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(54) **Titre : SYSTEME DE STOCKAGE ET DE RECUPERATION D'ENERGIE THERMIQUE**
(54) **Title: THERMAL ENERGY STORAGE AND RETRIEVAL SYSTEM**

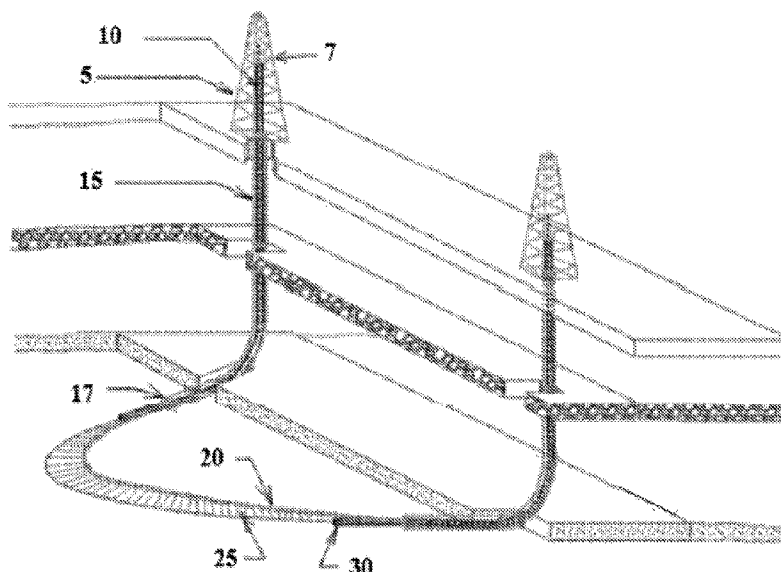


FIG. 1

(57) **Abrégé/Abstract:**

A system and method to store and retrieve energy includes a heat source or an energy consumer thermally connected to a fluid. The fluid is transported through a first well fluidically connected to a second well. A slot is sawed into a rock below the earth's surface and a cable and tubing connect the first well to the second well. The cable and the tubing are partially encapsulated by casing, wherein the cable stores heat. A plurality of materials is filled into the slot. A first hole is disposed beneath a first rig and surrounds the first well. A second hole is disposed beneath a second rig and surrounds the second well. The first hole and the second hole are configured to be vertical or slanted.



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(54) Title: THERMAL ENERGY STORAGE AND RETRIEVAL SYSTEM

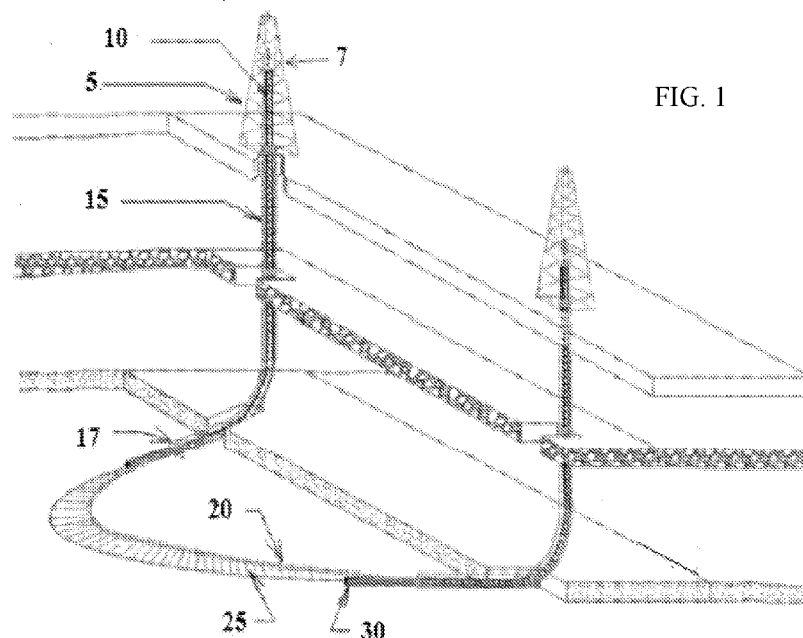


FIG. 1

(57) Abstract: A system and method to store and retrieve energy includes a heat source or an energy consumer thermally connected to a fluid. The fluid is transported through a first well fluidically connected to a second well. A slot is sawed into a rock below the earth's surface and a cable and tubing connect the first well to the second well. The cable and the tubing are partially encapsulated by casing, wherein the cable stores heat. A plurality of materials is filled into the slot. A first hole is disposed beneath a first rig and surrounds the first well. A second hole is disposed beneath a second rig and surrounds the second well. The first hole and the second hole are configured to be vertical or slanted.

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Thermal Energy Storage and Retrieval System**Technical Field**

[0001] The Systems and methods which store and retrieve heat in the subsurface or above surface region using fracked and non-fracked systems on a daily cycle or seasonal cycle are needed.

Background of the Invention

[0002] While there are heat storage systems, the heat storage systems do not use slot or fracked rock below the surface to store the heat. Instead, heat storage in the containers above the surface of the earth or in an aquifer is below the surface and within a single well. Also, surface level ponds are used to store heat on a seasonal basis. This makes heat compression recapture from compressed air storage systems and heat storage from solar, nuclear, biofuel, wind-generated heat, and waste heat sources inefficient or impractical.

Brief Summary of Embodiments of the Invention

[0003] In a variant, a system for storing and retrieving subsurface is provided. The system includes: a heat source or an energy consumer thermally connected to a first fluid, a slot sawed into a rock and then expanded (or not) by whatever means (e.g. Pressure), a cable and tubing operatively connected to the first well to the second well, a plurality of materials filled into the slot, a first hole disposed beneath a first rig, and a second hole disposed beneath a second rig. The first fluid is transported through a first well fluidically connected to a second well. The slot is below an earth surface. The cable and the tubing are partially encapsulated by casing, wherein the cable stores heat. The plurality of materials is in a liquid state or gas state. The first hole surrounding the first well and the second hole surrounding the second well are configured to be vertical or slanted.

[0004] In another variant, the tubing is operatively connected to the cable such that a first end of the tubing is clamped to a first end of the cable within the first rig and the second end of the tubing is clamped to a second end of the cable within the second rig.

[0005] In yet another variant, the plurality of materials is selected from the group consisting of steel balls, scrap steel, gravel, alumina, bauxite, water, air, and ropes for heat storage.

[0006] In a further variant, the slot is disposed in a vertical direction, a horizontal direction, or an inclined direction.

[0007] In yet a further variant, the first well and the second well are of a circular shape, a rectangular shape, an ellipsoidal shape, or a square shape.

[0008] In yet another variant, the heat source may be solar energy, nuclear energy, geothermal energy, electrical, organic wastes, heat of compression, and converted wind turbine energy.

[0009] In yet another variant, the fluid is in a gas phase, liquid phase, supercritical phase, or dual phase.

[0010] In yet another variant, the first fluid is transported through the slot, the heat source, and the energy consumer in a single closed-loop system, a binary closed-loop system, or an open loop system.

[0011] In yet another variant, the binary closed-loop system includes a second fluid and a heat exchanger. The heat exchanger is fluidically connected to the first fluid, the second fluid, and the slot.

[0012] In yet another variant, the single-loop system includes the first fluid transported from the heat source to the slot in a heated state and subsequently transported from the slot to the heat source in a cooled state.

[0013] In yet another variant, the single-loop system includes the first fluid transported from the energy consumer to the slot in a cooled state and subsequently transported from the slot to the energy consumer in a heated state.

[0014] In a variant, a system for storing and retrieving sub-surface energy is provided. The system includes: a fractured body of rock, a thermal fluid circulated through the fractured body of rock via tubing, a rock mass below the earth surface, a first well disposed within a first hole, and a second well disposed within a second hole. The fractured body of rock resides below an earth surface and the rock mass is a continuation of the fractured body of rock. The first hole is operatively connected to the fractured body of rock and the second hole is operatively connected to the fractured body of rock. The first well contains at least a first segment, a second segment, and a third segment. The second well contains at least a fourth segment and a fifth segment. The first segment, the second segment, the third segment, the fourth segment, and the fifth segment include perforations fitted with valves. The first hole and the second hole are configured to be vertical or slanted.

[0015] In yet another variant, the first well and the second well include the valves and a cement layer connected to a first tubing layer. The first tubing layer is connected to a first hollow layer. The first hollow layer is connected to a second tubing layer. The second tubing layer is connected to the second hollow layer. The valves span across the cement layer, the first tubing layer, the first hollow layer, and the second tubing layer.

[0016] In a further variant, the second segment and the third segment include at least one angled fin, at least one outer flange, a thin bearing, and a disc bearing.

[0017] In yet a further variant, the first segment and the fourth segment include at least one flange and a cement layer.

[0018] In yet another variant, the tubing is connected to (i) electrical motors for causing rotation, (ii) a thin bearing, and (iii) a disc bearing.

[0019] In yet another variant, the perforations on the outer tubing are covered with sieves to prevent sand from entering between the cylinders. The sieves are disposed on inner or outer faces or both the inner and outer faces of an outer cylinder.

[0020] In yet another variant, the thermal fluid flows from any combination of the first, second, third, fourth, and fifth segments such that the thermal fluid is hot when released by the first well and the thermal fluid is cold when received by any combination of segments in the second well.

[0021] In yet another variant, the thermal fluid flows from the second segment to the third segment such that the thermal fluid is hot when received by the first well and the thermal fluid is cold when released by the second well. A bottom level of the second well is higher than a bottom level of the first well, or the bottom level of the second well is identical level to the bottom level of the first well or the bottom level of the second well is lower than the bottom level of the first well.

[0022] In yet another variant, the thermal fluid flows from the second segment to the third segment such that the thermal fluid is hot when released by the first well and the thermal fluid is cold when received by the second well. A bottom level of the second well is higher than a bottom level of the first well, or the bottom level of the second well is identical level to the bottom level of the first well or the bottom level of the second well is lower than the bottom level of the first well.

[0023] In a variant, a system for storing and retrieving energy comprises: a first well comprising a first valve and a first set of segments, wherein the set of segments comprises a first set of perforations; a second well comprising a second valve and a second set of segments, wherein the second set of segments comprises a second set of perforations; a thermal fluid configured for transport between the first well and the second well, wherein a segment of the first set of segments of the first well and a segment of the second set of segments of the second well are disposed on an earth surface or below the earth surface, thereby remaining segments of the first set of segments of the first well and the second set of segments of the second well are disposed above ground; piping operatively connected to the first well and the second well, wherein the piping is disposed above the earth surface; wherein the first valve and the second valve are configured for movement, thereby controlling alignment states of the first set of perforations and the second set of perforations, thereby controlling flow properties of the thermal fluid; wherein the thermal fluid is transported bi-directionally within the piping between at least one of the remaining segments of the first set of segments of the first well and at least one of the remaining segments of the second set of segments of the second well.

[0024] In a variant, a system for storing and retrieving energy and fluid, comprises: a duct operatively connected to a first cylinder with insulation around the duct or phase change material, wherein the first cylinder is operatively connected to a first layer of insulation or phase change material, wherein the first layer of insulation is operatively connected to the second layer of insulation or phase change material; a first cylinder outlet/inlet gap and at least a second outlet/inlet gap operatively connected between a selected annulus, say between the first and second cylinder, wherein the gap between the first cylinder and the second cylinder comprise an annulus; wherein one or both of the outlet/inlet gaps are configured for intake or exit or both intake and exit in a one-gap-flow system of fluid; a double plate or single plate disposed with the system such that the system comprises an upper section and a lower section, wherein the double plate comprises perforations, wherein the perforations are configured for controlling fluid flow through control valves, wherein the control valves comprises a check valves; wherein the lower section comprises at least a third cylinder, a fourth cylinder, a first segment of the fifth cylinder; wherein the lower section comprises the first cylinder, the second cylinder, a second segment of the fifth cylinder, and the plurality of heat storage materials, placed across the entire cross-section or in an inner cylinder, or the annuluses of various combinations of cylinders.

[0025] In this variant, the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0026] In this variant, the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.

[0027] In this variant, system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.

[0028] In this variant, the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprising a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0029] In this variant, the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0030] In this variant, the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.

[0031] In this variant, the phase change material may be in part or whole of the inner cylinder or be in part or whole of selected annuluses or any combination of both.

[0032] In this variant, system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.

[0033] In this variant, the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides

opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

[0034] In this variant, the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.

[0035] In a variant, a system for storing and retrieving energy and fluid comprises: a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder wherein the first cylinder is operatively connected to a plurality of heat storage materials, wherein the plurality of heat storage materials is operatively connected to a plurality of insulator materials; a first cylinder outlet/inlet gap and/or selected annuluses with outlet/inlet gaps; a double plate or single plate disposed with the system such that the system comprises an upper section and a lower section, wherein the double plate comprises perforations, which are used for fluid flow through control valves, wherein the control valves comprises check valves; wherein the lower section comprises a third cylinder, a fourth cylinder or even more, a first segment of the fifth cylinder; and wherein the upper section comprises the first cylinder, the second cylinder, a second segment of the fifth cylinder, and the plurality of heat storage materials and concentric layers of insulators and phase change materials.

[0036] In this variant, the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0037] In this variant, the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.

[0038] In this variant, the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.

[0039] In this variant, the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprising a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0040] In this variant, the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0041] In this variant, the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.

[0042] In this variant, the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.

[0043] In this variant, the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material may be in part or whole of the inner cylinder or be in part or whole of selected annuluses or any combination of both.

[0044] In this variant, the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

[0045] In this variant, the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.

[0046] In this variant, the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0047] In this variant, the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0048] In this variant, the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.

[0049] In this variant, the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.

[0050] In this variant, the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0051] In this variant, the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0052] In this variant, the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.

[0053] In this variant, the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.

[0054] In this variant, the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change

materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

[0055] In this variant, the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.

[0056] In this variant, the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0057] In a variant, a one end flow system for storing and retrieving energy, comprises: a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder; a lower section of the inner cylinder is perforated, allowing thermal fluid to flow through to the lowest layered heat storage material, wherein the thermal fluid moves through the other heat storage material giving up heat in a forward flow and recaptures heat in a reverse flow; wherein a first cylinder outlet/inlet gap and at least one annulus with a second outlet/inlet gap operatively connected between, say the first and second cylinder, wherein the first cylinder outlet/inlet gap and the second outlet/inlet gap comprise the annulus; wherein the inlet/outlet gaps are optionally configured for intake or exit of thermal fluid; wherein the first cylinder is operatively connected to a plurality of heat storage materials that are cross-sectional layered with a hollow of the first cylinder forming a free flow duct, wherein the plurality of cross-sectional heat storage materials is operatively connected to a plurality of concentric insulator materials and/or phase change material, around the layered heat storage material; wherein the center cylinder is optionally a sole duct filled with the plurality of heat storage materials in a layered configured such that the center cylinder is concentrically surrounded by one or more of other cylinders;

wherein the annulus is configured in one of the ways: (i) to carry insulations or phase change materials or both and in which case, beyond these concentric layers of insulation/phase change materials a gap exists for the fluid to freely flow in or out of the system from yet another annulus, (ii) as layered material surrounded by concentric insulators and/or phase change materials, or (iii) be populated with layered heat storage materials with a free flow annular gap; wherein the heat storage material is configured to optionally occupy the entire cross-section or part of the cross-section of the annulus, optionally occupy parts of the length of the system across the cross-section or one or more sections of heat storage material separated by gaps.

[0058] In this variant, sections are disposed within cross-sectional gaps.

[0059] In this variant, the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0060] In this variant, the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.

[0061] In this variant, the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.

[0062] In this variant, the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0063] In this variant, the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0064] In this variant, the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.

[0065] In this variant, the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.

[0066] In this variant, the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

[0067] In this variant, the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.

[0068] In this variant, the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0069] In a variant, a two-end flow system for storing and retrieving energy comprises: a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder or possibly more, wherein the first cylinder is operatively connected to a plurality of heat storage materials that are cross-sectional layered within it; a plurality of gaps, wherein the plurality of gaps comprises a first cylinder outlet/inlet gap at one end and an inlet/outlet gap at the other end or inlet/output gaps from somewhere along the longitudinal side of the cylinder; wherein the plurality of heat storage materials is operatively connected to a plurality of insulator materials, concentrically around the layered heat storage material; wherein the heat storage material is configured to occupy the entire cross-section or part of the cross-section of the inner cylinder or parts of the length of the system across the cross-section, whereby multiple sections are disposed within cross-sectional gaps; wherein the entire length of the two-end system comprises at least a third cylinder and a fourth cylinder; wherein the concentric ducts between cylinders are filled either with insulators or phase change materials or both insulator or phase change materials; wherein the first cylinder outlet/inlet gap is disposed at both ends; wherein the inlet/outlet gaps may be operative for intake or exit; fluid is configured to move through the heat storage material to give up heat and flow in a reverse direction to recaptures the heat.

[0070] In this variant, the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.

[0071] In this variant, the system is used in large-scale or small-scale operations below the ground, whereby an earth surface is configured as an outer cylinder.

[0072] In this variant, the system is used in large-scale or small-scale operations as a single unit large scale heat storage capsule comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0073] In this variant, the system is used in large-scale or small-scale operations as a retro-fit as a single unit large scale heat storage capsule comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

[0074] In a variant, a system for separating heat from fluid and store heat and fluid in a fluid network with interconnected nodes comprises: a symbiotic system, plurality of conduits; a heat storage system in each conduit; wherein the fluid is hot, which enters and exits through individual nodes meters or kilometers apart wherein each conduit of the plurality of conduits is configured for: fluid flow through the heat storage system, connect to other conduits to deliver more fluid flow and thermal energy to a particular node by opening a combination of valves; wherein the fluid flow is configured to be thermal, thereby giving up heat when transported to a storage unit or residing in extended conduits beyond the heat storage unit; wherein the flow from each node can superimpose on that of others in case of emergency to provide more energy to one or more selected nodes.

[0075] In a variant, the system resides completely below ground, partially above the ground, or completely above ground.

[0076] Other features and aspects of the invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the features in accordance with embodiments of the invention. The summary is not intended to limit the scope of the invention, which is defined solely by the claims attached hereto.

Brief Description of the Drawings

[0077] The present invention, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The drawings are provided for purposes of illustration only and merely depict typical or example embodiments of the invention. These drawings are provided to facilitate the reader's understanding of the invention and shall not be considered limiting of the breadth, scope, or applicability of the invention. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

[0078] Some of the figures included herein illustrate various embodiments of the invention from different viewing angles. Although the accompanying descriptive text may refer to such views as "top," "bottom" or "side" views, such references are merely descriptive and do not imply or require that the invention be implemented or used in a particular spatial orientation unless explicitly stated otherwise.

[0079] Fig. 1 is a depiction of an energy storage and retrieval environment where the slot is horizontal and filled with thermal material for heat storage and retrieval.

[0080] Fig. 2 is a depiction of an energy storage and retrieval environment where the slot is vertical and filled with thermal material for heat storage and retrieval.

[0081] Fig. 3 is a depiction of an energy storage and retrieval environment where the slot is U-shaped.

[0082] Fig. 4A and Fig. 4B are depictions of the flow of thermal fluid in an energy storage and retrieval environment.

[0083] Fig. 5 and Fig. 6 are depictions of a binary loop where there is slot filled with thermal material for heat storage and retrieval.

[0084] Fig. 7 and Fig. 8 are depictions of a single loop where there is a slot with thermal material for heat storage and retrieval.

[0085] Fig. 9, Fig. 10, Fig. 11, and Fig. 12 are depictions of a rock reservoir where there is fractured rock used for heat storage and retrieval.

[0086] Fig. 13 is a depiction of the vertical well for controlling flow through different segments (segmented flow). For non-segmented flow the wells are not perforated (not shown).

[0087] Fig. 14 is a depiction a cross-section of the vertical well for segmented flow.

[0088] Fig. 15 is another depiction of the rock reservoir containing fractured rock.

[0089] Fig. 16 and 17 are depictions of a binary loop containing fractured rock.

[0090] Fig. 18, Fig. 19, Fig. 20, Fig. 21, Fig. 22, and Fig. 23 are depictions of segments in the vertical wells.

[0091] Fig. 24 is a depiction of a flow-controlled bi-cylindrical (FCB) valve.

[0092] Fig. 25, Fig. 26, and Fig. 27 are depictions of cross sections of the FCB valve.

[0093] Fig. 28A, Fig. 28B, Fig. 29A, Fig. 29B, Fig. 30A, Fig 30B, and Fig. 31 are depictions of a non-binary arrangement of wells in fractured rock environments.

[0094] Fig. 32A, Fig. 32B, Fig. 32C, Fig 32D, Fig. 33A, Fig. 33B, Fig. 34A, Fig. 34B, Fig. 35A, Fig. 35B, Fig. 36A, Fig. 36B, Fig. 37A, Fig. 37B, Fig. 38A, Fig. 38B, Fig. 39A, and Fig. 39B are depictions of variants for charging (i.e., storing) and discharging (i.e., retrieving) energy in an adiabatic encapsuled CAES system.

[0095] Fig. 40 is a depiction of a symbiotic distributed compressed air energy storage system.

Detailed Description of the Embodiments of the Invention

[0096] The systems and methods herein use slot drilling or rock fracturing at the subsurface level. During slot drilling, a slot is abrasively sawed into a rock (which can be expanded, for example, by pressurizations) and using a rope studded with: (i) industrial diamonds or (ii) other hard abrasive material within a Non-Fracking Thermal Energy Storage and Retrieval (NF-TESR) system. The rope itself may be made with the abrasive material. The

slot may have a thickness of a fraction of an inch to a few inches, but may be larger. Once a slot is sawed, the slot may be expanded by other mechanical techniques. The slot may be formed by the sectors of two concentric circles or in such a way that the center portion is wide and then tapers off to the dimensions of the wells at the two ends. This is more like a flattened banana where the middle portion is thicker than the edges in both the horizontal and vertical planes. However, the slot may also be of uniform thickness throughout. The slot, which is filled with steel balls, scrap steel, gravel, or other materials (SFM), may be below the surface of the earth or oriented in a vertical, horizontal, or inclined position. A thermal fluid circulates through the slot to exchange thermal energy with the material that has filled the slot. Above the surface of the earth, this heat is removed from the fluid that is coming up from the subsurface region by a second fluid. The heat may be delivered to a consumer directly. During compression of air, a heat of compression from the Compressed Air Energy Storage (CAES) system is stored. Sub-Surface Thermal Energy Storage/Retrieval System (SS-ThEnStoR) of the systems and methods herein (not CAES) uses the fractured rock at the subsurface level (below the earth's surface) to store or retrieve the heat of compression within the subsurface reservoir environment. The heat may also derive from other sources, such as solar, chemical, or electrical sources.

[0097] The systems and methods involve, but are not limited to, the following enumerated aspects [1] - [14].

[0098] Aspect [1]: In the case of non-segmented flow, there are two or more vertical or slanted wells (holes) used to introduce and retrieve heat to the subsurface region via thermal fluid.

[0099] Aspect [2]: Tubes (circular, ellipsoidal, rectangular, or any cross-sectional shape) are inserted into the vertical or slanted wells.

[0100] Aspect [3]: The tubes in aspect [2] can be of insulated material or heat storage material. The cement can be of either material, as described above or below.

[0101] Aspect [4]: A slot or fracked rock is in between the vertical or slanted wells.

[0102] Aspect [5]: The slot may be horizontal or slanted.

[0103] Aspect [6]: The slot may be filled with material for absorbing and storing heat. The one or more of the wells may also be partially or fully filled with this material.

[0104] Aspect [7]: Thermal fluid (liquid or gas) may flow through the slot or fracked rock to deposit heat and remove heat from the fracked rock or slot.

[0105] Aspect [8]: In the case of segmented flow, the two or more vertical or slanted wells (holes) may be used to introduce and retrieve heat from the subsurface region via thermal fluid may be perforated.

[0106] Aspect [9]: For the non-segmented flow, tubes (circular, ellipsoidal, rectangular, or any cross-sectional shape) are inserted into the wells and cemented to the surrounded earth, wherein the wells are not perforated.

[0107] Aspect [10]: For the segmented flow, the two or more vertical or slanted wells (holes) are equipped with and an additional internal concentric well each.

[0108] Aspect [11]: The additional concentric tubes from aspect [4] are separated by the outer tube by thin bearings and rest at the bottom on disk bearings. One or more of these bearings may be used in cases of very low friction or none may be necessary.

[0109] Aspect [12]: From aspect [5], the internal tubes are fixed with fins such that water flow can rotate the fins to a particular angle, at which stoppers are disposed to stop the rotational motion.

[0110] Aspect [13]: From aspect [6], the rotational motion may also be achieved by an electrical motor attached to the inner tube. In this case, the fins are optional.

[0111] Aspect [14]: The lower ends of the entrance wells and the exit wells may be at the same vertical heights or at different vertical heights with respect to each other.

[0112] Referring to Fig. 1, slot drilling is performed to yield a thermal storage and retrieval environment with a horizontal slot. In this NF-TESR system, the horizontal slot is below the surface of the earth and has a thickness between a fraction of an inch to a few inches. Slot filled materials (SFM) are filled into the horizontal slot. The SFM is in a liquid phase, gas phase, or solid phase (e.g., cables made from selective materials, or various shapes of pebbles (spherical etc.)) for storing and retrieving heat. Some examples of the SFM include steel balls, scrap steel, gravel, alumina, bauxite, water, air, ropes for heat storage, or any other material used for heat storage. In Fig. 1, cable 20 is within the horizontal slot 25 (i.e., a single slot, shaded with lines). Cable 20 cuts the slot in this horizontally, thin formation. The horizontal cut increases the surface area through which thermal fluid circulates through the slot. The thermal fluid is in a gas phase, liquid phase, supercritical phase, or dual phase. In other embodiments, the slot may be vertical or inclined (not shown). In the NF-TESR system, wells A and B are vertically aligned but may be inclined to the vertical, which may be of a circular shape, rectangular shape, ellipsoidal shape, or a square shape. The dimensions of wells A and B may be adjusted to adjust the rate of flow (or transport) of the thermal fluid. Tubing 10 surrounding cable 20 is disposed within a first vertical hole and a second vertical hole extending through the sub-surface region of the earth and horizontal slot 25 in the sub-surface region of the earth. Part of tubing 10 surrounding cable 20 extends out of a first vertical hole at a first end at rig 5 and a second vertical hole at a second end at rig 5. Tubing 10 is clamped to the end of cable 20 by clamp 7 in rig 5. Tubing 10 may be tensioned and reciprocated by rig 5.

[0113] Well A and well B contain casing 15 (e.g., cement) surrounding tubing 10, wherein tubing 10 surrounds cable 20. Cable 20 is composed of an abrasive within tubing 10. Well A is disposed within the first vertical hole at the first end and well B is disposed within the second vertical hole at the second end. Well A disposed in the first vertical hole and well B disposed in the second vertical hole are operatively connected to each other by cable 20 in horizontal slot 25. End 17 terminates casing 15 into the horizontal slot at a first end and at a second end such that a portion of tubing 10 surrounding cable 20 in horizontal slot 25 is in direct contact with sub-surface rock (i.e., the contact zone). Within the NF-TESR system, movement 30 occurs where tubing 10 moves with cable 20 inside casing 15.

[0114] Referring to Fig. 2, slot drilling is performed to yield a thermal storage and retrieval environment with a vertical slot. In this NF-TESR system, the vertical slot is below the surface of the earth and has a thickness between a fraction of an inch to a few inches. Slot filled materials (SFM) are filled into the vertical

slot, wherein the SFM is in a liquid phase, gas phase, or solid phase (e.g., a cable) for storing and retrieving heat. Some examples of the SFM include steel balls, scrap steel, gravel, alumina, bauxite, water, air, ropes for heat storage, or any other material used for heat storage. In Fig. 2, cable 22 is within the vertical slot. Cuts 27 are disposed in cable 22 such that there are upward cuts in thin formation. The upward cuts increase the surface area through which thermal fluid circulates through the slot. The thermal fluid is in a gas phase, liquid phase, supercritical phase, or dual phase. In the NF-TESR system, wells A and B are vertically aligned, which can be of a circular shape, rectangular shape, ellipsoidal shape, or a square shape. The dimensions of wells A and B can be adjusted to adjust the rate of flow (or transport) of the thermal fluid. Tubing 10 surrounding cable 20 is disposed within a first vertical hole and a second vertical hole extending through the sub-surface region of the earth and the vertical slot in the sub-surface region of the earth. Part of tubing 10 surrounding cable 20 extends out of a first vertical hole at a first end at rig 5 and a second vertical hole at a second end at rig 5. Tubing 10 is clamped to the end of cable 22 by clamp 7 in rig 5. Tubing 10 may be tensioned and reciprocated by rig 5.

[0115] Well A and well B contain casing 15 (e.g., cement) surrounding tubing 10, wherein tubing 10 surrounds cable 22. Cable 22 is composed of an abrasive within tubing 10, whereby cable 22 does not move relative to reciprocating tubing 10. Well A is disposed within the first vertical hole at the first end and well B is disposed within the second vertical hole at the second end. Well A in the first vertical hole and well B in the second vertical hole are operatively connected to each other by cable 22 in the vertical slot. End 19 terminates casing 15 into the vertical slot at a first end and at a second end such that a portion of tubing 10 surrounding cable 22 in the vertical slot is in direct contact with sub-surface rock (i.e., the contact zone). For example, cable 22 is cutting upward within the 140 degree contact zone.

[0116] Referring to Fig. 3, slot drilling is performed to yield a thermal storage and retrieval environment with a U-shaped slot. In this NF-TESR system, the U-shaped slot is below the surface of the earth and has a thickness between a fraction of an inch to a few inches. Slot filled materials (SFM) are filled into the vertical slot, wherein the SFM is in a liquid phase, gas phase, or solid phase (e.g., a cable) for storing and retrieving heat. Some examples of the SFM include steel balls, scrap steel, gravel, alumina, bauxite, water, air, ropes for heat storage, or any other material used for heat storage. If the U-shaped slot is not filled with SFM, the heat is stored in the surrounding rock 29. The thermal fluid is in a gas phase, liquid phase, supercritical phase, or dual phase. In the NF-TESR system, wells A and B are vertically aligned, which may be of a circular shape, rectangular shape, ellipsoidal shape, or a square shape. The dimensions of wells A and B may be adjusted to adjust the rate of flow (or transport) of the thermal fluid. Tubing 24 is disposed within a first vertical hole and a second vertical hole extending through the sub-surface region of the earth and the vertical slot in the sub-surface region of the earth. Tubing 24 extends out of a first vertical hole at a first end at rig 5 and a second vertical hole at a second end at rig 5.

[0117] Well A and well B contain casing (e.g., casing 15) surrounding tubing 24. Well A is disposed within the first vertical hole at the first end and well B is disposed within the second vertical hole at the second end. Well A in the first vertical hole (but may be inclined) and well B in the second vertical hole (but may be inclined) are operatively connected to each other by tubing 24 in the U-shaped slot. The casing terminates just before tubing 24 curves into the U-shaped slot at a first end and at a second end such that a portion of tubing 24 in the U-shaped slot is in direct contact with surrounding rock 29.

[0118] Referring to Fig. 4A and Fig. 4B, heat is: (i) collected from any source, such as solar energy, nuclear energy, geothermal energy, electrical, organic wastes, converted wind turbine energy, and other forms of energy; and (ii) then delivered into the ground and to the materials (e.g., SFM) in the slot or to the fracked rock. Also, heat is retrieved from the subsurface region (e.g., the slot containing cable 20 in Fig. 4A) and delivered to the surface region (e.g., the interface between rigs 5 and B and wells A and B). This is accomplished by the thermal fluid. The thermal fluid is siphoned to and from the subsurface region containing a slot through wells A and B. The thermal fluid flows over the SFM in the slot. The thermal fluid delivers the heat to the SFM, thereby increasing the surface area over which heat transfer takes place. When there is demand for the heat, the flow of the thermal fluid is reversed through the slot to recover the heat. Instances where NF-TESR system is used only for heat mining (just removing heat from the ground), the SFM gathers heat from the surrounding subsurface rock and delivers the heat to the thermal fluid, such the thermal fluid enters into the NF-TESR system in a cold state and leaves the NF-TESR system in a hot state. The thermal fluid also takes heat directly from the walls of the slot (as depicted by arrows). In these instances, the only heat source is the subsurface rock. Thereby, a single directional flow with no accompanying reverse flow is achieved.

[0119] Processes where the NF-TESR system is used for both heat storage and retrieval involves: (i) Flow 1, where the thermal fluid in a hot state from well A is transported through the slot and over the SFM and then exits from well B at the other end (see Fig. 4A); (ii) heat deposited to the SFM and the surrounding rocks through the slot walls; and (iii) Flow 2, where heat is retrieved with thermal fluid in the cold state entering through well B and leaving through well A (i.e., Flow 1 is reversed). In Fig. 4A, a 3-dimensional graph represents Flow 1 where: the thermal fluid in a hot state enters into the sub-surface earth via Well A, the thermal fluid flows through slot, and the thermal fluid in a cold state exits out of the sub-surface earth via Well B. Thermal fluid may flow through the slot in a binary closed loop system (two independent loops) or a single closed loop system.

