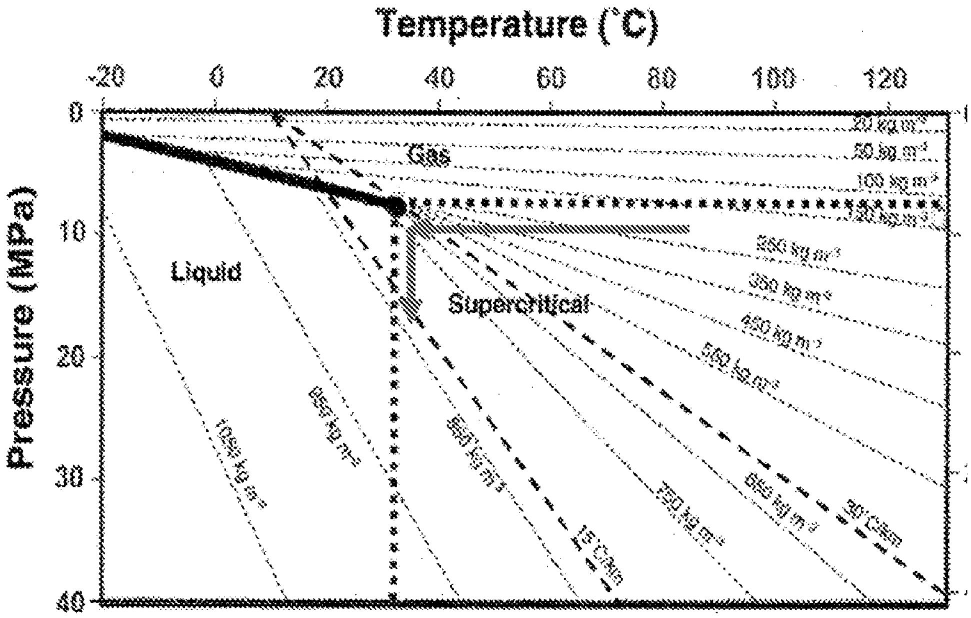

Figure 2, Temperature reduction and pressure increase of CO2 in supercritical phase.

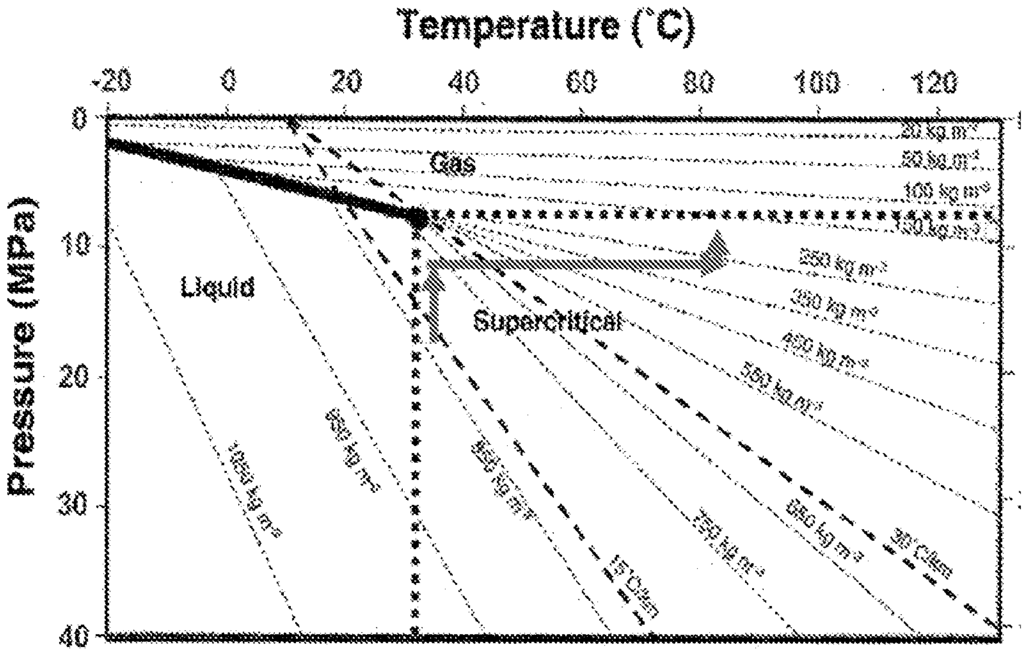

Figure 3, Pressure reduction and temperature increase of CO2 in supercritical phase

