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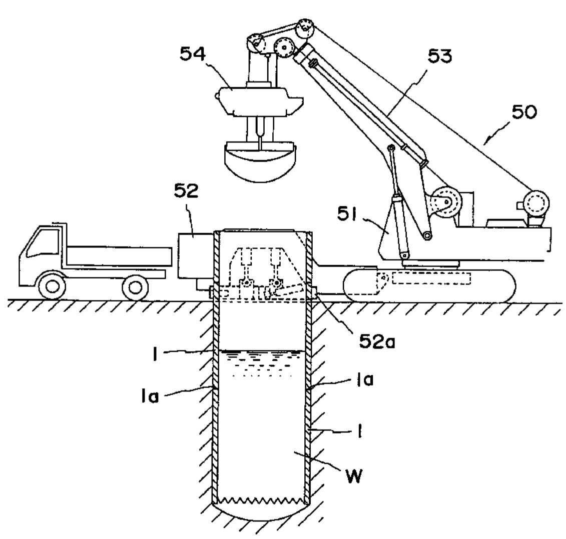
(54) **Method of constructing a shaft and an apparatus for constructing a shaft**

(57) A high strength shaft, by which wasteful consumption of casing material is reduced, is constructed. After an excavation casing (1) is pressed and driven into the ground and earth inside the driven excavation casing (1) is discharged, an earth-retaining casing (2) is inserted into the excavation casing (1) and a concrete bottom plate (7) is cast in the earth-retaining casing (2), and thereafter, the excavation casing (1) is removed from the ground while a hardening agent (8) is poured into the space between the excavation casing (1) and the earth-retaining casing (2) so that a shaft is constructed.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a technique of constructing a shaft in the ground for constructing sewerage, laying electric wires, constructing a manhole or the like.

Description of the Prior Arts:

In sewerage or manhole construction, a shaft is excavated by using an excavating apparatus such as a grab bucket or an earth auger, and excavation for constructing a sewer is performed from a starting pit entrance of the shaft by a shield machine. In shaft excavating work, before excavating, a cylindrical casing is clamped by a pressing and driving apparatus provided on the excavating apparatus, and is pressed into the ground with an oscillating rotational motion around the axis of the casing or a rotational motion to one direction around the axis of the casing. Then, the earth within the casing is excavated and discharged by the grab bucket onto the ground, and additional casings are successively joined and pressed until the intended depth of the shaft is reached. Accordingly, the cylindrical casing is used as an excavating means when excavating a shaft in the ground, and also serves as a retaining wall to be left in the ground after construction.

As mentioned above, after the cylindrical casing has been driven in, followed by removal of earth from the casing, a concrete bottom plate is cast on the bottom, and any remaining water within the shaft is pumped out. Thus, a shaft enclosed with a casing is constructed.

In the conventional construction method, the casing must act as a retaining wall, and also be strong enough to withstand the thrust of pressing-driving and torque and impact of the edge of the excavating blade during excavation. Accordingly, in order to improve the rigidity, casings of 10 to 25 mm in thickness or double-structured casings having a total thickness of about 45 mm have been employed.

However, in the above case, the total weight of the casing is increased, and production costs also significantly increase with the increased thickness.

Additionally, in the conventional construction method, since the thicker casing is left in the ground after the shaft has been constructed, a large amount of structural steel is wasted. In this case, the increased structural steel which remains in the ground would eventually cause environmental problems due to corrosion, which is not something that can be disregarded. Further, when a new underground structure is built after the former structure is removed, it is necessary to pull out the entire casing or to remove it by cutting and scrapping. Casings of the conventional construction method are difficult to cut and scrap due to their thick walls.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a shaft excavating technique which can reduce wasteful consumption of casing material and which can result in a high strength shaft.

In order to solve the problems mentioned above, in accordance with the present invention, there is provided a method of constructing a shaft comprising a step of inserting a cylindrical earth-retaining casing into a shaft excavated in the ground, and a step of corrugating said earth-retaining casing to form the circumferential wall thereof into a wave-like longitudinal cross section. By the above steps, the corrugated earth-retaining casing is installed inside the excavated shaft. The waveform corrugation provides increased rigidity so that the earth-retaining casing will not be deformed by the pressure of the earth even when the thickness thereof is less than that of the casing in accordance with the conventional construction method. Accordingly, a shaft of high strength can be constructed, and wasteful consumption of the casing material can be reduced.

Further, in accordance with the present invention, there is provided a method of constructing a shaft comprising a step of pressing and driving a cylindrical excavation casing in the ground, a step of discharging earth from the excavation casing after it has been driven into the ground, a step of inserting a cylindrical earth-retaining casing into the excavation casing, and a step of removing the excavation casing from the ground while corrugating the earth-retaining casing to form a wave-like pattern on the circumferential wall thereof. By the above steps, the corrugated earth-retaining casing is installed in the ground. The waveform corrugation provides increased rigidity so that the earth-retaining casing will not be deformed by the pressure of the earth even after the excavation casing is removed from the ground, and the constructed shaft has high strength. Further, since the strength of the earth-retaining casing is improved by waveform corrugation, an earth-retaining casing with less thickness than that of the excavation casing can be used, and material waste can be reduced.

Still further, in accordance with the present invention, there is provided a method of constructing a shaft comprising a step of pressing and driving a cylindrical excavation casing into the ground, a step of discharging earth from the driven excavation casing, a step of inserting a cylindrical earth-retaining casing into the excavation casing, a step of pouring a hardening agent into the space between the excavation casing and the earth-retaining casing, and a step of removing the excavation casing from the ground concurrently or subsequently to the pouring of the hardening agent. By the above steps, the earth-retaining casing and the hardening agent layer formed on the outer surface of the casing are installed in the ground. Since the integration of the earth-retaining casing and the hardening agent layer increases the rigidity, the earth-retaining casing will not be deformed by the pressure of the surrounding earth even after the excavation casing is removed from the ground. Thus, a shaft having high strength can be constructed. Further, since the strength is improved by integrating the earth-retaining casing with the hardening agent layer, an earth-retaining casing with a thinner wall than that of the excavation casing can be employed. Accordingly, over-consumption of casing material can be reduced.

In this case, when a earth-retaining casing prefabricated a corrugation is used, the thickness can be reduced while the rigidity is secured so that the consumption of the casing material can be even further reduced.

Further, a shaft construction method provided in the present invention includes a step of connecting earth-retaining casings by inserting a non-corrugated earth-retaining casing into a corrugated earth-retaining casing, to a depth where they overlap each other at the adjacent ends, and by corrugating the overlapping portions of said two earth-retaining casings together.

Thus, since it is possible to construct a shaft by successively joining earth-retaining casings, this method is readily applicable to the construction of deep shafts. Further, since the end portions of the earth-retaining casings overlap and are corrugated, a secure connection with high strength and excellent watertightness can be obtained. When the waveform on the corrugated earth-retaining casing has been given by using an apparatus for constructing a shaft to be mentioned below, said earth-retaining casing has been wholly expanded in diameter thereof, so that it is possible to insert the end portion of the earth-retaining casing which has not yet been corrugated into the end portion of the earth-retaining casing which has been, and the two ends easily overlap.

Further, in a shaft construction method in accordance with the present invention, the use of an earth-retaining casing having a bottom plate which includes a water inlet and a grout inlet with a check valve for each of said inlets increases the strength of the earth-retaining casing. Thus increased strength can prevent the deformation of the earth-retaining casing while it is being inserted into a shaft or into an excavation casing in the ground. Still further, a concreting and curing process for the bottom of the shaft is saved, while the watertightness of the shaft after construction can be improved.

Here, if there is water remaining within the shaft or the excavation casing when inserting the earth-retaining casing having the bottom plate, subsidence of the earth-retaining casing will be prevented due to the buoyancy of the water. However, leading the water into the earth-retaining casing through the water inlet with the check valve can promote the subsidence of the earth-retaining casing. In this case, it is necessary to keep the water inlet open while the earth-retaining casing settles, and it is necessary to close it afterwards. When a spring which works in the inlet closing direction is provided for the check valve and a water soluble solid is held between the check valve and a valve seat before inserting the earth-retaining casing into the shaft or the excavation casing, the check valve is kept open during the subsidence of the earth-retaining casing. After the subsidence, the water soluble solid dissolves and disappears so that the check valve automatically closes.

Further, the grout inlet with the check valve provided in the bottom plate of the earth-retaining casing can be used for a mortar filling operation from above-ground to under the bottom plate, and the deposited mortar will never flow backward through the grout inlet before being cured.

In this case, if a tubular guide column is set up on the bottom plate or on the grout inlet in a way to communicate with it, said column can be used as a supporting member for guiding and holding a shaft constructing apparatus, to be mentioned below, in a corrugating operation for the earth-retaining casing. Thus the stability of operation is improved. Further, the mortar filling operation from above-ground to under the bottom plate can be performed through the hollow inside of the tubular guide column.

In accordance with the present invention, there is further provided an apparatus for constructing a shaft comprising an expanding means structured in such a manner as to be installable inside a cylindrical earth-retaining casing in the ground and to be capable of expanding and contracting in the radial direction of the earth-retaining casing, and a moving means for moving the expanding means in the axial direction of the cylindrical casing. As being structured in the above manner, the apparatus can apply corrugation treatment on the cylindrical earth-retaining casing, without using any other moving apparatus, by alternately repeating an operation of expanding diameter of the earth-retaining casing by means of the expanding means and an operation of moving the expanding means in the axial direction by means of the moving means. Since the waveform corrugation of the earth-retaining casing greatly enhances rigidity in comparison with a simple cylindrical body, a high-strength shaft which will not be deformed by the pressure of the earth can be constructed. Further, the thickness of the earth-retaining casing can be reduced so that wasteful consumption of the casing material can be restricted.

Further, in accordance with the present invention, there is provided an apparatus for constructing a shaft, wherein the expanding means comprises an upper expanding mechanism and a lower expanding mechanism having press molds which are disposed in a substantially circular manner along the inner periphery of the earth-retaining casing and can expand and contract in the radial direction of the earth-retaining casing, and the moving means comprises a length-extending mechanism capable of extending and shortening the distance between the upper and lower expanding mechanisms. As having the above structure, the shaft constructing apparatus can form a corrugated waveform on the earth-retaining casing by alternately repeating an operation of expanding and contracting the press molds in the upper expanding mechanism and the lower expanding mechanism and an operation of extending and shortening the distance between the upper and lower expanding mechanisms by means of the length-extending mechanism. In this case, since the shaft constructing apparatus can conduct a corrugating operation while ascending within the earth-retaining casing in a looping movement, it is not necessary to independently provide an apparatus to raise the shaft constructing apparatus, thus simplifying construction and making operation easy.

Still further, in a shaft constructing apparatus in accordance with the present invention, the expanding means is provided with a support column set up in the axial direction of the earth-retaining casing and a support bar mounted in a substantially horizontal manner on the support column. Thus, the shaft constructing apparatus can be securely held during a corrugating operation inside the earth-retaining casing. In this case, when the support column body is formed to be tubular or hollow, the mortar filling operation to under the bottom plate of the earth-retaining casing can be performed through the hollow inside of the support column.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view which shows a step of pressing and driving an excavation casing into the ground in accordance with the first embodiment;

Fig. 2 is a cross-sectional view which shows a step of inserting an earth-retaining casing into the excavation casing in accordance with the first embodiment;

Fig. 3 is a cross-sectional view which shows a step of casting a concrete bottom plate in the earth-retaining casing in accordance with the first embodiment;

Fig. 4 is a cross-sectional view which shows a step of pouring a hardening agent in the space between the excavation casing and the earth-retaining casing while removing the excavation casing in accordance with the first embodiment;

Fig. 5 is a cross-sectional view which shows a shaft constructed in accordance with the first embodiment;

Fig. 6A is a front elevational view which shows a corrugated segment applicable to the earth-retaining casing, Fig. 6B is a plan view of the same, Fig. 6C is a side elevational view of the same and Fig. 6D is a schematic view showing a state in which the corrugated segments are assembled;

Fig. 7A is a front elevational view which shows a liner plate segment applicable to the earth-retaining casing, Fig. 7B is a plan view of the same and Fig. 7C is a vertical cross-sectional view of the same;

Fig. 8A is a perspective view which shows a reinforcing ring for reinforcing the earth-retaining casing to be attached to press against the inner peripheral surface of the earth-retaining casing and Fig. 8B is a plan view of the same with portions broken away for clarity;

Fig. 9 is a cross-sectional view showing an example in which a manhole is constructed within a shaft;

Fig. 10 is a cross-sectional view showing an example in which an underground tank is constructed within a shaft;

Fig. 11 is a cross-sectional view which shows a step of inserting an earth-retaining casing into an excavation casing in accordance with the second embodiment;

Fig. 12 is a cross-sectional view which shows a step of expanding diameter in accordance with the second embodiment;

Fig. 13 is a cross-sectional view which shows a step of expanding diameter in accordance with the second embodiment;

Fig. 14 is a horizontal cross-sectional view taken along the line X-X in Fig. 12;

Fig. 15 is a horizontal cross-sectional view taken along the line Y-Y in Fig. 12;

Fig. 16A, 16B and 16C are schematic views showing the steps of the second embodiment;

Fig. 17 is a cross-sectional view which shows a shaft constructed in accordance with the second embodiment;

Fig. 18 is a cross-sectional view which shows the third embodiment;

Fig. 19 is a cross-sectional view which shows the fourth embodiment; and

Figs. 20A and Fig. 20B are schematic views showing the procedure of connecting earth-retaining casings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Four embodiments in accordance with the invention will be described below with respect to the attached drawings.

