United States Patent

[11] **3,572,506**

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[73] Assignee **the United States of America as represented by the Secretary of the Interior**

[54] **UNDERWATER STORAGE TANK**
6 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **210/86,** 210/120, 210/170, 210/242, 210/251
[51] **Int. Cl.** **B01d 21/24**
[50] **Field of Search** 210/85, 86, 109, 116, 120, 170, 172, 242

[56] **References Cited**

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1,548,400	8/1925	Walker	210/172
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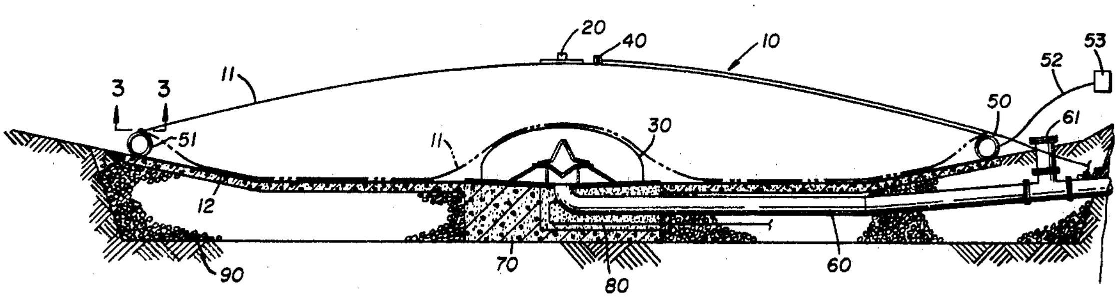
Primary Examiner—John Adee

ABSTRACT: This invention relates to an underwater storage tank for the temporary storage of liquids such as overflow storm water. The tank consists of top and bottom walls with at least the top wall being a flexible and collapsible membrane made of rubber or similar material and a metal framework of piping to which the membranes are secured. The structure is placed in position on the bottom of a lake, for example, and is connected, by means of an inlet-outlet pipe, to a sewer system. The pipes of the metal framework include jets which are connected to a source of liquid under pressure which can be used for flushing the tank. The tank also includes a cover for the inlet-outlet pipe which assists in disbursing large pieces of sediment and also assists in removing the same from the tank. The tank also includes vent valves for the escape of gases which may evolve while the sewage is in the tank and furthermore includes means for determining the volume of the tank at any given time.



