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(54) SUBMERGED GEO-OCEAN THERMAL ENERGY SYSTEM

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(52) **U.S. Cl.** **60/641.6**; 60/641.2; 60/641.7

(57) ABSTRACT

A system for generating electrical energy using a naturally occurring temperature difference is disclosed. The system provides electrical energy by thermally conduit a geothermal heat source and cold deep-level water to opposing sides of a thermoelectric element. The thermoelectric element generates electrical energy based on the temperature difference between these two surfaces.

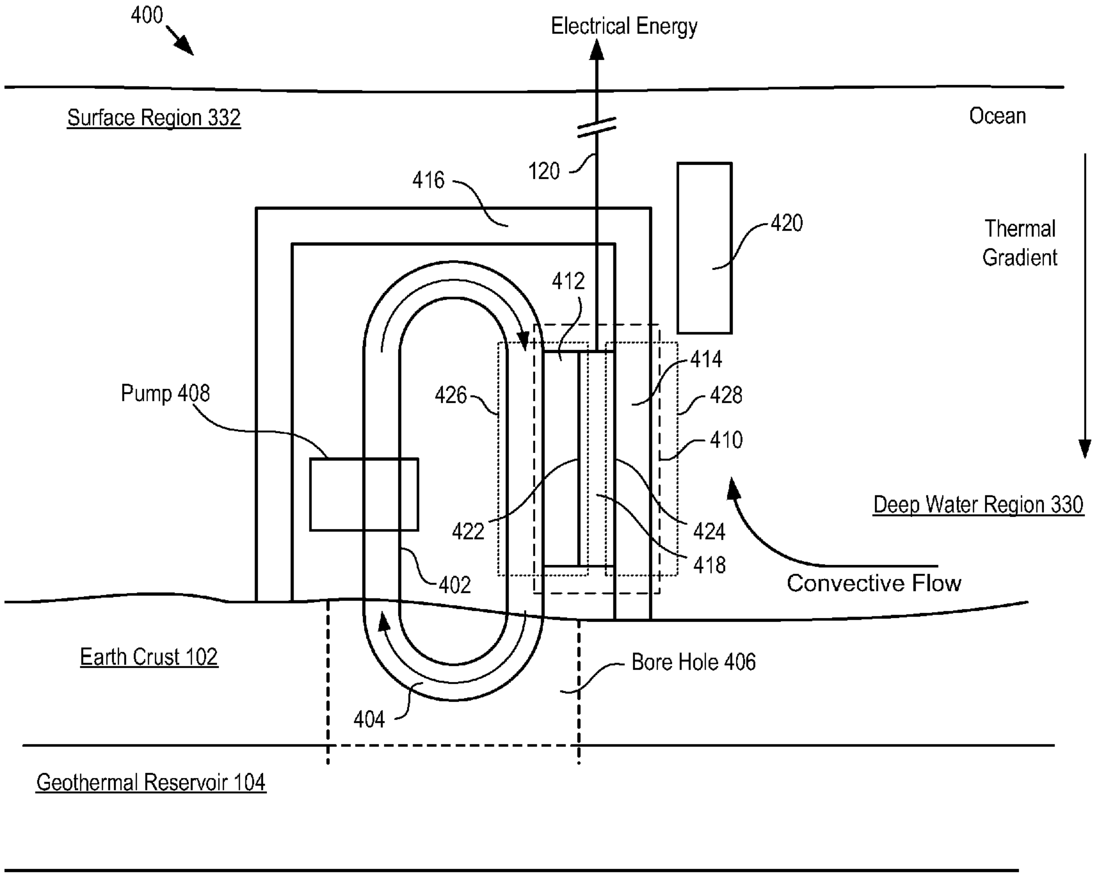


FIG. 1 (Prior Art)

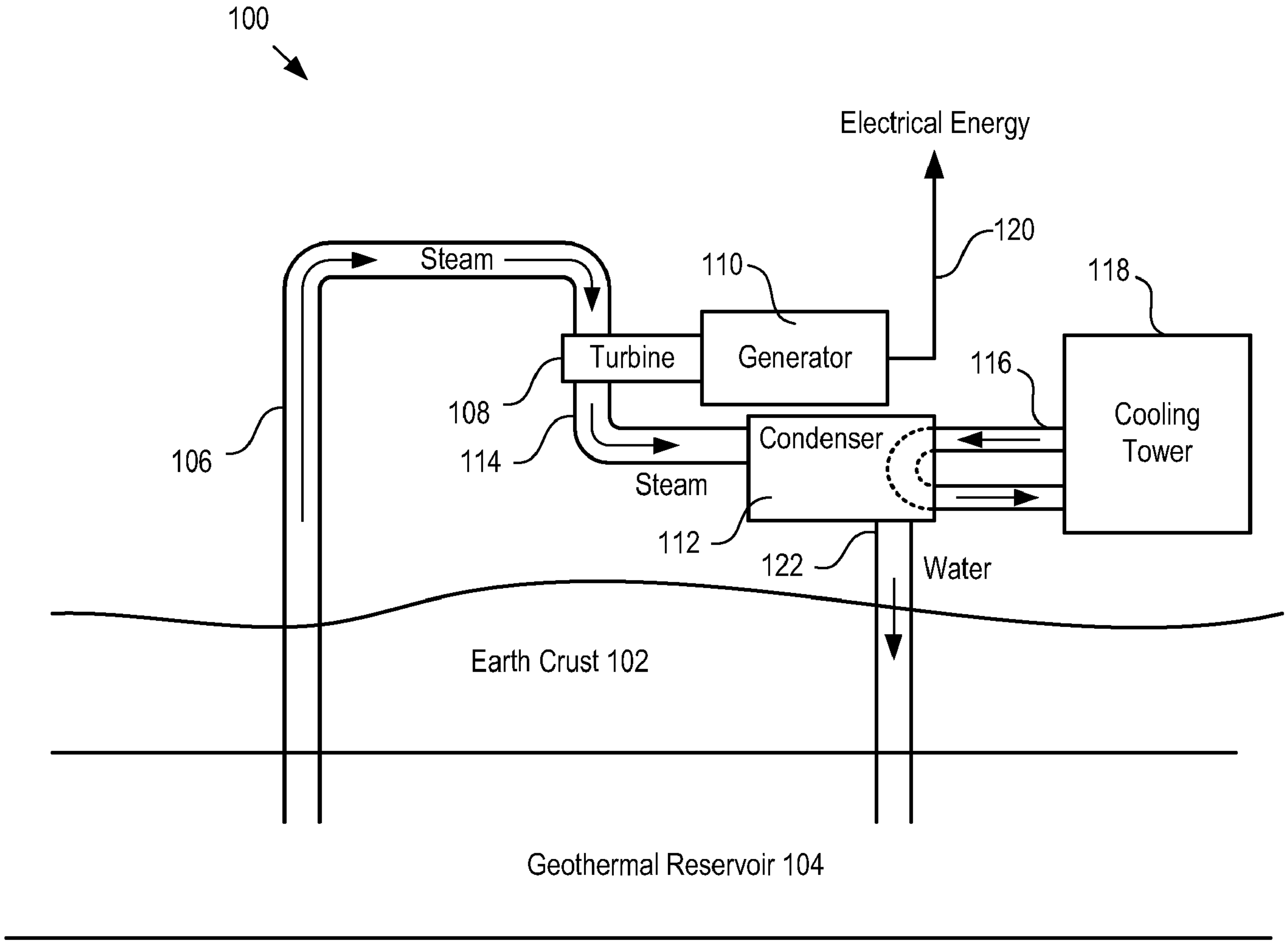


FIG. 2 (Prior Art)

