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CAISSON CONSTRUCTION

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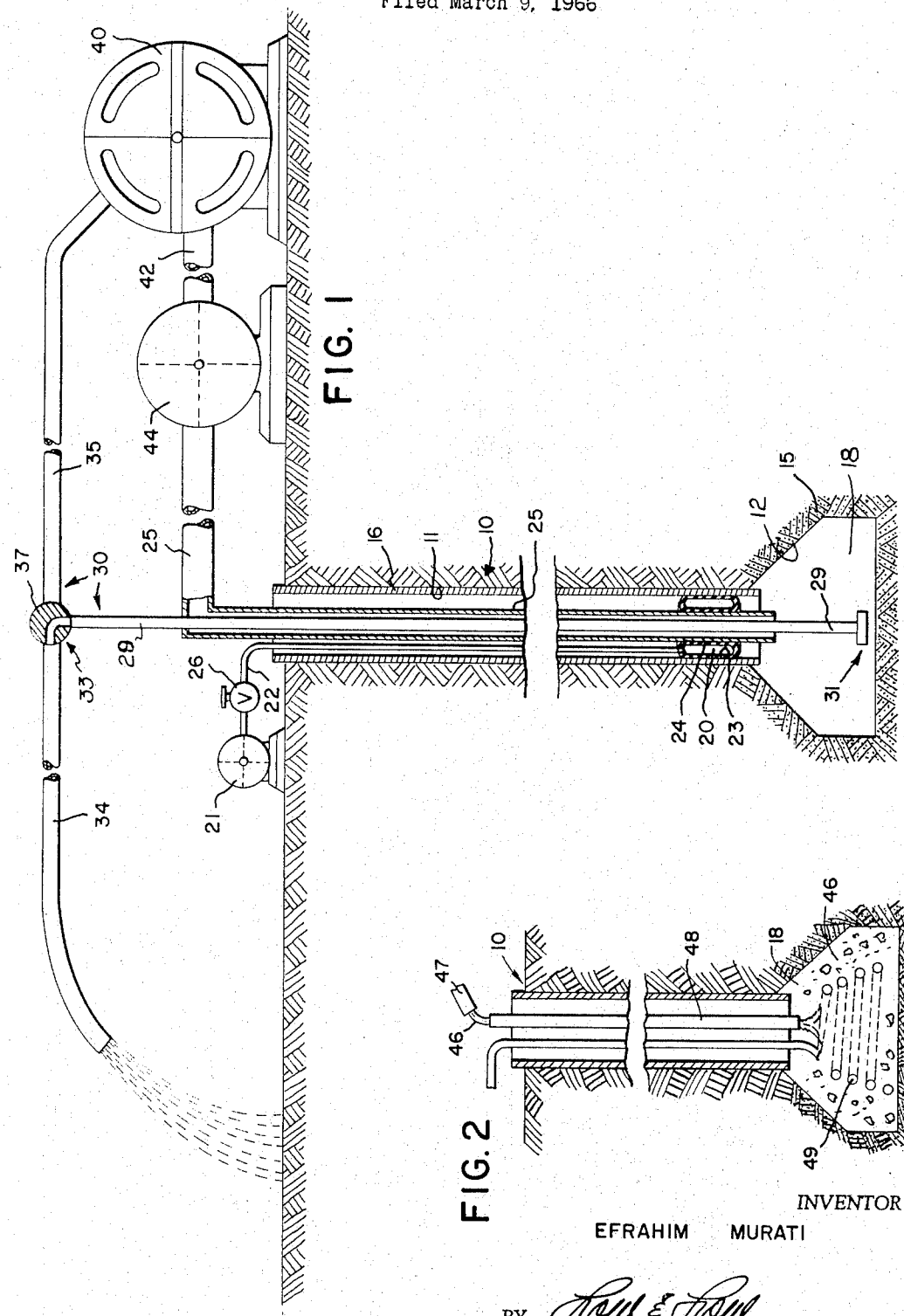

