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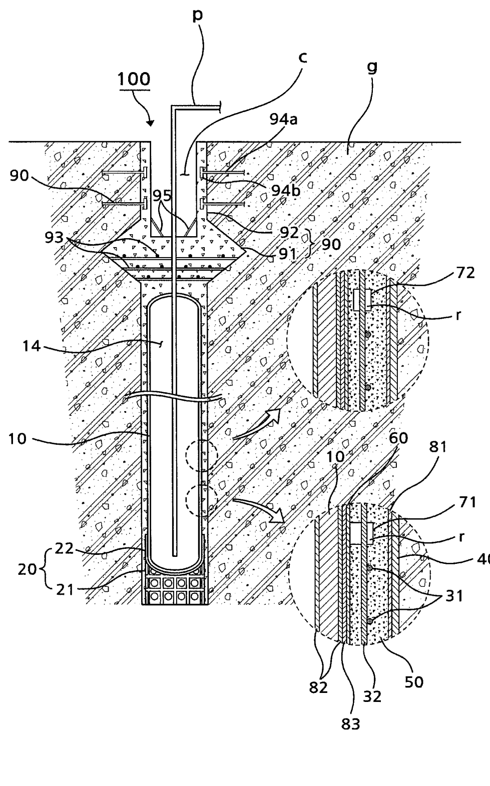
(54) **HIGH-PRESSURE FLUID STORAGE TANK AND CONSTRUCTION METHOD THEREOF**

(57) The present invention relates to a high-pressure fluid storage tank and a construction method thereof. The high-pressure fluid storage tank is buried in a cavern formed by excavating the ground to store high-pressure fluid, and comprises: a tank body which is formed of an airtight material, has a receiving part for storing the high-pressure fluid formed therein, and is formed in such a manner that a plurality of segments are sequentially stacked and coupled in the lengthwise direction thereof; a reinforcing member disposed to surround the tank body while being spaced apart from the tank body; a backfill layer in which the reinforcing member is buried and which is formed of a backfill material filled between the tank body and the cavern; and a plug for closing the cavern.

[FIG 1]



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Description

TECHNICAL FIELD

[0001] The present invention relates to a high-pressure fluid storage tank and a construction method thereof, and more particularly, to a high-pressure fluid storage tank and a construction method thereof 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 can 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 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 tank 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 tank 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 tank 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 thereof 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 tank body which is buried in a cavern formed by excavating the ground to store a high-pressure fluid, is formed of an airtight material, has a receiving part for storing the high-pressure fluid formed therein, and is formed in such a manner that a plurality of segments are sequentially stacked and coupled in the lengthwise direction thereof; a reinforcing member disposed to surround the tank body while being spaced apart from the tank body; a backfill layer in which the reinforcing member is buried and which is formed of a backfill material filled between the tank body and the cavern; and a plug for closing the cavern.

[0016] Also, to accomplish the above-described purpose, a method for constructing a high-pressure fluid storage system according to an aspect of the present invention includes: an excavating step of excavating the ground in a vertical direction to form a cavern; a filling step of filling a first fluid for providing buoyant force in the cavern; a tank manufacturing step of manufacturing a tank body comprising launching a lower segment for constituting a lower portion of the tank body on the first fluid filled in the cavern, sequentially stacking and coupling a plurality of body segments and an upper segment which constitute a body portion and an upper portion of the tank body on the lower segment, and installing 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.

ADVANTAGEOUS EFFECTS

[0017] 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.

[0018] 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

[0019]

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

FIG. 2 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 tank illustrated in FIG. 1.

FIG. 3 is a schematic exploded perspective view for describing a process in which segments are coupled to each other.

FIG. 4 is a schematic cross-sectional view taken along line a-a of FIG. 3.

FIG. 5 is a schematic cross-sectional view taken along line b-b of FIG. 3.

FIG. 6 is a schematic perspective view of a support frame illustrated in FIG. 1.

FIGS. 7 to 9 are perspective views illustrating another shape of a connecting member.

FIG. 10 is a schematic flowchart of a method for constructing a fluid storage tank according to the present invention.

FIGS. 11 and 12 are views for describing the construction method illustrated in FIG. 10.

BEST MODE FOR CARRYING OUT THE INVENTION

[0020] According to the present invention, the segments for forming the tank body comprises: a lower segment having a opened upper surface so as to form a lower end portion of the tank body; body segments each having an annular shape and sequentially stacked and coupled on the lower segment; and an upper segment stacked and coupled on the body segments and having an opened lower surface so as to form an upper portion of the tank body.

[0021] In an embodiment 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.

[0022] Also, the reinforcing member may include at least one or both of a plurality of horizontal reinforcing members disposed to be spaced apart from each other in the lengthwise direction of the tank body, or 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,

[0023] Especially, the vertical reinforcing members, each of which is formed of a plurality of segment members which are sequentially connected in the lengthwise direction, and the segment members are installed on the connecting member.

[0024] Also, although the vertical reinforcing members may be installed on the connecting members, the horizontal reinforcing members may be supported by the connecting members or both the horizontal reinforcing members and the vertical reinforcing members may be installed on the connecting members.

[0025] 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. Also, to increase the supporting capacity, the connecting members may be coupled to the tank body at predetermined height intervals.

[0026] 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.

[0027] Also, in an embodiment according to the present invention, at least one of a separation coating, an anti-corrosion coating, a waterproof coating, or a heat insulation coating may be further provided.

[0028] According to an embodiment of the present invention, 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.

[0029] According to an embodiment of the present invention, the segments are stacked and coupled to each other through welding while being spaced apart a predetermined distance from each other, and further provided with spacers each of which have a predetermined height so as to check the spaced distance between the segments when two segments are disposed adjacent to each other to perform welding and are detachably attached to an upper end portion or a lower end portion of the segments. 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, whereby the tank body is maintained in a state of being spaced apart upwardly from the bottom surface of the cavern may be further provided. Also, the mounting part may be formed in a shape corresponding to that of a lower surface of the tank body, or may be formed in an annular shape having a smaller diameter than that of the tank body.

[0030] Also, a binder inserted from the reinforcing part to the ground such that the plug reinforcing part and the ground are integrated may be provided. For example, a lock bolt may be used as the binder.

[0031] In the present invention, in the installing of the tank body, a second fluid may be filled in the manufactured portion of the tank body so as to adjust the floating force of the manufactured portion of the tank body. Especially, the first fluid filled in the cavern may be discharged to be thereby supplied to the manufactured portion of the tank body and used as the second fluid so as to adjust the floating force of the tank body. As another method for adjusting the floating force of the manufactured portion of the tank body, the first fluid filled in the cavern may be gradually discharged so as to lower the level. Important point is that when another segment is subsequently coupled to the manufactured portion, an operator is allowed to ensure a safe working position by making the manufactured portion of the tank body to be floated over the surface of the first fluid through the discharging of the first fluid and the filling of the second fluid.

[0032] According to an embodiment of the present invention, in the installing of the tank body, a position of the manufactured portion of the tank body may be fixed by using a first support unit such that the manufactured portion of the tank body is not biased in the cavern, and likewise, the body segment or the upper segment which are coupled to the manufactured portion of the tank body may be supported over the manufactured portion of the tank body by using a second support unit.

[0033] Also, in an embodiment according to the present invention, in the backfill step, 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. Here, water or compressed air may be used as the third fluid, and water and compressed air may be filled together to endure buoyant force and a pressure due to the backfill material. The backfill material may be dividedly filled at time intervals, or may be completely filled at once. When filling is dividedly performed and water is used as the third fluid, water may be filled to a height equal to or higher than the height of the backfill material. When the filling is performed at once, the third fluid may be filled fully in the tank body. However, when water is used as the third fluid, since the self weight of the tank body is excessively increased, compressed air may be filled together with water.

[0034] As the backfill material, water curable materials which can be cured by reacting with water, such as grout material, cement, milk, or mortar may be used. Also, in the back fill step, the backfill material may be injected by applying a pressure while the first fluid is filled in the cavern.

[0035] In an embodiment according to the present invention, an inner wall of the cavern is excavated in a direction crossing a length direction of the cavern, then an annular mold is installed along the inner wall of the cavern over the excavated portion, and then placing a filling material between the mold and the inner wall of the cavern to thereby form a plug.

MODE FOR CARRYING OUT THE INVENTION

[0036] The present invention relates to a high-pressure fluid storage tank and a method for constructing the same.