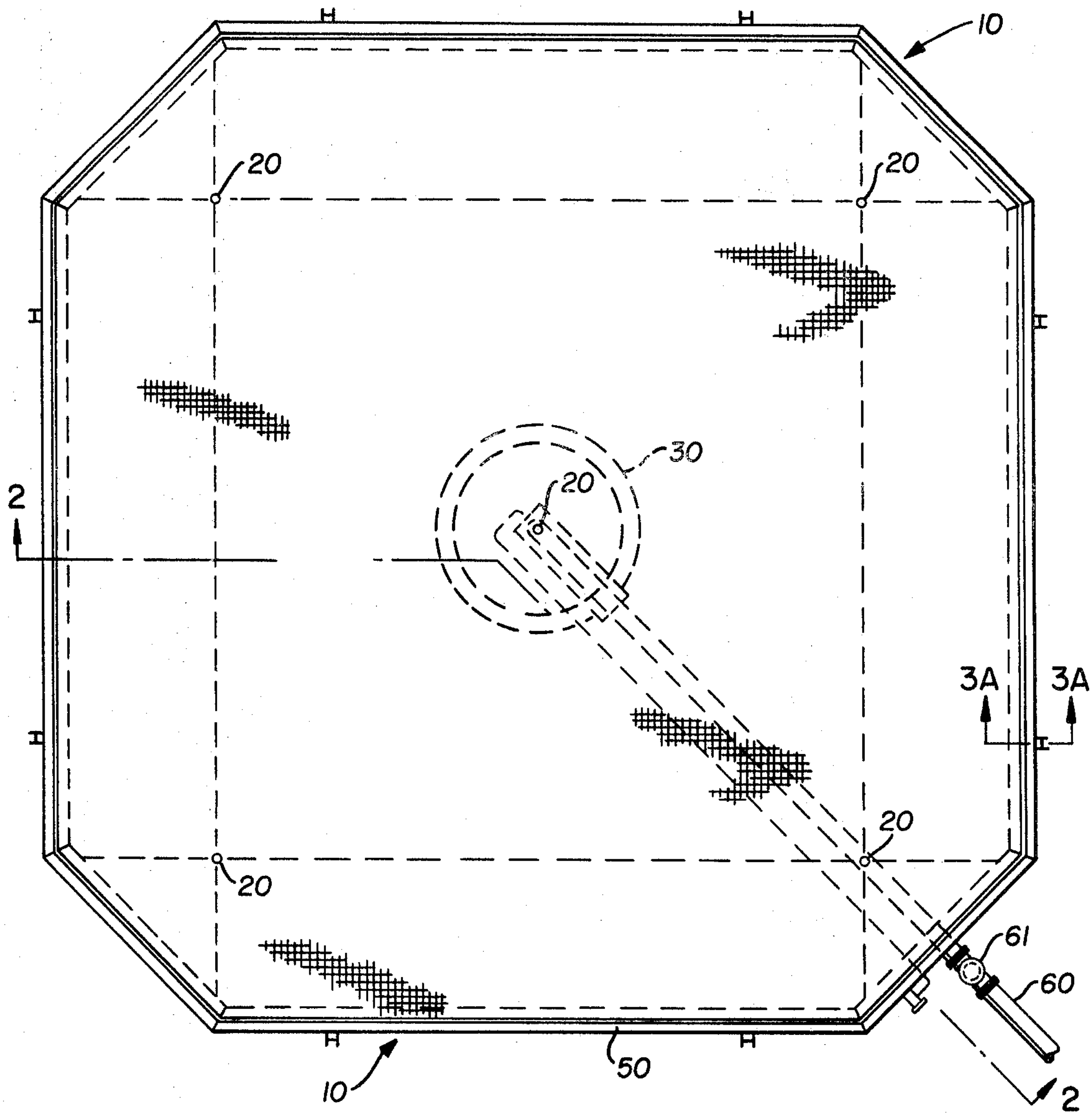


FIG. 1

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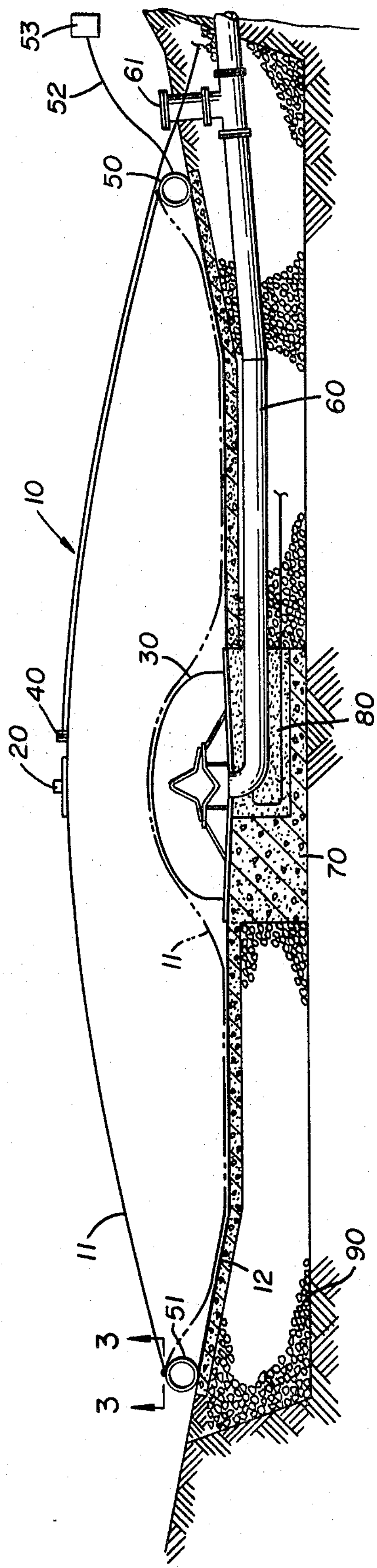

FIG. 2

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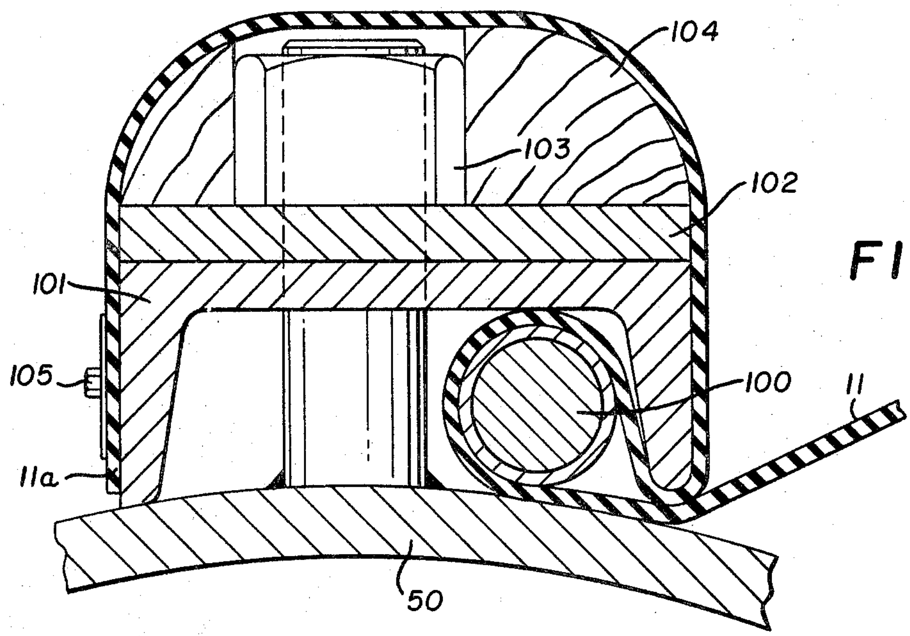


FIG. 3

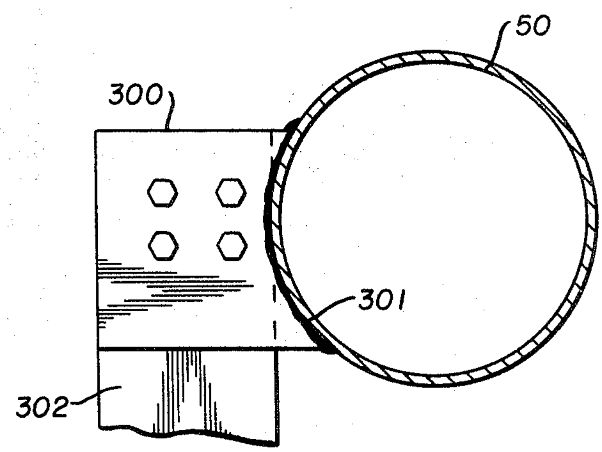
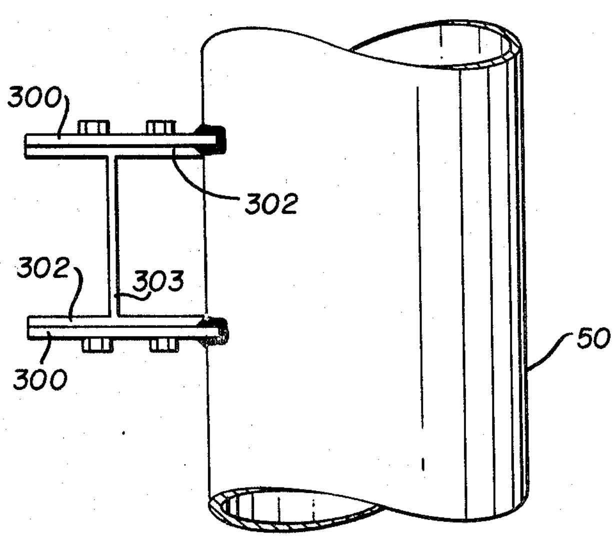