FIG. 1

FIG. 2

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CAISSON CONSTRUCTION

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ABSTRACT OF THE DISCLOSURE

The construction of caissons or the like, in non-cohesive water-permeated earth, wherein the construction includes the steps of boring a hole or shaft in the earth; forcing a water-tight liner into the shaft to support its walls; reaming out a laterally enlarged cavity, which may be bell-shaped, below the liner; sealing off the cavity. A freezant is uniquely fed under pressure through the seal and into the cavity for a dual purpose: (1) the freezant forces evacuation of water and/or slush in the cavity upwardly through another conduit passing through the seal; and (2) the freezant freezes the walls of the cavity. Finally, the cavity and shaft are filled with water-impermeable material such as concrete.

This invention relates generally to the construction of caissons, and more particularly to such construction in non-cohesive water-permeated earth.

In conventional construction of foundations and similar earth working operations in water-permeated earth, a caisson is formed by boring a hole, stem or shaft, then forcing water-tight liners into place against the walls of the shaft down to a predetermined level, and a bell-shaped cavity is reamed out below the liners.

By the time this work is done, the bell and the lined shaft above it are at least partly filled by inflowing ground water, or by water purposely pumped into the shaft to block inflow of ground water when it is necessary to preserve the ground water level in the nearby area. Subsequently, tremie concrete is poured to fill the flooded bell and shaft of the caisson, and to displace the water therein.

The presently employed tremie process or underwater emplacing of concrete is not only costly, but it does not assure the same quality of construction as obtained when the walls of the caisson are dry, as occurs in dry formations, when concrete is poured to fill it. Further, with the water-filled caisson and caisson bell, prior to tremie concreting, it is manifestly impossible to effect a dry inspection of the bell for the purpose of effecting reaming finish of the bell as required. The efforts necessary in caisson construction in water-bearing formations are large and commonly present considerable problems for the contractor as is evident, for example, from an article dealing with caisson construction in a water-bearing formation appearing in the Engineering News Record for Dec. 2, 1965, pages 30–32.

With increasing caisson construction being necessarily effected in water-bearing formations, or indeed in underwater or ocean sites, efforts are being made to reduce the need for tremie concreting as, for example, by utilization of larger precast units as disclosed in an article on bell pier construction in the October 1965 issue of the Journal of the American Concrete Institute.

It is therefore an important object of the present invention to provide a method and means whereby a caisson, formed in water-permeated earth, may be filled with concrete without recourse to the relatively undesirable tremie process. This object is uniquely achieved by emptying the caisson of water, and thereafter freezing the water-permeated walls to a depth sufficient to prevent the further

inflow of ground water while the dry frozen walls are subsequently covered as the caisson is filled with concrete.

Another object of the invention is the provision of a method and means wherein a fluid freezant, such as liquid petroleum gas, is admitted to the caisson to freeze the water permeated walls.

Still another object of the invention is the provision of means such as an inflatable and deflatable stopper for temporarily sealing a lower portion of the caisson while the freezant is pressure fed into the sealed off portion, and a conduit is provided to condut excess water from the bottom of the caisson to a point remote from the caisson, under the pressure exerted on the water by the freezant.

Yet another significant object of the invention is the provision of a method and means for freezing the walls of the caisson so that they may be inspected while dry and any finishing operations performed thereon, if the inspection indicates this to be desirable or necessary.

Numerous other objects and advantages of the instant invention will become apparent as the same is better understood from the following description thereof taken in connection with the accompanying drawing.

Referring to the drawings:

FIG. 1 is a schematic sectional view of a caisson and adjunct formation-freezing equipment according to the present invention; and

FIG. 2 is a schematic sectional view showing the pouring of concrete into the caisson.

With further reference to the drawing, the caisson **10** comprises a conventional shaft **11** and a bell **12** reamed out below the shaft in a water-permeable earth formation, as often occurs, so that seepage through the walls of the caisson would normally indicate use of the hitherto necessary tremie process to fill the caisson with cement.

Water permeable subsoil is shown at **15** and the caisson shaft **11** is lined in conventional manner with one or more tubular sections **16**, which may be steel plate cylinders, or tubing of other suitable material to block lateral inflow or seepage.