[0037] 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. Also, in the present invention, a storage tank mainly means a tank for CAES for storing energy using compressed air, but the meaning includes a high pressure- storage tank for purely storage which is not connected with a power generation facility.

[0038] Hereinafter, with reference to the accompanying drawings, a high-pressure fluid storage tank according to the present invention with an example of a compressed air storage tank in a CAES power generation system.

[0039] FIG. 1 is a schematic cross-sectional view of a high-pressure fluid storage system according to a first embodiment of the present invention,

[0040] FIG. 2 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 tank illustrated in FIG. 1, and

[0041] FIG. 3 is a schematic exploded perspective view for describing a process in which segments are coupled to each other.

[0042] Firstly, the overall configuration of a high-pressure fluid storage tank (hereinafter, referred to as "storage tank") according to the present invention will be described, and then detailed configuration will be described.

[0043] The storage tank 100 according to an embodiment of the present invention includes a tank body 10, a reinforcing member 30, a backfill layer 50 and a plug 90.

[0044] The tank body 10 has an 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 embedded 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.

[0045] In an aspect of safety, the depth and the height of the tank body 10 are determined according to the storing pressure and 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 3m to about 8 m, and the height of about 100 m to about 200 m.

[0046] 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 strength, the thickness of steel may be further thinned and the tank body 10 may be formed of a soft material such as rubber.

[0047] 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.

[0048] A backfill material is filled between the tank body 10 and the inner wall of the cavern 'c' to thereby 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 sealing property. 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.

[0049] Also, the reinforcing member 30 is preferably embedded 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.

[0050] 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.

[0051] 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 body10 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.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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'.

[0057] 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.

[0058] So far, the standards and materials of the high-pressure fluid storage tank 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 adopted according to an embodiment.

[0059] The present invention was derived not only from research on how to manufacture and/or construct the storage tank 100 configured as described above, but also from research on how to economically construct.

[0060] 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'.

[0061] 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.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] That is, the fluid storage tank 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.

[0070] Thus, the storage tank 100 according to the present invention was derived together while researching an economical construction method for burying the tank body having the height of greater than about 100 m into the cavern having the height of greater than about 150 m, and a optimal structure of the tank body for ensuring the realizability and economicality of the construction method.

[0071] In an aspect of construction method, water is filled in the cavern 'c', segments are then floated on the water surface in the 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 manufacture 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.

[0072] Also, developed is a segment structure optimized to realize the construction method using buoyant force. Of course, the fluid storage tank according to the present invention is not limitedly used only in the method using buoyant force, and the structure thereof also ensures originality.

[0073] The key technology of the fluid storage tank 100 according to the present invention is the structure formed such that the 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 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.

[0074] Hereinafter, specific configurations of the tank body 10, the supporting frame 20, the reinforcing member 30, and the connecting member 70, which are components of the high-pressure fluid storage tank 100 according to the present invention, will be described.

[0075] The tank body 10 includes a plurality of segments, and in the current embodiment, 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.

[0076] 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. 4, to thereby cover the spaced gap from the neighboring segment. In FIG. 4, 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.

[0077] Also, spacers 's' for adjusting a gap are detachably attached to the upper or lower end portions of the segment 11, 12, 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 two segments both 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.

[0078] 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 first 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.

[0079] However, to easily apply the construction method developed together with the storage tank 100 according to the present invention, the support frame 20 is preferably provided. The reason for this will be described in detail when the method for constructing the storage tank 100 according to the present invention.

[0080] As illustrated in FIG. 6, 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.

[0081] 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. 6, 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.

[0082] 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. 6, 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.

[0083] 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.

[0084] 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.

[0085] 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.

[0086] 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.

[0087] 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.

[0088] 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.

[0089] 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.

[0090] 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.

[0091] 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.

[0092] 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.

[0093] 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.

[0094] 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. 5, the segment members 33 are disposed to overlap each other in the mounting part 73 of the connection members 71 and 72.

[0095] 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 commmicate 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.

[0096] The important point is 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.

[0097] 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.

[0098] 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.

[0099] 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.

[0100] 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.

[0101] 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.

[0102] Also, inside the storage tank 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 tank 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.

[0103] Also, the upper side of the cavern 'c' is closed by placing concrete or the like to form the 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 plug 90.

[0104] In the current embodiment, the plug 90 includes a body part 91 formed over the tank body 10, and an annular reinforcing part 92 extending from the upper side of the body part 91 along the inner wall of the cavern 'c'. Furthermore, the body part 91 and the reinforcing part 92 are integrally formed by using a filling material such as concrete. In the current embodiment, the main reason for forming the annular reinforcing part 92 is to ensure the safety against stress in a longitudinal direction in an aspect of safety of the fluid storage tank. That is, it is to suppress a displacement in the lengthwise direction (height direction) of the fluid storage tank by forming the reinforcing part 92. Also, the reinforcing part 92 may perform additional function to protect the inner wall in the upper side of the cavern 'c'. Especially, the hole wall protection function of the reinforcing part 92 is increased when a backup layer is not formed by jetting shotcrete to the hole wall of the cavern 'c'. Also, the reinforcing part 92 is preferably integrated with surrounding rock bed. Accordingly, a binder 94 may be installed to integrate the reinforcing part 92 and the rock bed 'g'. A lock bolt or the like may be used as the binder 94. In the current embodiment, the binder 94 is installed in plurality along the circumferential direction of the cavern 'c' and includes an insertion part 94a which is inserted from the reinforcing part 92 to the rock bed 'g' and a head part 94b which extends from one end portion of the insertion part 94a in a direction crossing the lengthwise direction of the insertion part 94a. The head part 94b is preferably buried into the reinforcing part 92. A support member 95 such as H-beam may be installed in a bent portion between the body part 91 and the reinforcing part 92. In addition, water may be filled into an inner receiving space formed by being surrounded by the reinforcing part 92.

[0105] Also, a reinforcing member 93 is buried in the body part 91 to thereby increase the tensile strength of the plug. The reinforcing member 93 may adopt a method of disposing reinforcing bars in a lattice shape, and since tensile force is mainly applied to a lower end of the body part 91, corresponding to this, the reinforcing member is also installed at a lower side of the body part 91 of the plug 90.

[0106] As described above, 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.

[0107] 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. 7, 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.

[0108] 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. 8, 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 long segments (formed in relatively long lengths 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.

[0109] Also, as illustrated in FIG. 9, 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.

[0110] 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.

[0111] 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.

[0112] Hereinafter, with reference to the drawings, a method for constructing a high-pressure fluid storage tank 100 according to the present invention will be described.

[0113] FIG. 10 is a schematic flowchart of a high-pressure fluid storage tank according to the present invention, and FIGS. 11 and 12 are views for describing the construction method illustrated in FIG. 10.

[0114] Referring to FIGS. 10 to 12, a method for constructing a storage tank includes an excavating step (M10), a filling step (M30), a tank manufacturing step (M50), and a backfill step (M70).

[0115] 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. As a method for forming a vertical cavern 'c', a top-down blasting and a bottom-up blasting may be considered. The top-down blasting excavation is a method of excavating the ground vertically from the ground surface through gunpowder blasting. However, in the current construction method, since the excavation depth is very deep, there is a disadvantage in that the deeper the depth, the more difficult the blasting work, and a technical supplementation is required to discharge broken rocks generated by blasting to the ground surface.

[0116] The bottom-up blasting excavation is a method in which a separate access tunnel is formed up to a lowermost position of the cavern 'c', and then blasting is performed upwardly from the bottom. In this method, since broken rocks generated by blasting fall downwards, there is a merit of easy discharging of broken rocks through the access tunnel. However, when the diameter of the cavern is about 10 m or so, it is uneconomical to excavate a separate access tunnel. When excavating a large silo shape or a tunnel shape of about several ten meters or when small but a plurality of caverns are formed in parallel, the bottom-up blasting method through an access to the access tunnel can be considered.

[0117] In the present invention, aside from the above-described method, the method of downwardly excavating from the ground surface by using a vertical excavator can be adopted. For example, it is possible to perform an excavation by using a hammer exactor disclosed in Korean Patent No. 0683909, Korean Patent No. 1068578, and Korean Patent No. 1334298. 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 an 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.

[0118] 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 can form a backup layer 40 (M20). The backup layer 40 can also be temporarily formed 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.

[0119] In vertically excavating the cavern 'c', when reaching a predetermined depth, excavation is performed slightly widely in the horizontal direction such that the plug 90 can be installed. An excavation cross-section for installing the plug may be variously selected from a wedge type, a taper type, or a block type.