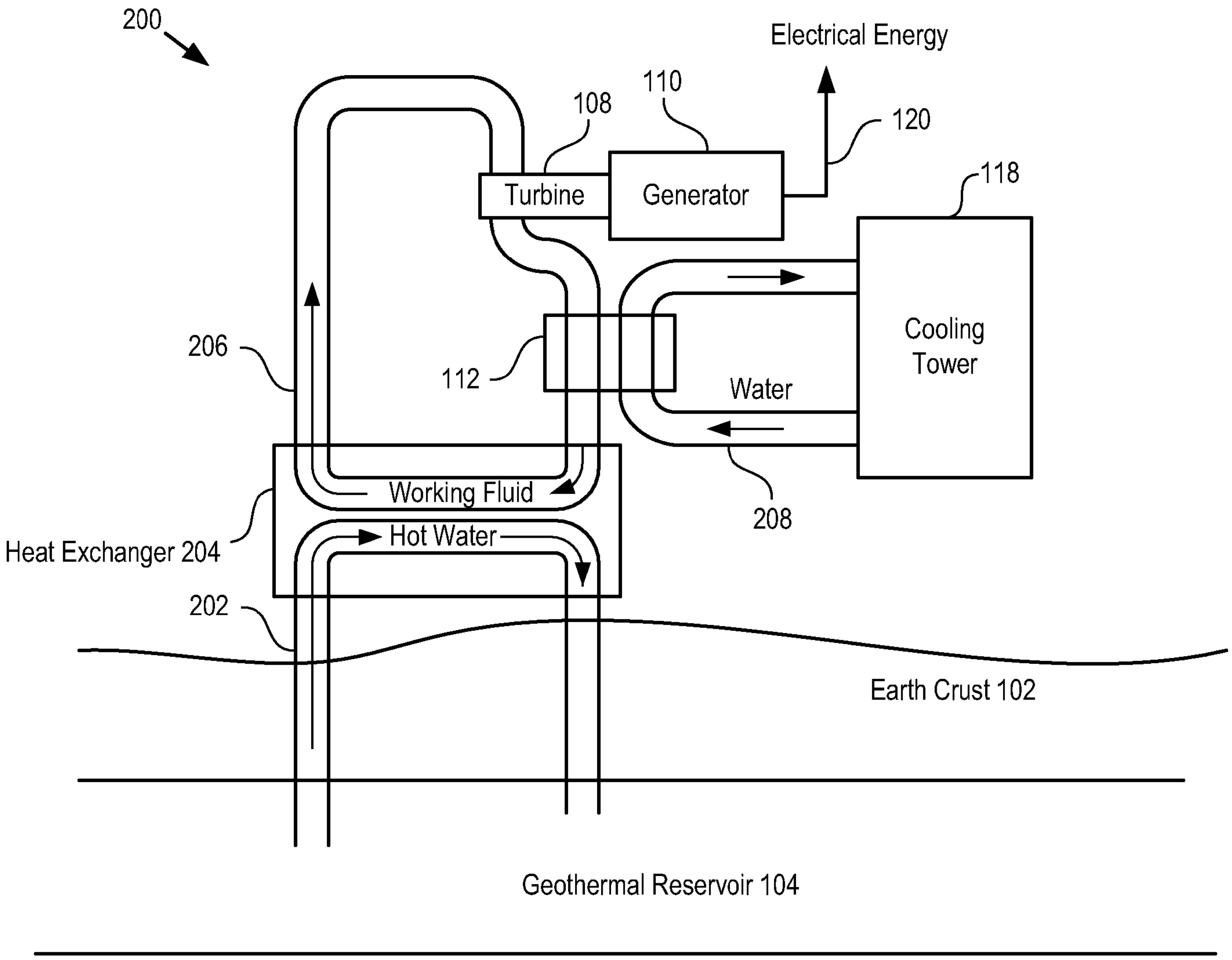


FIG. 3 (Prior Art)

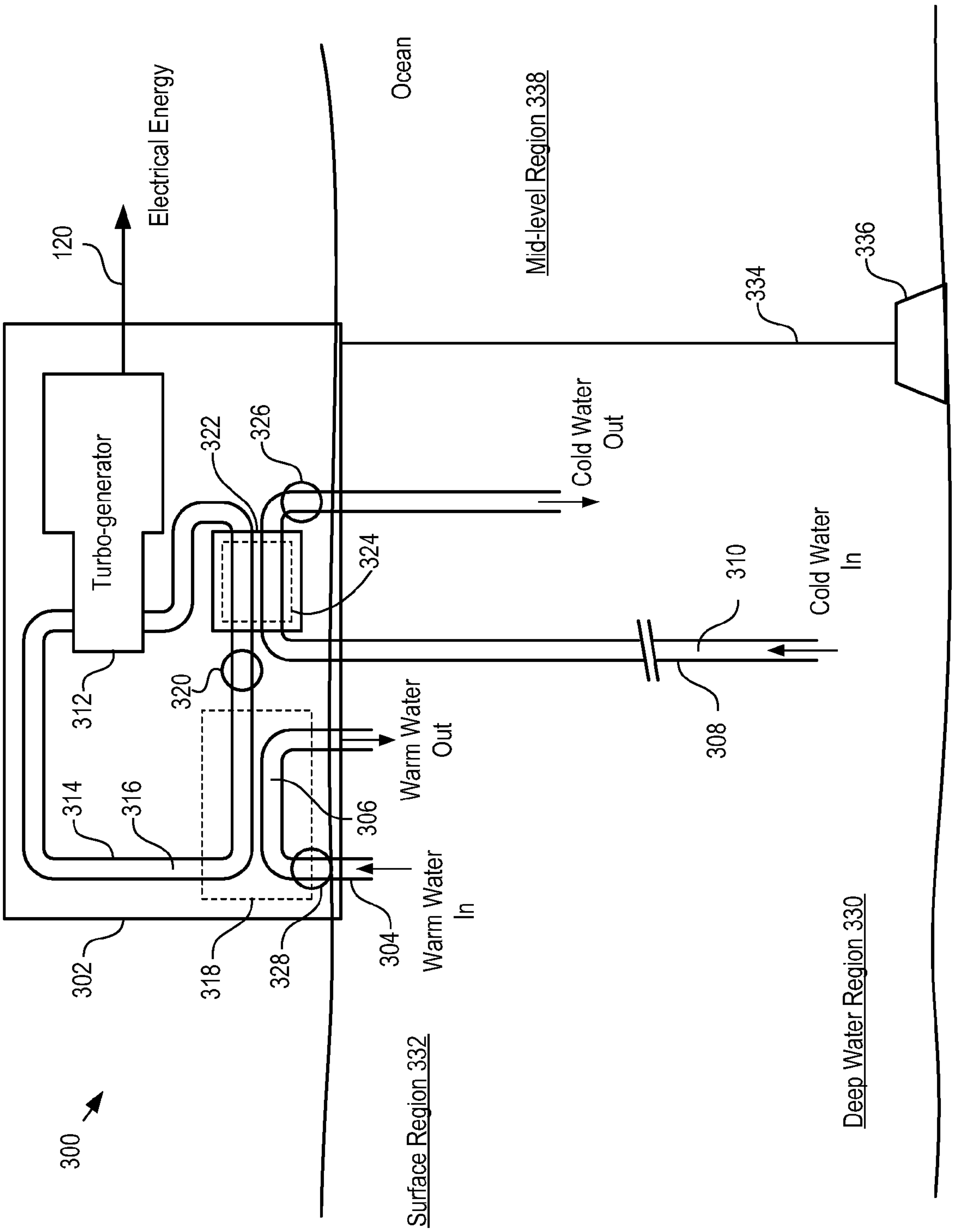
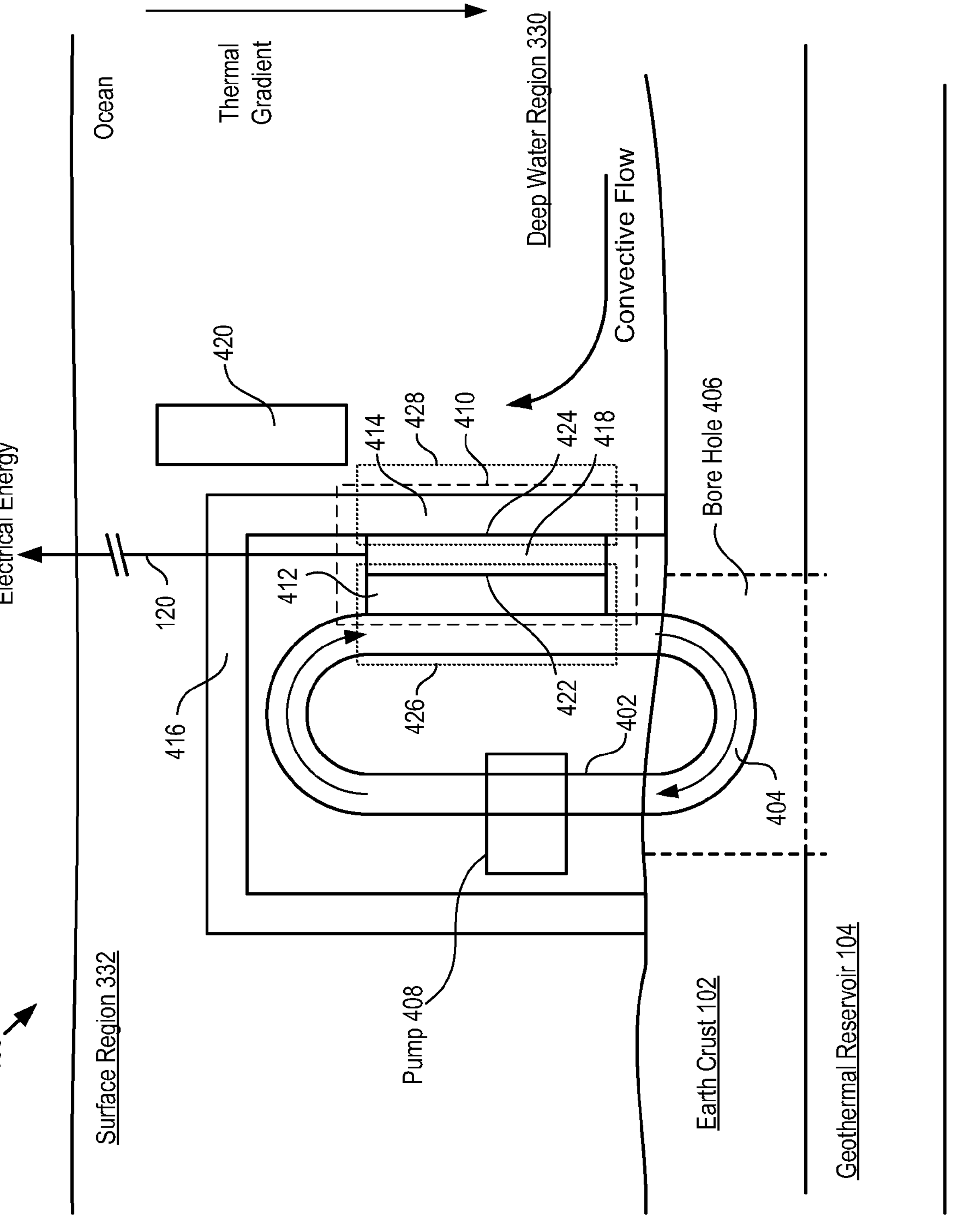


