United States Patent [19]

Closner et al.

[11] **3,863,408**

[45] **Feb. 4, 1975**

[54] **PRESTRESSED CONCRETE TANKS FOR LIQUID NATURAL GAS TANKERS**

[75] Inventors: **John J. Closner**, Douglaston; **Tadeusz Josef Marchaj**, New York; **Sven Hjalmar Wichman**, Yaphank, all of N.Y.

[73] Assignee: **Preload Technology, Inc.**, Garden City, N.Y.

[22] Filed: **Sept. 27, 1972**

[21] Appl. No.: **292,727**

[52] **U.S. Cl.** **52/224**, 52/227, 220/3

[51] **Int. Cl.** **E04c 3/26**

[58] **Field of Search** .... 220/5 A, 3, 9 LG; 52/224, 52/227; 137/357

[56] **References Cited**

UNITED STATES PATENTS

2,360,391	10/1944	Birchall	220/3
3,256,069	6/1966	Peterson	220/3 X
3,293,139	12/1966	Bellier	52/224 X
3,329,297	7/1967	Jordan	220/5 A
3,503,171	3/1970	Frohly	52/224

FOREIGN PATENTS OR APPLICATIONS

1,524,285	4/1968	France	52/227
214,464	8/1967	Sweden	52/224

Primary Examiner—Alfred C. Perham
Attorney, Agent, or Firm—Curtis, Morris & Safford

[57] **ABSTRACT**

A tank for cryogenic liquids, specifically liquid natural gas, adapted for placement within a conventional marine transportation vessel is shown. The tank is preferably cylindrical and of circular cross section and is comprised of prestressed concrete with steel heads. The tank wall is made up of a series of concrete, modular tank wall sections which are circumferentially prestressed by steel tendons and which have holes therein for through-passage of axial prestressing tendons. A steel sheath anchored to the concrete wall provides a secondary barrier against leakage of the liquid natural gas cargo within the tank. The modular wall sections are separated by concrete or steel stiffening disks. The tank is formed by alternately positioning a number of modular wall sections and stiffening disks. Flat, concrete, stiffening plates which are integral with the modular tank wall sections and are radially-axially positioned within the tank further stiffen the structure. The walls and the stiffening plates are axially prestressed and the heads are attached. The tank is supported on the annular stiffening disks which are joined to the tank wall. The tank makes efficient use of the vessels cubic and is inexpensive to construct. By preforming and prestressing the modular units and thereafter erecting them rapidly at the ship-building site or at a removed fitting out site, important economies are achieved.

