Jan. 21, 1969 R. R. H. MIRON ETAL 3,423,264

METHOD OF BUILDING A CORROSION-RESISTANT STORAGE TANK

Filed March 29, 1965

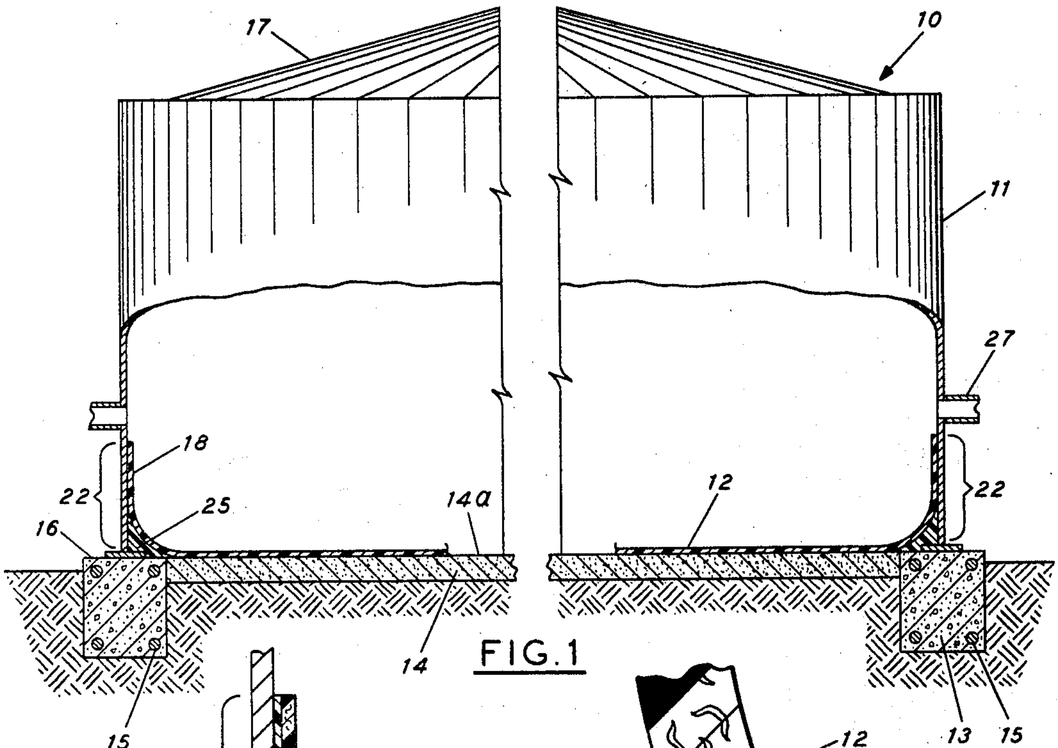


FIG. 1

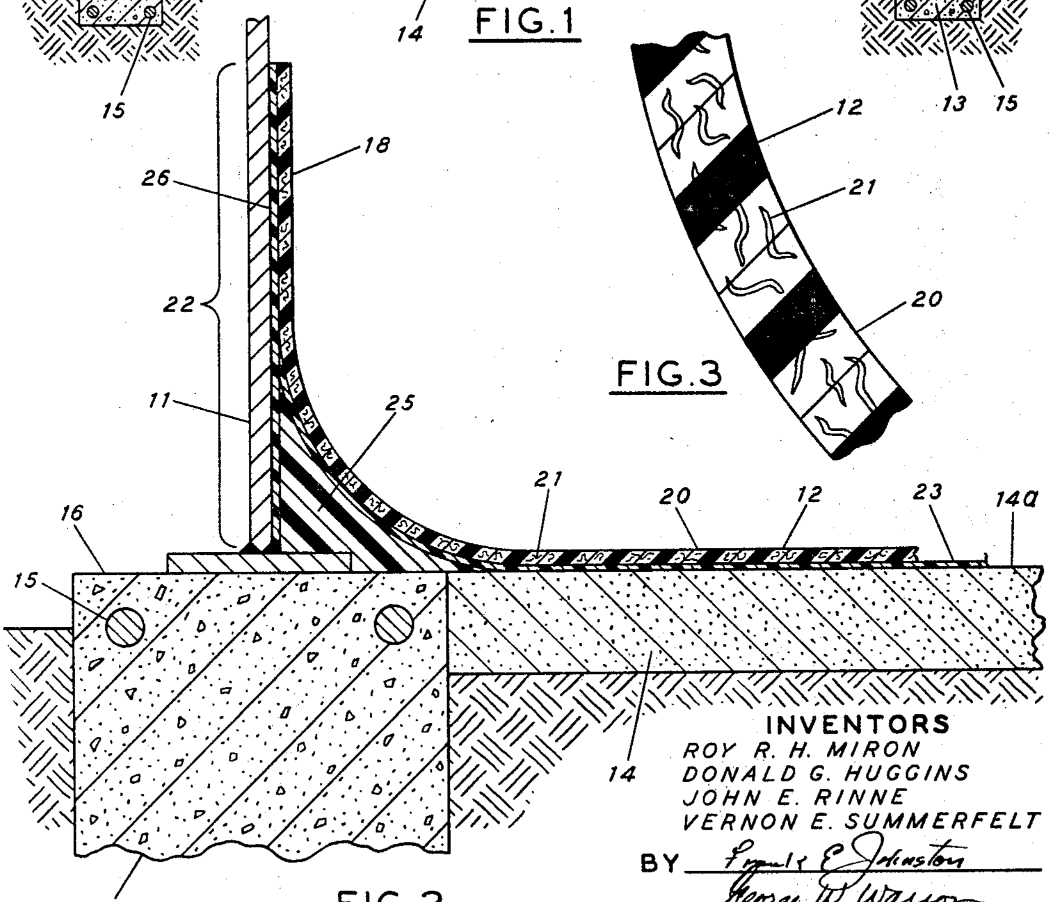


FIG. 2

FIG. 3

INVENTORS
ROY R. H. MIRON
DONALD G. HUGGINS
JOHN E. RINNE
VERNON E. SUMMERFELT

BY Frank E. Johnston
George W. Wasson
ATTORNEYS

United States Patent Office

3,423,264

Patented Jan. 21, 1969

3,423,264

METHOD OF BUILDING A CORROSION-RESISTANT STORAGE TANK

Roy R. H. Miron, Corte Madera, Donald G. Huggins, Walnut Creek, John E. Rinne, Berkeley, and Vernon E. Summerfelt, Anaheim, Calif., assignors to Chevron Research Company, a corporation of Delaware

Filed Mar. 29, 1965, Ser. No. 443,420

U.S. Cl. 156—71 4 Claims

Int. Cl. E04f *5/12;* E04g *21/00;* E04h *7/04*

ABSTRACT OF THE DISCLOSURE

The method of forming a storage tank suitable for corrosive fluids consisting of the steps of:

(1) forming a foundation suitable for support of said storage tank having a base enclosed by a concrete support annulus,

(2) forming said annulus so that its depth is greater than that of said base,

(3) assembling a closed enclosure formed of ferrous metal having a roof and a side wall,

(4) placing the lower edge of said wall in contact with said annulus, with said roof being positioned at a location remote from said foundation, and

(5) thereafter constructing a bottom for said enclosure exclusively of a fibrous glass reinforced thermosetting resin selected from the group consisting of epoxy resins, and the reaction product of ethylenically unsaturated polyesters with a vinyl monomer.

This invention relates to the construction of large diameter tanks or containers for storage of corrosive fluids.

The objects of the present invention are:

(1) To provide a low-cost storage tank construction for fluids in which the occurrence of both corrosion of the bottom of said tanks and breakdown of the joint between the bottom and side wall are minimized, and

(2) To provide a novel method for constructing such tanks.

The invention is useful in the construction of storage tanks for the containment of corrosive fluids such as crude petroleum oil stock, fuel oils, kerosene, gasolines, propane, butane, etc. either at atmospheric or at higher pressures.