[0120] Referring to Fig. 5, thermal fluid obtains the heat from the above ground heat source 35 (using fluid H in a hot state) in a two-loop system. In this variant of the NF-TESR system, the heat of fluid H is transferred to another fluid, resulting in fluid K in a hot state via heat exchanger 40. The heat from fluid K in a hot state is transported to slot 45 (i.e., the horizontal, vertical, and U-shaped slot as described above). The heat may remain in slot 45 such that fluid K is now in a cold state. Fluid K in a cold state is transported to heat exchanger 40, from which fluid H in a cold state is transported to heat source 35. Stated another way, both fluids K and H are in independent loops. More specifically, well A may be connected to well B through a pump as to force fluid K through the slot for the retrieval and storage of heat.

[0121] Referring to Fig. 6, heat is retrieved from slot 45, SFM, and surrounding bedrocks in a two-loop system. In this variant of NF-TESR system, fluid H in a cold state is transferred to another fluid, resulting in fluid K in a cold state via heat exchanger 40. Fluid K in a cold state is transported to slot 45 (i.e., the horizontal, vertical, and U-shaped slot above). The heat may exit slot 45 such that fluid K is now in a hot state. Fluid K in a hot state is transported to heat exchanger 40, from which fluid H in a hot state is transported to above ground heat source 35. Stated another way, both fluids K and H are in independent loops. More specifically, well A may be connected to well B through a pump as to force fluid K through the slot for the retrieval and storage of heat.

[0122] Referring to Fig. 7 and Fig. 8, a single-loop system circulates a single fluid within a NF-TESR system for operating a heat-loading phase and heat-unloading phase, respectively. In certain instances, a pump is

not required. For example, if supercritical carbon dioxide (CO₂) is used as the thermal fluid, supercritical CO₂ absorbs heat from the sub-surface slot 45 and rises by sheer buoyancy force to the surface level through well B. The heat of the supercritical CO₂ is released at the surface level as the supercritical CO₂ flows from well B to well A above the surface. The supercritical CO₂ becomes heavier, whereby gravity is enough to cause supercritical CO₂ to flow down well A. This cycle repeats. In the single-loop heat loading phase, thermal fluid in a hot state from above ground heat source 35 is transported to slot 45 and returns thermal fluid in a cold state to the above ground heat source 35. Heat from thermal fluid has been absorbed by slot 45. Thereby, the single-loop heat loading phase stores energy. In the single-loop heat unloading phase, thermal fluid in a cold state from above ground energy consumer 37 is transported to slot 45 and returns thermal fluid in a hot state to the above ground energy consumer 37. Heat from thermal fluid has been released from slot 45. Thereby, the single-loop heat unloading phase retrieves energy.

[0123] While Fig. 1 - Fig. 8 depict a NF-TESR system, Fig. 9 - Fig. 27 depict a Sub-Surface Thermal Energy Storage/Retrieval (SS-ThEnStoR) system.

[0124] Referring to Figs. 9-12, the fractured rock at the subsurface level (below the earth's surface) stores heat of compression from the Compressed Air Energy Storage (CAES) system or any other heat source. Fig. 9 depicts a semi-heat reservoir used in the SS-ThEnStoR, which is a cut through the center of the reservoir about the xz-plane that is symmetrical about the front face (xz-plane). Fig. 9 depicts a fractured body of rock represented as region C, which is a semi-cuboid. The outer region D, which is a semi-cuboid, is a continuation of the rock mass below the earth's surface. Region C, which is a semi-cuboid, has been frequently fracked. Thereby, region C has a much larger permeability than region D. While regions C and D are depicted as semi-cuboids in Fig. 9, regions C and D may be ellipsoids, cylinders, or any three-dimensional shape necessary for the dynamics of the system. Also, regions C and D can be a single body of rock of the same permeability or region C can have a larger or smaller permeability than region D. In Fig. 9, well A is at one end of the entrance of the vertical hole to the body of fractured rock below and well B is the other end. Well A and B may be of a circular shape, rectangular shape, ellipsoidal shape, or a square shape. The dimensions of wells A and B may be adjusted to control the rate of flow (or transport) of the thermal fluid. A thermal fluid circulates through the slot to exchange thermal energy with the material stores in it. The dimensions shown on the diagram of Fig. 9 provide a perspective of scalability. These dimensions can be as modified as necessary to store the amount of heat that needs to be stored. As per Fig. 9, the top of region D is 520 meters (m) below the surface of the earth but can be deeper because the type of rock needed might not be at that depth and the temperature of the earth at that depth might not be sufficient. The depth may also be smaller than this for the same reasons.

[0125] Fig. 10 and Fig. 15 depict the frontal view of the reservoir shown in Fig. 9. The vertical well A is depicted as having three segments - section J, K, and L, but there may be more. The vertical well B is depicted as having two segments - M and N, but there may be more. The uppermost segments for Wells A and B are segments J and M, which continue all the way to the earth's surface. The other three segments, K, L, and N are contained within the region C, which is semi-cuboid. The bottom of the wells A and B are closed off from the fractured rock. The bottom of well B is higher than well A. This difference may be adjusted to accommodate the dynamics of the system. The top view of the reservoir is shown in Fig. 11. The side view of the reservoir is shown in Fig. 12. Wells A and B are perforated with holes in sections J, K, L, M, and N. These holes may be of any diameter

necessary to accommodate the dynamics of the system. The number of these perforations is also determined by the system dynamics. These perforations are fitted with break valves. The type of break valves is chosen based on the dynamics of the system.

[0126] Referring to Fig. 13, wells A and B are depicted as circular for the sake of simplicity. As described above, wells A and B may be of any shape (round, square, etc.). In Fig. 13, sections K and L of well A are depicted in the upper-left diagram where there are two units of angled rectangular fin 50 attached to thin bearing 55. The outer flange 65 surrounds the walls of well A on the sides and is operatively connected to disc bearing 60. The walls of well A contain perforations 105. In Fig. 13, the upper right diagram is the top view of sections J and M of wells A and B. In Fig. 13, the middle right diagram is sections K and L of wells A and B. In Fig. 13, the lower right diagram is the cover section of sections K and L.

[0127] In the upper-right diagram of Fig. 13, cement 95 is depicted as a ring structure binding outer wellbore tubing material 75 (depicted as an outer cylinder) to the subsurface rock. The inner wellbore tubing material 80 (depicted as an inner cylinder) is bounded. The tubing materials 75 and 80 may be PVC, metal, ceramic, or any other material deemed appropriate for the dynamics of this system. The middle right diagram of Fig. 13, there is a slight gap 90 between the wellbore tubing (outer cylinder) and a second wellbore tubing (inner cylinder) in sections K and L well A. The second wellbore tubing may be optional.

[0128] Gap 90 allows for a thin film of lubrication (perhaps the thermal fluid itself) to maintain inner well tubing material 80. This film makes moving and removing inner well tubing material 80 to and from the surface of the earth easier. Cap 100 may be placed on top of sections K and L, wherein cap 100 is disposed over the base of the inner cylinder and gap between the inner cylinder and outer cylinder.

[0129] At the top of gap 90 and between the two cylinders, thin bearing 55 may be used, depending on the dynamics of the system. Disc bearing 60 may also be placed at the bottom of the inner tubing (not represented in diagram). The base of the inner tubing is secured to a thin disc bearing.

[0130] There are two rectangular flanges - flange 65 - on the outer surface of the inner cylinder. The two unit of flange 65 run longitudinally and are diametrically opposite to each other. Similarly, there are two diametrically opposite units of flange 70 that run longitudinally along the inside of the outer cylinder.

[0131] For another mode of operation, angled rectangular fins 50 are placed on the inside of the inner ring. Angled rectangular fins 50 may be placed at random locations such that they appear in pairs and are diametrically opposite to each other. Angled rectangular fins 50 may be angled in the same direction. The length, width, and thickness of angled rectangular fins 50 are determined by the dynamics of the system. Instead of fins, electrical motors can be connected at the top or bottom of the wells (not shown) for actuating the rotation.

[0132] Referring to Fig. 14, a cross-section through a vertical well through break valves 110 is depicted. Both of the well tubing materials in sections K and L are perforated with numerous holes as perforations 105. Placement of break valves 110 in perforations 105 is one way to accommodate flow in a single direction. There may be six units of break valves 110, which are: (i) fitted across (i.e., span across) cement 95 (outermost cylinder in Fig. 14), outer tubing 75 (second outer most cylinder in Fig. 14), gap 90 (third outermost cylinder in Fig. 14), and inner tubing (fourth outermost cylinder in Fig. 14); and (ii) terminated at hollow region 115. The break valves

110 are not placed on the outer wellbore tubing in instances of the optional inner wellbore tubing. The break valves may be placed in the perforations of the optional inner tubing only, despite both the inner and outer wellbore tubing are perforated. The perforations for both the inner and outer wellbore tubing are precisely aligned for flow to take place. Additionally, if the optional tubing is used, maintenance is obviated where the break valves may be fitted in the perforations and across the tubing for stability purposes. The inside and/or the outside of the outer cylinder may or may not be covered with a sieve to block sand particles to be introduced in between the cylinders.

[0133] Referring to Fig. 16, thermal fluid obtains the heat from the above ground heat source 35 (using fluid H in a hot state) in a two-loop system. In this variant of SS-ThEnStoR, the heat of fluid H is transferred to another fluid, resulting in fluid K in a hot state via heat exchanger 40. The heat from fluid K in a hot state is transported to fractured rock 45. The heat may remain in fractured rock 45 such that fluid K is now in a cold state. Fluid K in a cold state is transported to heat exchanger 40, from which fluid H in a cold state is transported to heat source 35. Stated another way, both fluids K and H are in independent loops. More specifically, well A may be connected to well B through pump 120 as to force fluid K through fractured rock 45 for the storage of heat.

[0134] Referring to Fig. 17, heat is retrieved from the fractured rock in a two-loop system. In this variant of SS-ThEnStoR, fluid H in a cold state is transferred to another fluid, resulting in fluid K in a cold state via heat exchanger 40. Fluid K in a cold state is transported to fractured rock 45. The heat may exit the fractured rock such that fluid K is now in a hot state. Fluid K in a hot state is transported to heat exchanger 40, from which fluid H in a hot state is transported to above ground heat source 35. Stated another way, both fluids K and H are in independent loops. More specifically, well A may be connected to well B through two units of pump 120 as to force fluid K through the fractured rock for the retrieval of heat.

[0135] While not depicted, a single-loop system circulates a single fluid within SS-ThEnStoR for operating a single loop heat-loading phase and single loop heat-unloading phase, respectively. In certain instances, a pump is not required. For example, if supercritical CO₂ is used as the thermal fluid, supercritical CO₂ absorbs heat from fractured rock 45 and rises by sheer buoyancy force to the surface level through well B. The heat of the supercritical CO₂ is released at the surface level as the supercritical CO₂ flows from well B to well A above the surface. The supercritical CO₂ becomes heavier. Thereby, gravity is enough to cause supercritical CO₂ to flow down well A. This cycle repeats. In the single-loop heat loading phase, thermal fluid in a hot state from above ground heat source 35 is transported to fractured rock 45 and returns thermal fluid in a cold state to the above ground heat source 35. Heat from thermal fluid has been absorbed by fractured rock 45. Thereby, the single-loop heat loading phase stores energy. In the single-loop heat unloading phase, thermal fluid in a cold state from above ground energy consumer 37 is transported to fractured rock 45 and returns thermal fluid in a hot state to the above ground energy consumer 37. Heat from thermal fluid has been released from fractured rock 45. Thereby, the single-loop heat unloading phase retrieves energy. For the case of removing heat from compressed air from a compressor (as in the case of Compressed Air Energy Storage System), the single loop can be an open loop (not shown). This means that the compressed air is sent directly to the subsurface region via one of the vertical or slant well to give up its heat to the material in the slot or to the fractured rock. The cooler air exits from the other vertical or slants well and goes for storage in a cavern or a storage tank. Additionally, heated air from above surface (heated by a compressor) may also be sent directly to the subsurface region through a well to give up its

heat to the material in fractured rock 45 (or slot 45). The cool air is returned to the surface through another well to go to storage.

[0136] Referring to Fig. 18 - Fig. 24, SS-ThEnStoR provides for a break valve operation mode, flow-controlled bi-cylindrical valve operation mode, mechanical lift operation mode, and electrical lift operation mode. While only a single break valve is shown per segment of the wells, there is actually a break valve for each perforation and each segment has multiple perforations.

[0137] Referring to Fig. 18, heat is stored in the subsurface fractured rock (i.e., loading or charging phase). During this operation, thermal fluid in a hot state is pushed from the lower half of well A through the perforations on LB, facing the lower half of well B, NF. LF and NF are not necessarily aligned horizontally. The alignments are also shown in Fig. 14. Thermal fluid in a cold state is received by well B through the perforations on NF. The thermal fluid deposits heat to the fractured rock in between wells A and B. For this operation to be possible, break valves are placed in each perforation of each segment of the wells as shown in Fig. 18.

[0138] Referring to Fig. 19, the heat is removed where thermal fluid in a hot state flows out of well A (i.e., unloading phase). The reverse flow as depicted in Fig. 19 enters well A from segments KB, KF, and LB from NF of well B.

[0139] Referring to Fig. 20, heat is stored in the subsurface fractured rock (i.e., loading or charging phase). During this operation, thermal fluid in a hot state is pushed from the lower half of well A through the perforations on LF, facing the lower half of well B, NF. LF and NF are not necessarily aligned horizontally. The alignments are also shown in Fig. 14. Thermal fluid in a cold state is received by well B through the perforations on NF. The fluid deposits heat to the fractured rock in between wells A and B. For this operation to be possible, break valves are placed in each perforation of each segment of the wells as shown in Fig. 20.

[0140] Referring to Fig. 21, the depicted mode of operation incorporates the charging phase of Fig. 18 or Fig. 20 and the discharging phase where the reverse flow, as depicted in Fig. 21, enters well A from segments KB and LB from NF of well B.

[0141] Referring to Fig. 22, the depicted mode of operation incorporates the charging phase of Fig. 18 or Fig. 20 and discharging phase where the reverse flow, as depicted in Fig. 22, enters well A from segments KB and KF from segment NF of well B.

[0142] Referring to Fig. 23, the depicted mode of operation incorporates the charging phase of Fig. 18 or Fig. 20 and discharging phase where the reverse flow, as depicted in Fig. 23, enters well A from segments KF and LF from segment NF of well B.

[0143] Other modes of operation involve: (i) the charging phase of Fig. 20 and the discharging phase of Fig. 23; (ii) unloading phases in each mode of operation above combined with in-flow to well A through the bottom of well A; and (iii) well A divided into more segments than depicted and the reverse flow (i.e., unloading) into well A can be any combination of these segments.

[0144] Referring to Fig. 25, a flow-controlled bi-cylindrical (FCB) valve is depicted. The FCB valve is

made up of two concentric cylinders that are separated by thin bearing 55 at the top and bottom positions, and any other place along the length of cylinders that may be necessary for stability.

[0145] Inner cylinder 80 has angled rectangular fin 50 on its inside that are so angled as to cause this cylinder to rotate when a flow goes through inner cylinder 80. Flow through the cylinder in the opposite direction causes inner cylinder 80 to rotate in the opposite direction. Inner cylinder 80 also has flanges 65 on the outside. There may be as many flanges 65 as is necessary. Outer cylinder 75 has corresponding flanges 70 on its inside. Flanges 70 may be rectangular in cross-section or any other shape that achieve a seal. The seal should be formed when the flanges of inner cylinder 80 and outer cylinder 75 come in contact due to the rotation of inner cylinder 80, as depicted in the middle right diagram of figure 25. If a seal is not critical, then the flanges can be more "loosely" designed without expending effort to achieve a tight seal. The left diagram of figure 25 shows inner cylinder 80 only, which is perforated with holes (perforations 105). Each segment may be perforated differently to suit the purpose. Depending on the intended operation, the entire outer and inner cylinders may be fully perforated or each may be perforated differently. Outer cylinder 75 may be perforated to match the inner cylinder 80 depending on the dynamics required. In one instance, a rotation of inner cylinder 80 line-up the holes of the inner and outer cylinder. The opposite rotation misaligns these holes. When the holes are aligned, the flow takes places. The cylinders may be perforated to cause flow to the left, to the right, or straight through, depending on the alignment of the holes.

[0146] Referring to Fig. 25, the activation of FCB valve causes flow to change direction by 90° to the left or to the right. Fin 50, as depicted in Fig. 25, causes the thermal fluid that comes up the inner cylinder rotate the said cylinder counter-clockwise until the flanges 65 and 70 jam. The flow of fluid is actuated where a unit of orifice 125 of the outer cylinder aligns with a unit of orifice 125 of the inner cylinder, as depicted by the dotted line. At this point the rotation stops. Since the flanges 65 and 70 go all the way to the bottom of the cylinders, the flow does not enter the gap between the two cylinders on the left side. Additionally, the flow is blocked from flowing through the orifices on the left side. The right side is now in play and hence the flow goes to the right. When flow goes down the inner cylinder all the actions are reversed. While Fig. 25 shows only one pair of flanges on each cylinder, there may be multiple pairs which facilitate less rotational movement of the inner cylinder. As per figure 25, there is 180° rotation of the inner cylinder.

[0147] Referring to Fig. 26, the flow activates the FCB valve to either cause the flow to continue straight through or to cause flow to go through all sections of the side walls of the cylinder. In Fig. 26, the flow is up. The orientation of the rectangular fin 50 causes the inner cylinder to rotate counter-clockwise. Flanges 65 (attached to the outside of the inner cylinder) jam flanges 70 (attached to the inner wall of the outer cylinder) to stop the rotation. The flow then goes out through the perforations as shown. When the flow goes down the inner cylinder, the inner cylinder rotates in the opposite direction. This action closes off the flow through the perforations. Thereby, the fluid is transported straight through the cylinder.

[0148] Referring to Fig. 27, the flow activates the FCB valve to either cause the flow to continue straight through or to cause flow to go through some sections of the side walls of the cylinder. In Fig. 27, the flow is up. The orientation of the rectangular fin 50 causes the inner cylinder to rotate counter-clockwise. Flanges 65 (attached to the outside of the inner cylinder) jam flanges 70 (attached to the inner wall of the outer cylinder) to stop the rotation. The flow then goes out through the perforations as shown. When the flow goes down the inner

cylinder, the inner cylinder rotates in the opposite direction. This action closes off the flow through the perforations. Thereby, the fluid is transported straight through the cylinder.

[0149] In a mechanical lift may be used such that the inner cylinder is lifted by rods or wires by a few inches or far enough to: (i) misalign the holes through which flow is not needed and (ii) align the ones for which flow is needed. Releasing the inner cylinder reverse the effect. These rods or wires are connected to the lift mechanism on the surface of the earth.

[0150] An electrical motor is attached to the base of the inner cylinder. The motor is secured to the ground and the inner cylinder is attached to the disc bearing upon which it rests. Power leads to the motor are in the cement between the outer cylinder and the rock or inside the inner cylinder. Alternatively, the motor can be remote controlled. This motor can produce the same rotations as the fins in the FCB valve. For the various operations of the wells, different combinations of valves maybe needed. For all operations, the Electronic Lift Model and the Mechanical Lift Model can be used as long as the relevant perforations are made in the relevant locations. Otherwise, the models of the FCB valve in Fig. 25 - Fig. 27 can be combined in different ways to accommodate the modes of operation of wells A and B (Fig. 18 - Fig. 23). For instance, where the mode of operation in Fig. 18, the upper segment of well A can use model of the FCB valve depicted in Fig. 27. In contrast, the lower half can use the mode of operation in Fig. 18. Other combinations are possible for different flow patterns. Note that these two models of the valve can be used as separate entities or combined as a single entity (meaning a single inner cylinder for both and a single outer cylinder for both). Based on the operation of the wells, any two models can be combined as a single entity. Further, for multiple segments, these valves can be combined as described above, separately or as single entities.

[0151] Referring to Fig. 28A, Fig. 28B, Fig. 29A, Fig. 29B, Fig. 30A, and Fig. 30B, and 31 Sub-Surface Thermal Energy Storage/Retrieval (SS-ThEnStoR) system are depicted where there is a non-binary topology of wells in fracked rock environments. The non-binary topology, which results from one or more combination of the binary arrangement of wells, allows for linear or non-linear enhancement of fluid transfer in comparison to a solely binary arrangement of wells. The wells may be non-segmented variants or one or more segmented variants (as described above).

[0152] In an example of a solely binary arrangement wells in a fracking environment, the conditions of the system are: (i) 500 meter depth of the heat reservoir; (ii) sandstone rock; (iii) 26% porosity of the rock; (iv) a rock permeability of $67 \times 10^{-12} \text{ m}^2$; (v) hot fluid at 250°C flowing down one of the wells in a binary well setup for 12 hours to charge the system; the system resting for 1 hour after charging for 12 hours; (vi) the flow of fluid reserves for 4 hours; and (vii) the system rests for 8 hours after reversing the flow. The flow of fluid, charging, and resting steps of the conditions above undergo 10 cycles. For the 10th cycle, the efficiency of the amount of sensible heat (which is extracted from the system) in relation to the amount of sensible heat (which is entering the system) is 96.9%. Additionally for the 10th cycle, the efficiency of the amount of sensible heat (which is leaving the system) to the amount of sensible heat (which is entering the system) is 99.1%. The amount of sensible heat extracted is 1.41×10^9 kilo-Joules. A combination of these type of binary arrangements which results in the non-binary topologies approaches efficiency values of 100%, while also accommodating heat flows for larger scale applications.

[0153] In the non-binary topology of wells, three or more wells can be arranged as an array of wells. The array of wells may be arranged and placed in the formation of circles, triangles, squares or other quadrilateral shapes, pentagons, hexagons, and other polygon shapes to send water down to the bottom region through any number of wells and cold water returns to the top region from unused wells (Fig. 28A). To retrieve heat from the group, cold fluid flows in the reverse direction. All of these topologies may also come with a larger central well.

[0154] In another non-binary topology, six wells can be placed around a central well in the center (Fig. 28B) instead of six wells disposed at the vertices of the hexagon (Fig. 28A). Hot fluid may enter through the central well, pass to the ground, and leave through any number of the surrounding wells. For heat retrieval, cold fluid enters through any of the surrounding wells and leaves through the central well. For heat storage, hot fluid may enter from any combination of wells surrounding the central well and leaving from the unused wells. For heat retrieval, cold fluid may enter from any combination of used wells and leave through the unused wells. Other non-binary topologies may be arrays of wells which form a two dimensional rectangular pattern or concentric circular patterns. These numbers of wells can be as large as necessary for the application at hand.

[0155] In the non-binary topology of wells, three wells can be arranged and placed in the formation of a straight line (Fig. 29A) or a triangle (Fig. 29B). Fractured rock below the surface of the earth are connected to the bottom ends of these wells. Hot fluid may enter one or two of the wells, thereby delivering heat to the subsurface region (fractured rock) and returning cold fluid from the other well(s). If there are two unused wells, then the cold fluid can return from one or two of the used wells. Stated another way, not all of the unused wells retrieve heat from the ground, cold fluid is flown in the reverse direction.

[0156] In the non-binary topology of wells, three wells can be arranged and placed in the formation of a straight line (Fig. 29A) or a triangle (Fig. 29B). Fractured rock below the surface of the earth are connected to the bottom ends of these wells. Hot fluid may enter one or two of the wells, thereby delivering heat to the subsurface region (fractured rock) and returning cold fluid from the other well(s). If there are two unused wells, then the cold fluid can return from one or two of the used wells. Stated another way, not all of the to retrieve heat from the ground, cold fluid is flown in the reverse direction.

[0157] In the non-binary topology of wells, four wells can be arranged and placed in the formation of a straight line (Fig. 30A) or a quadrilateral (Fig. 30B). Fractured rock below the surface of the earth are connected to the bottom ends of these wells. Hot fluid may enter one, two, or three of the four wells (wells in use), thereby delivering heat to the subsurface region (fractured rock) and returning cold fluid from the unused well(s). To retrieve heat from the ground, cold fluid is flown in the reverse direction.

[0158] In the non-binary topology of wells, an array of wells can be arranged, such as a 4 x 3 array of wells (Fig. 31). Other array combinations are possible. By way of example, in this 4 x 3 array of wells, the number of wells is increased in all directions. Of the 12 total wells, any amount can be used for charging (i.e., the in-use wells) and any amount of un-used can be for discharging. For example, 2 wells are used for charging (e.g., well in row 1, column 1 and the well in row 3 column 2, then there are remaining 10 wells which are unused. If there are two or more unused wells, not all of the unused wells are used for discharging. In this topology, not all 10 of the wells need to be used for discharging. One or more of the 10 unused wells can be used for discharging. As exhibited in the other non-binary topologies mentioned herein, heat is extracted by the combination of

charging and noncharging wells.

[0159] In the above description of the binary and non-binary topologies, the wells are applied in subsurface conditions when transporting fluid. In the case of the subsurface operation, the entire wells with all the segments are below ground. And the flow pattern can be from one or more than one segments from the first well to one or more than one segments of the second well. This segments well principle can be use in its entirety above ground for fluid flow in various fluid flow operations, including pipe flow. For example, the systems and methods herein can also be applied in above surface condition when transporting fluid. The segments of the wells are supported a disc bearing. In above surface instances, the disc bearing is not necessary as the bottom segments of well A and well B are disposed on the surface or slightly below the surface. The remaining segments which comprise perforations can be aligned with each other, as described above, with the FCB valve and other valves. Thus, piping or other transporting devices, which is above ground, connects well A and well B to each other and can allow for bidirectional flow of thermal fluid above the surface. In other instances where piping and thermal and non-thermal fluid flow is above the surface, a single well can be used for some simple fluid operations without the need for the second well. Further, the transported fluid can be hot or cold. Thus, a flow control mechanism is achieved by the wells herein.

[0160] In all of the embodiments, while air and fluid may be used interchangeably, more generally any thermal fluid can be used (any fluid acting to collect, transport and deliver heat). A non-fracking single unit heat and fluid storage/retrieval system can be implemented as an encapsulated compressed air storage system. The adiabatic encapsulated compressed air energy storage systems store air and heat in the same chamber (or vessel but compartmentalized). In one instance, the encapsulated compressed air storage system may be used to only store heat, where a chamber may be: (1) below the ground or about the ground; and (2) existing wells that are repurposed for this technology. It may be noted that these are not drawn to scale and some of the parts may be removed from subsequent diagrams for the purposes of clarity, even though these removed parts are present in the actual implementation of these diagrams. In all of the embodiments below, annular is taken to mean the gap between two concentric vessels. In all of the embodiments, the adiabatic encapsulated compressed air energy storage (CAES) systems are can be sold as a single unit for above ground, small scale operations. However, they may also be used for subsurface storage. The compressor to compress the air and the gas turbine to generate electricity are each an external unit where the adiabatic encapsulated CAES systems store air and heat in the same chamber. Further, compressed air from windmills, compressors etc. can pass through the focal point (or focal line) of solar parabolic reflectors to further heat it up. The adiabatic encapsulated CAES system is also referred to as the adiabatic CAES capsule.

[0161] Note: In all of the embodiments, there are cylinder separators, insulation on the double perforated plates, and multilevel insulation/heat shield around the inner cylinders. The double perforated plate has a gap between them to allow the movement of check valves to allow the flow in one direction or the other. Some of these valves are reversed (explained in earlier invention). However, a single plate may be used as long as there is a gap between the upper heat storage materials. For clarity, since check valves have been shown in other embodiments in this patent, they are not shown here. Check valves are standard valves selling in most hardware stores and is therefore not a part of this

invention. However, for the purpose of clarity, and to avoid cluttering the diagrams, these depictions are only shown in the first two diagrams (Figures 32A and 32B). Their absence in the subsequent diagrams (Figures 33A, 33B, 33C, 34A, 34B, 35A, 35B, 36A, 36B, 37A, 37B, 38A, 38B, 39A, 39B, and 40) does not indicate that they are removed from the designs.

[0162] Further, while the diagrams show only two levels of insulation on the inner cylinder, there may be more or less than two levels of insulation on the inner cylinder. Also, these levels can be a mixture of insulation and phase change materials. For example, LI-900 Silica Tiles are used as one of the layers of insulation. This is the tile used in the space shuttle to block heat from reaching the inner parts of the fuselage, which is recommended in extreme cases. In preferred embodiment, LI-900 Silica Tiles are used on level surfaces, which means that the inner “cylinder” may not be a cylinder but rather made of straight faces as in a prism. However, they can still be used on curved surfaces but would have to be in smaller sizes. These tiles are not exclusive. Other types of insulation can be used (even the spray on ones). To avoid repetition, the insulation layers or heat shield layers around the inner cylinder will not be discussed again unless necessary.

[0163] Note that while is some of the descriptions, air may be stated as the heat transport fluid. However, the heat transport fluid is not limited to air. Carbon dioxide (CO₂), nitrogen (N₂), water (H₂O), oil, etc. can be used instead of air as the heat transport fluid. While the shape in the description is a cylinder, other shapes are possible, such as rectangular, square, elliptical, etc.

[0164] The cylinder, as depicted in Fig. 32C, may be placed horizontally, in which hemispherical or semi-elliptical ends are typically used. Flanges are connected to the center cylinder to accommodate flow through the center cylinder. The more complex case of having flow from the entrance and exit of the annular region and the entrance and exit from center cylinder at the same time are shown in figures 37A and 37B. For flow just through the entrance or exit of annular region, the flange from the center cylinder is blinded. In other figures, the flanges are not explicitly shown for the sake of clarity.

[0165] Specifics regarding the features of the various configurations of encapsulated CAES systems are described below.