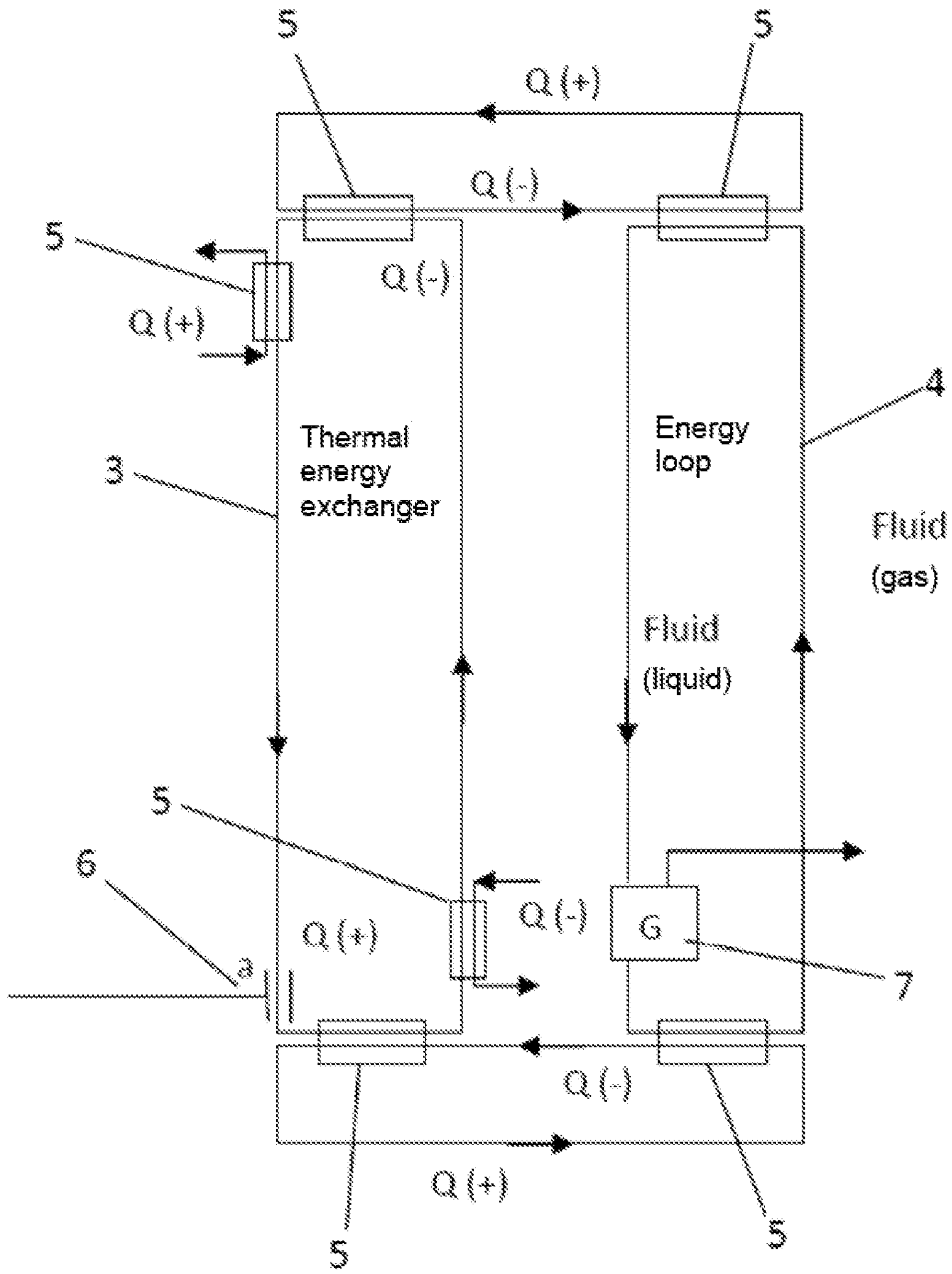
5
5
Q (+)
Q (-)
5
Q (-)
Q (+)
Thermal energy exchanger
3
Energy loop
4
Fluid (gas)
Fluid (liquid)
5
6
a
Q (+)
Q (-)
G
7
Q (-)
Q (+)
5
5