The bell **12** may be formed in conventional manner, such as by use of a "bucket" that is provided with laterally extensible blades which cut and ream the walls to the desired shape, and which in a water-bearing formation would likely be performed under water.

In accordance with the instant invention, instead of displacing the water with tremie concrete, the lower, water filled portion **18** of the caisson is largely sealed off and a fluid freezant, such as liquid nitrogen or liquified petroleum gas (LPG), is fed under pressure into this sealed off portion of the caisson so that at least some water is forced back into the subsoil and the excess water and/or slush is forced upwardly and outwardly through a conduit. The fluid freezant also freezes the walls of the caisson as the water recedes, and the freezing operation is continued after the water and/or slush is evacuated, and until the walls and subsoil **15** are frozen to a desired depth.

Means for sealing off the lower portion **18** of the caisson may be a transverse seal including an annular distensible stopper **20** made of rubber, or the like. The stopper is inflatable by an air pump **21** which forces air into the stopper through a conduit **22**. When inflated, the outer wall **23** of the stopper is in sealing contact with the caisson liner **16**, and the inner wall **24** of the stopper is pressed into sealing engagement with the outer wall of the vertical leg of freezant conduit or pipe **25**. When desired, deflation of the stopper **20** is effected by venting air from the stopper by opening a suitable control valve **26** in the conduit **22**.

Disposed substantially concentrically within the ver-

tical pipe leg **25** is a vertical section **29** of a discharge conduit or pipe **30** which extends downwardly through and below the lower and open end of the freezant pipe **25** upwardly to a point close to the bottom of the caisson bell **18** where it terminates in an inlet or head **31**. Section **29** of the discharge pipe also extends upwardly, through a wall of the freezant pipe **25** and enters a "T" juncture at **33** with a waste section **34** and a tank section **35** of the discharge pipe **30**. A two-way and closing valve **37** at the junction **33** permits direction of the upward flow of either water, slush or freezant from section **29** to either section **34** or **35** for purposes more fully explained below.

With the stopper **20** inflated to sealing position, the fluid freezant, such as LPG stored in a tank or other source **40**, is withdrawn therefrom through a conduit **42** by a suitable pump **44** which forces the freezant, under pressure, through the pipe **25** and into the sealed off lower portion **18** of the caisson.

Where the inflowing freezant contacts the side walls of the bell it forces some of the water on the wall back while freezing it, thus stopping further seepage. Simultaneously, the freezant applies pressure and freezing action to the surface of the seepage water in the bell. The freezing action will inherently produce some slush, a mixture of water and ice particles, and the pressure will cause the seepage water and/or slush to enter inlet **31** and then to pass upwardly through section **29** of the discharge pipe to the valve **37**, which at this time, is turned to direct water to and through the discharge section **34** to a discharge point remote from the caisson. The inlet **31** is, of course, spaced sufficiently above the bottom of the bell so that it will lie above solidly frozen water and/or slush at the bottom of the bell.

Hereinafter, the term "water" is intended to include slush where the water may carry particles of ice.

When the water is substantially fully evacuated from the caisson, fluid freezant will follow the water upward through section **29**, at which time valve **37** is turned either to closed position for a time and/or turned to direct the freezant through section **35** of conduit **30** back to the tank **40**.

While water is being evacuated from the caisson and usually for some time interval after such evacuation, the fluid freezant continues to be fed into the bell until the water-permeated walls are frozen to a desired length. The inward flow or seepage of water from the formation is thus effectively blocked.

The stopper **20** is then deflated and the stem **11** sufficiently cleared to permit visual inspection of the dry frozen walls by the use of conventional mirrors, television, or other suitable means. If indicated by the inspection, additional reaming or other finishing operations may be performed to give the dry, frozen walls a desired shape or form before the caisson is cleared and then filled with concrete. This filling is shown schematically in FIG. 2 wherein concrete **46** is being poured by conventional means which may include an inclined conduit **47** leading to the open end of the caisson where the concrete is received by a second conduit **48** which directs it to a lower level in the caisson. When desirable or necessary, heat may be introduced into the poured concrete by electric heating coils **49** or other conventional means used to facilitate setting of concrete under freezing conditions.

