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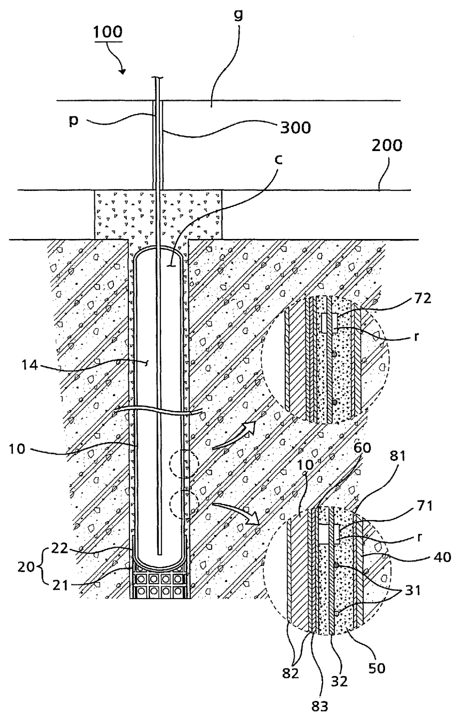
(54) HIGH-PRESSURE FLUID STORAGE SYSTEM AND CONSTRUCTION METHOD THEREFOR

(57) The present invention relates to a high-pressure fluid storage system and a construction method therefor. The high-pressure fluid storage system according to the present invention includes: a first horizontal tunnel formed at a predetermined depth in the underground in a lateral direction; a cavern formed by excavating the ground downwardly from the first horizontal tunnel; and a fluid storage reservoir including a tank body for storing fluid and inserted into the cavern; a backfill layer formed by a backfill material filled between the tank body and an inner wall of the cavern; and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

[FIG 3]



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Description

TECHNICAL FIELD

[0001] The present invention relates to a high-pressure fluid storage system and a construction method therefor, and more particularly, to a high-pressure fluid storage system and a construction method therefor which are capable of storing a high-pressure fluid in underground so as to guarantee safety and air tightness of natural gas compressed with a high pressure or compressed air.

BACKGROUND ART

[0002] Stable supply of energy corresponds to a fundamental infrastructure of a country.

[0003] Due to an increase in population and expansion of industry, the demands for energy has been increasing, but exhaustion of natural resources affects the supply of energy as a limiting factor, so that the demands and supply of energy are showing a serious imbalance.

[0004] In these situations, an energy policy of each country is trying to solve the imbalance between the demands and supply of energy in three aspects. Firstly, since the development of conventional resources such as petroleum or natural gas has reached a limit, non-conventional resources such as shale gas or tight gas are actively developed. Secondly, a new energy source such as wind power generation other than fossil fuel is developed. Thirdly, as an approach from an aspect of improving efficiency between the supply and consumption of energy, smart grids using information technology (IT) are being built up. The above three methods may be understood to be complementary with each other.

[0005] To improve energy efficiency means to be capable of supplying energy in time corresponding to demands of energy, which results in a problem of storing energy. This will be described below in detail.

[0006] In case of a base load power station such as thermal power generation or nuclear power generation, once performing power generation, a certain amount of electric energy is generated and the amount itself cannot be adjusted. Accordingly, while the amount of power generation may not handle all power demands in a peak electricity consumption time in daytime, the amount of power generation far outstrips the demands, and thus substantial amounts of generated power are forced to be discarded. To resolve such a difference between the amounts of power generation and power consumption, it is necessary to store surplus electricity at midnight and replenish lacking power supply in daytime peak hours.

[0007] For this, it is essential to store electric energy. Typically, pumped storage power generation has played an important role in storing energy, but the energy storage by the pumped storage power generation can no longer be counted on due to environment problems and limitation in location conditions.

[0008] Thus, compressed air energy storage (CAES) or a secondary battery as an energy storing means has emerged as a keyword of national energy strategy. At present, the CAES and the secondary battery are respectively expected to be mainly used for large-capacity energy storage and small and medium capacity energy storage. The CAES refers to a system which compresses and stores air by using electricity generated by a base load power generation such as thermal power generation or by a new regeneration power generating means such as wind power generation, and later, converts the compressed air again to electricity by power generating means such as a turbine or piston and supplies the converted electricity.

[0009] Energy storage highly relates to not only an aspect of resolving imbalance of the demands and supply of electric power but also to the quality of electric power supply. For example, in case of wind power generation, since the time and the strength of wind blow are not constant, high-quality electricity cannot be produced. Also, when a great amount of electricity is abruptly produced through wind power generation, there is a problem of causing frequency disturbance of power system. Also, in an aspect of solving such a problem, energy storage is emerging as an important concept.

[0010] Thus, in conjunction with base load power generation sources and new regeneration energy power generation sources, the CAES has a strategic meaning in future energy supply policy in terms of increasing elasticity of energy supply.

[0011] CAES type power plants in operation include Huntorf power plant in Germany, and McIntosh power plant in U.S, and these use caverns constructed by melting a rock salt layer as the spaces for storing compressed air. However, to overcome a limitation of location condition, CAES storage reservoir will be developed in the direction of being constructed underground.

[0012] In designing a storage facility for compressed air, one of important points is to secure the safety and air tightness of the storage facility of compressed air. In case of storage reservoir of compressed air, fluid is stored at a high pressure of at least about 50 bars, and therefore, a safety issue is the most important issue. Furthermore, when a highly compressed fluid leaks through a crack formed in a rock bed, the efficiency as a storage reservoir is degraded, and therefore, securing safety becomes another important technological issue.

[0013] In a practical aspect, one of the key issues in the CAES fluid storage plant is the problem of economic feasibility of construction. This is because, although it is reasonable to approach an energy policy from a strategic viewpoint, the usability of CAES is remarkably increased when the problem of economic feasibility is solved.

DISCLOSURE OF THE INVENTION

TECHNICAL PROBLEM

[0014] A purpose of the present invention is to provide a high-pressure fluid storage system and a construction method therefor which are capable of storing a high-pressure fluid by excavating an underground space so as to guarantee safety and air tightness and being economically constructed, and to thereby increase the applicability of CAES.

TECHNICAL SOLUTION

[0015] To accomplish the above-described purpose, a high-pressure fluid storage system according to an aspect of the present invention includes: a first horizontal tunnel formed in a lateral direction at a first depth in the underground; a cavern formed by excavating the ground downwardly from the first horizontal tunnel; a tank body for storing the fluid and inserted into the cavern; a backfill layer formed by a backfill material filled between the tank body and an inner wall of the cavern; and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

[0016] In addition, to accomplish the above-described purpose, another structure of a high-pressure fluid storage system according to an aspect of the present invention includes: a first horizontal tunnel formed in a lateral direction at a first depth in the underground; a second horizontal tunnel formed in a lateral direction at a second depth deeper than the first depth in the underground; a cavern formed by excavating the ground between the first horizontal tunnel and the second horizontal tunnel; a tank body for storing the fluid and inserted into the cavern; a backfill layer formed by a backfill material filled between the tank body and an inner wall of the cavern; a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern; and a second plug formed by filling the backfill material into the second horizontal tunnel to close the lower portion of the cavern.

[0017] Further, to accomplish the above-described purpose, a method for constructing a high-pressure fluid storage system according to an aspect of the present invention, the method includes: (a) excavating a first horizontal tunnel in a lateral direction at a predetermined depth in the underground; (b) forming a connecting hole through drilling from the ground surface to the first horizontal tunnel; (c) forming a cavern by excavating the ground downwardly from the first horizontal tunnel at a point, at which the connection hole is formed, through the connection hole by using a construction equipment installed on the ground surface; and (d) installing a tank body for storing the fluid therein and inserted into the cavern, a backfill layer formed of a backfill material filled between the tank body and an inner wall of the cavern, and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

[0018] Furthermore, too accomplish the above-described purpose, a method for constructing a high-pressure fluid storage system according to another embodiment of the present invention, the method includes: (a) excavating a first horizontal tunnel in a lateral direction at a first depth in the underground; (b) forming a connecting hole through drilling from the ground surface to the first horizontal tunnel; (c) forming a cavern by excavating a second horizontal tunnel in the horizontal direction at a second depth deeper than the first depth, and by upwardly excavating the ground from the first horizontal tunnel to the first horizontal tunnel at a point, at which the connection hole is formed; (d) installing a second plug for closing a lower portion of the cavern in the second horizontal tunnel; (e) installing a tank body for storing the fluid therein and inserted into the cavern, a backfill layer formed of a backfill material filled between the tank body and an inner wall of the cavern, and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

ADVANTAGEOUS EFFECTS

[0019] The present invention provides a practical technique capable of installing a high-pressure fluid storage plant, having a diameter of several meters or more and a height of several tens of meters at a deep portion underground, in a state n which safety and air tightness are maintained, and thus may increase usability of CAES.

[0020] Furthermore, the present invention is expected to expedite the commercialization of the CAES by providing a method for economically constructing a high-pressure fluid storage system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a schematic view of a high-pressure fluid storage system according to a first embodiment of the present invention.

FIG. 2 is a plan view of a first horizontal tunnel viewed from above according to another embodiment of the present invention.

FIG 3 is a schematic cross-sectional view of a fluid storage reservoir in the storage system illustrated in FIG. 1.

FIG. 4 is a schematic front view illustrating a state in which a tank body, a connecting member, and a reinforcing member are combined in a high-pressure fluid storage system illustrated in FIG. 1.

FIG. 5 is a schematic exploded perspective view for describing a process in which segments are coupled to each other.

FIG. 6 is a schematic cross-sectional view taken along line a-a of FIG. 5.

FIG. 7 is a schematic cross-sectional view taken along line b-b of FIG. 5.

FIG. 8 is a schematic perspective view of a support frame illustrated in FIG. 1.

FIGS. 9 to 11 are perspective views illustrating another shape of a connecting member.

FIG. 12 is a schematic flowchart illustrating a method for constructing a high-pressure fluid storage system according to an embodiment.

FIGS. 13 and 14 are views for describing a method for constructing a fluid storage reservoir.

FIG. 15 is a schematic view of a high-pressure fluid storage system according to a second embodiment of the present invention.

FIG. 16 is a schematic flowchart of a method for constructing a high-pressure fluid storage system according to the second embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] According to the present invention, the cavern may be formed in plurality to be spaced apart from each other along the first horizontal tunnel and may be provided with the plurality of fluid storage reservoir.

[0023] In addition, the first horizontal tunnel may include a main tunnel, and at least one auxiliary tunnel which is branched from the main tunnel and formed in the lateral direction, wherein the plurality of caverns may be formed to be spaced apart from each other under the main tunnel or the auxiliary tunnel.

[0024] Also, in an embodiment of the present invention, a connecting hole may be further provided, the connecting hole being formed by penetrating the ground from the ground surface to the first horizontal tunnel.

[0025] According to the present invention, the back fill layer and the first plug may be integrally formed by means of a backfill material.

[0026] In an embodiment of the present invention, the tank body is formed of a airtight material and has a receiving part in which a high-pressure fluid is stored and which is formed therein, wherein a plurality of segments are sequentially stacked and coupled in the lengthwise direction thereof, and a reinforcing member disposed to surround the tank body while being spaced apart from the tank body is further provided, wherein the backfill layer contains the reinforcing member.

[0027] According to the present invention, a plurality of connecting members which are disposed along an outer circumferential surface of the tank body and spaced apart from each other in the lengthwise direction of the tank body are further provided, and the reinforcing member is installed on the connecting member.

[0028] In an embodiment of the present invention, the reinforcing member includes: a plurality of horizontal reinforcing members disposed to be spaced apart from each other in the lengthwise direction of the tank body; and a plurality of vertical reinforcing members connected to the horizontal reinforcing members to cross the horizontal reinforcing members and disposed to be spaced apart from each other, wherein the vertical reinforcing members each is formed of a plurality of segmented members which are sequentially connected in the lengthwise direction, the segmented members being installed on the connecting member.

[0029] Also, connecting members each is disposed in a circumferential direction of the tank body, is coupled to or to be spaced apart from a circumferential surface of the tank body, and has a mounting part which is formed therein and in which the vertical reinforcing member is inserted. At least one of the plurality of connecting members is coupled to the tank body, and particularly, the connecting member disposed at a lowest portion may be connected to the tank body.

[0030] In an embodiment according to the present invention, an additional weld member attached to an inner side surface or an outer side surface of the segment so as to protrude with respect to an upper end surface or a lower end surface of the segment may be further provided.

[0031] In an embodiment according to the present invention, at least one of a separation coating formed on an outer side surface of the tank body so as to prevent the tank body and the backfill layer from being coupled to each other, a anti-corrosion coating formed on at least an inner circumferential surface and an outer circumferential surface of the tank body so as to prevent the corrosion of the tank body, a waterproof coating formed on the circumferential surface of the tank body so as to prevent the tank body from contacting surrounding water, and a heat insulation coating formed on at least an inner circumferential surface and an outer circumferential surface of the tank body so as to prevent a fluid stored in the tank body from heat-exchanging with surroundings is provided.

[0032] Also, the tank body may be formed of a metal material and may be further provided with a corrosion inhibitor for a metal material electrically connected to the tank body so as to delay corrosion of the tank body by a galvanic effect.

[0033] In an embodiment according to the present invention, a supporting frame which comprises: a supporting part installed on a bottom surface of the cavern; and a mounting part which is formed on an upper portion of the supporting part and on which the tank body is mounted such that the tank body is maintained in a state of being spaced apart upwardly from the bottom surface of the cavern. Especially, the supporting part may be formed in a lattice shape such that the backfill material is filled inside the supporting part of the supporting frame, or formed of a plurality of plates in which multiple introduction holes are formed.

[0034] A CAES system according to the present invention includes a high-pressure fluid storage system formed at a deep portion underground and having a configuration described above, and a power generating system which compresses air in the high-pressure fluid storage system and generates power using the compressed air.

[0035] Especially, in an embodiment according to the present invention, the first plug may be formed by filling the backfill material into the first horizontal tunnel. For example, both sides of the first horizontal tunnel are closed with the cavern therebetween, and the backfill layer and first plug are formed together by injecting the backfill material into the cavern and the horizontal tunnel.

[0036] In an embodiment according to the present invention, the forming of the tank body and the backfill layer in the cavern includes: a filling step of filling a first fluid for providing buoyant force in the cavern; a tank manufacturing step of launching a lower segment constituting a lower portion of the tank body, and sequentially stacking and coupling a plurality of body segments and a lower segment which constitute a body portion and an upper portion of the tank body on the lower segment to install the tank body in the cavern; and a backfill step of forming a backfill layer by filling a backfill material between the tank body and an inner wall of the cavern so as to transfer an inner pressure of the tank body to a rock bed, wherein in the manufacturing of the tank body, an upper end portion of a manufactured portion of the tank body inserted into the cavern may be floated over the surface of a first fluid by buoyant force of the first fluid.

[0037] Furthermore, before the filling of the backfill material, reinforcing members spaced apart from the tank body to surround the tank body are installed, and when the backfill material is filled, the backfill layer contains the reinforcing members. Specifically, after installing the reinforcing members to be spaced a predetermined distance from outer surfaces of the upper segment, the body segments, the lower segment, when each of the segments are coupled to each other in the manufacturing of the tank body, the reinforcing members which has been respectively installed on the segments may be installed by being connected to each other.

[0038] The backfill material may be filled after a third fluid is filled into the tank body so as to prevent the tank body from being deformed due to a pressure of the backfill material. As the third fluid, water or compressed air may be filled, or water and compressed air may be filled together

[0039] After excavating the cavern, a supporting frame capable of supporting the tank body is installed on a bottom surface of the cavern and thus may improve constructability

MODE FOR CARRYING OUT THE INVENTION

[0040] The present invention relates to a high-pressure fluid storage system and a method for constructing the same.