Fig. 4

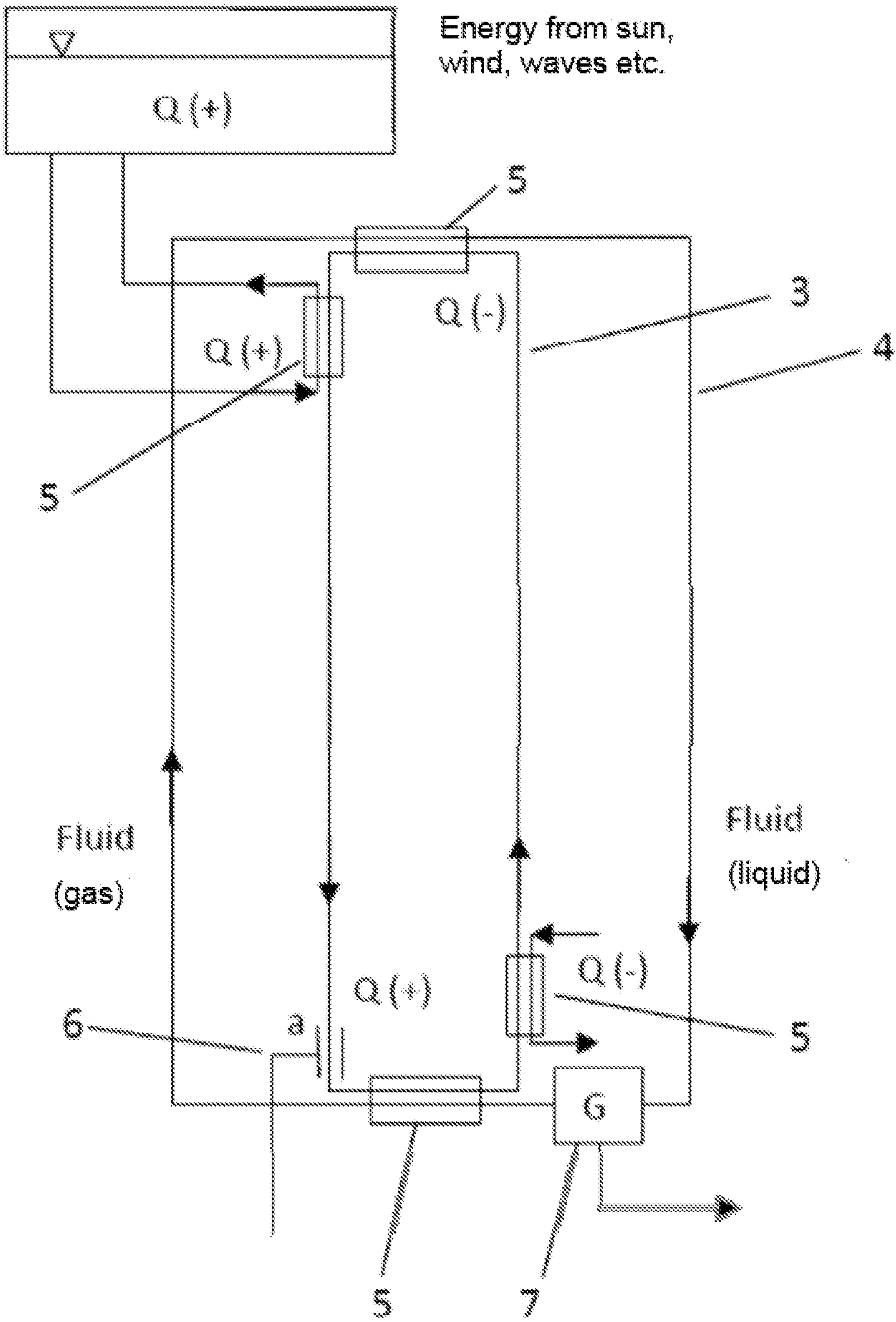
Energy from sun, wind, waves etc.
Q (+)
5
3
4
Q (-)
Q (+)
5
Fluid (gas)
Fluid (liquid)
Q (-)
Q (+)
6
a
5
G
5
7