Although not limited thereto, the invention has particular utility in the storage of volatile liquids such as gasoline and the like. In storing volatile liquids, the enclosing tank is constructed, inter alia, (a) to prevent escape of vapor, (b) to withstand internal pressure owing to both vapor pressure and the weight of the liquid above a particular point within the tank, and (c) to minimize the effect of corrosive reactions both interior and exterior of the tank. The vapor pressure depends on several factors such as volatility of the contained liquid and its temperature. The head-pressure depends upon the density of the stored liquid, and varies with the weight of the liquid above the measuring point within the tank, reaching a maximum at the bottom. The corrosion of the tank depends upon the nature of the stored fluid (direct corrosion) and upon the nature of the soil exterior of the tank (electrochemical corrosion).

Experience has shown that the tank may be constructed to withstand the vapor pressure and moreover, may incorporate safety features such as safety valves for the escape of pressure if a maximum pressure, for some reason, is exceeded. But such tanks may still develop leaks along their bottoms owing to direct and/or indirect electrochemical corrosion. Furthermore, inasmuch as the intersection of the bottom and side wall is often structurally weaker than other portions of the tank, a stressed concentration may occur there due to the weight of the stored fluid, with a corresponding break-down of the joint irrespective of the safeguards taken to prevent corrosion, namely, by coating or lining the bottom with noncorrosive materials familiar to those skilled in the art.

In accordance with the present invention, a storage tank comprises a side wall and roof formed of ferrous metal to maximize structural rigidity, and a bottom formed of reinforced thermosetting resinous materials to maximize corrosion resistance. The side wall is attached at its lower edge to a concrete support annulus reinforced by annular steel bars to prevent edge settlement of the tank. The bottom includes a dished periphery attached to the side wall, but, over its central region, is supported by a base composed of substantially compacted aggregate materials or alternatively, by bituminous materials such as asphalt or coal tar. The base is preferably located concentrically within the concrete annulus, and has a density that is a function of the amount of compacted force supplied during its formation as by large steel rollers drawn across the near surface.

In accordance with other aspects of the invention, a corrosion-resistant storage tank may be formed with relative ease at minimum cost by forming a foundation consisting of a concrete reinforced support annulus and a base of substantially compacted aggregate or bituminous material. The base is preferably enclosed within the annulus. After the foundation is formed, a vertically extending side wall enclosed at its open end by a roof and composed of a ferrous metal, is assembled to a unitary structure as by welding or riveting. The lower edge of the side wall is located in contact with the annular concrete support. After the side wall and roof are assembled, a sheet or film of plastics or some other substrate material such as extruded polyethylene or polypropylene film, is laid over the base in snug contact with the edges of the side wall. A coved support is provided at the intersection of the side wall and bottom to provide a base for the dished periphery of the bottom to be formed. The coved support extends in a vertical direction over a section of the side wall. Thereafter, the bottom is formed by depositing a layer of thermosetting resinous material such as isophthalic polyester upon the base and the lower section of the side wall. The thermosetting resinous material contains glass fiber reinforcement, the glass fibers being either chopped strands deposited with the resin or continuous strands attached together in a cross-linked mat or woven fabric saturated with the resin. As the resin is cured, the atmosphere within the tank may be controlled by closing the interior to the movement of air, or if a higher curing temperature is desired, the temperature of the interior may be increased by a heated medium such as steam, heated air, etc.

Heretofore, it has been proposed to line storage tanks with various materials to resist both corrosive effects of the stored fluid within the tank and soil exterior of the tank. Examples of lining materials include glass, enamel, concrete, various elastomers such as rubber, neoprene, etc., as well as plastics materials formed of resinous materials such as orthophthalic and isophthalic polyesters and various epoxies. However, these materials have often proved unsatisfactory either because of chipping, nonadhesiveness, interaction of the lining with the fluid contained within the tank, or because of the fabrication problems they present. Moreover in using concrete liners or supports, experience has shown that owing to their weight, overstressing of the joint formed between the bottom and side wall may occur and require the introduction of expensive, prestressed joints.

Further objects and advantages of the invention will become more apparent after reading of a preferred embodiment of the invention in which:

FIGURE 1 is a side elevational view of a storage tank constructed in accordance with the invention, partially cut away to illustrate the attachment of the bottom formed of thermosetting resins to the ferrous metal side wall;

FIGURE 2 is an enlarged diagrammatical view of the region of the tank where the bottom is attached to the side wall and particularly illustrates the use of a concrete support annulus for support of the tank shell and the use of a compressible base for support of the tank bottom; and

FIGURE 3 is an enlarged view of the bottom of the tank of FIGURE 1.