[0166] A first variant of the adiabatic Encapsulated CAES system is a HeF-StoR system with lower level heat and fluid storage and retrieval system, as depicted in Fig. 32A, Fig. 32B, Fig. 32C, and Fig. 31D. In the Central Flow Lower Annular Heat Reservoir Central Hot Fluid Duct variation (see Fig. 32A), hot fluid uses the center cylinder as its conduit. Heat is stored in the lower part of this system. The first cylinder has a controlled opening at the top. It can open and close whenever the need arises. During the charging (heat and fluid storage) process (see Fig. 32A), hot air is forced down the first cylinder. The double plates with perforations facilitate the flow of air to the region below it and to the region above it. The double plates are configured in such a way that they can close off the perforations when there is no flow (this is the nature of the check valves). These check valves on the plates are between the first and second cylinders. The extension of this plate between the second and third and between the third and fourth cylinders are not necessarily perforated. These extensions serve to help keep the cylinders in place. They may also be flanges from the cylinders to seal those gaps. The bottom of the

system may be plates joined to the bottom of the cylinders or welded in the case of metals. The top plate that covers the system (with the only hole through the first or inner cylinder) can also be joined or welded or tightly pressed against the head with a gasket in between them. The bottom plate may simply be the ground if the cylinders can be placed in grooves on the floor. Extremely high pressures may not make this possible in some cases. Also, additional support may be placed between the cylinders to maintain rigidity. These are called cylinder separators in the diagram. The first cylinder is the innermost one, which has: (i) perforations disposed on its lower portion and (ii) venting to the lowest level of heat storage material (e.g., heat storage material C). The inner cylinder may also be equipped with the bidirectional valve described in an earlier embodiment or perforations on the lower portion of the inner cylinder. Furthermore, the upper segment of the first cylinder (above the heat storage materials) may have a smaller cross-sectional area than the bottom part. This depiction is shown in figure 34A and 34B. In other cases they may be used but not necessarily shown in the other diagrams. This allows for greater storage volume in the cold storage duct between the first and the second cylinders. As the air passes through the perforations, the air is forced upward and passes through the other heat storage materials (heat storage materials B and A). The heat storage material separators might be a physical or just a virtual boundary. In the case of a physical boundary, made of a plate of an appropriate material (e.g., copper, steel, aluminum, etc.), the physical boundary can be perforated to facilitate the flow of fluid. While there are three heat storage materials shown, there may be more or less than three heat storage materials. The cold air exits the heat storage material 'A' and gets stored in the upper segment between the first and the second cylinder. Material A, B, and C can be chosen depending on the pressure, flow velocity, temperature, fluid type, and other factors. In the case of fast flowing air, material C may be aluminum, alumina, or copper. While these materials have fairly low heat capacities, relatively high heat conductivity is a property allowing a material to quickly absorb heat from the faster flowing fluid. As the air passes through material C, the air flow slows down and thereby, material B can have a smaller heat conductivity than material C. Material B can be steel but other materials can be used as material B as well. For the same reasons above, material A can be gravel or another material. However, some applications may consider the order of these materials differently. Concentric insulation layers surround the lower part (heat storage segment of the system). While three insulation materials A, B, and C are depicted that correspond to the concentric insulation layers, there may be more or less than insulation layers used in other examples. Depending on the temperature of operation, various materials may be selected for these concentric insulation layers from the group of materials comprising fiber glass, mineral wool, poly styrene, etc. The lower part and the upper part of the third cylinder (between the second and third cylinder) may have different insulation. The space between the third and the fourth cylinders maybe used to trap a phase change material. Segment A and B can have two different kinds of phase change material or the same, which can arrest heat trying to bleed off into the surrounding environment. For example in underground applications, in regions beyond areas corresponding insulation materials C, the temperature and the environment, which is rock, just outside of the system are both 50 degrees Celsius. In this example, wax may be used as the phase change material, in which the rock has a specific heat capacity of 2 to 3 kJ/kg. Some wax, in that temperature range have a latent heat of fusion of about 170 kJ/kg. After the wax takes in a substantial amount of heat (135 times that of rock for the same mass), the wax starts to lose heat to the formation and thus functions as a heat capacitor. While wax is just cited as an example, other phase change materials can be used in the system depicted in Fig. 32A and Fig. 32B. Instead of a phase change material, a material of high heat capacity that does not necessarily go through phase change in the desired temperature range can be used in the system depicted in Fig. 32A and Fig. 32B. In place of insulation materials A,

B and C, various kinds of phase change (or non-phase change) materials may be used. A mixture of phase change materials, non-phase change material (in the desired temperature range) and insulations may also be used. Also, more concentric layers beyond the fourth cylinder may be used. During the discharge process, the valve at the top of the inner cylinder is opened and the fluid reverses its direction of flow, flows down the gap between the first cylinder and the second cylinder, through the heat storage materials (heat storage material A to heat storage material B to heat storage material C), through the perforations at the bottom of the inner cylinder, and up the inner cylinder then out at the top of the inner cylinder (See Fig. 32B.) The setup of the system in Fig. 32C and Fig. 32D have semi-elliptical heads whereas those in Fig 32A and Fig 32B do not. The semi-elliptical head comes with a gasket inside to seal the cylinders against it. While not explicitly depicted, open and shut valves may be disposed along the first, second, third, and fourth cylinders in Fig. 32A through Fig. 32D, to further control the transport of fluid or phase change material as the need arises. Figures 32A and 32C are referred to as the encapsulated versions while Figures 32B and 32D are referred to as the non-encapsulated versions. However, this is for ease of communication because both can be used as encapsulated versions. As per the discussion at hand, the encapsulated versions (figures 32A and 32B) can be used differently from figures 32C and 32D. The sections of all embodiments that encase the heat storage materials and the cylinders that carry the hot fluids will be made of much thicker walls from the rest of the system. This saves on the cost by not making the entire cylinder with this thickness. If it is desired that all cylinders be of the same thicknesses (on the thinner side), then the ones that carry the hot fluids and the ones that enclose the heat storage materials have to be made of much stronger material than the rest of the system. The two sections are separated by gaskets (not shown on the diagrams to avoid clutter). The two sections can be secured by many methods, however, the one shown in figure 32A and 32C use flanges with bolts and nuts. There are valves in the upper flanges (inlet/outlet) that are shown in these figures. To avoid cluttering, these depictions will not be shown again.

[0167] The encapsulated versions may be ideal for above ground storage. The non-encapsulated versions, may be used both above ground and from the surface to below the surface of the earth. In the subsurface case, the cylinder surrounding the heat storage material may not necessarily need to be thicker as the surrounding earth may suffice to withstand the pressure. However, if the pressure is high, then it may be necessary to revert to a case with the thicker cylinder that stores the heat storage material. These ones may also be ideal to re-purpose wells. There may be cases where the outer cylinder may not even be needed, with the earth serving that purpose. In all cases of figures 32, the inner cylinder maybe designed with a smaller diameter for the segment above the heat storage material.

[0168] It should be noted that the heat storage material may also be placed in the lower portion of the inner cylinder, making the entire lower portion of the first and second cylinders filled with these layers of the material. Different conductive and insulation materials may be selected from the ones mentioned above. More or less layers of heat storage materials may be used. More or less concentric cylinders with phase change materials or insulations may also be used.

[0169] A second variant of the adiabatic Encapsulated CAES system is a HeF-StoR system with lower level heat and fluid storage and retrieval system, as depicted in Fig. 33A and Fig. 33B. A third variant of the adiabatic Encapsulated CAES system CAES system is a HeF-StoR system with lower level heat and fluid storage

and retrieval system that contains a rocket-shaped portion for storing cold fluid, as depicted in Fig. 34A and Fig. 34B. In the Annular Flow Lower Annular Heat Reservoir Annular Hot Fluid Duct variation, the annulus between the first and second cylinders is used for the hot air conduit (see Fig. 33A). However, the entire length of the annulus may also be filled with the heat storage material. During the heat storage phase, hot air may enter through the top between the center cylinder and the second cylinder and deliver heat to the layered heat storage materials (which may be placed in a reverse order compared with the Central Hot Fluid Duct variation). Material A may be the highest thermal conductivity material and be disposed in combination with material B as the second highest conductivity material and material C as the lowest conductivity material. (See Fig. 33A.) More or less layers of heat storage materials may be used. More or less concentric cylinders with phase change materials or insulations may also be used. In other instances, the order of conductivity may vary among materials A, B, and C. In Fig. 33B, the heat extraction process is shown for the second variant of the encapsulated CAES system. The cold air from the cold storage flows down the inner cylinder and through the perforations at the bottom of the inner cylinder and up through the gap between the inner cylinder and the second cylinder, thereby picking up heat from the layered heat storage materials, C, B, and A, in that order. The hot fluid exits the system at the top of the annulus. The upper segment of the inner cylinder may be made larger than the lower portion. This increased the volume of air stored in the inner cylinder. However, due allowances may be made to get the air from the annulus to the heat storage materials, which are achieved by tapering the lower part of the upper segment of the inner cylinder to reach the diameter of the lower segment. This is similar in some aspects to a rocket nose (see Fig. 34A and Fig. 34B). In the case of figures 34A and 34B, the heat storage material is stored in the lower central cylinder, otherwise the principles of operation is the same as those for the variants in figures 33A and 33B. In both the Annular and Central Hot Fluid variations, the heat storage materials may also be placed in the lower part of the central cylinder, thereby occupying the entire lower region of the first and second cylinders.

[0170] A fourth variant of the adiabatic Encapsulated CAES system CAES system is a HeF-StoR system with lower level heat and fluid storage and retrieval system, as depicted in Fig. 35A and Fig. 35B. This is basically the same as variants in figures 34A and 34B but more compatible with subsurface usage.

[0171] A fifth variant of the adiabatic encapsulated CAES system is a HeF-StoR system with upper level heat and fluid storage and retrieval system, as depicted in Fig. 36A and Fig. 36B. This is referred to as The Center Flow Upper Central Heat Reservoir Lower Central Cold Fluid Duct variation Heat is stored in the upper part of this system and the fluid is stored below the heat storage materials, all in the center cylinder. (See Fig 36A.) The first cylinder has a controlled opening at the top, which can open and close. During the charging (heat and fluid storage) process, hot air is forced down the first cylinder (which is not a full length cylinder.) The second cylinder is also not a full length cylinder. The double plates with perforations facilitate the flow of air to the region below it and to the region above it. These double plates and associated check valves are described above. The extension of this plate between the second and third and between the third and fourth cylinders are: (i) not necessarily perforated and (ii) aid in keeping the cylinders in place. The bottom of the system may be plates joined to the bottom of the cylinders or welded (in the case of metals). The top plate that covers the system (with the only hole through the first or inner cylinder) may also be joined to the bottom the cylinders or welded. The bottom plate may simply be the ground if the cylinders can be placed in groves. Also, additional support may be placed between the cylinders to maintain rigidity. The entire first cylinder (inner cylinder) is filled with heat storage material as described above. During the charging phase, hot air comes in from the top of the first cylinder

such that the hot air is forced through the different layers of heat storage materials and then through the perforations through the bottom plate and into the fluid storage segment below. In this case, the air goes through the highest conductivity material first, which is disposed at the top most position (i.e., material A), then the material with the second highest conductivity disposed in the intermediate position (i.e., material B), and finally the material with the lowest conductivity disposed at the lowest position (i.e., material C). The order may be materials like aluminum (or alumina), followed by steel, then gravel. However, the order may change depend on other factors, as described above. The heat storage material separators might be a physical boundary or just a virtual boundary. For a physical boundary, a plate of an appropriate material (e.g., copper, steel, aluminum, etc.) may be perforated to facilitate the flow of fluid. While there are three heat storage materials shown, there may be more layers or less. The cold air, which exits the heat storage material 'C', is adapted to be stored in the lower segment, inside first cylinder. Materials A, B, and C can be chosen depending on the pressure, flow velocity, temperature, fluid type, and other factors. In the case of fast flowing air, material A may be aluminum or alumina. Although aluminum has fairly low heat capacity, aluminum has relatively high heat conductivity, which allows aluminum to quickly absorb heat from the faster flowing air. As the air passes through material A, the flow of air slows down. Because of this, material B can be one with a smaller heat conductivity than material A. Steel can be used, for example, as material B. For the same reasons described above, material C can be gravel. However, materials A, B, and C may be selected from the ones mentioned above. Concentric insulation materials are surrounding the upper part (heat storage segment of the system). There may be more or less than three concentric insulation materials in other examples. Depending on the temperature of operation, various materials may be selected for these concentric layers. Such materials may be fiber glass, mineral wool, polystyrene, etc. The lower part and the upper part of the third cylinder (between the second and third cylinder) may have different insulation. The space between the third and the fourth cylinders may be used to trap a phase change material. Segments A and B can have two different kinds of phase change materials. The phase change material arrests heat trying to bleed off into the surrounding environment. For instance, if the temperature of the region beyond insulation C and the environment just outside of the system are each 50 degrees Celsius, wax can be used as the phase change material. If the environment just outside of the system is rock, then the rock has a specific heat capacity of only 2 to 3 kJ/kg. Some waxes in that temperature range have a latent heat of fusion of about 170 kJ/kg. After the wax takes in or absorbs a substantial amount of heat (135 times that of rock for the same mass), the wax starts to lose heat to the formation, thereby the wax functions as a heat capacitor. In place of insulation materials A, B and C, various kinds of phase change materials can be used. A mixture of phase change materials and insulations may be used. Fewer or more concentric layers than the four cylinders (first, second, third, and fourth cylinders) may be used. More or fewer layers of heat storage materials may also be used. During the discharge process, the top of the inner cylinder is opened and the fluid reverses the direction of flow. This fluid is: (i) flowing up through the double perforated plates at the bottom of the first cylinder, (ii) flowing through the heat storage material C; (iii) flowing through material B; (iv) flowing through material A; and (v) finally flowing out of the first cylinder. (See Fig 36B.)

[0172] A sixth variant of the adiabatic encapsulated CAES system is a non-fracking heat and retrieval storage system, as depicted in Fig. 37A and Fig. 37B. In the sixth variant, heat is separated from the heat transport fluid and store the heat in a single side central heat storage-retrieval setup. A flange is operatively connected to a center cylinder and another flange is operatively connected to the hot fluid source. In the storage or charging state, hot fluid flows through the annulus. The fluid may be recycled to bring more heat to the system, in a closed loop

system or in an open loop system. Also, the reversal of fluid flow retrieves the previously stored heat. As shown in Fig. 37A, the heat is stored in between the first and second cylinders. In contrast to above described systems in Fig. 32A, Fig. 32B, Fig. 32C, Fig. 33A, Fig. 33B, Fig. 34A, Fig. 34B, Fig. 35A, Fig. 35B, Fig. 36A, and Fig. 36B, both of the first cylinder and the second cylinder can open and close to accommodate flow of the thermal fluid. Heat storage material layers are disposed between the first and the second cylinders. The storage material separators are perforated and may be physical plates or just virtual boundaries, in which case there may be no perforations. During the charging phase, air flows down the gap between the first cylinder and the second cylinder (see Fig. 37A) and through the heat storage material. Materials A, B, and C may be of different heat conductivities and heat capacities, as described above. There may also be more or less layers of heat storage materials than depicted in Fig. 37A and Fig. 37B. When the air reaches the bottom of the gap between the first cylinder and the second cylinder, the air is forced through perforations at the bottom of the inner cylinder from the annulus. The air then rises inside of the inner cylinder and exits at the top of cylinder one. To extract the heat, the reverse flow is engaged (see Fig. 37B). In this case, the cold air is (i) entering through the top of first cylinder, (ii) forced to the bottom and through the perforations there; and (iii) forced in the gap between the first cylinder and the second cylinder. As the cold air rises between the gaps, heat is picked in the reverse order in which it was deposited and goes through the layers of heat storage material. Thus, the hot air exits at the top of the second cylinder. The gaps between the subsequent concentric cylinders (the third and fourth cylinders, the fourth and fifth cylinders, and the fifth and sixth cylinders), may be filled with either insulation or phase change materials or some gaps with one or the other. There may be more or less concentric cylinders than depicted, in which the number of concentric cylinders is dictated by the application at hand.

[0173] A seventh variant of the adiabatic encapsulated CAES system is a non-fracking heat and retrieval storage system, as depicted in Fig. 38A and Fig. 38B. In the seventh variant, heat is separated from the heat transport fluid and store the heat in a two-sided flow central heat storage-retrieval setup. The fluid may be recycled to bring more heat to the system in the seventh variant in a closed loop system or an open loop system. Also, the reversal of fluid flow can retrieve the previously stored heat. As depicted in Fig. 38A, the heat is stored in the first cylinder. Unlike the previous systems, both the first cylinder and the second cylinder can open and close to accommodate flow of the thermal fluid. Heat storage material layers are in the first cylinder. The storage material separators are perforated and may be physical plates or just virtual boundaries, in which case no perforations. During the charging phase, air flows down the first cylinder (see Fig. 38A) and through the heat storage materials A, B, and C. Heat storage materials A, B, and C may be of different heat conductivities and heat capacities. There may also be more or less layers of heat storage materials than depicted in Fig. 38A and Fig. 38B. When the air reaches the bottom of the first cylinder, the air is forced through perforations at the bottom of the inner cylinder. The air then rises inside the annulus between the inner and second cylinder and exits at the top of this annulus. To extract the heat, the reverse flow is engaged (see Fig. 38B). In this case, the cold air is: (i) entering through the top of the annulus between the first and second cylinders; (ii) forced to the bottom and through the perforations therein; and (iii) forced into the inner cylinder. As the cold air rises in the first cylinder one, heat is picked up in the reverse order in which it was deposited and goes through the layers of heat storage materials. Thus, the hot air exits at the top of first cylinder. The gaps between the subsequent concentric cylinders (the third and fourth cylinder, fourth and fifth cylinders, and fifth and sixth cylinders), may be filled with either insulation or phase change materials or some gaps with one or the other. There may be more or less concentric cylinders and/or heat storage materials than depicted, in which the number of concentric cylinders and/or heat

storage materials is dictated by the application at hand.

[0174] An eighth variant of the adiabatic encapsulated CAES system is a non-fracking heat and retrieval storage system, as depicted in Fig. 38A and Fig. 38B. In the eighth variant, heat is separated from the heat transport fluid and store the heat in a two side flow central heat storage-retrieval setup. The fluid may be recycled to bring more heat to the system, in a closed loop system, or it may not, in an open loop system. Also, the reversal of fluid flow will retrieve the previously stored heat. However, this is different from the Singe Side Flow system because in this case hot fluid enters one side and leaves through the other. As shown in Fig. 39A, the heat is stored in the first cylinder. Heat storage material layers are in the first cylinder. The storage material separators are perforated and may be physical plates or just virtual boundaries, in which case there may be no perforations. During the charging phase, air flows down the first cylinder (see Fig. 39A) and through the heat storage materials A, B, and C. Heat storage materials A, B, and C may be of different heat conductivities and heat capacities. There may also be more or less layers of heat storage materials than depicted in Fig. 39A and Fig. 39B. When the air reaches the bottom of the first cylinder, the air exits. To extract the heat, the reverse flow is engaged (see Fig. 39B). In this case the cold air enters through the opposite side of the mechanism. As the cold air rises in the first cylinder, heat is picked up in the reverse order in which it is deposited and going through the layers of heat storage materials. The hot air exits at the top of the first cylinder. The gaps between the subsequent concentric cylinders (the third and fourth cylinder, fourth and fifth cylinders, and fifth and sixth cylinders), may be filled with either insulation or phase change materials or some gaps with one or the other. There may be more or less concentric cylinders and/or heat storage materials than depicted, in which the number of concentric cylinders and/or heat storage materials is dictated by the application at hand.

[0175] In all of the embodiments where the air is stored in the annulus, the central cylinder may have a smaller diameter in its segment above the heat storage material. This facilitates a greater volume of storage. Further, in ALL cases, the cylinders that are responsible to accommodate the flow of the hot fluid are thicker than the other cylinders although they may not all be shown on the diagrams. However, they may also be of the same thickness if the operational pressures and temperatures allow that. In all of the embodiments, the inner cylinder has one or more layers of insulation or surrounded by phase change material or a mixture of concentric layers of phase change materials and insulators.

[0176] A symbiotic distributed adiabatic compressed air energy storage system is depicted in Fig. 40. Unlike distributed CAES systems known in the art, the adiabatic compressed air energy storage system is characterized by the following aspects.

[0177] The nodes, A, G, M, D, J, and P may be close to each other or far apart. STUV is a reference surface, which is the earth's surface. WX is a fluid storage unit, which may be of any shape and shown to be a cylinder. WX is located below the earth's surface in the diagram, which may be on or above the earth's surface in other instances. A, G, M, D, J, and P are inlets/outlets for the pipe segments ABC, DEF, GHI, JKL, MNO, and PQR (i.e., the conduits of storage). The segments AB and BC are shown at an angle, as with all the other conduits, and may be acute, obtuse or straight-line or even larger than 180 degrees, depending on the application and ABC may also be curved. If the conduit ABC happens to be above ground, it may be in the horizontal plane or any plane angled to the horizontal. The same can be said for it below the ground. The same can be said for all the other conduits. In the case of ABC being in the horizontal plane below the surface, a vertical pipe will have to

protrude from A to the surface. The conduits may be of any shape, e.g., curved, several straight-line segments, etc. Each segment (AB, BC, DE, DF, etc.) or the entire lengths of the conduits (ABC, DEF, etc.) are equipped with heat reservoir on its inside.

[0178] In contrast to heat storage systems in the prior art, the heat storage systems are in the conduits (not outside on the surface of the earth) where: (i) the heat storage systems are layered; (ii) there is inter-connectivity between the nodes, A, G, M, D, J, and P via valves; (iii) all or some of the fluid flow can be directed to one or more nodes by adjusting the valves shown in Fig. 40; (iv) each node can share in each other's heat content, as based on (iii), which is ideal in emergencies (e.g., one town is hit with a storm and needs extra power). The nodes are equipped with valves to intake or release fluid to or from an external source, which may be in a separate town. Town 'A' may be windy and therefore can produce compressed air by way of wind energy. Other towns may be using other means, for instance pumped hydro or solar power. The compressed air flows through the conduit ABC to the storage WX, which gives the heat to a built in heat storage unit (built in to ABC). The heat storage unit used in Fig. 40 may be similar or identical to the heat storage unit in Fig. 39A and Fig. 39B. Modifications of Fig. 39A and Fig. 39B can also be made, although not necessary to conform to the adiabatic environment depicted in Fig. 40. Some of the modifications may include: removing all of the concentric cylinders and use the part of ABC as the enclosure; using some or all or one of the layered heat storage materials; and/or using some or all of the layered heat storage material along with perhaps one outer cylinder with phase change material or maybe one or two or more concentric cylinders with phase change materials. The system in Fig. 39A and Fig. 39B can be placed longitudinally inside ABC or take the shape of the inside of ABC. In the event of not using any concentric cylinders, the layered heat storage materials may simply be packed to fill the cross-section of ABC, with the material that has the highest heat conductivity being closest to A, which is the point of entry for hot air. Other arrangements may be possible as well.

[0179] For example, when the town that has inlet 'A' produces compressed air, the air flows from A to B to C and into WX. In this flow, heat is deposited to the inbuilt heat storage system. When that town needs electricity, a valve at A allows air to exit, thereby reversing the flow of air from WX and now through CBA. It absorbs the heat from the built in heat storage and exits A as hot air. The same process occurs from other sites, namely, G, M, D, J, and P. The symbiotic relationship comes in to play when a town has an emergency. There may be instances where say site G needs to generate more electricity. In this case, the valves between A and G and between M and G may be opened. This way, not only do the valves combine airflow in emergencies, the valves also share the heat content from each conduit. The valves between S and V and between T and U may also be opened to accommodate flows from the other side. Note, that WX is shown as a horizontal cylinder but maybe a vertical one or an incline or an arc or any other shape. And the shapes are not limited to cylinders. In the case of a disc shape, the conduits maybe placed around the circumference. If there is enough piping volume beyond the heat storage material, a vessel may not be employed. To give a sense of the lengths, BC and AB may be a fraction of a kilometer to several kilometers long. Note there may be more than one node in a small town and while the diagram shows only these nodes and conduits, other nodes and conduit combinations are possible.

Other Embodiments

[0180] The detailed description set forth above is provided to aid those skilled in the art in practicing the

present invention. However, the invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed because these embodiments are intended as illustration of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description which does not depart from the spirit or scope of the present inventive discovery. Such modifications are also intended to fall within the scope of the appended claims.

References Cited

[0181] All publications, patents, patent applications and other references cited in this application are incorporated herein by reference in their entirety for all purposes to the same extent as if each individual publication, patent, patent application or other reference was specifically and individually indicated to be incorporated by reference in its entirety for all purposes. Citation of a reference herein shall not be construed as an admission that such is prior art to the present invention.

Claims

What is claimed is:

1. A system for storing and retrieving subsurface energy, comprising:
 - a heat source or an energy consumer thermally connected to a first fluid, wherein the first fluid is transported through a first well fluidically connected to a second well;
 - a slot sawed into a rock and expanded through pressure or mechanical means, wherein the slot is below an earth surface;
 - a cable and tubing operatively connected to the first well to the second well, wherein the cable and the tubing are partially encapsulated by casing, wherein the cable stores heat;
 - a plurality of materials filled into the slot, wherein the plurality of materials is in a liquid state or gas state;
2. The system of claim 1, wherein the plurality of materials is selected from the group consisting of steel balls, scrap steel, gravel, alumina, bauxite, water, air, and ropes for heat storage.
3. The system of claim 1, wherein the slot is disposed in a vertical direction, a horizontal direction, or an inclined direction for the purpose of storing heat.
4. The system of claim 1, wherein the first well and the second well are of a circular shape, a rectangular shape, an ellipsoidal shape, or a square shape for the purpose of storing heat.
5. The system of claim 1, wherein the heat source comprises solar energy, nuclear energy, geothermal energy, electrical energy, organic wastes, and converted wind turbine energy.
6. The system of claim 1, wherein the fluid is in a gas phase, a liquid phase, a supercritical phase, or a dual phase.
7. The system of claim 1, wherein the first fluid is transported through the slot, the heat source, and the energy consumer in a single closed-loop system, a binary closed-loop system, or an open loop system.
8. The system of claim 8, wherein the binary closed-loop system further comprises a second fluid and a heat exchanger, wherein the heat exchanger is fluidically connected to the first fluid, the second fluid, and the slot.
9. The system of claim 8, wherein the single-loop system comprises the first fluid transported from the heat source to the slot in a heated state and subsequently transported from the slot to the heat source in a cooled state.

10. The system of claim 8, wherein the single-loop system comprises the first fluid transported from the energy consumer to the slot in a cooled state and subsequently transported from the slot to the energy consumer in a heated state.
11. A system for storing and retrieving sub-surface energy, comprising:
 - a fractured body of rock, wherein the fractured body of rock resides below an earth surface;
 - a thermal fluid circulated through the fractured body of rock via tubing;
 - a rock mass below the earth surface, wherein the rock mass is a continuation of the fractured body of rock;
 - a first well disposed within a first hole, wherein the first hole is operatively connected to the fractured body of rock;
 - a second well disposed within a second hole, wherein the second hole is operatively connected to the fractured body of rock;
 - wherein the first well contains at least a first segment, a second segment, and a third segment, the second well contains at least a fourth segment and a fifth segment;
 - wherein the first segment, the second segment, the third segment, the fourth segment, and the fifth segment comprise perforations fitted with valves; and
 - wherein the first hole and the second hole are configured to be vertical or slanted.
12. The system of claim 12, wherein the first well and the second well comprise the valves and a cement layer connected to a first tubing layer, wherein the first tubing layer is connected to a first hollow layer, wherein the first hollow layer is connected to a second tubing layer, wherein the second tubing layer is connected to the second hollow layer, wherein the valves span from the cement layer, the first tubing layer, the first hollow layer, and the second tubing layer.
13. The system of claim 12, wherein the second segment and the third segment comprise at least one angled fin, at least one outer flange, a thin bearing, and a disc bearing.
14. The system of claim 12, wherein the first segment and the fourth segment comprise at least one flange and a cement layer.
15. The system of claim 12, wherein the tubing is connected to (i) electrical motors for causing rotation, (ii) a thin bearing, and (iii) a disc bearing.
16. The system of claim 12, wherein the perforations on the outer tubing are covered with sieves to prevent sand from entering between the cylinders, wherein the sieves are disposed on inner faces or outer faces or both the inner and outer faces of an outer cylinder.
17. The system of claim 12, wherein the thermal fluid flows from any combination of the first, second, third, fourth, and fifth segments such that the thermal fluid is hot when released by the first well and the thermal fluid is cold when received by any combination of segments in the second well.

18. The system of claim 12, wherein the thermal fluid flows from the second segment to the third segment such that the thermal fluid is hot when received by the first well and the thermal fluid is cold when released by the second well, wherein the second well has a bottom level higher than a bottom level of the first well or the second well has the bottom at an identical level to the bottom level of the first well.
19. The system of claim 12, wherein the thermal fluid flows from the second segment to the third segment such that the thermal fluid is hot when released by the first well and the thermal fluid is cold when received by the second well, wherein the second well has a bottom level higher than a bottom level of the first well or the second well has the bottom at an identical level to the bottom level of the first well.
20. A system for storing and retrieving energy, comprising
 - a first well comprising a first valve and a first set of segments, wherein the set of segments comprises a first set of perforations;
 - a second well comprising a second valve and a second set of segments, wherein the second set of segments comprises a second set of perforations;
 - piping operatively connected to the first well and the second well, wherein the piping is disposed above the earth surface; and
 - a thermal fluid configured for transport between the first well and the second well via the tubing, wherein a segment of the first set of segments of the first well and a segment of the second set of segments of the second well are disposed on an earth surface or below the earth surface, thereby remaining segments of the first set of segments of the first well and the second set of segments of the second well are disposed above the earth surface;
 - wherein the first valve and the second valve are configured for movement, thereby controlling alignment states of the first set of perforations and the second set of perforations, thereby controlling flow properties of the thermal fluid;
 - wherein the thermal fluid is transported bi-directionally within the piping between at least one of the remaining segments of the first set of segments of the first well and at least one of the remaining segments of the second set of segments of the second well.
21. A system for storing and retrieving energy and fluid, comprising:
 - a duct operatively connected to a first cylinder with insulation around the duct or phase change material, wherein the first cylinder is operatively connected to a first layer of insulation or phase change material, wherein the first layer of insulation is operatively connected to the second layer of insulation or phase change material;
 - a first cylinder outlet/inlet gap and at least a second outlet/inlet gap operatively connected between a selected annulus, say between the first and second cylinder, wherein the gap between the first cylinder and the second cylinder comprise an annulus;
 - wherein one or both of the outlet/inlet gaps are configured for intake or exit or both intake and exit in a one-gap-flow system of fluid;

a double plate or single plate disposed with the system such that the system comprises an upper section and a lower section, wherein the double plate comprises perforations, wherein the perforations are configured for controlling fluid flow through control valves, wherein the control valves comprises a check valves;

wherein the lower section comprises at least a third cylinder, a fourth cylinder, a first segment of the fifth cylinder;

wherein the lower section comprises the first cylinder, the second cylinder, a second segment of the fifth cylinder, and the plurality of heat storage materials, placed across the entire cross-section or in an inner cylinder, or the annuluses of various combinations of cylinders.

22. The system of claim 21, wherein the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
23. The system of claim 22, wherein the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.
24. The system of claim 22, wherein the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.
25. The system of claim 21, wherein the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprising a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
26. The system of claim 22, wherein the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
27. The system of claim 21, wherein the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.
28. The system of claim 21, wherein the phase change material may be in part or whole of the inner cylinder or be in part or whole of selected annuluses or any combination of both.
29. The system of claim 21, wherein the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.
30. The system of claim 21, wherein the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the

side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

31. The system of claim 21, wherein the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.
32. A system for storing and retrieving energy and fluid, comprising:
 - a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder wherein the first cylinder is operatively connected to a plurality of heat storage materials, wherein the plurality of heat storage materials is operatively connected to a plurality of insulator materials;
 - a first cylinder outlet/inlet gap and/or selected annuluses with outlet/inlet gaps;
 - a double plate or single plate disposed with the system such that the system comprises an upper section and a lower section, wherein the double plate comprises perforations, which are used for fluid flow through control valves, wherein the control valves comprises check valves;
 - wherein the lower section comprises a third cylinder, a fourth cylinder or even more, a first segment of the fifth cylinder; and
 - wherein the upper section comprises the first cylinder, the second cylinder, a second segment of the fifth cylinder, and the plurality of heat storage materials and concentric layers of insulators and phase change materials.
33. The system of claim 31, wherein the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
34. The system of claim 32, wherein the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.
35. The system of claim 32, wherein the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.
36. The system of claim 31, wherein the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprising a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
37. The system of claim 32, wherein the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
38. The system of claim 31, wherein the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.

39. The system of claim 31, wherein the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.
40. The system of claim 31, wherein the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material may be in part or whole of the inner cylinder or be in part or whole of selected annuluses or any combination of both.
41. The system of claim 31, wherein the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.
42. The system of claim 31, wherein the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.
43. The system of claim 31, wherein the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
44. The system of claim 31, wherein the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
45. The system of claim 32, wherein the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.
46. The system of claim 32, wherein the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.
47. The system of claim 31, wherein the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprising a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.

48. The system of claim 32, wherein the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
49. The system of claim 31, wherein the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.
50. The system of claim 31, wherein the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.
51. The system of claim 31, wherein the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.
52. The system of claim 31, wherein the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.
53. The system of claim 31, wherein the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
54. A one end flow system for storing and retrieving energy, comprising:
 - a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder;
 - a lower section of the inner cylinder is perforated, allowing thermal fluid to flow through to the lowest layered heat storage material, wherein the thermal fluid moves through the other heat storage material giving up heat in a forward flow and recaptures heat in a reverse flow;
 - wherein a first cylinder outlet/inlet gap and at least one annulus with a second outlet/inlet gap operatively connected between, say the first and second cylinder, wherein the first cylinder outlet/inlet gap and the second outlet/inlet gap comprise the annulus;
 - wherein the inlet/outlet gaps are optionally configured for intake or exit of thermal fluid;
 - wherein the first cylinder is operatively connected to a plurality of heat storage materials that are cross-sectional layered with a hollow of the first cylinder forming a free flow duct, wherein the plurality of cross-sectional heat storage materials is operatively connected to a plurality of concentric insulator materials and/or phase change material, around the layered heat storage material;

wherein the center cylinder is optionally a sole duct filled with the plurality of heat storage materials in a layered configured such that the center cylinder is concentrically surrounded by one or more of other cylinders;

wherein the annulus is configured in one of the ways: (i) to carry insulations or phase change materials or both and in which case, beyond these concentric layers of insulation/phase change materials a gap exists for the fluid to freely flow in or out of the system from yet another annulus,(ii) as layered material surrounded by concentric insulators and/or phase change materials, or (iii) be populated with layered heat storage materials with a free flow annular gap;

wherein the heat storage material is configured to optionally occupy the entire cross-section or part of the cross-section of the annulus, optionally occupy parts of the length of the system across the cross-section or one or more sections of heat storage material separated by gaps.