[0041] In the present invention, a "storage system" mainly means that a plurality of fluid storage reservoirs constitute a system but also means a system constituted by only one fluid storage reservoir.

[0042] Also, in the present invention, a "high-pressure fluid" means air compressed with a high-pressure of at least about 50 bar to operate a CAES, but does not exclude compressible fluids, such as natural gas, which can be compressed by applying a pressure, and a range of the pressure is not necessarily limited to a pressure of at least about 50 bar, but the meaning is expanded to include a high pressure the safety of which is required to consider even when the high pressure is less than about 50 bar.

[0043] Also, in the present invention, a storage reservoir mainly means a reservoir for CAES for storing energy using compressed air, but the meaning includes a high pressure-storage reservoir for purely storage which is not connected with a power generation facility.

[0044] Hereinafter, with reference to the accompanying drawings, a high-pressure fluid storage system (hereinafter, referred to as a "storage system") according to the present invention with an example of a compressed air storage reservoir in a CAES power generation system.

[0045] FIG. 1 is a schematic view of a high-pressure fluid storage system according to a first embodiment of the present invention, FIG. 3 is a schematic cross-sectional view of a fluid storage reservoir in the storage system illustrated in FIG. 1, and FIG. 4 is a schematic front view illustrating a state in which a tank body, a connecting member, and a reinforcing member are combined in a high-pressure fluid storage system.

[0046] Referring to FIGS. 1, 3 and 4, the storage system 500 according to the present invention is provided with an access tunnel e, a fluid storage reservoir 100, a first horizontal tunnel 200, and a connecting hole 300.

[0047] The access tunnel e is used as a passage for a work vehicle to enter from the ground surface to the first horizontal tunnel 200. In the current embodiment, as illustrated in FIG. 1, the access tunnel e is vertically formed from the ground surface and an elevator is installed thereinto and may thereby be used as an entrance means. Alternatively, the access tunnel e is formed to lengthily extend with a slight inclination in consideration of the climb angle of the vehicle so as to directly drive the vehicle, or is formed in a spiral shape and thus an installation area thereof can be reduced.

[0048] The first horizontal tunnel 200 is formed in the lateral direction from the first depth in the underground. The "horizontal tunnel" does not mean only the horizontal direction perpendicular to the gravitational direction, but the meaning thereof includes a case of having a slight slope with respect to the "horizontal direction". This is expressed as the "lateral direction" in the present invention. The first horizontal tunnel 200 is used as a work space required to excavate the cavern 'c' and to manufacture the fluid storage reservoir 100. Furthermore, when the installation of the fluid storage reservoir is completed, the horizontal tunnel 200 is closed to be used as the space for installing a first plug 90.

[0049] The connecting hole 300 is formed by penetrating the ground through drilling or the like from the ground surface to first horizontal tunnel 200. In a construction sequence, it is not necessary to excavate the connecting hole 300 after firstly forming the first horizontal tunnel 200, but in a reverse order, it may be also possible to firstly form the connecting hole 300 and then form the first horizontal tunnel 200. In the current embodiment, a plurality of connecting holes 300 are installed along the first horizontal tunnel 200 so as to be spaced apart from each other. The connecting holes 300 connect construction equipment prepared on the ground surface such as cranes, concrete filling equipment, excavating equipment or the like and the first horizontal tunnel 200 with each other. For example, the main body of a crane is installed on the ground surface, and a traction rope of the crane is inserted to the first horizontal tunnel 200 through the connecting holes 300. Also, the main body of an excavator for excavating the ground through a rotational method is installed on the ground surface, and while the drilling head of the excavator is disposed inside the horizontal tunnel 200, a rotating shaft extending from the main body of the excavator is connected to the drilling head through the connecting holes 300 and may thereby supply power.

[0050] The fluid storage reservoir 100 serves to store compressed air with a high-pressure, and is formed under the first horizontal tunnel 200. In the present invention, the fluid storage reservoir 100 is formed in a longitudinal direction (a direction slightly inclined with respect to the vertical and horizontal directions. Also, a single fluid storage reservoir 100 may be installed, but the fluid storage reservoir 100 is desirably provided in plurality in consideration of economical construction. In an embodiment of the present invention, while the first horizontal tunnel 200 is used as a work space, the ground is excavated by using construction equipment connected through the connecting holes 300 to form the cavern c, and then the fluid storage reservoir 100 is installed inside the cavern 'c'.

[0051] Especially, the present invention is characterized in that the first plug 90 for closing an upper portion of the cavern 'c' by suing the first horizontal tunnel 200. That is, both ends of the first horizontal tunnel 200 located over the cavern 'c' are closed to form a space, and then a filling material such as concrete is placed in the closed space to manufacture the first plug 90.

[0052] As described above, the construction method in which a first horizontal tunnel 200 is formed, and the fluid storage reservoir 100 is vertically formed under the first horizontal tunnel 200 is much more advantageous than a method of directly forming the fluid storage reservoir from the ground surface in terms of economic feasibility and safety.

[0053] The technique of excavating the ground in a vertical shape can be divided into a blasting method and a method of excavating a rock bed while rotating a head equipped with a bit. The blasting method includes a top-down method of downwardly excavating from the ground surface and a bottom-up method in which, on the contrary, a separate access tunnel is firstly formed followed by upwardly excavating from a lower end portion. Both the bottom-up and top-down methods have problems in that blasting work itself is difficult when the cavern has a great depth, and treatment of rocks broken by blasting is difficult. Also, the blasting cannot always be free from a civil complaint. When an excavator is used in place of blasting, there is a problem in that it is difficult to use the excavator due to a technical limit in large area construction with a large cavern diameter and construction costs are increased. Especially, in case of high pressure fluid reservoir, since the cavern is downwardly formed from the depth of several ten meters underground, it is not necessary to excavate from the ground surface to the upper end of the cavern. However, since being installed on the ground surface to be used, existing excavators necessarily excavate the ground also from the ground surface to the upper end of the cavern. This is the reason why the economic feasibility of construction is remarkably degraded. Accordingly, when constructing an existing fluid storage reservoir, the method of forming the cavern downwardly from the ground surface is not adopted.

[0054] In the present invention, a practical method capable of avoiding excavating from the ground surface to the upper end of a cavern even though an excavator is used is derived and thereby improves the economic feasibility of construction. That is, a horizontal tunnel 200 is excavated after forming an access tunnel, so that it is not necessary to excavate from the ground surface to the upper end of a cavern. Also, in the current construction method, while using a vertical excavator disclosed in, for example, Korean Patent No. 0683909, Korean Patent No. 1068578, and Korean Patent 1334298, since the main body of the excavator is installed on the ground, and since the head portion and the main body portion can be connected through a connecting hole 300 after only the head portion for actually excavating the ground is installed in the first horizontal tunnel, the vertical excavator has become normally usable. The above-mentioned vertical excavators were not designed to be used in a separated state, but although not having construction experience, the present research members determined that the separation of the vertical excavators was practically possible through sufficient study on the mechanical structure. Also, besides the equipment disclosed in the above-mentioned Korean patents, it is expected that a head portion for excavating while actually grinding a rock bed and a main body portion for providing power to the head portion can be made in a shape of being separated from each other on the ground surface and in the first horizontal tunnel. Also, in the present invention, according to miniaturization of equipment, the possibility that a vertical excavator is introduced inside the first horizontal tunnel to perform excavation is not excluded.

[0055] As mentioned above, it is possible to prepare an alternative of not excavating from the ground surface to the upper end of a cavern by introducing an excavator into a first horizontal tunnel through separately installing the head portion and the main body portion of the excavator and miniaturization of the excavator.

[0056] As such, when comparing the construction method in which a first horizontal tunnel is formed at a first depth in the underground to downwardly excavate the cavern and the construction method of directly excavating a vertical cavern from the ground surface, one matter to be considered is the increase in construction costs according to the formation of an access tunnel e and the first horizontal tunnel 200. This is because while it is not necessary to excavate the ground from the ground surface to the upper end of a cavern, economic feasibility of construction may be rather degenerated by forming the access tunnel e and the first horizontal tunnel 200. Accordingly, the present invention is more advantageous mainly in case of being used to construct a compressed air storage plant of a scale having at least a predetermined size by installing a plurality of fluid storage reservoirs than in case of forming a single fluid storage reservoir.

[0057] Also, another advantage of the method of forming a fluid storage reservoir downwardly from a first horizontal tunnel after forming the first horizontal tunnel is safety with regard to a plug. When a plug is formed on an upper portion of the fluid storage reservoir after excavating vertically from the ground surface, the upper side from the plug becomes vacant. That is, since the plug has a structure which should endure a pressure toward the upper side of the fluid storage reservoir, attention is needed in designing the plug. However, when installing the plug directly I the first horizontal tunnel, since a rock bed is formed over the plug, there is an advantage of superior safety.

[0058] Also, when a vertical cavern is formed underground, a side plug is formed on an upper portion or lower side portion of the cavern so as to be connected to an access tunnel except for a method of excavating from the ground surface. Since the size of the plug is not only much larger than that of the access tunnel, and since the plug has a required shape such as a tapered shape or a wedge shape, there is a problem of enlarging the access tunnel again. However, in the present invention, by virtue of the above-mentioned structural stability, a first plug is formed by only placing concrete after closing the first horizontal tunnel as it is, it is advantageous in the aspect of economic feasibility.

[0059] As described above, the construction method according to the present invention has a technical characteristic in that through a first depth in the underground is approached through an access tunnel e, a first horizontal tunnel 200 is then formed, and then a fluid storage reservoir 100 is constructed downwardly from the first horizontal tunnel 200 while using construction equipment installed on the ground surface through a connecting hole 300. Also, there is an advantage in that in comparison of a case of forming a single fluid storage reservoir, economic feasibility of construction can be remarkably improved and the safety of the fluid storage reservoir is increased in a case in which a plurality of fluid storage reservoirs are installed to form a storage plant.

[0060] Although in FIG. 1, the plurality of fluid storage reservoirs 100 are installed to be spaced apart from each other in the single first horizontal tunnel 200, the first horizontal tunnel may be disposed in various shapes as another embodiment illustrated in FIG. 2. FIG. 2 is a plan view of the first horizontal tunnel when viewed from the above.

[0061] Referring to FIG. 2, the first horizontal tunnel includes a main tunnel 210 and auxiliary tunnels 220. The main tunnel 210 is formed in both directions from the access tunnel e, and the auxiliary tunnels 220 are branched in a lateral direction from the main tunnel 210. Also, the fluid storage reservoirs 100 are formed under the auxiliary tunnels 220, and the first plugs 90 are formed by closing the auxiliary tunnels 220.

[0062] Also, although not shown, in another embodiment, a combination in which the fluid storage reservoirs are formed under the main tunnel and the auxiliary tunnels may be considered.

[0063] Hereinafter, with reference to the drawings, a specific configuration of the fluid storage reservoir 100 (hereinafter, referred to as "storage reservoir") which is used in a storage system 500 according to an embodiment of the present invention will be described.

[0064] The storage reservoir 100 used in an embodiment of the present invention includes a tank body 10, a reinforcing member 30, a backfill layer 50 and a first plug 90.

[0065] The tank body 10 has a sealed inner space portion formed therein to thereby provide a space in which compressed air is stored. The tank body 10 is disposed in an upward/downward vertical direction, preferably, in the vertical direction to be buried in a cavern 'c' formed in a rock bed g in a deep portion underground. The depth (of the point at which an upper end portion is disposed) of the tank body 10 relates to safety and economic feasibility.

[0066] In an aspect of safety, the depth and the height of the tank body 10 are determined according to the storing pressure and the storing capacity of compressed air, and in the current embodiment, the tank body 10 may be formed to have the disposition depth of about 30 m to about 60 m, the diameter of about 3 m to about 8 m, and the height of about 100 m to about 200 m.

[0067] One of the most important functions of the tank body 10 is to maintain air tightness with respect to compressed air. Accordingly, the tank body 10 is made of a material capable of preventing a gas leak such as steel, rubber, or plastic. In the current embodiment, although the tank body 10 is made of steel having the thickness of about 4 mm to about 10 mm, since the tank body 10 does not endure the pressure of compressed air by the self stiffness, the thickness of steel may be further thinned and the tank body 10 may be formed of a soft material such as rubber.

[0068] Also, the shape of the tank body 10 may be formed in various shapes, and in the current embodiment, the tank body 10 is formed in a cylindrical pillar shape such that a pressure is not concentrated on one side, and the upper and lower portions thereof are respectively formed in dome shapes.

[0069] A backfill material is filled between the tank body 10 and the inner wall of the cavern 'c' to form the backfill layer 50. The backfill layer 50 functions to transfer the pressure of the tank body 10 to the rock bed g. Accordingly, it is important for the backfill layer 50 to be completely filled with the backfill material without a vacant space. In the current embodiment, the backfill layer 50 may be formed in the thickness of about 30 cm to about 100 cm. Concrete is widely used as the backfill material, but various grout materials such as cement, milk, or mortar may be used. That is, all water curable materials which can be cured by reacting with water can be used as a back filing material. However, in selecting the backfill material, a material which can be formed to have a small porosity of the back filing layer after curing is preferably selected, considering the aspects of safety and air tightness. Especially, when the porosity is great, it is undesirable because underground water can be easily introduced toward the tank body 10 from the rock bed.

[0070] Also, the reinforcing member 30 is preferably buried inside the back filing layer 50. However, according to the condition of the rock bed or the pressure condition of the fluid to be stored in the tank body 10, the reinforcing member may not be provided. The backfill material has cement as the main component, but cement has a property of being strong against a compressive stress but being very weak against a tensile stress. Accordingly, to reinforce the tensile strength, the back filing layer 50 preferably includes the reinforcing member 30 such as a reinforcing bar or a wire mesh. The reinforcing bars are formed in a shape having horizontal and vertical lattices and disposed to surround the tank body 10. The tensile force applied to the backfill layer 50 is mainly applied in a tangential direction of the tank body 10, and a crack in the backfill layer 50 may be mainly formed in the vertical direction. Accordingly, when the reinforcing member 30 is disposed in the horizontal direction (the circumferential direction of the storage tank) rather than in the vertical direction (the lengthwise direction of the storage tank), the reinforcing member 30 has the more important meaning in an aspect of reinforcing the tensile strength.

[0071] Also, a backup layer 40 may be formed by jetting a quick curing material such as shotcrete on the inner wall of the rock bed g, when there is a concern about falling rocks or ground failures during excavation.

[0072] Also, a separation coating 60 may be formed between the tank body 10 and the backfill layer 50. The separation coating 60 serves to prevent the tank body 10 from being coupled to the backfill layer 50 and thereby to reduce shearing force on a friction surface which is in contact with the tank body 10 and the backfill layer 50. Although the tank body 10 and the backfill layer 50 should closely contact each other without a gap therebetween, it is undesirable that the tank body 10 and the backfill layer 50 be physically coupled to each other. That is, this is because when a pressure is applied to the tank body 10 by compressed air, a shearing force is generated on the contact surface of the tank body 10 and the backfill layer 50 to thereby cause physical damage, but when the tank body 10 and the backfill layer 50 are not coupled to each other but separated, the pressure is distributed and the shearing force is reduced. In the current embodiment, the separation coating 60 may be formed by applying a fluidal material such as bitumen or grease on the outer wall of the tank body 10, or by attaching a film or a sheet which are formed of material not coupled to cement to the outer wall of the tank body 10.

[0073] Also, a waterproof coating 81 is formed between the separation coating 60 and the backfill layer 50 and can thereby prevent the corrosion of the tank body 10 caused by penetration of underground water. The waterproof coating 81 may be formed through a method of applying a waterproof agent or attaching a waterproof sheet. Also, aside from the waterproof coating 81, to prevent the corrosion of the tank body 10, an anti-corrosion coating 82 may be formed by applying a corrosion inhibitor on at least one of the inner circumferential surface or the outer circumferential surface of the tank body 10.