[0120] When the excavation of the cavern 'c' is completed, a support frame 20 is installed in advance 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 the filling step (M30) of filling the cavern 'c' with a first fluid 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.

[0121] When the filling with the first fluid is completed, the tank manufacturing step (M50) is performed. The tank manufacturing step (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 at the same time is installed in the cavern 'c'.

[0122] In the tank manufacturing step (M50), a plurality of segments for constituting the tank body 10 are manufactured by being welded to each other in the cavern 'c'.

[0123] 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 method for supporting the segments 11, 12, and 13 by the crane 'a' may be variously employed, 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 employed.

[0124] 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.

[0125] 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 up 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 up 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.

[0126] 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.

[0127] 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 up on the crane 'a' and the position thereof is fixed by the second supporting unit M2.

[0128] 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.

[0129] 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.

[0130] As 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.

[0131] 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.

[0132] 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.

[0133] 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.

[0134] 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.

[0135] 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.

[0136] 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.

[0137] Now, as a final step, the backfill step (M70) is performed. That is, a backfill material is filled between the tank body 10 and the rock bed 'g' to form a backfill layer 50. The backfill 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 at a high pressure to perform the back filing.

[0138] The point to remember in filling the backfill material is that a third fluid f3 should be first filled in the tank body 10. The backfill material, when filled, exerts two actions on the tank body 10. First, as the backfill 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 backfill material. Accordingly, before the backfill 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 backfill material.

[0139] As the third fluid, water or compressed air may be used.

[0140] When water is used, the level of water filled in the tank body 10 is formed slightly higher than the height to which the backfill material is filled. That is, when backfill is dividedly performed, water has only to be filled to the level slightly higher than the height of backfill material which is filled for each divided placement, and when the backfill 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 tons 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.

[0141] 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 backfill 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 backfill material. This is because even though air is compressed, the air has a very small weight.

[0142] 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 employed, but more preferably, a method in which water and compressed air are used together is employed. 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 backfill material.

[0143] When a predetermined time elapses after the backfill material is entirely placed, the back filing material is cured. In addition, when the upper side of the plug is filled by using rocks or soil, the high-pressure fluid storage tank 100 is completed.

[0144] In the current embodiment, the reinforcing member 90 includes a horizontal reinforcing member 19 and a vertical reinforcing member 92. To make the shape of the plug according to the current embodiment, an annular mold is previously installed along an inner wall in an upper portion of the cavern, then a plurality of binders 94 are inserted and installed on the inner wall of the cavern, and then the backfill material is placed.

[0145] A power generating system according to the present invention is formed by connecting a pipe 15 of the high-pressure fluid storage tank 100 with 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 tank 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 tank 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 tank 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.

[0146] 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.

[0147] Although the present invention has been described with reference to embodiments illustrated in the accompanying drawings, these embodiments are merely exemplary, and it could be understood that various changes and modifications can be made hereto by those 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 tank comprising:

a tank body which is buried in a cavern formed by excavating the ground to store a high-pressure fluid, is formed of an airtight material, has a receiving part for storing the high-pressure fluid formed therein, and is formed in such a manner that a plurality of segments are sequentially stacked and coupled in the lengthwise direction thereof;

a reinforcing member disposed to surround the tank body while being spaced apart from the tank body;

a backfill layer in which the reinforcing member is buried and which is formed of a backfill material filled between the tank body and the cavern; and

a plug for closing the cavern.

2. The high-pressure fluid storage tank of claim 1, wherein the segments for forming the tank body comprise:

a lower segment having an opened upper surface so as to form a lower end portion of the tank body;

body segments each having an annular shape and sequentially stacked and coupled on the lower segment; and

an upper segment stacked and coupled on the body segments and having an opened lower surface so as to form an upper portion of the tank body.

3. The high-pressure fluid storage tank of claim 1, 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 members are installed on the connecting members.

4. The high-pressure fluid storage tank of claim 3, wherein the reinforcing member comprises at least one of
a plurality of horizontal reinforcing members disposed to be spaced apart from each other in the lengthwise direction of the tank body, or
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.

5. The high-pressure fluid storage tank of claim 4, wherein the reinforcing member comprises the vertical reinforcing members, each of which is formed of a plurality of segment members which are sequentially connected in the lengthwise direction, and the segment members are installed on the connecting member.

6. The high-pressure fluid storage tank of claim 5, wherein the connecting members each is provided with a mounting part in which the segment members which are adjacent to each other in a lengthwise direction thereof are joined with each other.

7. The high-pressure fluid storage tank of claim 6, wherein
the segment members adjacent to each other are inserted together into the mounting part, and
the segment members inserted into the mounting part are joined with each other by a resin in the mounting part.

8. The high-pressure fluid storage tank of claim 7, wherein
insertion holes which respectively communicate with the mounting parts and to which the segment member is respectively inserted are provided in an upper and lower surfaces of the connecting members, and
injection holes which respectively communicate with the mounting parts are formed in the connecting members so as to inject a resin for joining the segment members with each other.

9. The high-pressure fluid storage tank of claim 8, wherein the insertion holes formed in the upper and lower surfaces of the connecting members are disposed such that center points thereof are spaced apart from each other, and thereby the segment members are disposed to overlap each other in the mounting parts.

10. The high-pressure fluid storage tank of claim 4, wherein
the connecting members are formed in an annular shape to be coupled to an outer circumferential surface of the tank body or formed in an annular shape which is spaced apart from the tank body to surround the tank body like a hollow pipe, and
mounting parts in which the vertical reinforcing members are inserted are formed therein.

11. The high-pressure fluid storage tank of claim 4, wherein
the connecting members are installed in plurality to be spaced apart from each other in the circumferential direction of the tank body and are disposed to be coupled to the tank body or to be spaced apart from the tank body, and
mounting parts in which the vertical reinforcing members are inserted are formed therein.

12. The high-pressure fluid storage tank of claim 4, wherein the reinforcing member comprises horizontal reinforcing members, and the horizontal reinforcing members are supported by the connecting members.

13. The high-pressure fluid storage tank of claim 3, wherein
at least one of the plurality of connecting members is coupled to the tank body.

14. The high-pressure fluid storage tank of claim 13, wherein a connecting member disposed at a lowermost portion from among the plurality of connecting members is coupled to the tank body.

15. The high-pressure fluid storage tank of claim 1, further comprising additional weld members each attached to an inner surface or an outer surface of each segment so as to protrude with respect to an upper end surface or a lower end surface of each segment.

16. The high-pressure fluid storage tank of claim 1, further comprising a separation coating formed on an outer surface of the tank body such that the tank body and the backfill material are not coupled to each other.

17. The high-pressure fluid storage tank of claim 1, further comprising an anti-corrosion coating formed on at least one of an inner surface or an outer surface of the tank body so as to prevent the corrosion of the tank body.

18. The high-pressure fluid storage tank of claim 1, further comprising a waterproof coating formed on an outer surface of the tank body so as to prevent the tank body from contacting water in surroundings.

19. The high-pressure fluid storage tank of claim 1, further comprising a heat insulation coating formed on at least one of an inner surface or an outer surface of the tank body so as to prevent the fluid stored in the tank body from heat-exchanging with the surroundings.

20. The high-pressure fluid storage tank of claim 1, 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.

21. The high-pressure fluid storage tank of claim 1, wherein the segments are stacked and coupled to each other through welding while being spaced apart a predetermined distance from each other, and
are further provided with spacers each of which has a predetermined height so as to check the spaced distance between the segments when two segments are disposed adjacent to each other and are detachably attached to an upper end portion or a lower end portion of the segments.

22. The high-pressure fluid storage tank of claim 1, 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,
whereby the tank body is maintained in a state of being spaced apart upwardly from the bottom surface of the cavern.

23. The high-pressure fluid storage tank of claim 22, 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.

24. The high-pressure fluid storage tank of claim 22, wherein the mounting part is formed in a shape corresponding to that of a lower surface of the tank body.

25. The high-pressure fluid storage tank of claim 22, wherein the mounting part is formed in an annular shape having a smaller diameter than that of the tank body.

26. The high-pressure fluid storage tank of claim 1, wherein the plug comprises:

a body part disposed in an upper portion of the tank body; and
an annular reinforcing part upwardly extending along an inner wall of the cavern from the body part.

27. The high-pressure fluid storage tank of claim 26, further comprising a binder inserted from the reinforcing part to the ground such that the plug reinforcing part and the ground are integrated.