55. The system of claim 52, further comprises sections disposed within cross-sectional gaps.
56. The system of claim 52, wherein the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
57. The system of claim 52, wherein the heat storage material section is designed as a separate section with stronger walls attached to other segment of the system thorough via bolts, nuts, and other connectors.
58. The system of claim 52, wherein the system is used in large-scale or small-scale operations below the ground, whereby a well is configured as an outer cylinder.
59. The system of claim 52, wherein the system used in large-scale or small-scale operations as a single unit Capsular Adiabatic Compressed Air Energy Storage System (Adiabatic CAES Capsule) comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
60. The system of claim 54, wherein the system used on small-scale operations comprises a retro-fit configured to be placed below ground as a single unit Compressed Air Energy Storage System in a capsule comprising a head configured as a semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
61. The system of claim 52, wherein the system is configured to use a cross-sectional layered heat storage technique coupled with phase change material to extract and deliver heat to and from a thermal fluid.
62. The system of claim 52, wherein the system is configured to use a concentric layered technique coupled with phase change material and/or insulation to prevent heat loss, wherein the phase change material traps heat.
63. The system of claim 52, wherein the lower section comprises perforations disposed on a surface of a second portion of the first cylinder, a second segment of the fourth cylinder, one or more insulation materials and phase change materials, and one or more heat storage materials such that a side of one or

more insulation materials resides opposite to a side of one or more heat storage materials, wherein the side of one or more insulation materials and the side of one or more heat storage materials are separated by the duct.

64. The system of claim 52, wherein the system is configured as a single unit for separating heat from a thermal fluid and store the heat and the fluid and a reverse flow of fluid recaptures the heat with the stored fluid as it exits the system.
65. The system of claim 52, wherein the system is used in large-scale or small-scale operations above ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
66. A two-end flow system for storing and retrieving energy, comprising:
 - a duct operatively connected to at least a first cylinder, a second cylinder, and a third cylinder or possibly more, wherein the first cylinder is operatively connected to a plurality of heat storage materials that are cross-sectional layered within it;
 - a plurality of gaps, wherein the plurality of gaps comprises a first cylinder outlet/inlet gap at one end and an inlet/outlet gap at the other end or inlet/output gaps from somewhere along the longitudinal side of the cylinder;
 - wherein the plurality of heat storage materials is operatively connected to a plurality of insulator materials, concentrically around the layered heat storage material;
 - wherein the heat storage material is configured to occupy the entire cross-section or part of the cross-section of the inner cylinder or parts of the length of the system across the cross-section, whereby multiple sections are disposed within cross-sectional gaps;
 - wherein the entire length of the two-end system comprises at least a third cylinder and a fourth cylinder;
 - wherein the concentric ducts between cylinders are filled either with insulators or phase change materials or both insulator or phase change materials;
 - wherein the first cylinder outlet/inlet gap is disposed at both ends;
 - wherein the inlet/outlet gaps may be operative for intake or exit;
 - fluid is configured to move through the heat storage material to give up heat and flow in a reverse direction to recaptures the heat.
67. The system of claim 64, wherein the system is used in large-scale or small-scale operations above ground or below the ground with the heat storage material section comprises a stronger material and optional thicker wall cylinders, wherein the stronger material and the operational thicker wall cylinder are optionally separate from each other.
68. The system of claim 64, wherein the system is used in large-scale or small-scale operations below the ground, whereby an earth surface is configured as an outer cylinder.

69. The system of claim 64, wherein the system used in large-scale or small-scale operations as a single unit large scale heat storage capsule comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
70. The system of claim 64, wherein the system used in large-scale or small-scale operations as a retro-fit as a single unit large scale heat storage capsule comprises a head configured as semi-hemispherical, semi-ellipsoidal, or flat or of any shape.
71. A system for separating heat from fluid and store heat and fluid in a fluid network with interconnected nodes, comprising:
a symbiotic system,
plurality of conduits;
a heat storage system in each conduit;
wherein the fluid is hot, which enters and exits through individual nodes meters or kilometers apart
wherein each conduit of the plurality of conduits is configured for: fluid flow through the heat storage system, connect to other conduits to deliver more fluid flow and thermal energy to a particular node by opening a combination of valves;
wherein the fluid flow is configured to be thermal, thereby giving up heat when transported to a storage unit or residing in extended conduits beyond the heat storage unit;
wherein the flow from each node can superimpose on that of others in case of emergency to provide more energy to one or more selected nodes.
72. The system of claim 69, wherein the system resides completely below ground, partially above the ground, or completely above ground.