Figs. 1 to 4 are schematic views which show steps of the first embodiment in accordance with the present invention. First, as shown in Fig. 1, an excavation casing 1 is pressed and driven into the ground and earth within the excavation casing 1 is excavated and discharged by using a shaft excavating apparatus 50 disposed on the ground. The shaft excavating apparatus 50 is provided with a swingable pressing apparatus 52 and a boom 53 on a moving vehicle 51 and has a grab bucket 54 at the front of the boom 53. The swingable pressing apparatus 52 has a function of holding the excavation casing 1 by means of a clamp 52a and of driving the excavation casing 1 into the ground by pressing and oscillating the same, and can excavate and discharge the earth within the driven excavation casing 1 onto the ground by means of the grab bucket 54.

The excavation casing 1 is a hollow cylindrical body made of a steel plate having a thickness of 10 to 25 mm, and after the earth within the excavation casing 1 driven first in the ground is excavated and discharged by the grab bucket 54, another excavation casing 1 is driven on top of the first. In this case, the joint portions between the excavation casings 1 which are vertically disposed, are joined by a dedicated joint or integrally connected by welding. In this embodiment, two excavation casings are driven in, and the second casing is mounted on top of the first.

After the earth within the excavation casing 1 is discharged, as shown in Fig. 2, an earth-retaining casing 2 is inserted into the excavation casing 1. In this case, instead of the grab bucket 54, a hook 55 is mounted on the boom 53, to which a wire (not shown) is hooked, thereby hanging the earth-retaining casing 2 during insertion.

After the earth-retaining casing 2 is immersed in the water W remaining within the excavation casing 1, as shown in Fig. 3, a tremie 56 is inserted into the earth-retaining casing 2, and a ready mixed concrete 6 is filled in a bottom portion of the earth-retaining casing 2 from above-ground through the tremie 56. Thus, a concrete bottom plate 7 is cast in such a manner that the entire bottom of the earth-retaining casing 2 is covered. It is necessary to cure the concrete bottom plate 7 until it is completely hardened so that the earth-retaining casing 2 will not come off with the excavation casing 1 when it is pulled out from the ground.

When the concrete bottom plate 7 is hardened, as shown in Fig. 4, a hardening agent 8 is filled in the space between the excavation casing 1 and the earth-retaining casing 2 while, at the same time, the excavation casing 1 is pulled out while being oscillated by the swingable pressing apparatus 52. During this operation, since the concrete bottom plate 7 has already been cast in the earth-retaining casing 2, the hardening agent 8 does not flow into the earth-retaining casing 2. Thus, by pulling out the excavation casing 1 while pouring the hardening agent 8, the hardening agent 8 backfills the earth-retaining casing 2 throughout its outer periphery from the periphery of the concrete bottom plate 7 to the ground surface.

In this embodiment, as shown in Fig. 4, the hardening agent 8 consisting of a material of cement, inorganic salt, sodium silicate or the like is mixed by a hardening agent mixer 57 on the ground, and is cast into the space between the excavation casing 1 and the earth-retaining casing 2 through a filling hose 59 by a hardening agent filling pump 58. Instead of the above filling method, a nozzle for injecting the hardening agent 8 may be used, or the hardening agent 8 may be supplied through a hose connecting the hardening agent filling pump 58 to a hole which is opened near the lower end of the earth-retaining casing 2.

There is a gap between the excavation casing 1 and the earth-retaining casing 2. When the excavation casing 1 is pulled out as the hardening agent 8 is being cast, the hardening agent 8 forms its layer in this gap. Therefore, the excavation casing 1 can be pulled out without interfering with the outer surface of the earth-retaining casing 2. Furthermore, the excavation casing 1 does not sustain damage even if the wall of the earth-retaining casing 2 is relatively thin. Since the hardening agent 8 is in a near-liquid phase, the friction coefficient between the excavation casing 1 and the earth-retaining casing 2 can be kept low. Thus, the excavation casing 1 can be pulled out smoothly and quickly.

The removal of the upper and the lower excavating casings 1 may be conducted as a continuous operation. However, the removing and transporting operation on the ground can be carried out more efficiently by disconnecting the upper excavating casing 1 from the lower excavating casing 1, being still in the ground, by means of removing the joint 1a upon its appearance above the ground during the pulling-out process of the excavating casing 1, or melting and removing the weld bead if connected by welding. If a reinforcing ring 5 (refer to Fig. 8) mentioned below is used for the earth-retaining casing 2, it should be kept in the reinforcing state.

After the above steps, all pieces of equipment including the shaft excavating apparatus 50 are removed. In half a day or one day, after the concrete bottom plate 7 and the hardening agent 8 have completely hardened and cured, the remaining water W within the earth-retaining casing 2 is pumped out, and thereafter the reinforcing ring 5 is removed. Thus, the shaft as shown in Fig. 5 is constructed.

The shaft mentioned above is provided with a strong cylindrical construction because the earth-retaining casing 2 is integrally covered with the hardening agent 8 around its outer periphery. Accordingly, the shaft is strong enough to withstand an external load due to the pressure of the earth, buoyancy due to underground water and a bending load due to shifting earth, thereby preventing collapse and deformation of the earth-retaining casing. In this embodiment, the earth-retaining casing 2, being formed in a corrugated shape, has sufficient strength against compressing forces in axial and radial directions even if the wall is relatively thin, which leads to more effective maintenance of the shaft. Further, since the earth-retaining casing 2 which is left in the ground is relatively thin, less steel is needed in comparison with the conventional method in which the excavation casing 1 is left in the ground, and thus economy is improved.

In this embodiment, as the earth-retaining casing 2, a corrugated pipe having a cross section of a uniformly continuous waveform may be employed. In addition, a liner plate or a segment type may also be used.

Referring to Fig. 6, a corrugated segment which is applicable as a member of the earth-retaining casing 2 as well as a method of assembling the same will be described below. A corrugated segment 3 comprises a rectangular steel plate 3a having a thickness of about 1.6 to 4 mm which is bent to make an arc as shown in Fig. 6B, of which the cross section is a waveform as shown in Fig. 6C. The steel plate 3a has connection holes 3b in the peripheral portion thereof, and can be disposed overlapping other steel plates 3a at the side end portions as shown in Fig. 6D with rivets or bolts passing through the connection holes 3b, thereby forming a hollow cylindrical body to make the earth-retaining casing 2. Further, a plurality of hollow cylindrical bodies can be connected in a vertical direction with rivets or bolts passing through the connection holes 3b in the axial ends which overlap in order to make the earth-retaining casing 2 longer.

The above-described corrugated segments 3 can be prefabricated, and assembled into the earth-retaining casing 2 at the construction site. Therefore, an earth-retaining casing with a larger diameter can be easily transported by truck. Of course, it is also possible that the corrugated segments 3 be assembled into the earth-retaining casing 2 in a shop, and then the thus assembled earth-retaining casing 2 is transported to the construction site and installed.

Next, referring to Fig. 7, a liner plate segment which is applicable to the earth-retaining casing 2 and a method of assembling the same will be described below. A liner plate segment 4 is arc-shaped as shown in Fig. 7B, and has connection flanges 4a and 4b projecting toward the inside of the shaft and extending throughout the length of the periphery thereof. Its wall 4c is corrugated for improved strength as shown in Fig. 7C. A hollow cylindrical body can be formed by matching and fixing the two side connection flanges 4a by means of bolts or the like passing through connection holes 4a-1. Further, the long body needed for the earth-retaining casing 2 can be formed by vertically piling up the hollow cylindrical bodies to match the flanges 4b and fix them with bolts passing through connection holes 4b-1.

As mentioned above, along with the corrugated segment 3, the liner plate segment 4 is also corrugated. Thus, they maintain high compression strength in both axial and radial directions even if the material is relatively thin, which enhances the strength of the earth-retaining casings. If, to reduce costs, a hollow cylindrical body made of a thin, plane plate is used as the earth-retaining casing, a reinforcing ring as shown in Fig. 8 should be employed for safety.

Fig. 9 is a cross sectional view showing a manhole constructed within the shaft as an underground structure. In this example, a plurality of frames 61 are vertically stacked within the earth-retaining casing 2 to constitute a manhole. The lowest frame 61 is held by mortar 63 which is cast to fill the gaps above the concrete bottom plate 7. After a manhole cover 62 is mounted on top of the frame 61, the gaps around the outer periphery of the manhole are filled with backfill soil 64.

Fig. 10 is a cross sectional view showing an underground tank constructed within the shaft. In this example, a tank body 31 is inserted into the earth-retaining casing 2 so as to be mounted on the concrete bottom plate 7, and the gaps between the earth-retaining casing 2 and the tank body 31 are filled with backfill soil 32. Further, mortar 33 is cast on the ground surface.

In the above examples, the pre-constructed shaft has high strength due to the earth-retaining casing 2 being integrated with the hardening agent 8. An underground structure such as a manhole or an underground tank constructed in this way remains in good condition, without sustaining damage or breakage.

Further, in either of the above constructions, the excavation casing 1 is recovered from the ground when pouring the hardening agent 8 after excavation and discharge of the earth from the excavation casing 1 is completed. Thus, the excavation casing 1 can be reused many times. Since the excavation casing 1 will not be wasted, it may be made of a more expensive construction: for example, the excavation casing 1 may have a specially designed blade tip made of a special alloy to improve the excavation efficiency, or may be made of a special steel for further enhanced durability. Further, it is possible to make the excavation casing 1 a lightweight double structure with high strength. Further, a large-sized excavation casing which exceeds the width limit of vehicle transportation may have a vertically dividable type structure.

Next, the second embodiment of the present invention will be described below with reference to Figs. 11 to 15. Fig. 11 is a vertical cross-sectional view wherein an earth-retaining casing is inserted into an excavation casing; Fig. 12 is a vertical cross-sectional view which shows a mechanism for increasing diameter; Fig. 13 is a vertical cross-sectional view which illustrates an extending operation with a length-extending mechanism; and Figs. 14 and 15 are transverse sectional views taken along the line X-X and Y-Y in Fig. 12, respectively.

In this embodiment, in the same manner as the steps shown in Fig. 1 in accordance with the first embodiment, an excavation casing 12 is driven into the ground, and the earth within the pressed excavation casing 12 is excavated and discharged using a shaft excavating apparatus 50 disposed on the ground. After the above operation is completed, as shown in Fig. 11, an earth-retaining casing 13 to which a bottom plate 15 with a tubular guide column 14 is mounted is inserted into the excavation casing 12. During this operation, the remaining water 18, if present within the excavation casing 12, can be introduced into the earth-retaining casing 13 through a water inlet 16 in the bottom plate 15 by setting a check valve 16v thereof, also provided in the bottom plate 15, to the open position beforehand. Thus, the earth-retaining casing 13 can easily subside.