Referring now to FIGURE 1, there is illustrated a storage tank **10** in accordance with the invention consisting of a vertical cylindrical tank shell or side wall **11** formed of stainless steel or other suitable ferrous metals in which structural strength does not decline excessively with changes in temperature, and a bottom **12** formed of a polymerized thermosetting resinous material reinforced with glass fibers. The shell **11** and bottom **12** are supported by a foundation usuallly comprising a concrete support annulus **13** and a base **14**. The base **14** is formed of materials commonly classified as "highway materials" concentrically located within the annulus as shown. Shell **11** attaches at a lower end to the concrete support annulus **13** preferably along broad surface **16** thereof. The annulus **13** is reinforced with annular metal bars **15** and preferably has a vertical dimension much greater than that of base **14**. Consequently, the support not only minimizes the occurrence of edge settlement of the completed tank (without the added bulk and cost of a continuous concrete base across the entire bottom) but also prevents horizontal movement of the base as pressure is applied to bottom **12**, as by the pressure of fluid stored within the tank.

The base **14** may be formed of both fine and coarse aggregates, e.g., sand, crushed stone, broken slag, gravel, brick, as well as bituminous materials such as asphalts and tars. These materials are characterized by the ability to undergo compaction as a function of applied weight in the vertical direction viewed in FIGURE 1.

The shell is closed in its upper end by roof **17**. The roof is attached to the shell by means of brackets or other suitable fasteners which may be slidable in a vertical direction to allow movement of the roof relative to the side wall. The side wall level and roof **17** are preferably fabricated into a unitary structure prior to the formation of the bottom **12**, for reasons that appear below.

Bottom **12** as viewed includes a dished periphery attached to the side wall **11** and is supported over its central region by the base **14**. As illustrated in FIGURE 3, bottom **12** preferably comprises a blended formation **20** of polymerized thermosetting resins preferably reinforced by fibrous glass generally indicated at **21**.

In accordance with the invention, resins constituting formation **20** are classified as bistable materials, the resin changing from a viscous state to a solid state by reacting the resin with a curing agent, such as catalyst or crosslinking agent.

Illustrations of resinous materials useful with the invention are the polymerized resins such as ethylenically unsaturated alkyd resins, i.e., unsaturated polyesters, such as those derived from a polyhydric alcohol, an alpha, beta-ethylenically unsaturated aliphatic acid, such as a maleic, a portion of which is replaced, if desired, with a phthalic acid and/or a saturated aliphatic dibasic acid, and a monomer polymerizable therewith containing the group

$$CH_2{=}C\Big\langle$$

in an amount, for example, of 30 to 70 percent based on it and unsaturated polyester, the whole curable to the final solid state by treatment with a catalyst, such as a peroxy catalyst; epoxy resins, obtained by condensing epichlorohydrin with a polyhydroxy compound, the condensation product being finally cured to the solid, insoluble, infusible state by means of a curing, cross-linking agent, such as an amine, a dicarboxylic acid anhydride or other resins, such as urea formaldehyde, and melamine formaldehyde.

In carrying out the process of the invention, a curable resin of the type defined is caused to adhere to the side wall and base of the storage tank. Surprising adhesion of the polymerized resin relative to the side wall is achieved by careful preparations prior to the deposition of the resin, namely, applying an abrasive to rid the wall of rust, oil, grease, and other like matter. The wall surface to be cleansed depends upon the area required for adhesion of the bottom floor to the side wall and varies from approximately one to four feet in the vertical direction of FIGURE 2. Usually, the cleansed wall surface is cylindrical and is indicated in that form at **22** in FIGURES 1 and 2.

Inasmuch as preparing the side wall of the tank and the insertion of the plastic bottom may not be accomplished in one day, rusting and contamination of the cleansed metal surface begins to take place almost immediately. It may, therefore, be necessary that a protective primer coat **26** be applied as soon as the metal area has been cleaned. The material chosen as a primer coat is desirably quick-drying to avoid picking up excessive contaminants and must be compatible with the resins to be subsequently deposited thereon. A nonexclusive listing of such primer coatings useful in this regard includes amine-cured epoxy primers, two-component wash primers and thin coats of the same thermosetting resins to be subsequently used to form the bottom.

