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(54) **THERMAL ENERGY STORAGE SYSTEM**

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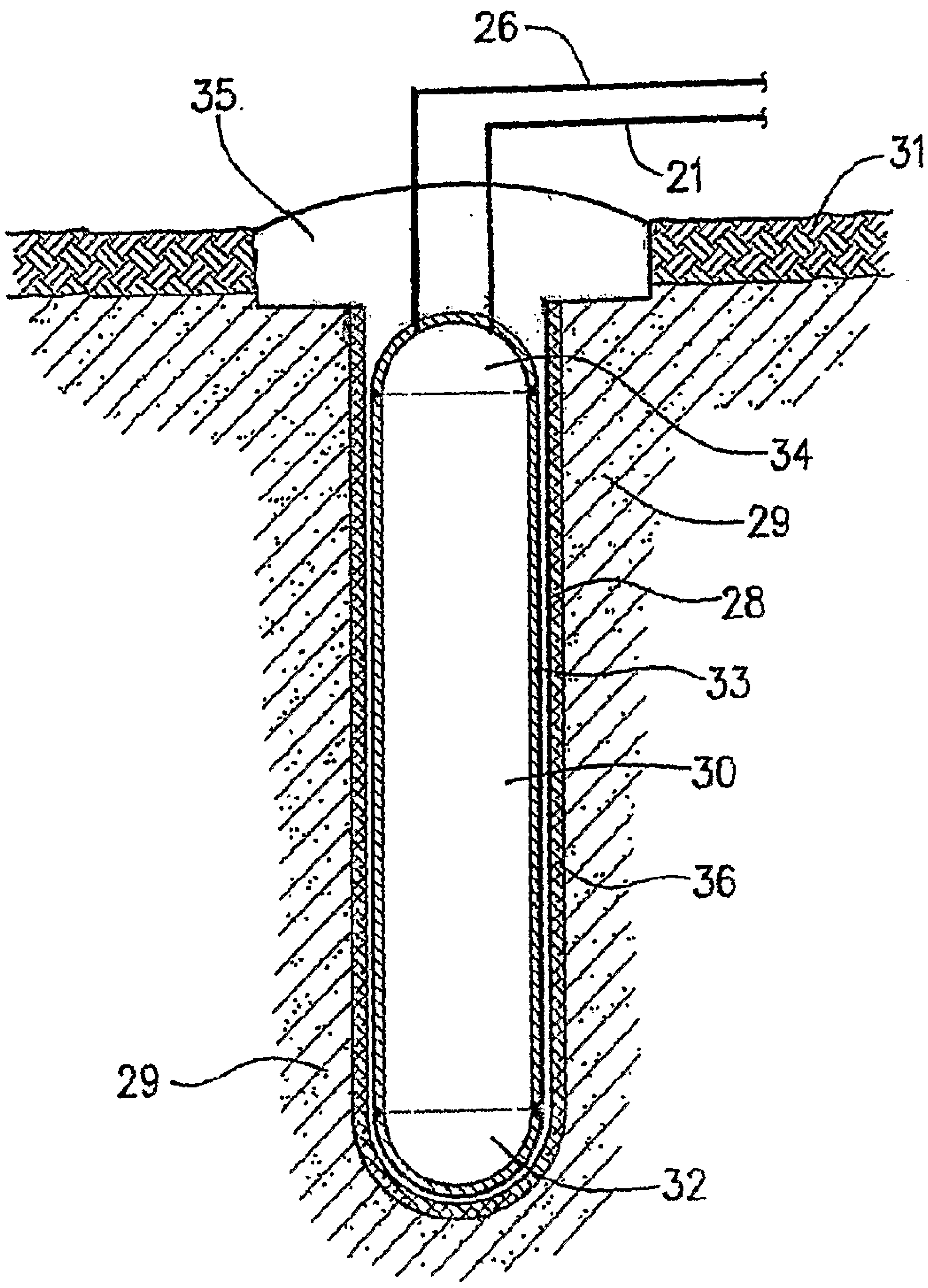
(57) **ABSTRACT**

A thermal energy storage system in which at least one vertically extending cavity is formed within ground constituted by geologically stable consolidated rock, and at least one cylindrical steel vessel having a diametral dimension smaller than its longitudinal dimension is positioned within the cavity and surrounded peripherally by a containment material. Conduits are provided for directing pressurised water in vapour and/or liquid phase into the vessel and for conveying steam from an upper region of the vessel. The vessel has a peripheral wall acting as a liner for the containment material and internal pressure-induced forces are transferred from the vessel to the containment material via the peripheral wall. The containment material in one embodiment of the invention includes the surrounding rock. In a further embodiment the containment material includes a filler material and the internal pressure induced forces are transferred from the vessel to the surrounding rock via the filler material.