It is necessary to keep the check valve 16v of the water inlet 16 open while the earth-retaining casing 13 subsides, and it is necessary to eventually close it when pumping out the water 18 remaining within the earth-retaining casing 13. Therefore, a material which has a predetermined hardness in open air and dissolves in water over a predetermined length of time, such as a sugar material, is placed between the check valve 16v and the valve seat.

When the earth-retaining casing 13 is completely inserted into the excavation casing 12, a corrugating 13 starts.

The structure of the corrugating apparatus 20 which is a part of the shaft constructing apparatus will be described below. The corrugating apparatus 20 consists of an upper expanding mechanism A and a lower expanding mechanism B which are vertically disposed. Fig. 14 shows the upper expanding mechanism A, and Fig. 15 shows the lower expanding mechanism B. Eight hydraulic actuators 21 and 23 which are extendable and contractible are radially disposed in the expanding mechanisms A and B, respectively, and arc-shaped press molds 22 and 24 are mounted at the ends of the hydraulic actuators 21 and 23, respectively, so as to form a substantially circular shape along the inner periphery of the earth-retaining casing 13. Further, as shown in Figs. 12 and 13, an extendable hydraulic actuator 25 for changing the distance between the expanding mechanisms A and B is provided.

An anti-rotation member S is also provided for each of the hydraulic actuators 21, 23 so that the press molds 22 and 24 will not slip out of place with the rotation of rods R of the hydraulic actuators 21 and 23. The hydraulic actuators 21, 23 and 25 are operated by hydraulic pressure supplied through a hydraulic hose from a hydraulic pump controlled by a control panel located on the ground, which is not shown in the drawings.

Next, described below is a corrugating operation for the earth-retaining casing 13 by use of the corrugating apparatus 20. After the corrugating apparatus 20 is completely inserted into the earth-retaining casing 13, as shown in Fig. 12, the excavation casing 12 is lifted up to a depth not interfering with the diameter-expanding operation, and the hydraulic actuators 23 of the lower expanding mechanism B are extended so that the earth-retaining casing 13 is given a waveform crest by the press molds 24. Then, the hydraulic actuators 21 of the upper expanding mechanism A is extended so that the earth-retaining casing 13 is given another waveform crest by the press molds 22. The distance between the upper expanding mechanism A and the lower expanding mechanism B at this stage determines the interval between waveform crests.

Next, the press molds 22 are removed from the second waveform crest on the earth-retaining casing 13 by contracting the hydraulic actuators 21 of the upper expanding mechanism A. Then, the hydraulic actuator 25 is extended so that the upper expanding mechanism A is lifted up a step as shown in Fig. 13, and the hydraulic actuators 21 are again extended so that the earth-retaining casing 13 is given the next crest by the press molds 22. During this operation, the lower expanding mechanism B keeps the press molds 24 pressed against the first waveform crest of the earth-retaining casing 13. Thus, the corrugating apparatus 20 does not fall or slip. The excavation casing 12 is gradually pulled up in accordance with the progress of the operation so as not to disturb the corrugating operation.

Then, the press molds 24 are removed from the first waveform crest of the earth-retaining casing 13 by contracting the hydraulic actuators 23 of the lower expanding mechanism B, and the hydraulic actuator 25 is contracted to raise the lower expanding mechanism B a step. The hydraulic actuators 23 are again extended so that the press molds 24 are pressed against the second waveform crest previously formed by the press molds 22 of the upper expanding mechanism A, thereby adjusting the waveform into a proper shape. While the lower expanding mechanism B is in motion, the upper expanding mechanism A keeps the press molds 22 pressed against the newest waveform crest on the earth-retaining casing 13. Thus, the corrugating apparatus 20 does not fall or slip.

As shown in Figs. 14 and 15, the press molds 22 and 24 in the upper expanding mechanism A and the lower expanding mechanism B are disposed to project evenly around the tubular guide column 14 covering alternating areas. Thus, the concave portions 13r, which have not been properly pushed out due to their positions corresponding to gaps between the press molds 22 in the upper expanding mechanism A, can be shaped properly by the press molds 24 of the lower expanding mechanism B. Accordingly, irregularity in the waveform is eliminated so that the strength, particularly resistance to pressure, is greatly improved. Further, since the press molds 22 and 24 have an arc shape and are disposed in a substantially circular manner along the inner periphery of the earth-retaining casing 13, the waveform created in the earth-retaining casing 13 is a series of substantially concentric circles.

Thereafter, the hydraulic actuators 21 in the upper expanding mechanism A are contracted again to detach the press molds 22 from the current waveform crest positions, and the hydraulic actuator 25 is extended so that the upper expanding mechanism A is further raised a step. The hydraulic actuators 21 are again extended so that the earth-retaining casing 13 is given another waveform crest by the press molds 22. By repeating the above operation further while the excavation casing 12 is gradually raised, the corrugating apparatus 20 forms the waveform on the earth-retaining casing.

In other words, the corrugating apparatus 20 ascends in a looping movement by alternately repeating the operation of expanding diameter of the earth-retaining casing 13 by means of the upper expanding mechanism A and the lower expanding mechanism B and the operation of extending and shortening the distance between the upper expanding mechanism A and the lower expanding mechanism B by means of the hydraulic actuator 25, as shown in Figs. 16A to 16C, to form a continuous, uniform waveform on the earth-retaining casing 13.

If the ground in the outer periphery of the earth-retaining casing 13 to be corrugated by the upper expanding mechanism A is not homogeneous, the pressing force applied by the press molds 22 may not be uniform. However, since the press molds 22 are held by both the lower expanding mechanism B and the tubular guide column 14, the operation of molds 22 will not be affected by differences in reaction force, and the corrugating operation will progress evenly. In this case, the tubular guide column 14 also serves as a guide for the vertical motion of the hydraulic actuator 25, which changes the distance between the upper expanding mechanism A and the lower expanding mechanism B.

After the waveform is formed up to a predetermined position of the earth-retaining casing 13, mortar M is grouted under the bottom plate 15 through a grout hole 17 (see Fig. 11) provided on the tubular guide column 14. The mortar M does not flow backward because a check valve 19v is provided in a grout inlet 19 of the bottom plate 15. Thus, after the grouting of the mortar is finished, the tubular guide column 14 can be removed regardless of the hardness of the mortar M. Thereafter, the water inside the earth-retaining casing 13 is pumped out, and the shaft will be in a state as shown in Fig. 17. Thus, the shaft construction is completed. In the example described above, the corrugating apparatus 20 has two diameter-expanding mechanisms; also, the earth-retaining casing 13 can be corrugated with a corrugating apparatus having three or more diameter-expanding mechanisms by following the procedure as described above.

Next, a third embodiment of the invention will be described below with reference to Fig. 18. In this embodiment, a corrugating apparatus 40 consists of an upper expanding mechanism A and a lower expanding mechanism B which are vertically disposed. A tubular guide column 42 having a longitudinal through hole 41 guides the movement of the corrugating apparatus 40. The tubular guide column 42 is fixed to a fixing metal fitting 45 provided in a bottom plate reinforcing bar 44 which is fixed to the bottom portion of an earth-retaining casing 13 while the corrugating apparatus 40 is applying corrugation treatment. After the corrugating operation is completed, the tubular guide column 42 is removed from the fixing metal fitting 45, and a concrete bottom plate is cast. The bottom plate reinforcing bar 44 also serves as a reinforcing bar for the concrete bottom plate.

The corrugating apparatus 40, like the corrugating apparatus 20 mentioned above, applies corrugation treatment to the earth-retaining casing 13 inserted inside the excavation casing 12 while raising the upper expanding mechanism A and the lower expanding mechanism B by using the tubular guide column body 42 as a guide. In the case of supporting the tubular guide column 42 by the bottom plate reinforcing bar 44, deviation of the upper portion of the tubular guide column 42 due to the softness of the fixing metal fitting 45 is prevented by a substantially horizontal support bar member 43 which supports the upper portion of the tubular guide column 42 so that the center of the waveform formed on the earth-retaining casing 13 does not shift. In this case, the earth-retaining casing 13 descends in relation to the position of support bar member 43 as the corrugating progresses, and therefore a slight clearance is provided between an end 43a of the support bar member 43 and the inner surface of the earth-retaining casing 13.

Next, a fourth embodiment of the invention will be described below with reference to Fig. 19. In this embodiment, a corrugating apparatus 60 consists of an upper expanding mechanism A and a lower expanding mechanism B which are vertically disposed. Eight hydraulic actuators 21 and 23 which are extendable and contractible are radially disposed in each of the expanding mechanisms A and B, and arc-shaped press molds 22 and 24 are mounted at the ends of the hydraulic actuators 21 and 23, respectively, so as to form a substantially circular shape along the inner periphery of the earth-retaining casing 13. Further, an extendable and contractible hydraulic actuator 25 for changing the distance between the expanding mechanisms A and B is provided. Since the corrugating apparatus 60 ascends in a looping movement while supporting the apparatus itself by pushing the press molds 22 and 24 against the earth-retaining casing 13, it can carry out a corrugating operation for the earth-retaining casing 13 without having a tubular guide column set up on the bottom plate.

However, without the tubular guide column, the corrugating apparatus 60 is likely to move upward in a zigzag manner. This can be prevented by controlling the corrugating apparatus 60 to vertically climb within the earth-retaining casing 13 by means of a hollow support column 26 set up on the lower expanding mechanism B and a substantially horizontal support bar 27 provided at an upper position of the hollow support column 26. Further, a slight clearance provided between a pad 27a mounted at the end of the support bar 27 and the earth-retaining casing 13 enables the corrugating apparatus 60 to smoothly ascend.

With reference to Fig. 20, a method of connecting the earth-retaining casing 13 will be described below. Fig. 20 is a schematic view which illustrates the procedure of connecting two earth-retaining casings 13. In the method of constructing a shaft in accordance with this embodiment, the excavation casing 12 is extended by connecting the members by use of bolts or by welding. The earth-retaining casings 13 are assembled by putting an end portion of an earth-retaining casing 13a on an end portion of another earth-retaining casing 13b, which are disposed in a vertically adjacent manner as shown in Fig. 20, and corrugating the overlapping ends together.

Specifically, as shown in Fig. 20A, the lower end of the earth-retaining casing 13b which has not yet been corrugated is inserted inside the upper end of the corrugated earth-retaining casing 13a to the extent that the lower end of the non-corrugated casing 13b covers one or two wave crests on the upper end of the corrugated casing 13a, and the lower end of the non-corrugated casing 13b is corrugated as it overlaps with the end of the corrugated earth-retaining casing 13a. The corrugation firmly connects the earth-retaining casings 13a and 13b as shown in Fig. 20B. In this case, the diameter of the earth-retaining casing 13a has been enlarged even at the troughs 13v in the waveform along with the diameter expansion at the crests 13m by the original corrugation. This makes it easy to insert the non-corrugated earth-retaining casing 13b therein.

Further, a paste or the like may be applied to the joining faces between the earth-retaining casings 13a and 13b to gain complete watertightness. As mentioned above, in the method of constructing the shaft according to this embodiment, relatively thin earth-retaining casings 13a and 13b can be used, and the casings can be easily and securely joined without using bolting or other troublesome means.

The present invention has advantages as follows:

(1) The method of constructing a shaft includes a step of inserting a cylindrical earth-retaining casing into a shaft excavated in the ground, and a step of applying corrugation to the earth-retaining casing inserted into the shaft. Therefore, a shaft constructed by this method has high strength, being protected by an earth-retaining casing which has gained increased rigidity by being corrugated. This method also realizes lessened wasteful consumption of casing material because casings can secure sufficient strength with walls thinner than those used in the conventional method. Further, as corrugation treatment is applied within the shaft, the earth-retaining casing and the ground around the casing are firmly pressed against each other to generate strong friction, thereby preventing the earth-retaining casing from floating due to the pressure of the underground water.