Fig. 5

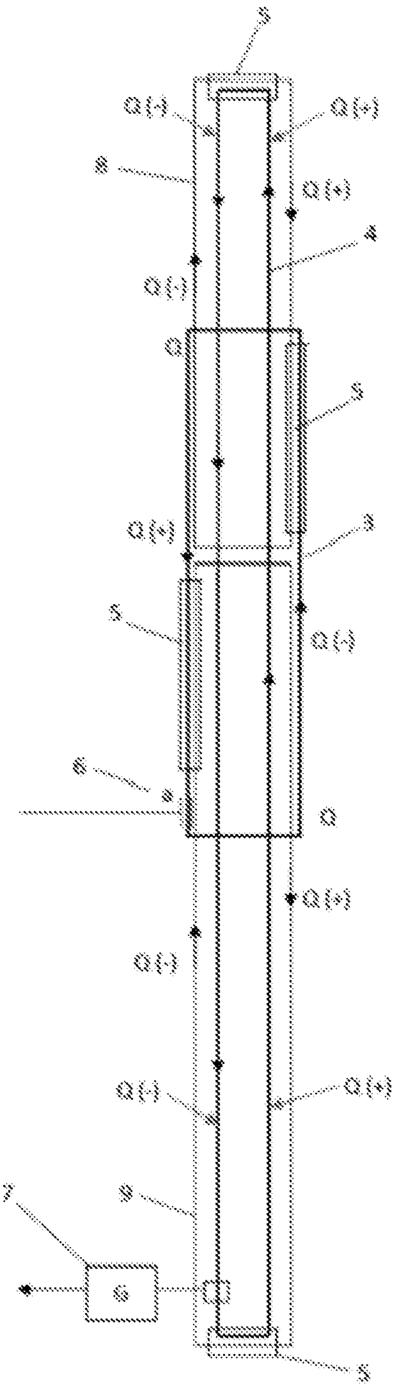

Fig. 6

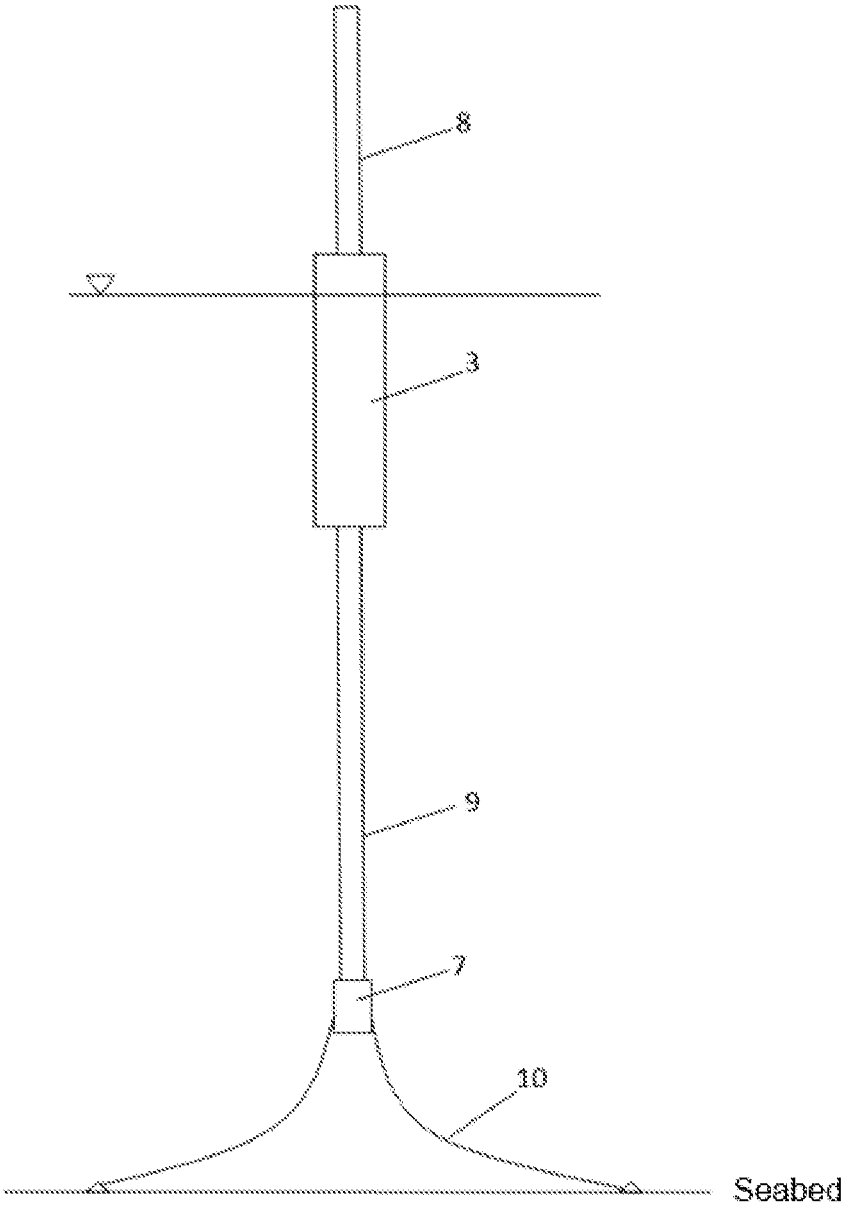

Fig. 7

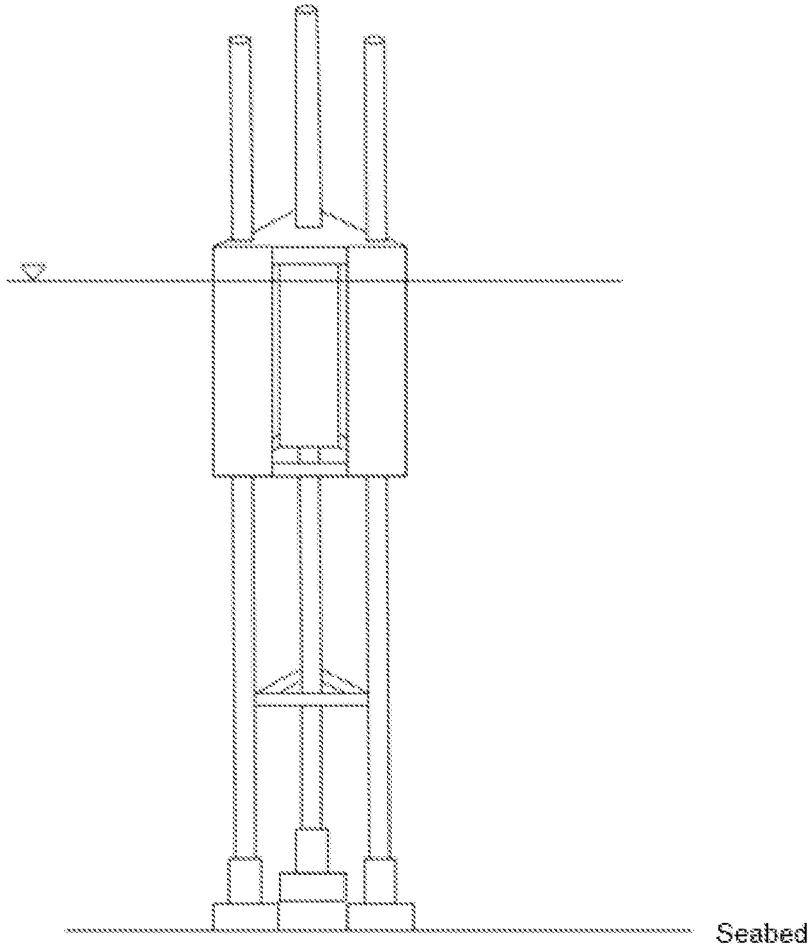

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2014/000027

A. CLASSIFICATION OF SUBJECT MATTER
F24J 3/08 (2006.01), F24J 3/06 (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
F24J, F03G

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

DK, NO, SE, FI: Classes as above.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, FULDTEKST: ENGELSK, TYSK, FRANSK

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3945218 A (LENNOX IND INC) 1976.03.23 Description column 3, lines 53-65; claim 1	10, 12
A		1-9, 11, 13-17
A	EP 0018719 A1 (SORENSEN JENS OLE) 1980.11.12 Claim 1	4, 5
A	DE 4131990 A1 (LESKER HEINRICH) 1993.04.01 Description column 2, lines 9-16	1-17
A	US 4221115 A (KRAUS ROBERT A; KRAUS EDMUND J) 1980.09.09 Claim 1	1-17
A	WO 9641079 A1 (OTEC DEVELOPMENTS) 1996.12.19 The whole document	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20/06/2014	23/06/2014
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. + 45 43 50 80 08	Authorized officer Knut Bråten Telephone No. +47 22 38 75 06

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NO2014/000027

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