Application of the prime coat may be achieved by means of open molding techniques well understood in the art. For example, in spray molding, one of the better-known open molding techniques, an assemblage of spray tips (one or more) directs a spray containing as for example, an unsaturated polyester resin, catalyst and accelerator or promoter toward a desired focal area on the surface of the side wall. As a layer is deposited, the resin spray is redirected to new surfaces until a uniform deposit is achieved on the desired portion of the side wall. With reference to FIGURE 2, the above-identified portion would cover previously cleansed portion **22**. In the lay-up method, another well-known open molding technique, the prime coat is applied by brush, trowel, etc. Although the lay-up method is somewhat slower than the spray technique, it may be preferred in some cases because of the more uniform and predictable results provided. After the spray has been deposited, the coating is allowed to stand overnight to cure.

A thin layer of plastics film or sheeting **23**, formed of extruded polyethylene or polypropylene or other material, is placed in contact with the near surface of base **14** terminating in the horizontal in snug contact with the inner surface of the side wall **11**. Layer **23** may be of unitary construction, as by thermowelding the overlapping edges of separate rows of the plastic material, or be of a more loosely formed construction as by overlapping rows of the film or other material without permanently attaching the edges. The purpose of the film is to prevent escape of the resin as the latter is deposited on the near surface **14*a*** of the base **14**, FIGURE 1, and to provide a flexible sliding joint between side wall **11** and bottom **12** above cove support **25**.

Coved support **25** formed of plastic putty is constructed at the junction of the base **19** with the side wall **11**. It is curved with respect to the interior of the tank, and may be resilient to provide a stress-freeing support for the resin as attachment of the bottom to the side wall is achieved, as explained below.

Application of resin to form the reinforced bottom **12** is performed in a convenient manner. The central region may be formed in a continuous manner or in segments having ends that extend into contact with the side wall to form the dished periphery. In forming the wall **12** using, for example, the spray technique, the assemblage previously described is augmented by a chopping means intermediate between the spray of resinous material for the purpose of flowing short lengths of reinforcement material such as fibrous glass into contact with the target area and the sprayed resinous material. Glass roving may serve as a reservoir for the chopper, and the chopped residue, approximately one inch in length, is propelled from the chopper by a steady stream of air. In practice, the chopping means is controlled to give a final consistency to the formed bottom of approximately 15–30% reinforcing material by weight.

After the described mixture has been applied to a uniform thickness, e.g., to a thickness of from 1/32 to 3/8 inch, it is rolled with reticulated metal rollers about 3 to 5 inches in diameter, made of 1/4-inch wire cloth or fine-mesh expanded metal. The roller presses the random fibers together in planes parallel to the surface being coated, and due to its reticulated structure, repeatedly presses fibers below the surface of the still-liquid or unset resin, thus removing the strength-reducing air bubbles that otherwise tend to cling to the individual fibers. As a practical test, the rolling operation is terminated when the plastics mass is substantally transparent, i.e., when the individual glas fibers are so thoroughly flattened and wetted with resin that they are not visible.

To render the formed surface resistant to solvents and chemicals, a surface coat of the same resin used to form the bottom is made to adhere to the deposited resin. This coating may contain a standard, refined wax such as a paraffin wax or other inert filler having a melting range of 125–160° F. in a 0.05–0.5% solution. This final "seal-coat" prevents "wicking" (capillary travel) of the contained liquid along the surface of the exposed glass fibers.

In forming the bottom by the lay-up technique, the reinforcing material is not added simultaneously with the deposition with the resins as in the spray technique. Specifically, the reinforcement is a unitary structure, as for example, fibrous glass woven fabric, woven roving, or fibrous glass matting. The reinforcement is thereafter deposited with the resin, and the mixture is permitted to cure. Additional layers of resin and reinforcement may be added to increase the thickness of the wall if desired and overlap seams formed in the prior deposited layer. After the resin and reinforcement are worked to completely saturate the reinforcement with resin, a thin topcoat or seal-coat similar to that previously described may be applied to the exposed surface to prevent wicking and provide a more solvent and chemical resistant surface.