(2) The shaft constructing method involves a step of pressing and driving a cylindrical excavation casing into the ground, a step of discharging earth from the excavation casing inserted in the ground, a step of inserting a cylindrical earth-retaining casing inside the excavation casing, and a step of removing the excavation casing from the ground while applying corrugation treatment to the earth-retaining casing. Thus, this method can construct a highly strong shaft because the earth-retaining casing installed inside the shaft in the ground has increased rigidity gained by corrugation, and can withstand the pressure of the earth and other forces without sustaining deformation even after the excavation casing is removed from the ground. Further, since sufficient strength can be secured by an earth-retaining casing thinner than the excavating casing, wasteful consumption of casing material can be reduced.

(3) The shaft constructing method involves a step of pressing and driving a cylindrical excavation casing into the ground, a step of discharging earth from the excavation casing inserted in the ground, a step of inserting a cylindrical earth-retaining casing into the excavation casing, a step of pouring a hardening agent into the space between the excavation casing and the earth-retaining casing, and a step of removing the excavation casing from the ground concurrently or subsequently to the pouring of the hardening agent. Thus, this method can construct a highly strong shaft because the earth-retaining casing installed inside has increased rigidity by being integrated with the hardening agent layer and withstands the pressure of the surrounding earth or other forces without sustaining deformation even after the excavation casing is removed. Further, since sufficient strength can be secured by an earth-retaining casing thinner than the excavating casing, wasteful consumption of casing material can be reduced.

(4) In the case (3) mentioned above, when an earth-retaining casing which has been corrugated before insertion underground is used, the thickness can be reduced while maintaining high rigidity so that consumption of casing material can be further reduced.

(5) The shaft construction method further includes a step of connecting the corrugated earth-retaining casing with another earth-retaining casing which has not yet been corrugated by inserting the non-corrugated casing into the corrugated casing to the extent that the lower end portion of the non-corrugated casing just overlaps the upper end portion of the corrugated casing, and then by corrugating the overlapping portions. This method, which allows successive connection of additional earth-retaining casings, is easily applicable for construction of a deep shaft. Further, since the overlapping ends of the two earth-retaining casings are corrugated together, the joint gains high strength and excellent watertightness.

(6) The earth-retaining casing having a bottom plate which is provided with a water inlet and a grout inlet respectively including a check valve has

high strength and thus prevents deformation thereof during the insertion operation into the shaft excavated in the ground or into the excavation casing inside the shaft. Further, the use of this earth-retaining casing not only saves the concreting and curing process for the bottom of the shaft, but it can improve watertightness of the constructed shaft. In addition, mortar can be filled from above-ground to under the bottom plate through the grout inlet, and the check valve can prevent the deposited mortar from backwashing.

(7) A tubular guide column, which is set up (on the bottom plate of the earth-retaining casing or) on the grout inlet in the bottom plate of the earth-retaining casing in a way to communicate with the inlet can secure stability of operation by being used as a supporting member for guiding and holding the shaft constructing apparatus during the corrugating operation for the earth-retaining casing. Further, mortar can be filled from above-ground to under the bottom plate through the hollow inside of the tubular guide column.

(8) The apparatus for constructing a shaft comprises an expanding means which can be inserted into a cylindrical earth-retaining casing inserted in the ground and is expandable and contractible in the radial direction of the earth-retaining casing, and a moving means for moving the expanding means in the axial direction of earth-retaining casing. By having this structure, the shift constructing apparatus can give a continuous uniform waveform to the earth-retaining casing while it climbs within the casing by its own force without using any other moving means.

(9) The expanding means comprises an upper expanding mechanism and a lower expanding mechanism having press molds which are disposed along the inner periphery of the earth-retaining casing in a substantially circular manner, and is expandable and contractible in the radial direction. The moving means comprises a length-extending mechanism capable of extending and shortening the distance between the upper and lower expanding mechanisms. Thus structured shaft construction apparatus forms a waveform on the earth-retaining casing by alternately repeating an operation of extending and contracting the press molds in the upper expanding mechanism and the lower expanding mechanism and an operation of changing the distance between the upper and lower expanding mechanisms by means of the length-extending mechanism. In this case, since the shaft constructing apparatus can apply corrugation treatment while climbing within the earth-retaining casing in a looping movement by its own force, it is not necessary to provide a separate lifting apparatus, which means simple construction of the apparatus, and easy and efficient operation.

(10) The expanding means is further provided with a support column set up in the axial direction of the earth-retaining casing and a support bar mounted on the support column in a substantially horizontal manner. Accordingly, the shaft constructing apparatus can be securely held during the corrugating operation for the earth-retaining casing so that a properly shaped waveform can be formed.

Claims

1. A method of constructing a shaft comprising: a step of inserting a cylindrical earth-retaining casing into a shaft excavated in the ground; and a step of corrugating said earth-retaining casing to form the circumferential wall thereof into a wave-like longitudinal cross section.

2. A method of constructing a shaft comprising: a step of pressing and driving a cylindrical excavation casing into the ground; a step of discharging earth from said inserted excavation casing; a step of inserting a cylindrical earth-retaining casing into said excavation casing; and a step of removing said excavation casing from the ground while corrugating said earth-retaining casing to form the circumferential wall thereof into a wave-like longitudinal cross section.

3. A method of constructing a shaft comprising: a step of pressing and driving a cylindrical excavation casing into the ground; a step of discharging earth from said inserted excavation casing; a step of inserting a cylindrical earth-retaining casing into said excavation casing; a step of pouring a hardening agent into the space between said excavation casing and said earth-retaining casing; and a step of removing said excavation casing from the ground concurrently or subsequently to the pouring of said hardening agent.

4. A method of constructing a shaft as claimed in any one of claims 1 to 3 comprising: a step of connecting said earth-retaining casing which has been corrugated with another earth-retaining casing which has not been corrugated by inserting the non-corrugated casing into the corrugated casing to the extent that the upper end of the corrugated casing just overlaps the lower end of the non-corrugated casing, and by thereafter corrugating the overlapping portions of said two casings together.

5. A method of constructing a shaft as claimed in claim 3, wherein said earth-retaining casing is corrugated before insertion to form the circumferential wall thereof into a wave-like longitudinal cross section.

6. A method of constructing a shaft as claimed in any one of claims 1 to 5, wherein said earth-retaining casing is provided with a bottom plate which includes a water inlet and a grout inlet each of which is provided with a check valve.

7. A method of constructing a shaft as claimed in claim 6, wherein said earth-retaining casing is provided with a tubular guide column vertically set up on said grout inlet in a way to communicate therewith.

8. An apparatus for constructing a shaft comprising: an expanding means which can be installed in a cylindrical earth-retaining casing inserted in the ground and is expandable and contractible in the radial direction of said earth-retaining casing; and a moving means for moving said expanding means in the axial direction of said cylindrical casing.

9. An apparatus for constructing a shaft as claimed in claim 8, wherein said expanding means comprises an upper expanding mechanism and a lower expanding mechanism, each having press molds which are disposed along the inner periphery of said earth-retaining casing in a substantially circular manner, and which are expandable and contractible in the radial direction of said earth-retaining casing; and said moving means comprises a length-extending mechanism capable of extending and shortening the distance between the upper expanding mechanism and the lower expanding mechanism.

10. An apparatus for constructing a shaft as claimed in claim 8 and 9, wherein said expanding means is provided with a support column set up in the axial direction of said earth-retaining casing and a support bar mounted on said support column in a substantially horizontal manner.