28. The high-pressure fluid storage tank of claim 27, wherein the binder comprises:

an insertion part inserted from the reinforcing part to the ground; and
a head part extending from an end portion of the insertion part in a direction crossing a lengthwise direction of the insertion part and disposed in the reinforcing part.

29. The high-pressure fluid storage tank of claim 26, wherein a reinforcing member is buried in the body part of the plug so as to improve a tensile strength of the plug.

30. A method for constructing a high-pressure fluid storage tank, the method comprising:

an excavating step of excavating the ground in a vertical direction to form a cavern;
a filling step of filling a first fluid for providing buoyant force in the cavern;
a tank manufacturing step of launching a lower segment for constituting a lower portion of a tank body on the first fluid filled in the cavern, and sequentially stacking and coupling a plurality of body segments and an upper 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 the first fluid by buoyant force of the first fluid.

31. The method of claim 30, wherein in the installing of the tank body, a second fluid is filled in the manufactured portion of the tank body so as to adjust the floating force of the manufactured portion of the tank body.

32. The method of claim 31, wherein the first fluid filled in the cavern is discharged to be thereby supplied to the manufactured portion of the tank body and is used as the second fluid so as to adjust the floating force of the tank body.

33. The method of claim 30, wherein in the installing of the tank body, a first fluid filled in the cavern is gradually discharged so as to adjust the floating force of the manufactured portion of the tank body.

34. The method of claim 30, wherein in the installing of the tank body, a position of the manufactured portion of the tank body is fixed by using a first support unit such that the manufactured portion of the tank body is not biased in the cavern.

35. The method of claim 30, wherein the body segment or the upper segment which are coupled to the manufactured portion of the tank body are fixedly positioned over the manufactured portion of the tank body by using a second support unit.

36. The method of claim 30, 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.

37. The method of claim 36, wherein the third fluid is water or compressed air.

38. The method of claim 36, wherein water and compressed air are filled together into the tank body as the third fluid.

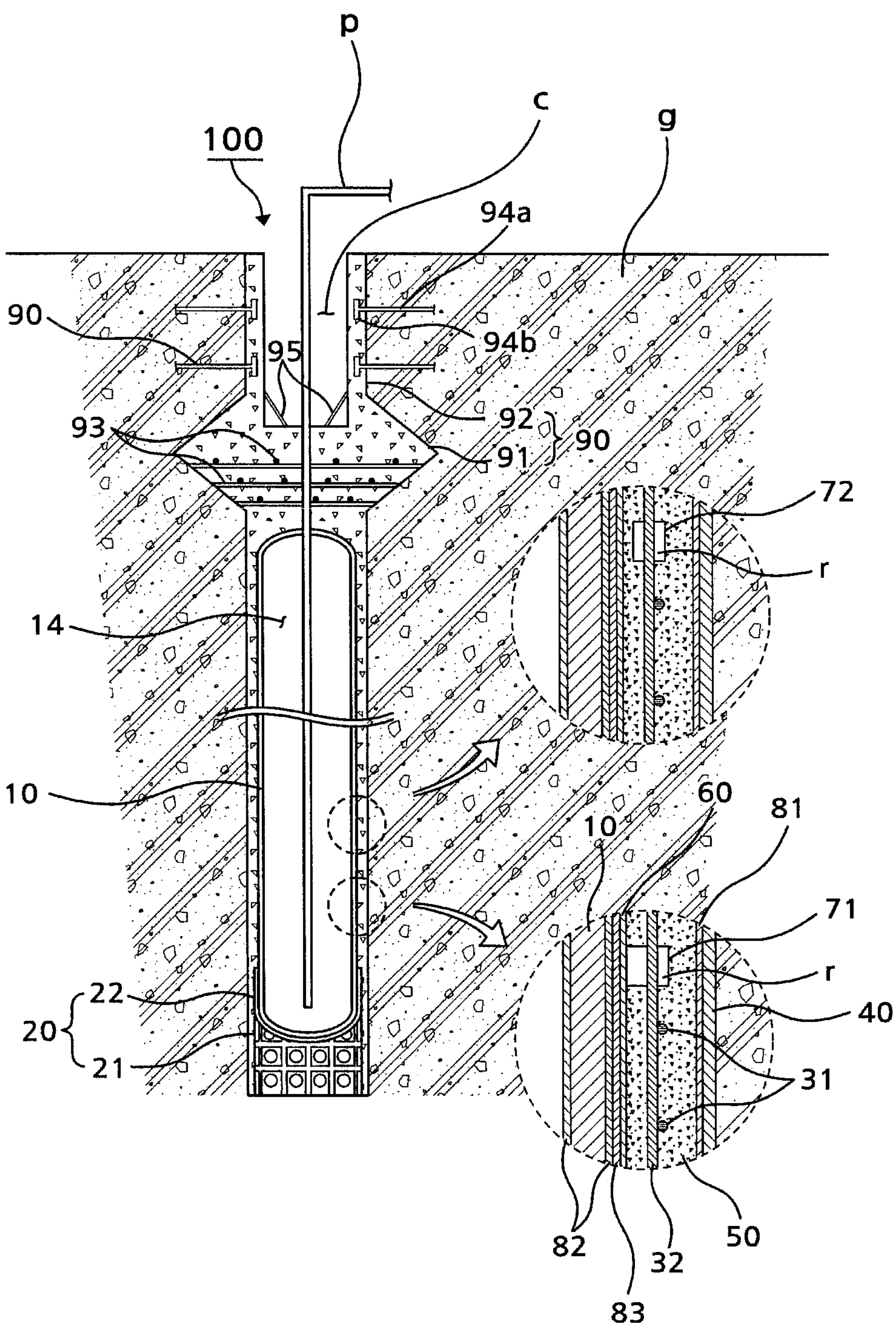
39. The method of claim 30, wherein in the forming of the backfill layer, the backfill material is injected by being applied with a pressure while the first fluid is filled in the cavern.

40. The method of claim 30, wherein before the filling of the backfill material, reinforcing members surrounding the tank body are installed, and when the backfill material is filled, the backfill layer contains the reinforcing members.

41. The method of claim 40, wherein after respectively installing the reinforcing members to be spaced a predetermined distance from outer surfaces of the upper segment, the body segments, and 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.

42. The method of claim 30, wherein an inner wall of the cavern is excavated in a direction crossing a length direction of the cavern, then an annular mold is installed along the inner wall of the cavern over the excavated portion, and then placing a filling material between the mold and the inner wall of the cavern to thereby form a plug.

