ABSTRACT OF THE DISCLOSURE

A double wall structure to be lowered into a liquid containing shaft in the earth has annular space between the walls containing reinforcing elements. These prevent collapse under pressure of liquid in the shaft during installation, and cooperate after completion of installation with cementitious material introduced into the space to form with the double walls a continuous trussed beam.

This application is a division of my copending application Serial No. 405,432, filed October 21, 1964, now U.S. Patent 3,295,327. That application was a continuation-in-part of my earlier application Serial No. 207,658, filed July 5, 1962, now abandoned.

This invention relates to underground structures and is particularly directed to an improved underground storage vessel.

An object of the present invention is to provide an underground double wall vessel having a metal liner encircled by a metal shell, with reinforcing elements positioned in the space between the liner and the shell, the remainder of the space being filled with cementitious material to form a trussed continuous beam.

Briefly stated, the space between the liner and the shell is closed at the lower end so that the double wall vessel develops buoyancy while being lowered into the liquid-containing shaft in the earth. The reinforcing elements prevent collapse of the double wall structure by hydrostatic pressure during the lowering operation. After full depth is reached the space between the liner and shell is filled with cementitious material, which cooperates with the reinforcing elements to form a continuous trussed beam.

In the drawings:
FIGURE 1 is a sectional elevation showing a preferred embodiment of this invention.
FIGURE 2 constitutes an enlargement of a portion of FIGURE 1.
FIGURE 3 is a sectional detail taken substantially on the lines 3—3 as shown in FIGURE 1.

Referring to the drawings, a hole 10 is drilled in the earth having a diameter and depth to accommodate the size of the storage vessel 11. As an example, the diameter may be about 20 feet and the depth about 250 feet, for a vessel of 10,000-barrel volume. A portion 12 of the hole 10 is reamed to a larger diameter near the upper end of the vessel 11, for example, about 25 to 32 feet below the ground surface 13. This reamed section 12 of the hole 10 provides space for the later construction of a concrete dike or cap 14 that is thus effectively keyed to undisturbed earth materials.

The double wall vessel 11 is preferably constructed in sections in the shop under ideal conditions and is transported to the job site. It comprises a cylindrical metal liner 15 encircled by a cylindrical metal shell 16. The metal shell 16 is longitudinally corrugated, as shown in FIGURE 3. A cage 17 of metal reinforcing bars is positioned in the annular space 18 between the liner 15 and the corrugated shell 16. The cage 17 includes vertical bars 19 welded to the liner 15, vertical bars 20 spaced therefrom in a circumferential series, and horizontal crimped reinforcing bars 21 welded to the vertical bars 19 and 20 and welded to the liner 15. The vertical bars 19 are spaced so that they extend into the outer portions of the longitudinal corrugations 22 in the shell 16. Vertical grout pipes 23 are loosely positioned within the reinforcing cage 17.

The hole 10 is initially filled with drilling fluid and the double wall vessel 11 is "floated" into the hole, additional sections being connected end to end as the lowering operation progresses. The space 15, closed at the bottom by means of the annular steel ring 24, but the lower end of the liner 15 is open. The space 18 provides buoyancy for the vessel 11 and the rate of lowering the vessel is controlled by pumping water into this annular space.

When the vessel 11 has been placed in position adjacent the bottom of the hole 10, a sand layer 25 is placed in the annular space between the corrugated shell 16 and the hole 10.

After placement of the sand layer 25, the annular space 18 and the interior of the liner 15 are both filled with water. Cement is then poured through the pipe 26 in the absence of the pump to form the concrete floor 27 and is allowed to set. Grout is then pumped under pressure through the grout pipes 23 to fill the space 18 with cementitious material. The grout pipes 23 are withdrawn upwardly while the pumps continue to force grout through the pipes 23 to fill the annular space containing the reinforcing cage 17. The pumping pressure is controlled by limiting the flow of water displaced from the annular space 18. The pressure grouting expands the outer shell 16 against the sand layer 25, but the liner 15 is substantially unaffected, because the pump pressure of the grout acts upon the water confined within the liner 15.

After the grouting operation is complete and the grout pipes 23 are completely withdrawn from the annular space, the curing of the grout takes place while the interior of the liner 15 is still full of water. The earth exerts a wing compression force against the corrugated shell 16 for effectively closing any longitudinal cracks that may develop in the concrete grout. Circumferential cracks are closed by the weight of the vessel and to some degree by elastic rebound of the steel liner and shell and of the reinforcing cage 17. After the water has been removed from the interior of the liner, the reinforced concrete cap 14 is poured in position within the enlarged portion 12 of the hole 10.

It will be observed that after construction of the vessel 11 has been completed by the steps described above, the corrugated steel shell 16 exerts compressive stresses on the concrete in the annular space 18 between the liner 15 and the shell 16. No unbalanced forces are exerted on the shell 16 during the cementing operation because the closed interior of the vessel is filled with water at that time. The water may be removed from the storage area within the vessel by pumping through a product pipe 28 which projects through the pipe 29 connected directly to the interior of the vessel at its upper end. Liquid petroleum gas may be pumped into the vessel through the annular space between the pipes 28 and 29, thereby forcing the water in the vessel to be discharged through the pipe 28.
A submersible pump 30 is then attached to the lower end of the pipe 28 for the purpose of discharging the liquid petroleum gas through the product pipe 28. Suitable valve connections, not shown, are provided at the ground surface.

The completed underground vessel comprises a steel and prestressed concrete structure that is capable of storing vapor-phase products under high pressures.

Having fully described my invention it is to be understood that I am not to be limited to the details herein set forth but that my invention is of the full scope of the appended claim.
I claim:

In a structure for installation underground in a liquid-containing shaft in the earth, the combination of: a double wall vessel having a metal liner encircled by a metal shell, the liner and shell defining a space between them, a wall closing the lower end of said space to provide buoyancy in the liquid in the shaft, the lower end of said liner being open, metal reinforcing elements positioned in said space and extending into contact with said liner and said shell to resist collapsing pressure of the liquid in the shaft outside said shell and inside said liner when said vessel is lowered into the shaft, and means for introducing cementitious material into said space to cooperate with the liner and shell and reinforcing elements to form a continuous trussed beam, said means including a plurality of retractable grout pipes extending axially through said space for filling the space from the bottom up.

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