FIG. 1

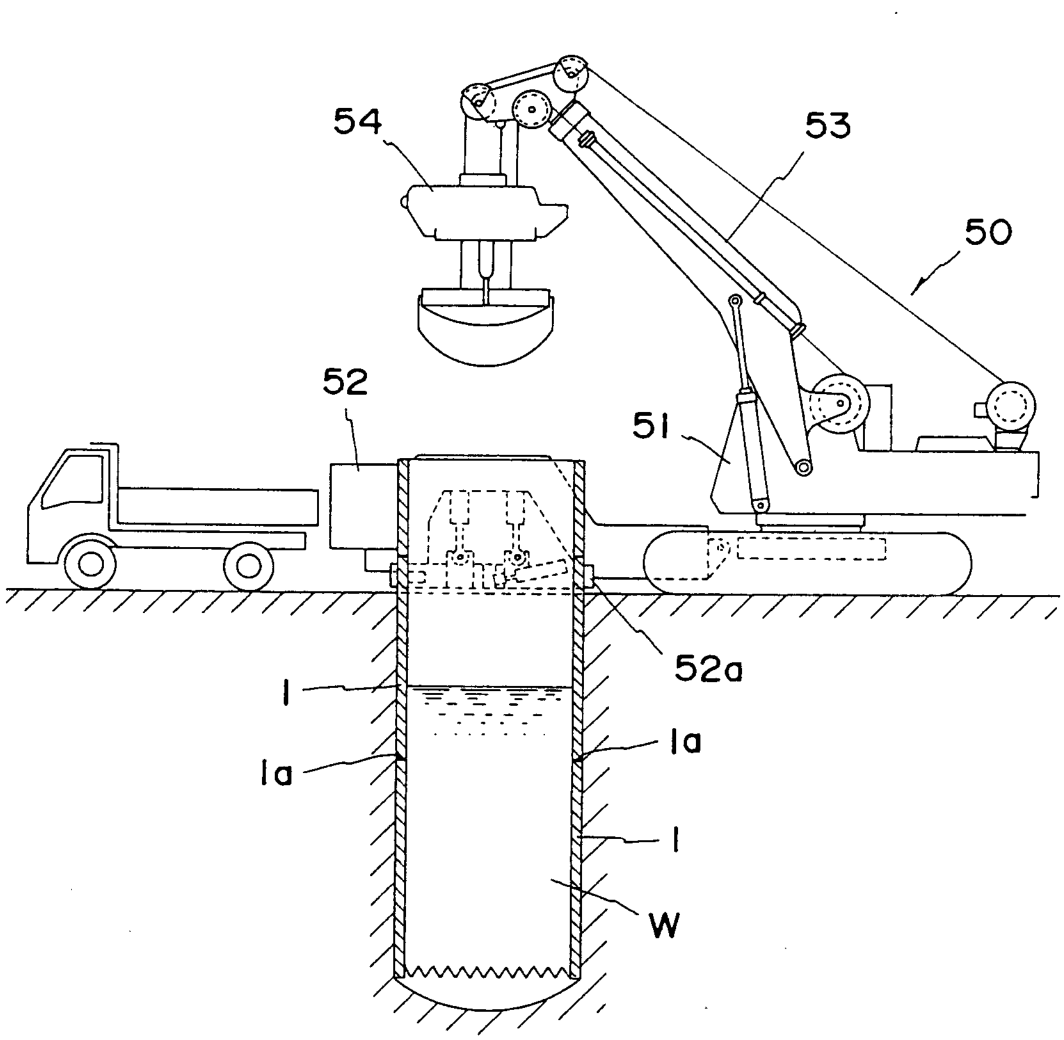


FIG. 2

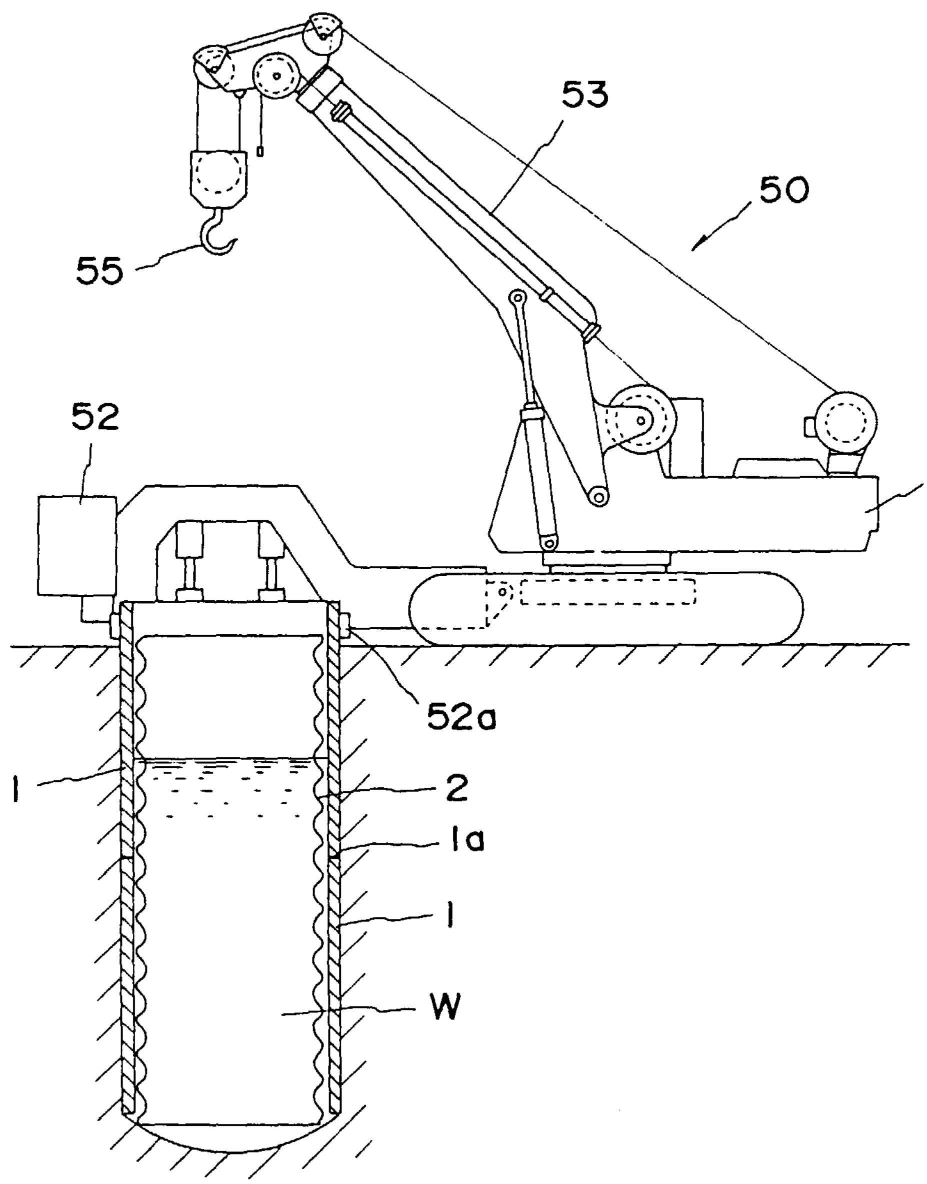


FIG. 3

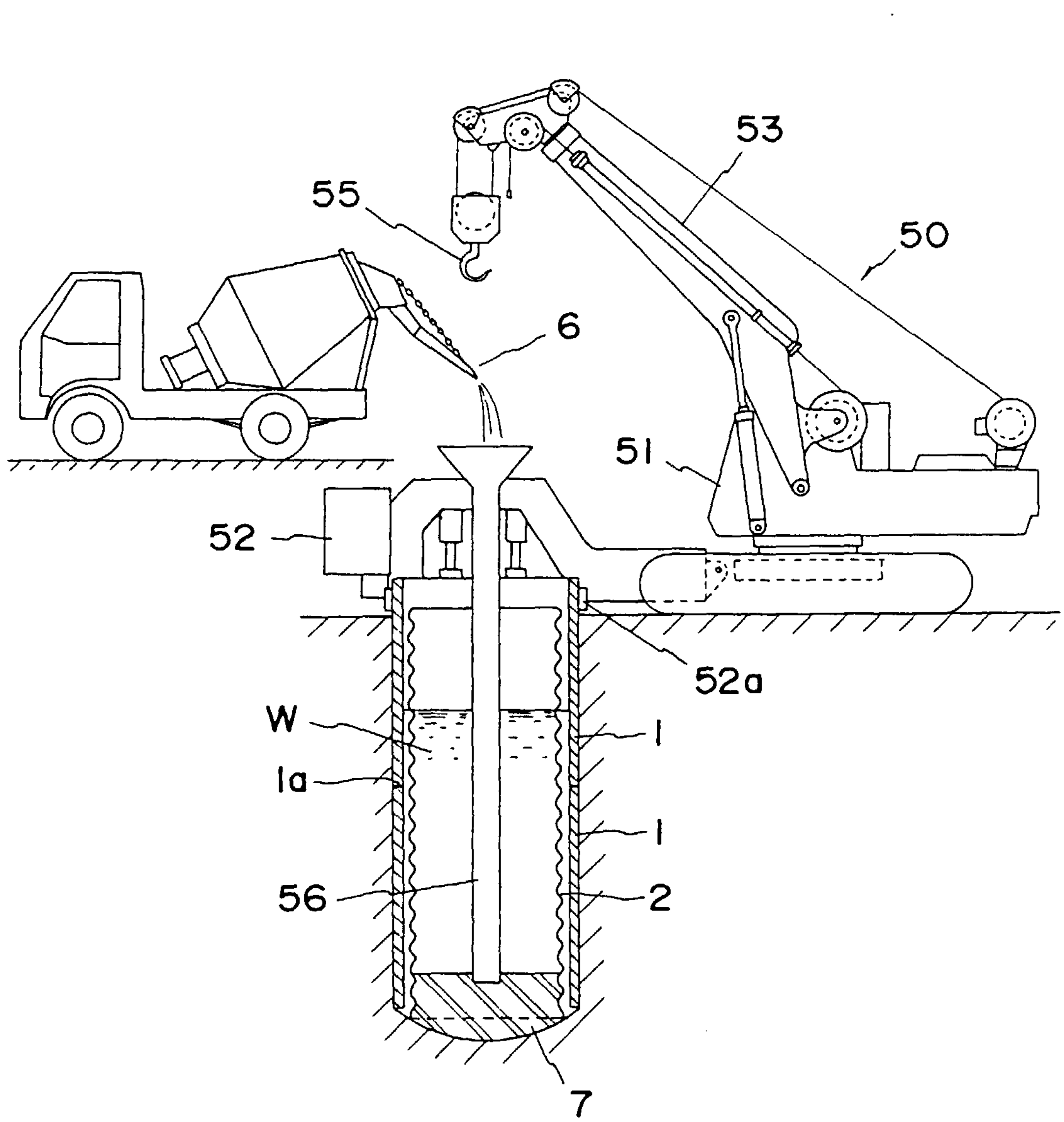


FIG. 4

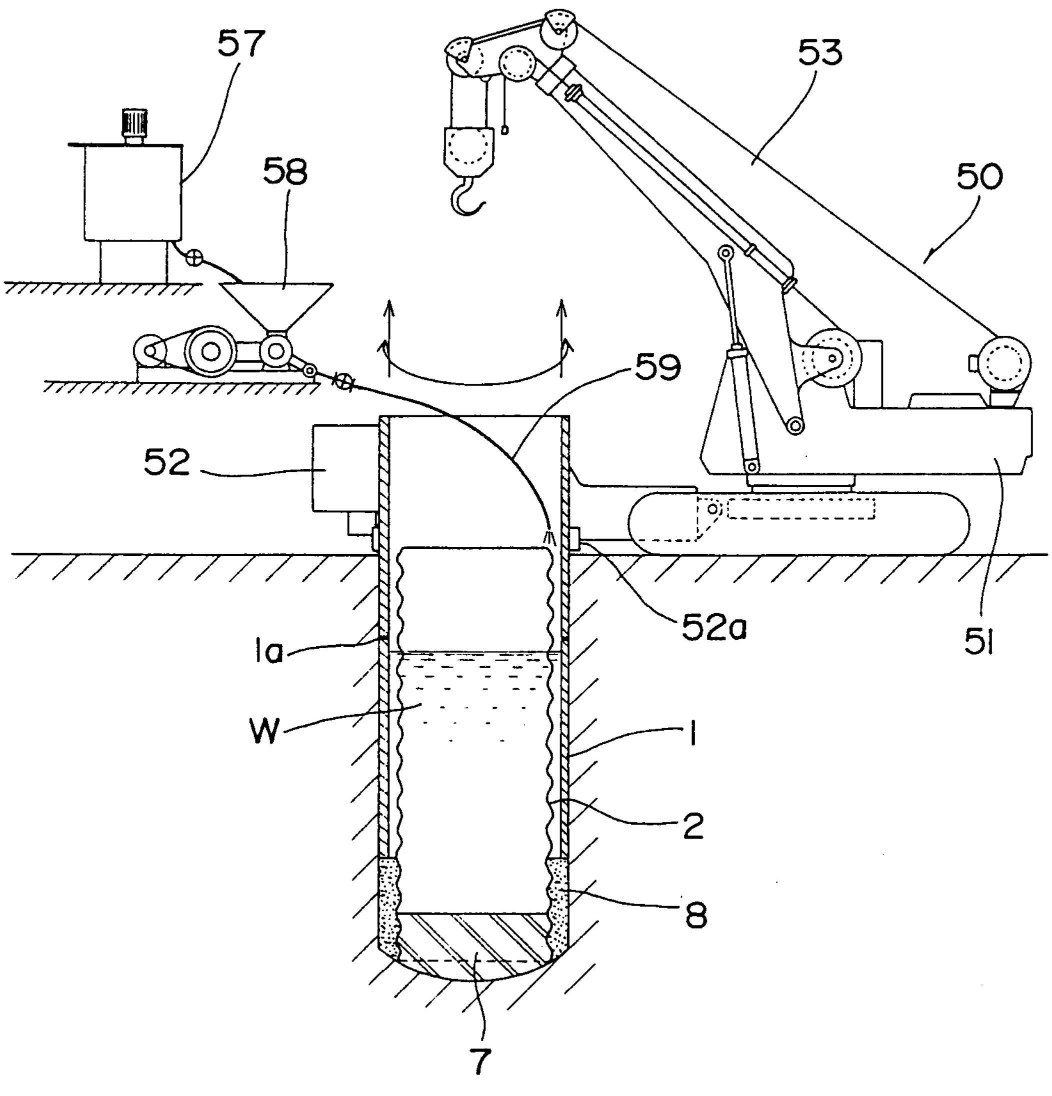


FIG. 5

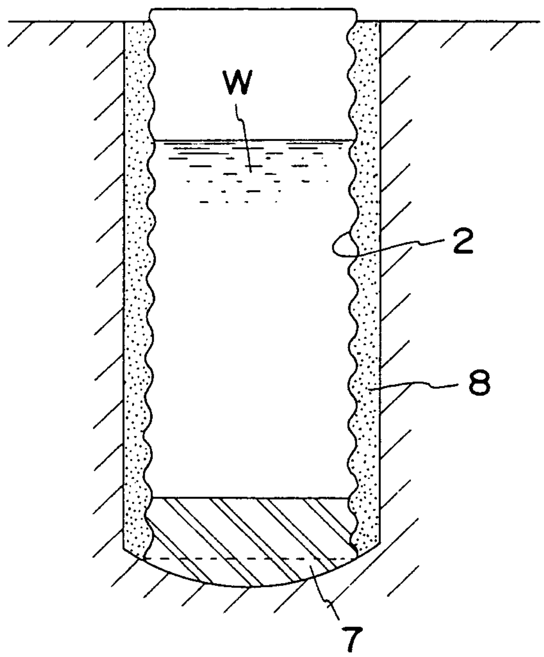


FIG. 6A

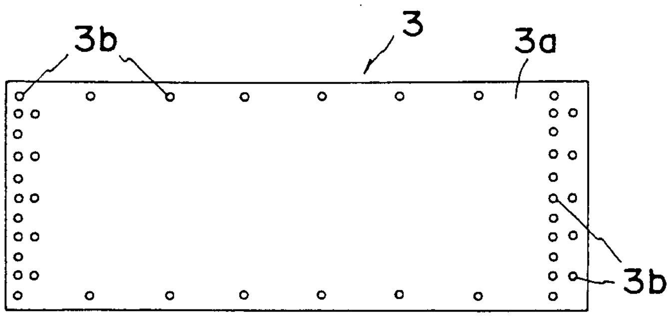


FIG. 6C

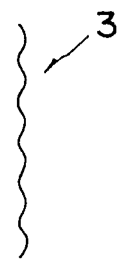


FIG. 6B

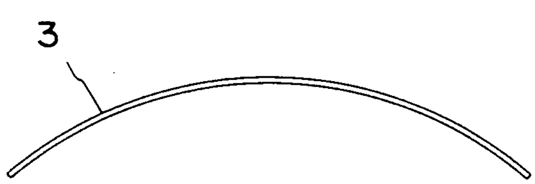


FIG. 6D