FIG. 4


400
Surface Region 332
Electrical Energy
120
Ocean
Thermal Gradient
420
416
414
428
410
412
424
418
422
426
402
404
Pump 408
Deep Water Region 330
Convective Flow
Bore Hole 406
Earth Crust 102
Geothermal Reservoir 104

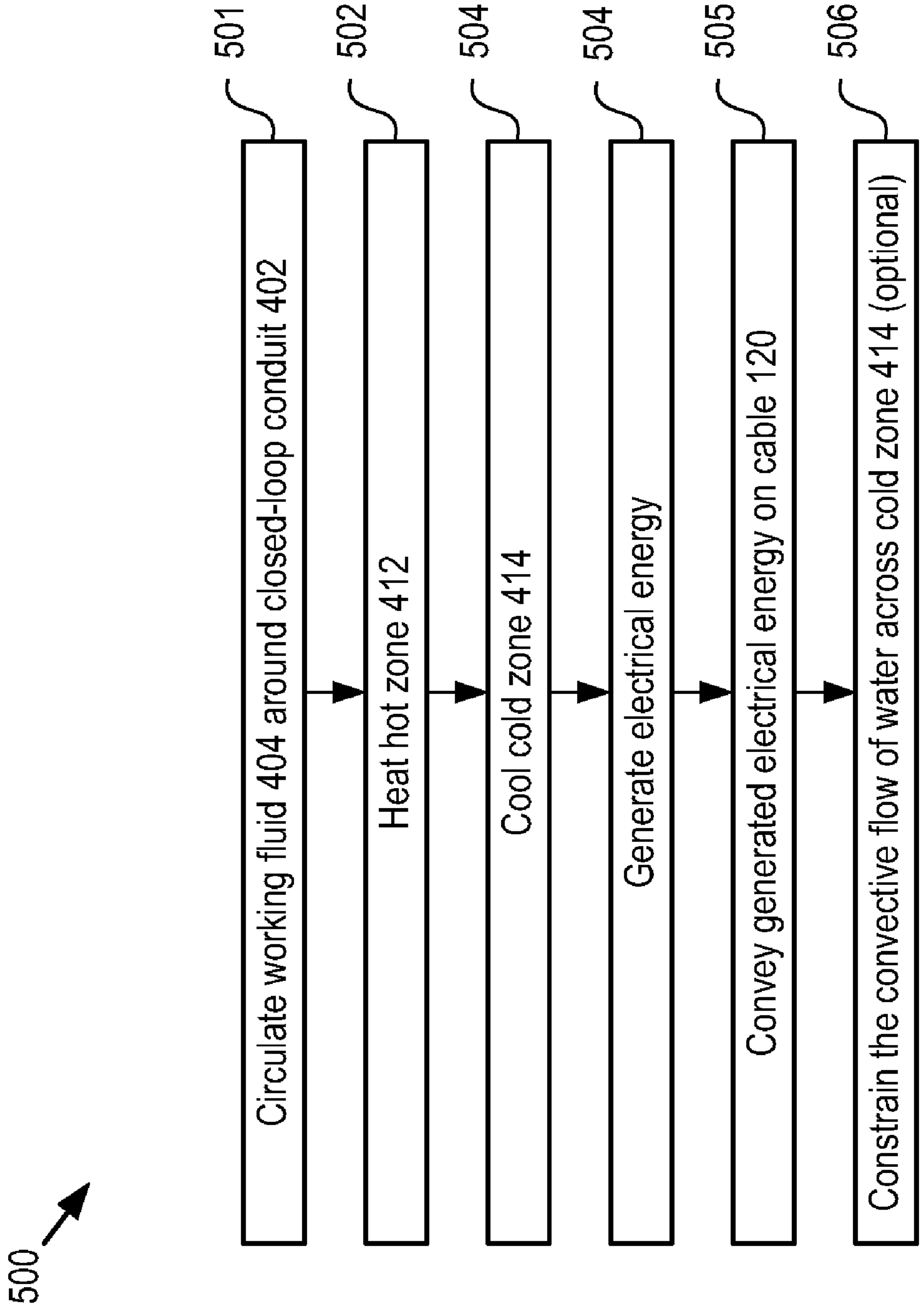
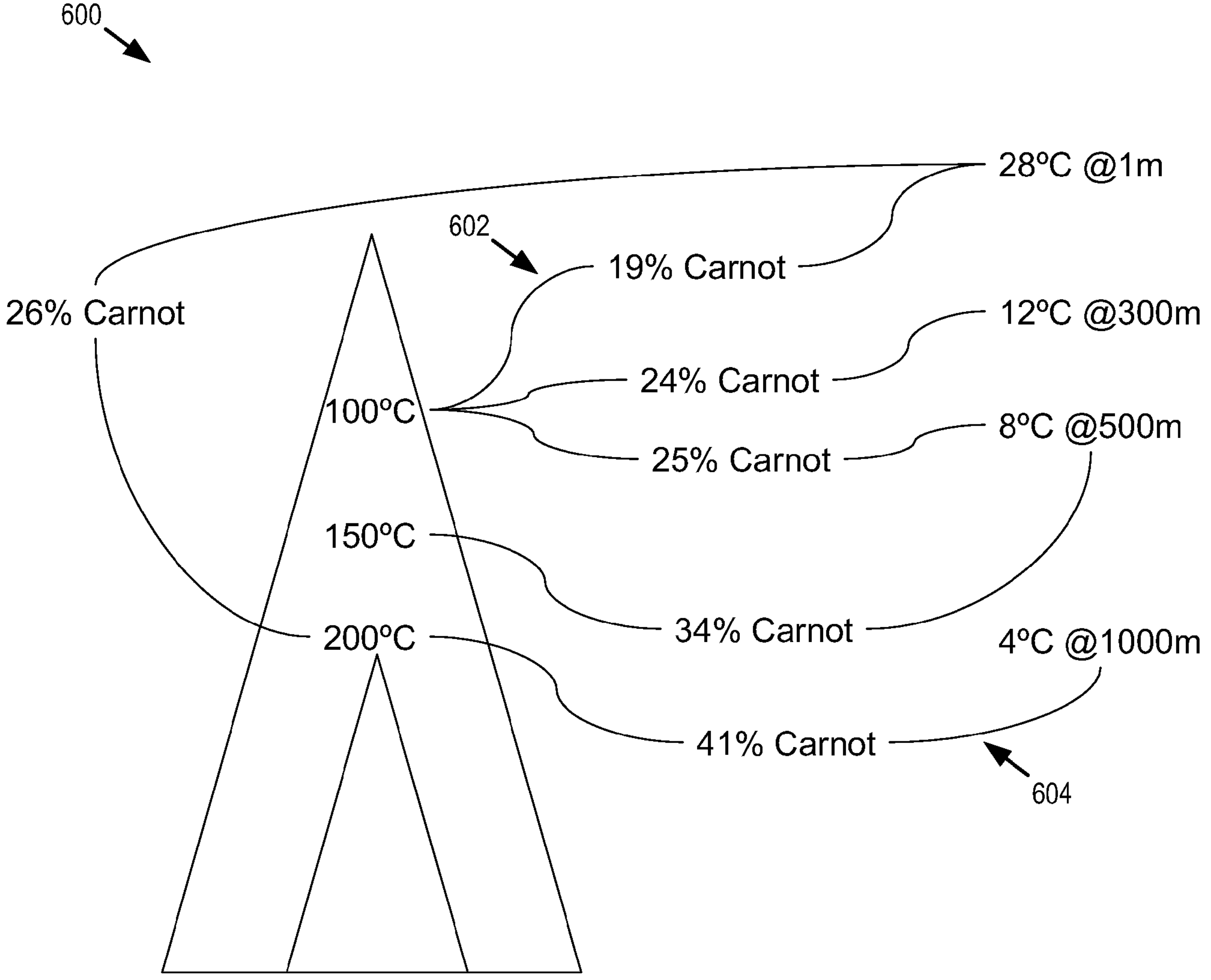