[0074] Also, the temperature of the fluid stored in the tank body 10 rises during a compression process. To prevent the temperature of the fluid from decreasing through heat exchange with the surroundings, a thermal insulation coating 83 may be formed on at least one of the inner circumferential surface or the outer circumferential surface of the tank body 10. The heat insulation coating 83 is also formed through a method of attaching or applying a heat insulating material.

[0075] The above-described backup layer 40, the separation coating 60, the waterproof coating 81, the anti-corrosion coating 82, and the heat insulation coating 83 are applied according to a condition in a manner that all thereof may be applied, some thereof selectively may be applied, or none thereof may be applied.

[0076] In the current embodiment, the anti-corrosion coating 82 is first formed on the inner and outer surfaces of the tank body 10, and the heat insulation coating 83 and the separation coating 60 are sequentially formed from the surface of the anti-corrosion coating 82 positioned outside the tank body 10. Furthermore, the waterproof coating 81 is formed on the surface of the separation coating 60, and the backup layer 40 is formed on the inner wall of the rock bed g. Also, according to an embodiment, a thin film foil (not shown) formed of a non-coupling material such as aluminum is interposed between the waterproof coating and the anti-corrosion coating and can thereby prevent the waterproof coating and the anti-corrosion coating from being mechanically coupled to each other. The foil is made of waterproof material and can function as both the waterproof coating 81 and the separation coating 60.

[0077] Furthermore, a support frame 20 is installed on the bottom of the cavern 'c'. The support frame 20 serves to maintain the tank body 10 in a state of being spaced apart from the bottom surface of the cavern 'c'.

[0078] Also, the plug 90 is installed over the tank body 10 to close the upper side of the tank body 10. In addition, a pipe p for air inflow/outflow is inserted to the tank body 10, and the pipe p is connected to air compression equipment and power generating equipment which are provided on the ground surface.

[0079] So far, the standards and materials of the high-pressure fluid storage reservoir such as the height, the diameter, and the disposition depth has been described, but these standards and materials are merely examples, and various standards and materials may be used according to an embodiment.

[0080] The present invention was derived not only from research on how to manufacture and/or construct the storage reservoir 100 configured as described above, but also from research on how to economically construct.

[0081] As described above, the height of only the tank body 10 is about 100 m to about 200 m, and considering the disposition depth of the tank body 10, the cavern 'c' should be formed by excavating downwardly from the ground surface by at least about 150 m. It is technically not easy to excavate the cavern having diameter of about 7 m to about 8 m vertically by about 150 m, but it is also very difficult to insert the tank body 10 into the cavern 'c'.

[0082] Although having an experience of constructing such equipment at a deep portion underground for example, a petroleum storage base, since the petroleum storage base or the like has a remarkably easy condition than compressed air in terms of pressure-resistance and air tightness, it was such a level that a sealed tank was not introduced and underground inner walls were finished with only a concrete lining.

[0083] However, in case of compressed air, since air tightness should be guaranteed, a technical problem of a totally different level from that in the petroleum storage base or the like emerges, for example, introduction of a sealed tank or the like. Firstly, there is a realizability problem of how to install, in the cavern, the tank body having the height of about 100 m to about 200 m and the reinforcing member surrounding the tank body. Not only domestically but also internationally, there has been no experience of actually constructing a sealed tank body and a reinforcing member in a cavern having the diameter of about 5 m to about 8 m and the height of about 150 m to about 200 m. Such a scale is directly connected to a problem of whether the construction is possible rather than a problem of size difference.

[0084] Also, even when the construction is possible, since actual industrial applicability is degraded in case of causing a serious disadvantage in economic feasibility, the problem of economic feasibility of construction strongly emerges.

[0085] Consider only the problem of installing the tank body in a cavern under a condition that a cavern has been vertically excavated underground. A tank body having the height of at least about 100 m cannot be manufactured as a single body, and therefore, segments thereof should be coupled through a method such as welding. Since welding quality significantly affects air tightness, it is advantageous to manufacture in a factory equipped with a perfect working condition, but the tank body of a huge scale manufactured in a factory cannot be transported.

[0086] Then, the welding may be performed on the ground surface at site. However, it is also not technically easy to lift the tank with the height of about 150 m and to insert the tank into a cavern after the tank is manufactured. A crane for hanging the tank body should guarantee a height of about 200 m, and since the tank body is formed of steel, the weight endured by the crane is substantially great. Probably, a tower crane for constructing a high-rise building can endure the height, but cannot endure the weight. Although a goliath crane of shipyard or the like can perform this kind of work, it is nearly impossible in reality to use the goliath crane considering economical conditions.

[0087] As another alternative, in a state in which segments are sequentially inserted into the cavern, welding can then be performed, but considering the narrow working condition and environment of the cavern, the welding quality which is essential to maintain air tightness cannot be expected. For all that, widening of the cavern is unrealistic because it is uneconomical and may cause a problem in safety.

[0088] In case of reinforcing member, there is a more difficult problem. It is also very difficult to install the reinforcing member having the height of about 150 m to be spaced apart from the tank body. Even when reinforcing bars are used as the reinforcing member, a middle portion thereof is bent at the height of about 150 m, and therefore, it is difficult to maintain the required shape. For all that, when all vertical reinforcing members are fixed to inner walls of the rock bed, work processes become very complicated, the construction period becomes longer, and degradation of economic feasibility is inevitably involved.

[0089] Although several examples are given in the above, these are most typical problems arising from the construction, it may cause much difficulty in terms of realizability and economic feasibility to install, in the cavern, the tank and the reinforcing member which have a scale of about 150 m with a space having the diameter of about 5 m to about 8 m.

[0090] That is, the fluid storage reservoir 100 manufactured according to the present invention seems very easy when considering only the structural aspect after completion, but when actually trying to construct this, one cannot but experience a limit in construction technology.

[0091] Researched are: a construction method for burying a tank body having the height of more than 100 m into a cavern having the height of more than about 150 m according to the present invention; and a structure of the tank body optimized to ensure the realizability and economic feasibility of the construction method.

[0092] In an aspect of construction method, water is filled in the cavern c, segments are then floated on the water surface in cavern 'c' by using buoyant force, and then the tank body is progressively manufactured while the segments are sequentially stacked and coupled.

Manufactured portion which is completely welded is allowed to sink by adjusting buoyant force, and only the upper end portion of the manufactured portion is floated over the water surface, and thus welding with another segment can be performed on the ground surface. As such, the method capable of safely manufacturing the tank body in the cavern 'c' by using buoyant force was prepared. The construction method will be described in detail.

[0093] Also, developed is a segment structure optimized to realize the construction method using buoyant force. However, the configuration of the high-pressure fluid storage reservoir and the configuration of the segments which will be described below are merely an example. That is, the construction method according to the present invention has an aspect of method in which segments are floated using buoyant force and then segments are sequentially stacked and coupled, and therefore, it is clarified that the mechanical configuration of the fluid storage reservoir may be variously changed.

[0094] An optimal storage reservoir 100 for applying the construction method developed by the present inventors is configured as a structure in which a tank body 10 is formed in a structure in which a plurality of segments are stacked and coupled, and reinforcing members 30 can be supported by the segments through connecting members 70. Furthermore, the reinforcing member 30, particularly a vertical reinforcing member 32 is configured as a shape in which a plurality of segment members 33 are coupled to each other, and the segment members are structured to be easily joined to each other through the connecting members 70. Also, the separation coating 60, the waterproof coating 81, the anti-corrosion coating 82, the heat insulation coating 83, and the like are previously formed in the segments constituting the tank body 10. This will be described in detail.

[0095] The tank body 10 includes a plurality of segments, and segments are made of a steel material and include a lower segment 11, a plurality of body segments 12, and an upper segment 13. The lower segment 11 which forms a lower end portion of the tank body 10 is formed in a bowl shape having an opened upper surface. The body segments 12 which form a body portion of the tank body 10 are formed in an annular shape having lower and upper surfaces which are both opened. The body segments 12 are formed in plurality, and are sequentially stacked and coupled on the lower segment 11. The upper segment 13 which forms the upper end portion of the tank body 10 is stacked and coupled on the body segments 12. The upper segment 13 is formed in a shape which is an inverted shape of the lower segment 11, that is, formed in a bowl shape having an opened lower surface. When the lower segment 11, a plurality of body segments 12, and the upper segment 13 are stacked and coupled, a sealed space in which a high-pressure fluid is stored is formed inside the tank body 10.

[0096] Additional weld members 15 are respectively attached to the segments 11, 12, and 13. When the segments are stacked and coupled, a butt welding is performed at a gap while the segments are slightly spaced apart from each other by the gap. When performing the butt welding, a backing plate for covering the spaced gap is required. Accordingly, in the segments, the additional weld member 15 is allowed to protrude as illustrated in FIG. 6, to thereby cover the spaced gap from the neighboring segment. In FIG. 6, the portion represented as w is the welded portion. The additional weld member 15 may be installed to protrude from the upper portion or from the lower portion of the segment. Also, when the segments are welded at the side of the outer surface, the additional weld member 15 should be attached to the inner surface of the segment, and on the contrary, when the segments are welded at the side of the inner surface, the additional weld member 15 should be attached to the outer surface of the segment When the annular segments are welded, it is advantageous to weld at the outer surface of the segment, and therefore, in the present invention, the additional weld member 15 is attached to the inner surface of the segment.

[0097] Also, spacers 's' for adjusting a gap are detachably attached to the upper or lower end portions of the segment 11, 12 and 13, respectively. Although described above, the segments should be disposed to be spaced apart a predetermined distance from each other to perform welding between the segments. When a segment to be newly welded is positioned over the coupled segment by using a crane or the like, gaps between the segments can be determined by means of the spacers 's'. That is, in a state in which spacers 's' are attached to the lower end portion of the segment to be newly welded or to the upper portion of the already coupled segment, when both two segments contact the spacers 's', welding gap is accurately formed. In the state in which the gap is thus formed, the spacers 's' are detached, and then welding is performed.

[0098] Also, to maintain the tank body 10 in a state of being spaced apart upwardly from the bottom surface of the cavern c, the support frame 20 may be selectively provided. The function of the support frame 20 is not to make the tank body 10 directly contact the bottom surface of the cavern c, but to make the tank body 10 and the bottom surface of the cavern 'c' be spaced apart from each other, and to interpose the backfill layer 50 between the tank body 1 and the bottom surface of the cavern 'c'. Accordingly, when the backfill layer is placed on the bottom surface of the cavern 'c' before the tank body 10 is buried, or when the backfill material can be filled in a state in which the tank body 10 is hung to be spaced apart from the bottom surface of the cavern c, the support frame 20 is not necessarily required.

[0099] However, to easily apply the current construction method, the support frame 20 is preferably provided. The reason for this will be described when the construction method is described, and only a structure is described here.

[0100] As illustrated in FIG. 8, the support frame 20 includes a support part 21 installed on the bottom surface of the cavern c, and a mounting part 22 formed on the supporting part 21.

[0101] Since the backfill material should be also filled at the inner side of the support part 21, the support part 21 is formed in a lattice type by using reinforcing bars or the like such that the backfill material is filled between the reinforcing bars. Alternatively, as illustrated in FIG. 8, the support part 21 is formed by a plurality of plates and a plurality of introducing holes 23 through which the backfill material can be introduced.

[0102] Since the tank body 10 is mounted on the mounting part 22, the mounting part 22 is preferably formed in a shape corresponding to the lower end portion of the tank body 10. As illustrated in FIG. 9, the mounting part 22 is formed in a bowl shape corresponding to the lower end portion of the tank body 10. Also, although not shown, a spherical sheet may be installed such that the tank body 10 is flatly mounted. The spherical sheet makes a core maintain the flatly disposed state such that the core is vertically applied with a force when the compressive strength of the concrete core is tested.

[0103] Furthermore, in another embodiment, the mounting part may be formed in an annular shape having a diameter smaller than that of the tank body 10. The tank body may be mounted on the annular mounting part.

[0104] The reinforcing member 30 serves to reinforcing the tensile strength of the backfill layer 50. Although also described above, concrete or the like used as the backfill material is strong against compressive force but weak against tensile force. Therefore, the reinforcing member 30 such as a reinforcing bar or a wire mesh is buried in the backfill layer 50 to improve the tensile strength of the backfill layer 50. Accordingly, the reinforcing member 30 is installed to be spaced apart from the tank body 10 and to surround the tank body 10. Like the current embodiment, when the support frame 20 is provided, the reinforcing member 30 functions to surround the tank body except for the portion of the support frame, and the support frame 20 serves as a reinforcing member disposed on the lower end portion of the tank body 10. Furthermore, when the support frame is not provided, the reinforcing member 30 is disposed to completely surround the tank body 10.

[0105] In the current embodiment, the reinforcing member 30 includes a horizontal reinforcing member 31 and a vertical reinforcing member 32. The horizontal reinforcing member 31 is formed in the circumferential direction of the tank body 10, and disposed in plurality to be spaced apart from each other in the lengthwise direction of the tank body 10. The vertical reinforcing member 32 is disposed to cross the horizontal reinforcing member 31, and disposed in plurality to be spaced apart from each other in the circumferential direction of the tank body 10. The horizontal reinforcing member 31 and the vertical reinforcing member 31 are joined to each other and the entirety thereof is integrally connected as one member. That is, the reinforcing member 30 is formed in an overall net shape by the horizontal reinforcing member 31 and the vertical reinforcing member 32 to thereby surround the tank body 10.

[0106] A single horizontal reinforcing member 31 has a length of about 9 m to about 10 m considering the diameter of the tank body 10, and therefore can be integrally formed, but the vertical reinforcing member 32 should correspond to the total height of the tank body 10, and therefore, should be formed in the length of about 150 m. Accordingly, the vertical reinforcing member 32 is difficult to be integrally formed, and has a shape in which the plurality of segment members 33 is connected with each other.

[0107] To easily install the reinforcing member 30 to be spaced apart from the tank body 10, the connecting member 70 is provided. More specifically, the connecting member 70 serves as a medium for making the reinforcing member 30 which are totally connected in a net shape be supported by the tank body 10. This is because since the horizontal reinforcing member 31 and the vertical reinforcing member 32 are connected as one net, when the connecting member 70 is coupled to a portion of the reinforcing member 30, the entirety of the reinforcing member 30 can be supported by the tank body 10. Accordingly, the connecting member 70 functioning as such may be formed in very various shapes. The various configuration examples of the connecting member will be described later, and firstly, the connecting member 70 applied in the current embodiment will be described.

[0108] The connecting member adopted in the current embodiment has a characteristic in that aside from the basic function to support the entirety of the reinforcing member 30, a function for very easily joining the segment members 33 constituting the vertical reinforcing member 32 is added.

[0109] In the current embodiment, the connecting member 70 is formed in an annular shape to surround the tank body 10, and is disposed in plurality to be spaced apart from each other in the lengthwise direction of the tank body 10.

[0110] The plurality of connecting members 70 may be disposed one by one for each segment, and may be disposed in a manner of one for several segments. Also, the connecting member 70 may be also coupled to a segment, and may also surround a segment while being separated from the segment. At least one of the plurality of connecting members 70 is preferably coupled to a segment, and particularly, the connecting member 70 is preferably coupled to the lower segment 11.

[0111] In the current embodiment, the connecting members 70 are coupled to the lower segment 11, and the connecting members 70 are connected to the segment at intervals of several segments in the height direction of the tank body 10. Furthermore, the remaining connecting members 70 are not coupled to a segment, but functions as a connection parts for joining the segment members 33 to each other. For convenience of description, the connecting members coupled to the segment are represented as reference number 71, and the connecting members not coupled to the segment are represented as reference number 72.