14 Claims, 9 Drawing Figures

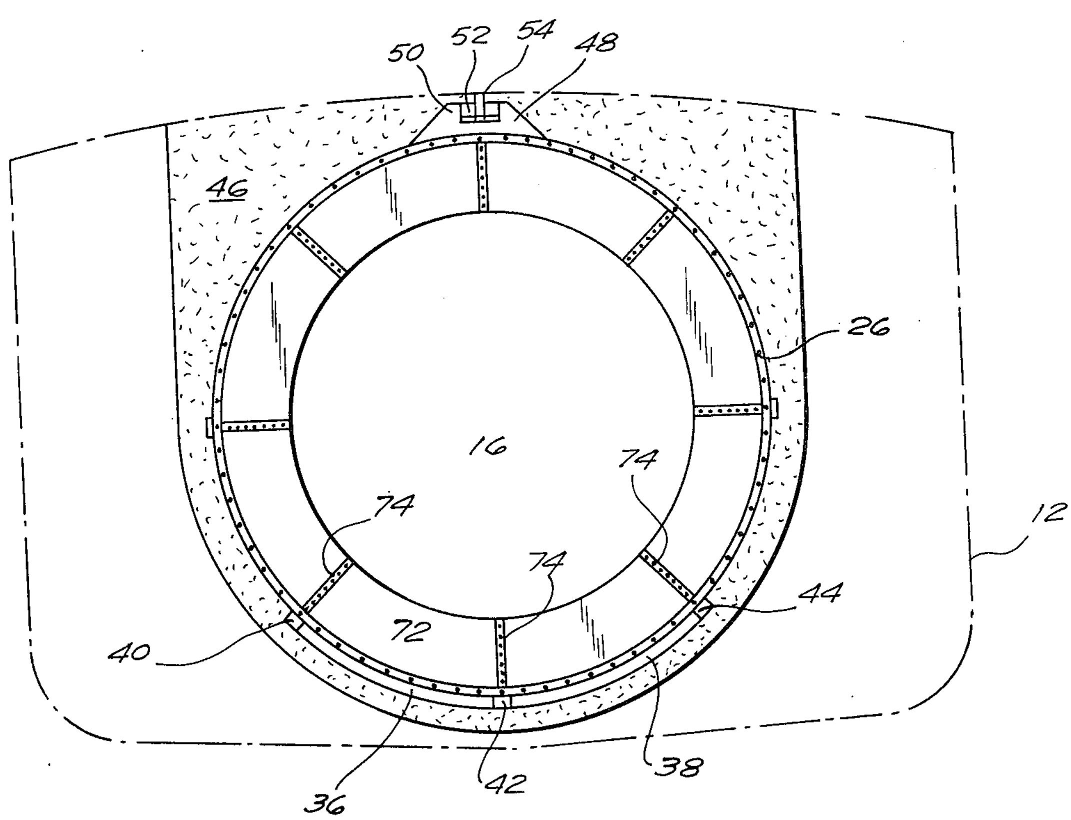
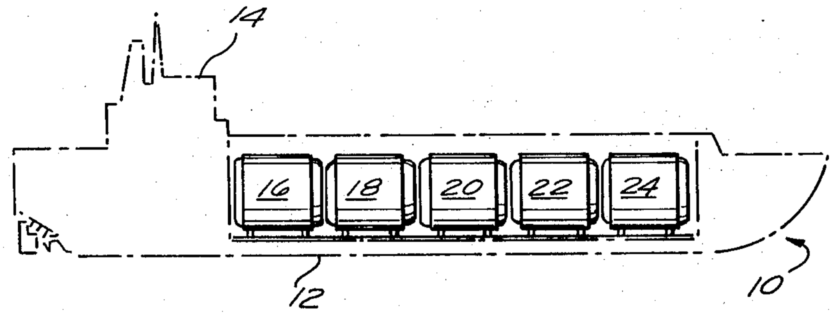