As a further aid to curing, the temperature of the atmosphere within the formed tank may be carefully stabilized during curing as by closing the apertures of vents (not shown) formed integral with the roof or ports **27** formed at the side wall **11** to prevent entry of wind, rain, etc., into the tank. Moreover, if desired, the temperature of the curing atmosphere may also be altered by a heating medium such as steam, air, etc., to increase the temperature within the tank. Inasmuch as many thermosetting resins require relatively high curing temperatures, the number and effectiveness of resins compatible with construction of a storage tank in accordance with the present invention are correspondingly increased. For example, in the formation of the bottom using described unsaturated polyester resins cured with suitable catalysts, the curing time may be conveniently aided by heating the resin, as by circulating warm air within the interior of the tank.

The following examples illustrates the practice of the invention.

Example 1

Isophthalic acid, 1 mol, is reacted with 2.1 mols of of propylene glycol under an inert atmosphere of nitrogen and at a temperature of 400° F. Heating is continued for six hours. Water of condensation is removed by a steam-jacket reflux condenser. Heating is terminated when water ceases to be expelled from the reaction zone and the acid number is below 5. There is then added 1 mol of maleic anhydride, the reactants being maintained under and atmosphere of nitrogen as before. The temperature is maintained at 240° F. for eleven hours. The resin is then mixed with varying proportions to styrene. The specification of the resin is as follows in accordance with standard methods:

Acid number	10–15
Color (Gardner-Holdt)	3–5
Viscosity (Gardner-Holdt):	
30% styrene	Z6–Z7
40% styrene	X–Y
50% styrene	I–K
60% styrene	A–B
Gel time [1]	5–10

[1] Resins contain 40% styrene, 1% Lupersol DDM (60% methylethyl ketone peroxide in dimethyl phthalate), 0.6% cobalt naphthenate.

As is known in the art, the viscosity of the resin can be made to vary over a wide range as shown. In general, resins prepared as above described having an acid number below 20 when mixed with 40–50% by weight of styrene will given viscosities satisfactory for the purposes of this invention. To provide adequate stability against premature gelation during dilution in styrene and storage, suitable stabilizing agents, such as hydroquinone or tertiary-butyl catechol, are also incorporated.

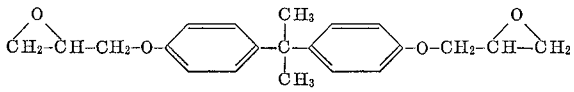
The resinous mixture is then transported to the tank site where the side walls and roof have been assembled into a unitary enclosure. The mixture is then caused to be introduced to a precleaned portion of the side wall by forming methods previously described. A catalyst is either simultaneously introduced to the mixture or is later caused to be deposited within the resin, to initate polymerization. In order to supplement catalyst activity, a promoter is used along with the catalyst in amounts of 0.1–2% based on the finshed resin. Suitable catalysts are the hydroperoxide and peroxide initiators, such as benzoyl peroxide, methyl-ethyl ketone peroxide, and the like. They are employed in the customary amounts of 0.5–2% based on the finished resin. A suitable promoter is also added, such as cobalt naphthenate, (6% cobalt solution) used in amounts of 0.1–2% by weight based on the finished resin.

The primer coat is then cured, aided by a motionless or heated atmosphere provided the interior of the tank. Thereafter, when the primer coat is substantially solid, glass fibrous reinforcement together with additional resin is deposited over the primer coat as well as on the near surface of the foundation of the tank to conveniently form the bottom. The bottom may be formed in layers and each layer is rolled and worked to expel air and press the fibrous glass reinforcement below the surface before the next layer is added. The reinforced layer is permitted to cure to a point where it is substantially solid, whereupon, a finish coat of unreinforced resin similar to the composition of the primer coat is applied in similar fashion. Since oxygen prevents or inhibits cure of the resin, the final coat of resin may contain an oxygen resisting agent. For this purpose, 0.1–0.5% by weight of standard refined paraffin wax of melting point range 125–160° F. is dissolved in the finish coat prior to application. The wax migrates to the surface and prevents oxygen from contact with the mass of resin.

After a reasonable set time, aided by a warmed atmosphere within the interior of the tank, the tank is allowed to receive corrosive fluids.