FIG. 3A

FIG. 3B



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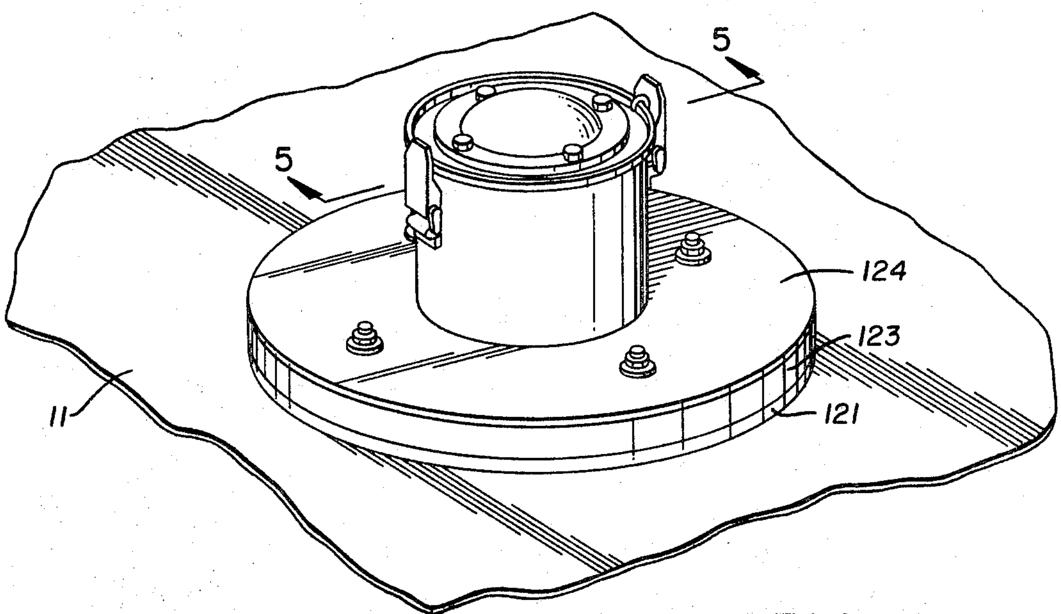