FIG. 1


14
16
18
20
22
24
12
10

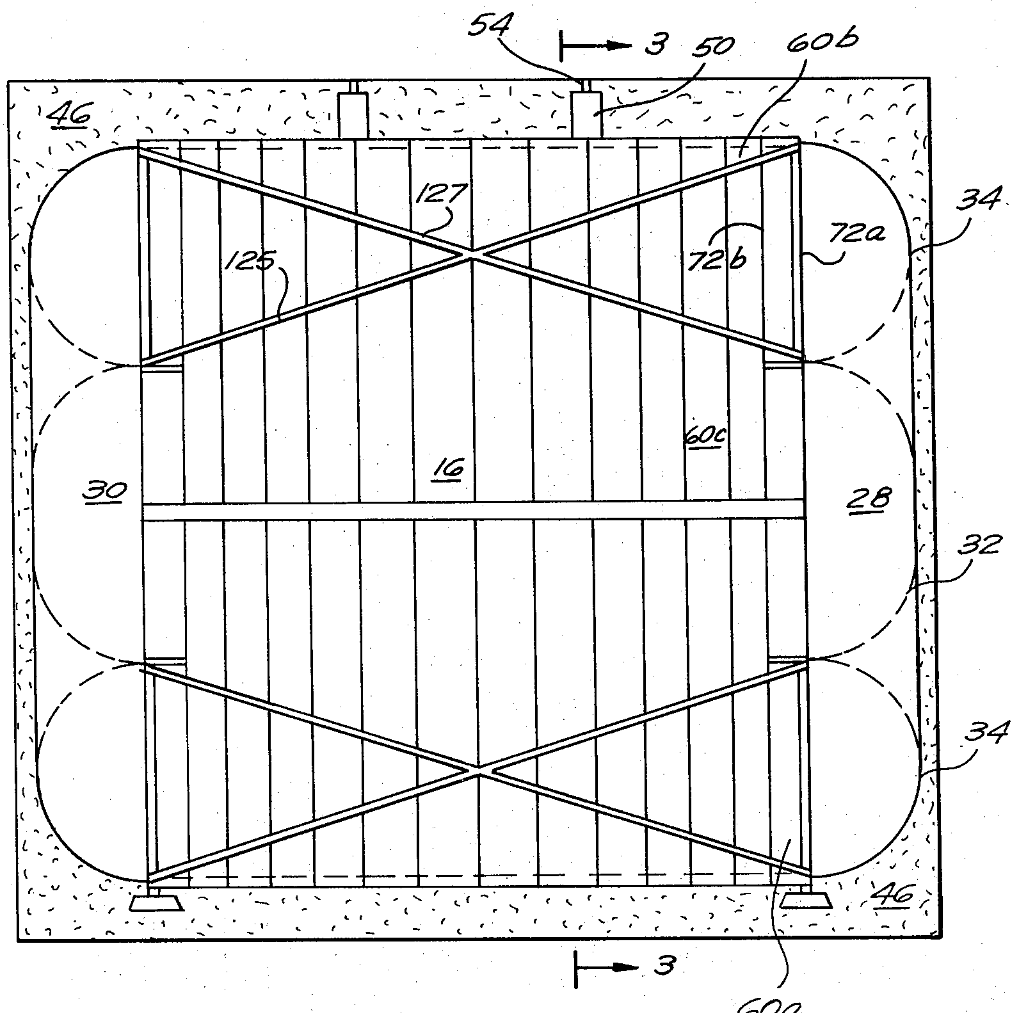

54
3
50
60b
46
127
34
72a
125
72b
60c
16
30
28
32
34