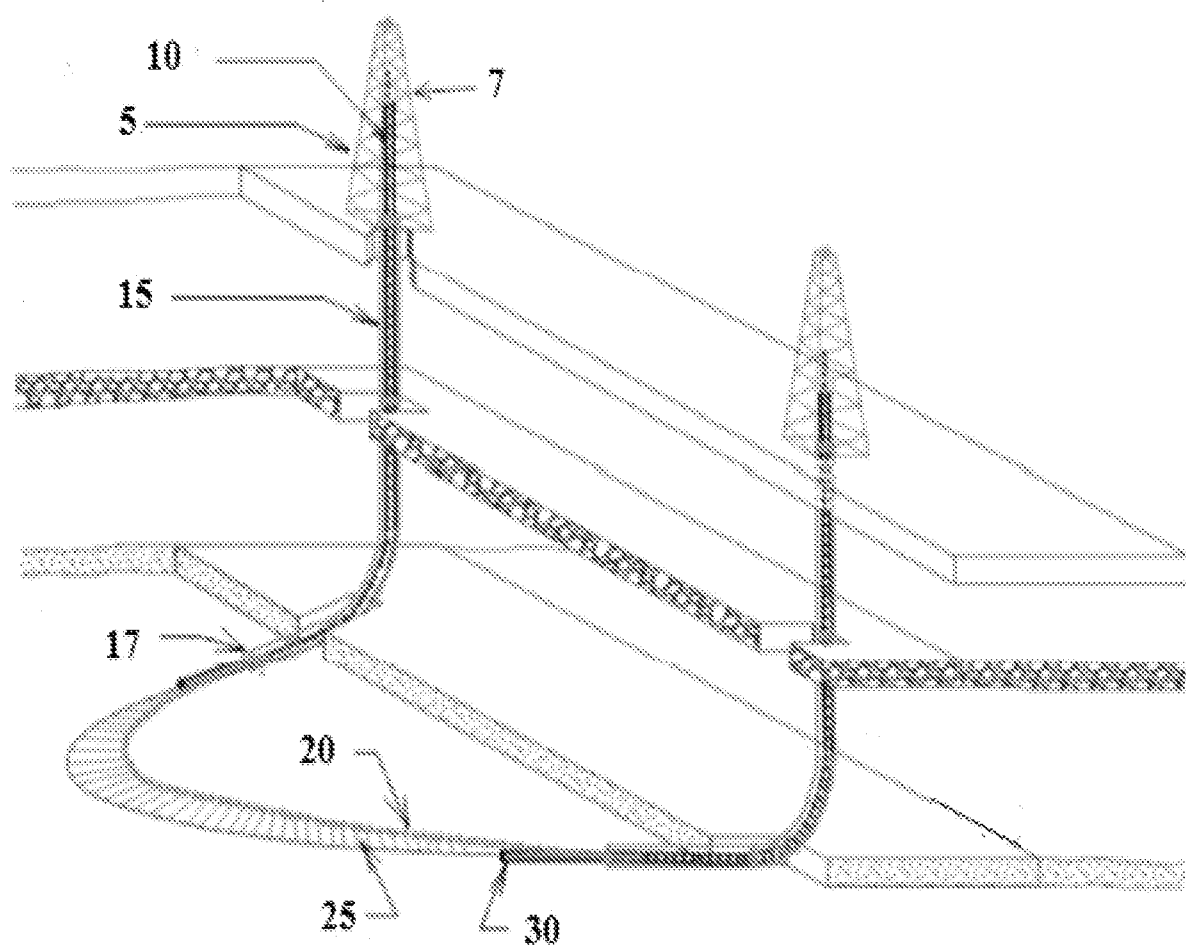


FIG. 1

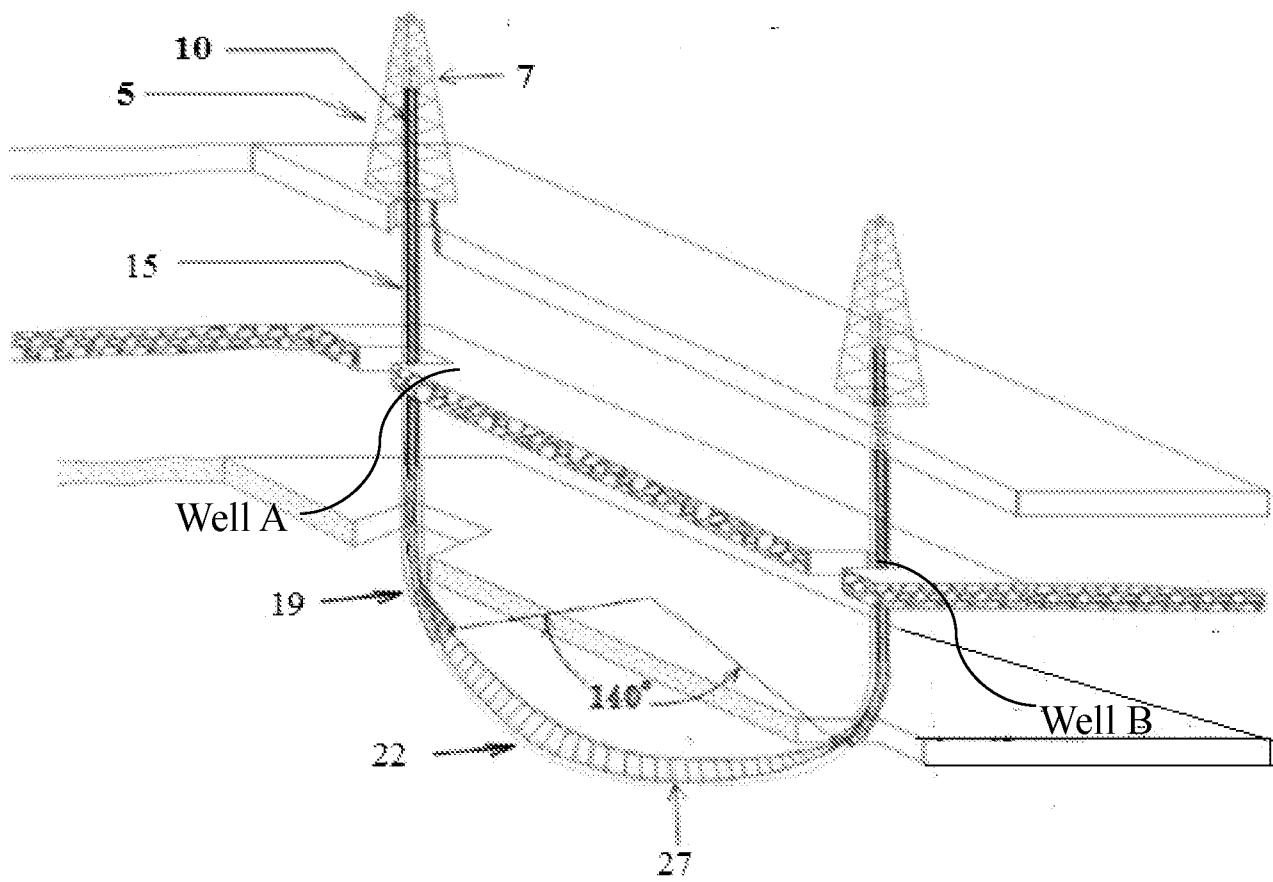


FIG. 2

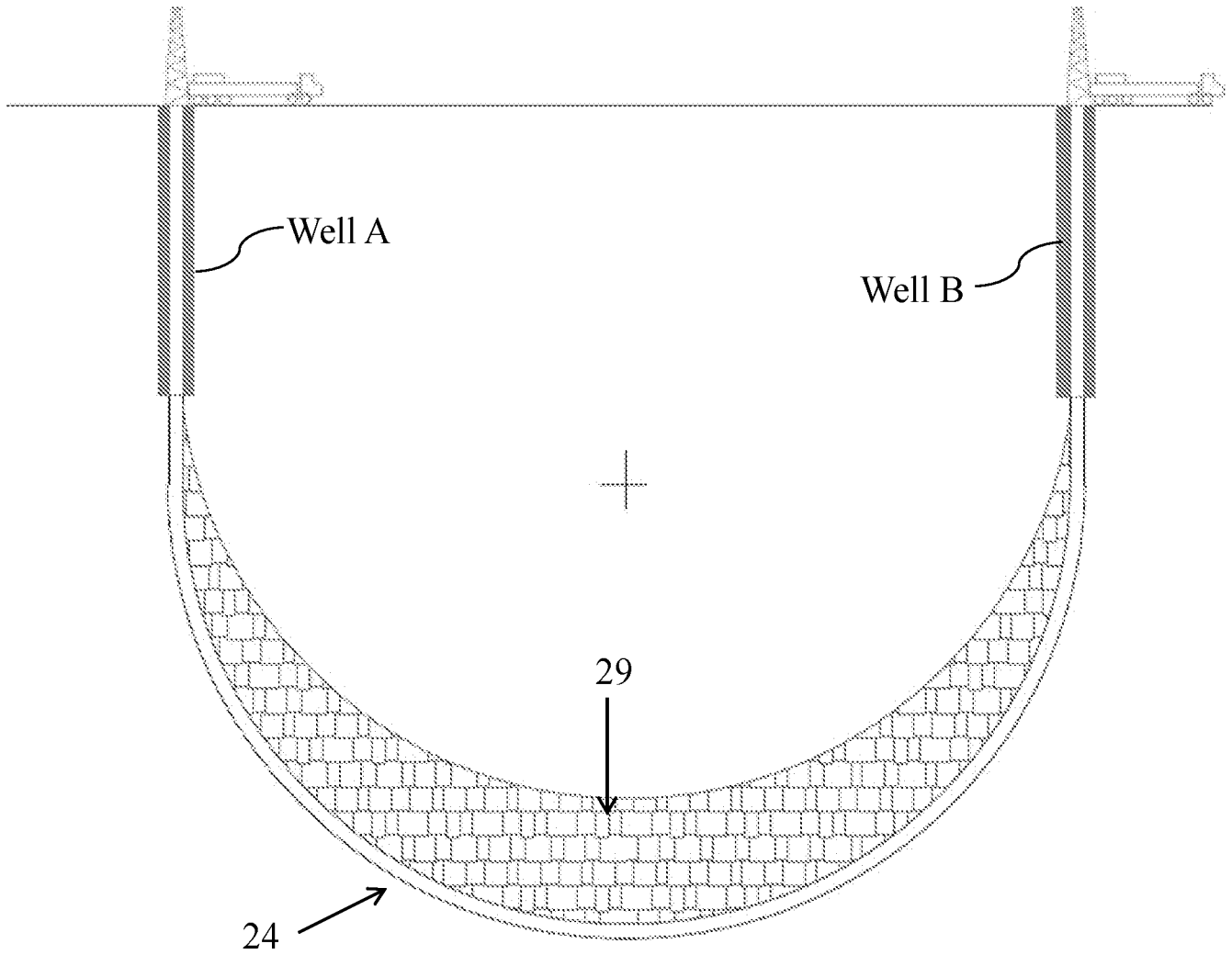


FIG. 3

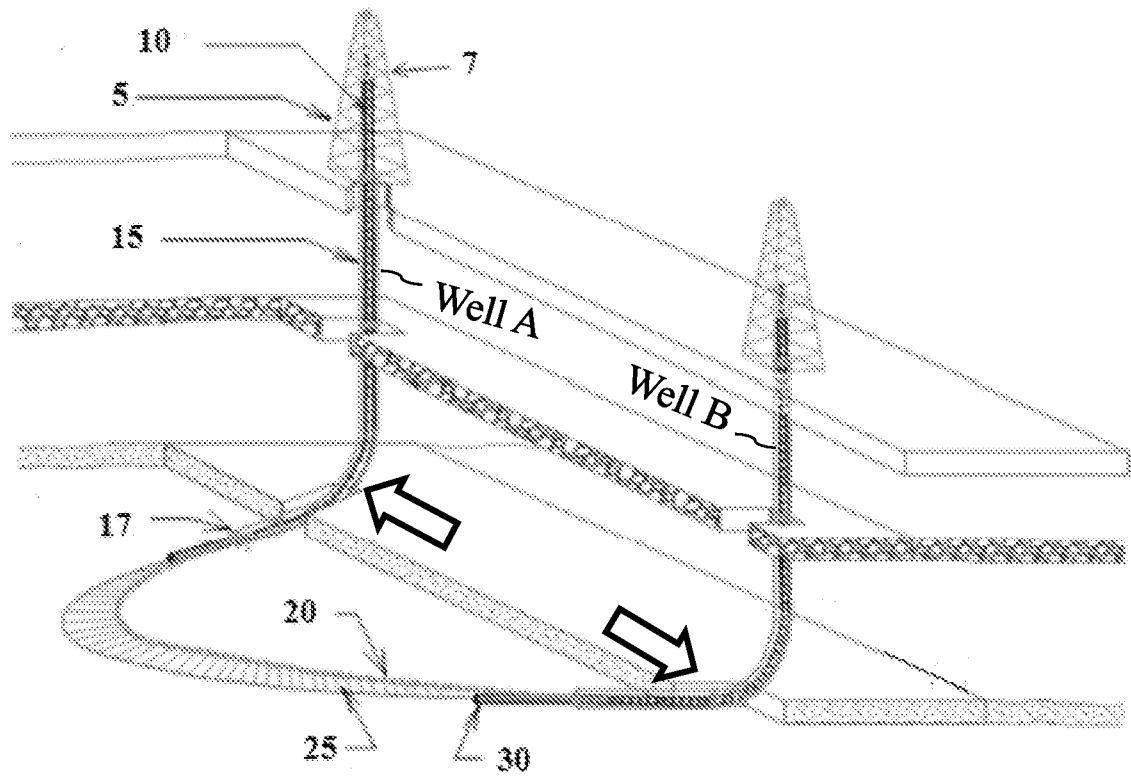


FIG. 4A

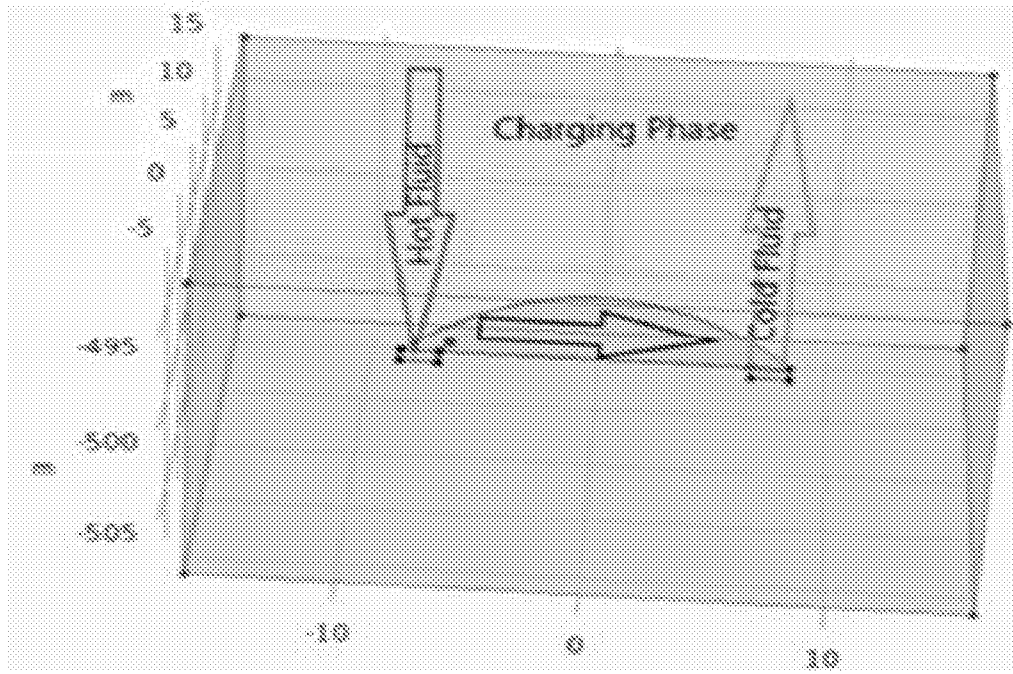


FIG. 4B

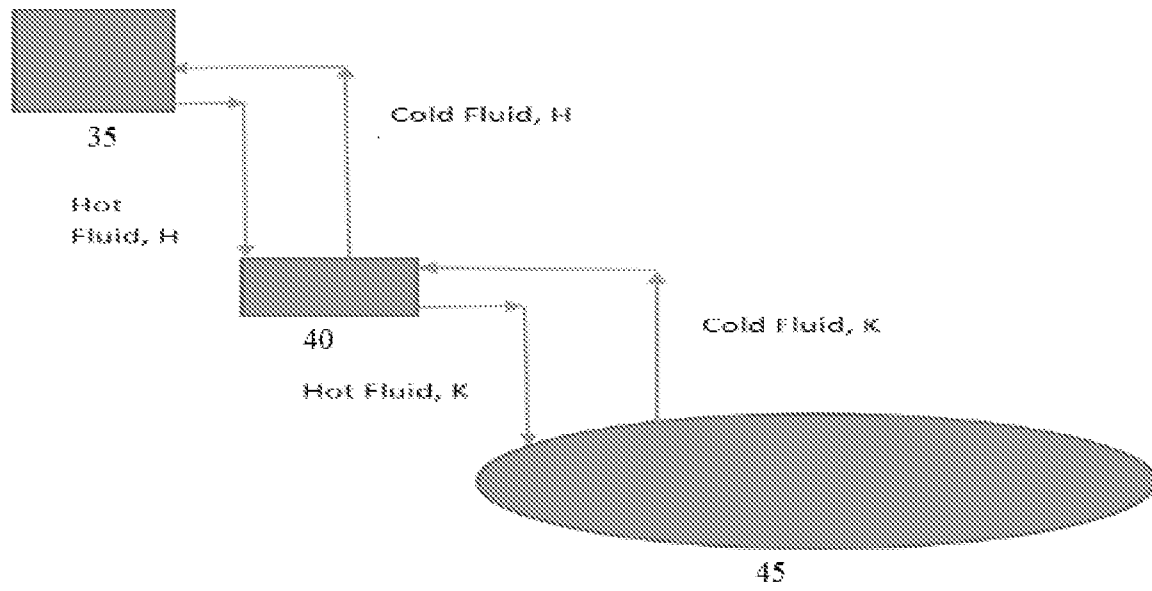


FIG. 5

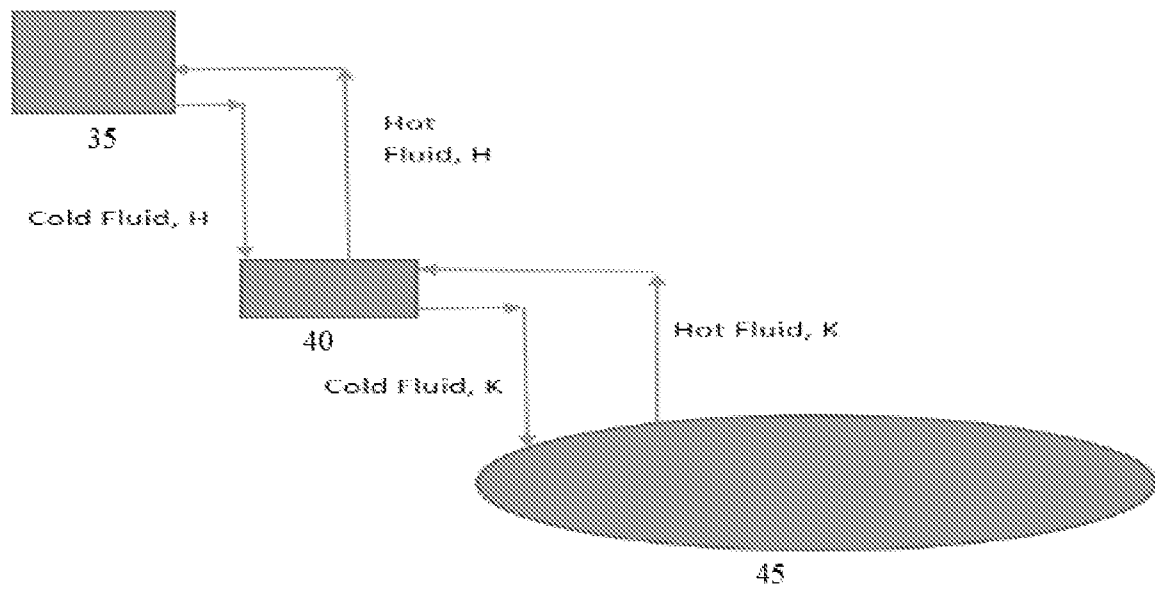


FIG. 6

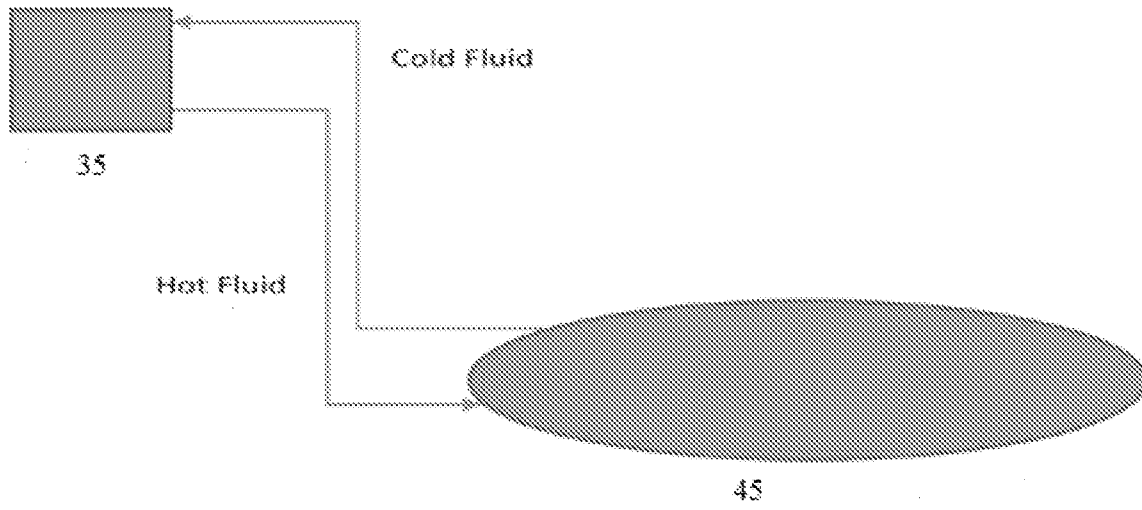


FIG. 7

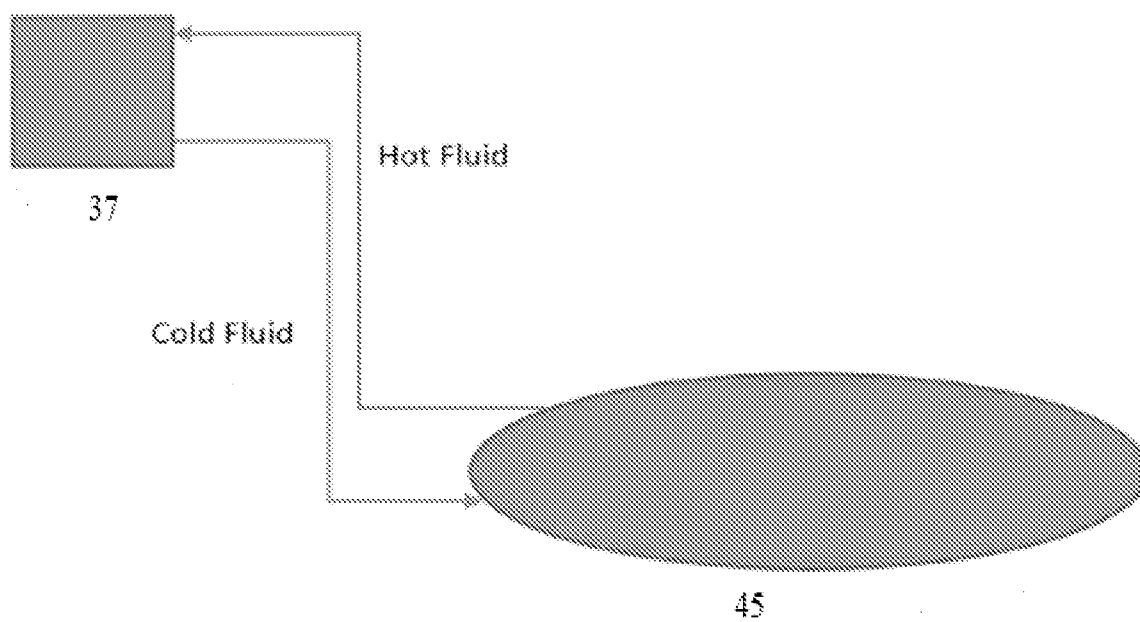


FIG. 8

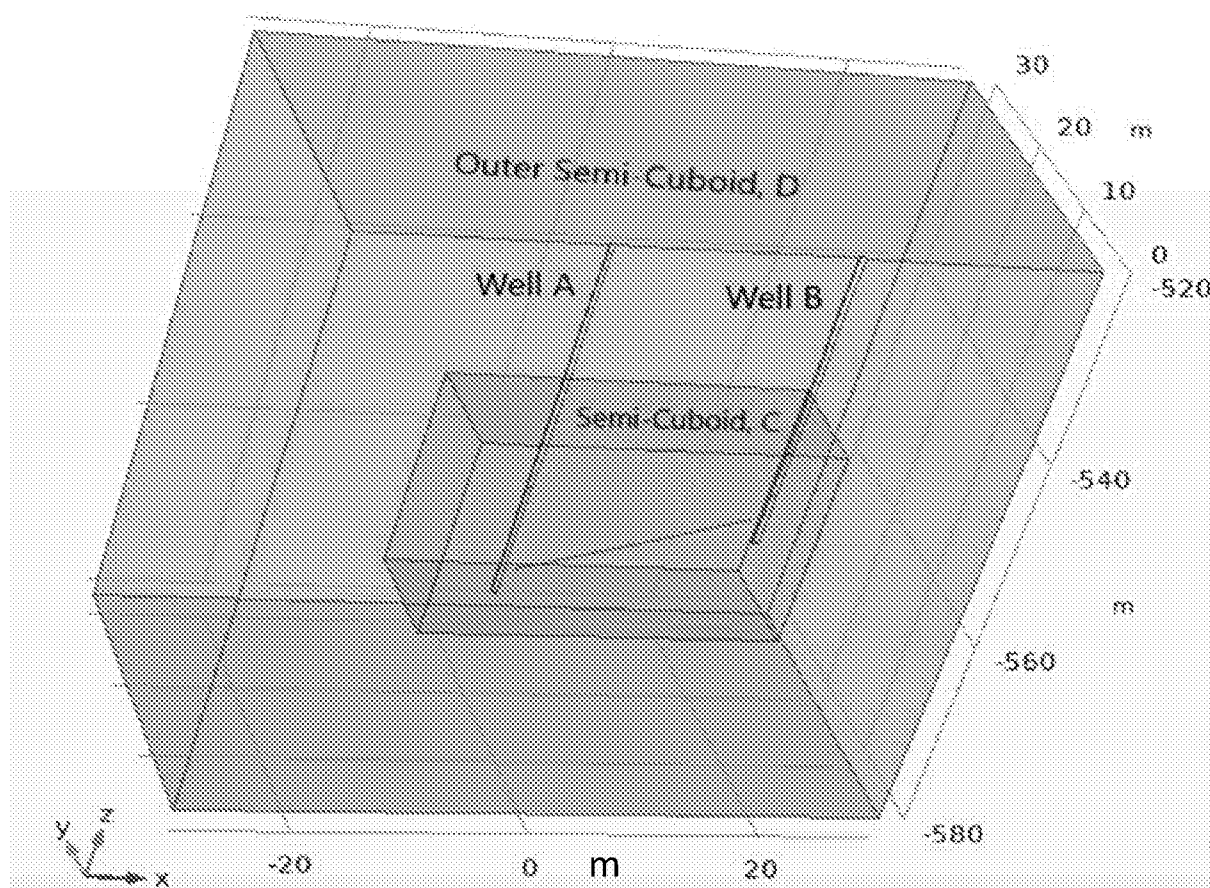


FIG. 9

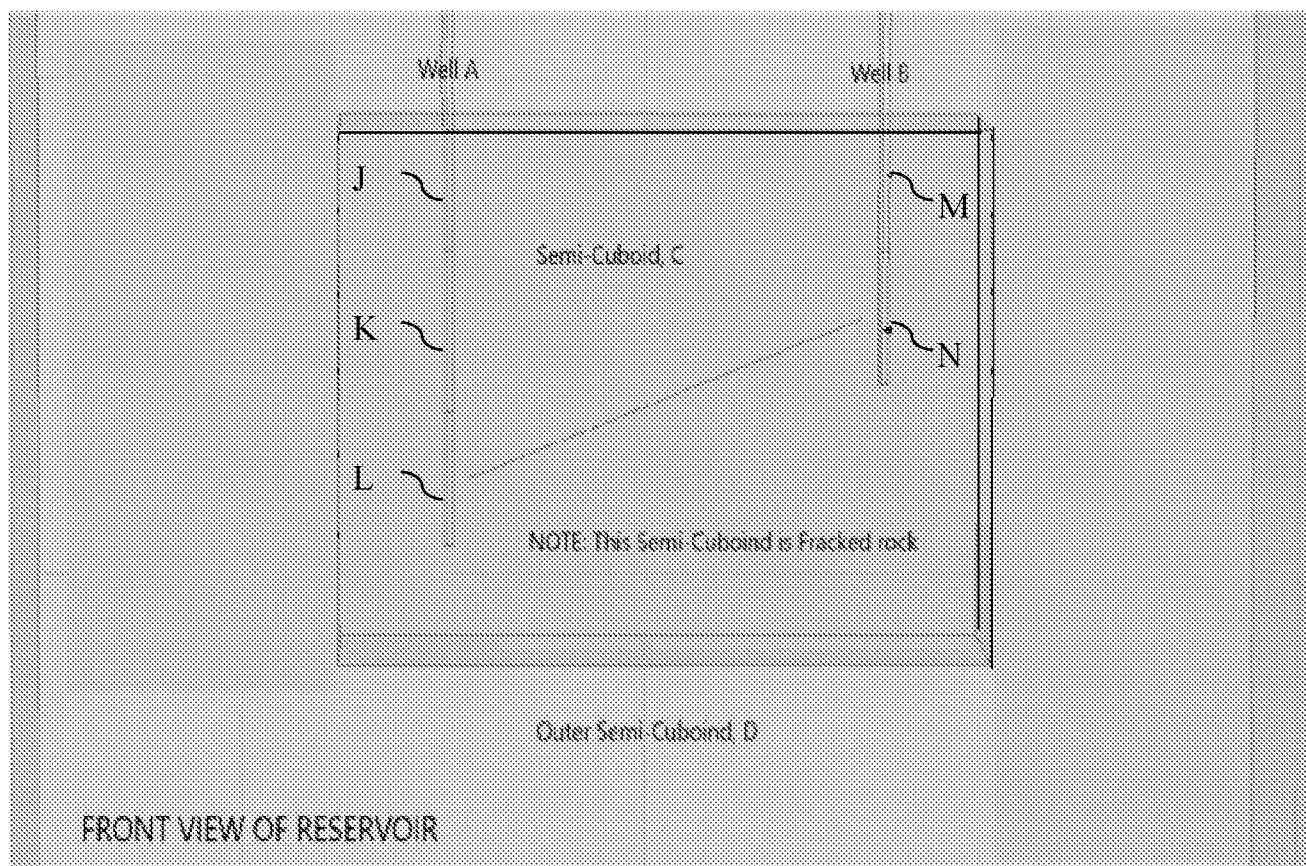


FIG. 10

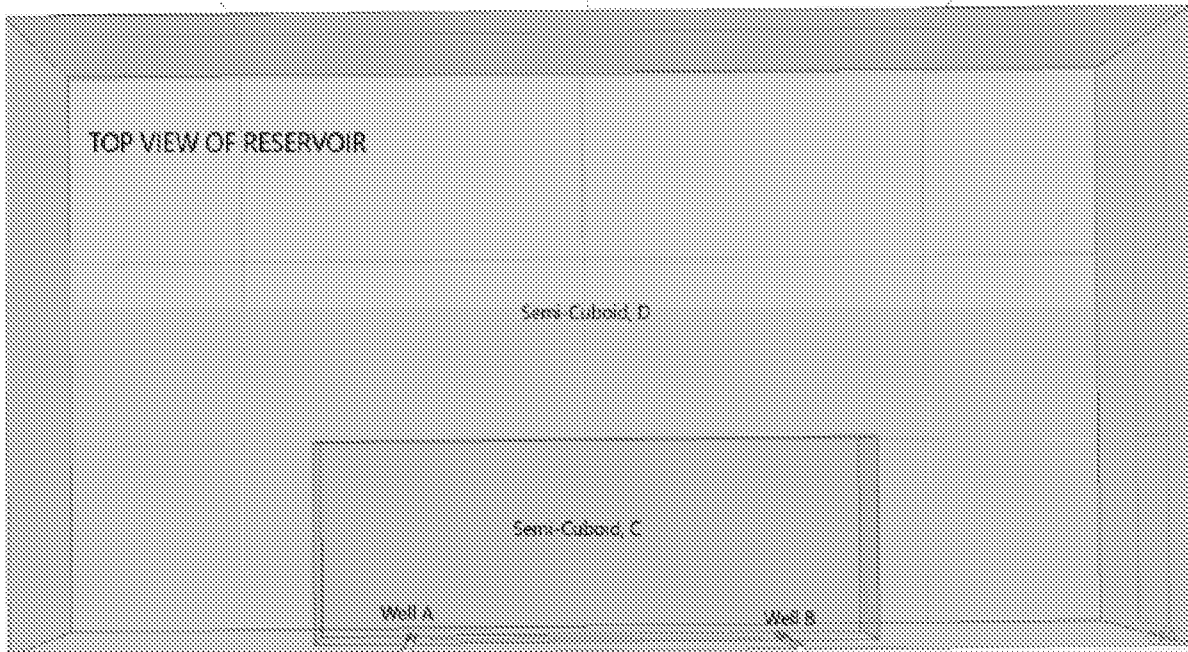


FIG. 11

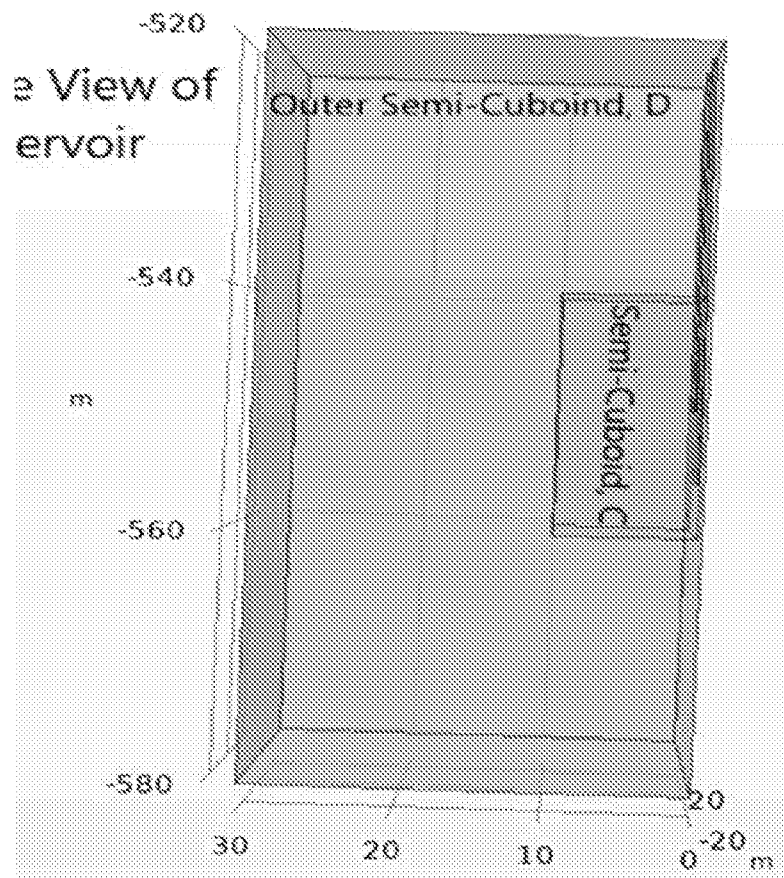


FIG. 12

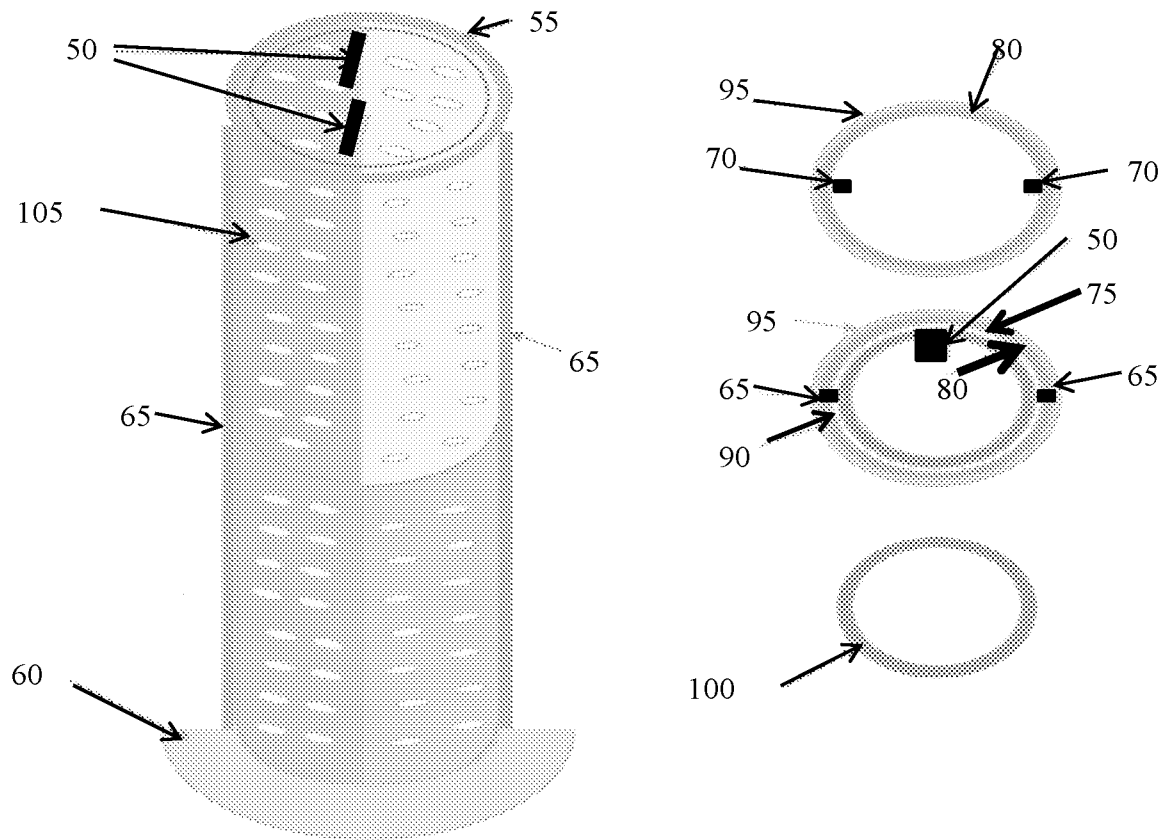


FIG. 13

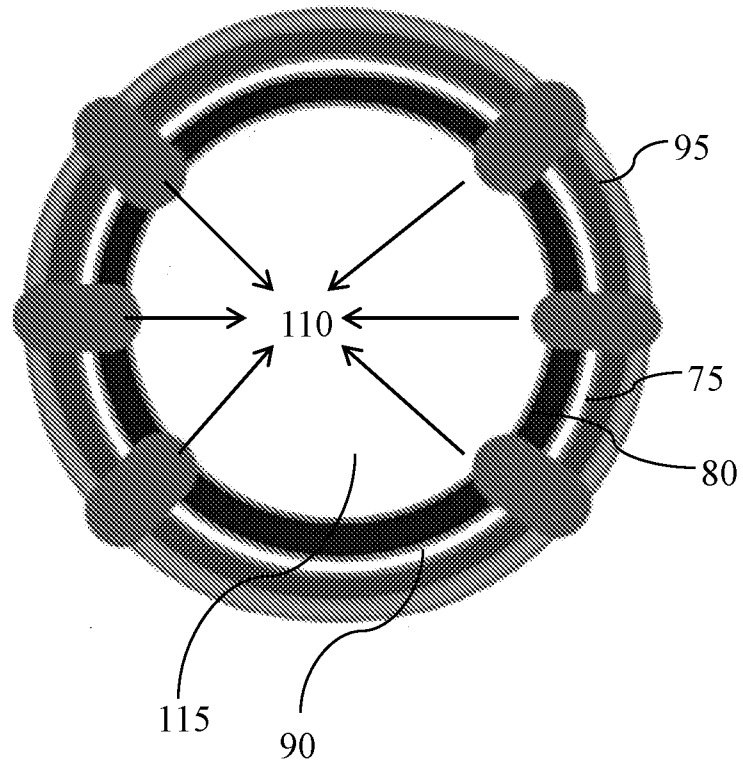


FIG. 14

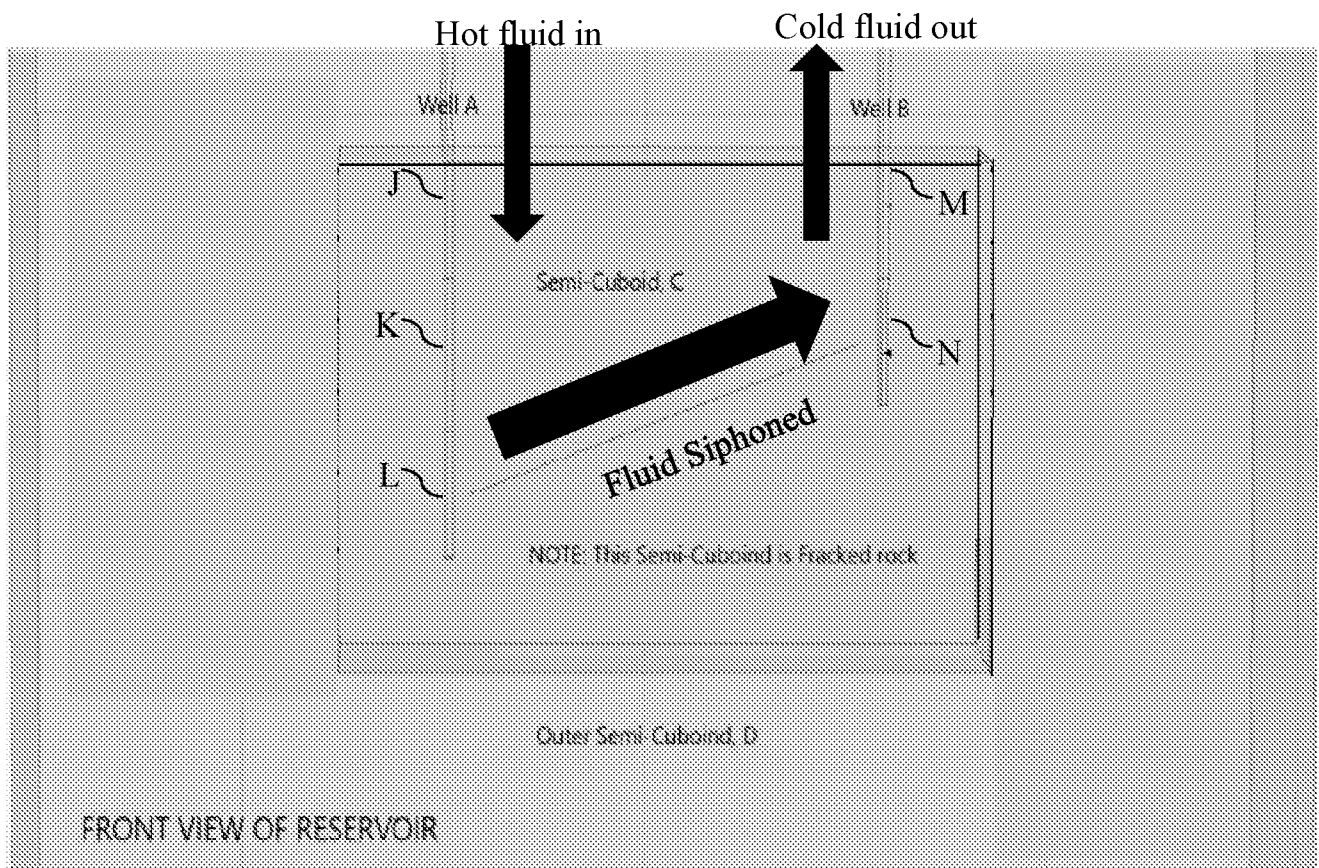


FIG. 15

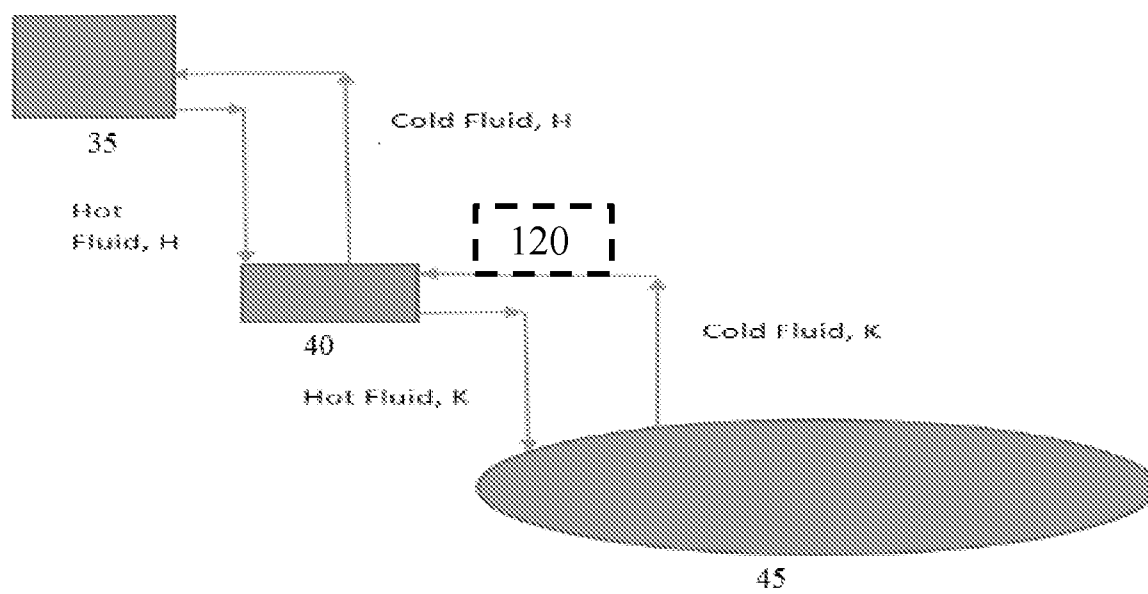


FIG. 16

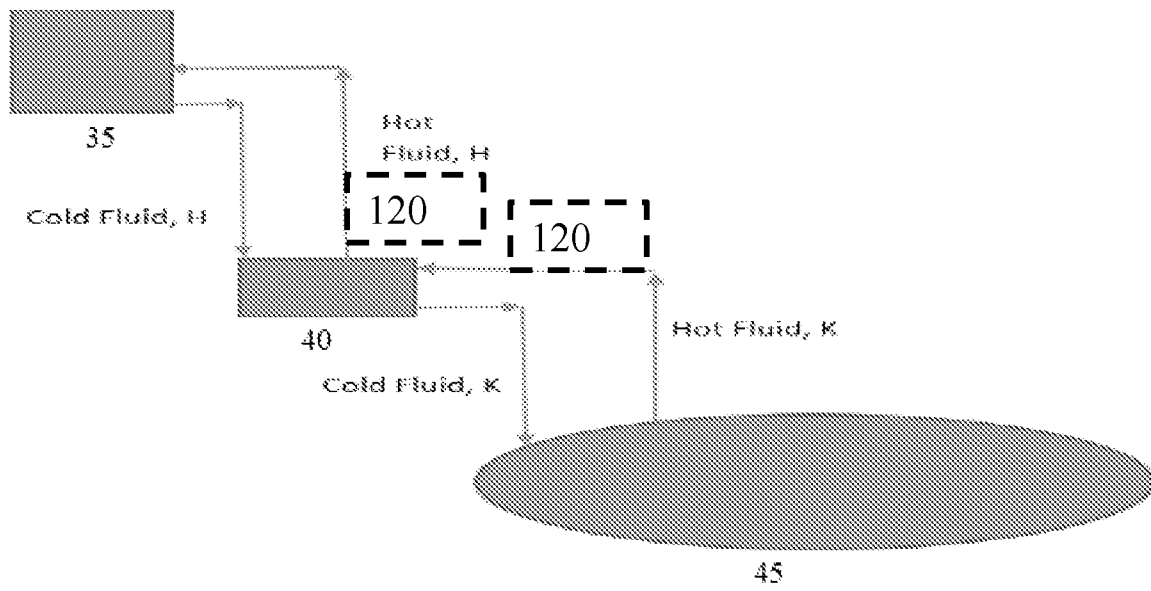


FIGURE 17

Mode 1:

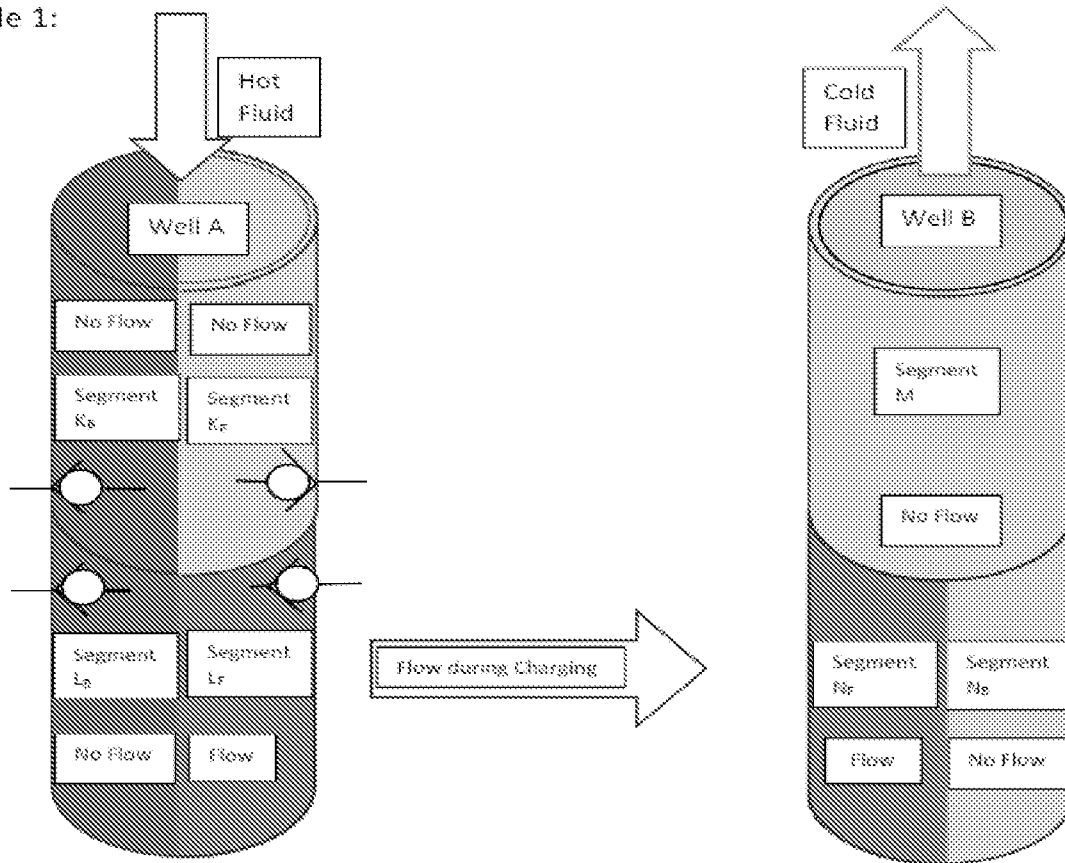


FIG. 18

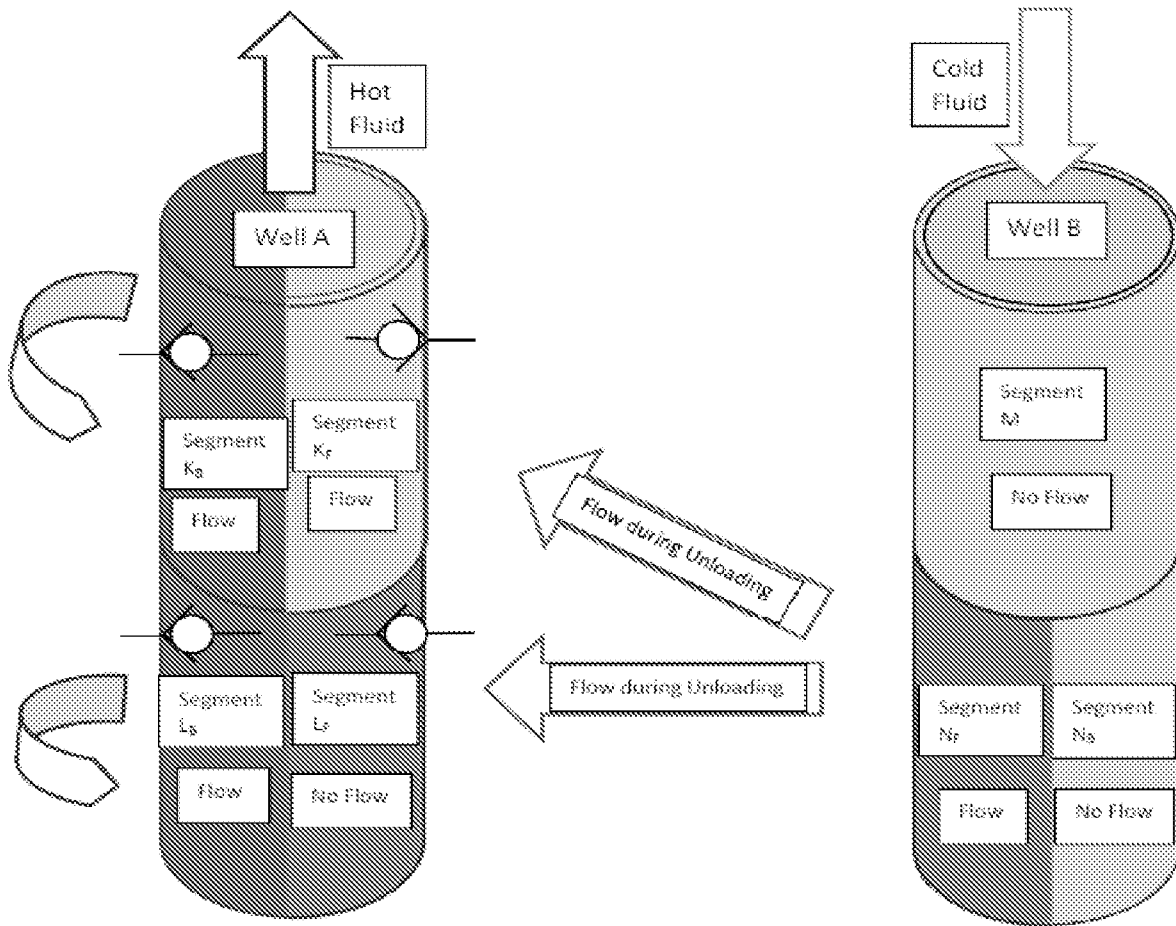


FIG. 19

Mode 2:

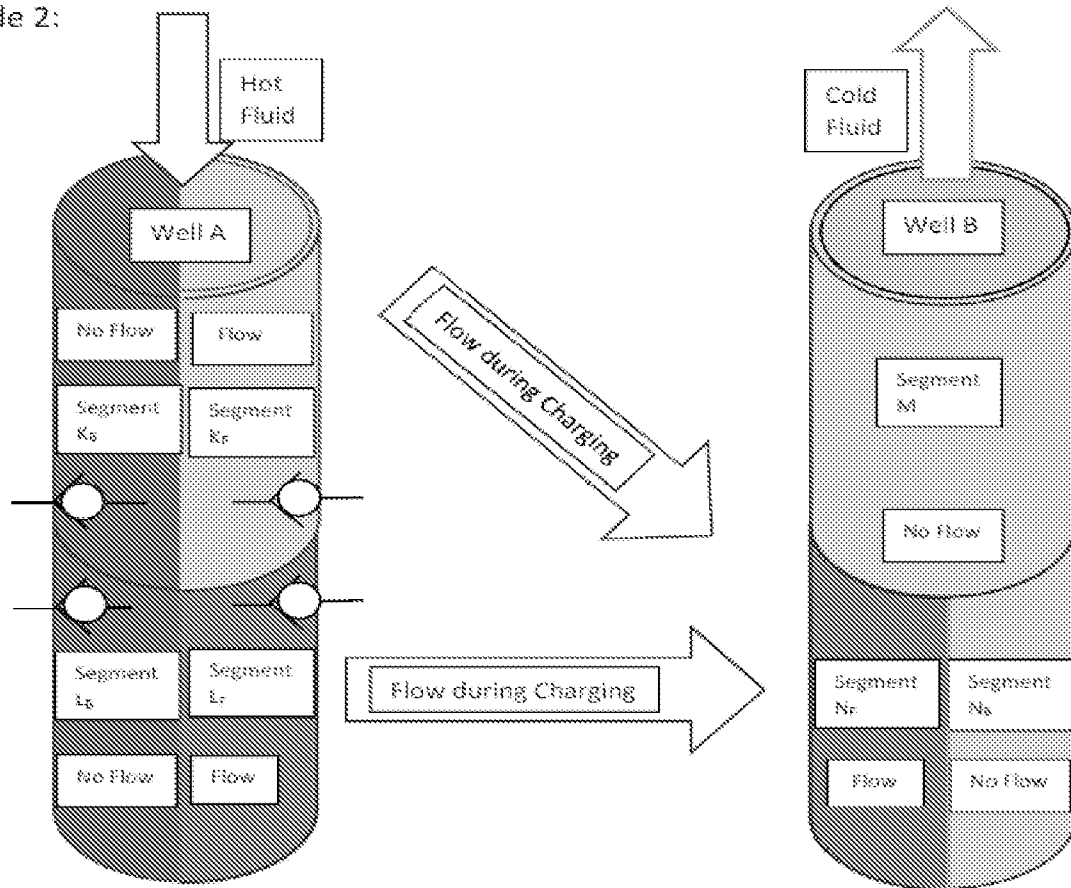


FIG. 20

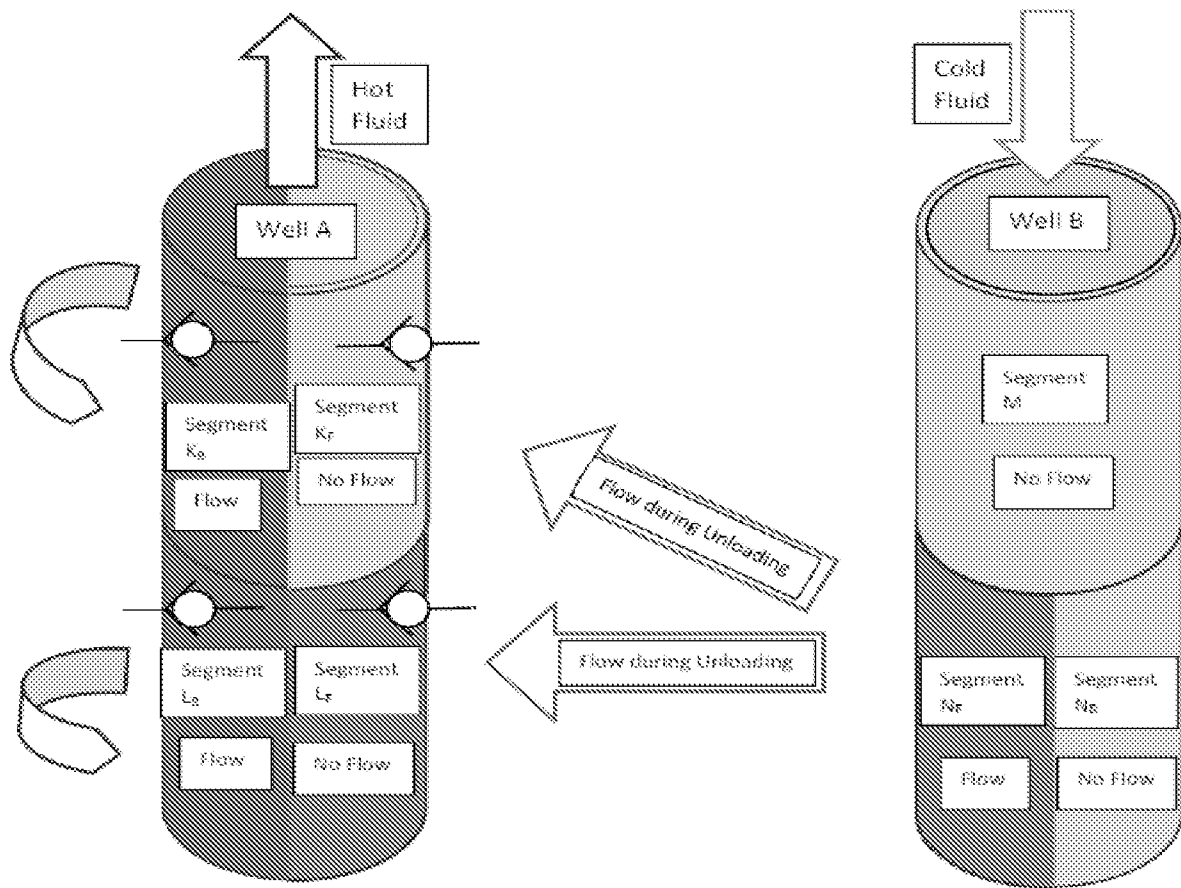


FIG. 21

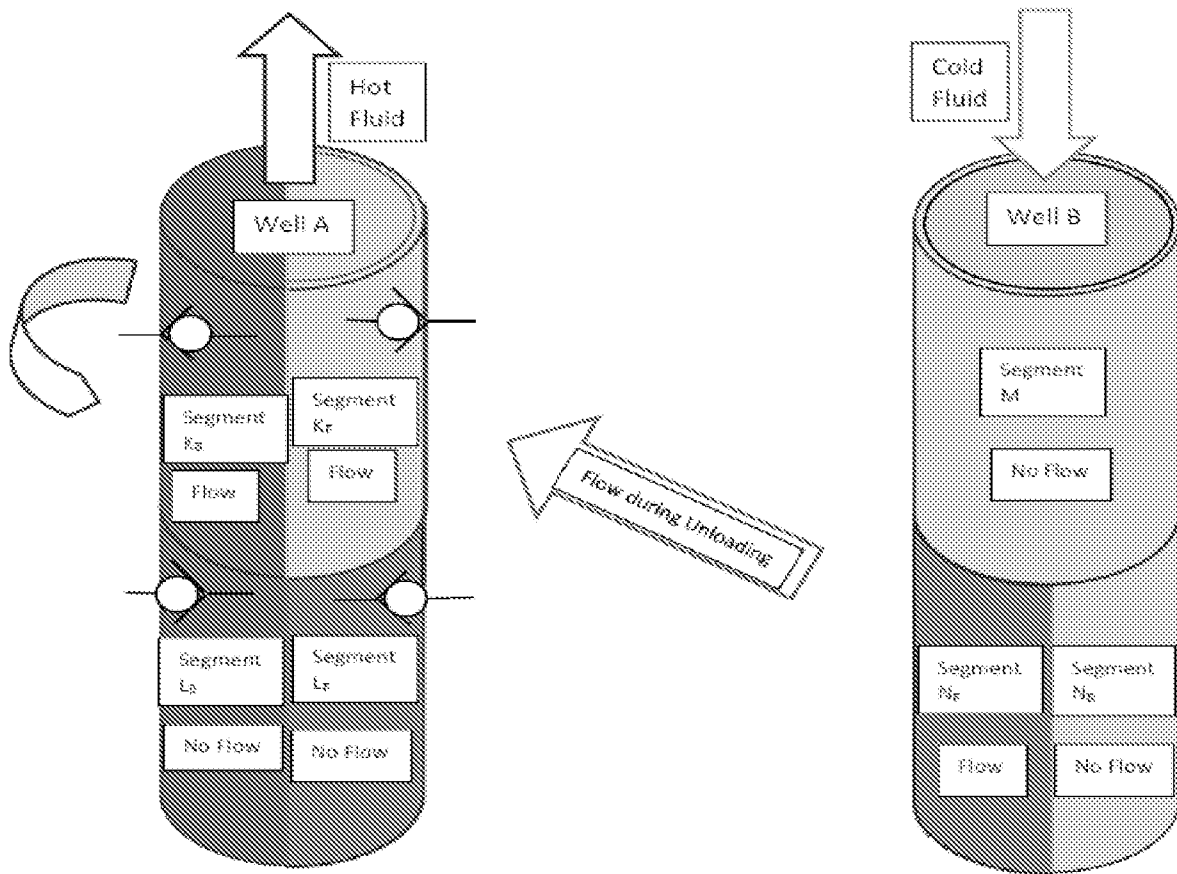


FIG. 22

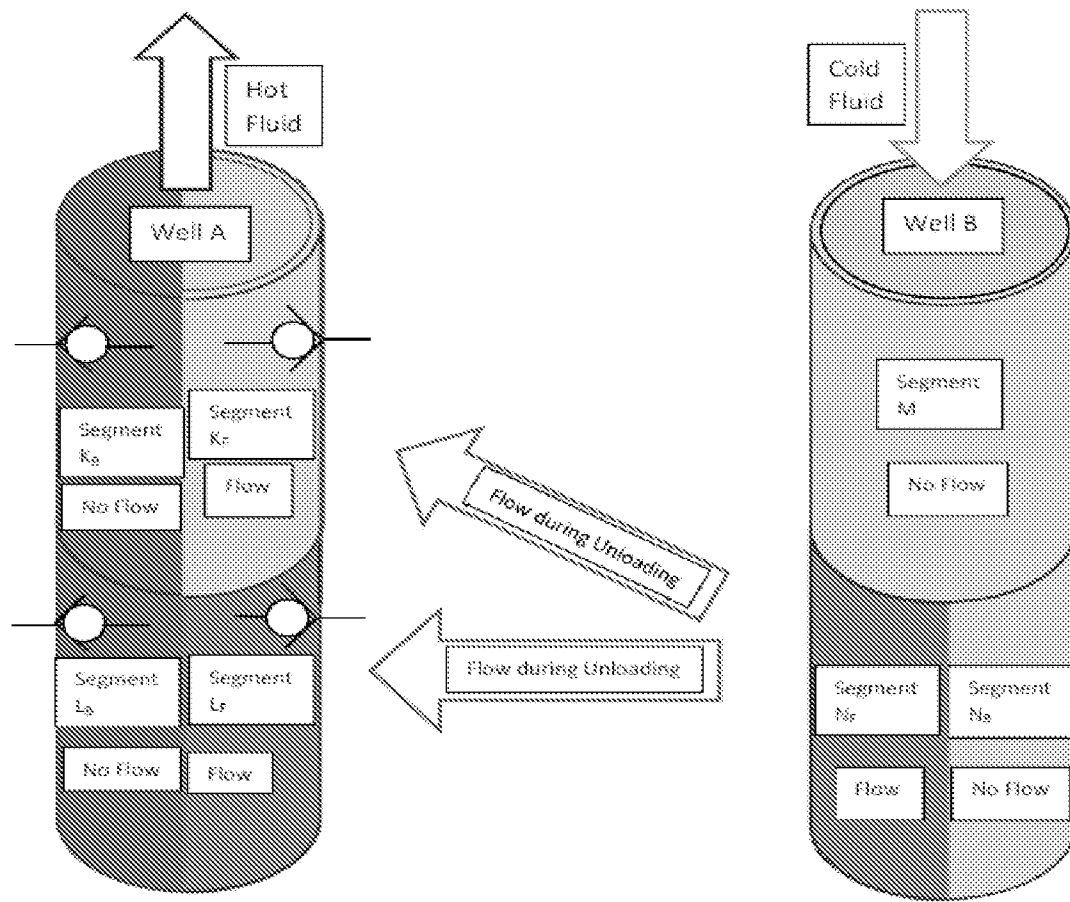


FIG. 23

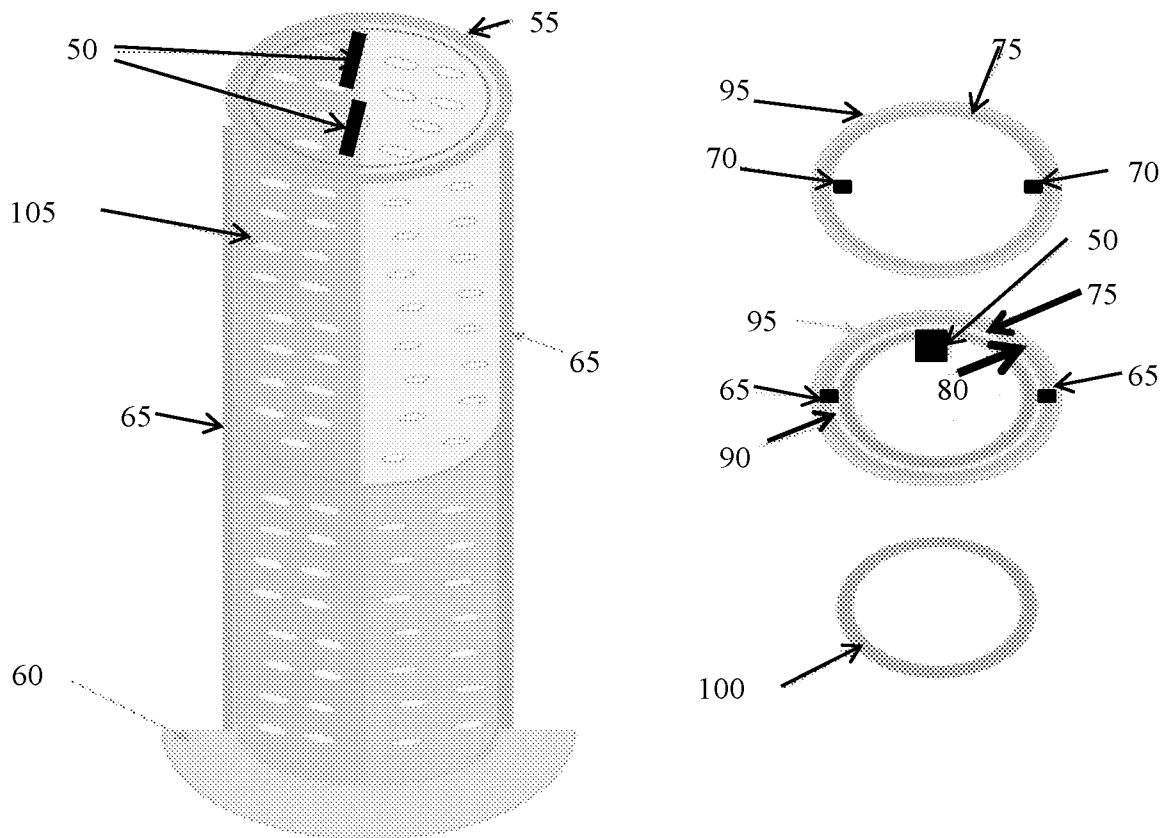


FIG. 24

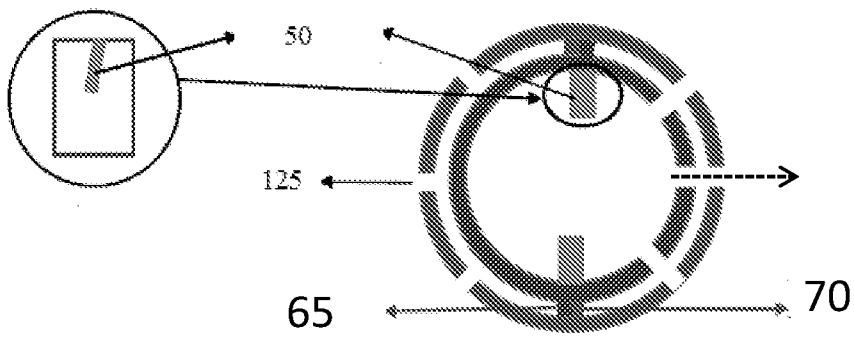


FIG. 25

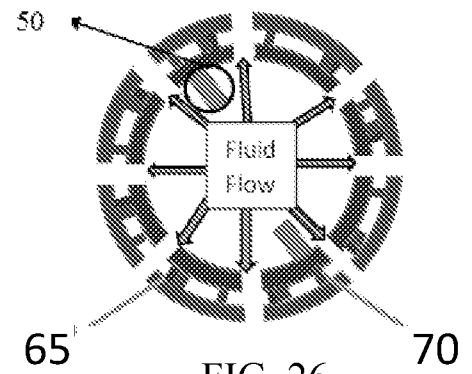


FIG. 26

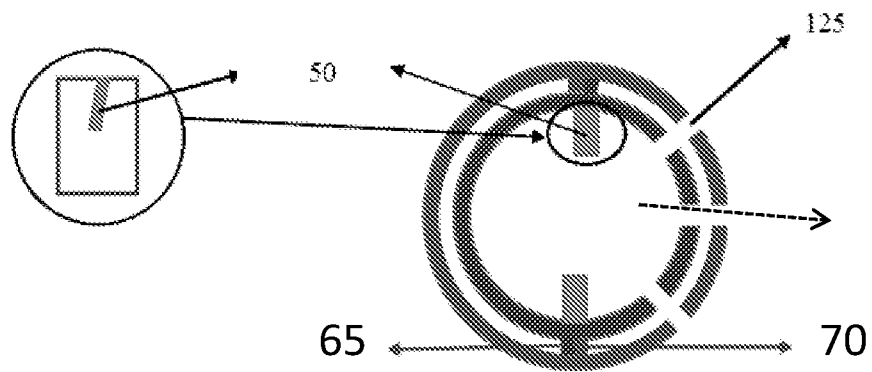


FIG. 27

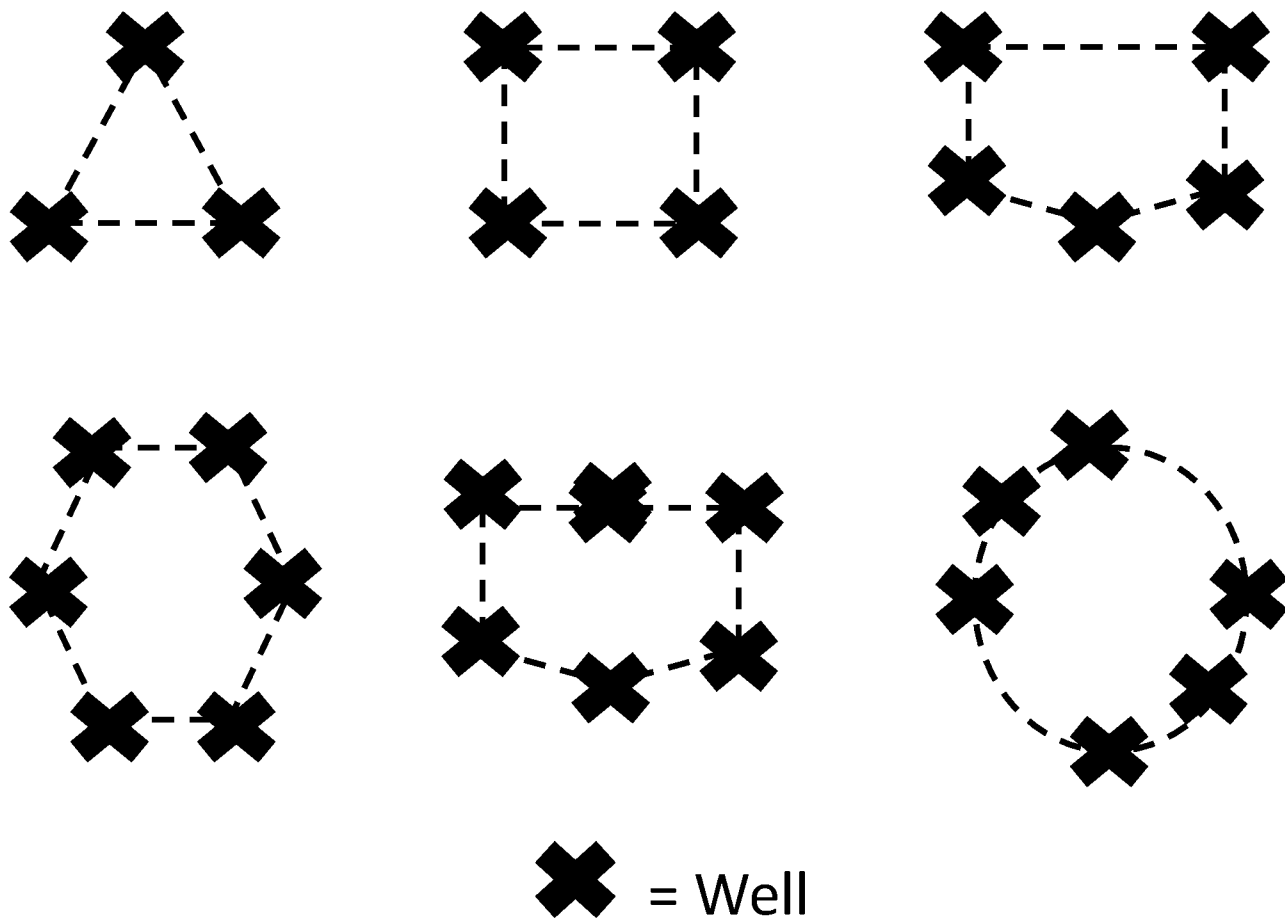


FIG. 28A

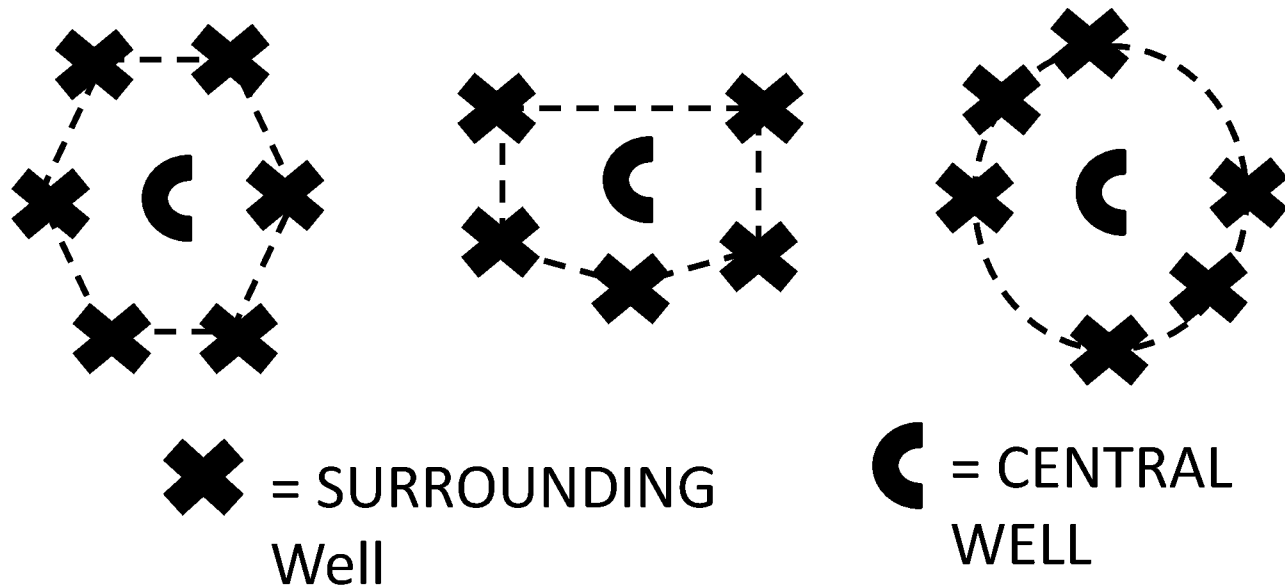


FIG. 28B

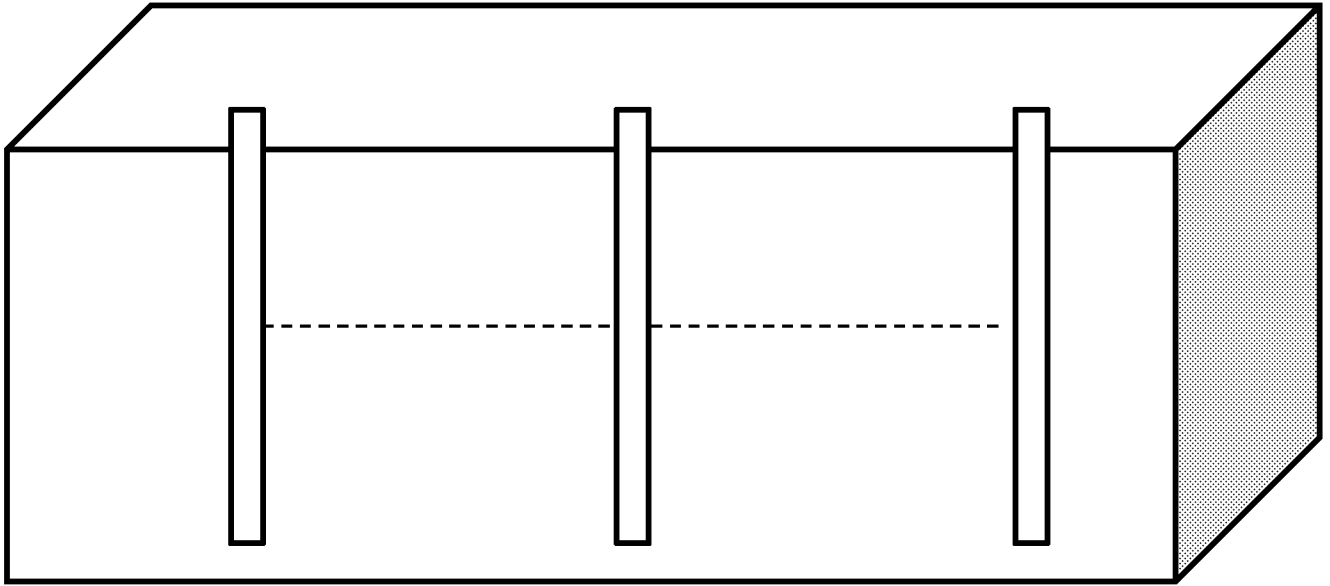


FIG. 29A