FIG. 4

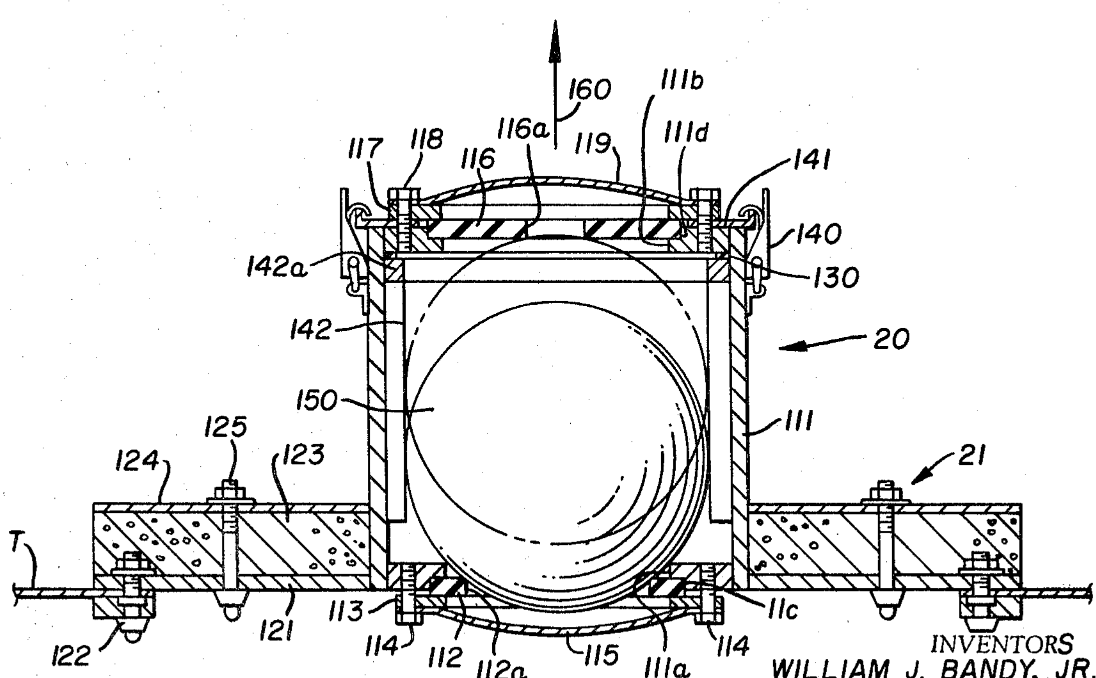

FIG. 5

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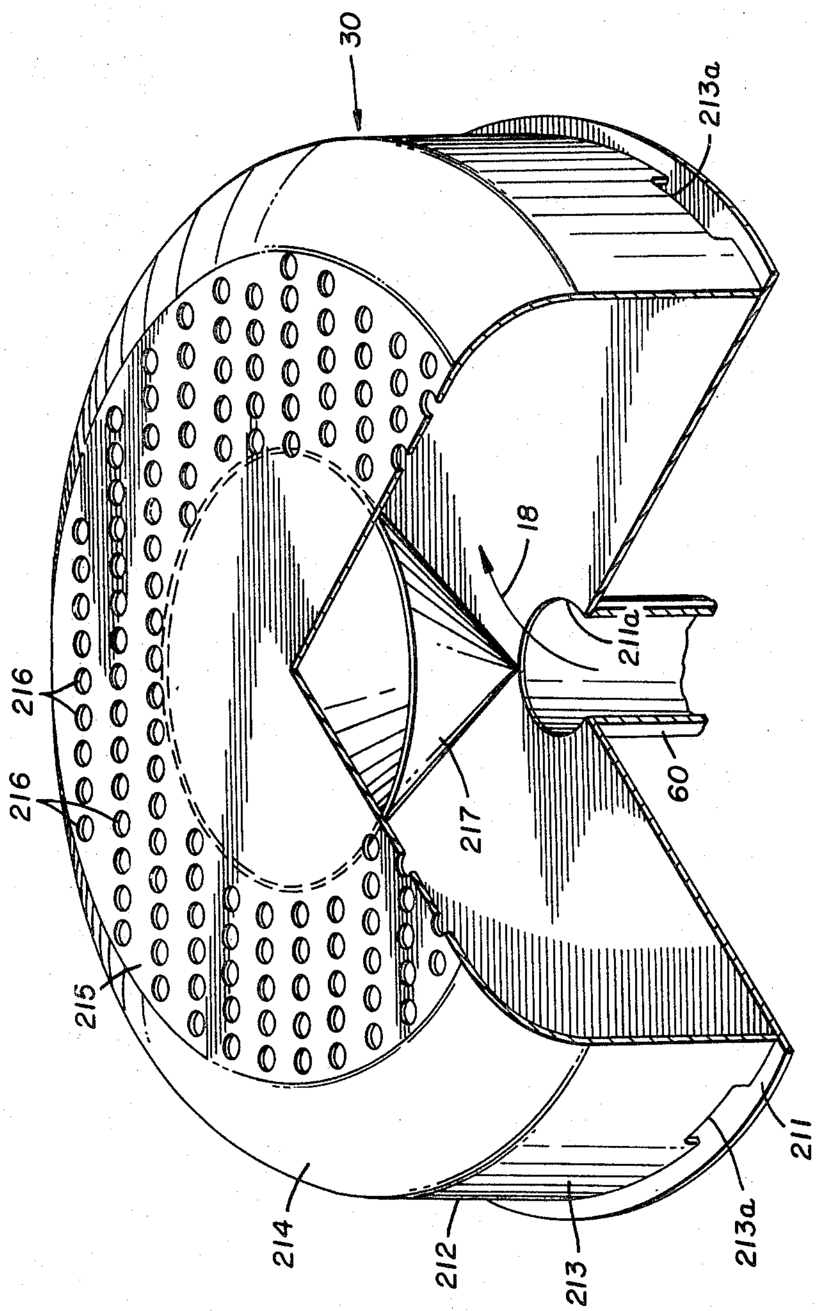

FIG. 6

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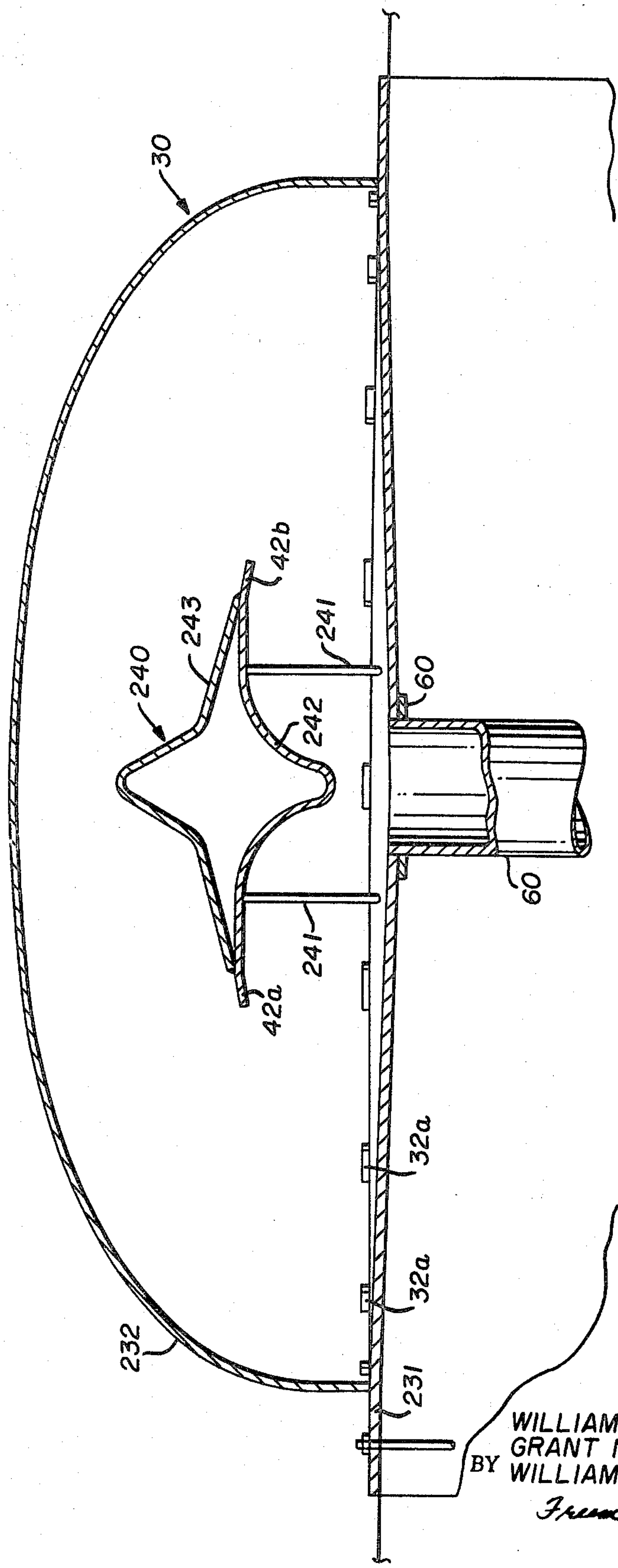