Example 2

Epoxy resin having the formula



or other suitable thermosetting epoxy, is transported to the tank site where the side walls and roof have been assembled into a unitary enclosure. The mixture is then caused to be introduced to a precleaned portion of the side wall by open-molded forming methods previously described. A curing agent is either previously mixed into the resin simultaneously introduced to the mixture or is later caused to impale on the resin, to initiate polymerization. Suitable curing agents are amines, dicarboxylic acid anhydrides or other resins, such as urea formaldehyde and melamine formaldehyde. They are employed in the customary amounts based on the finished resin and may include styrene oxide or other reactive diluent in an amount of about 35% by weight to give viscosities satisfactory for the purposes of this invention.

The primer coat is then cured, aided by a motionless or heated atmosphere provided the interior of the tank. Thereafter, when the primer coat is substantially solid, glass fibrous reinforcement together with additional epoxy resin and curing agent is impaled on the primer coat as well as on the near surface of the foundation of the tank to form the bottom. The layer is then rolled and worked to expel air and press the fibrous reinforcement below the surface. The reinforced layer is permitted to cure to a point where it is substantially solid, whereupon, a finish or sealcoat of unreinforced resin is applied.

After a reasonable set time, aided by a warmed atmosphere within the interior of the tank, the tank is allowed to receive corrosive fluids.

While certain preferred embodiments of the invention have been specifically disclosed, it should be understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims:

1. The method of forming a storage tank suitable for corrosive fluids consisting of the steps of:

(a) forming a foundation suitable for support of said storage tank,

(b) assembling an enclosure formed of ferrous metal having at least a side wall in contact with said foundation, and

(c) thereafter constructing a bottom for said enclosure substantially of a reinforced thermosetting resin, said bottom of reinforced resin being in supporting contact with said foundation at least over a central portion thereof and being circumferentially secured to said side wall adjacent to the bottom of said side wall so as to form at least in part the load-bearing bottom structure of said storage tank.

2. The method of claim **1** in which the step (b) of assembling said enclosure in contact with said foundation includes the substep of attaching a roof to said side wall atop said foundation so as to provide control of environmental conditions within said enclosure as step (c) related to the construction of the bottom of said enclosure is performed.

3. The method of forming a storage tank suitable for corrosive fluids consisting of the steps of:

forming a foundation suitable for support of said storage tank having a base enclosed by a concrete support annulus,

forming said annulus so that its depth is greater than that of said base,

assembling a closed enclosure formed of ferrous metal having a roof and a side wall,

placing the lower edge of the side wall in contact with said annulus, with said roof being positioned at a location remote from said foundation, and

thereafter constructing a bottom for said enclosure exclusively of a fibrous glass reinforced thermosetting resin selected from the group consisting of epoxy resins, and the reaction product of ethylenically unsaturated polyesters with a vinyl monomer.

4. The method of forming a storage tank suitable for corrosive fluids consisting of the steps of:

forming a foundation suitable for support of said storage tank having a base enclosed by a concrete support annulus,

forming said annulus so that its depth dimension is greater than that of said base,

assembling a closed enclosure formed of ferrous metal having a roof and a side wall, placing the lower edge of said side wall in contact with said annulus,

preparing the metal surface of said side wall of said enclosuer to expose an oxide-free metal surface in the region adjacent to said foundation,

providing a coved support formed of plastic putty at the junction of said enclosure and said foundation,

causing a continuous layer of thermosetting resin and curing agent to adhere to said prepared surface and to said foundation to thereby form a disked bottom exclusively of said resin and fibrous reinforcement,

working said bottom to expel air,

increasing the temperature of the atmosphere within the enclosure and,

curing said bottom.

References Cited

UNITED STATES PATENTS

1,339,062	5/1920	Johnson	52—247
3,050,208	8/1962	Irvine	52—249 X
3,054,523	9/1962	Batzer et al.	52—249 X

OTHER REFERENCES

Concrete: "Concrete Sealed by Glass Cloth and Resin," June 1949, pp. 12 & 45, copy in class 52, subclass 309.

HAROLD ANSHER, *Primary Examiner.*

U.S. Cl. X.R.

52—247, 249, 309, 741; 156—293, 330, 332; 220—18