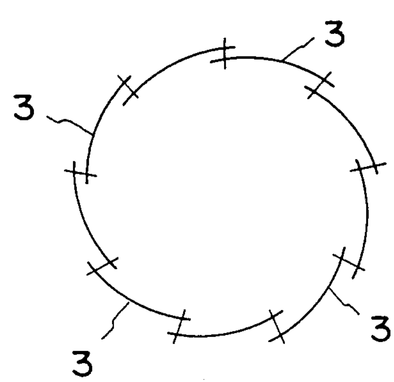


FIG. 7A

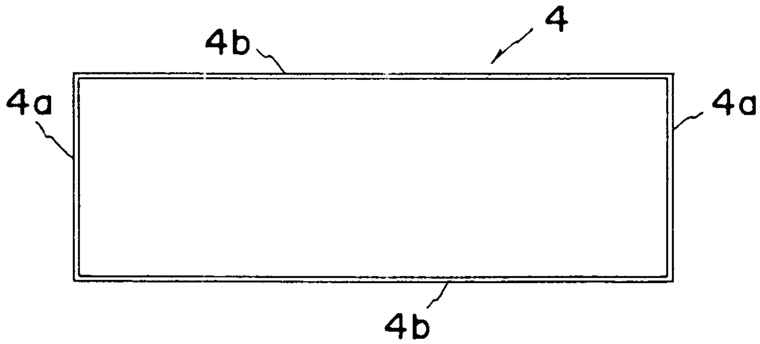


FIG. 7B

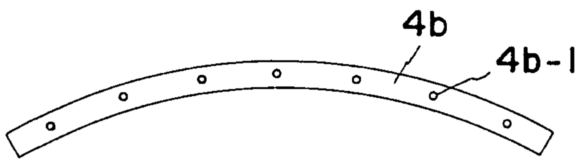


FIG. 7C

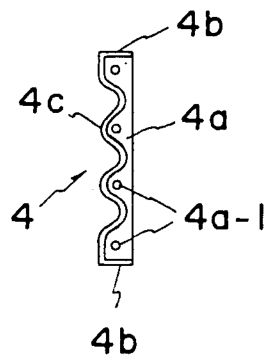


FIG. 8A

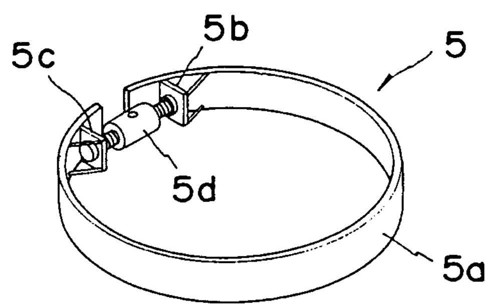
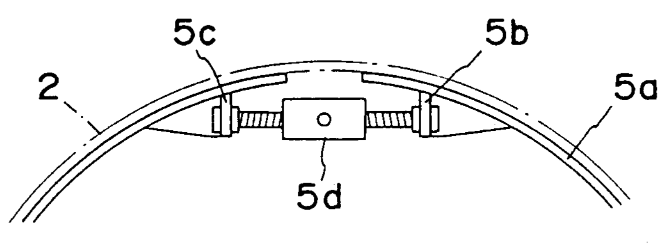


FIG. 8B



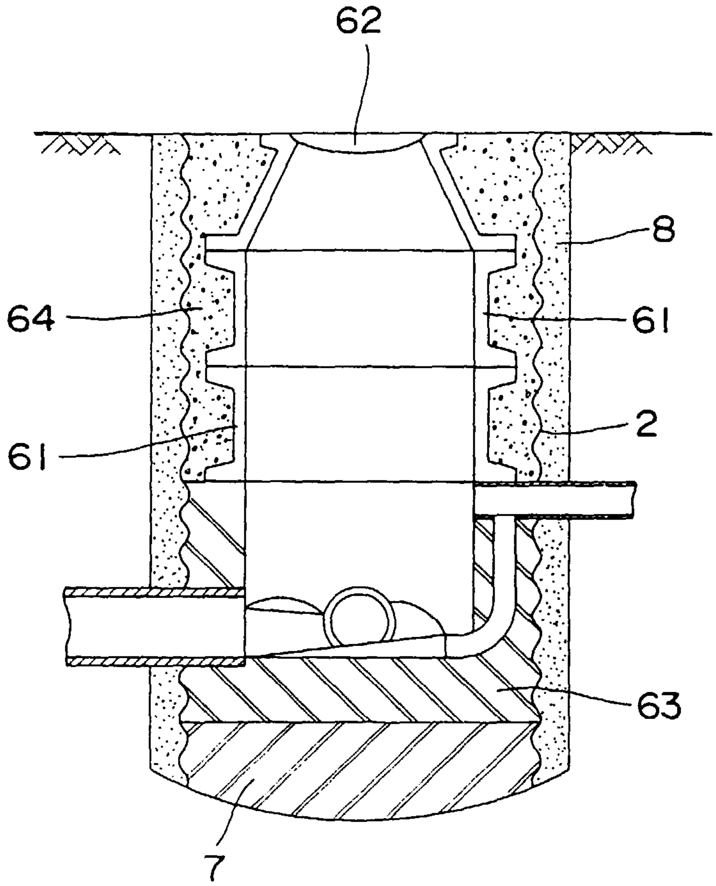


FIG. 9

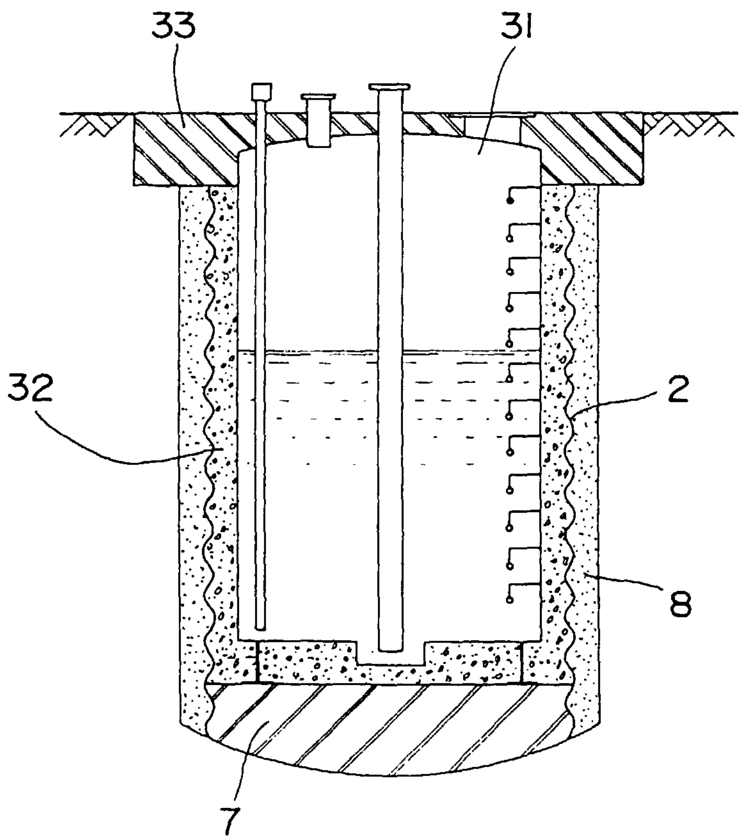
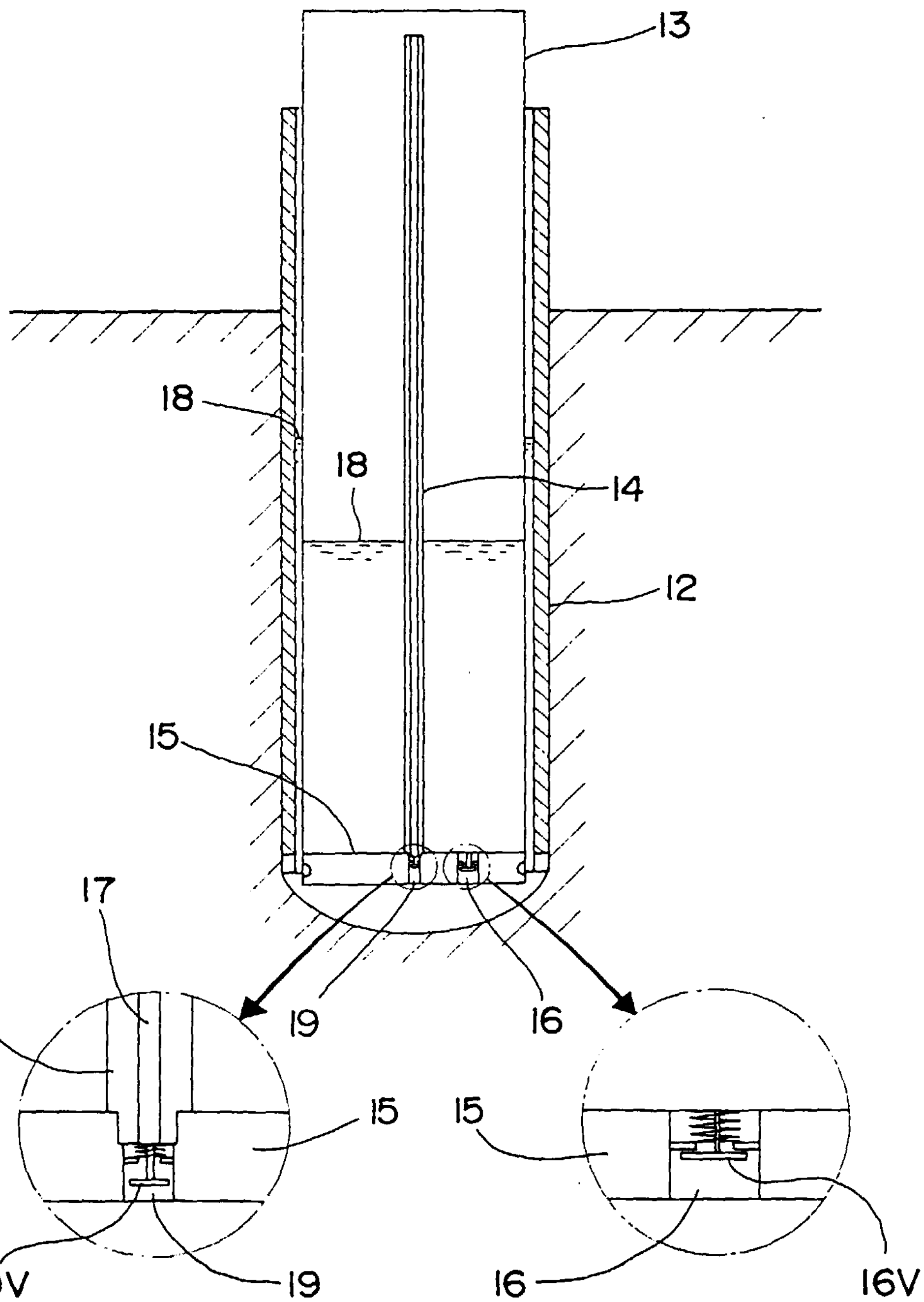