500
501
Circulate working fluid 404 around closed-loop conduit 402
502
Heat hot zone 412
504
Cool cold zone 414
504
Generate electrical energy
505
Convey generated electrical energy on cable 120
506
Constrain the convective flow of water across cold zone 414 (optional)

FIG. 5

FIG. 6


600
28ºC @1m
602
19% Carnot
26% Carnot
12ºC @300m
24% Carnot
100ºC
8ºC @500m
25% Carnot
150ºC
34% Carnot
200ºC
4ºC @1000m
41% Carnot
604

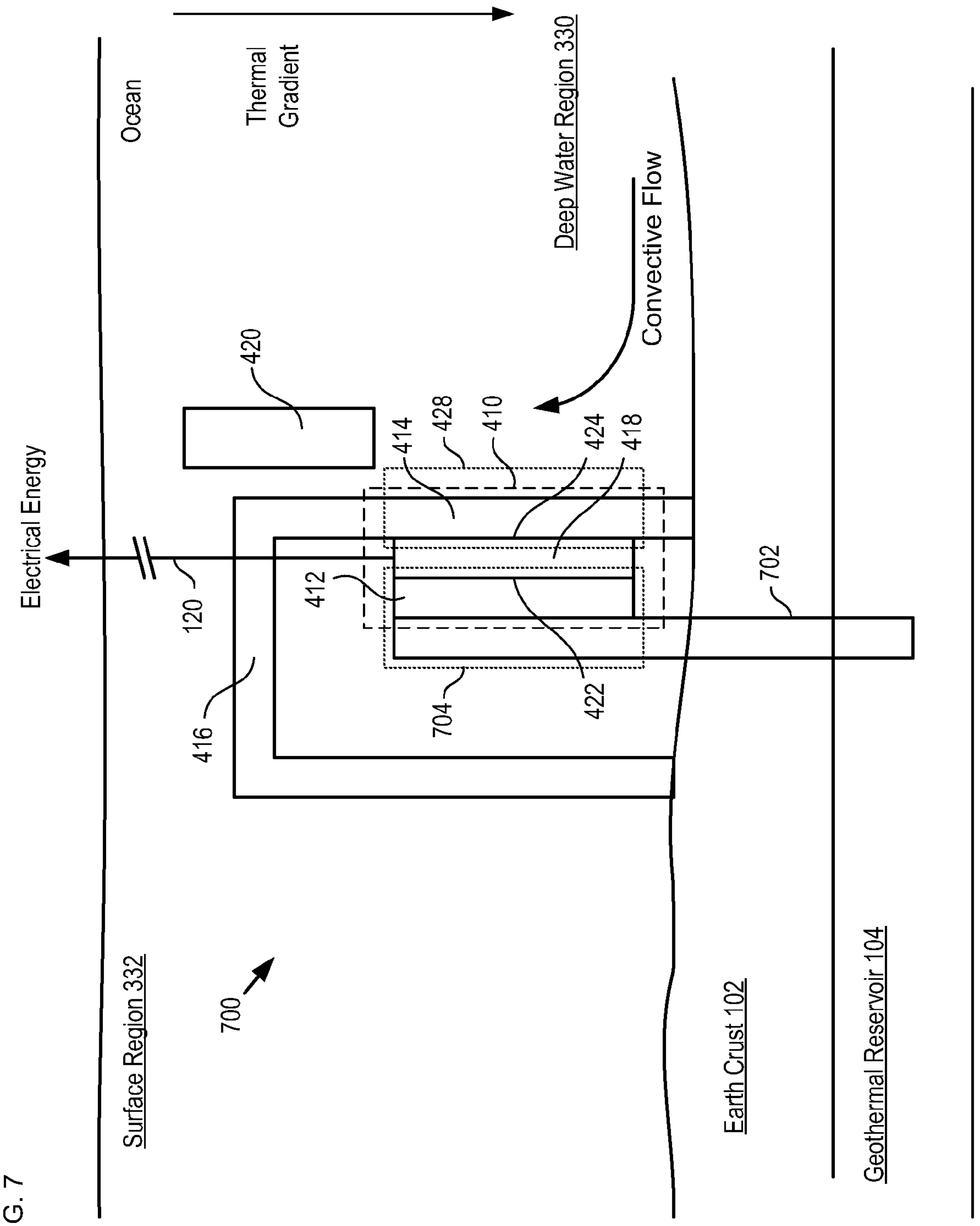
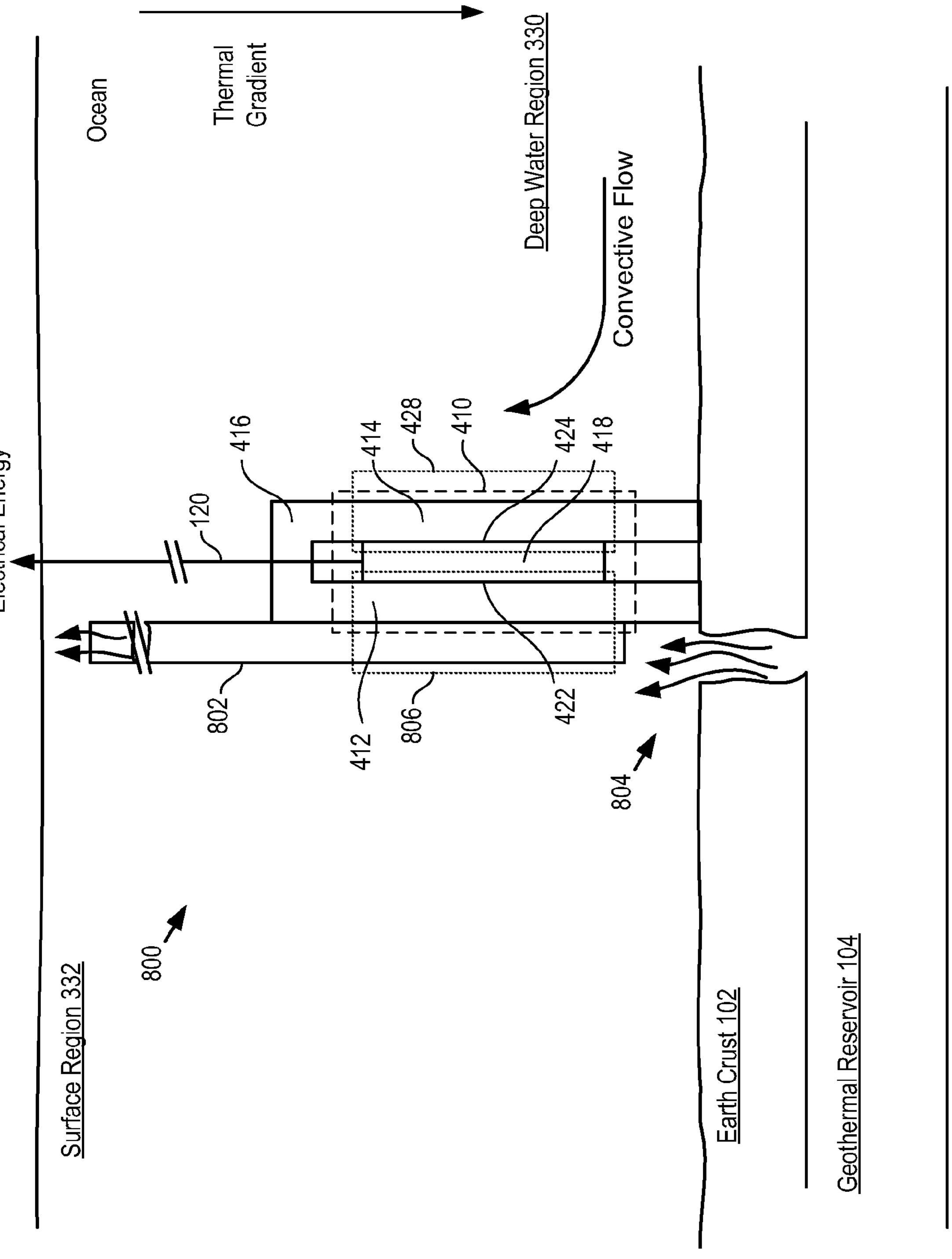

Electrical Energy
120
Ocean
Surface Region 332
700
Thermal Gradient
420
416
412
414
428
704
410
422
424
418
702
Deep Water Region 330
Convective Flow
Earth Crust 102
Geothermal Reservoir 104

FIG. 7

FIG. 8


Surface Region 332
Ocean
Thermal Gradient
Deep Water Region 330
Convective Flow
Electrical Energy
120
416
414
428
410
424
418
412
806
422
802
804
800
Earth Crust 102
Geothermal Reservoir 104

SUBMERGED GEO-OCEAN THERMAL ENERGY SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This case claims priority to: U.S. Provisional Patent Application Ser. No. 61/033,415, filed Mar. 3, 2008 (Attorney Docket: 711-136US); and U.S. Provisional Patent Application Ser. No. 61/042,185, filed Apr. 3, 2008 (Attorney Docket: 711-189US); each of which is incorporated herein by reference.

[0002] If there are any contradictions or inconsistencies in language between this application and one or more of the cases that have been incorporated by reference that might affect the interpretation of the claims in this case, the claims in this case should be interpreted to be consistent with the language in this case.

FIELD OF THE INVENTION

[0003] The present invention relates to energy systems in general, and, more particularly, to geothermal energy systems.

BACKGROUND OF THE INVENTION

[0004] Non-petroleum-based energy sources are desirable. Geothermal and Ocean Thermal Energy Conversion (OTEC) systems represent two attractive such sources. Each can provide electrical energy through the exploitation of a naturally occurring temperature differential. In the case of geothermal systems, this temperature differential is between a naturally-occurring hot spot well below the earth's surface and the ambient temperature at the location of the geothermal system. For OTEC systems, this differential is between the temperature of ocean water at a deep level (e.g., >100 meters) and the temperature of water at the ocean's surface.

[0005] Geothermal systems have been in operation for many years. A conventional geothermal system typically uses a gas-driven turbine to turn an electrical generator. The electrical generator, in response, provides output electrical energy. The blades of the turbine are driven by either hot gas that come directly from the geothermal heat source or working fluid that is vaporized by the hot gas at a heat exchanger.