[0112] In the current embodiment, the connecting members 71 coupled to the segment has a shape of letter 'ㄷ' or letter '⊂' approximately, and coupled to the circumferential surface of the segment. Accordingly, a space into which the segment members 33 can be inserted is provided inside the connecting members 71. This space is referred to as mounting part 73. Since the connecting members 72 not connected to a segment are formed in a hollow pipe shape, the mounting parts 73, into which the segment members 33 can be inserted, are also formed inside thereof.

[0113] Insertion holes 74 and 75 through which the segment member 33 can be inserted into the mounting part 73 are formed respectively in upper and lower portions of the connecting members 71 and 72. The insertion holes 74 and 75 are continuously disposed at predetermined intervals in the circumferential directions of the connecting members. The lower end portion of the segment members 33 is inserted through the insertion hole 74 formed in the upper portion, and the upper end portion of the segment members 33 is inserted through the insertion hole 74 formed in the lower portion.

[0114] Also, in the current embodiment, the upper insertion holes 74 and the lower insertion holes 75 are disposed such that the center points thereof are spaced apart from each other. Accordingly, as illustrated in FIG. 7, the segment members 33 are disposed to overlap each other in the mounting part 73 of the connection members 71 and 72.

[0115] Furthermore, a separate hole is formed beside the upper insertion hole 74. The hole is an injection hole 76 for injecting a resin r into the mounting part 73. That is, when the resin r is injected through the injection hole 76 in a state in which two segment members 33 are disposed to overlap each other, the two segment members 33 are joined to each other by the resin r in the mounting part 73. When all the mounting parts inside the connecting members 71 and 72 communicate with each other across the entirety of the connection members 71 and 72, the injection hole 76 is not necessarily formed for each insertion hole. However, when a partition d is installed inside the connection members 71 and 72 and the mounting parts 73 separated for each of the insertion holes 74 and 75 are formed, the injection holes 76 are formed for each of the insertion holes 74 and 75.

[0116] The important point is that it is undesirable that a vacant space be formed inside the connecting members 71 and 72. Accordingly, as in the current embodiment, when the space for the mounting parts is provided inside the connecting members 71 and 72, all the mounting parts should be filled with a resin or a backfill material. Thus, a plurality of holes should be formed in the connecting members, so that the backfill material can be introduced and filled in the portion in which the resin is not filled. Alternatively, the connecting members are preferably not formed in a hollow shape such that a space is not formed inside the connecting members except for the mounting parts.

[0117] As described above, in the current embodiment, the resin r is injected in a state in which each of the segment members 33 constituting the vertical reinforcing member 32 is inserted into the insertion holes 74 and 75 of the connecting members 71 and 72, and thereby, the segment members 33 are very easily and integrally connected to form the single vertical reinforcing member 32. Furthermore, since several connecting members 71 in a state of being coupled to the segments support the vertical reinforcing member 32, the vertical reinforcing member 32 formed in the height of about 150 m can be maintained in a required shape without being bent. When all connecting members 71 are coupled to the segments, the supporting force with respect to the vertical reinforcing member 32 can be further increased. Furthermore, the horizontal reinforcing member 31 can be coupled to the vertical reinforcing member 32 which is disposed in the circumferential direction by means of steel wires or the like.

[0118] In the current embodiment, the connecting wire provides not only provides a basic function of allowing the reinforcing member to be supported by the tank body in a state of being spaced apart from the tank body, but also provide a function of very simply and easily joining the segment members which constituting the vertical reinforcing member 32.

[0119] In a classical method in which the connection member is not used unlike in the current embodiment, the vertical reinforcing member 32 should be supported by the inner wall of the rock bed by using a separate fixing means, and therefore, there are accompanying difficulties in the technological and economical aspects. Also, even though being supported by the tank body, if the method does not use a mounting part and a resin as in the current embodiment, it is not economical because all the segment members should be coupled by welding or reinforcing bars. That is, the work of integrally connecting the segment members 33 by the connecting members having a special configuration which is used in the current embodiment can be very easily performed, and thus the economic feasibility of construction can be improved.

[0120] Furthermore, in the current embodiment, the waterproof agent, anti-corrosion agent, and the heat insulation material are previously applied for each segment, so that when all the segments are coupled, the waterproof coating 81, anti-corrosion coating 82, and the heat insulation coating 83 can be formed on the entirety of the tank body 10. Likewise, the separation coating 60 is formed for each segment, when all the segments are combined, the separation coating 60 can be formed on the entirety of the tank body 10.

[0121] In the current embodiment, only the anti-corrosion coating 82 is formed on the inner circumferential surface of each segment, and the anti-corrosion coating 82, the heat insulation coating 83, the separation coating

60, and the waterproof coating 81 are sequentially formed on the outer circumferential surface of each segment.

[0122] Also, inside the storage reservoir according to the current embodiment, not only gas is contained but also water is contained together with air according to kinds of power generating equipment using compressed air. Furthermore, even though being provided with a waterproof coating and the anti-corrosion coating, the storage reservoir may be exposed to underground water. Thus, when the tank body 10 made of steel is used for a long time, there may be a corrosion problem. Accordingly, in the current embodiment, the corrosion of the tank body is prevented by using a galvanic effect. That is, although not shown, a corrosion inhibitor (a galvanic anode) formed of a metal material is installed so as to be electrically connected to the inside or the outside of the tank body 10. Since the corrosion inhibitor has only to be electrically connected to the tank body, the corrosion agent may be directly attached to the tank body, but it may be fine to be electrically connected to each other by means of a conductor in a state of being spaced apart from the tank body. Since the corrosion inhibitor has an active potential than the material of the tank body, the corrosion inhibitor functions as a positive electrode and the thank body functions as a negative electrode, and thus the corrosion inhibitor quickly corrodes and the tank body 10 is prevented from corroding. Since the corrosion inhibitor is completely consumed by the corrosion when a predetermined time elapses, the corrosion inhibitor preferably has a replaceable configuration. To facilitate the replacement of the corrosion inhibitor, it is desirable that the corrosion inhibitor is disposed at the outside to be spaced apart from the tank body and electrically connected to the tank body rather than directly attached to the tank body.

[0123] Also, the upper side of the cavern 'c' is closed by placing concrete or the like to form the first plug 90. Of course, the pipe p connected with the tank body 10 is connected to the power generating equipment and the compression equipment on the ground surface through the first plug 90.

[0124] As described above, the storage reservoir according to the present invention is configured such that the tank body is formed by stacking and coupling the segments, wherein the anti-corrosion coating, the waterproof coating, the separation coating, and the heat insulation coating are previously formed in the segments and thus various functional coatings can be formed between the tank body and the rock bed by only coupling the segments. Also, the vertical reinforcing members and the horizontal reinforcing members are previously installed in the segments, and the reinforcing members are supported by the segments, and thus the manufacturing of the tank body and the installation of the reinforcing members can be simultaneously performed. Most of all, it is advantageous in terms of construction in that the reinforcing members can be very easily installed in a state of being spaced apart from the tank body. Also, it is further advantageous in that segment members constituting the vertical reinforcing members can be very easily connected with each other by using the specially configured connecting members. As described above, the present invention may be important in that the tank body and the reinforcing members are installed by a unit of segments and segment members, and thus realizability and economic feasibility of construction is improved.

[0125] So far, the connecting members are described and illustrated as being formed in an annular shape, but is not necessarily formed in an annular shape, and as illustrated in FIG. 9, the connection member 70a can be installed in plurality to be spaced apart from each other in the circumferential direction of the tank body 10. A mounting part is installed inside the connecting member 70a having an independent shape, and insertion holes and injection holes are formed the same as described above.

[0126] Also, so far, it is described and illustrated that the mounting parts are formed inside the connecting members and the segments are joined to each other inside the mounting parts, but as illustrated in FIG. 10, through holes 77 are simply formed and the vertical reinforcing members may be lengthily inserted into the through holes 77. Alternatively, each of the vertical reinforcing members is divided into a long segment (formed in a relatively long length than the above-described segment members), the segments are then inserted into the through holes 77, and then the segments may be connected by a method such as welding.

[0127] Also, as illustrated in FIG. 11, a method in which the connecting members 70c may be used to support the horizontal reinforcing members 31 may be applied. That is, the connecting members 70c are formed in the lengthwise direction of the tank body 10, are disposed in plurality to be spaced apart from each other in the circumferential direction of the tank body 10, and when the through holes 78 are provided in the connecting members, the horizontal reinforcing members 31 are inserted into the through holes 78 and may thereby be supported. The vertical reinforcing members 32 may be supported while being connected to the horizontal reinforcing members 31.

[0128] Furthermore, in another embodiment, a connecting member for supporting the horizontal reinforcing member and a connecting member for supporting the vertical reinforcing member may be separately provided.

[0129] Although not shown, in another embodiment, a method in which a through hole is simply formed in the connecting member, and a segment member is fixed to the connecting member while the segment member is inserted into the through hole is also possible. That is, in a state in which upper and lower end portions of the segment member respectively protrudes after passing through the connecting members in the upper segment and the lower segment and protrudes, bolts are fastened respectively to the upper and lower end portions of the segment member. The bolt fastened to the upper end will contact the upper surface of the upper connecting member, and the bolt fastened to the lower end will contact the lower surface of the lower connecting member. Accordingly, the segment member is fixed by the bolts between the two connecting members and is prohibited to move in the vertical direction. Even when the bolts are not used, the segment member inserted in the through hole of the connecting member may also be fixed to the connecting member by welding.

[0130] Hereinafter, a method for constructing a fluid storage reservoir under a first horizontal tunnel will be described.

[0131] FIG. 12 is a schematic flowchart of a method for constructing a high-pressure fluid storage system according to an embodiment of the present invention, and FIGS. 13 to 14 are views for describing a method for constructing a fluid storage reservoir.

[0132] Referring to the drawings, a method for constructing a storage reservoir includes an excavating step (M10), a filling step (M30), a tank manufacturing step (M50), and a backfill step (M70).

[0133] In the excavating step (M10), the ground is excavated from a first horizontal tunnel, and a cavern 'c' is formed in an upward/downward direction, preferably, in the vertical direction.

[0134] In the present invention, as described above, a method of excavating downwardly from a first horizontal tunnel by using a vertical exactor may be adopted. When the vertical excavator is used, since the broken rocks are discharged through drilling mud injected when the bit of the excavator drills the rock bed, there is an advantage in treating the broken rocks. Aside from the equipment described in the above invention, a cavern having the diameter of less than about 10 m can be easily formed by using existing vertical excavator. The vertical excavator is evaluated to have the most superior applicability if economic feasibility can be guaranteed in comparison of that in a blasting method.

[0135] When the cavern 'c' is formed through excavating, quick-curing shotcrete is jetted to an inner wall of the cavern 'c' so as to prevent the collapse of the inner wall and thereby may form a backup layer 40 (M20). The backup layer 40 can also be formed at once after completing excavating, but may be dividedly placed during excavating process. However, when the rock bed is strong, the backup layer 40 may not be provided.

[0136] When the excavation of the cavern 'c' is completed, a support frame 20 is previously in a lower portion of the cavern 'c'. When the installation of the support frame 20 is completed, a tank body 10 should be installed, but filling the cavern 'c' with a first fluid (M30) is performed as a preliminary work. The first fluid serves to provide buoyant force and water can be used. As the first fluid, various fluids capable of providing buoyant force other than water may be used. When excavating using a blasting method, the first fluid should be separately filled, but when the above-mentioned vertical excavator is used, the cavern 'c' is already filled with water injected during excavation.

[0137] When the filling with the first fluid is completed, the manufacturing of a tank (M50) is performed. The manufacturing of a tank (M50) is an important process in which the tank body 10 having the height of about 100 m to about 200 m is manufactured, and is installed in the cavern 'c'.

[0138] In the manufacturing of a tank (M50), a plurality of segments for constituting the tank body 10 is manufactured by being welded to each other in the cavern 'c'.

[0139] When connecting members 71 and 72 are prepared for the segments 11, 12, and 13, firstly, a lower segment 11 is transported by using a crane 'a' and is launched on a first fluid f1 filled in the cavern 'c'. The main body of the crane 'a' is installed on the ground surface, and a traction rope 'b' of the crane is introduced in the first horizontal tunnel 200 through the connecting hole 300.

[0140] The method for supporting the segments 11, 12, and 13 by the crane a may be variously adopted, for example, a method in which an electromagnet is attached to the traction rope 'b' of the crane and the electromagnet is coupled to the inner circumferential surface of the segment according to whether to apply power may be adopted.

[0141] After launching the lower segment 11, the connection with the crane 'a' is released, and the upper end portion of the lower segment 11 is then floated on the surface of the first fluid f1 by buoyant force. When the upper end portion of the lower segment 11 is floated higher than a work position for welding later with the body segment 12, a portion of the first fluid is discharged to be supplied into the lower segment 11 to adjust the height. When the height of the lower segment 11 is adjusted 11, the posture and the angle of the lower segment 11 is fixed by a first supporting unit M1 installed in the first horizontal tunnel so as not to be biased. Since the lower segment 11 is floated by buoyant force, the first supporting unit M1 only functions to fix the center on the surface of the lower segment.

[0142] After the position of the lower segment 11 is fixed, the body segment 12 is stacked on the lower segment 11 to be coupled to each other, and in the current embodiment, the segments are coupled by welding considering air tightness and safety. As described above, the welding quality between the segments is the most important point in the air tightness of the entire tank body 10. Describing more specifically about the welding process, a first body segment 12 is hung by the crane 'a' and is positioned on the lower segment 11 in a state of being spaced apart a predetermined distance from the lower segment. Since a spacer 's' is attached to the upper end portion of the lower segment 11, the body segment 12 is disposed to contact the spacer 's'. Then, the position of the body segment 12 hung on the crane 'a' is fixed so as not to be biased to the left or right and to be flat by a second supporting unit M2 installed in the first horizontal tunnel. Since the body segment 12 is supported by the crane a, the second supporting unit M2 functions to centering the body segment 12. When the body segment 12 is disposed at a correct position, the center points of the body segment 12 and the lower segment 11 coincide with each other, and the upper end surface of the lower segment 11 and the lower end surface of the body segment 12 are disposed to be flat and slightly spaced apart from each other.

[0143] When the position adjustment of the two segments to be coupled is completed, the spacer 's' attached to the upper end portion of the lower segment 11 is detached. Since additional weld members 15 are attached between the segments, the welding space is exposed in a state in which rear side is closed. After completing welding, it is desirable to check the welding quality through an inspection.

[0144] As described above, when the coupling of the lower segment 11 and the first body segment 12 is completed, a plurality of body segments 12 are sequentially stacked and coupled by the same method. The manufactured portion which are already coupled are supported by buoyant force as described above, the position thereof is fixed by the first supporting unit M1, and the segment to be newly coupled is hung on the crane 'a' and the position thereof is fixed by the second supporting unit M2.

[0145] Also, the upper end portion of the manufactured portion is always disposed at a predetermined height by floating force to perform welding. To adjust the upper end portion of the manufactured portion to a position at which welding is performed, the floating force should be adjusted. As a method for adjusting the floating force, firstly, there is a method in which the first fluid f1 in the cavern 'c' is slowly discharged. As the water level is lowered, the manufactured portion is also inserted together into the cavern c, and therefore, the work position can be maintained. Also, a second fluid f2 is supplied into the manufactured portion so as to increase the weight, and thereby, the manufactured portion can be lowered. In the current embodiment, while the segments are progressively coupled, the first fluid f1 in the cavern 'c' is pumped to be supplied to the manufactured portion and thus the manufactured portion is lowered and the position thereof is adjusted. That is, the first fluid f1 is discharged and then used as the second fluid f2.