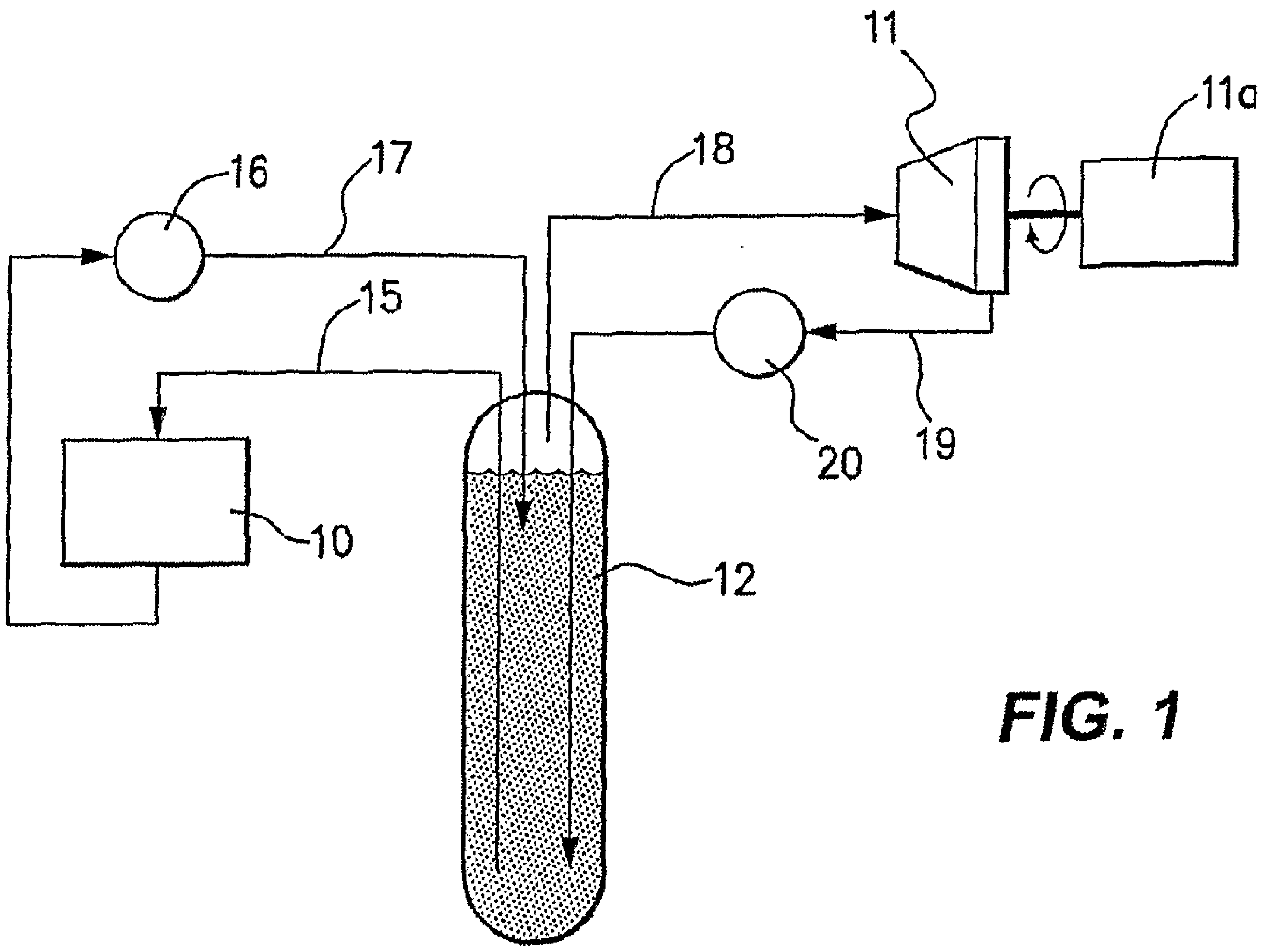


FIG. 1

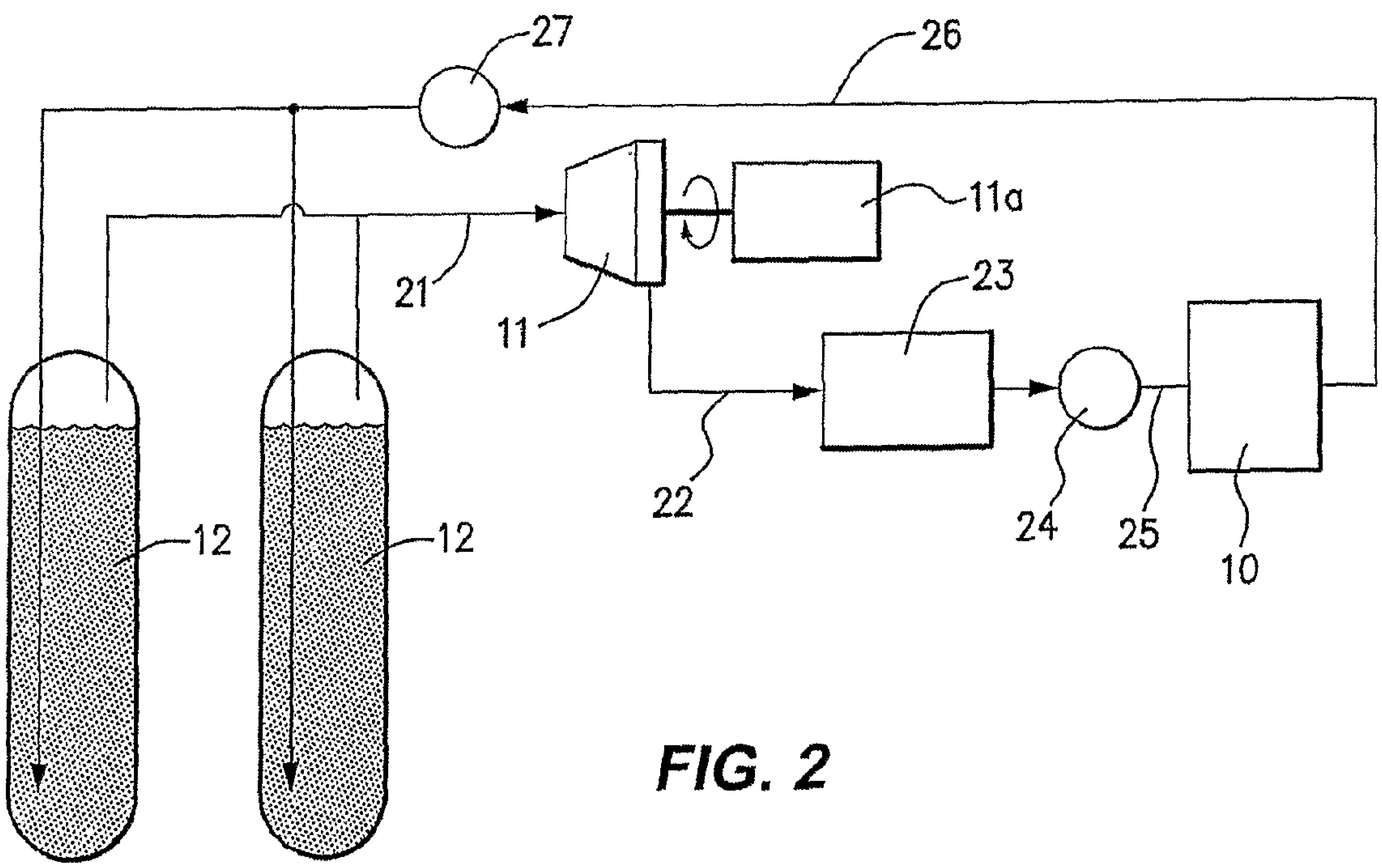


FIG. 2

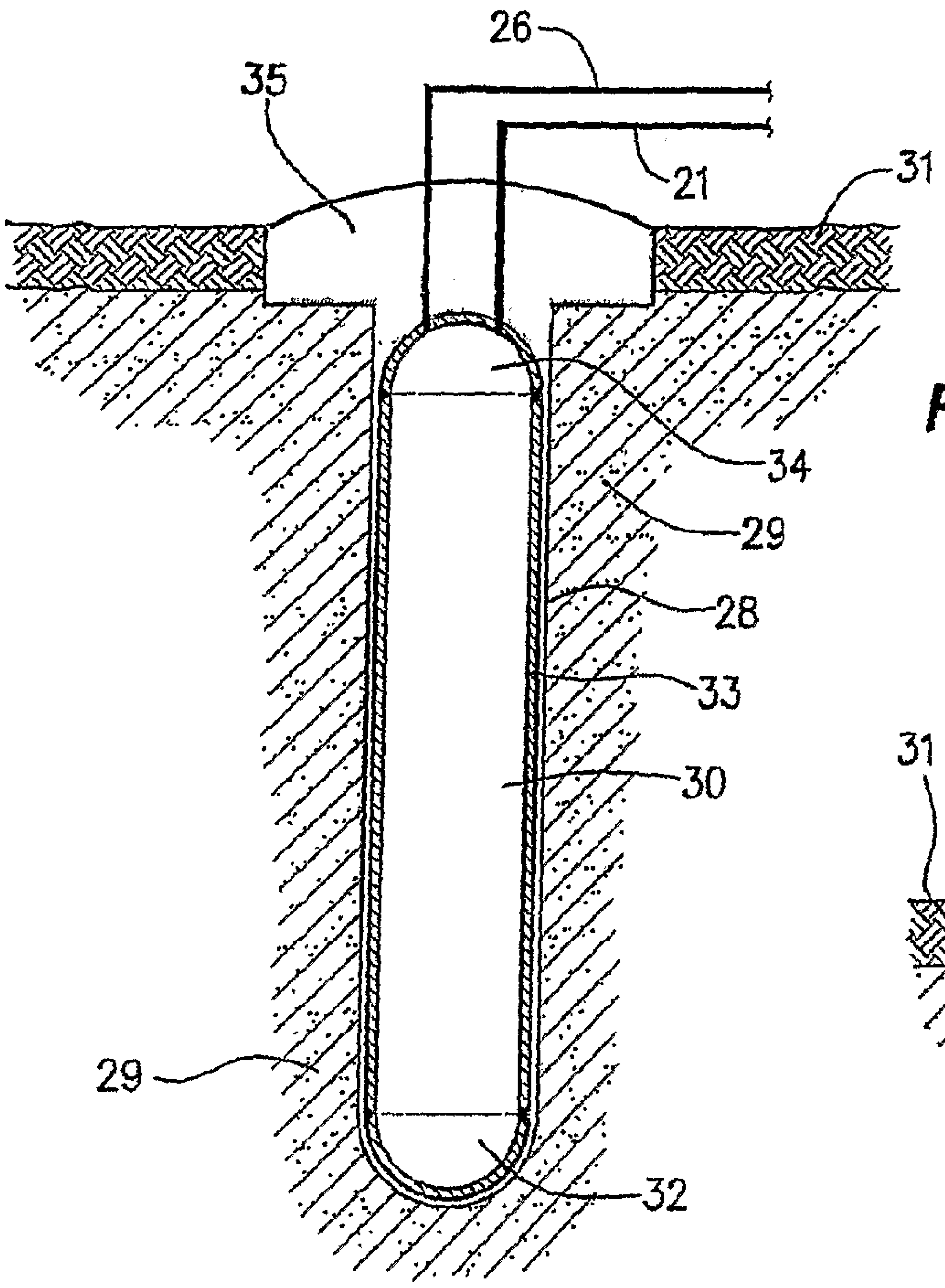


FIG. 3

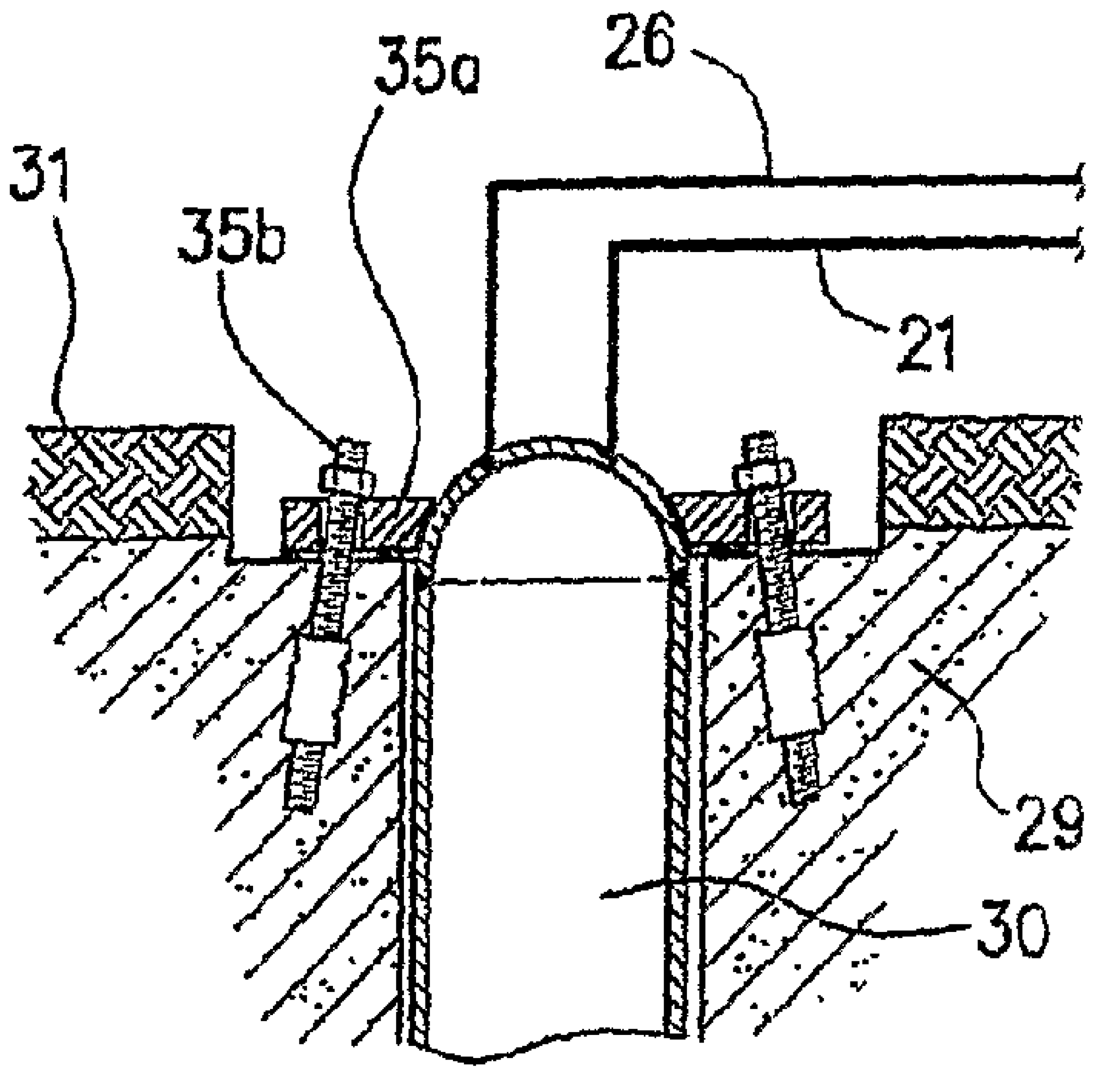


FIG. 4

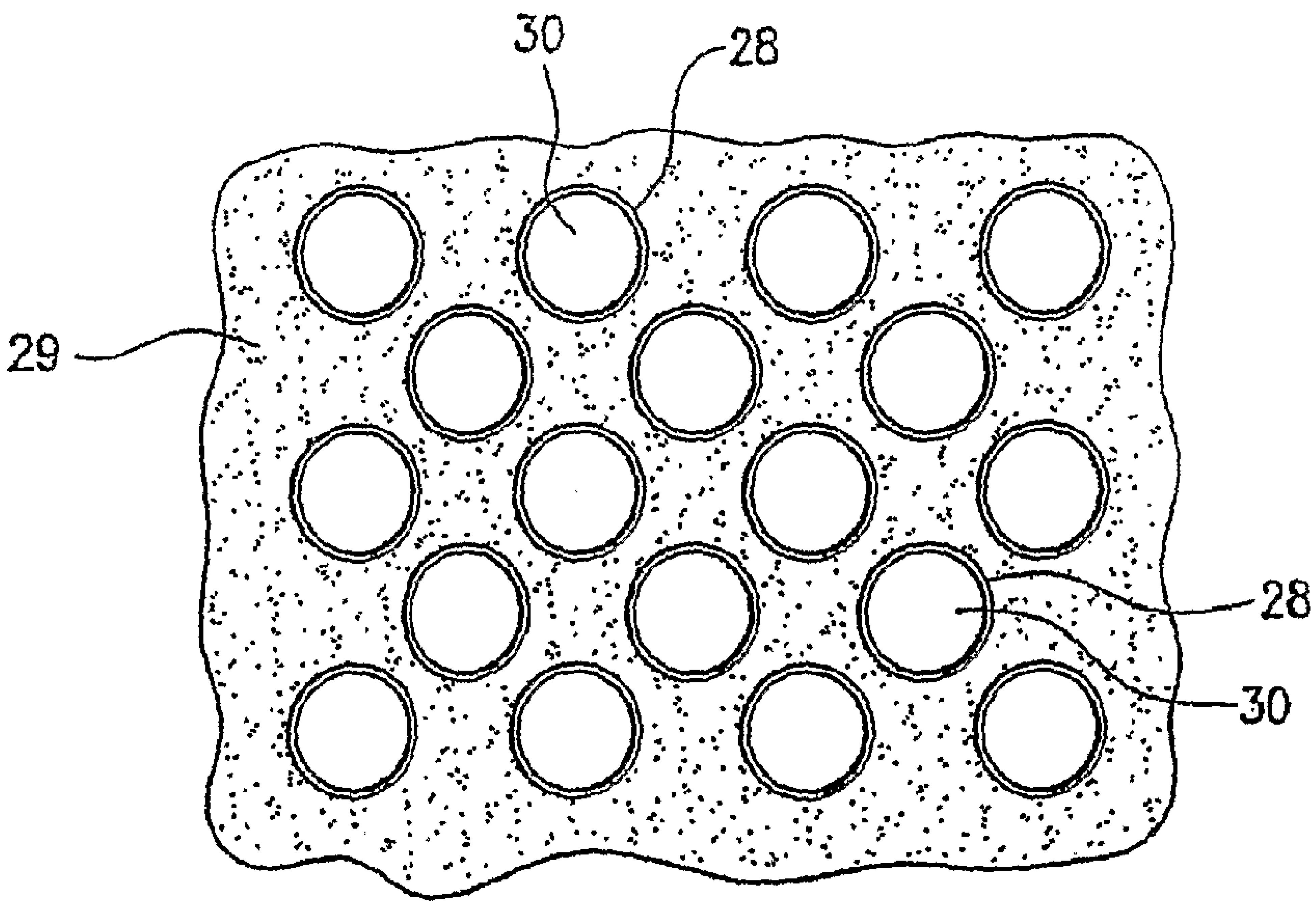


FIG. 5