46
3
60a

FIG. 2

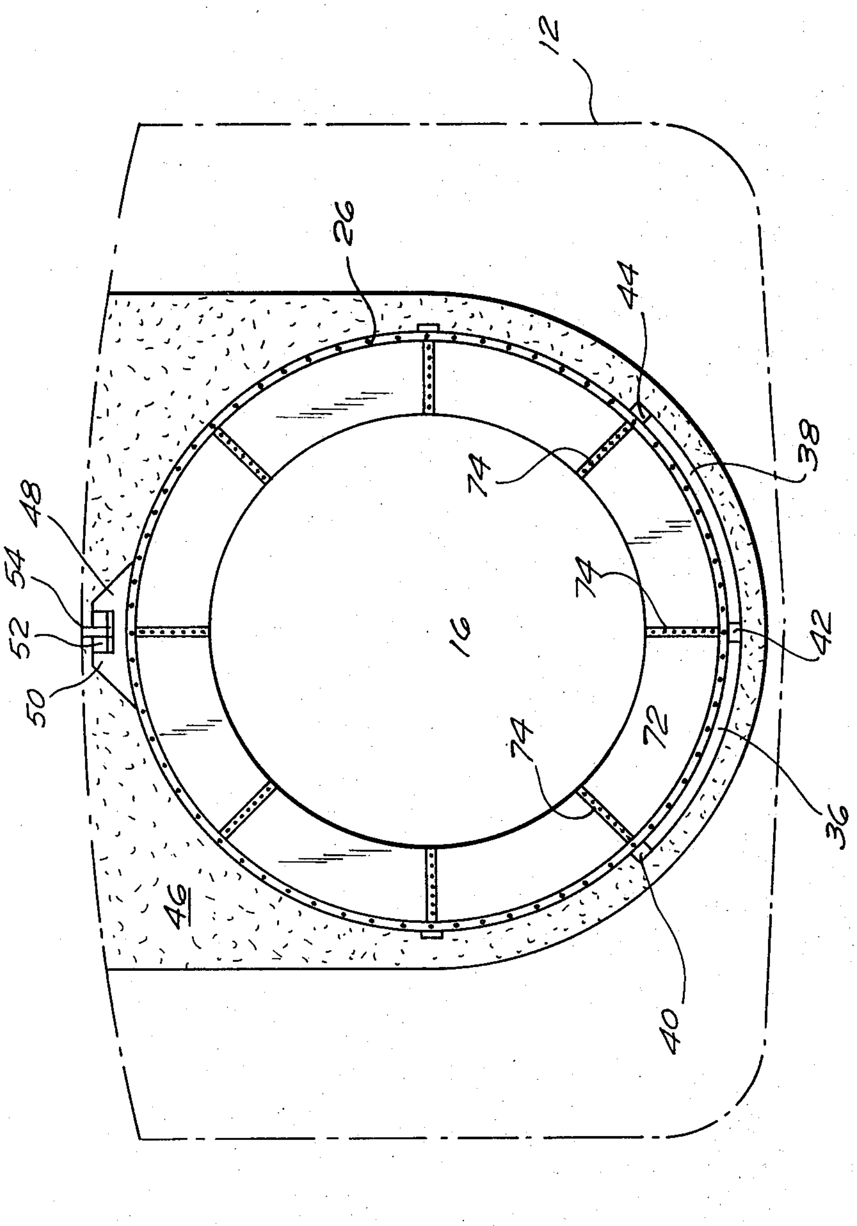


FIG. 3

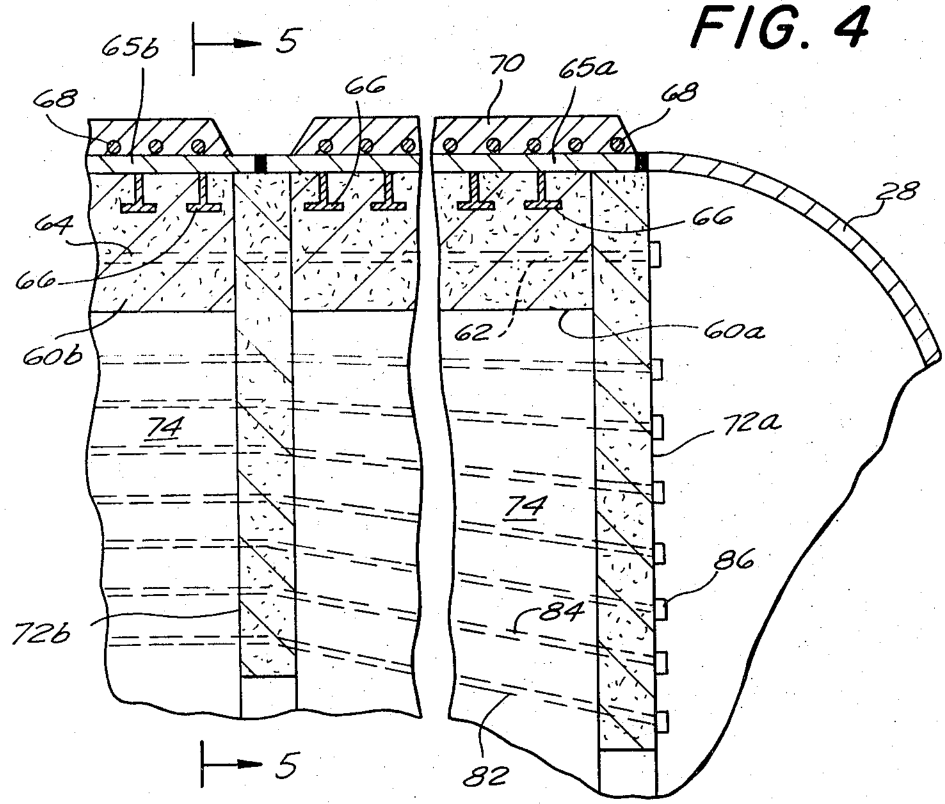

5
65b
68
66
70
65a
68