[0006] There are several problems with conventional geothermal systems that have thus far limited their use. First, the hot gas from the geothermal source is highly corrosive. As a result, the lifetime of the turbine and other system components can be compromised. Second, atmospheric temperature acts as the heat sink for conventional geothermal systems. The power generation capacity of a conventional geothermal system decreases as the ambient temperature at the turbine increases. This is due to the fact that the power generation is directly related to the temperature differential of the system. To further exacerbate matters, the reduction in power generation capacity tends to occur at times when such power is needed most (e.g., when it is hot out and air conditioning demand increases, etc.) Further, latitude and seasonal temperature variation cause variability in the power generation capability of these systems.

[0007] In a typical OTEC system, electrical energy is also generated by a generator that is driven by a turbine. The turbine is driven by means of a heat engine that forces vapor forced across its blades. The heat engine results from the temperature differential between deep ocean water and surface water. Conventional OTEC systems can either be open-cycle or closed-cycle. In an open-cycle system, warm seawater flows into a low-pressure container, wherein it boils and creates steam that drives the blades of the turbine. In closed-cycle system, warm surface seawater is pumped through a first heat exchanger where its heat vaporizes a working fluid. The vaporized working fluid then drives the turbine blades. Cold water is pumped from a deep water level through a second heat exchanger, where the working fluid is condensed to complete a closed cycle.

[0008] Like geothermal systems, OTEC systems also have several problems in practice. At most latitudes, seasonal temperature variations cause variations in their power generation capability. As a result, the deployment of OTEC systems is substantially limited to tropical regions. Further, the daily solar cycle induces variations in the temperature of the uppermost surface seawater. As a result, OTEC system deployment is practical primarily only in areas that have a thermocline with a deeper hot surface region so that the OTEC systems are not subject to diurnal fluctuations. Still further, localized weather conditions can temporarily obstruct sunlight or strengthen winds at the location of the OTEC system. Decreased solar energy and wind-driven evaporation will lower surface water temperature in the region.