The above described technique finds utilization in a number of similar environments. Thus the same is workable in sand subsoil to establish a load-bearing concrete column where heretofore it has not been possible to provide a reamed out caisson bell. Thus a vertical hole can be made below a liner as at **16** in such a sand subsoil using a betonite or drill mud thick density suspension. The suspension is then displaced upwardly by the LPG which in turn freezes the "sand"-like walls close thereto. Thereafter reaming into the "iced sand" is effected with alternating LPG freezing to successively enlarge the hole while preventing any tendency to collapse, resulting in a bell as at **12** in a sandy subsoil for receiving a conventional concrete footing.

I have described my invention as principally applied to machine-reamed caissons and bells in non-cohesive water-permeated earth, as is commonly encountered and wherein my invention finds frequent utility. It should be noted that in addition thereto as well as to non-cohesive sandy and relatively waterless soils as discussed in the preceding paragraph, my invention may with similar benefit be employed in connection with virtually any earth formation, as for example decomposed rock soils, whether cohesive or non-cohesive, or whether water-permeated or water-permeable. In like manner, my invention is obviously not restricted to machine-reamed bell caissons, but may be employed with larger man-made bells and excavations as for example in connection with bridge pier caissons.

Further, under particular operating conditions as may occur in a given installation, or with specific concrete formations in connection therewith, it is possible that the low caisson bell or wall temperatures may unduly retard or interfere with setting of the concrete. Such an eventuality may be overcome as for example by the introduction through shaft **11** of flexible or rigid heating coils or conduits to insure proper temperature conditions for the concrete, while the poor thermal conductivity thereof coupled with the low-temperature, radial-depth freeze of the surrounding earth will preclude any significant difficulty with water seepage-control.

It is thought that the invention and many of its attendant advantages will be understood from the foregoing description, and it is obvious that various changes may be made in the form, construction and arrangement of parts without departing from the spirit and scope of the invention.

What is claimed is:

1. In the construction of caissons in water permeable earth, a method comprising the steps of:

sinking a shaft in the earth;

lining said shaft to a predetermined depth with a water impermeable material;

sealing off a lower portion of said shaft below said lined portion with a transverse seal;

feeding a liquid freezant under elevated pressure through said seal and freely into said sealed off lower portion of the shaft to freeze water present in the surrounding earth walls thereof;

unsealing and opening said lower portion of the shaft; and

filling said lower portion and said upper lined portion of the shaft with a water impermeable material while said surrounding earth walls are still sufficiently frozen to prevent undesirable water seepage.

2. The method set forth in claim **1**, wherein said freezant is a liquified gas.

3. The method set forth in claim **1** including the further step of reaming said frozen walls to enlarge said shaft lower portion to a desired shape before filling it with said water impermeable material.

4. The method set forth in claim **1** including the further steps of successively and alternately reaming and freezing said frozen walls to enlarge said shaft lower portion to the desired dimensions before filling it with said material.

5. The method set forth in claim **1** wherein said lower portion of the shaft is formed as an enlarged cavity.

6. The method set forth in claim **5** wherein said cavity is reamed to bell shape before the walls are frozen.

7. The method set forth in claim **1** wherein the water impermeable material is concrete and said cavity and shaft above it are filled with concrete.

8. The method set forth in claim **1** wherein the cavity is bell shaped and its dry frozen walls are inspected, and

a finishing operation is performed on the walls when and where indicated by the inspection.

9. The method set forth in claim **1** wherein said step of feeding freezant under pressure includes forcing at least some of the water in said shaft lower portion back into the soil while freezing it, and also forcing any excess water at the bottom of the cavity upwardly through a discharge conduit passing through said seal and away from said shaft.

10. The method set forth in claim **9** wherein the final freezing stage is effected with the freezant circulated between the source and the cavity.

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