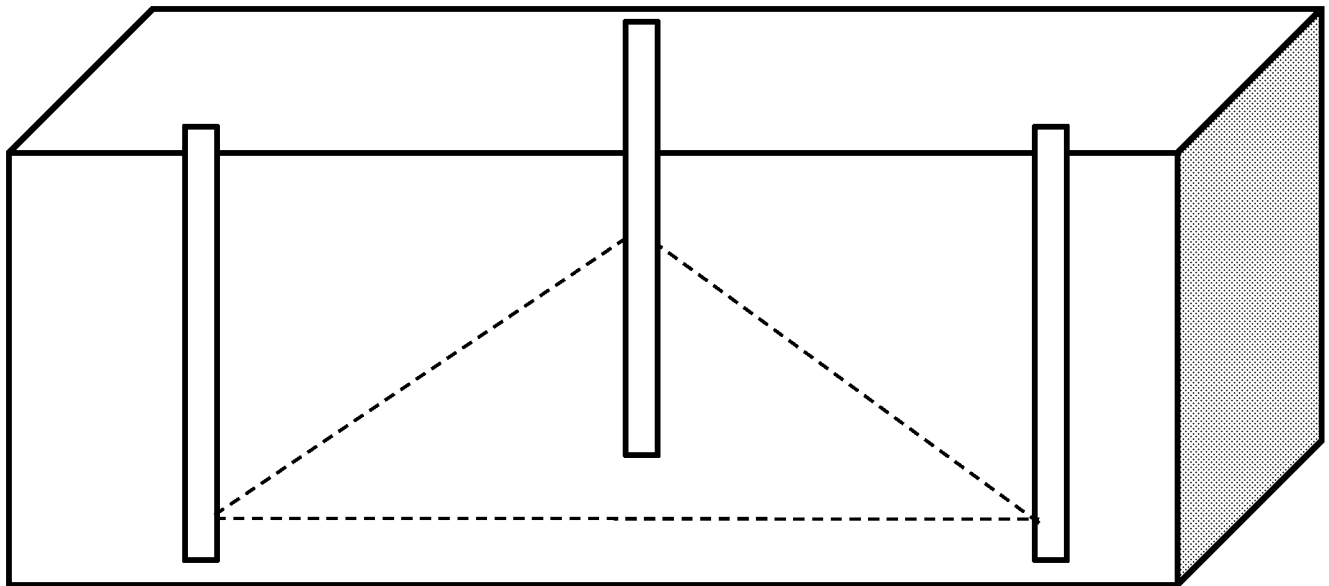


FIG. 29B

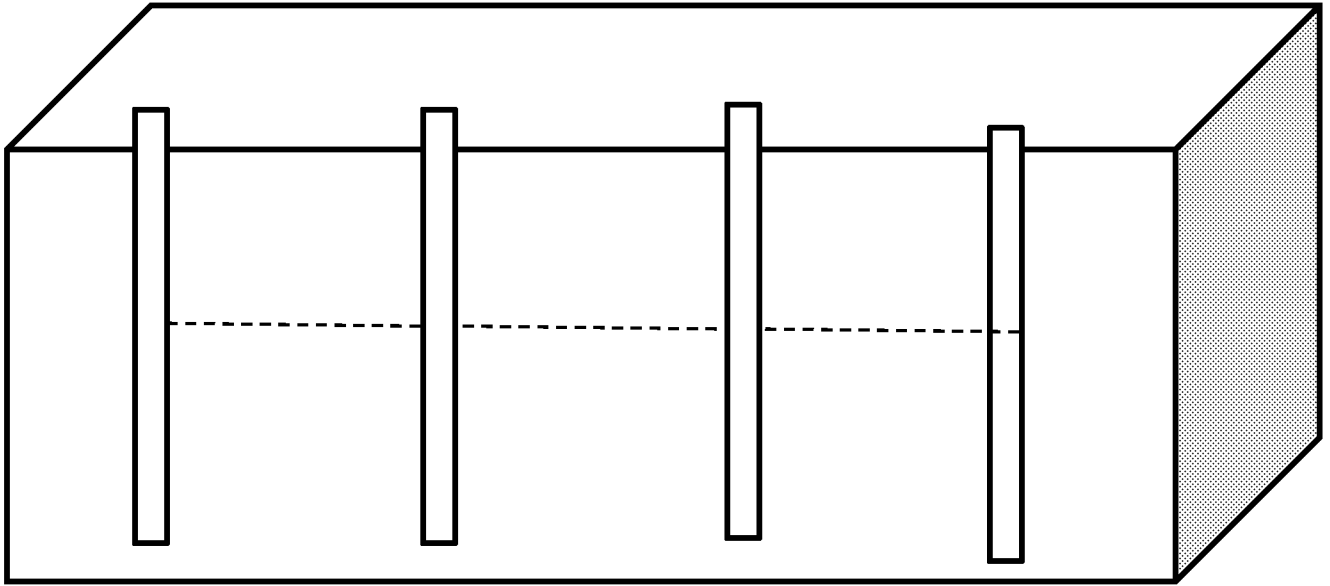


FIG. 30A

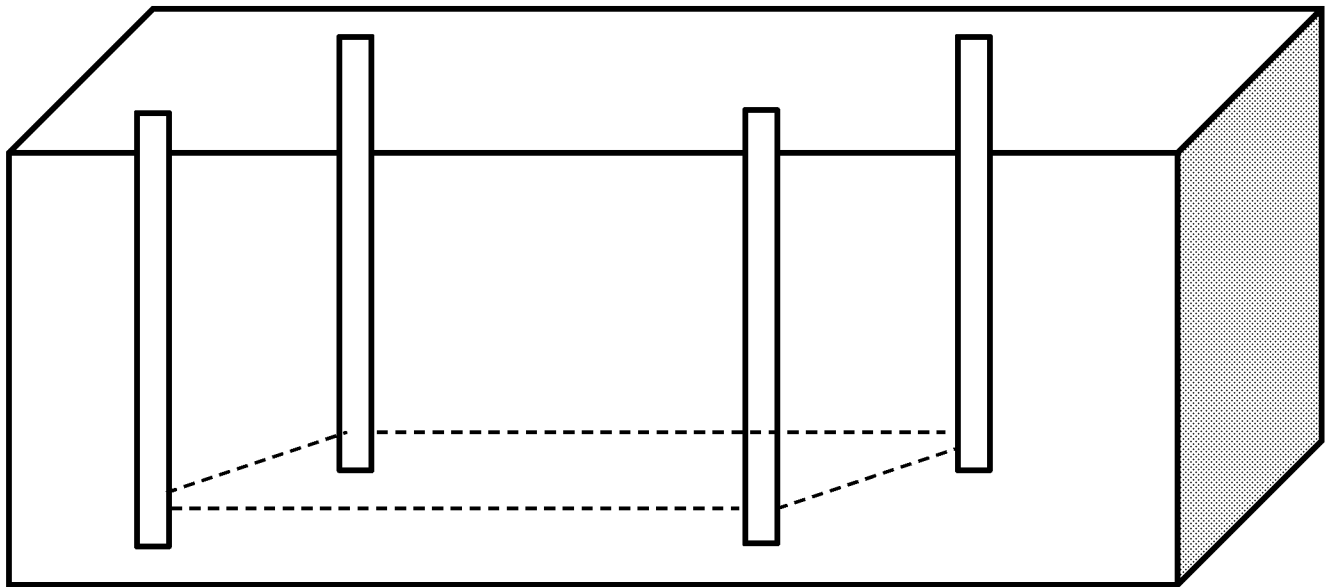


FIG. 30B

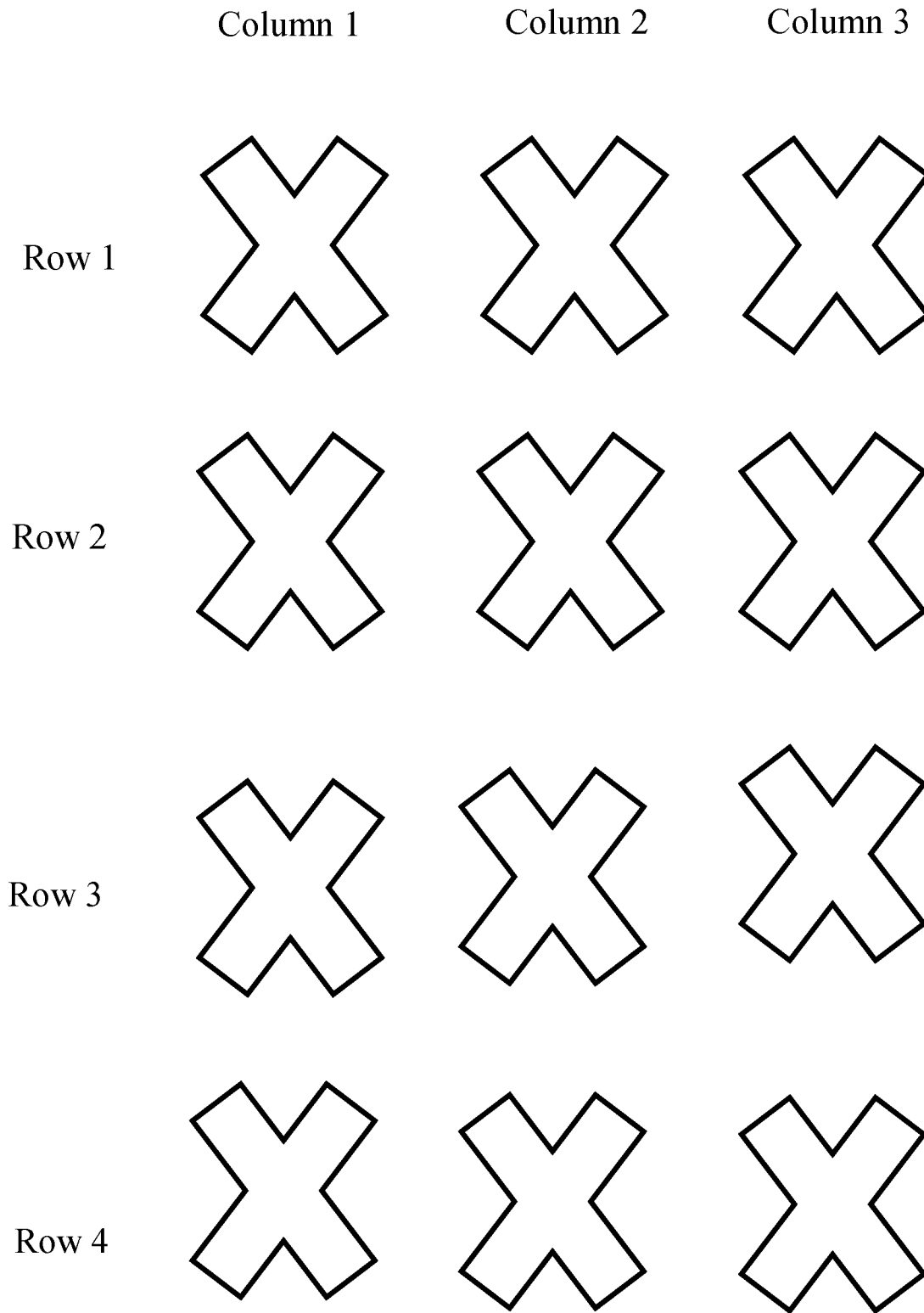


Fig. 31

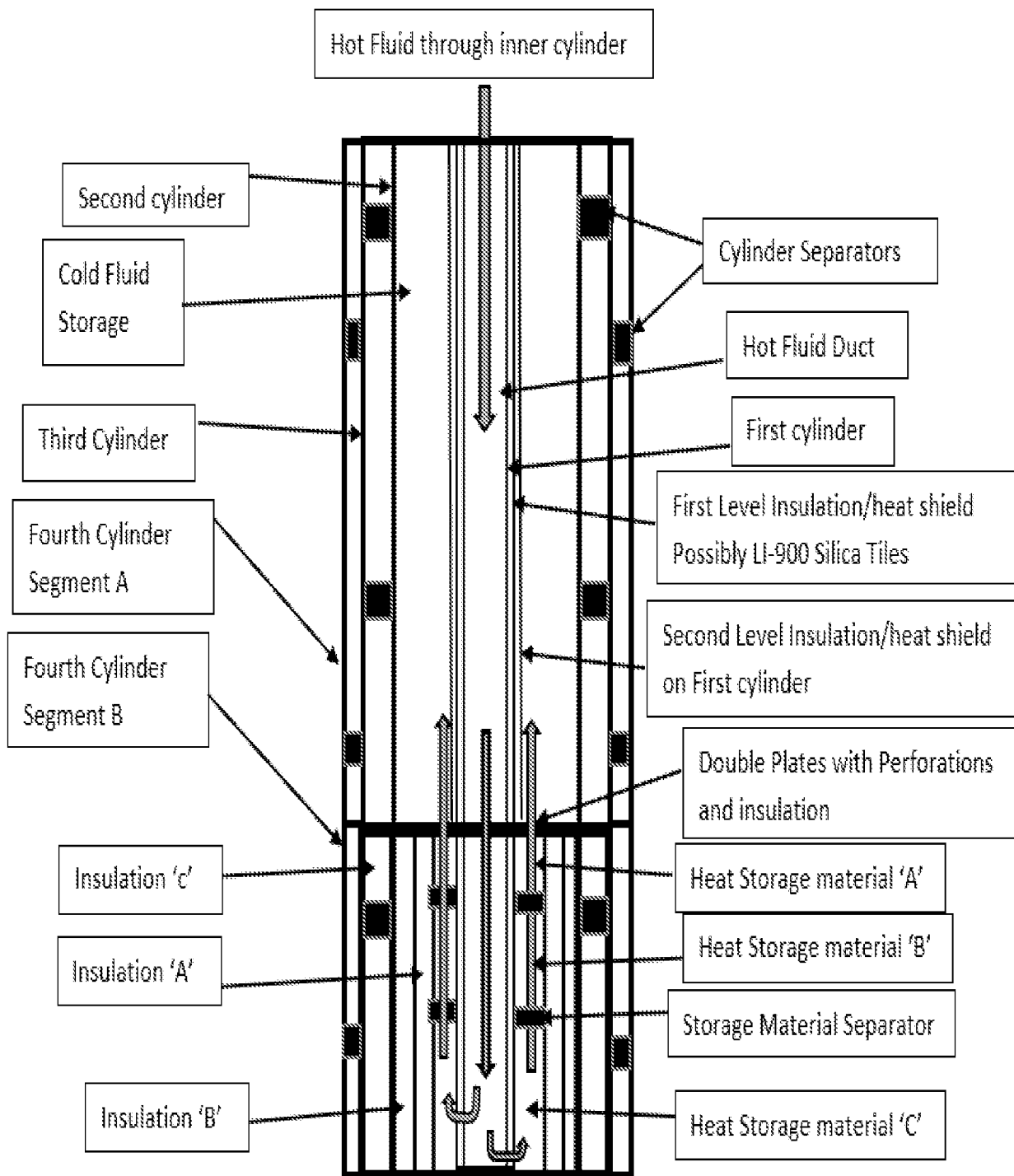


Fig. 32A

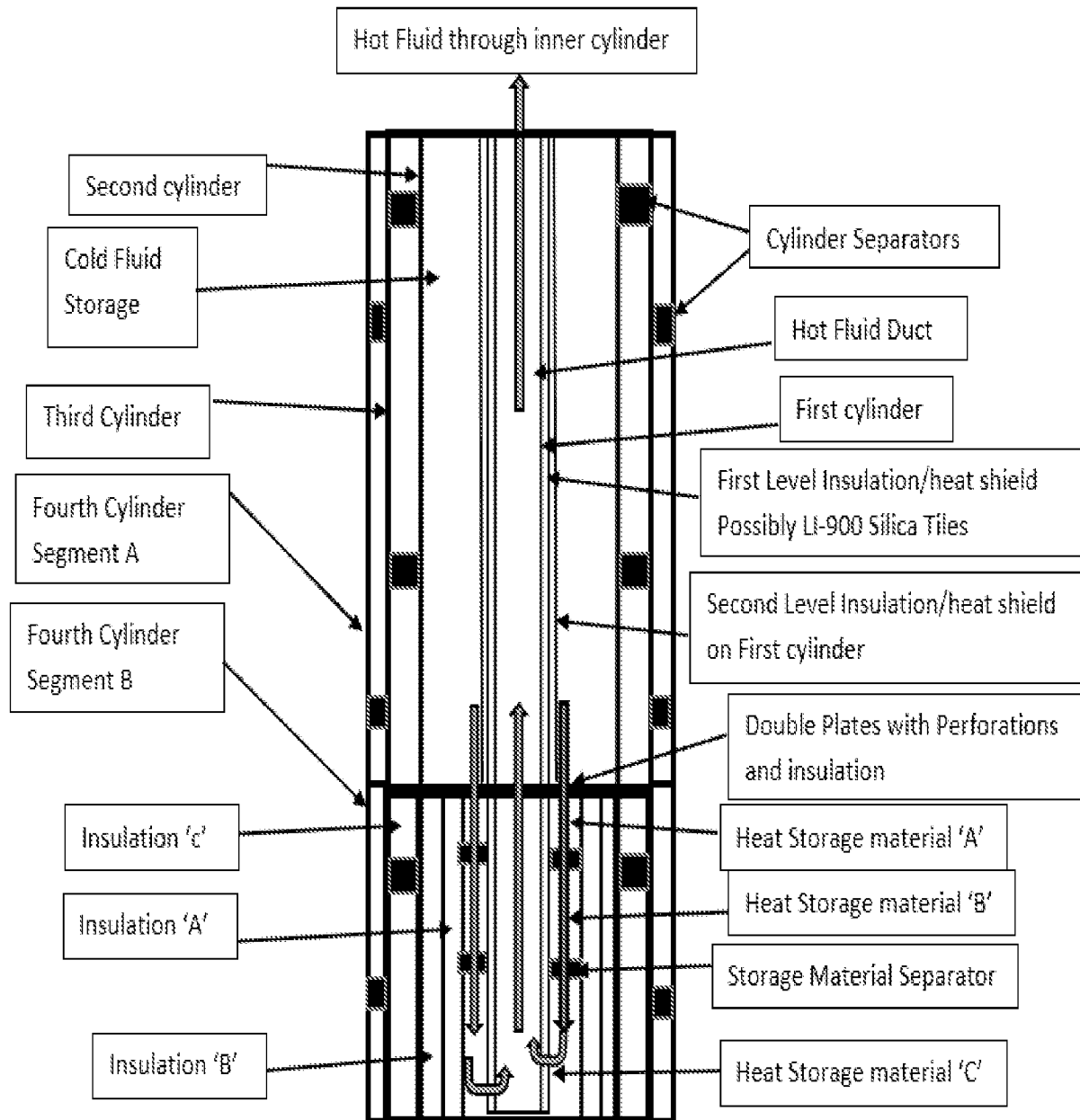


Fig. 32B

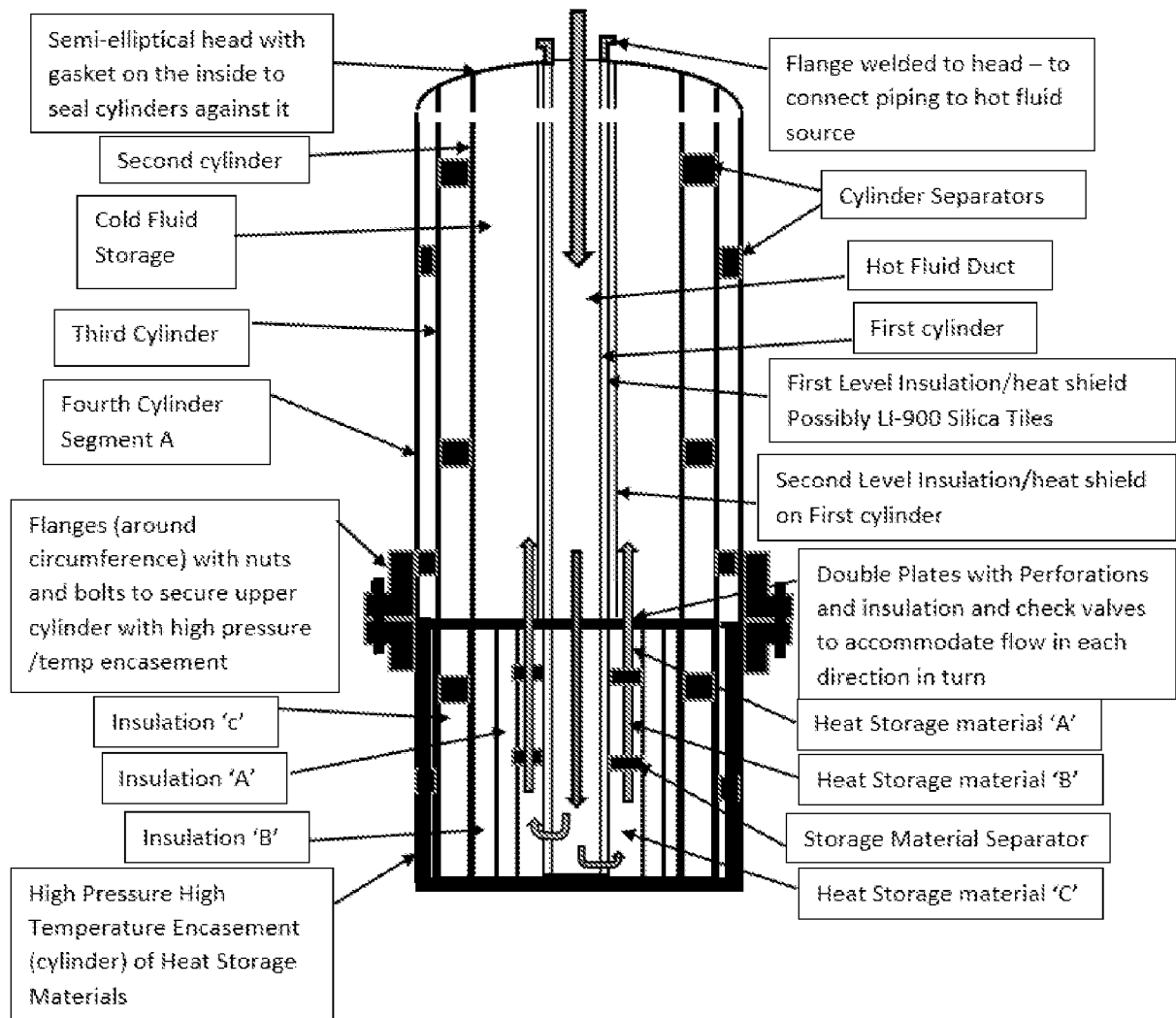


Fig. 32D

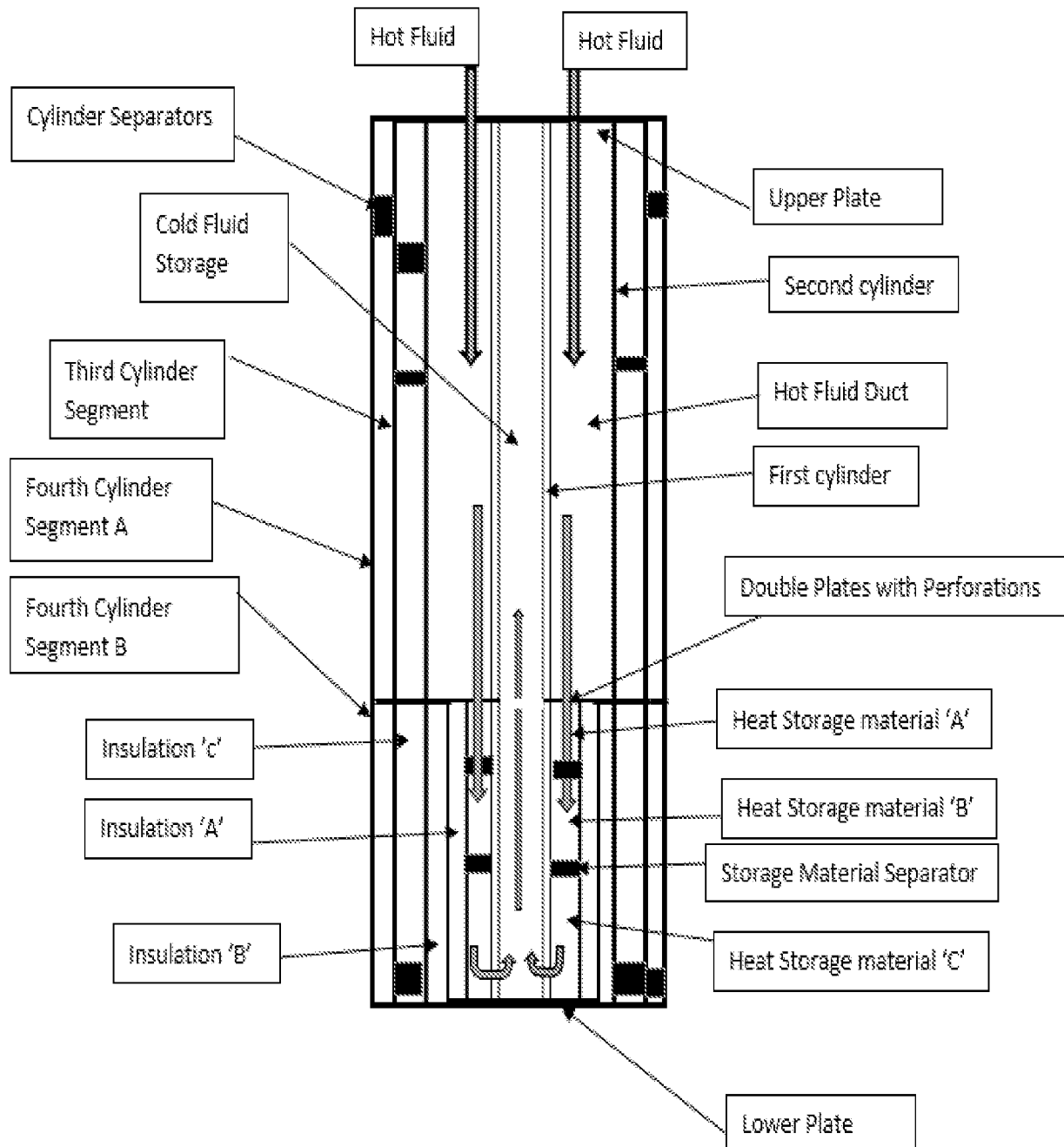


Fig. 33A

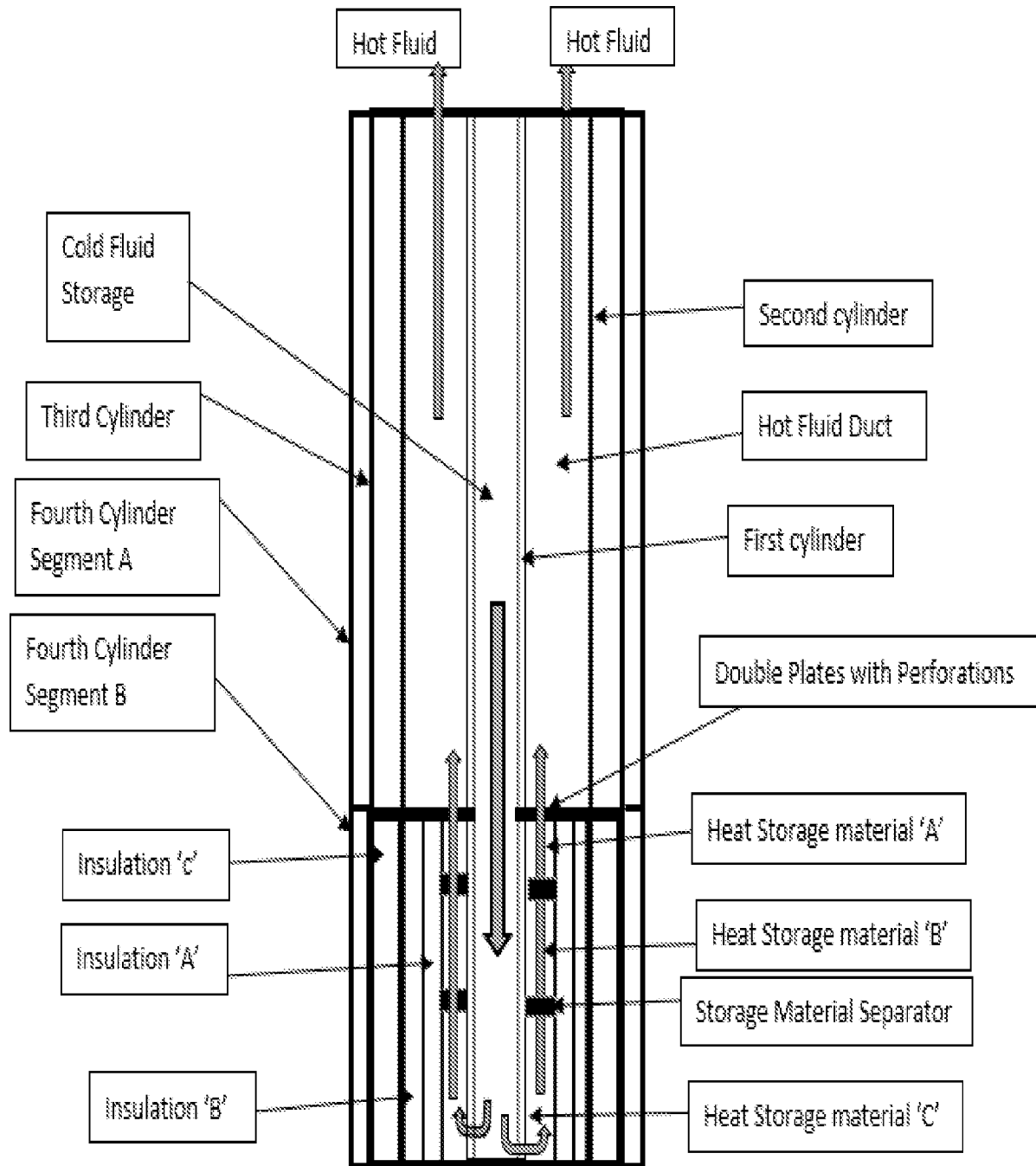


Fig. 33B

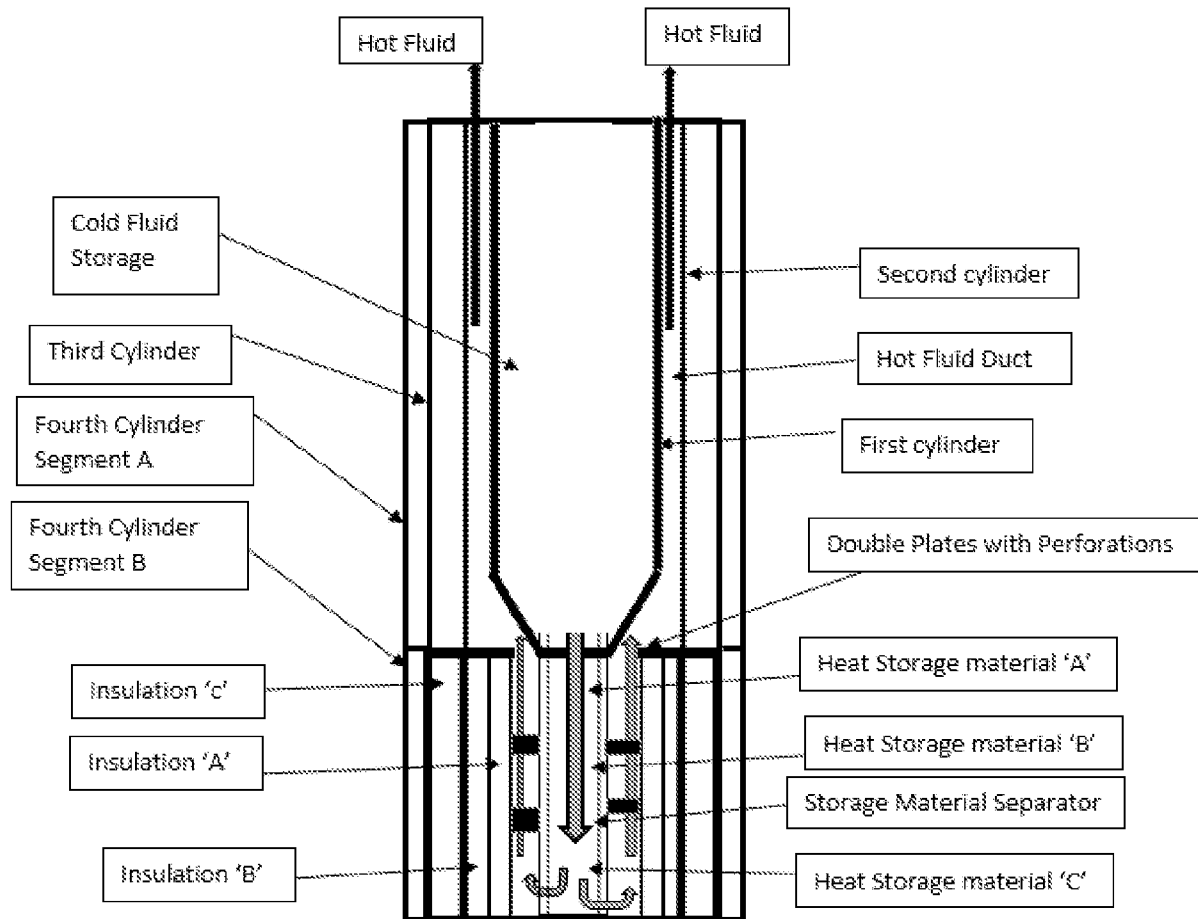


Fig. 34A

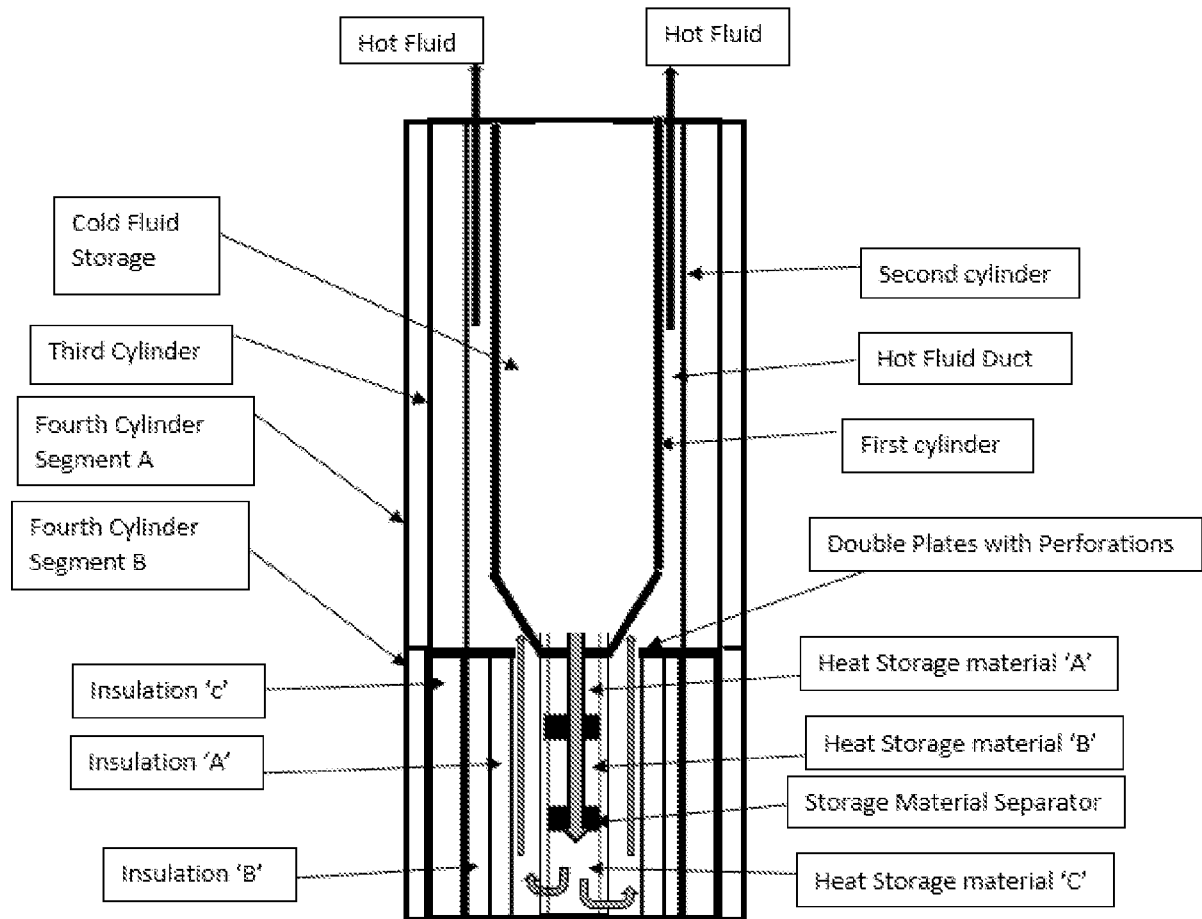


Fig. 34B