SUMMARY OF THE INVENTION

[0009] The present invention provides an energy generation system that avoids or mitigates some of the problems of prior-art energy generation systems. The present invention is an energy generation system that is based on a temperature differential between a geothermal heat source and a deep-water layer. Some embodiments of the present invention are particularly well-suited for deployment in deep-ocean environments that comprise a geothermal heat source, such as near a volcanic island.

[0010] In some embodiments, an energy generation system comprises an energy conversion unit that includes a first heat exchanger having a hot zone, a second heat exchanger having a cold zone, and a thermoelectric system for converting a temperature difference between the hot zone of the first heat exchanger and the cold zone of the second heat exchanger into electrical energy.

[0011] In some embodiments, the hot zone of the first heat exchanger and the geothermal heat source are thermally coupled through a closed-loop fluid system. In some embodiments, the hot zone of the first heat exchanger and the geothermal heat source are thermally coupled through a hydrothermal vent. An open-loop conduit conveys at least a portion of the hydrothermal vent through the first heat exchanger where it is thermally coupled with the hot zone. In some embodiments, the hot zone of the first heat exchanger and the geothermal heat source are thermally coupled through an earth crust penetrating rod. The penetrating rod is inserted into the geothermal heat source and conducts heat from the geothermal heat source to the first heat exchanger where the rod is thermally coupled with the hot zone.

[0012] The second heat exchanger comprises a cold zone whose temperature is regulated by the fact that it is thermally coupled to a deep-water layer. Preferably, the deep-water layer exhibits a high heat capacity and a temperature that is substantially constant regardless of latitude, weather conditions, the annual solar cycle, or even the daily solar cycle. The thermoelectric system interposes the first heat exchanger and the second heat exchanger.

[0013] In some embodiments, the hot zone of the first heat exchanger and cold zone of the second heat exchanger are interposed by a thermoelectric element having a first surface and a second surface. This thermoelectric element generates electrical energy as a function of temperature difference between the first and second surfaces. In some embodiments, this thermoelectric element comprises an element that generates electrical energy by means of the Peltier effect. In some embodiments, this thermoelectric element comprises a quantum-well thermoelectric element.

[0014] In still some other embodiments, the energy conversion unit is operatively coupled to a Rankine-cycle engine.

[0015] An embodiment of the present invention comprises: an energy conversion unit wherein the heat exchanger comprises a hot zone that is thermally coupled to a subterranean geothermal heat source, and a cold zone that is thermally coupled to a region of a body of water; a thermoelectric element that generates electrical energy based on a thermal differential between the hot zone and the cold zone; and a chamber for enclosing the heat exchanger and the thermoelectric element, wherein the chamber comprises a physical adaptation for withstanding external pressure that exceeds 1 atmosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** depicts a schematic diagram of details of a prior-art dry steam geothermal energy conversion system.

[0017] FIG. **2** depicts a schematic diagram of details of a binary-cycle geothermal energy conversion system.

[0018] FIG. **3** depicts a schematic diagram of a portion of a representative OTEC power generation system in accordance with the prior art.

[0019] FIG. **4** depicts a schematic diagram of details of an energy conversion system in accordance with an illustrative embodiment of the present invention.

[0020] FIG. **5** depicts a method for generating electrical energy in accordance with the illustrative embodiment of the present invention.

[0021] FIG. **6** depicts calculated efficiencies of energy conversion cycles versus temperature differential for an energy conversion system in accordance with the present invention.

[0022] FIG. **7** depicts a schematic diagram of details of an energy conversion system in accordance with a first alternative embodiment of the present invention.

[0023] FIG. **8** depicts a schematic diagram of details of an energy conversion system in accordance with a second alternative embodiment of the present invention.

DETAILED DESCRIPTION

[0024] FIG. **1** depicts a schematic diagram of details of a prior-art dry steam geothermal energy conversion system. Energy system **100** comprises inlet conduit **106**, turbine **108**, generator **110**, condenser **112**, conduits **114** and **116**, cooling tower **118**, and outflow conduit **122**. Turbine **108** and generator **110** collectively define a turbogenerator. In cases, a water pump is coupled to the outflow of condenser **112** to drive the return water to greater depths or to facilitate flow in a very long or narrow outflow conduit **122**.

[0025] Inlet conduit **106** is inserted through earth crust **102** into geothermal reservoir **104**. Inlet conduit **106** conveys steam from geothermal reservoir **104** to turbine **108**. Turbine **108** is operatively coupled to generator **110**.

[0026] The steam from geothermal reservoir **104** drive turbine **108**, which turns generator **110** to produce electrical energy. The generated electrical energy is conveyed to an end user or storage facility on output cable **120**.

[0027] Conduit **114** receives the steam that passes through turbine **108** and conveys it to condenser **112**. At condenser **112**, the steam is cooled by heat transfer fluid that circulates between cooling tower **118** and condenser **112** via conduit **116**. The heat transfer fluid acts as a heat sink for the steam, inducing the steam to condense into water in condenser **112**. Outlet conduit **122** conveys the condensate back to geothermal reservoir **104**. Cooling tower **118** removes the absorbed heat in the heat transfer fluid by vaporizing water into the surrounding atmosphere prior to circulating the heat transfer fluid back to condenser **112**.

[0028] FIG. **2** depicts a schematic diagram of details of a binary-cycle geothermal energy conversion system. Energy system **200** comprises inlet conduit **202**, heat exchanger **204**, closed-loop conduit **206**, turbine **108**, generator **110**, condenser **112**, conduit **208**, and cooling tower **118**.

[0029] In operation, inlet conduit **202** conveys hot water and/or steam from geothermal reservoir **104** to heat exchanger **204**. At heat exchanger **204**, the heat of the hot water/steam in inlet conduit **202** heats a working fluid contained within closed-loop conduit **206**. This working fluid evaporates into a pressurized vapor, which drives through turbine **108** to the condenser **112**. The flow of pressurized vapor through turbine **108** causes the turbine to turn generator **110**. In response, generator **110** generates electrical energy, which is conveyed to an end user on output cable **120**.

[0030] After passing through the turbine, the depressurized vapor enters condenser **112**. At condenser **112**, the vapor is thermally coupled with cold water that flows through conduit **208**, which induces the vapor to condense back into a liquid working fluid. Conduit **208** conveys cold water to and from cooling tower **118**. Condensate pumps and filters are often included in the working fluid circuit to facilitate flow between condenser **112** and heat exchanger **204**.

[0031] FIG. **3** depicts a schematic diagram of a portion of a representative OTEC power generation system in accordance with the prior art. OTEC system **300** comprises platform **302**, surface water conduit **304**, deep water conduit **308**, turbogenerator **312**, closed-loop conduit **314**, heat exchanger **318**, pump **320**, and condenser **322**.

[0032] Platform **302** is a conventional floating energy-plant platform. Platform **302** is anchored to the ocean floor by mooring line **334**, which is connected to anchor **336**. Anchor **336** is embedded in the ocean floor. In some instances, platform **302** is not anchored to the ocean floor and platform **302** is allowed to drift. Such a system is sometimes referred to as a "grazing plant."

[0033] Surface water conduit **304** is a large-diameter conduit suitable for pumping water, by means of pump **328**, from surface region **332** into heat exchanger **318**.

[0034] Closed-loop conduit **314** is a closed-circuit loop of conduit that contains working fluid **316**. Ammonia is commonly used as such a working fluid; however, there are many other fluids that can be used as working fluid **314**.