[FIG 1]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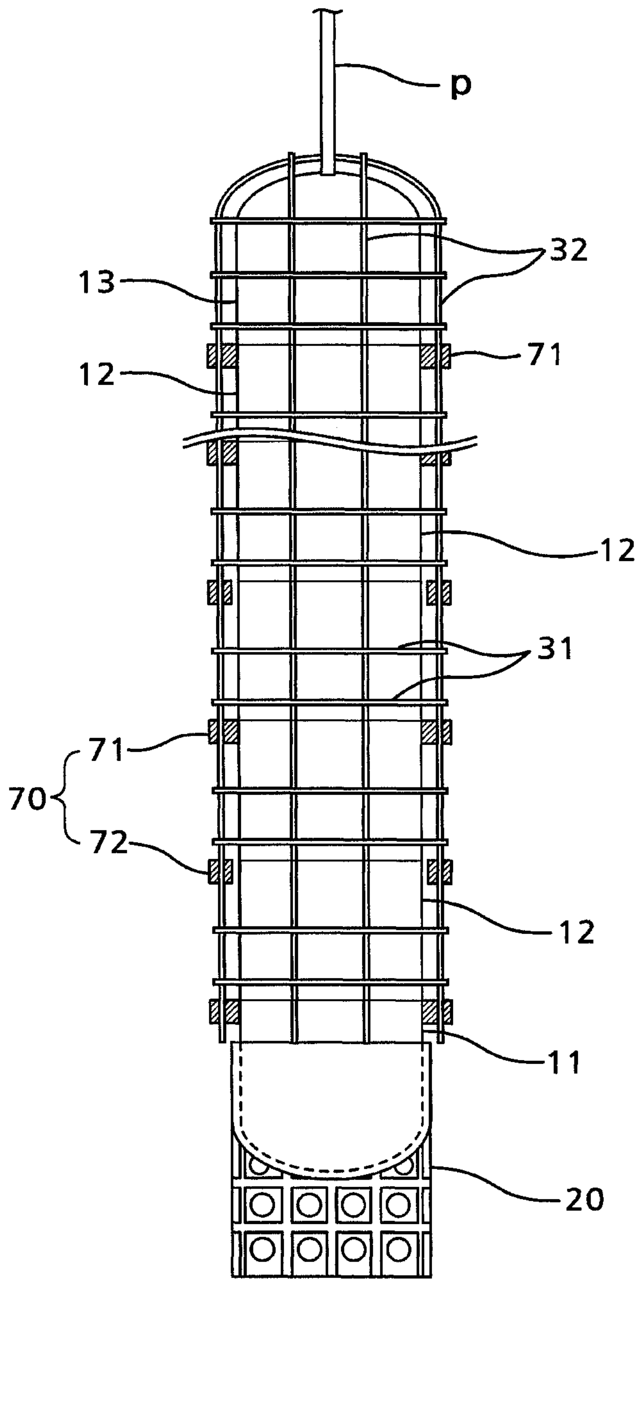
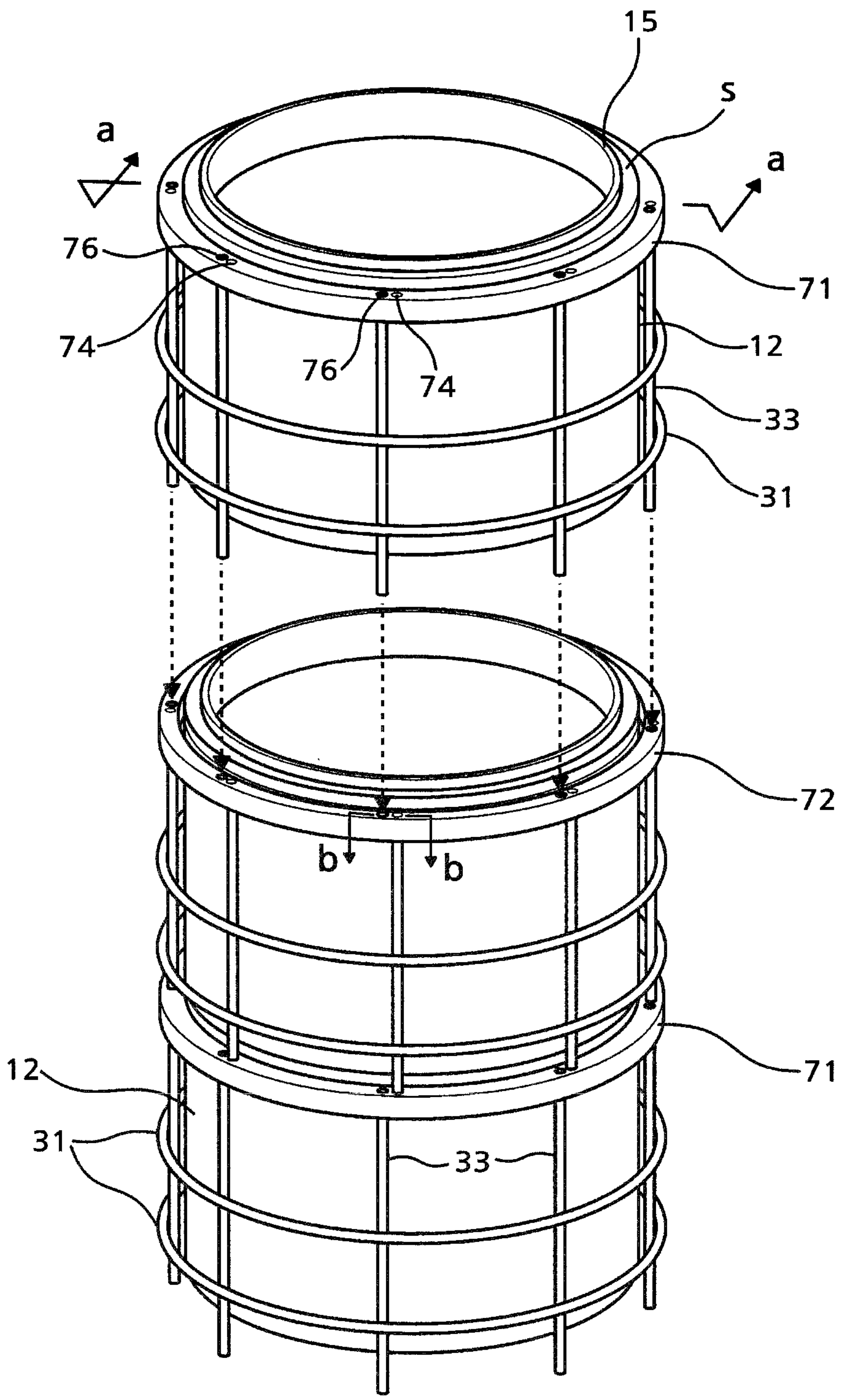
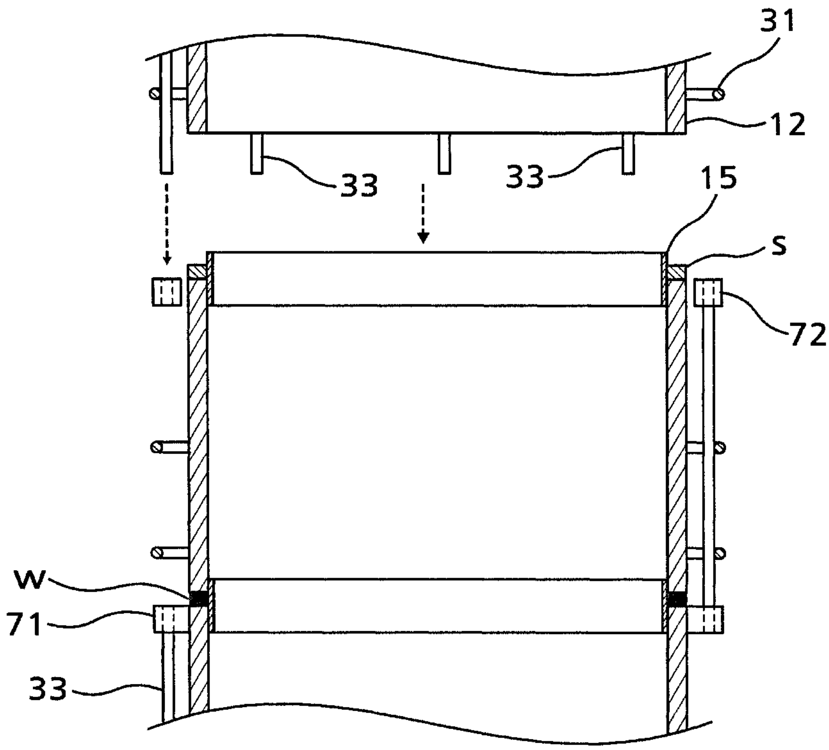
[FIG 2]



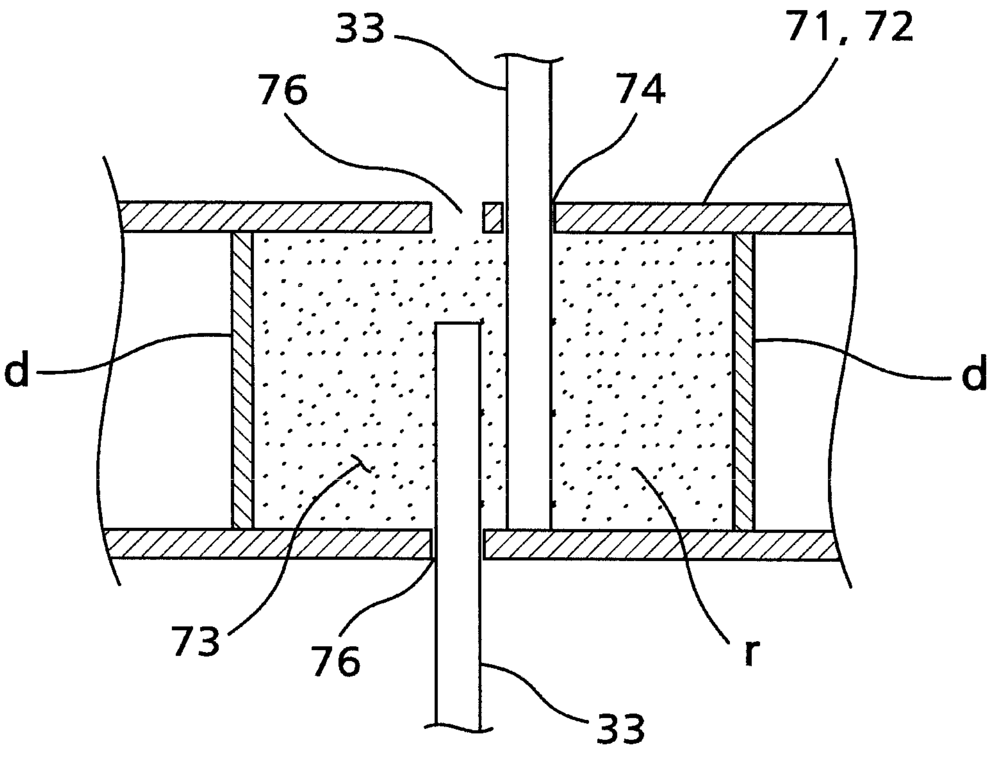
[FIG 3]