FIG. 10

FIG. 11



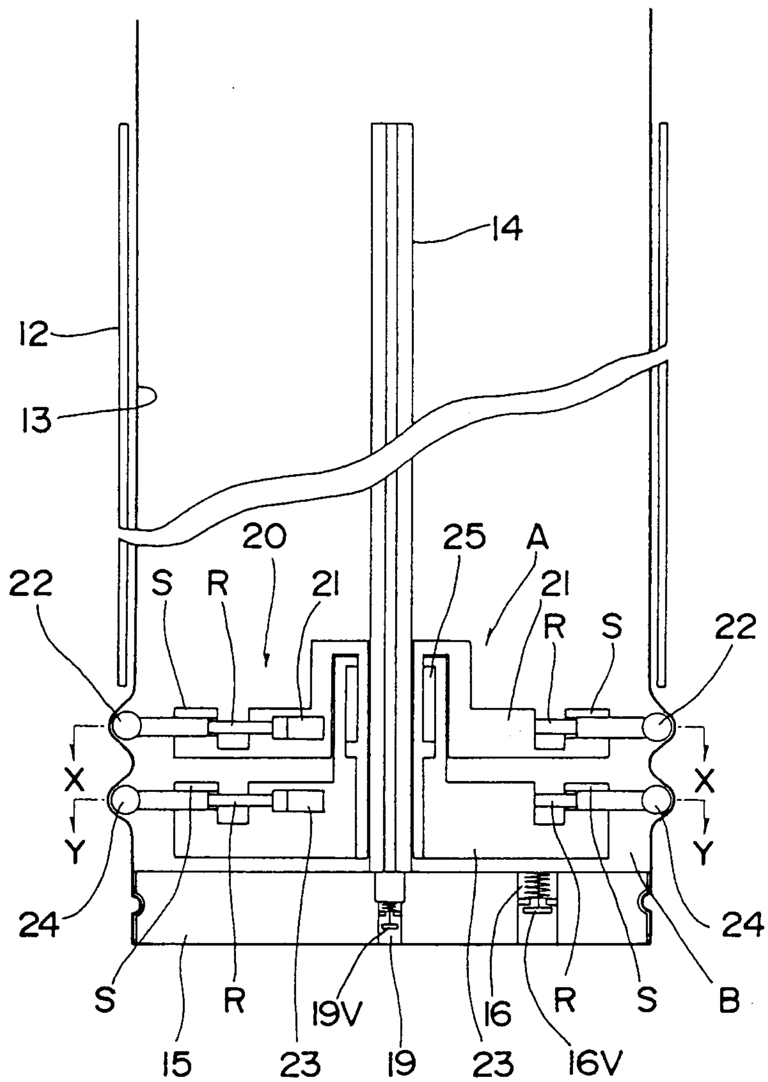

14
12
13
20
25
A
22
S
R
21
X
Y
24
B
15
23
19V
19
16
16V

FIG. 12

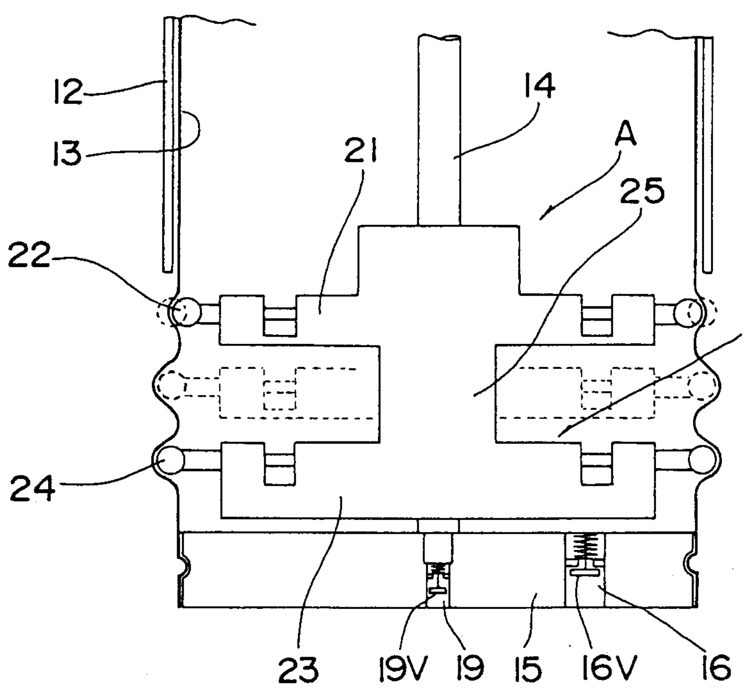
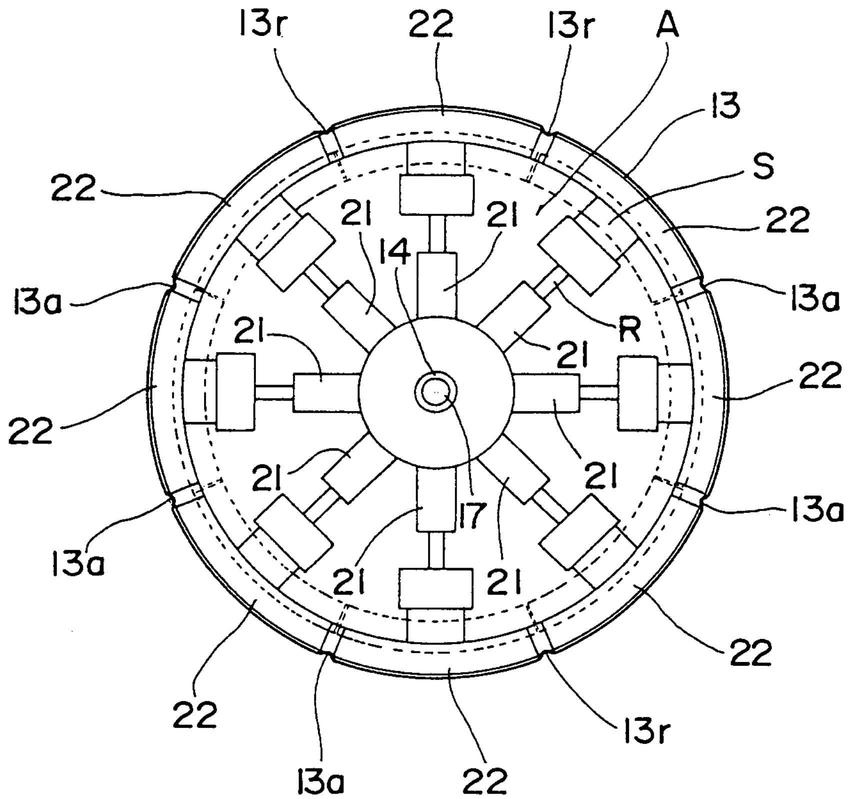

12
13
14
21
A
25
22
B
24
23
19V
19
15
16V
16

FIG. 13


13r
22
13r
A
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S
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13a
13a
21
21
14
R
21
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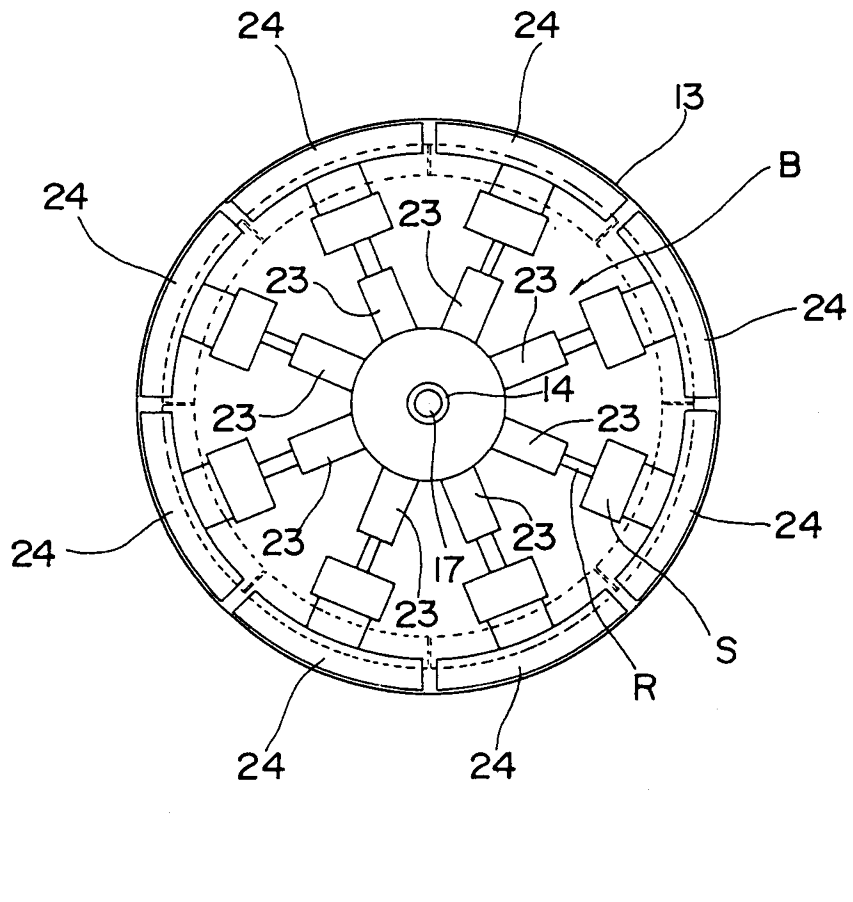
13r
22
13a
22

FIG. 14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B
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R
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24