FIG. 7

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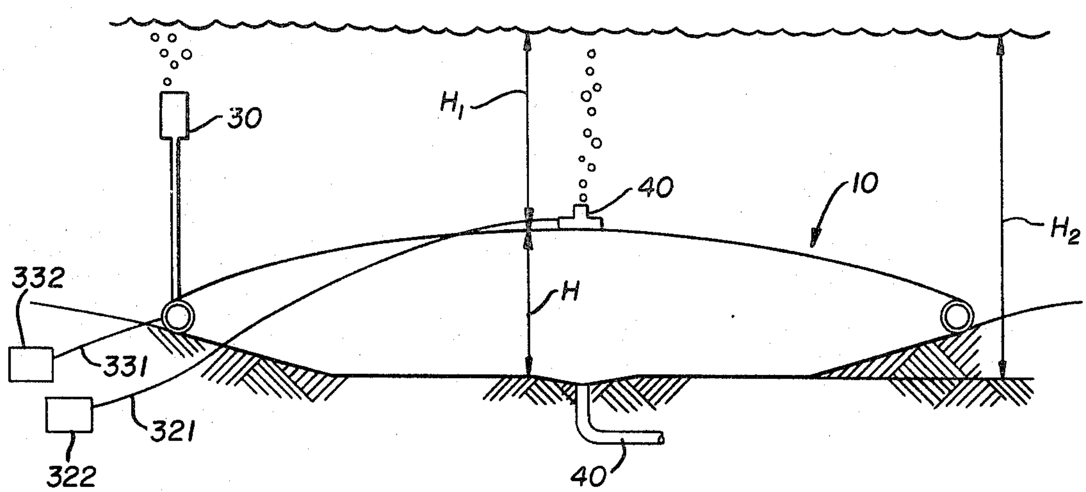

FIG. 8

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UNDERWATER STORAGE TANK

BACKGROUND OF THE INVENTION

This invention relates in general to the temporary underwater storage of liquids such as, for example, sewage which would otherwise normally overflow the sewer system during storms.

The invention relates in particular to a collapsible tank structure which is both inexpensive to construct and easy to install.

DESCRIPTION OF THE PRIOR ART

The following prior art patents are known to applicant Crawford et al. U.S. Pat. No. 3,113,699; Quase, U.S. Pat. No. 3,114,384; Quase, U.S. Pat. No. 3,114,468; Quase, U.S. Pat. No. 3,155,280.

All of the references referred to above relate to various means for storing liquids under water. Most of them, however, while proving satisfactory in many instances, require a relatively elaborate framework and do not have the simplified collapsible structure disclosed herein. Furthermore, the tanks shown in these references are much more cumbersome, bulky and difficult to install than the tank which is the subject of this invention.

SUMMARY OF THE INVENTION

It is often desirable, for a number of reasons, to store liquids under water. One of these reasons would be, of course, a saving in space by avoiding the use of valuable surface land. Aesthetic reasons also are important since an underwater installation is largely unseen.

It is also well known that under storm conditions an unusual amount of sewage will pass through combined sewers sometimes causing the same to overflow and thereby bypassing the normal treatment facilities. Therefore it is desirable to have a capability of handling overflow and underwater tanks provide an advantageous method for doing this.

The problem can be solved cheaply and efficiently by providing a collapsible flexible underwater tank which essentially consists of a framework of metal piping with top and bottom walls secured thereto and with the top wall, at least, being a flexible membrane. This structure can then be laid in a suitable excavation in the bottom of a lake, for example.

It has also been found that the tank in question can be provided with a gas vent to permit any gases which may evolve while the sewage is being stored to escape from the tank. A ball type valve can be installed at the high point of the tank and designed so that when there is no gas present in the tank, the buoyancy thereof will cause the ball to close off the valve to the outside.

It has also been found that when gas is present, the buoyancy of the ball or float becomes negligible which allows the same to drop by gravity from its upper seat thereby permitting any gas present in the tank to be vented. This occurs regardless of whether there is zero pressure within the tank or a positive pressure.

Utilization of a float valve of this type will permit the ball to seat against the lower seat when the tank is being pumped out thereby preventing inadvertent entry of outside water into the interior of the tank.

It also has been found that, especially when utilizing the improved valve with a flexible storage tank, that a flotation collar can be provided to insure that the valve is positioned at the high point in the tank.

It has also been discovered that the problem of controlling and removing large particles of sediment sludge from the tank can be reduced by providing an inlet-outlet cover which is placed over the influent-effluent opening. By providing this cover with a bottom reinforcing plate seated in the bottom of the tank and a top cover member having a plurality of velocity reducing openings therein and also providing a diversion cone over the inlet-outlet opening that all but the smallest particles of sludge will be effectively diverted to the bottom of the tank during the time the overflow water is being pumped in and will be readily removed from the tank upon pumping of the water out.

By controlling the size of the velocity reduction openings relative to the size of the influent-effluent port upon entry of the liquid, the reduction of the flow velocity will be sufficient to cause the large particles to settle to the bottom. Similarly, when pumping out the tank, the top wall will collapse on the inlet-outlet cover to close off the openings and cause an increase in velocity which will permit the particles to be drawn into the inlet-outlet cover and on out through the inlet-outlet pipe.

It has also been discovered that by providing an inlet-outlet cover of this type that the possibility of the tank collapsing of its own weight during the pumping operation and closing the inlet-outlet port itself is eliminated.

It is also, of course, necessary and desirable to know precisely how much liquid is inside the tank at any given time and this has proved very difficult to ascertain with any accuracy. This problem is further complicated by the fact that the water level of the body of water in which the tank is placed also varies.

It has been discovered that if two factors can be determined, the volume of the tank can be ascertained. This, if a standard fixed bubbler type gauge is utilized, the depth at which the gauge is located beneath the water surface at any given time can be ascertained. The distance between the tank bottom and the gauge being known, the sum of these two will give the distance from the bottom of the tank to the surface of the water. If a second bubbler gauge is mounted at the high point on the tank, the depth beneath the surface at which the top of the tank is disposed can also be ascertained.

Then, by subtracting the second reading from the first, the actual height of the tank can be ascertained and a calibration curve can be constructed showing the volume within the tank as a function of the height of the highest projecting portion of the tank.