28
64
66
66
60b
62
60a
74
72a
74
86
84
72b
5
82

FIG. 4

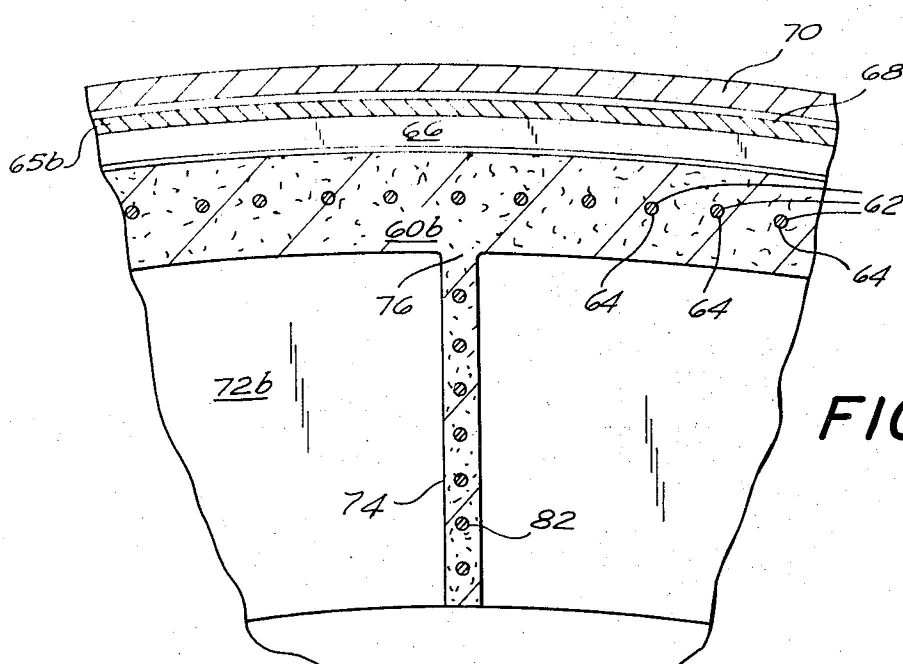

70
68
65b
66
62
60b
64
64
64