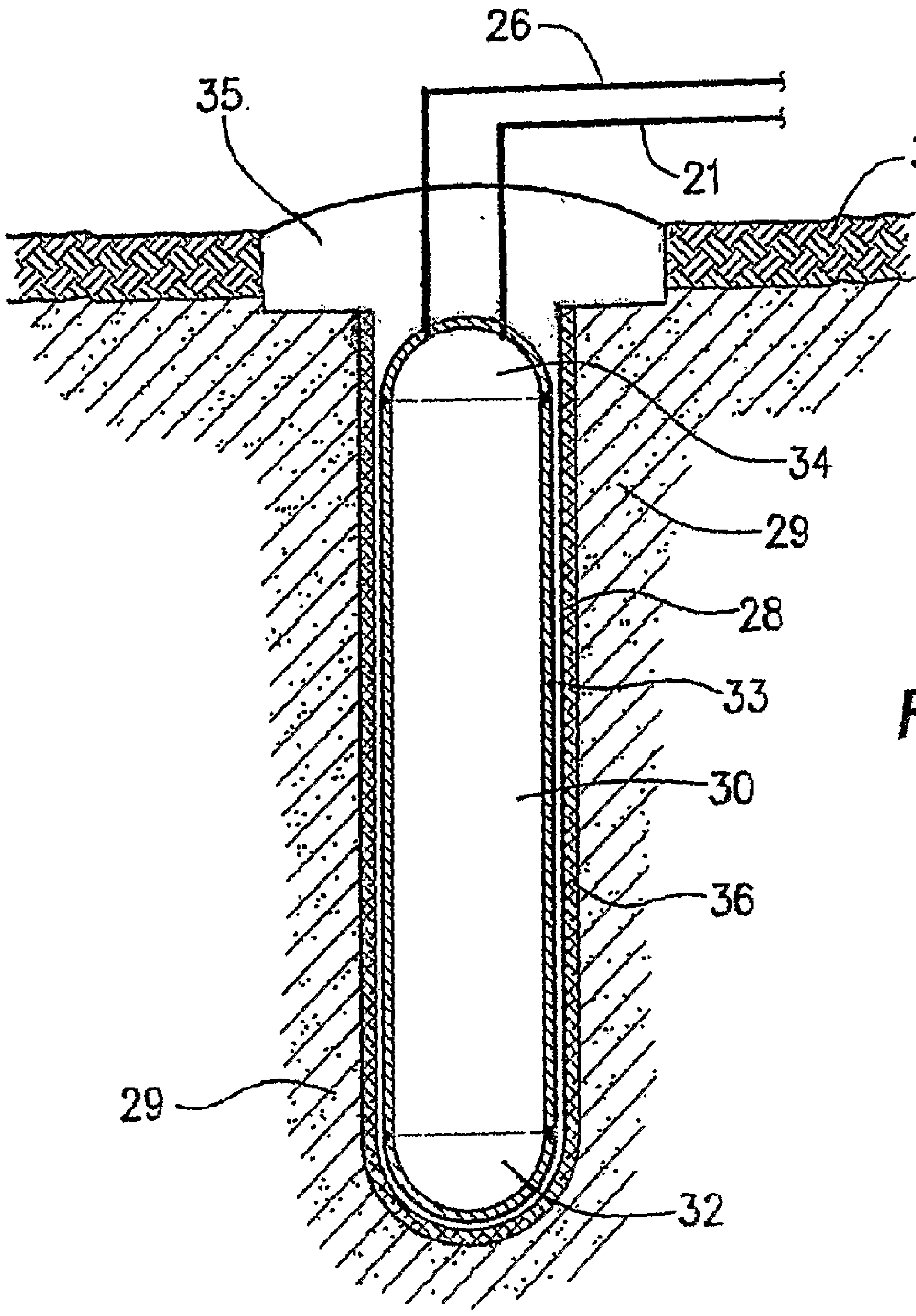


FIG. 6

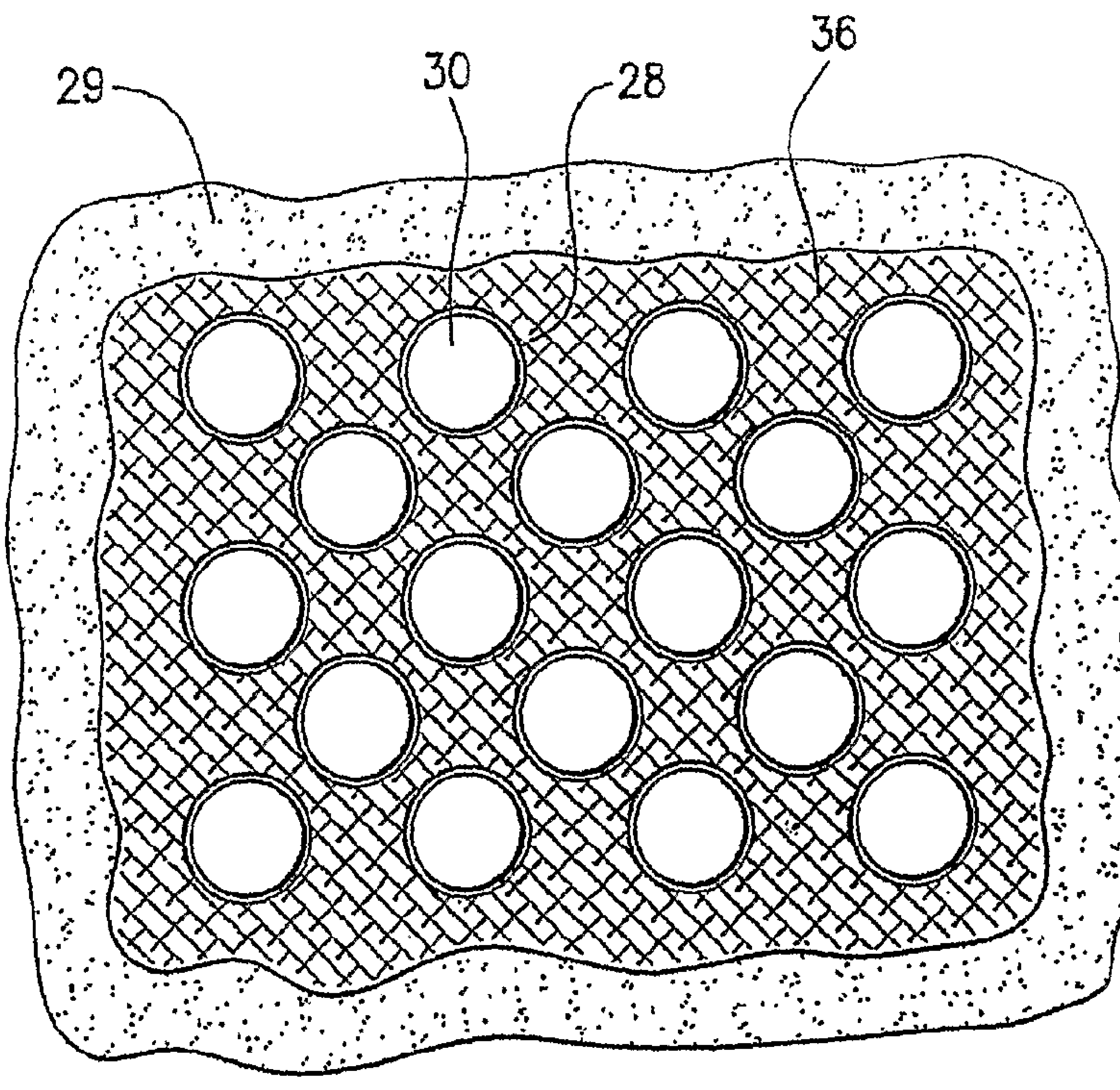


FIG. 7

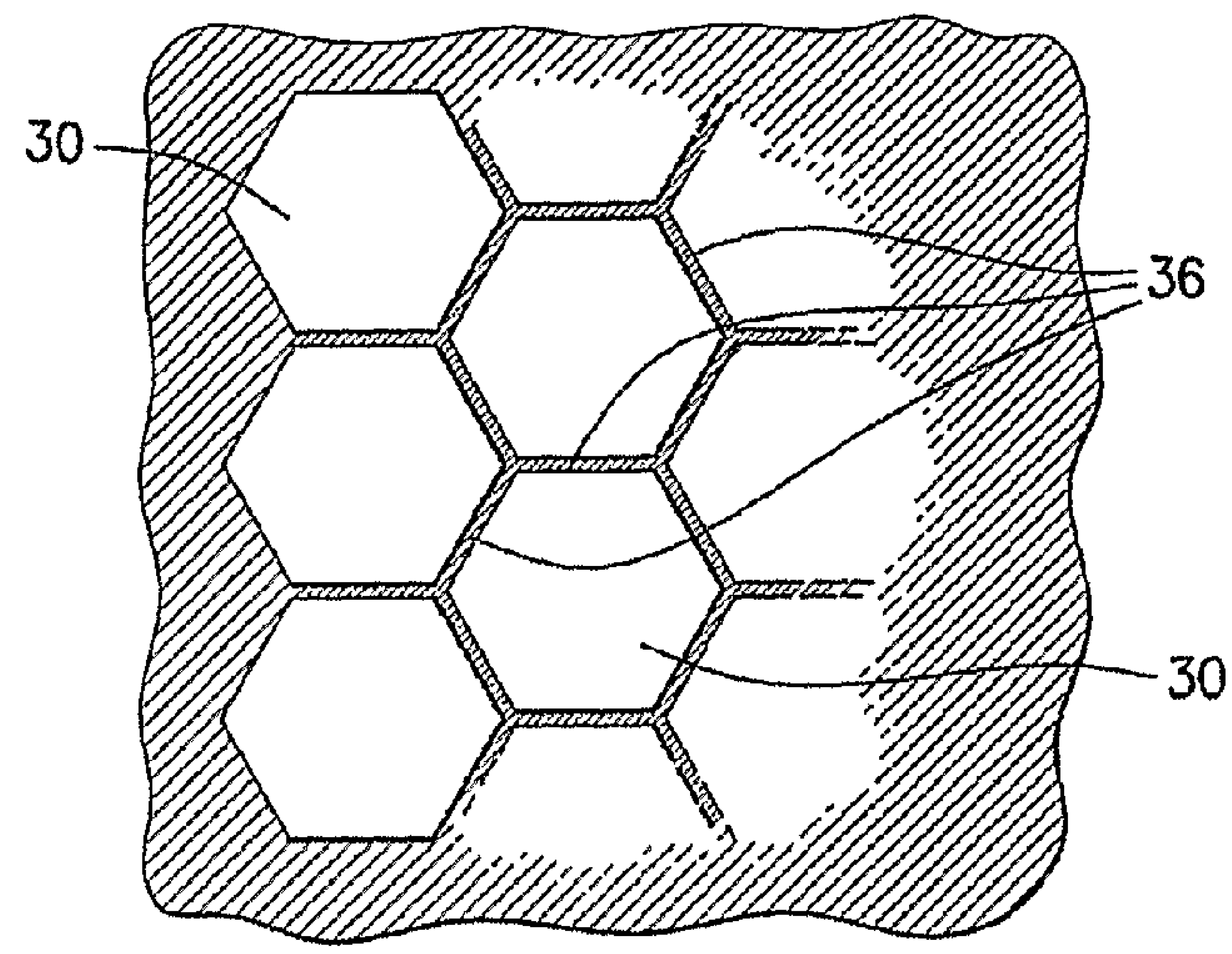


FIG. 8

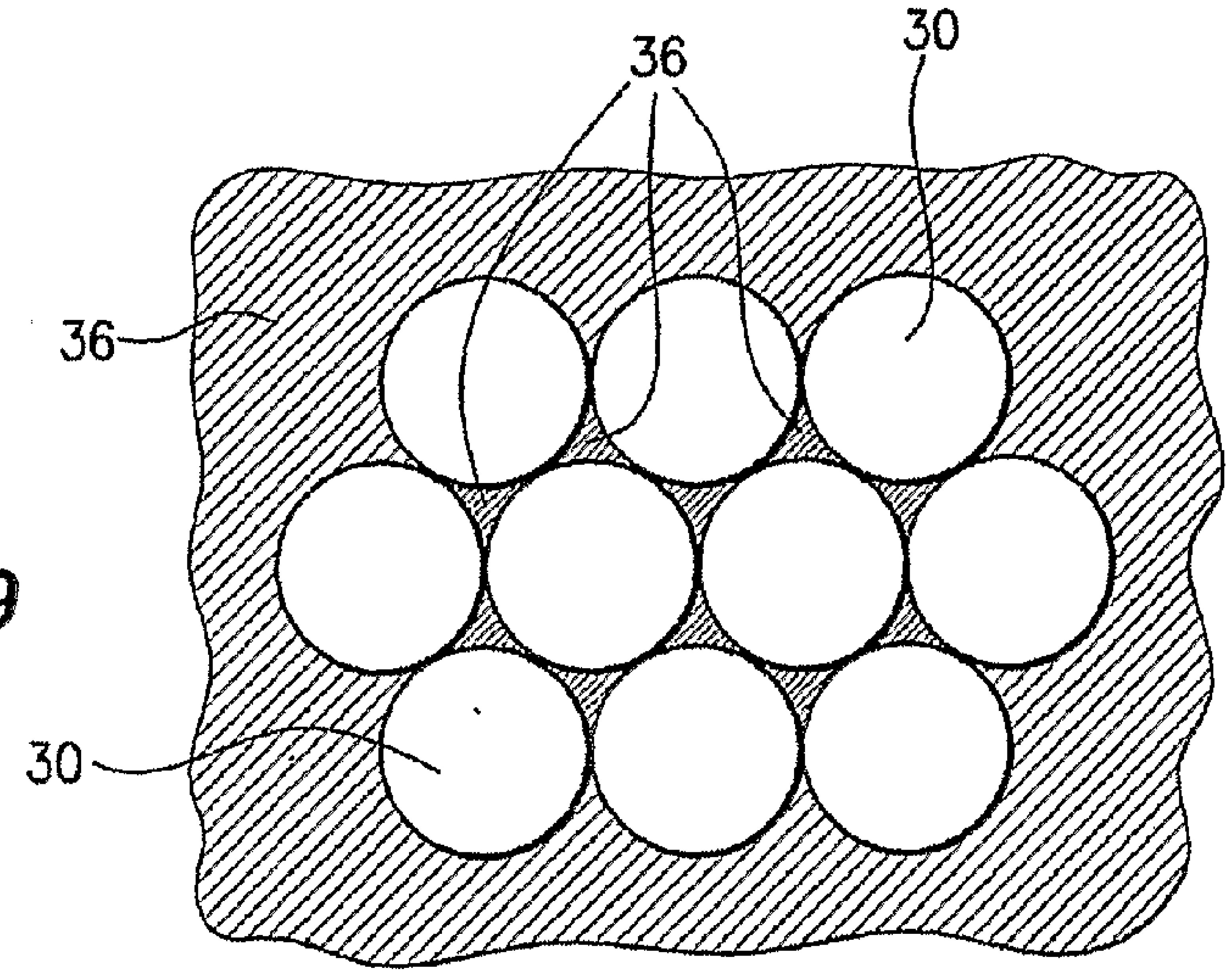


FIG. 9

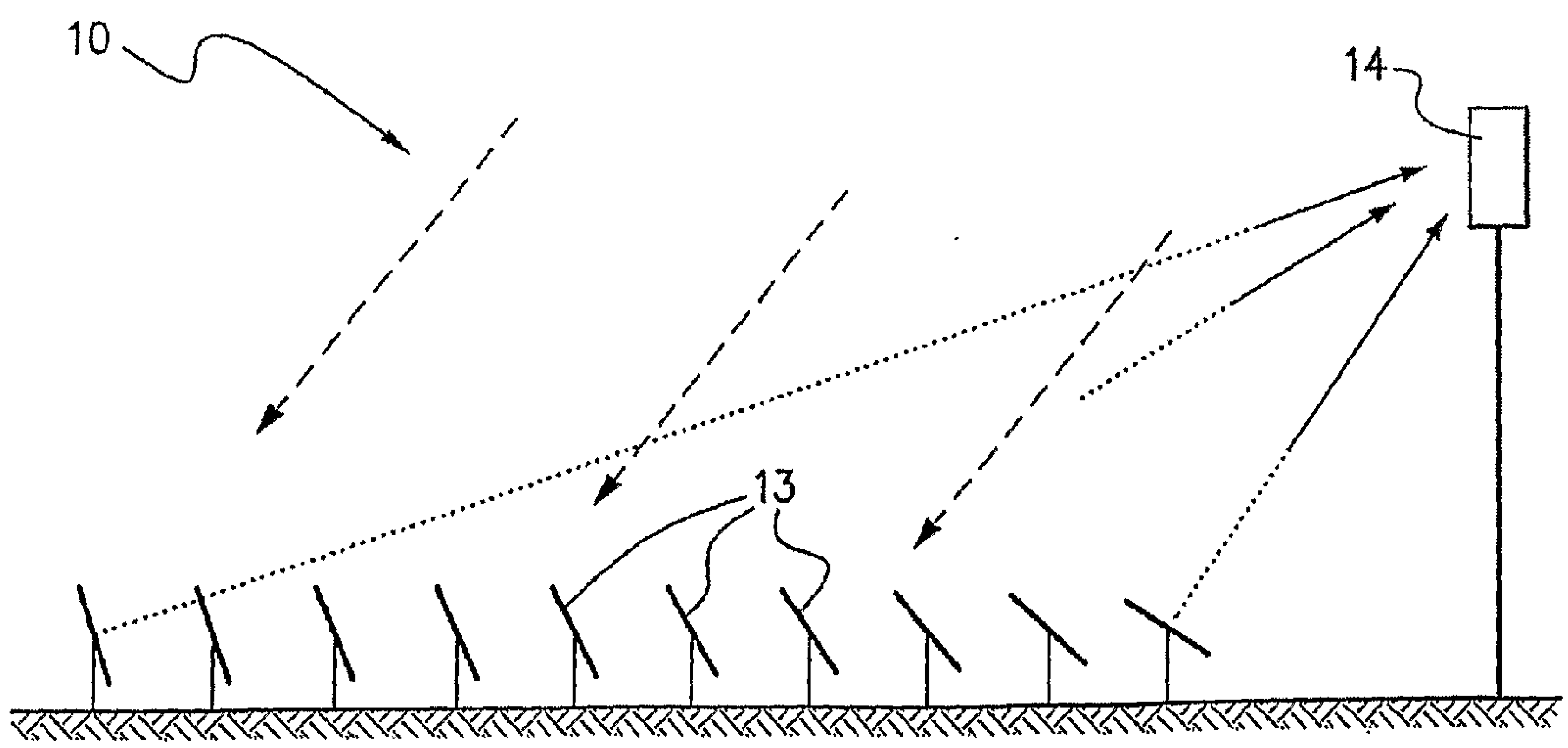


FIG. 10

THERMAL ENERGY STORAGE SYSTEM

FIELD OF THE INVENTION

[0001] This invention relates to a thermal energy storage system for use in association with steam raising plant. The invention might be employed, for example, in association with such plant as nuclear reactors and package boilers that may be required to meet transient peak demands that exceed the steady state output capacity of the plants. A further application of the invention is in conjunction with solar energy collector systems of the type that are employed for converting solar energy to thermal energy.