[0146] When the lower segment 11, the body segment 12, and the upper segment 13 are all welded, the manufacturing to the tank body 10 is completed.

[0147] Ad described above, when the manufacturing of the tank body 10 is completed, the tank body 10 is in the state of being completely inserted into the cavern 'c' and floated by buoyant force. Then, the tank body 10 is mounted on a supporting frame 20. Similarly to the above processes, when the first fluid f1 remaining in the cavern 'c' is slowly discharged and supplied to the tank body 10, the tank body 10 is lowered, and at the instant when the self weight of the tank body 10 becomes greater than the buoyant force, the tank body 10 is mounted on the mounting part 22. When the tank body 10 is lowered and mounted on the supporting frame 20, the first supporting unit M1 performs assisting such that the center is not shaken and the tank body 10 is vertically disposed. When the tank body 10 is mounted on and supported by the supporting frame 20, the installation of the tank body 10 is completed.

[0148] Also, in the manufacturing and installing processes of the tank body 10 as described above, the first support unit M1 and the second supporting unit M2 respectively function to fixing the positions of the manufactured portion and the portion to be newly coupled, various apparatuses can be used as the first and second supporting units M1 and M2. Although not shown, a plurality of cylinders are installed at predetermined angle intervals along the outer circumferential surface of the portion to be newly coupled or the manufactured portion, and pistons installed in the cylinders are allowed to independently push the segments and thus the segment to be newly coupled can be disposed at an accurate position. Also, after installing a ring disposed to surround the segments and the manufactured portion, a plurality of hinge members are installed along the inner circumferential surface of the ring, and the positions of the segments and the manufactured portions can be fixed while all the hinge members are fixed in a radial direction. That is, while the hinge members are fixed in the radial direction of the ring, the segments which are disposed to be biased can be pushed to be disposed at a correct position.

[0149] In the above, the first and second supporting units M1 and M2 are described as examples, and the positions of the manufactured portion or the newly coupled may be adjusted through various kinds of apparatuses. Also, even though these first and second supporting units M1 and M2 are not used, the manufactured portion is supported by buoyant force, and the portions to be newly coupled are supported by the crane, and therefore, when the segments are coupled, the positions of the manufactured portion and the segment to be newly coupled may be simply and accurately adjusted. Likewise, after completing the manufacturing of the tank body, when the tank body is mounted on the supporting frame 20, the tank body may be adjusted such that the tank body is vertically disposed without biasing to the left or to the right.

[0150] As described above, while the manufactured portion is supported, the upper end portion of the manufactured portion is floated up to a welding position (in general, the upper portion of the first horizontal tunnel), and thus, a method for easily coupling other segments is provided. Through such a method, the tank body having the height of greater than about 100 m could be directly manufactured at site to be installed in the cavern.

[0151] When the tank body is installed in the cavern without using buoyant force, a crane for carrying the manufactured portion and a crane for carrying the segment to be newly coupled are separately required, and therefore, the manufacturing work becomes very difficult. Especially, since the manufactured portion and carrying the segment to be newly coupled should be coaxially disposed, it may be even impossible to use two cranes. That is, in the present invention, a method capable of performing the manufacturing and installing of the tank body which has the height of greater than about 100 m in the most economical manner and thus, the present invention has a contribution in increasing actual applicability of CAES.

[0152] Also, while the tank body 10 is installed, the reinforcing member 30 is installed together. That is, while each of the segments is coupled to manufacture the tank body 10, the segment members 71 and 72 which are installed in each segment are inserted into the connecting members 71 and 72 and are filled with a resin. In the above process, the segment members 33 are connected to each other, and are integrally formed when the manufacturing of the tank body 10 is completed. Since the horizontal reinforcing member 31 is coupled to the vertical reinforcing member 32, the reinforcing member 30 is formed in an overall net shape to surround the tank body 10.

[0153] Also, as described above, in the stacking and coupling of the segments, since the separation coating 60, the waterproof coating 81, the anti-corrosion coating 82, and the heat insulation coating are formed together, remarkably economical construction can be performed.

[0154] Now, as a final process, back filling (M70) is performed. That is a back filling material is filled between the tank body 10 and the rock bed g to form a back filling layer 50. The back filling material may be dividedly placed with a time difference or may be placed at one time. Furthermore, in the current embodiment, a grout material is jetted with a high pressure to perform the back filing.

[0155] The point to remember in filling the back filling material is that a third fluid f3 should be first filled in the tank body 10. The back filling material, when filled, exerts two actions on the tank body 10. First, as the back filling material is filled, buoyant force is applied to the tank body 10, and secondly, the tank body 10 is pressed by the weight of the back filling material. Accordingly, before the back filling material is filled, the third fluid f3 is preferably filled into the tank body so as to prevent the damage to the tank body 10 due to the pressure of the back filling material.

[0156] As the third fluid, water or compressed air can be used.

[0157] When water is used, the level of water filled in the tank body 10 is formed slightly higher than the height to which the back filling material is filled, that is, when back filling is dividedly performed, water has only to be filled to the level slightly higher than the height of back filling material which is filled for each divided placement, and when the back filling is performed at once, water has only to be fully filled in the tank body 10. When water is used as the third fluid, it is advantageous because the water is suitable to a pressure and buoyant force, but there is a problem in that since water is fully filled in the tank body 10, the self weight of the tank body 10 becomes too great. For this, in the current embodiment, the support frame 20 is previously installed. If the support frame does not support the tank body 10, the crane 'a' should support and carry all the weight of the tank body, but there may be a problem of crane output because the weight of the tank body exceeds about 2,000 ton when water is fully filled in the tank body which has the diameter of about 5 m and the height of about 100 m. In the current invention, since the supporting frame 20 is previously installed to support the tank body 10, such technical problems can be solved.

[0158] When water is used, since the self weight of the tank body 10 is problematic, a method of using compressed air as the third fluid may be considered. This is because when a pressure is applied to the inside by compressed air, it is possible to cope with the pressure of the back filling material. However, when compressed air is used as the third fluid, there is a problem in that it is impossible to use buoyant force required for the back filling material. This is because even though air is compressed, the air has a very small weight.

[0159] In the current embodiment, since the supporting frame 20 is previously installed, a method in which only water is used as the third fluid may be adopted, but more preferably, a method in which water and compressed air are used together is adopted. That is, after filling water partially in the tank body 10, air is compressed with a high pressure and injected to the tank body 10, and thus it is possible to cope with both the buoyant force and the pressure of the back filling material.

[0160] When a predetermined time elapses after the back filling material is entirely placed, the back filing material is cured.

[0161] A first plug 90 may be formed together with the back filling, and may be separately formed from the back filling. That is, in a state in which the first horizontal tunnel 200 in the upper portion of the cavern is closed by using a mold, when the back filling material is injected into both the cavern and the first horizontal tunnel, the back filling layer and the first plug can be integrally formed. Alternatively, after forming the back filling layer, the first horizontal tunnel 200 is closed, and then the first plug may also be separately formed by using a filling material such as concrete.

[0162] The reservoir 100 used in the present invention may be connected to the power generating system on the ground surface. As a CAES power generating system, a turbine power generating method, a cylinder-motor power generation method, or the like may be used. In the turbine power generation method, a plurality of compressors, a heat exchanger, a expander, and a turbine are provided, air is then compressed in multiple stages by the compressors and is then stored in a high pressure fluid-storage reservoir 100, and then the air is supplied to the turbine to generate power. The cylinder-motor method is a method for generating power such that an engine shaft connected to the motor is driven to drive a plurality of cylinders, air is then compressed and stored in the high-pressure fluid storage reservoir 100, and then the compressed air is supplied to the cylinders again to rotate the engine shaft in the reverse direction. Besides, the high-pressure fluid storage reservoir may be used to improve power generation efficiency by being connected to a complex thermal power generation system combining a turbine system and thermal power.

[0163] As described above, the present invention provides a practical technique capable of installing a high-pressure fluid storage plant, having a diameter of several meters or greater and a height of several tens of meters at a deep portion underground, in a state in which safety and air tightness are maintained, and thus may increase applicability of CAES. Furthermore, the present invention is expected to expedite the commercialization of the CAES by providing a method for economically constructing a high-pressure fluid storage system.

[0164] While the above-described first embodiment discloses a structure in which the ground is excavated downwardly from the first horizontal tunnel, a second embodiment which will be hereinafter described and illustrated in FIGS. 15 and 16, discloses a slightly different structure from that disclosed in the first embodiment described so far in which a structure configured such that the first horizontal tunnel is formed, the cavern is then formed by excavating the ground downwardly from the first horizontal tunnel is disclosed.

[0165] Referring to FIGS. 15 and 16, in the second embodiment, a second horizontal tunnel 210 is formed in a lateral direction separately from the first horizontal tunnel, and the second horizontal tunnel is disposed at a second depth deeper than a first depth at which the first horizontal tunnel is formed. To form the second horizontal tunnel 210, an access tunnel e should be formed up to the second depth.

[0166] Furthermore, in the first embodiment, the ground is excavated downwardly from the first horizontal tunnel 200, but in the second embodiment, the ground is excavated upwardly from the second horizontal tunnel 210 and thereby, the cavern is formed between the first horizontal tunnel and the second horizontal tunnel. In this case, although an excavator may be used, it is effective to employ a method using blasting. Although it may be possible to blast downwardly from the first horizontal tunnel 200, to remove broken rocks, it is desirable to blast upwardly from the second horizontal tunnel 210. Since the broken rocks caused by the upward blasting drop freely to the second horizontal tunnel 210, the broken rocks can be discharged through the access tunnel e. The second horizontal tunnel 210 is preferably formed in a shape corresponding to that of the first horizontal tunnel 200. For example, similar to the first horizontal tunnel, a main tunnel and an auxiliary tunnel may be formed.

[0167] As described above, after the cavern is formed upwardly from the second horizontal tunnel 210, the second horizontal tunnel 210 is then closed by using a mold or the like, and then concrete or the like is placed to install a second plug 91 for closing the lower portion of the cavern. Since the lower portion of the cavern is closed by the second plug 91, the shape in the second embodiment becomes structurally the same as that in the first embodiment in which the cavern is excavated downwardly from the first horizontal tunnel. Accordingly, from here, since the fluid storage reservoir 100 can be constructed by using buoyant force from the first horizontal tunnel in the same way as the first embodiment described above, detailed descriptions of the second embodiment will not be provided.

[0168] The portion of the second embodiment different from the first embodiment is consequently the method for excavating the cavern. There is a difference in that, in the first embodiment, the cavern is excavated downwardly from the first horizontal tunnel, but in the second embodiment, the cavern is excavated upwardly from the second horizontal tunnel 210 up to the first horizontal tunnel and the second plug 91 is installed to close the lower end portion of the cavern. According to conditions of a rock bed or an excavator, there may be a case in which it is difficult to excavating the ground from in a top-down manner as in the first embodiment. Furthermore, when there is no advantage in technical or economical aspects to use an excavator, the second embodiment discloses a method of excavating the ground in a bottom-up manner through blasting. However, in case of upward excavating method, since the lower side of the cavern is opened, a fluid for providing buoyant force cannot be filled at once, the second plug 91 is installed to close the lower portion of the cavern. Even when a method using buoyant force is not used and the fluid storage reservoir is constructed by other method, the lower portion of the cavern is closed after the second horizontal tunnel is formed because the fluid storage reservoir can have basic function as a fluid storage reservoir only if the lower portion of the cavern is closed.

Although the present invention is described with reference to embodiments illustrated in the drawings, it is merely exemplary embodiments, and it would be understood that various modifications and other equivalent embodiments can be made hereto by one ordinary skilled in the art Therefore, the true protection scope of the present invention would be defined only by the appended claims.

Claims

1. A high-pressure fluid storage system comprising:

    a first horizontal tunnel formed at a first depth in the underground in a lateral direction;
    a cavern formed by excavating the ground downwardly from the first horizontal tunnel; and
    a fluid storage reservoir including a tank body for storing fluid and inserted into the cavern, a back filling layer formed by a back filling material

filled between the tank body and an inner wall of the cavern, and a first plug formed by filling the back filling material into the first horizontal tunnel so as to close an upper portion of the cavern.

2. A high-pressure fluid storage system comprising a fluid storage reservoir comprising:

a first horizontal tunnel formed at a first depth in the underground in a lateral direction;
a second horizontal tunnel formed at a second depth in the underground deeper than the first depth in the lateral direction;
a cavern formed by excavating the ground between the first horizontal tunnel and the second horizontal tunnel; and
a fluid storage reservoir including a tank body for storing the fluid and inserted into the cavern, a backfill layer formed by a backfill material filled between the tank body and an inner wall of the cavern, a first plug formed by filling the backfill material into the first horizontal tunnel so as to close an upper portion of the cavern, and a second plug formed by filling the backfill material into the second horizontal tunnel so as to close a lower portion of the cavern.

3. The high-pressure fluid storage system of claim 1 or 2, wherein the cavern is formed in plurality to be spaced apart from each other along the first horizontal tunnel such that the fluid storage reservoir is provided in plurality.

4. The high-pressure fluid storage system of claim 1 or 2, wherein the first horizontal tunnel comprises a main tunnel, and at least one auxiliary tunnel which is branched from the main tunnel and formed in a lateral direction,
wherein the plurality of caverns are formed to be spaced apart from each other under the main tunnel or the auxiliary tunnel.

5. The high-pressure fluid storage system of claim 1 or 2, further comprising a connecting hole formed by penetrating through the ground from the ground surface to the first horizontal tunnel.

6. The high-pressure fluid storage system of claim 1 or 2, wherein the backfill layer and the first plug are integrally formed by the backfill material.

7. The high-pressure fluid storage system of claim 1 or 2, wherein the tank body is formed of an airtight material and has a receiving part in which high-pressure fluid is stored and which is formed therein,
wherein a plurality of segments are sequentially stacked and coupled in the lengthwise direction thereof.

8. The high-pressure fluid storage system of claim 1 or 2, further comprising a reinforcing member disposed to surround the tank body while being spaced apart from the tank body, wherein the backfill layer contains the reinforcing member

9. The high-pressure fluid storage system of claim 8, further comprising a plurality of connecting members which are disposed along an outer circumferential surface of the tank body to be spaced apart from each other in the lengthwise direction of the tank body,
wherein the reinforcing member is installed on the connecting members.

10. The high-pressure fluid storage system of claim 9, wherein the reinforcing member comprises:

a plurality of horizontal reinforcing members disposed to be spaced apart from each other in the lengthwise direction of the tank body; and
a plurality of vertical reinforcing members connected to the horizontal reinforcing members to cross the horizontal reinforcing members and disposed to be spaced apart from each other,
wherein the vertical reinforcing members each is formed of a plurality of segmented members which are sequentially connected in the lengthwise direction, the segmented members being installed on the connecting member.

11. The high-pressure fluid storage system of claim 9, wherein the reinforcing material comprises:

a plurality of horizontal reinforcing members disposed to be spaced apart from each other in the lengthwise direction of the tank body; and
a plurality of vertical reinforcing members connected to the horizontal reinforcing members to cross the horizontal reinforcing members and disposed to be spaced apart from each other,
wherein the connecting members each is disposed in a circumferential direction of the tank body, is coupled to or installed to be spaced apart from a circumferential surface of the tank body, and has a mounting part which is formed therein and in which the vertical reinforcing member is inserted.

12. The high-pressure fluid storage system of claim 11, wherein at least one of the plurality of connecting members is coupled to the tank body.

13. The high-pressure fluid storage system of claim 7, further comprising an additional weld member attached to an inner side surface or an outer side surface of the segment so as to protrude with respect to an upper end surface or a lower end surface of the segment.