[0035] Closed-loop conduit **314** and surface water conduit **304** are thermally coupled at heat exchanger **318**. As a result, working fluid **316** and surface water **306** are also thermally coupled at heat exchanger **318**. This enables the heat of surface water **306** to vaporize the working fluid **316**. The expanding vapor turns turbogenerator **312**, which generates electrical energy. The generated electrical energy is provided on output cable **120**.

[0036] After passing through turbogenerator **312**, the vaporized working fluid enters condenser **322**, which comprises heat exchanger **324**. At heat exchanger **324**, closed-loop conduit **314** and deep water conduit **308** are thermally coupled, which enables the thermal coupling of the vaporized working fluid **316** and cold water **310**. Cold water **310** is drawn from deep water region **330** by pump **326**. Typically, deep water region **330** is 1000+ meters below the surface of the body of water. Water at this depth is at a substantially constant temperature of a few degrees centigrade. After passing through heat exchanger **324**, cold water **310** is ejected into mid-level region **338** to avoid cooling the surface water near platform **302**.

[0037] Cold water **310** acts as a heat sink for vaporized working fluid **316** at heat exchanger **324**. As a result, the hot vaporized working fluid **316** is cooled by cold water **310** and condenses back into its liquid state. Once working fluid **316** is condensed, pump **320** recycles it back into heat exchanger **318** where it can be vaporized again to continue the cycle that drives turbogenerator **312**.

[0038] Conventional OTEC systems have several drawbacks. First, it is difficult and energy intensive to pump cold water up from depths of 1000+ meters. This challenge is further exacerbated by the fact that cold water is more dense than warm water, which increases the energy required to draw it up to the surface. This significantly increases the cost and reduces the benefits of using an OTEC approach for power generation.

[0039] Second, for an OTEC generation system capable of generating 10's to 100's of megawatts, deep water conduit **308** typically has a diameter within the range of 3-10 meters and a length greater than 1000 meters. Such a conduit is difficult and expensive to manufacture.

[0040] Third, the size and length of deep water conduits makes them susceptible to damage from environmental conditions, such as strong currents, storms, and wave action. As a result, complicated and expensive infrastructure is required to protect these conduits from damage. For example, numerous recent efforts have been made to improve the reliability of cold water conduits. These include the development of flexible conduits, inflatable conduits, rigid conduits made from steel, plastics, and composites, and gimbal-mounted conduits. Even with such proposed innovations, long cold water conduits remain a significant reliability and cost issue.

[0041] FIG. **4** depicts a schematic diagram of details of an energy conversion system in accordance with an illustrative embodiment of the present invention. Energy conversion system **400** comprises close-loop conduit **402**, optional pump **408**, energy conversion unit **410**, pressure hull **416**, and chimney **420**. One skilled in the art will recognize, after reading this specification, that the present invention is suitable for operation in any suitable body of water, including, without limitation, oceans, seas, lakes, straights, gulfs, and bays.

[0042] Energy conversion unit **410** is a solid-state thermoelectric energy conversion system. Energy conversion unit **410** comprises hot zone **412**, thermoelectric element **418**, and cold zone **414**, which is a portion of pressure hull **416**.

[0043] Hot zone **412** comprises a substantially thermally conductive plate that enables the transfer of heat from close-loop conduit **402** to surface **422** of thermoelectric element **418**.

[0044] Cold zone **414** is a portion of pressure hull **416** that is substantially thermally conductive. Cold zone **414** enables the thermal coupling of surface **424** of thermoelectric element **418** and cold water outside pressure hull **416**.

[0045] Thermoelectric element **418** is a solid-state device that generates an open-circuit voltage based on a temperature difference between surfaces **422** and **424**. In some embodiments, thermoelectric element **418** comprises a bismuth-telluride alloy. Commercial examples of thermoelectric element **418** include HZ modules available from Hi-Z Technology, Inc.

[0046] In some embodiments, thermoelectric element **418** is a solid-state element that generates electrical energy by means of the Peltier effect.

[0047] In some embodiments, energy conversion unit **410** comprises a classic Rankine-cycle engine instead of a solid-state thermoelectric element. In such embodiments, hot zone **412** and cold zone **414** are included in heat exchangers, such as heat exchangers **318** and **324** described above and with respect to FIG. **3**. As a result, in these embodiments, hot zone **412** and cold zone **414** enable vaporization and condensation, respectively, of a working fluid as part of a Rankine cycle.

[0048] FIG. **5** depicts a method for generating electrical energy in accordance with the illustrative embodiment of the present invention. Method **500** is described herein with continuing reference to FIG. **4**.

[0049] Method **500** begins with operation **501**, wherein working fluid **404** is circulated through closed-loop conduit **402**. Working fluid **404** is analogous to working fluid **316**, described above and with respect to FIG. **3**. In some embodiments, working fluid **404** is pumped through closed-loop conduit **402** by optional pump **408**. Closed-loop conduit **402** passes through bore hole **406** into geothermal reservoir **104**.

[0050] In some embodiments, pump **408** is not necessary since the temperature gradient between energy conversion unit **410** and geothermal reservoir **104** can inherently induce the flow of working fluid **404** through closed-loop conduit **402**. As working fluid **404** loses its heat at energy conversion unit **410**, it cools and naturally descends toward geothermal reservoir **104**. This creates a natural convective flow (clockwise, as depicted in FIG. **4**) around closed-loop conduit **402**.

[0051] At operation **502**, hot zone **412** is heated by virtue of thermally coupled working fluid **404**. Hot zone **412** and a portion of closed-loop conduit **402** collectively define heat exchanger **426**. Heat exchanger **426** thermally couples geothermal reservoir **104** and surface **422** of thermoelectric element **418**.

[0052] At operation **503**, cold zone **414** is cooled by cold water in deep water region **330**. Cold zone **414** is cooled by virtue of heat exchanger **428**, which comprises a portion of pressure hull **416** and is, therefore, in direct contact with the deep-level water. Heat exchanger **428** thermally couples surface **424** of thermoelectric element **418** with the deep-level water. Although in the illustrative embodiment cold zone **412** is a portion of pressure hull **416**, it will be clear to one skilled in the art, after reading this specification, how to make and use alternative embodiments wherein cold zone **412** is a separate component from pressure hull **416**. In some embodiments, one or more bore-hole fittings are used to couple closed-loop conduit **402** to a permanent conduit that resides within bore hole **406**. In such embodiments, therefore, a substantial portion of energy conversion system **400** is detachable and removable.

[0053] Pressure hull **416** is a shell of structural material with sufficient strength to withstand the pressures that exist at deep water levels. The specific design of pressure hull **416** is based upon the intended application and deployment depth. For example, a pressure hull intended to be deployed at a depth of 1000 meters must be able to withstand water pressure that exceeds 100 atmospheres. In addition, pressure hull **416** comprises an electrical feed-through to enable generated electrical energy to be conveyed on cable **120**.

[0054] In some embodiments, pressure hull **416** is a vessel that is filled with an incompressible, electrically non-conductive fluid. As a result, the need for the walls of pressure hull **416** to withstand externally applied high pressure is mitigated.

[0055] In some embodiments, energy conversion system **400** is suitable for deployment in environments wherein the water in surface region **332** has a substantially constant temperature of a few degrees centigrade, such as arctic regions. In such embodiments, the need for pressure hull **416** to withstand high external pressures is mitigated and pressure hull **416** can be replaced by a less robust, substantially water-tight chamber.

[0056] It is an aspect of the present invention that the water at a deep level of an ocean or similar body of water provides a heat sink with sufficient heat capacity to enable it to maintain a substantially constant temperature at all times. It is well-known that ocean temperatures drop with depth. For example, tropical and semi-tropical ocean temperatures at depths of 400, 500, and 1000 meters remain substantially constant at 12, 8, and 4° C., respectively. Deep water levels, therefore, have a heat-sink capability that is well-suited to the present invention.

[0057] At operation **504**, thermoelectric element **418** generates electrical energy based on the temperature difference between hot zone **412** and cold zone **414**.