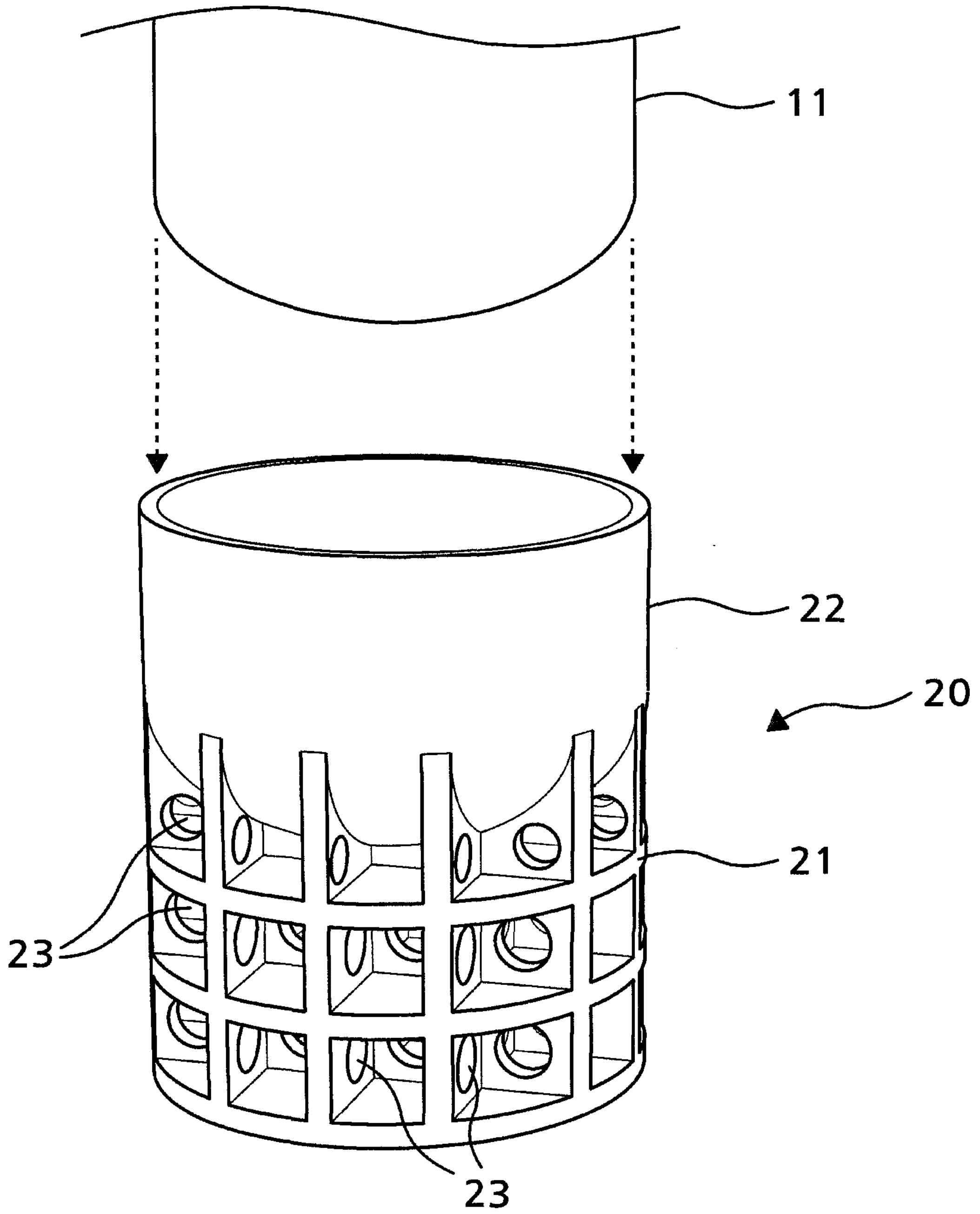
[FIG 4]



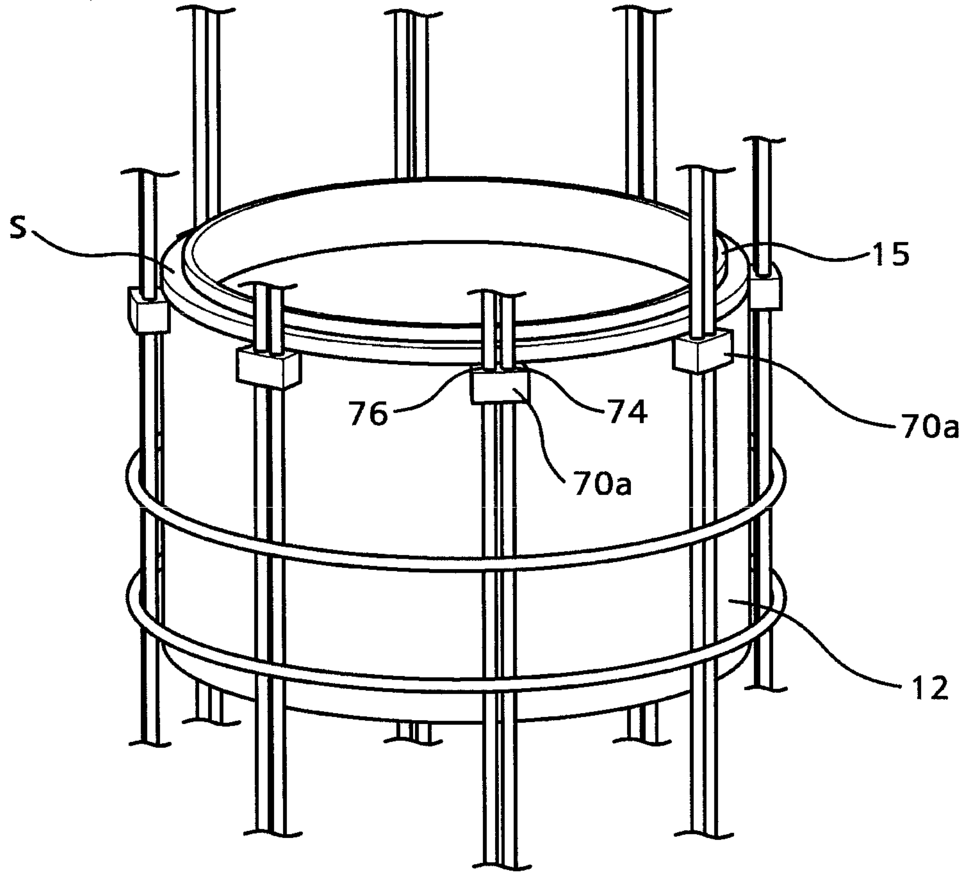
[FIG 5]