14. The high-pressure fluid storage system of claim 1 or 2, wherein
at least one of a separation coating formed on an outer side surface of the tank body so as to prevent the tank body and the backfill layer from being coupled to each other,
an anti-corrosion coating formed on at least an inner circumferential surface and an outer circumferential surface of the tank body so as to prevent the corrosion of the tank body,
a waterproof coating formed on the circumferential surface of the tank body so as to prevent the tank body from contacting surrounding water, and
a heat insulation coating formed on at least an inner circumferential surface and an outer circumferential surface of the tank body so as to prevent a fluid stored in the tank body from heat-exchanging with surroundings is provided.

15. The high-pressure fluid storage system of claim 1 or 2, wherein the tank body is formed of a metal material and is further provided with a corrosion inhibitor for a metal material electrically connected to the tank body so as to delay corrosion of the tank body by a galvanic effect.

16. The high-pressure fluid storage system of claim 1 or 2, further comprising a supporting frame which comprises:

a supporting part installed on a bottom surface of the cavern; and
a mounting part which is formed on an upper portion of the supporting part and on which the tank body is mounted such that the tank body is maintained in a state of being spaced apart upwardly from the bottom surface of the cavern.

17. The high-pressure fluid storage system of claim 16, wherein the supporting part is formed in a lattice shape such that the backfill material is filled inside the supporting part of the supporting frame, or is formed of a plurality of plates in which multiple introduction holes are formed.

18. A method for constructing a high-pressure fluid storage system, the method comprising the steps of:

(a) excavating a first horizontal tunnel in a lateral direction at a predetermined depth in the underground;
(b) forming a connecting hole through drilling from the ground surface to the first horizontal tunnel;
(c) forming a cavern by excavating the ground downwardly from the first horizontal tunnel at the point, at which the connection hole is formed, through the connection hole by using a construction equipment installed on the ground surface; and
(d) installing a tank body for storing the fluid therein and inserted into the cavern, a backfill layer formed of a backfill material filled between the tank body and an inner wall of the cavern, and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

19. A method for constructing a high-pressure fluid storage system, the method comprising the steps of:

(a) excavating a first horizontal tunnel in a lateral direction at a first depth in the underground;
(b) forming a connecting hole through drilling from the ground surface to the first horizontal tunnel;
(c) forming a cavern by excavating a second horizontal tunnel in the lateral direction at a second depth deeper than the first depth, and by upwardly excavating the ground from the first horizontal tunnel to the first horizontal tunnel at a point, at which the connection hole is formed;
(d) installing a second plug for closing a lower portion of the cavern in the second horizontal tunnel;
(e) installing a tank body for storing the fluid therein and inserted into the cavern, a backfill layer formed of a backfill material filled between the tank body and an inner wall of the cavern, and a first plug formed by filling the backfill material into the first horizontal tunnel to close an upper portion of the cavern.

20. The method of claim 18 or 19, wherein the forming of the tank body and the backfill layer in the cavern comprises:

a filling step of filling a first fluid for providing buoyant force in the cavern;
a tank manufacturing step of launching a lower segment constituting a lower portion of the tank body, and sequentially stacking and coupling a plurality of body segments and a lower segment which constitute a body portion and an upper portion of the tank body on the lower segment to install the tank body in the cavern; and
a backfill step of forming a backfill layer by filling a backfill material between the tank body and an inner wall of the cavern so as to transfer an inner pressure of the tank body to a rock bed, wherein
in the manufacturing of the tank body, an upper

end portion of a manufactured portion of the tank body inserted into the cavern is floated over the surface of a first fluid by buoyant force of the first fluid.

21. The method of claim 20, wherein
before the filling of the backfill material, reinforcing members spaced apart from the tank body to surround the tank body are installed, and
when the backfill material is filled, the backfill layer contains the reinforcing members.

22. The method of claim 21, wherein after installing the reinforcing members to be spaced a predetermined distance from outer surfaces of the upper segment, the body segments, the lower segment, when each of the segments are coupled to each other in the manufacturing of the tank body, the reinforcing members which has been respectively installed on the segments are installed by being connected to each other.

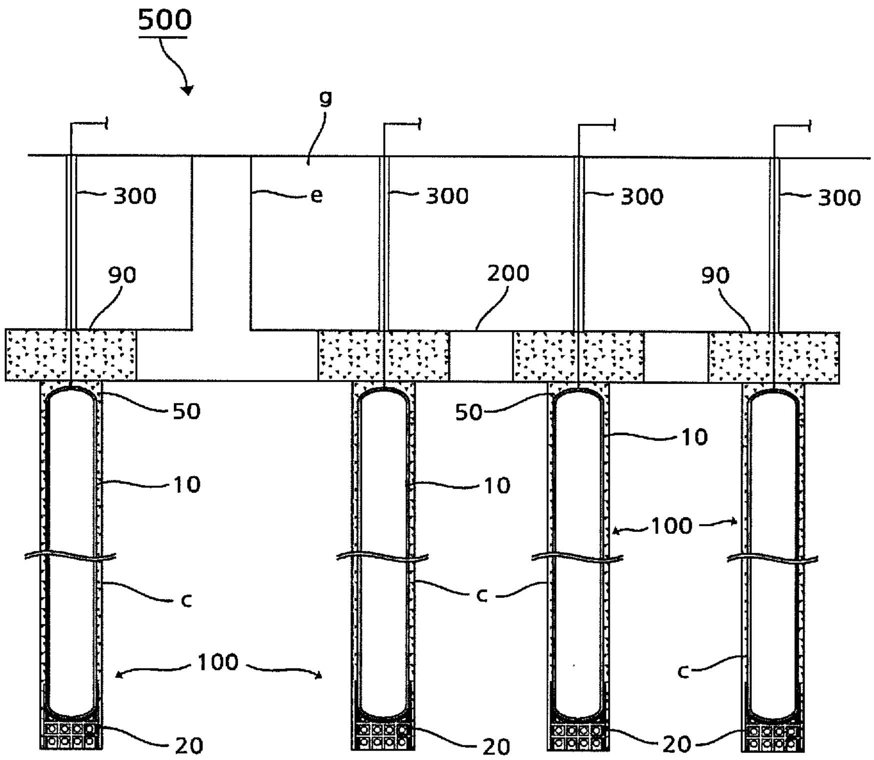
23. The method of claim 20, wherein the backfill material is filled after a third fluid is filled into the tank body so as to prevent the tank body from being deformed due to a pressure of the backfill material.

24. The method of claim 23, wherein water or compressed air is filled as the third fluid, or water and compressed air is filled together.

25. The method of claim 20, wherein after excavating the cavern, a supporting frame capable of supporting the tank body is installed on a bottom surface of the cavern.

26. The method of claim 20, wherein at least one of a anti-corrosion coating, a separation coating, a heat insulation coating, or a waterproof coating is formed on an inner surface or an outer surface of the upper segment, the body segment, and the lower segment of the tank body.

[FIG 1]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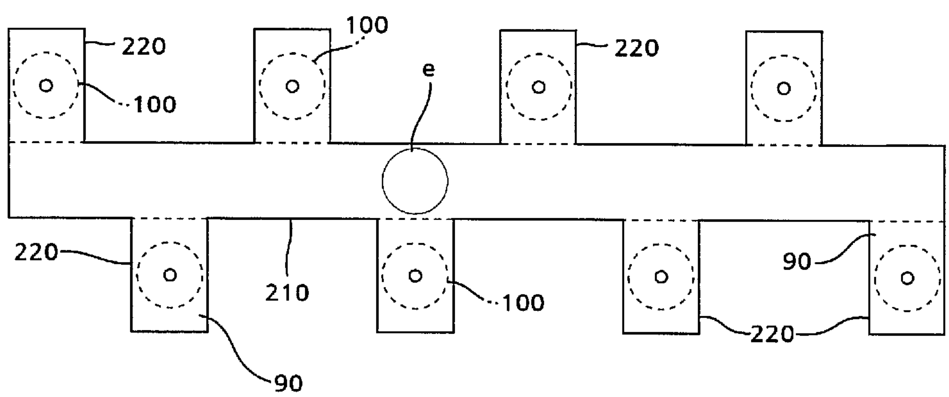
[FIG 2]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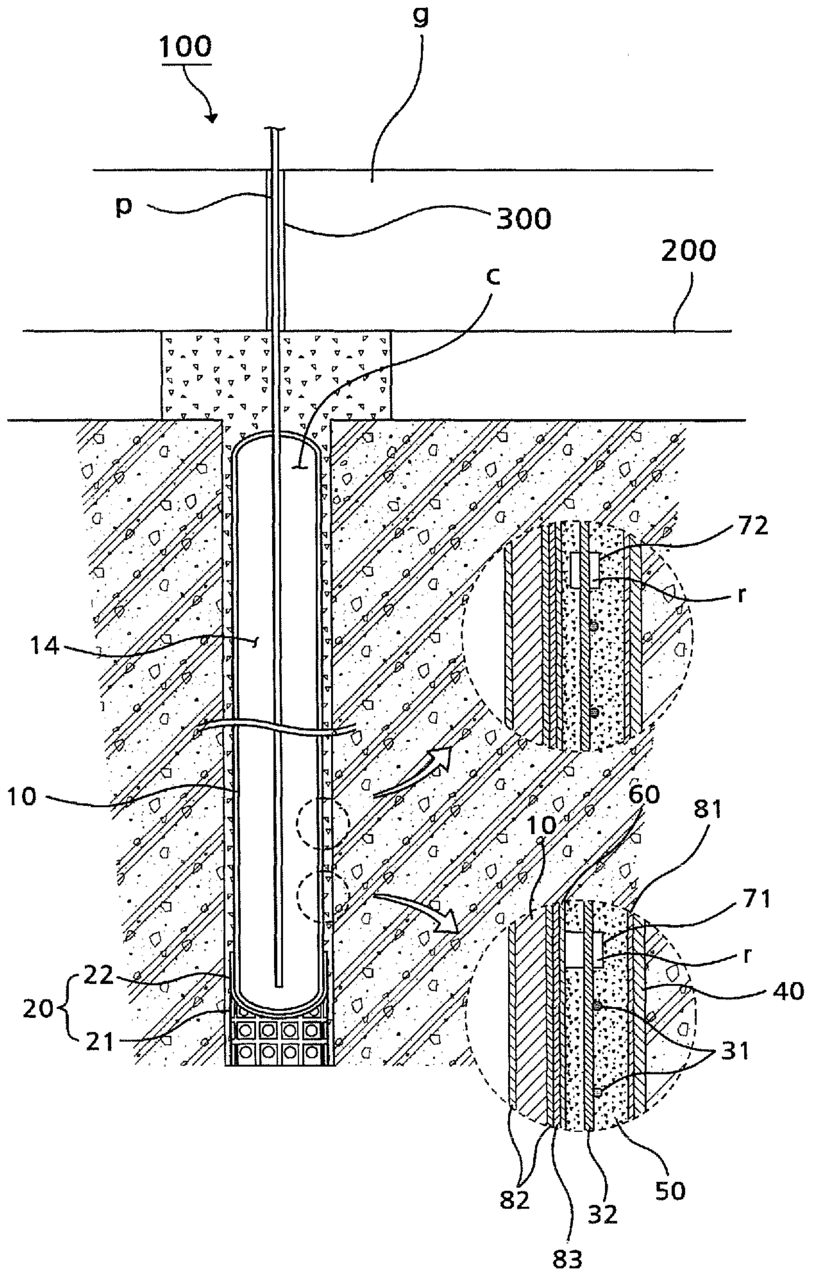
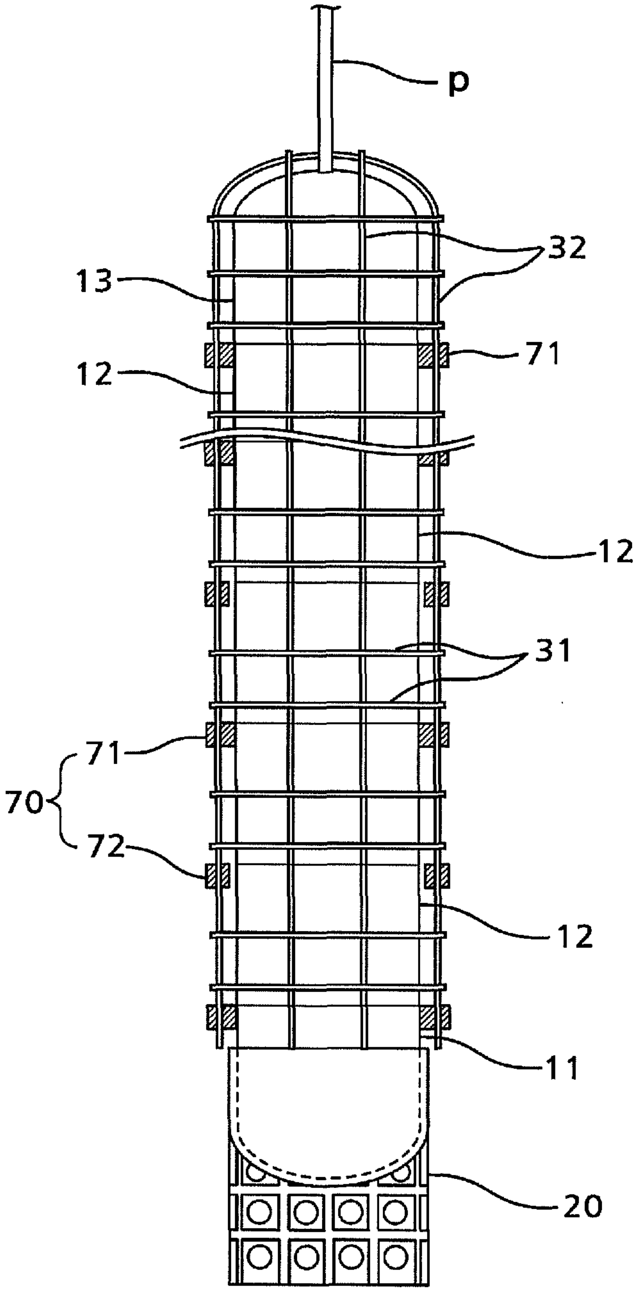
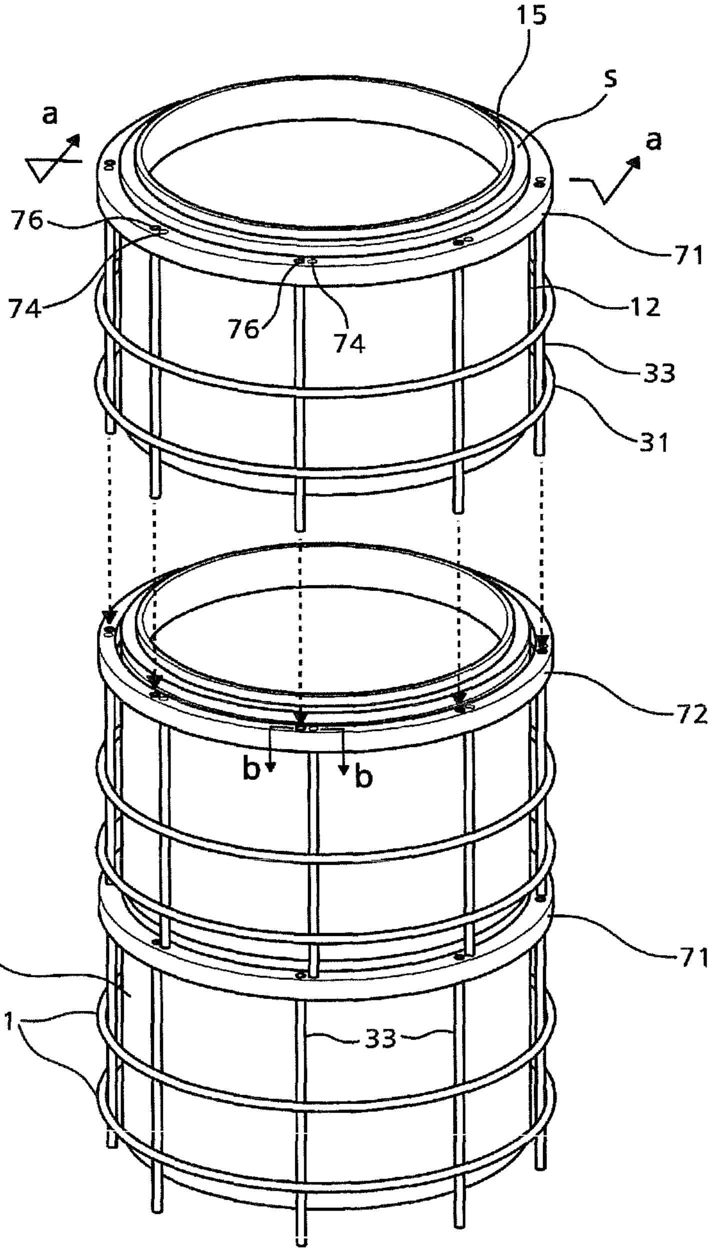