Accordingly, production of an improved underwater storage tank of the type described becomes the principal object of this invention with other objects thereof becoming more apparent upon a reading of the following brief specification, considered and interpreted in view of the accompanying drawings.

In the drawings:

FIG. 1 is a top plan view of the improved tank.

FIG. 2 is a sectional view of the tank showing the same in place in a lake bottom.

FIG. 3 is a sectional view taken on the lines 3–3 of FIG. 2 showing the method of attaching the upper and lower membranes to the framework.

FIG. 3A is a sectional view taken on the lines 3A–3A of FIG. 1 showing means for anchoring the tank in place.

FIG. 3B is a top plan view of the anchoring means shown in FIG. 3A.

FIG. 4 is a perspective view of the improved valve showing the same in place on the tank.

FIG. 5 is a vertical sectional view taken on the lines 2–2 of FIG. 4.

FIG. 6 is a perspective view of an improved inlet-outlet cover partially broken away in section.

FIG. 7 is a perspective view of a modified version of the inlet-outlet cover of FIG. 6 partially broken away and in section.

FIG. 8 is a schematic view of an underwater storage tank showing the means for ascertaining the volume thereof and illustrating the method involved.

THE OVERALL TANK

Turning first then to FIG. 2, it will be noted that the tank, generally indicated by the numeral 10, consists of a framework of pipes 50, a vent valve 20, an inlet and outlet cover 30 and a level indicating device 40.

Considering again FIG. 2 and referring particularly to the preparation of the bottom of the lake for reception of the tank, it will be noted that a hopper shaped bottom is first excavated. This is backfilled with stones 90 to provide a suitable base. A supporting block 70 of concrete is then placed in position to provide solid support for the tank.

An inlet and outlet pipe 60 runs from the sewer system to the inlet-outlet port of the tank with the area immediately adjacent the inlet-outlet port being filled with sand or other suitable material. A pressure relief valve 61 is also placed in the line 60 for safety purposes.

Turning next then to a consideration of the tank per se, it will be seen that the same includes upper and lower walls 11 and 12. At least top wall 11 is a flexible membrane which is inherently collapsible. Bottom wall 12 can be either of steel or a second flexible membrane as desired. The dotted lines of FIG. 2 show the top wall 11 collapsed as it would be when the tank is empty. These two walls are secured to the framework 50 at approximately the centerline of the pipe thus forming a substantially closed interior. The particular manner of securing the walls to the pipe will be treated in greater detail below.

FIG. 3A shows the method of anchoring the tank in place. A pair of plates 300,300 are provided with arcuate cutout areas 301 which conform to the contour of frame 50. The plates 300,300 are bolted or otherwise secured to pilings 302,302 which are embedded in the lake bottom and interconnected by cross bar 303. This piling assembly can then be secured to frame 50 by welding as clearly shown in FIG. 3A and 3B and the tank can be firmly held in place.

It should be noted that in the form of the invention shown that pipe framework 50 is of generally octagonal configuration in plan although this particular configuration is by no means mandatory. The piping also has a series of spray vents 51,51 opening into the interior of the tank for flushing purposes. In reality, the spray vents 51,51 are simply a series of openings disposed on the inside portion of the framework 50 opening into the interior of the tank. The framework 50 is interconnected by means of line 52 to a conventional pump 53 which is adapted to force water under high pressure through the line 52 into the framework 50 through the vents 51,51 and into the interior of the tank for flushing purposes. This enables the tank to be cleaned without dismantling the same.

Completing the overall tank structure, the same has at least one gas relief vent 20 disposed on its upper surface for purposes of relieving any gases which might evolve within the tank during storage of the sewage. A bubbler level mechanism 30 is also provided in order to ascertain how far the top of the tank is below the surface of the water at any given time and to enable the volume to be measured as will be described below.

Considering next the method of connecting the membranes 11 and 12 to frame 50, reference is had to FIG. 3.

Taking the top membrane 11, for example, it will be seen that the same is wrapped around pipe 100, under one leg of brace 101, and then passed over wooden form 104 and is bolted to the other leg of brace 101. This brace 101 is of U-shaped configuration and supports plate 102 and form 104. A stud 103 secures brace 101, plate 102 and form 104 to the pipe 59 to securely hold the membrane 11 in water tight connection. The lower membrane 12 is secured to pipe 50 in similar fashion if it is of flexible material. If the bottom 12 is of steel or similar material, it can merely be welded to the bottom of the frame to form a water tight connection.

The various features of the tank will now be described in detail.

THE VENT VALVE

Referring first to FIG. 1, it will be noted that a plurality of identical valves 20,20 are mounted on the top wall of the tank 10.

Considering next then FIG. 4, it will be seen that each valve per se, generally indicated by the numeral 20, is mounted on a supporting plate, generally indicated by the numeral 21, which is in turn mounted on the top surface 11 of the tank.

Considering first then the specific structure of the mounting means, it will be seen that the same include an anchor plate 121 which, in the form of the invention shown, is of generally circular planar configuration but which of course could be made of any desired configuration. The anchor plate 121 is secured to the top of the tank T by the nut and bolt arrangement generally indicated by the numeral 122. In the form of the invention illustrated, a foam flotation member 123 is mounted on the top surface of the anchor plate 21 and a plexiglass flotation support plate 124 is superimposed on the flotation means 123 with anchor plate 121, flotation means 123 and flotation support plate 124 being secured together by nut and bolt assembly 125 as clearly shown in FIG. 2.

It should be understood that the form of the invention illustrated would primarily be used in connection with a flexible underwater storage tank of the type described herein and that in the instance in which a nonflexible tank were involved, that the flotation means 123 and the flotation plate 124 could be eliminated with the purpose of these members being to insure that the vent valve is located at the high point on the tank.

In this regard, while one valve is mounted at the center point of the tank which would, under most circumstances, be the highest point of elevation, several other valves are provided due to the fact that air or gas within the tank conceivably can move about causing some distortion so that some point other than the midpoint of the tank could in fact be at the highest elevation at any given time. Provision of the additional valves insures, however, that a vent valve will be in position at the highest point, wherever that may be.