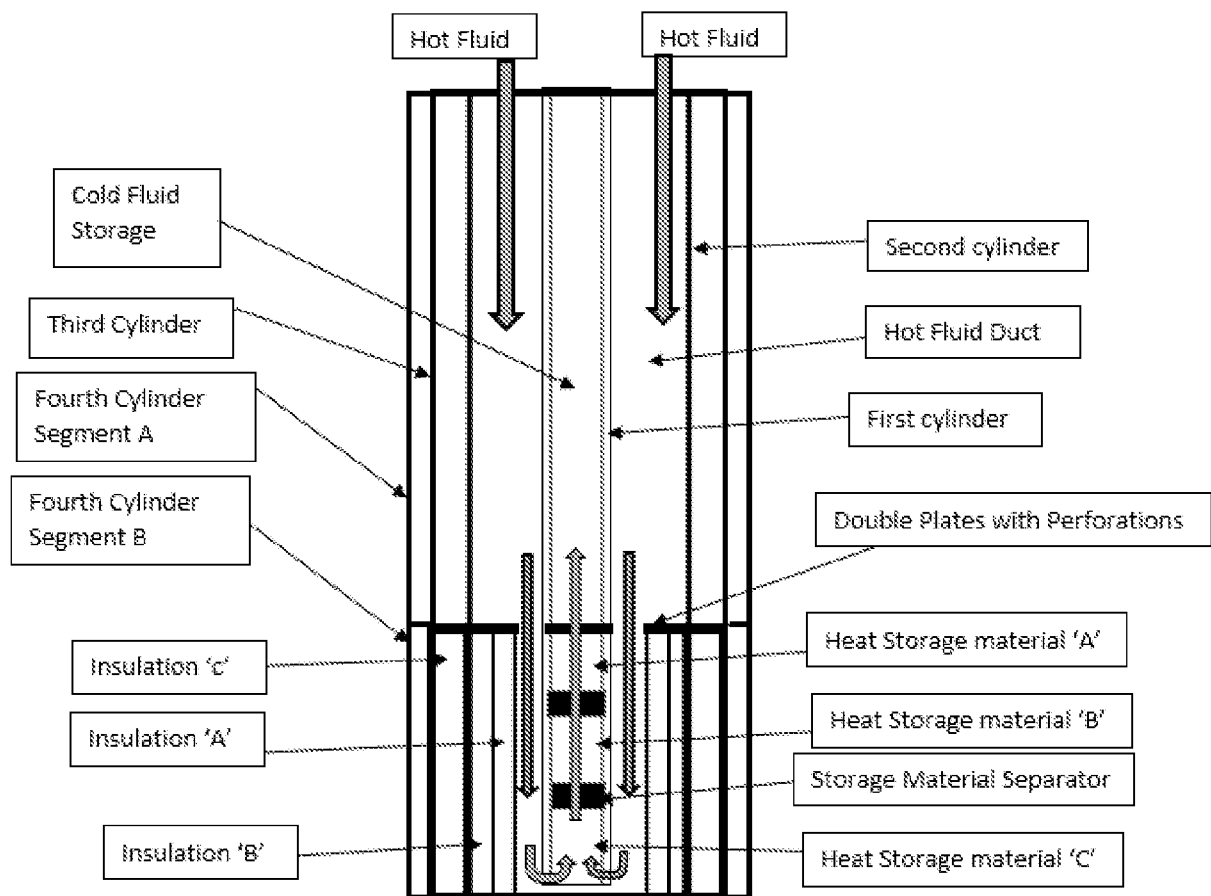


Fig. 35A

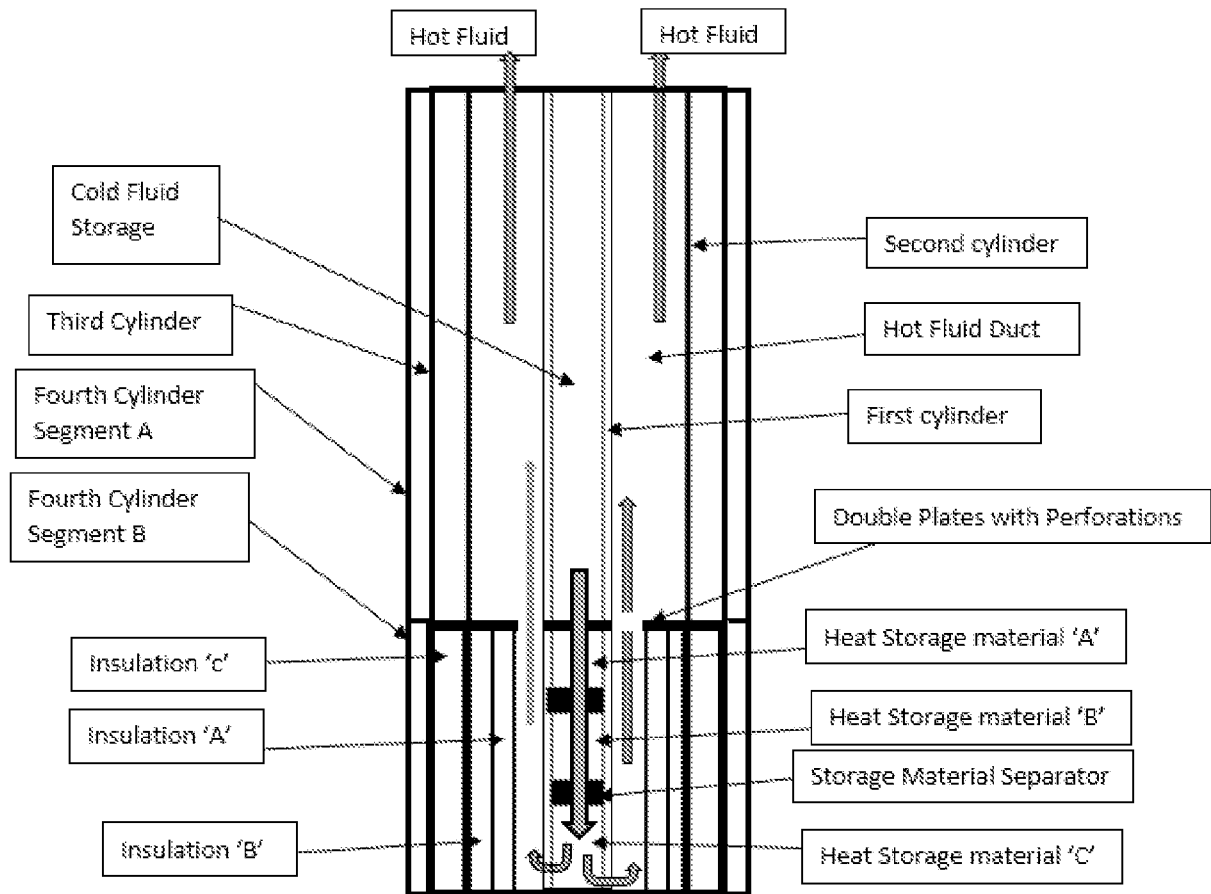


Fig. 35B

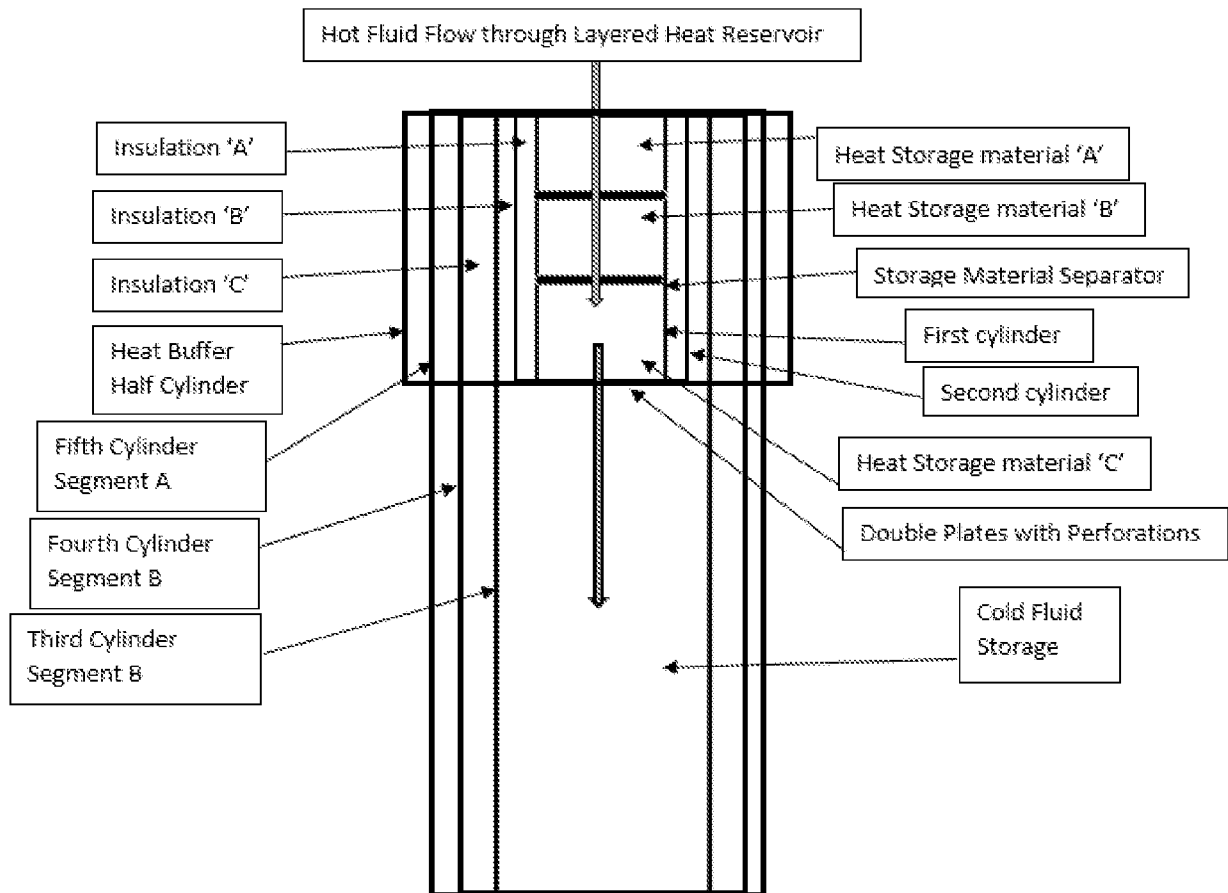


Fig. 36A

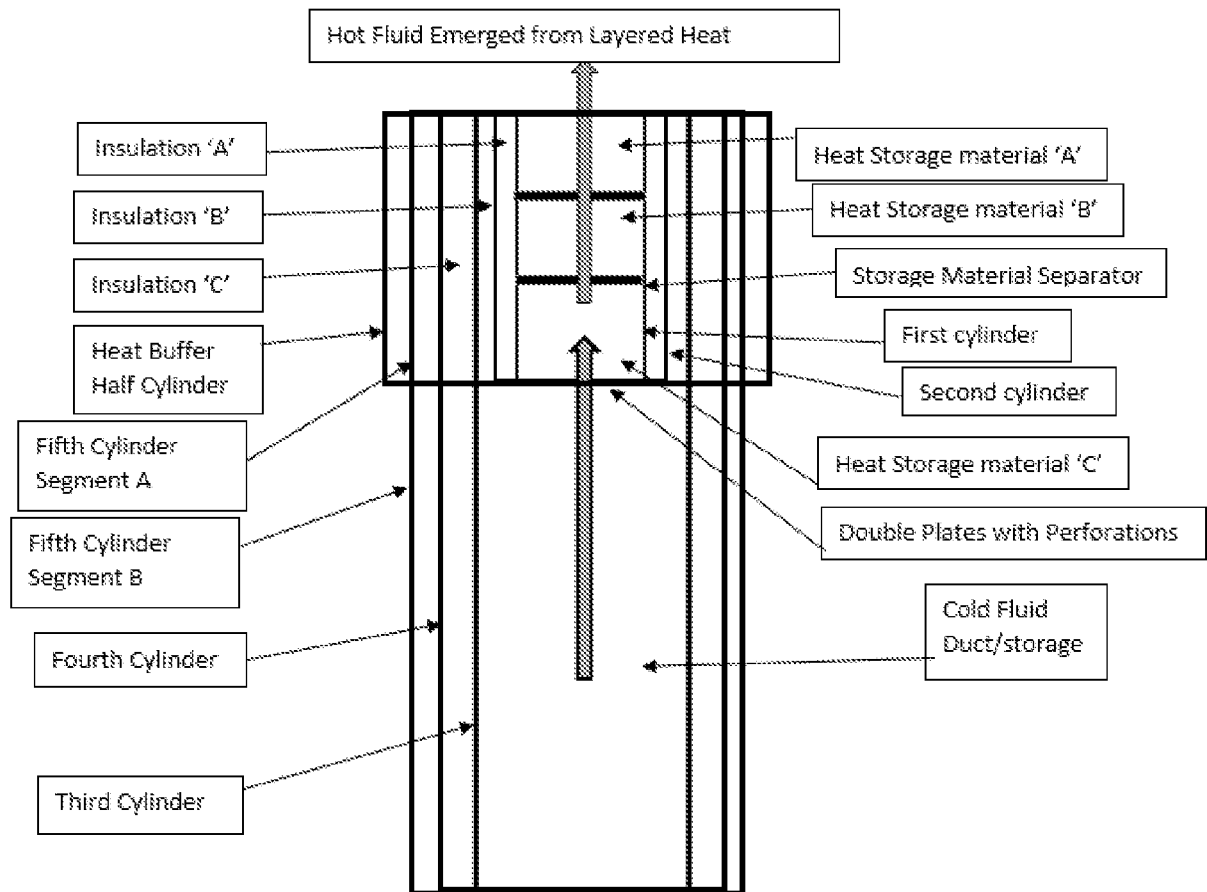


Fig. 36B

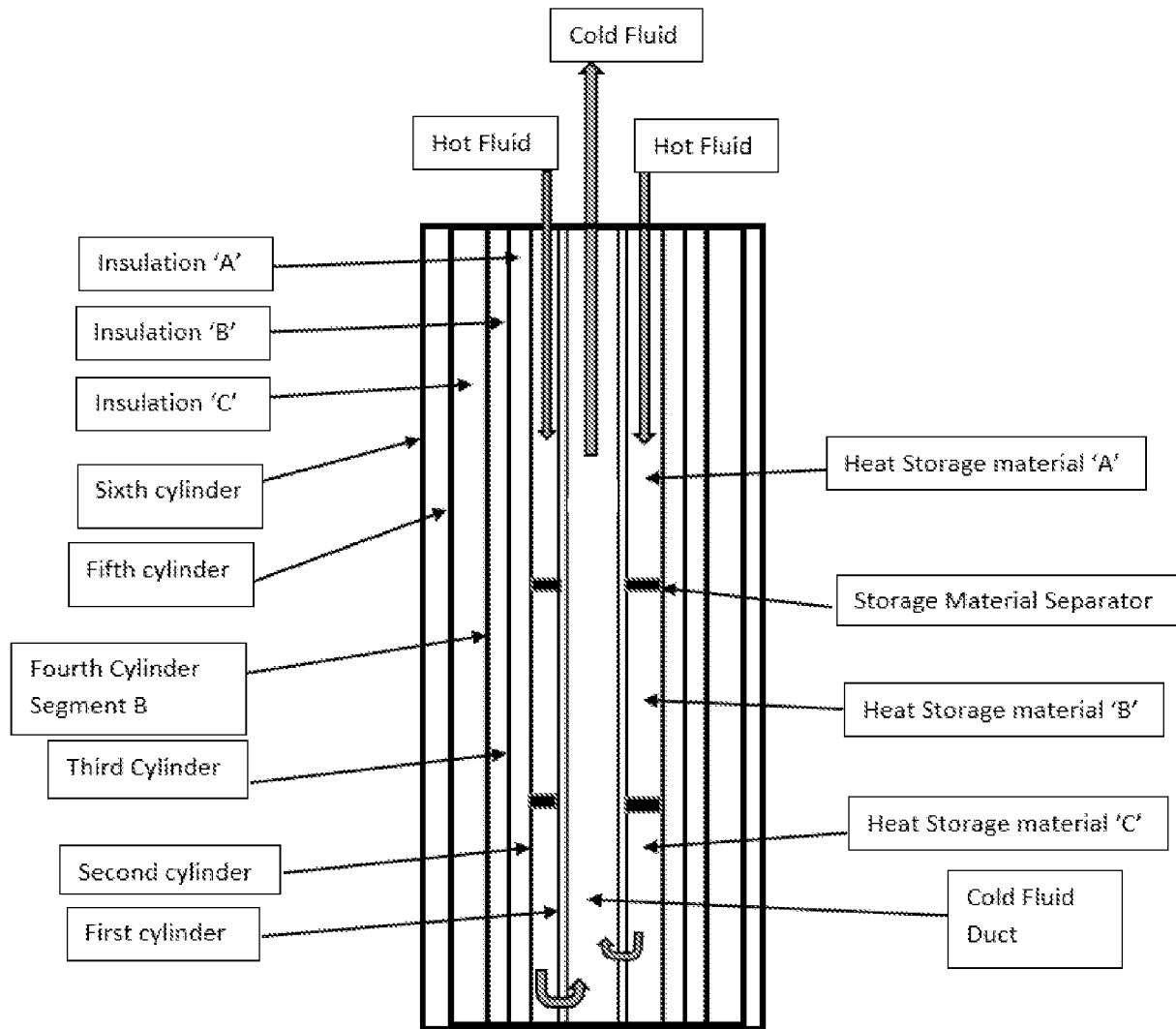


Fig. 37A

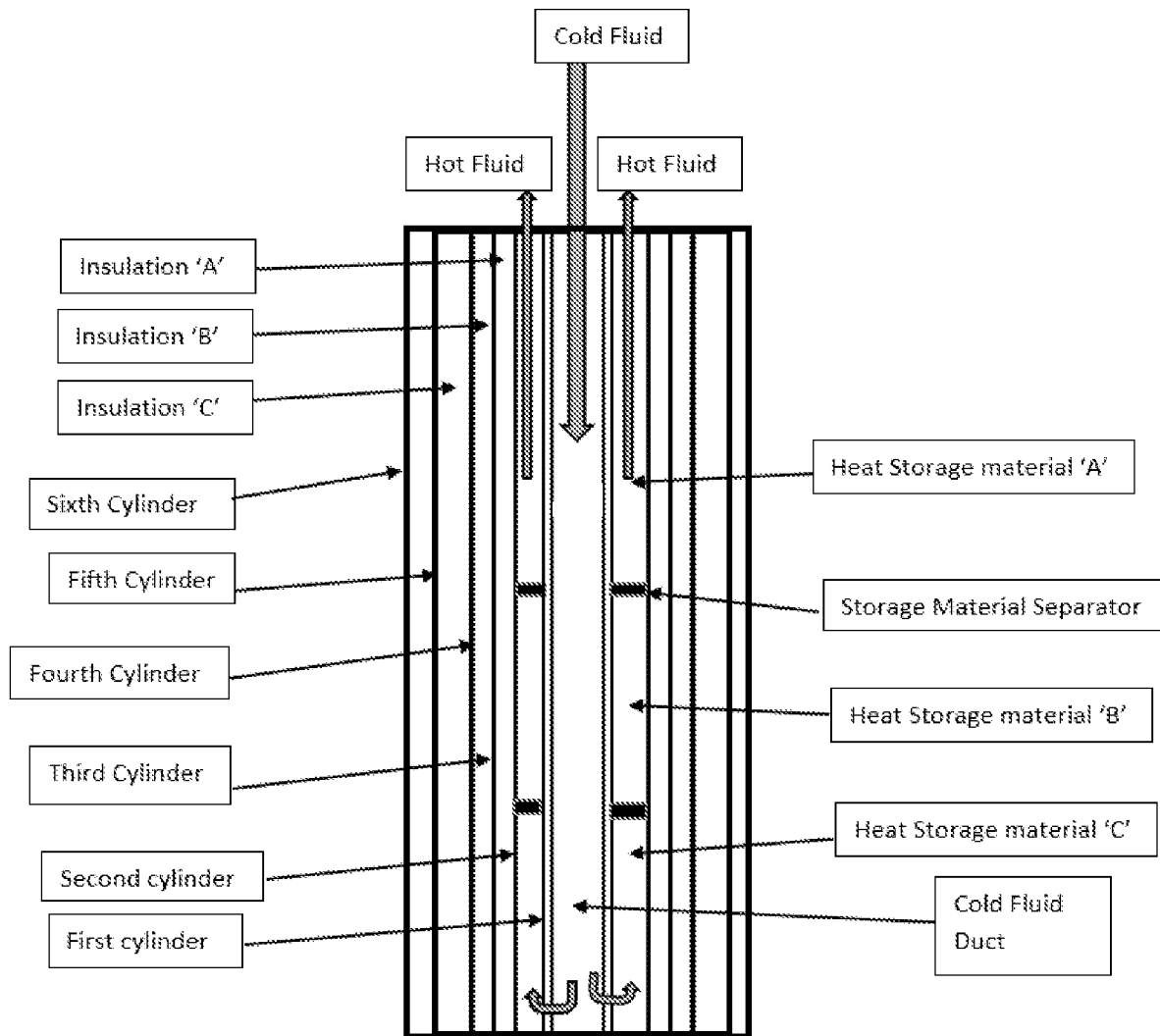


Fig. 37B

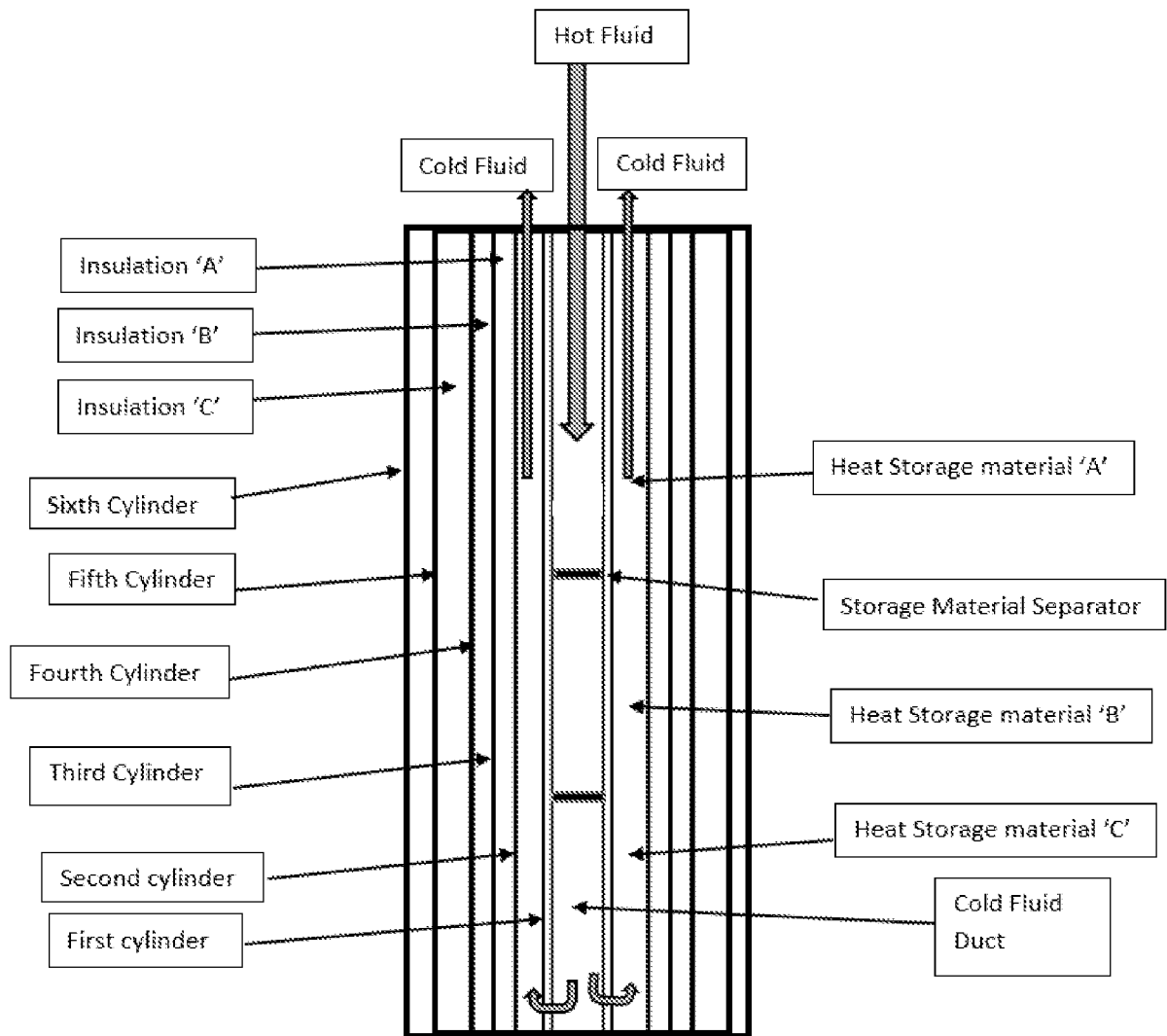


Fig. 38A

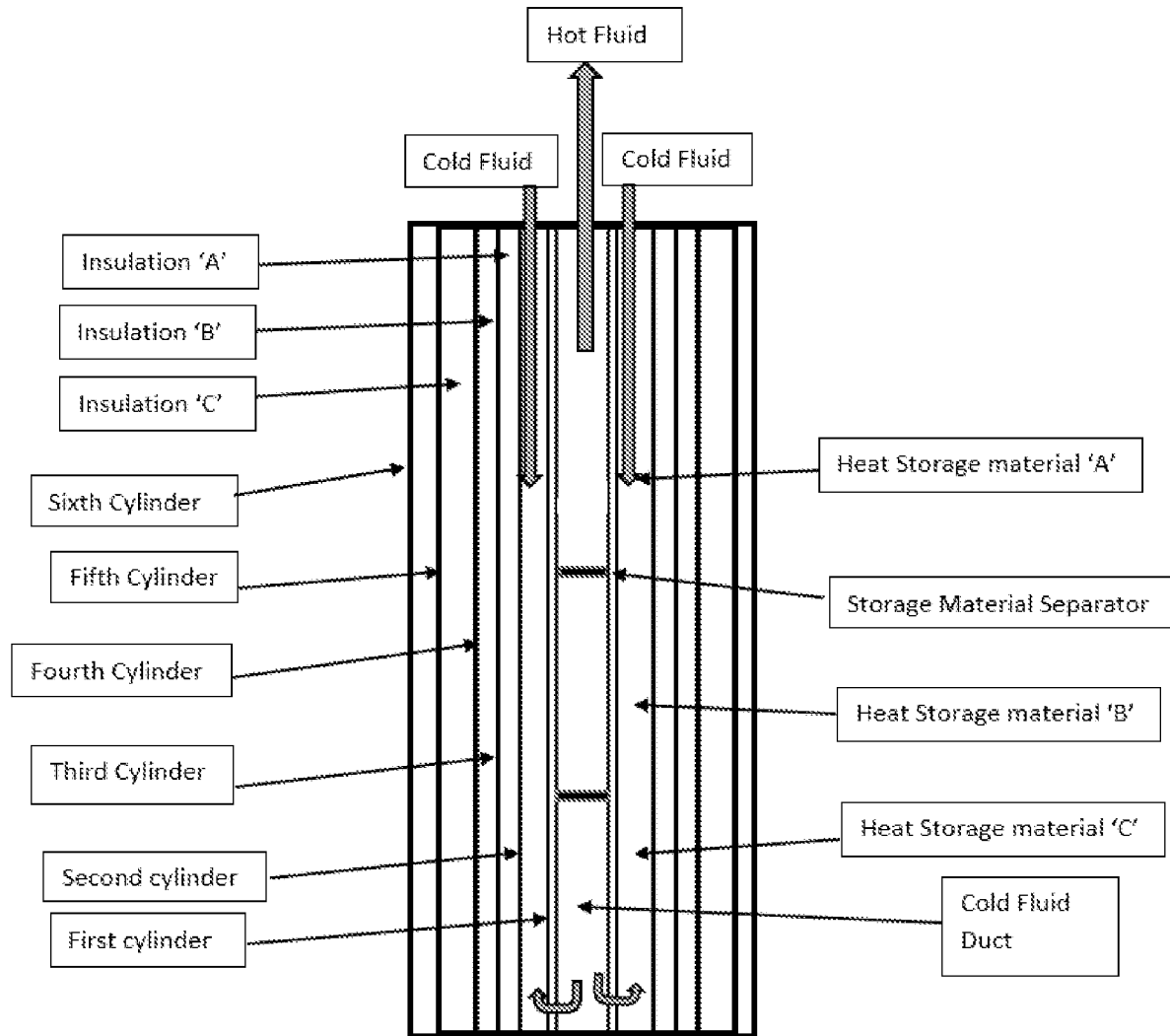


Fig. 38B

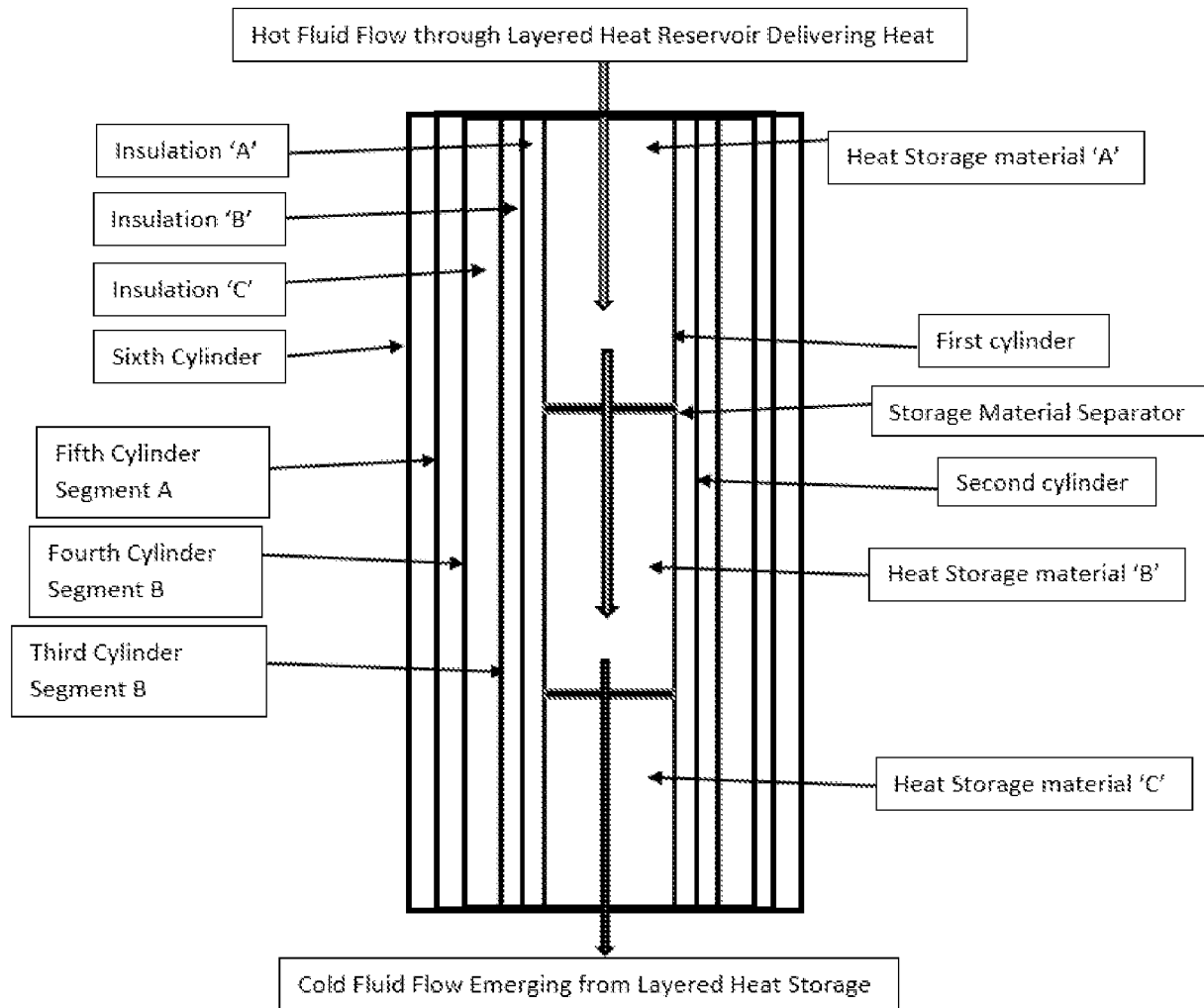


Fig. 39A

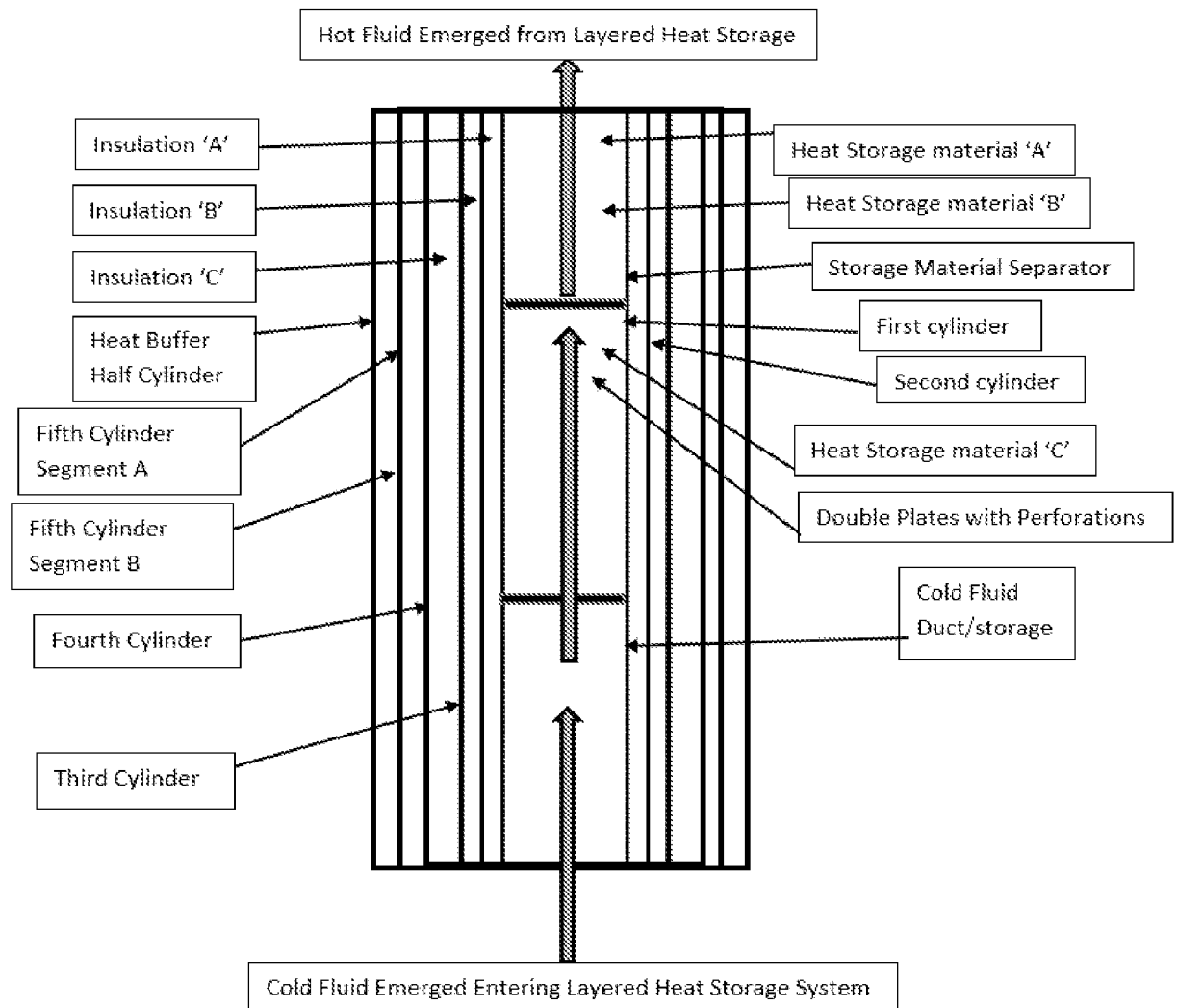


Fig. 39B

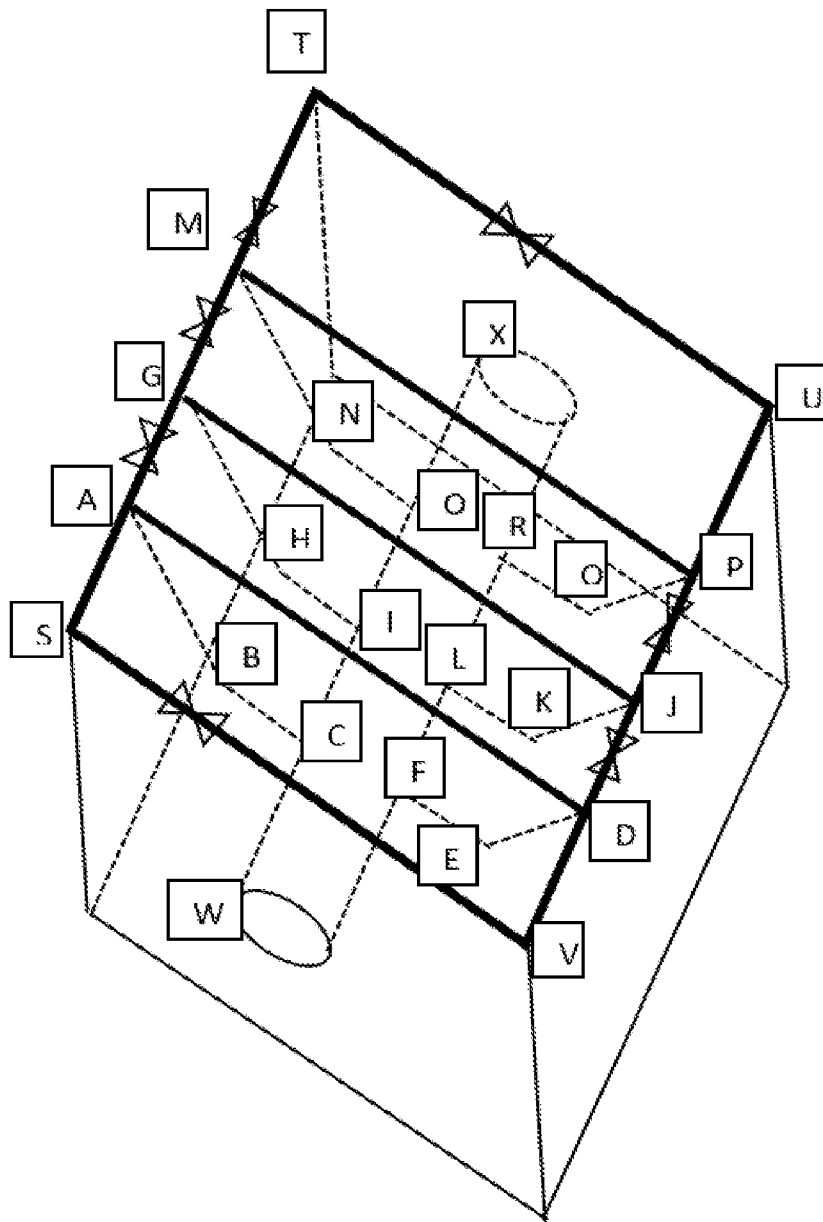


Fig. 40

FIG. 1