[0058] FIG. **6** depicts calculated efficiencies of energy conversion cycles versus temperature differential for an energy conversion system in accordance with the present invention. Plot **600** depicts the percentage of the Carnot cycle conversion efficiency for a range of temperature differentials that are based on water depths and geothermal heat source temperatures. As one skilled in the art will recognize, the Carnot cycle represents the most efficient cycle possible for converting a given amount of thermal energy into work.

[0059] Conversion cycle **602** depicts the efficiency for a thermoelectric energy conversion system based on the temperature differential between surface water (i.e., 1 m deep having a temperature of approximately 28° C.) and a relatively cool geothermal source (having a temperature of 100° C.). Although the systems in accordance with the present invention are operable for smaller temperature differentials, the temperature differential for conversion cycle **602** represents the smallest reasonable temperature cycle commonly available using a geothermal heat source. The energy conversion efficiency of conversion cycle **602** is a modest 19% of the Carnot cycle.

[0060] Conversion cycle **604**, on the other hand, represents the largest temperature cycle commonly available using a geothermal heat source. Conversion cycle **604** is based on the temperature difference between water at 1000 m depth (having a temperature of approximately 4° C.) and a hot geothermal source (having a temperature of approximately 200° C.), the energy conversion efficiency is approximately 41% of the Carnot cycle. Conversion cycle **604**, therefore, is characterized by a conversion efficiency that is 22% greater than that of conversion cycle **602**. This represents an efficiency improvement of more than 100%.

[0061] At operation **505**, the generated electrical energy is conveyed to the end-user via cable **120**. In some embodiments, cable **120** terminates at a land-based installation. In some embodiments, cable **120** terminates at an open ocean vessel, such as an anchored barge, ship, spar platform, oil rig, dedicated power production platform, and the like. An open ocean vessel could be moored to nearby sea mounts, pinnacles, or the ocean floor.

[0062] At optional operation **506**, the convective flow of cold water across cold zone **414** is constrained by chimney **420**, thereby increasing the heat flow through the heat exchanger and seawater. The length of the chimney **420** is a matter of design choice, but is based on the temperature difference between the convecting seawater as it passes by cold zone **414** and the depth of the average thermocline at that temperature. The heat sink included in cold zone **414** would be designed to exhibit less head loss than the pressure difference (inside and outside) at the bottom of the chimney **420**, minus the fluid drag up the chimney **420**. In some embodiments, chimney **420** is not used since the rate at which the convective flow of cold water flows across cold zone **414** is sufficient to ensure that the ambient temperature of the water in the local area of cold zone **414** does not substantially increase during operation of energy system **400**.

[0063] FIG. **7** depicts a schematic diagram of details of an energy conversion system in accordance with a first alternative embodiment of the present invention. Energy conversion system **700** comprises close-loop conduit **402**, optional pump **408**, energy conversion unit **410**, pressure hull **416**, chimney **420**, and rod **702**.

[0064] Rod **702** is a crust-penetrating rod suitable for insertion into the hot material of geothermal reservoir **104**. Rod **702** comprises structural material that is substantially thermally conductive. As a result, rod **702** conducts heat from geothermal reservoir **104** into heat exchanger **704**, which comprises rod **702** and hot zone **412**.

[0065] At heat exchanger **704**, heat from geothermal reservoir **104** is absorbed by hot zone **412**. Operation of system **700** is analogous to the operation of system **400**, described above and with respect to FIGS. **4** and **5**.

[0066] FIG. **8** depicts a schematic diagram of details of an energy conversion system in accordance with a second alternative embodiment of the present invention. Energy conversion system **800** comprises close-loop conduit **402**, optional pump **408**, energy conversion unit **410**, pressure hull **416**, chimney **420**, and conduit **802**.

[0067] Conduit **802** receives water of hydrothermal vent **804**. This water has been heated by the hot material of geothermal reservoir **104**. As a result, conduit **802** conducts heat from geothermal reservoir **104** into heat exchanger **806**, which comprises a portion of conduit **802** and hot zone **412**.

[0068] At heat exchanger **806**, therefore, heat from water of hydrothermal vent **804** is absorbed by hot zone **412**. After the water of ocean thermal vent **804** exits heat exchanger **806**, conduit **802** exhausts it to a region of the body of water that is sufficiently displaced from cold zone **404** to avoid heating the water outside of pressure hull **416**.

[0069] Operation of system **800** is analogous to the operation of system **400**, described above and with respect to FIGS. **4** and **5**.

[0070] It is to be understood that the disclosure teaches just one example of the illustrative embodiment and that many variations of the invention can easily be devised by those skilled in the art after reading this disclosure and that the scope of the present invention is to be determined by the following claims.

What is claimed is:

1. An apparatus for generating electrical energy comprising:

an energy conversion unit, wherein the energy conversion unit comprises;
  a hot zone that is thermally coupled to a subterranean geothermal heat source; and
  a cold zone comprising a first physical adaptation for thermally coupling with a region of a body of water;
a thermoelectric element, wherein the thermoelectric element generates electrical energy based on a thermal differential between the hot zone and the cold zone; and
a chamber, wherein the chamber encloses the energy conversion unit and the thermoelectric element, and wherein the chamber comprises a second physical adaptation for withstanding external pressure that exceeds **1** atmosphere.

2. The apparatus of claim **1** further comprising a closed-loop fluid system for thermally conduit the hot zone to the geothermal heat source.

3. The apparatus of claim **2** further comprising a pump for inducing circulation of a fluid through the closed-loop fluid system.

4. The apparatus of claim **1** wherein the body of water is an ocean.

5. The apparatus of claim **1** further comprising a conduit, wherein the conduit enables the thermally coupling of the hot zone and a hydrothermal vent from the geothermal heat source.

6. The apparatus of claim **1** further comprising a rod, wherein the rod is thermally coupled with the geothermal heat source, and wherein the rod thermally couples the geothermal heat source and the hot zone.

7. The apparatus of claim **1** wherein the region of the body of water has a temperature that is substantially constant, and further wherein the temperature differential between the region and the geothermal heat source is at least 70° C.

8. The apparatus of claim **7** further comprising a conduit for conveying water heated by the energy conversion unit away from the cold zone.

9. The apparatus of claim **1** wherein the thermoelectric element comprises a Rankine-cycle engine.

10. The apparatus of claim **1** wherein the thermoelectric element comprises a solid-state thermoelectric element.

11. The apparatus of claim **10** wherein the thermoelectric element generates electrical energy by means of the Peltier effect.

12. The apparatus of claim **10** wherein the thermoelectric element comprises a quantum-well thermoelectric element.

13. The apparatus of claim **1** wherein the physical adaptation comprises a pressure hull.

14. A method for generating electrical energy comprising:

thermally coupling a hot zone of an energy conversion unit to a subterranean geothermal heat source;
thermally coupling a cold zone of the energy conversion unit to a region of a body of water; and
generating electrical energy based on the temperature differential between the hot zone and the cold zone.

15. The method of claim **14** further comprising enabling the flow of a fluid through a closed-loop conduit, wherein the fluid and the geothermal heat source are thermally coupled, and wherein the fluid and the hot zone are thermally coupled, and wherein the fluid thermally couples the hot zone and the subterranean geothermal heat source.

16. The method of claim **14** wherein the cold zone and the region of the body of water are thermally coupled by exposing the cold zone to direct contact with water of the region.

17. The method of claim **16** further comprising:

sinking heat from the cold zone into a first volume of the water; and
constraining the flow of the first volume through the region to a conduit, wherein the conduit enhances the motion of the first volume away from the cold zone.

18. The method of claim **14** further comprising enabling the flow of a fluid from the subterranean geothermal heat source to the hot zone.

19. The method of claim **18** further comprising pumping the fluid from the subterranean geothermal heat source to the hot zone.

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