Turning next then to the valve 20 per se, it will be seen that the same includes a cylindrical housing 111 which is welded or otherwise attached to the anchor plate 121. The body 111 has generally enclosed ends with through openings 111*a* and 111*b* therein.

Considering the area adjacent the bottom of the body 111, it will be noted that the bottom wall is undercut as at 111*c* and receives a bottom seal member 112 which, in the preferred form of the invention, is made of polypropylene but which could be of course made of any thermoplastic resin material which will give the desired sealing qualities.

The bottom seal 112 is held in place in the undercut area 111*c* by the retaining ring 113. A screen 115 is also provided with the screen 115, ring 113 and seal 112 all being secured to the bottom of the body 111 by the bolts 114,114.

Considering next the top or opposed end of the valve 20, it will be seen that, first, three bars 142,142,142 are mounted inside body 111 and serve to center the ball 150. These bars also provide supporting ledges 142*a*,142*a*,142*a* at their top ends for purposes which will be described.

The top end of the body 111 is also undercut as at 111*d* to receive a top seal 116 similar in construction to the bottom seal 112 and also having a through opening 116*a*. Superimposed on the seal 116 is a top retaining ring 117 which overlies the seal 116. A screen 119 is also received on top of ring 117 and the entire structure is held together by the bolts 118,118. Additionally and for improved sealing purposes, a neoprene gasket 130 is disposed between the top of the body 111 and the shoulder 142*a* of sleeve 142.

Also and for purposes of gaining access to the interior of the valve for cleaning or repair purposes, a retaining ring 141 is mounted between ring 117 and the top of the body and is held in place by the latches 140,140 which are of conventional construction.

Finally, received within the interior of the body 11 is a buoyant ball 150.

In use or operation of the improved vent valve, it will be assumed that the same has been assembled to the condition shown in FIG. 6.

When there is no gas present, such as when the tank is empty, the buoyancy of the ball will cause the same to float to the position shown in broken lines in FIG. 5 at which time the ball will seal off the opening 116*a*. As soon as gas accumulates in the tank, the buoyant force of the ball becomes negligible at which time it drops free by the force of gravity from its upper seated position. This permits gas accumulated in the tank to escape through the opening 116*a* in the direction of arrow 160. As soon as the gas has all escaped, of course the buoyant force of the liquid will again cause the ball to move to the broken line position of FIG. 5 and again seal off the opening 116*a*.

In the event a positive pressure is present, the buoyant force on the ball 150 again becomes negligible and the ball again drops permitting the gas to escape. Again as soon as all of the gas has escaped through the opening 116*a*, the ball will again float back up to close the opening.

In a situation where there is negative internal pressure such as, for instance, when the tank is being pumped out, the ball will fall to the full line position of FIG. 2 at which time the lower opening 112*a* is closed off.

Provision of the screens 115 and 119 prevents foreign material from entering the housing 11 thereby preventing clogging or damage to the valve.

THE INLET-OUTLET COVER

Considering first then FIG. 6, it will be noted that the cover, generally indicated by the numeral 30, has a bottom reinforcing plate 211 which is mounted at the bottom of the tank and can be secured in place by conventional means such as, for example, bolting the same to the concrete support pad 70.

Mounted on the reinforcing plate 211 is a head 212 which, in the form of the invention shown in FIG. 6, consists of a circular sidewall member 213 and an integral wall portion 214 having an arcuate cross section and a relatively flat top surface 215. Top surface 215 has a plurality of velocity reduction openings 216,216 therein and also has a diversion cone 217 integrally suspended from the underside of the top surface 215.

The sidewall 213 of the head 212 has a plurality of effluent openings 213*a*,213*a* spaced about the lower edge of the sidewall adjacent the reinforcing plate 211 for purposes which will be described in greater detail below.

The height of the effluent openings 213*a*,213*a* is, in the preferred form of the invention, no greater than the diameter of the velocity reduction openings 216,216. This relative dimension is utilized to insure that any particles of sediment which might pass out through the openings 216,216 when the tank is being filled can be pulled back into the head through the openings 213*a*,213*a* when the tank is pumped out.

It will be noted that the reinforcing plate 211 has an inlet-outlet port 211*a* which is mounted over the inlet-outlet pipe 60. The cone 217 is mounted on the top 215 of the head so that it is in substantial concentric alignment with the port 211*a*.

It is known that the volumetric flow rate of material is equal to the average velocity of the flow times the cross sectional area of the flow with this formula being stated as $Q=AV$ for a substantially incompressible fluid. Since Q can be assumed to be constant and the velocity needed to transport a given material is known, the volumetric flow rate can be used to determine the total open area in the velocity reduction openings to produce the desired velocity in the inlet-outlet cover. Therefore it becomes a simple mathematical computation, once the average velocity and the area in the pipe are known, to compute the size of the velocity reduction openings.

Thus in practical application and referring again to the form of the invention shown in FIG. 6, after overflow material enters the pipe at a given average flow rate, the liquid is diverted up around cone 217. The liquid itself and the smallest particles thereof will pass on out through the velocity reduction openings 216,216. The larger sedimentary particles, however, will drop to the bottom of the cover onto the plate 211. The cone, by diverting the flow somewhat prevents the sediment from dropping back into pipe 60 and insures that the sediment will settle to the floor formed by plate 211.

For effluent flow, a sufficient velocity, which again is calculable, to cause erosion of the large particles must be achieved. By decreasing the area of the velocity reduction openings as compared to the area of the inlet-outlet pipe, this can be acquired over an effective distance on either side of the effluent slots 213*a*,213*a*. As the tank is being pumped out, the top 11 of the flexible tank will of course tend to settle to the bottom and once the volume of the liquid in the tank has decreased sufficiently, this material will lay on the top of the head 212 covering up the velocity reduction openings 216,216. Continued pumping increases velocity until the necessary effluent erosion velocity is achieved through the openings 213*a*,213*a* and a scouring action will occur within the head with the result that the sediment will pass on out through the pipe 60. As is believed obvious from the foregoing description, a major advantage to this structure is that the collapsing of the top of the tank itself does not prohibit effective operation of the tank and does not impede evacuation of the same.