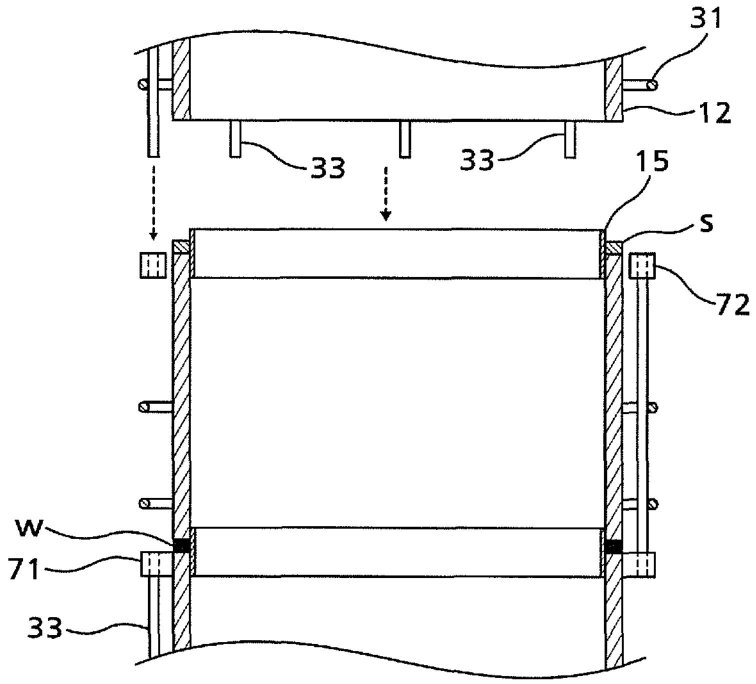
[FIG 4]



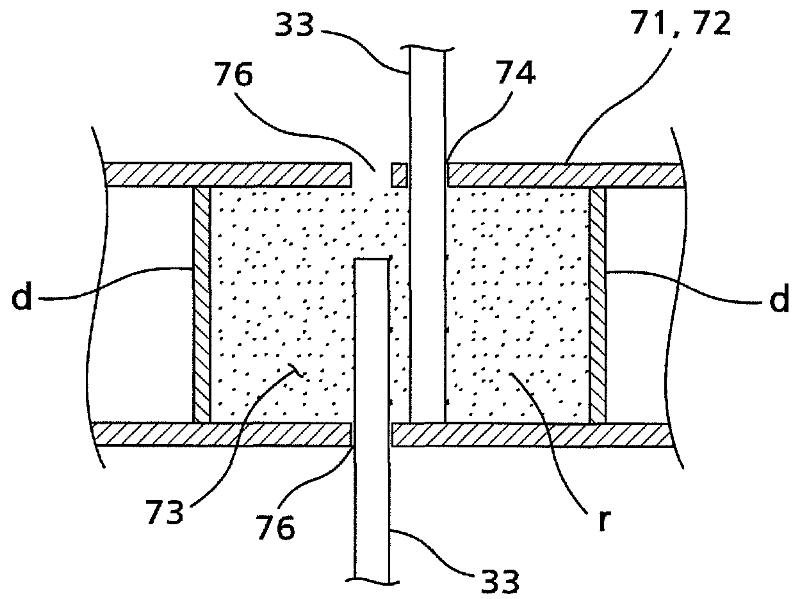
[FIG 5]



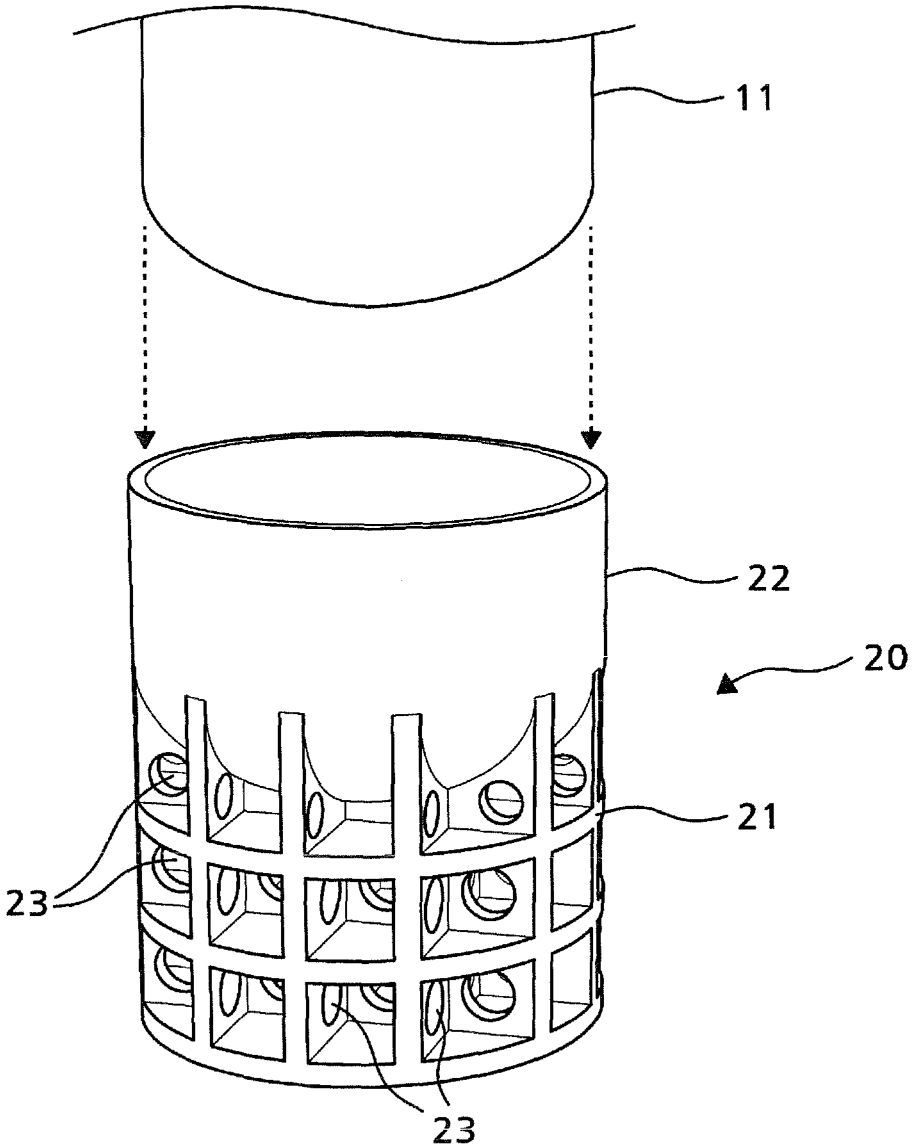
[FIG 6]



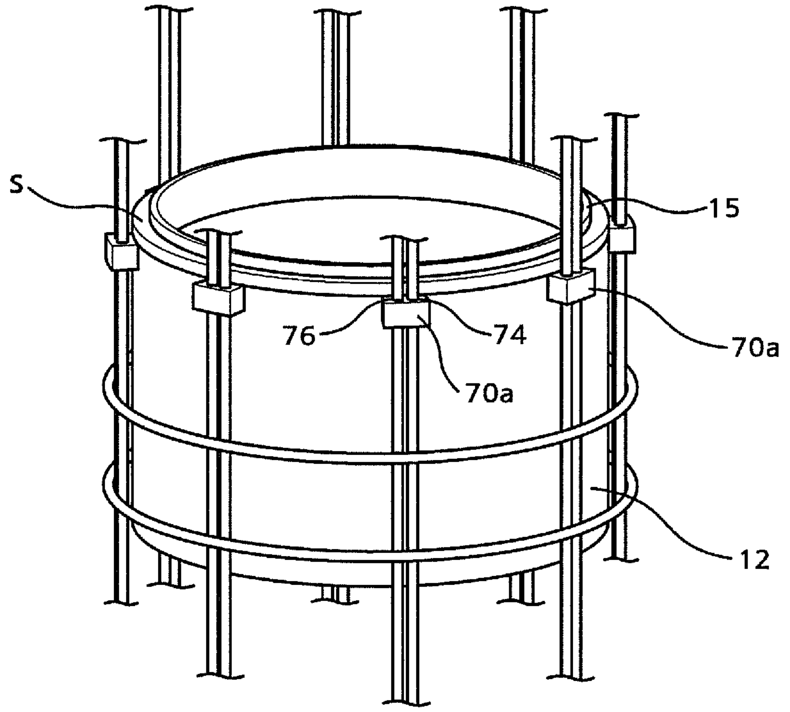
[FIG 7]



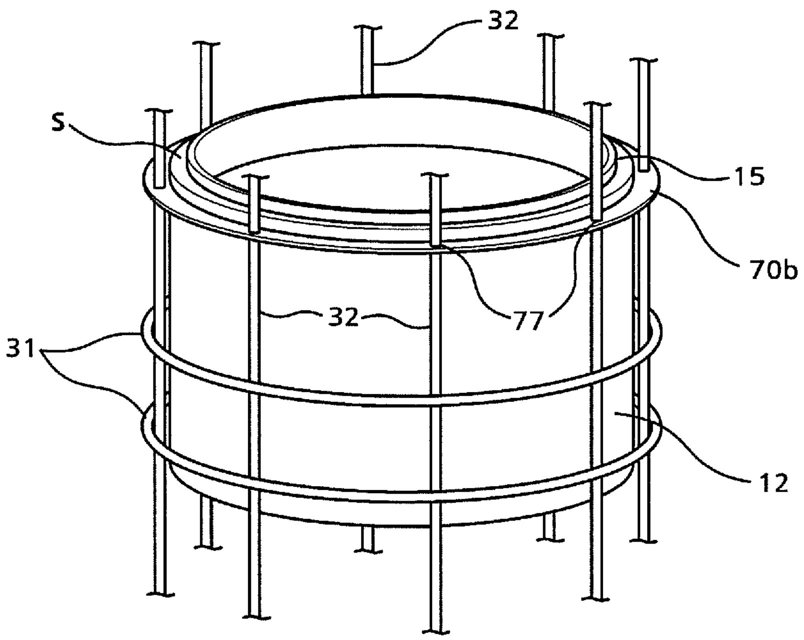
[FIG 8]



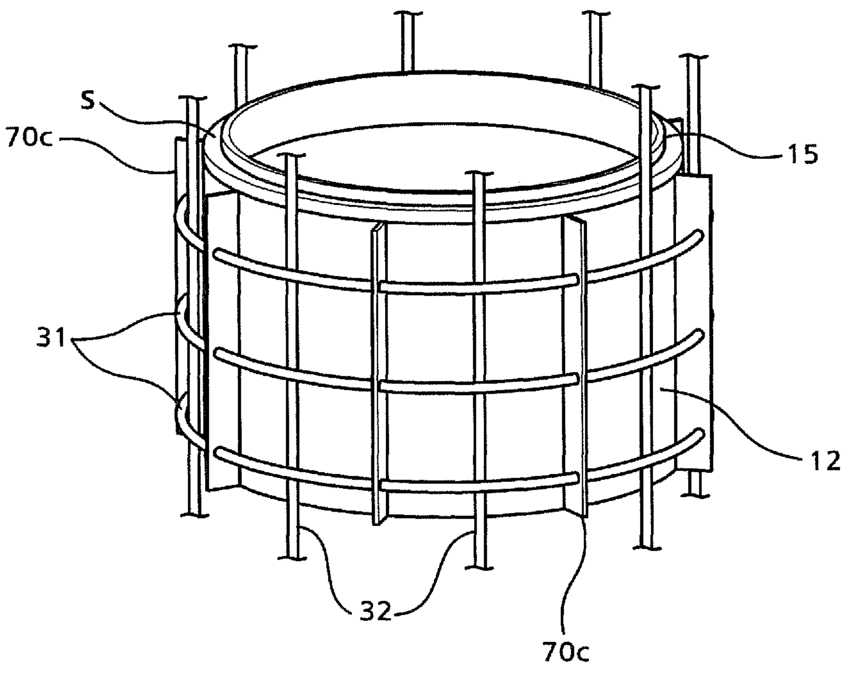
[FIG 9]



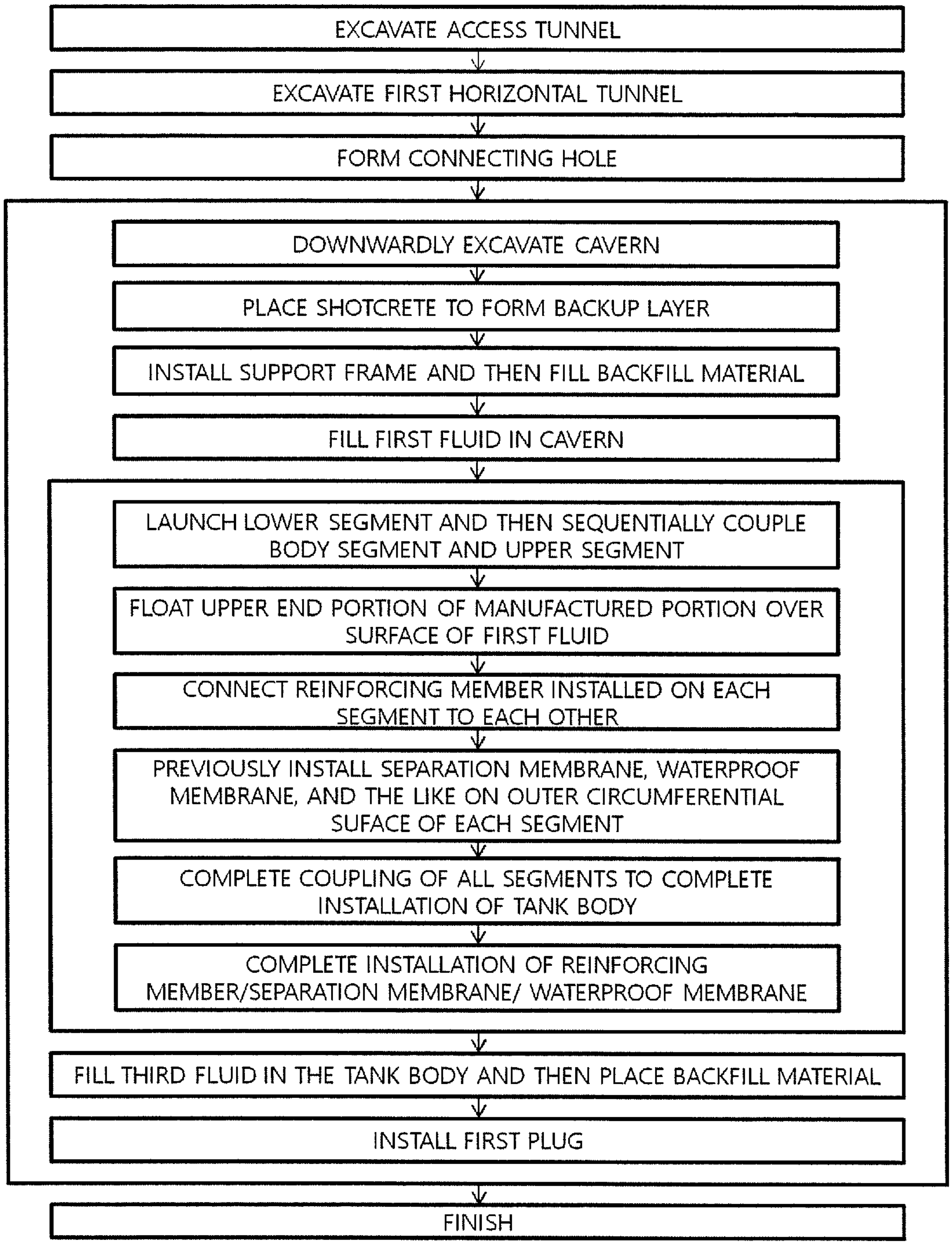
[FIG 10]