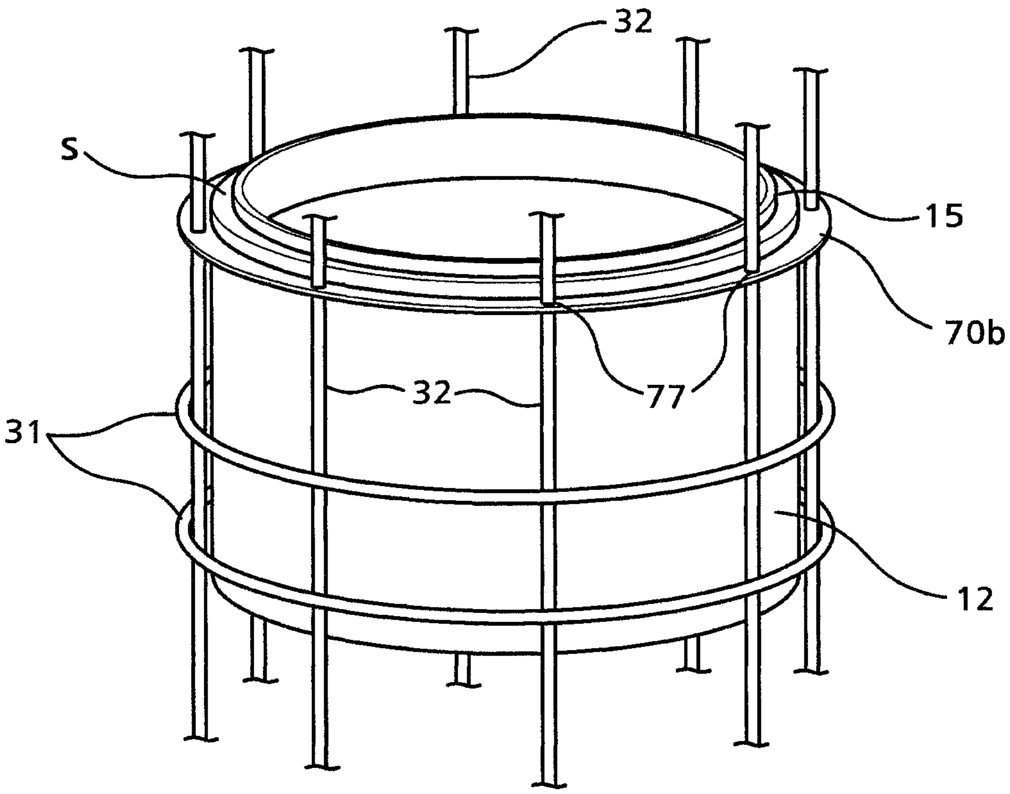
[FIG 6]



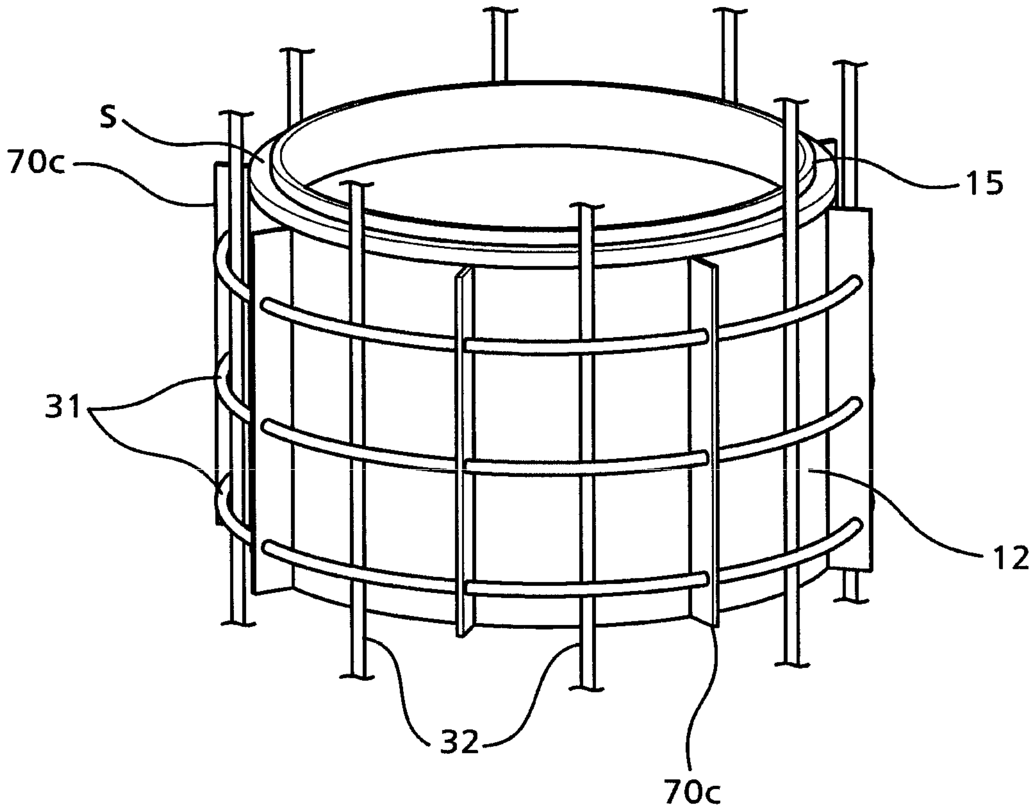
[FIG 7]



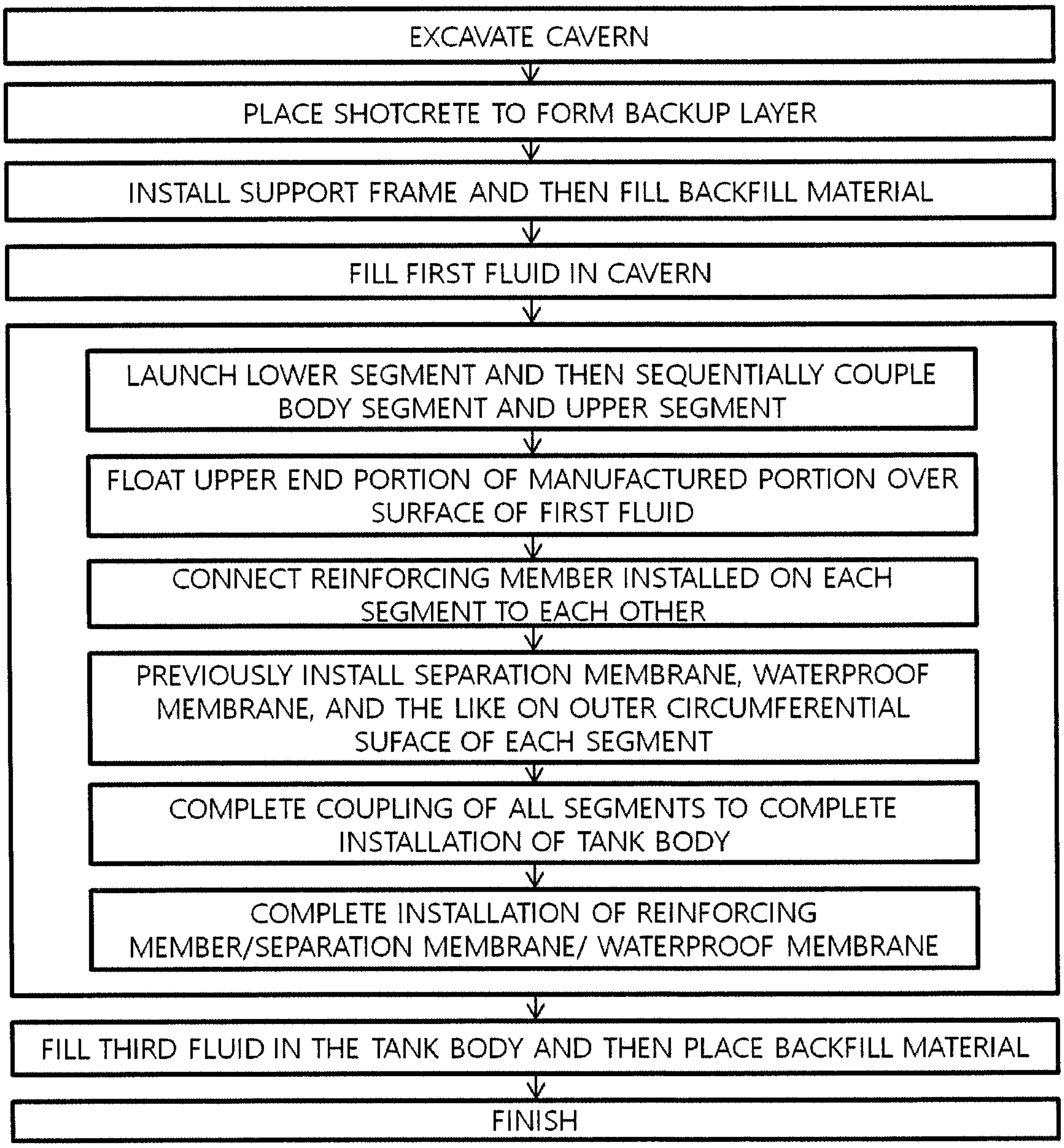
[FIG 8]