Turning next then to FIG. 7 which shows a modified form of the cover, it will be seen that the same includes a reinforcing plate 231 mounted over the inlet-outlet pipe 60 in much the same manner as described above with regard to FIG. 6. The head 232 of this form of the invention is generally dome-shaped and does have again a plurality of velocity reduction openings in its top area. The size of these openings is computed according to the above formula in the same manner as is the case in the form of the invention shown in FIG. 6.

In this form of the invention, however, a different type diversion cone 240 is disclosed. This cone is not suspended from the top of the head 232 but is mounted on supporting legs 241,241 which rest on the reinforcing plate 231. The cone itself is comprised of a lower V-shaped member 242 and an upper inverted V-shaped member 243. The member 242 has divergent legs 242*a* and 242*b* which are wide enough so that material entering the tank through the pipe 60 cannot go directly to the velocity reduction openings as is the case in the form of the invention shown in FIG. 6. This provides the added advantage that clogging of the velocity reduction openings is prevented.

Operation of the form of the invention shown in FIG. 7 is substantially the same as that in FIG. 6 and will not be repeated here.

THE VOLUME MEASUREMENT MEANS

Considering next FIG. 8 then, it will be seen that the tank, generally indicated by the numeral 10, has a flexible top membrane 11 and is mounted on the bottom of a lake or other body of water as described above. The tank 10 is shown schematically only in this view.

Mounted on the high point of the tank 10 is a bubbler 40 which is really a conventional depth type gauge. A hose 321 leads to a remote or metering device 322 and the gauge 320 generally operates on the principle that it takes a certain air pressure to force air out of the bubbler which will tell the person monitoring the meter 322 the amount of water above the level of the bubbler 320. Gauges of this type are well known in the prior art.

A separate bubbler 330 is also mounted on the tank at a fixed position. This bubbler leads, by way of hose 331, to a metering device 332 and operates in the same fashion as the bubbler 320.

In practicing the invention, it will be understood that when the tank 10 is empty, it will be in a collapsed state and that as liquid is pumped into the tank through the inlet-outlet pipe 60, the tank will expand. Of course, as the tank expands, its top surface will rise and the bubbler 320 will rise with it. The bubbler 330 remains in a fixed position.

When it is desired to ascertain the amount of liquid within the tank 10, the following steps are followed.

First, a reading is taken on the meter 332 which is connected to bubbler 330 which indicates the distance from the bubbler **330** to the water surface. Inasmuch as the distance from the bottom of the tank to the bubbler **330** is known, it is merely necessary to add these two distances to arrive at the figure generally indicated by the designation H_2.

A reading is then taken on the bubbler **320** which will indicate the height of the water above the bubbler, that is, above the top of the tank. This will give the reading H_1.

Therefore and in order to ascertain the dimension H, it is merely necessary to subtract H_1 from H_2.

Once this has been done, the volume of the liquid stored within the tank **10** can be easily determined since known mathematical formulas or prior calculations or test calibrations enable the internal volume of a tank to be measured once the tank height is known.

It has been shown, therefore, how an improved underwater storage tank can be provided having the advantages of being simple to construct, easy to install, but still completely performing the necessary storage function required of such tanks.

It has also been shown how the safety features of the tank can be enhanced by provision of a unique vent valve to remove gases from the interior of the tank which might otherwise cause damage to the tank itself.

It has further been shown how the volume of the tank, which is normally inaccessible, can be determined by utilization of a combination of bubbler type gauges.

While a full and complete description of the invention has been set forth in accordance with the dictates of the patent statutes, it should be understood that modifications can be resorted to without departing from the spirit hereof or the scope of the appended claims.

We claim:

1. In combination with a source of liquid supply a substantially collapsible underwater storage system, comprising:

- a. a hollow frame adapted to be anchored on the bottom of the body of water in which said system is placed;
- b. a substantially closed tank body
  1. of fluid impermeable material
  2. secured to said frame;
- c. a conduit adapted to interconnect the interior of said body with said source of liquid supply
  1. whereby said liquid can be passed into and out of the interior of said body;
- d. sediment control means
  1. disposed within said body adjacent the point of connection of said conduit means with said body and
  2. adapted to facilitate sediment removal from said body;
- e. vent means
  1. carried by said body and
  2. adapted to automatically permit the escape of gases accumulated within said body;
- f. measuring means mounted on said body and adapted to measure the volume of liquid within said tank; and
- g. flushing means adapted to flush the interior of said tank.

2. The system of claim **1** further characterized by the fact that said frame includes an integral hollow pipe system having a series of apertures directed toward the interior of said body; said flushing means including means adapted to force water under pressure into said pipe and through said openings into the interior of said body.

3. The system of claim **1** further characterized by the fact that said body includes:

- a. an upper wall having its edges secured to said frame;
- b. a lower wall having its edges secured to said frame; and
- c. at least said top wall being of flexible material.

4. The system of claim **1** further characterized by the fact that said sediment control means include

- a. a bottom plate
  1. mounted on the bottom of said body
  2. with a through opening therein which overlies said conduit;
- b. a head mounted on said plate
  1. having a series of through openings therein disposed adjacent its point of mounting on said plate and
  2. a top surface spaced from said plate having a series of velocity reduction openings therein; and
- c. diversion means
  1. mounted between said plate and said top surface of said head
  2. and adapted to divert the flow of liquid into said body.

5. The system of claim **1** further characterized by the fact that said vent means include at least one valve mounted on the highest point of said tank when said tank contains liquid.

6. The system of claim **1** further characterized by the fact that said measuring means include:

- a. a first depth gauge adapted to measure the distance from the surface of said body of water to the bottom of said tank body; and
- b. a second depth gauge adapted to measure the distance from the surface of said body of water to the top of said tank body
  1. whereby the height of said tank body can be ascertained and whereby the volume of said tank can be measured.