BACKGROUND OF THE INVENTION

[0002] A solar energy collector system that is employed in the generation of thermal energy comprises a Linear Fresnel Collector ("LFR") system. This system employs a field of reflectors and elevated energy receivers that are illuminated by reflected radiation for energy exchange with fluid that is carried through the receivers, and the thermal storage system of the present invention is hereinafter described by way of example in the context of an LFR system.

[0003] The LFR system is typically employed in the production of steam for delivery to electricity generating plant, either for admission directly to steam turbines or for heat exchange with a working fluid. However, the LFR and other solar collector systems are functional only in the presence of adequate incident solar radiation and, in order to prolong the duty cycle of solar-based electricity generation (and so minimise the demand on parallel sources of energy), thermal energy produced in excess of demand during periods of high-level solar radiation and/or low power consumption must be stored. Three storage systems have previously been proposed for this purpose; one involving the use of pre-existing or purpose-built deep subterranean cavities, the second involving the employment of an above-ground pressure vessel and the third involving the use of concrete-encased fluid feed pipes.

[0004] Subterranean cavity storage of water at required temperature and pressure, typically 270° C. to 340° C. at 100 to 200 Bar, offers certain advantages, in that surrounding rock provides a natural "pressure vessel" and large storage volumes can be accommodated. This type of storage currently is employed for combustible gases, for example LPG; but for high temperature water storage it would be necessary to completely line the cavity with an impermeable water-rock interface and the cavity would need be located at a depth that provides for a rock surface stratum of thickness sufficient to withstand the high fluid pressure within the cavity. These requirements impose formidable construction and costing constraints on deep cavity storage.

[0005] Above ground pressure vessels that are suitable for containing water at the required temperature and a pressure sufficient to maintain the fluid in a liquid phase have been built for various purposes and are commonly referred to as "steam accumulators". However, the fabrication and material costs inherent in building a vessel having the volumetric capacity required for storage of sufficient water to provide the steam mass flow rate required to sustain power generation, for example 1 to 5 MW for a period of 3 to 24 hours, has been determined to be disproportionately high relative to other components of the total power generating system.

[0006] In the third type of storage, cracks occur in the concrete encasement due to differential expansion between the concrete and the pipes. This leads to the appearance of gaps between the pipes and the concrete and, consequently, poor heat transfer (in both directions) between the pipes and the concrete. Cracks in the concrete also cause thermal islands which cannot usefully participate in thermal storage.

SUMMARY OF THE INVENTION

[0007] Broadly defined the present invention provides a thermal energy storage system that comprises at least one vertically extending cavity formed within ground that is constituted by geologically stable consolidated rock. At least one cylindrical steel vessel having a diametral dimension smaller than its longitudinal dimension is positioned within the at least one cavity and surrounded peripherally by a containment material. Conduits are provided for directing pressurised water (in vapour and/or liquid phase) into the vessel, and for conveying steam from an upper region of the vessel. The vessel has a peripheral wall that functions as a liner for the containment material whereby, in operation of the system, internal pressure-induced forces are transferred from the vessel to the containment material by way of the peripheral wall.

[0008] The invention is further defined as providing a method of storing thermal energy wherein water at a high temperature is maintained under pressure within a cylindrical steel vessel which is positioned within a cavity which is formed within ground that is constituted by geologically stable consolidated rock, wherein the vessel is surrounded peripherally by a containment material and wherein the vessel has a peripheral wall that functions as a liner for the containment material and internal pressure-induced forces are transferred from the vessel to the containment material by way of the peripheral wall.

[0009] Within the context of the present invention the term "cylindrical steel vessel" is to be understood as meaning a vessel having any desired cross-sectional configuration (for example, circular or hexagonal) but one that is substantially constant along its length.

OPTIONAL FEATURES OF THE INVENTION

[0010] The containment material optionally comprises surrounding rock and, in such case, the invention in one of its aspects may be defined as providing a thermal energy storage system that comprises at least one vertically extending cylindrical cavity formed within ground that is constituted by geologically stable consolidated rock, the cavity having a diametral dimension that is substantially smaller than the cavity's longitudinal depth. A cylindrical steel vessel is positioned within the cavity and conduits are provided for directing pressurised water (in vapour and/or liquid phase) into the vessel, whereby water is maintained within a major volumetric portion of the vessel, and for conveying steam from an upper region of the vessel. The vessel is dimensioned to function as a liner for the cavity and, in operation of the system, to transfer internal pressure-induced forces to the surrounding rock.

[0011] In functioning as a liner and, consequently, preventing movement of stored water into the surrounding rock, the vessel substantially eliminates the possibility of explosive rock fracturing that might otherwise occur with generation of steam pressure in pores and defects with conductive heating of the rock to temperatures above 100° C.

[0012] In a further embodiment the containment material optionally comprises a filler material and, in this case, the invention in accordance with another of its aspects may be defined as providing a thermal energy storage system that comprises a vertically extending cavity formed within ground that is constituted by geologically stable consolidated rock. At least one cylindrical steel vessel is positioned vertically within the cavity, and conduits are provided for directing pressurised water (in vapour and/or liquid phase) into the vessel and for conveying steam from an upper region of the vessel. Also, a thermally stable filler material is located between the vessel and a surrounding wall of the cavity. The vessel has a diametral dimension that is substantially smaller than the vessel's longitudinal length and the wall of the vessel functions as a liner for the filler material whereby, in operation of the system, internal pressure induced forces are transferred from the vessel to the surrounding rock by way of the filler material.

[0013] By "thermally stable filler material" is meant one that maintains its physical and chemical properties when exposed to operating temperatures of the storage system, for example temperatures of the order of 200° C. to 420° C.

[0014] In forming the vessel with a diametral dimension that is substantially smaller than its longitudinal length, the pressure-induced forces exerted on the ends (and, more relevantly, on the upper near-ground-surface end) of the vessel are reduced to a level that can reasonably be accommodated. This in turn permits practicable end-capping and securement of the upper end of the vessel against high internal pressures, typically of the order of 80 to 200 Bar. Also, in the case of the second aspect of the invention, by dimensioning the vessel as a liner for the filler material, the surrounding filler material and rock are (jointly) effectively integrated as side and lower end walls of the vessel. This in turn permits fabrication of the circumferential wall and lower end of the vessel from relatively small gauge (typically 6 mm to 16 mm thick) steel.

[0015] The cavity may be formed in ground constituted by high strength, low porosity rock such as granite. However, it has been determined that certain advantages are to be gained from location of the cavity in a rock mass having the stiffness of Triassic sandstone. But, because this rock typically has a porosity of 15% to 25%, care should be taken to form the cavity in dry rock above the level of any underlying water table. The cavity should be formed with a depth sufficient to locate the contained vessel below ground coverage and, thus, wholly within surrounding consolidated rock.

[0016] The size of the vessel will be determined by the required storage volume.

[0017] This might be of the order of 60 m^3 for approximately 5 hours of storage for a 1 MW heating module, and for this capacity the vessel may have dimensions of the following order:

[0018] About 3.0 m diameter and about 9 m length,

[0019] about 2.0 m diameter and about 20 m length,

[0020] about 1.5 m diameter and about 36 m length, or

[0021] about 1.0 m diameter and about 75 m length.

[0022] However, when the thermal storage requirement exceeds that which might optimally be met with a single conveniently sized vessel, the storage may be provided by a plurality of parallel vessels, disposed in a matrix of the filler material, either in a grid formation with regular mutual separation or in a cluster. When disposed in a grid formation each vessel may have a diameter of approximately 1.5 m and a depth in the range of 6 m to 36 m. A typical inter-vessel spacing of about 3 m may then be employed, with the filler material between adjacent vessels being loaded in compression by the radial forces attributable to pressure within the vessels. When disposed in a cluster, the vessels may be formed with a triangular, square, hexagonal or other polygonal cross-sectional configuration that permits close packing of the vessels. They may alternatively be formed with a circular cross-section and be close-packed with the filler material occupying interstitial spaces between the vessels.