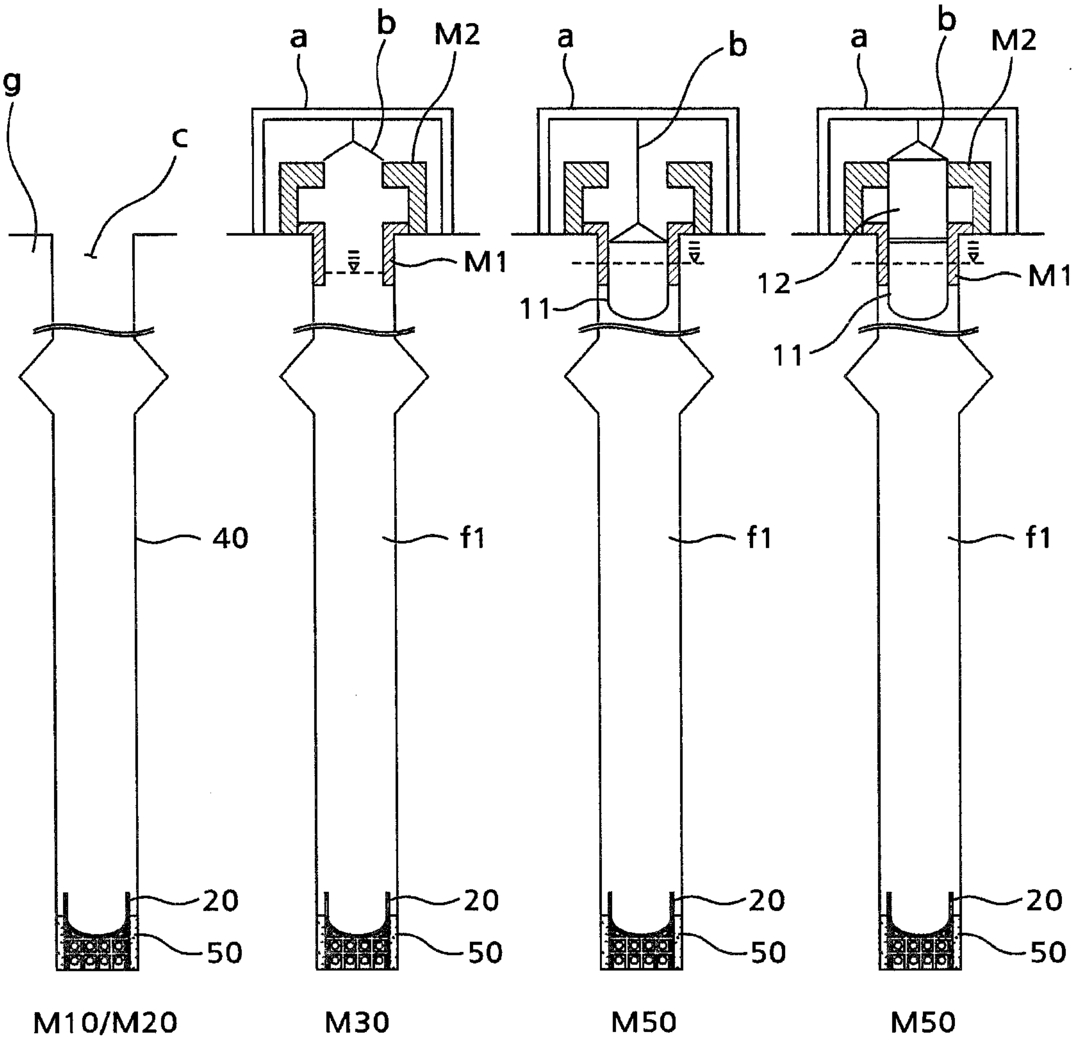
[FIG 9]



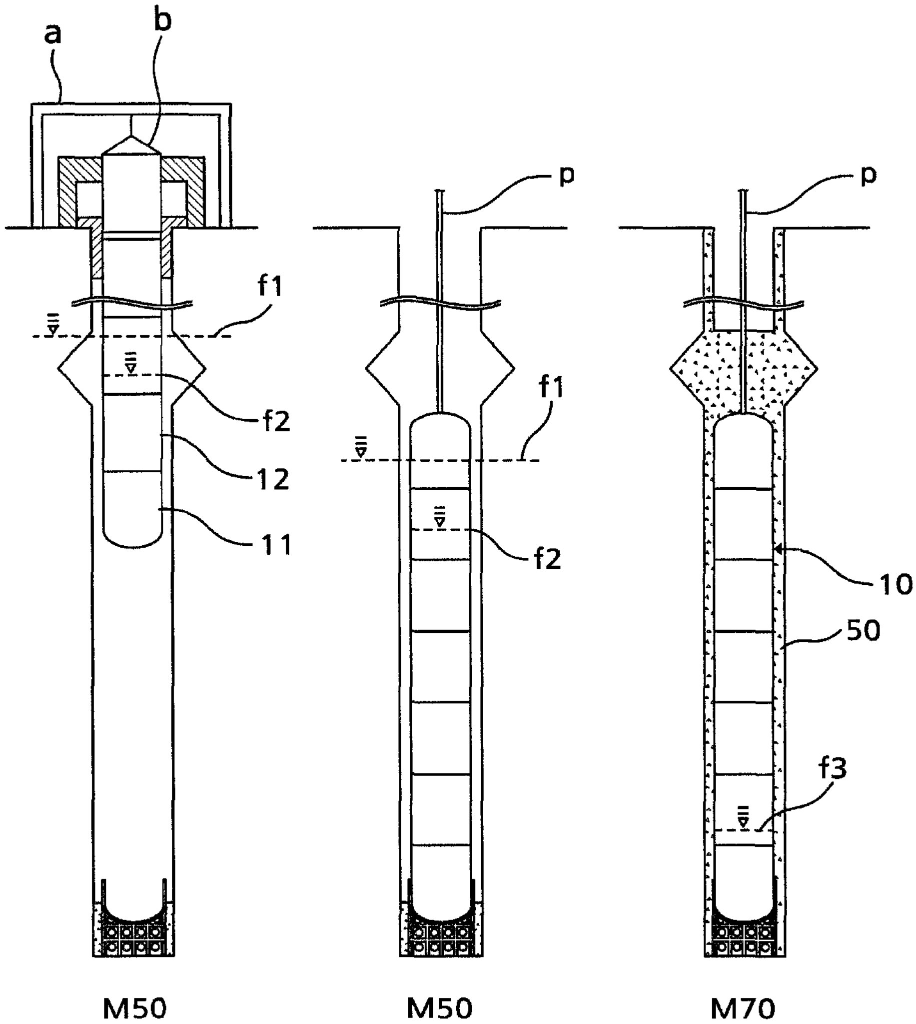
[FIG 10]


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
FINISH

[FIG 11]



[FIG 12]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/003748

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; E03B 11/14; E04H 7/04; E21D 13/00; B65G 5/00; E04H 7/06; B65D 88/76; E02D 29/045; B23K 9/225; E04H 7/18

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 voltage, air, gas, liquid, fluid, 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 07-034711A (HEAT PUMP GIJUTSU KAIHATSU CENTER et al.) 03 February 1995 See abstract, claim 1, page 3 and figure 1.	1-4,10-29,34-35,42
X		30-33,36-37,39-40
A		5-9,38,41
Y	JP 09-501377A (SOCIETE FRANCAISE DE STOCKAGE GEOLOGIQUE DITE GEOSTOCK) 10 February 1997 See page 7 and figures 1, 2.	1-4,10-29,42
A		5-9,30-41
Y	KR 20-0291960 Y1 (CONSTRUCTION TECHNIQUE NETWORK CO., LTD.) 11 October 2002	3-4,10-14
A	See claim 1 and figure 1.	1-2,5-9,15-42
Y	JP 56-099077X2 (TOYO KANETSU KK.) 10 August 1981 See figures 1-4.	15
A		1-14,16-42
Y	JP 2001-164588 A (SHIMIZU CORP.) 19 June 2001 See claim 1 and figure 1.	22-45
A		1-21, 26-42

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
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/KR2014/003748

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 05-321509A (NIPPON STEEL CORP.) 07 December 1993 See page 4 and figure 1.	26-29
A		1-25,30-42
Y	JP 11-021926A (HAZAMA GUMI LTD. et al.) 26 January 1999 See figures 3-5.	34-35
A		1-33,36-42

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2014/003748

Patent document cited in search report	Publication date	Patent family member	Publication date
JP 07-034711A	03/02/1995	NONE	
JP 09-501377A	10/02/1997	EP 0702656 A1	27/03/1996
		EP 0702656 B1	29/01/1997
		JP 03-548965B2	04/08/2004
		KR 10-0334395 B1	31/10/2002
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Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- KR 0683909 **[0117]**
- KR 1068578 **[0117]**
- KR 1334298 **[0117]**