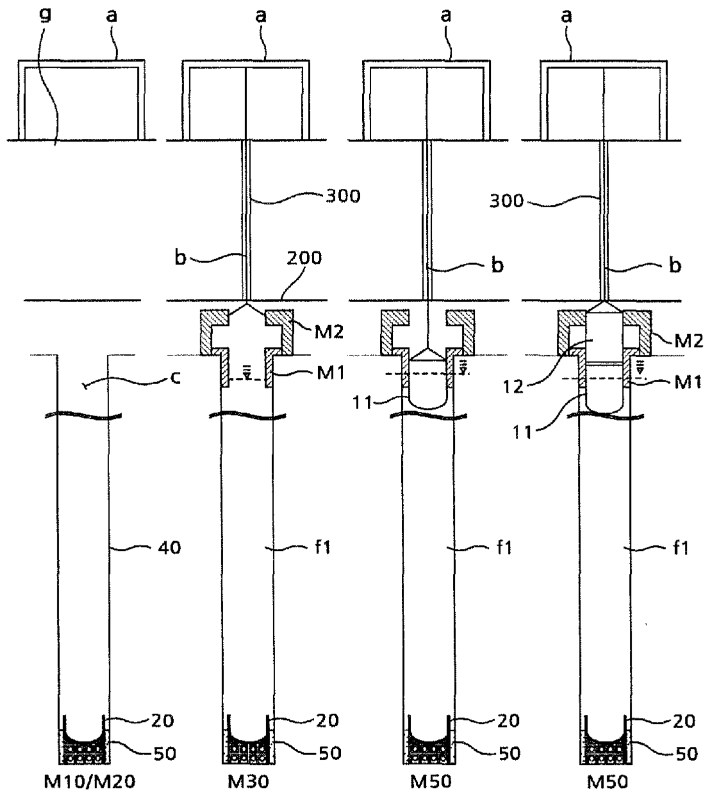
[FIG 11]



[FIG 12]


EXCAVATE ACCESS TUNNEL
EXCAVATE FIRST HORIZONTAL TUNNEL
FORM CONNECTING HOLE
DOWNWARDLY EXCAVATE CAVERN
PLACE SHOTCRETE TO FORM BACKUP LAYER
INSTALL SUPPORT FRAME AND THEN FILL BACKFILL MATERIAL
FILL FIRST FLUID IN CAVERN
LAUNCH LOWER SEGMENT AND THEN SEQUENTIALLY COUPLE BODY SEGMENT AND UPPER SEGMENT
FLOAT UPPER END PORTION OF MANUFACTURED PORTION OVER SURFACE OF FIRST FLUID
CONNECT REINFORCING MEMBER INSTALLED ON EACH SEGMENT TO EACH OTHER
PREVIOUSLY INSTALL SEPARATION MEMBRANE, WATERPROOF MEMBRANE, AND THE LIKE ON OUTER CIRCUMFERENTIAL SUFACE OF EACH SEGMENT
COMPLETE COUPLING OF ALL SEGMENTS TO COMPLETE INSTALLATION OF TANK BODY
COMPLETE INSTALLATION OF REINFORCING MEMBER/SEPARATION MEMBRANE/ WATERPROOF MEMBRANE
FILL THIRD FLUID IN THE TANK BODY AND THEN PLACE BACKFILL MATERIAL
INSTALL FIRST PLUG
FINISH

[FIG 13]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a
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300
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b
b
M2
M2
c
M1
M1
11
12
11
11
40
f1
f1
f1
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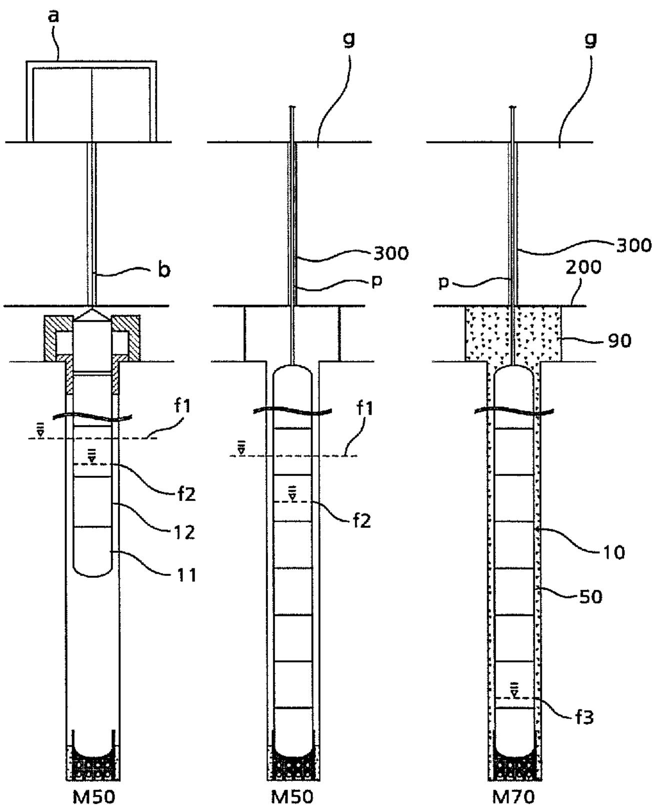
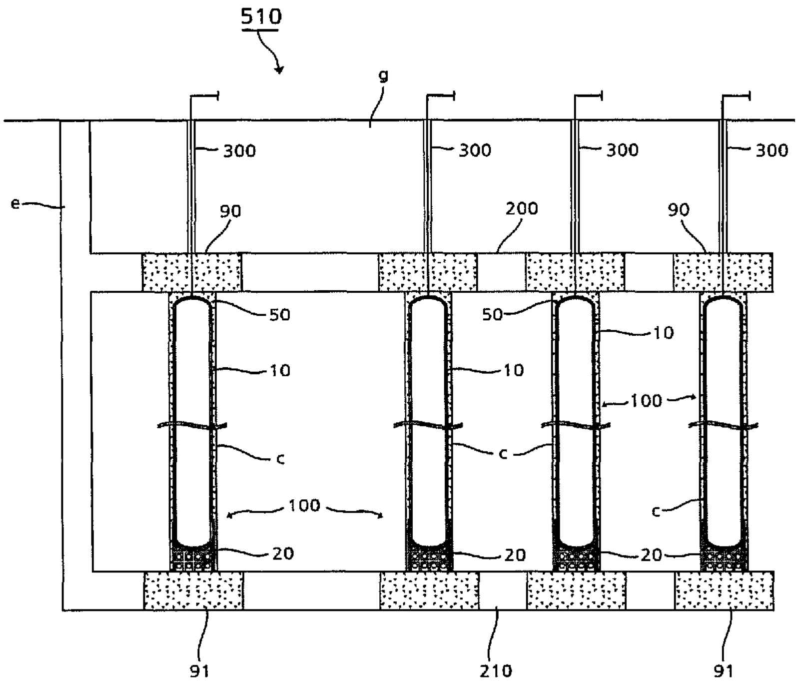
20
20
20
50
50
50
50
M10/M20
M30
M50
M50

[FIG 14]



[FIG 15]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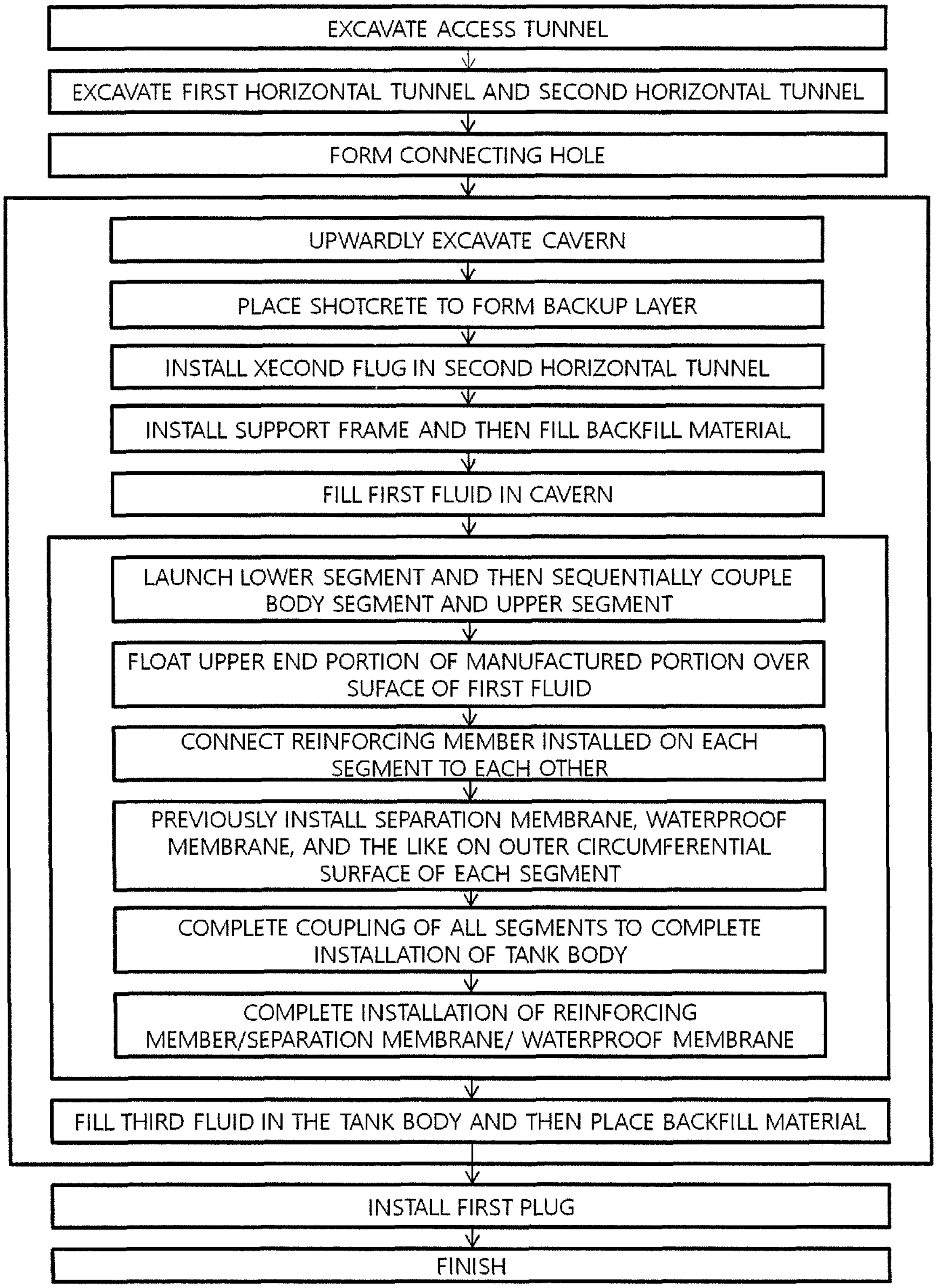
20
91
210
91

[FIG 16]


EXCAVATE ACCESS TUNNEL
EXCAVATE FIRST HORIZONTAL TUNNEL AND SECOND HORIZONTAL TUNNEL
FORM CONNECTING HOLE
UPWARDLY EXCAVATE CAVERN
PLACE SHOTCRETE TO FORM BACKUP LAYER
INSTALL XECOND FLUG IN SECOND HORIZONTAL TUNNEL
INSTALL SUPPORT FRAME AND THEN FILL BACKFILL MATERIAL
FILL FIRST FLUID IN CAVERN
LAUNCH LOWER SEGMENT AND THEN SEQUENTIALLY COUPLE BODY SEGMENT AND UPPER SEGMENT
FLOAT UPPER END PORTION OF MANUFACTURED PORTION OVER SUFACE OF FIRST FLUID
CONNECT REINFORCING MEMBER INSTALLED ON EACH SEGMENT TO EACH OTHER
PREVIOUSLY INSTALL SEPARATION MEMBRANE, WATERPROOF MEMBRANE, AND THE LIKE ON OUTER CIRCUMFERENTIAL SURFACE OF EACH SEGMENT
COMPLETE COUPLING OF ALL SEGMENTS TO COMPLETE INSTALLATION OF TANK BODY
COMPLETE INSTALLATION OF REINFORCING MEMBER/SEPARATION MEMBRANE/ WATERPROOF MEMBRANE
FILL THIRD FLUID IN THE TANK BODY AND THEN PLACE BACKFILL MATERIAL
INSTALL FIRST PLUG
FINISH

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/003753

A. CLASSIFICATION OF SUBJECT MATTER

E04H 7/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E04H 7/02; E02D 31/00; E02D 29/04; E03B 11/14; E04H 7/04; E21D 13/00; F17C 13/08; E04H 7/06; B65D 88/76; E02D 29/045; B23K 9/225

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: compression, high pressure, air, fluid, liquid, gas, storage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6003279 B1 (SHIMIZU CONSTR CO., LTD.) 12 January 1994 See claim 1, page 2 and figure 1.	1-9,11-17
A		10,18-26
Y	JP 07-034711A (HEAT PUMP GIJUTSU KAIHATSU CENTER et al.) 03 February 1995 See abstract, claim 1, page 3 and figure 1.	1-9,11-17
A		10,18-26
Y	JP 10-317394A (SHIMIZU CORP.) 02 December 1998 See claim 2, figure 1.	4
A		1-3,5-26
Y	KR 20-0291960 Y1 (CONSTRUCTION TECHNIQUE NETWORK CO., LTD.) 11 October 2002 See claim 1 and figure 1.	9,11-12
A		1-8,10,13-26
Y	JP 56-099077X2 (TOYO KANETSU KK.) 10 August 1981 See figures 1-4.	13
A		1-12,14-26
Y	JP 2001-164588 A (SHIMIZU CORP.) 19 June 2001 See claim 1 and figure 1.	16-17

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 AUGUST 2014 (27.08.2014)	**27 AUGUST 2014 (27.08.2014)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/003753

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A		1-15, 18-26

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2014/003753

Patent document cited in search report	Publication date	Patent family member	Publication date
JP 6003279 B1	12/01/1994	NONE	
JP 07-034711A	03/02/1995	NONE	
JP 10-317394A	02/12/1998	JP 3769707 B2	26/04/2006
KR 20-0291960 Y1	11/10/2002	NONE	
JP 56-099077X2	10/08/1981	JP 1483857 C	27/02/1989
		JP 56-099077A	10/08/1981
JP 2001-164588 A	19/06/2001	NONE	

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 0683909 **[0054]**
- KR 1068578 **[0054]**
- KR 1334298 **[0054]**