[0023] When close-packed as above described, the vessels when heated will expand effectively as a unit, so it is necessary that the surrounding filler material be constituted or structured in a way to accommodate the total effective expansion.

[0024] With these various arrangements, heat within the boundary of the total storage region will substantially be conserved and, allowing for the high rock-to-water relative heat capacities, the cavity-defining rock will make a useful dynamic contribution to the thermal storage. Also, the filler material may be selected to provide a high filler material-to-water relative heat capacity and so add a further useful dynamic contribution to the thermal storage.

[0025] Thermal expansion of the vessel or, if more than one, each vessel may be accommodated by selecting the filler material as one having a coefficient of thermal expansion approximately the same as that of the steel from which the vessel is fabricated or as one that exhibits resiliency sufficient to compress and expand with change in diameter of the vessel. The filler material might comprise a compressible material such as cork or other vegetable material, or a mineral material in either solid or particulate form. The filler material will be selected to withstand prevailing storage temperatures and, when in the form of a mineral, the filler material may comprise solid concrete or discrete particles of, for example, a thermally conductive material, capped in the latter case to prevent vertical displacement of the material. When in the form of concrete it may be laminated with a layer of a compressible material, either within the concrete or at the concrete/vessel interface. In the latter case, the compressible material may be wrapped about a vessel prior to placing the vessel in position and prior to surrounding the vessel with such other filler material as concrete. When the vessels are positioned in close-packed relationship, a compressible material may be positioned between adjacent vessels

[0026] The complete thermal energy storage system may be configured to provide for receipt and liberation of thermal energy by and from the vessel(s) either directly or by way of heat exchangers. Heated fluid to and flash steam from the (or each) vessel may be channelled through separate, parallel circuits or, in one application of the invention, by way of a series circuit incorporating a steam turbine, a condensate reservoir and a solar energy collection system.

[0027] The arrangements comprising a plurality of vessels may be employed to provide for storage volume adjustment and temperature control under variable load demands. This may be achieved by interconnected valving and pumping of at least some of the vessels.

[0028] Temperature and pressure conditions in a multi-vessel system may be maintained substantially constant across all vessels, by connecting all vessels in parallel to a common input header, to create uniform input temperature conditions, and by connecting all vessels in parallel to a common output header, for maintenance of uniform vessel pressure. The common output header will allow flow of steam between vessels, leading to temperature equalisation but possible water volume differences. However, the vessels may be interconnected to permit gravitational adjustment of water level differences.

[0029] The heating system that is employed to generate the thermal energy to be stored in the thermal energy storage system as above described may optionally comprise or incorporate any known type of heating system, such as for example a fossil-fuel-fired boiler or a nuclear-reactor-powered plant that is arranged to exchange heat with the working fluid. However, in one embodiment of the invention the heating system comprises a solar energy collector system in which incident solar radiation is reflected to illuminate receivers through which the working fluid is passed.

[0030] When the heating system comprises a solar energy collector system, such system may optionally incorporate at least one field of reflectors within which a plurality of receivers is located. Each receiver may be associated with a single reflector, for example a parabolic trough reflector, or each receiver may be associated with and receive reflected radiation from a plurality of reflectors. In the latter case the reflectors may comprise heliostats having either horizontal or vertical fixed axes, or linear reflectors. In each of these possible systems the working fluid is directed through tubes within the receivers and is heated by concentrated solar radiation from the reflectors.

[0031] The invention will be more fully understood from the following drawing-related description of illustrative embodiments of the thermal storage system and associated plant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] In the drawings—

[0033] FIG. **1** shows a schematic representation of a power generating plant incorporating an arrangement of a solar energy collection system, a steam turbine and a thermal energy storage system having a single ground cavity.

[0034] FIG. **2** shows a schematic representation of a power generating plant incorporating a series arrangement of a solar energy collection system, a steam turbine, a condensate reservoir and a thermal energy storage system having plural ground cavities,

[0035] FIG. **3** shows a diagrammatic representation of a ground cavity and a contained water storage vessel,

[0036] FIG. **4** shows a diagrammatic representation of an alternative capping/securing arrangement for the upper end of the vessel shown in FIG. **3**,

[0037] FIG. **5** shows (in plan) an example of a grid arrangement of plural cavities,

[0038] FIG. **6** shows a diagrammatic representation of a ground cavity containing a water storage vessel and, in accordance with a second embodiment of the invention, a filler material,

[0039] FIG. **7** shows (in plan) an example of a grid arrangement of plural water storage vessels located within a filler material matrix which is, in turn, located within a ground cavity,

[0040] FIG. **8** shows a representative cluster of hexagonal-section water storage vessels located within a filler material matrix,

[0041] FIG. **9** shows a representative cluster of circular-section water storage vessels located within a filler material matrix, and

[0042] FIG. **10** shows a schematic representation of a solar energy collections system portion of the power generating plant.

DETAILED DESCRIPTION OF THE INVENTION

[0043] As illustrated in FIG. **1**, the power generating plant incorporates a solar energy collector system **10**, a steam turbine **11** coupled to an electrical generator **11***a* and a thermal energy storage system **12**. Ancillary equipment, such as valves and metering devices, as would normally be included in such a plant have been omitted from the drawings as being unnecessary for an understanding of the invention. So too have been connections and valving arrangements that might be provided for bypassing the thermal storage system and directly feeding the steam turbine from the solar collection system and alternative energy sources.

[0044] As shown diagrammatically in FIG. **10** the solar energy collection system **10** comprises a field of arrayed ground-mounted, pivotal reflectors **13** that are driven to track the sun and, in so doing, to reflect incident solar radiation to illuminate an elevated receiver system **14**. The reflectors might typically comprise units as disclosed in International Patent Applications PCT/AU2004/000883 and PCT/AU2004/000884, and the receiver system might typically comprise a system as disclosed in International Application PCT/AU2005/000208.

[0045] Water at a temperature of approximately 180° C. and under pressure of the order of 100 Bar is delivered to the solar energy collection system **10** from a lower region of the thermal storage system **12** by a conduit **15** and, after gaining heat in the energy collection system, is returned to an upper region the thermal storage system **12** by way of a pump **16** and conduit **17**. The pump **16** is driven to adjust for any pressure drop in the circuit and to provide for any required pressure boost. In a typical system and under optimum conditions of solar heating, the heated water is returned to the thermal storage system **12** at a temperature within the range 220° C. to 360° C., with the pressure controlled by the pump **16** to maintain the major portion of the fluid in the thermal storage system **12** in its liquid phase.

[0046] Flash steam that is released (as required) from the upper region of the energy storage system is admitted to the steam turbine **11** at a temperature typically in the range of 215° C. to 340° C. by a conduit **18** and, after expanding through the turbine, is returned to the lower region of the storage system by way of a conduit **19** and a pump **20**.

[0047] The system as illustrated in FIG. **2** is conceptually similar to that of FIG. **1** and like reference numerals are used to identify like components. However, in this embodiment flash steam from the upper region of each of two thermal storage systems **12** is conveyed to the turbine **11** by a conduit **21**, and after expanding through the turbine the resultant vapour is directed into a ground level series-connected condensate reservoir **23**. The reservoir accommodates fluctuations in the water level in the thermal storage system **12** and provides for balancing of water transport throughout the system. Water, typically at about 30° C. to 50° C., is conveyed to the solar energy collection system **10** by way of a pump **24** and conduit **25** where it is heated to a temperature in the range of 270° C. to 340° C. and returned via conduits **26** and pumps **27** to the lower region of the thermal storage systems **12**, under a pressure of about 70 to 150 Bar.

[0048] FIG. **3** provides a diagrammatic illustration of a single thermal storage system **12** which comprises a vertically extending cylindrical cavity **28** which is formed by boring or by any other suitable excavation process within ground that is constituted by geologically stable consolidated rock **29**. The cavity **28** has a diametral dimension that is substantially smaller than the cavity's longitudinal depth, and a cylindrical steel vessel **30** that holds the pressurised water is positioned within the cavity at a level below that of unconsolidated ground cover **31**. The vessel **30** is formed with a relatively thin wall, having a thickness in the range 6 mm to 16 mm over a major portion of its extent, and the vessel is otherwise dimensioned to be a neat fit in the cavity **28** and thus to function as a liner for the cavity.