FIG. 15

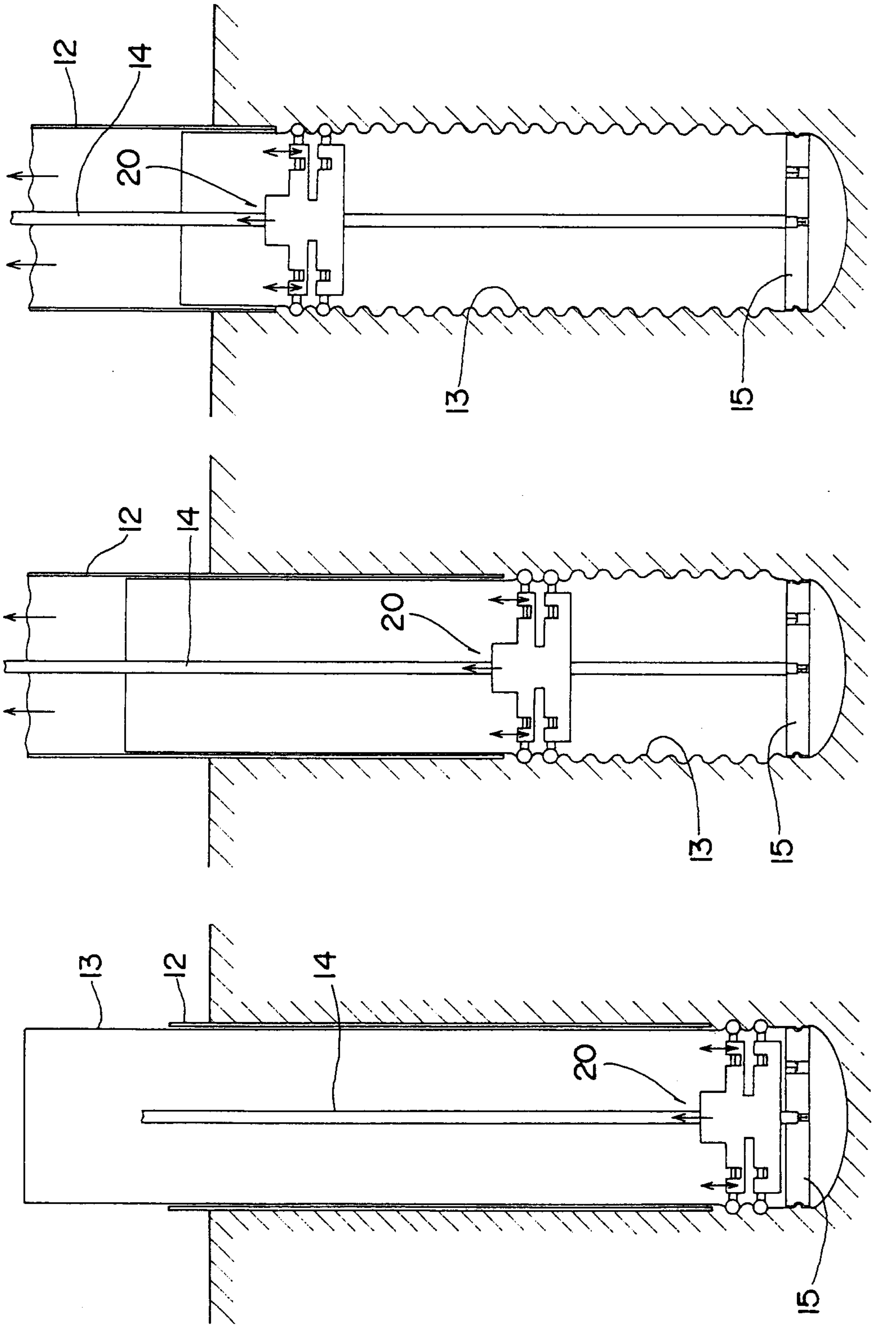

FIG. 16C

FIG. 16B

FIG. 16A

FIG. 17

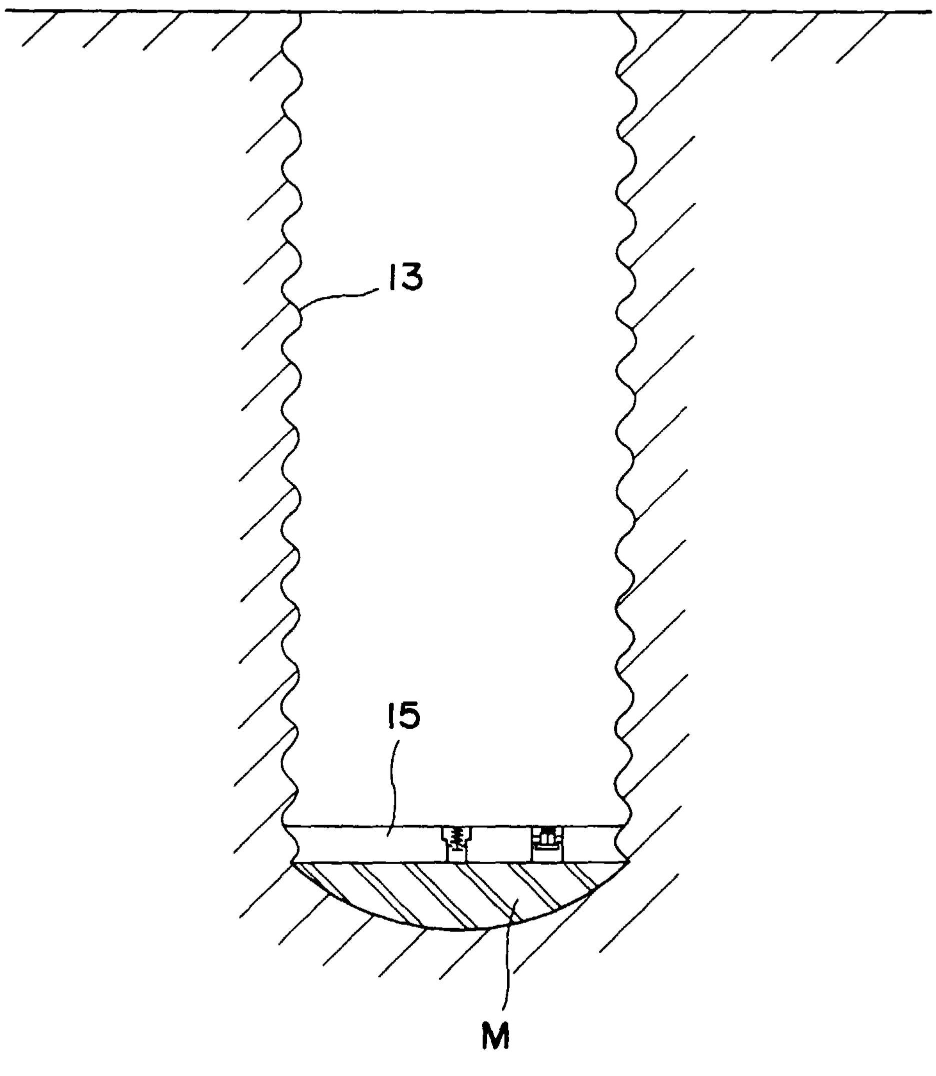

FIG. 18

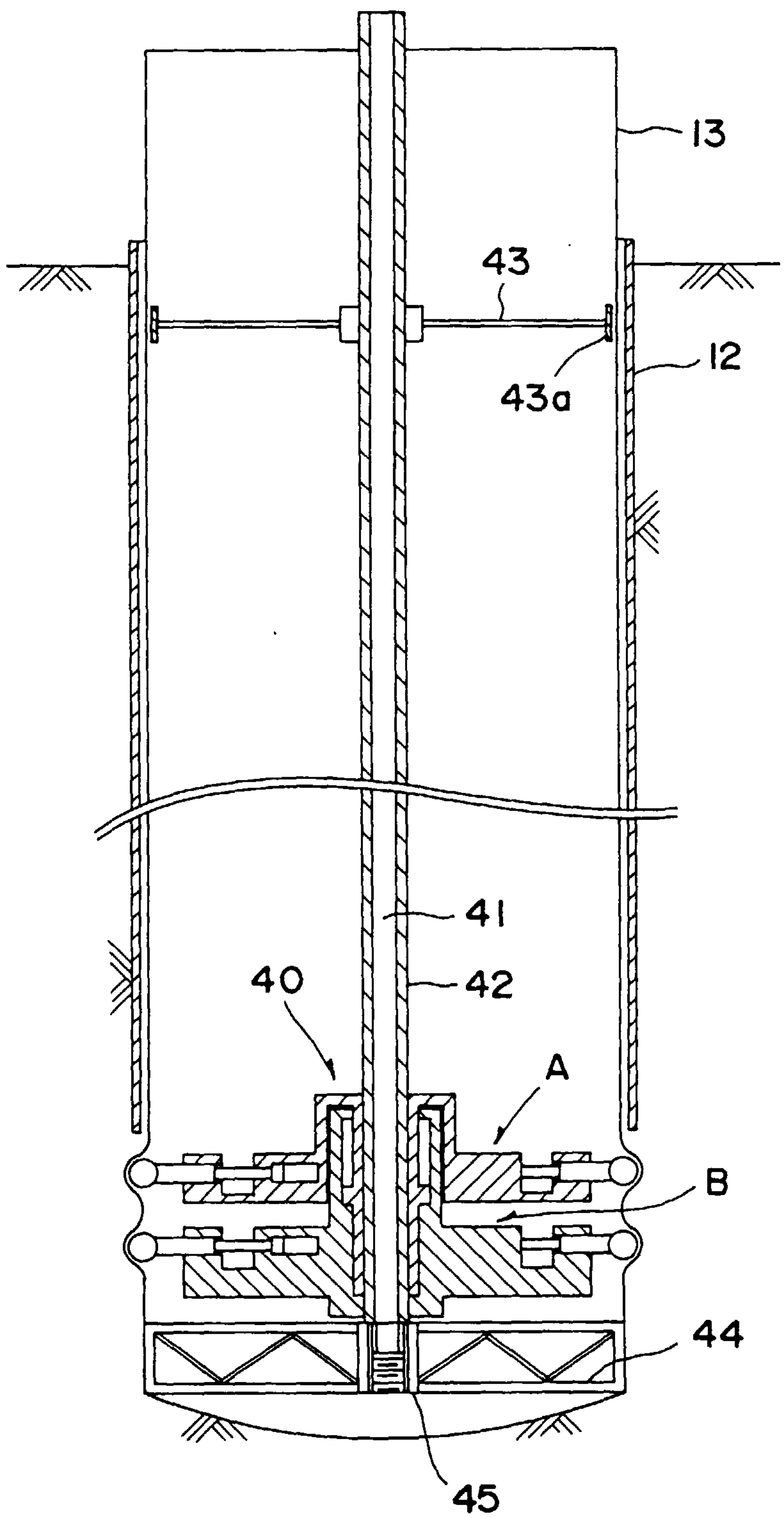

FIG. 19

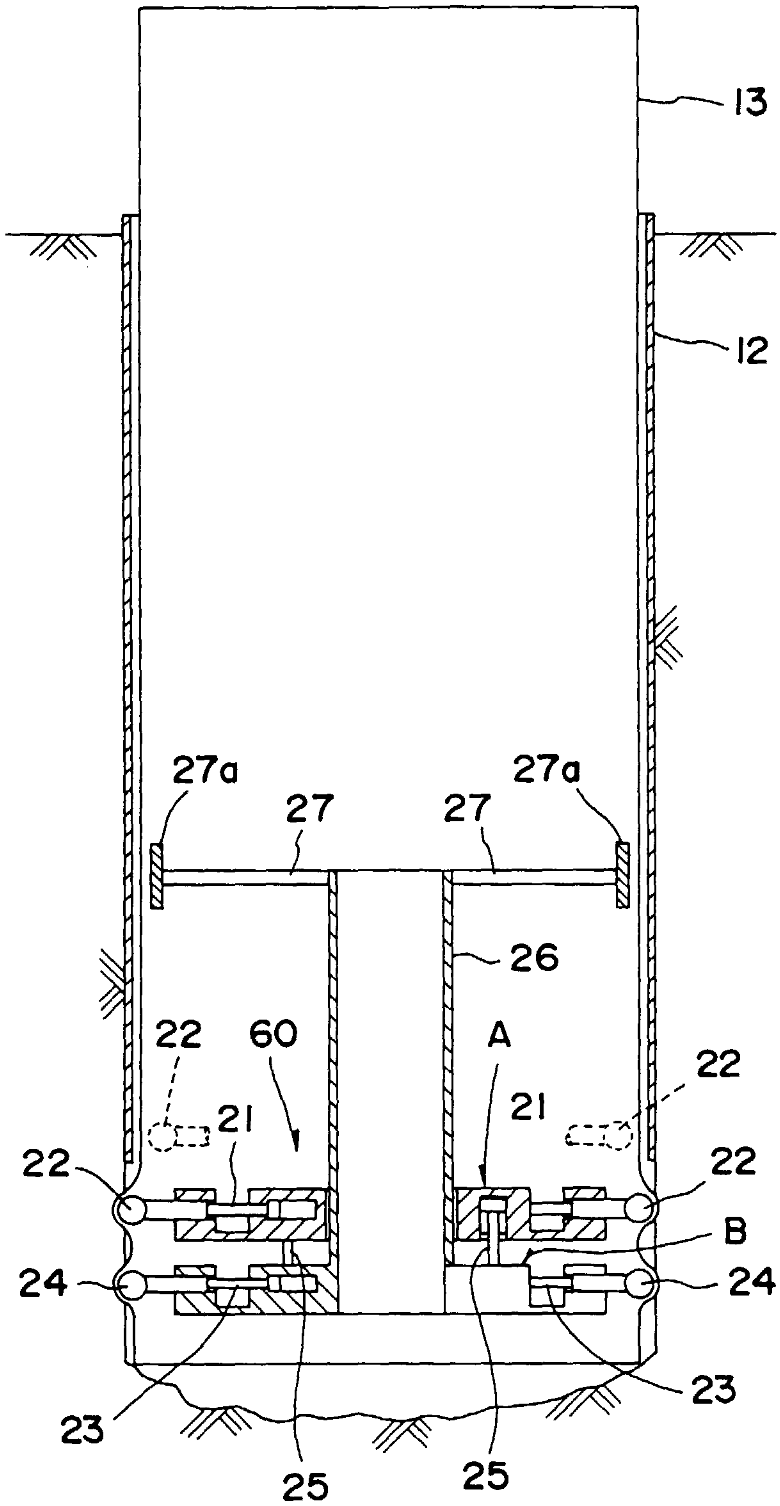

FIG. 20A

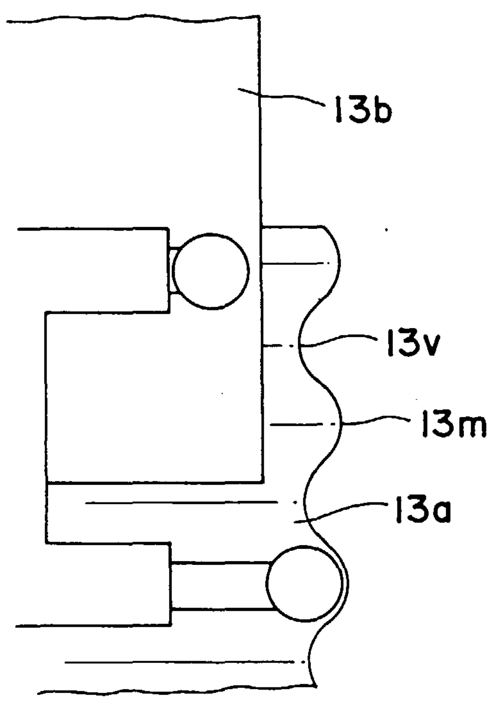

FIG. 20B