[0049] The lower end of the vessel is formed with a convex end portion **32** that is welded to the cylindrical wall portion **33** of the vessel, and the supporting rock **29** is formed with a complementary concavity for nesting the end portion. With this arrangement internal pressure-induced forces are transferred radially and downwardly through the vessel wall to the containing rock.

[0050] As illustrated in FIG. **3**, the upper end of the vessel is also formed with a convex end portion **34** that is welded to the cylindrical wall. However, allowing for the fact that there is no rock containment of the upper end of the vessel, the convex end portion **34** will be formed from steel having a thickness typically of at least 20 mm.

[0051] As an alternative and as shown in FIG. **4**, the upper end of the vessel may be closed by a heavy clamp **35***a* that is anchored to the rock stratum by rock bolts **35***b*. This approach might be adopted when, for example, larger diameter cavities are employed and greater upward forces would be applied to the welded end portion of the vessel.

[0052] The steel vessel **30** may be prefabricated, either partly or wholly, before being located in the ground cavity **28**. Alternatively, the vessel may be fabricated in situ by welding successive cylindrical sections together and by lowering the vessel into the ground cavity as fabrication progresses. When the installation has been completed and fluid connections have been made, the upper end of the vessel is covered with removable backfill, and roofing or another form of covering (not shown) may be employed to direct rain away from and/or to shield the area of hot ground.

[0053] As indicated previously, the thermal energy storage system may comprise a plurality of ground cavities **28**, each occupied by its own storage vessel **30**, and in such case the cavities may be arranged in a grid pattern such as shown in FIG. **5**.

[0054] FIG. **6** provides a diagrammatic illustration of a second embodiment of a thermal energy storage system **12** that is similar to that described with reference to FIG. **1** and like reference numerals are employed to designate like parts. However, in this case a thermally stable filler material **36** in the form of cork sheeting, a particulate material, a mortar, a compressible concrete or other compressible material is located about the vessel, and the vessel wall thus functions as an internal liner for the filler material.

[0055] As indicated previously, the thermal storage system may comprise a plurality of the water storage vessels **30** located within a single ground cavity **28**. In one such case the vessels may be arranged in a grid pattern and be positioned within a matrix of the filler material **36** in the form of concrete or particulate material as shown in FIG. **7**. With this arrangement each vessel **30** forms a liner for the filler material **36**, and the filler material surrounding and between adjacent vessels is loaded in compression by the radial forces attributable to pressure within the vessels.

[0056] In an alternative arrangement, as indicated in FIG. **8**, the water storage vessels **30** may be clustered in a close-packed contacting arrangement within a surrounding filler material **36**. In order to achieve this result each of the vessels may be formed with a hexagonal cross-section, as indicated, or with such other cross-section, such as a triangular cross-section, as permits their close packing.

[0057] FIG. **9** illustrates a further possible close-packed arrangement of multiple water storage vessels **30**, in this case with circular section vessels positioned within a matrix of filler material **36** and with the filler material located in the interstices between adjacent vessels.

[0058] The heating system **10**, in the form of a CLFR solar energy collector system **20**, is illustrated in a diagrammatic way in FIG. **10**. The illustrated solar energy collector system comprises a field of arrayed ground-mounted, pivotal reflectors **13** that are driven to track the sun and, in so doing, reflect incident solar radiation to illuminate an elevated receiver system **14**. In the form illustrated, the reflectors **13** pivot about horizontal axes.

[0059] Variations and modifications may be made in respect of the invention as above described and defined in the following claims.

1. A thermal energy storage system comprising at least one vertically extending cavity formed within ground that is constituted by geologically stable consolidated rock, at least one cylindrical steel vessel having a diametral dimension smaller than its longitudinal dimension positioned within the at least one cavity and surrounded peripherally by a containment material, conduits provided for directing pressurised water (in vapour and/or liquid phase) into the vessel and for conveying steam from an upper region of the vessel, the vessel having a peripheral wall that functions as a liner for the containment material whereby, in operation of the system, internal pressure-induced forces are transferred from the vessel to the containment material by way of the peripheral wall.

2. A thermal energy storage system comprising at least one vertically extending cylindrical cavity formed within ground that is constituted by geologically stable consolidated rock, the cavity having a diametral dimension that is substantially smaller than the cavity's longitudinal depth, a cylindrical steel vessel positioned within the cavity and conduits provided for directing pressurised water (in vapour and/or liquid phase) into the vessel and for conveying steam from an upper region of the vessel, the vessel being dimensioned to function as a liner for the cavity and, in operation of the system, to transfer internal pressure-induced forces to the surrounding rock.

3. A thermal energy storage system comprising a vertically extending cavity formed within ground that is constituted by geologically stable consolidated rock, at least one cylindrical steel vessel positioned vertically within the cavity, conduits provided for directing pressurised water (in vapour and/or liquid phase) into the vessel and for conveying steam from an upper region of the vessel, a thermally stable filler material located between the vessel and a surrounding wall of the cavity, the vessel having a diametral dimension that is substantially smaller than the vessel's longitudinal length and the wall of the vessel functioning as a liner for the filler material whereby, in operation of the system, internal pressure induced forces are transferred from the vessel to the surrounding rock by way of the filler material.

4. The thermal energy storage system as claimed in claim **3** wherein the thermally stable filler material comprises a material that maintains its physical and chemical properties when exposed to operating temperatures of the storage system.

5. The thermal energy storage system as claimed in claim **3** wherein the filler material is selected from a material that has the capacity to accommodate thermal expansion of the vessel.

6. The thermal energy storage system as claimed in any one of claims **1** to **3** wherein the steel vessel has circular cross-section and a diameter within the range of about 1.0 m to about 3.0 m.

7. The thermal energy storage system as claimed in any one of claims **1** to **3** wherein the steel vessel has a peripheral wall thickness within the range of about 6 mm to about 18 mm.

8. The thermal energy storage system as claimed in any one of claims **1** to **3** wherein the steel vessel has a lower end wall of convex form and thickness within the range of about 6 mm to about 18 mm.

9. The thermal energy storage system as claimed in claim **8** wherein the lower end of the cavity is formed as a concavity that complements the convex form of the lower end of the vessel.

10. The thermal energy storage system as claimed in any one of claims **1** to **3** wherein the steel vessel has an upper end wall of convex form and a thickness of at least 20 mm.

11. The thermal energy storage system as claimed in any one of claims **1** to **3** wherein the upper end of the vessel is anchored to surrounding rock strata by rock bolts.

12. The thermal energy storage system as claimed in claim **3** wherein the filler material is selected as one having a coefficient of thermal expansion approximately equal to that of the steel from which the vessel is formed.

13. The thermal energy storage system as claimed in claim **3** wherein the filler material is selected as one having a resiliency permitting compression and expansion with thermally induced changes in the dimensions of the vessel.

14. The thermal energy storage system as claimed in claim **3** wherein the filler material comprises a mineral material that solidifies in situ.

15. The thermal energy storage system as claimed in claim **3** wherein the filler material comprises a mineral material in particulate form.

16. The thermal energy storage system as claimed in any one of claims **1** to **3** and comprising a plurality of the vessels, with each vessel being located within its own cavity.

17. The thermal energy storage system as claimed in claim **3** wherein a plurality of the vessels is located in a matrix of the filler material.

18. The thermal energy storage system as claimed in claim **16** wherein each vessel has a diameter of approximately 1.5 m and the vessels are separated by approximately 3.0 m.

19. The thermal energy storage system as claimed in claim **16** wherein the vessels are clustered in closely-spaced relationship.

20. The thermal energy storage system as claimed in claim **17** wherein the vessels have a circular cross-section.

21. The thermal energy storage system as claimed in claim **17** wherein the vessels have a polygonal cross-section.

22. The thermal energy storage system as claimed in any one of claims **1** to **3** incorporated in a power generating plant having a solar energy collector system and a steam turbine connected in circuit with the thermal energy storage system.

23. The thermal energy storage system as claimed in claim **22** wherein the solar energy collector system comprises a field of arrayed ground-mounted pivotal reflectors that in use are driven to track the sun and reflect incident solar radiation to at least one elevated receiver system.

24. A method of storing thermal energy wherein water at a high temperature is maintained under pressure within a cylindrical steel vessel which is positioned within a cavity which is formed within ground that is constituted by geologically stable consolidated rock, wherein the vessel is surrounded peripherally by a containment material and wherein the vessel has a peripheral wall that functions as a liner for the containment material and internal pressure-induced forces are transferred from the vessel to the containment material by way of the peripheral wall.

25. (canceled)

26. (canceled)

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