76
72b
74
82

FIG. 5

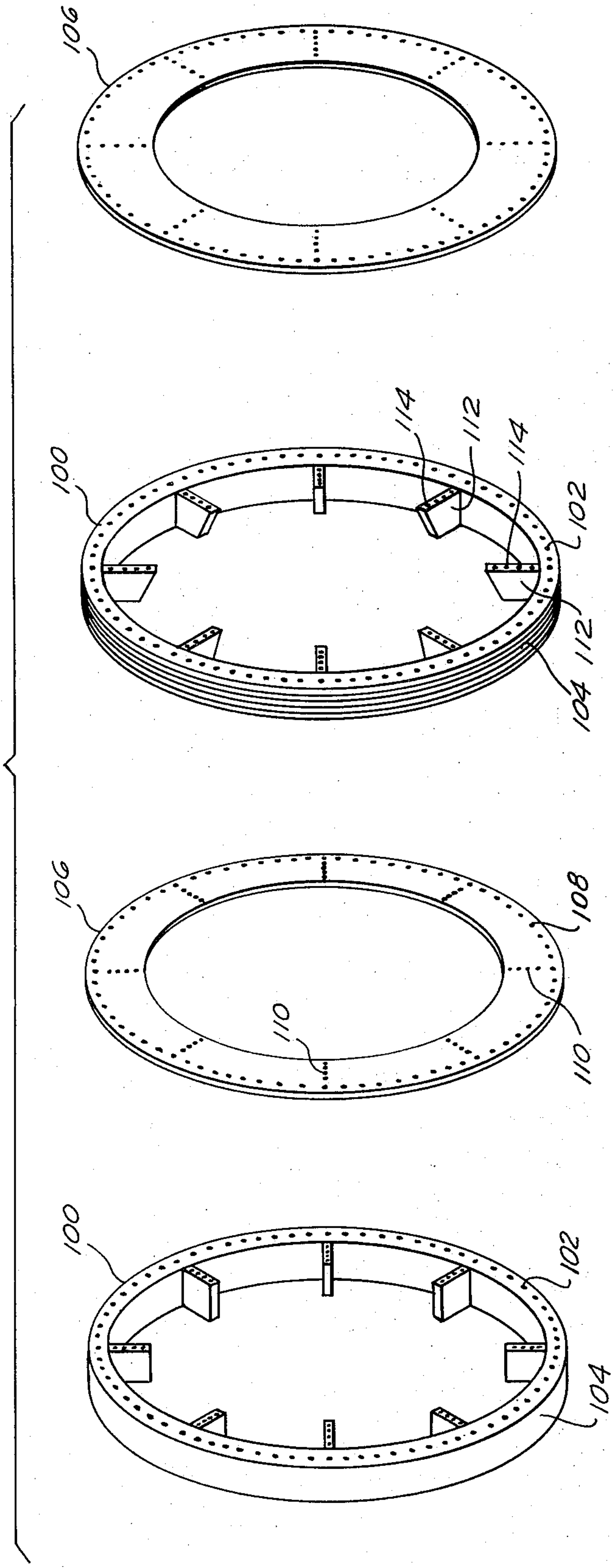


FIG. 6

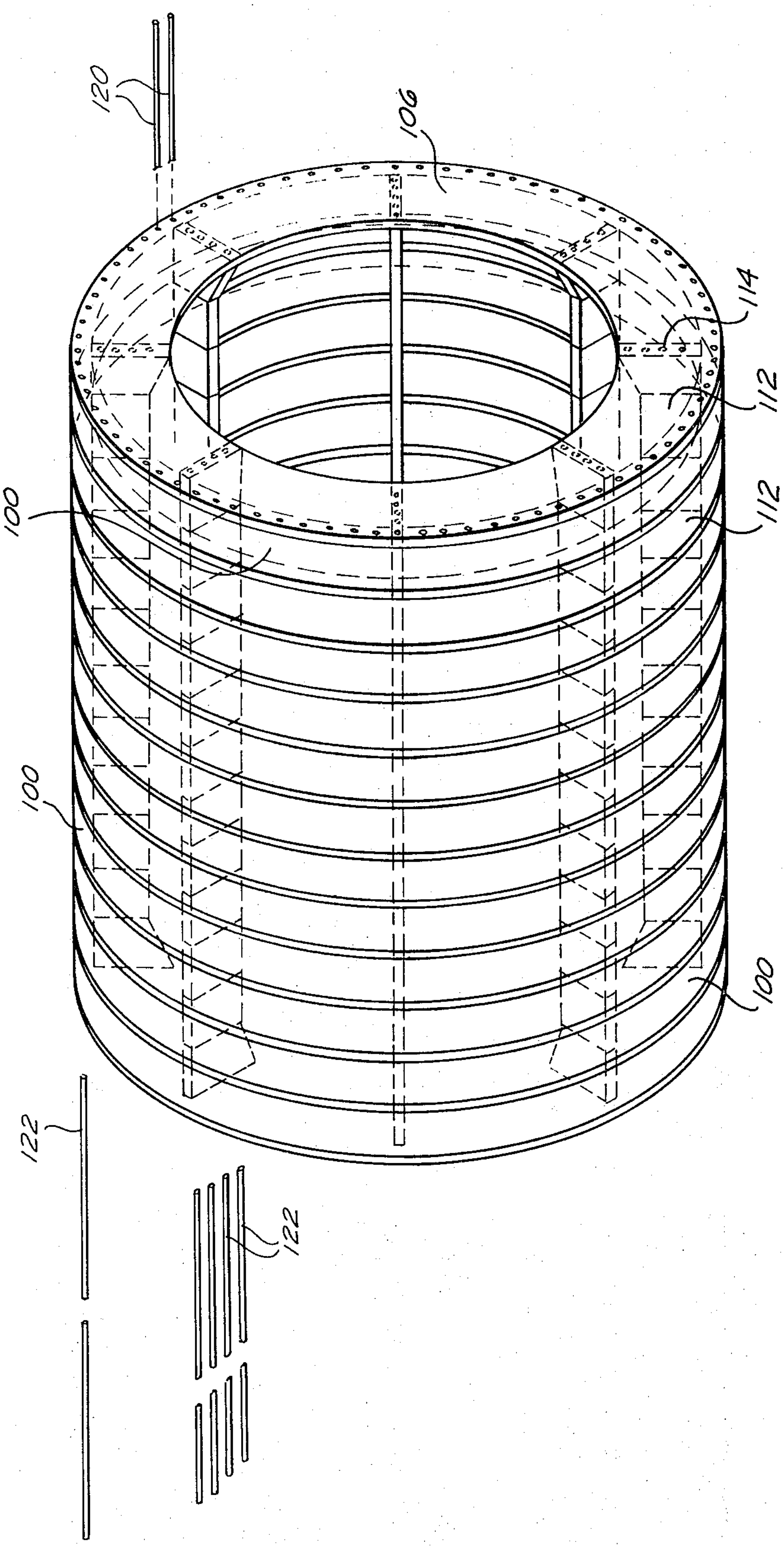


FIG. 7

FIG. 8

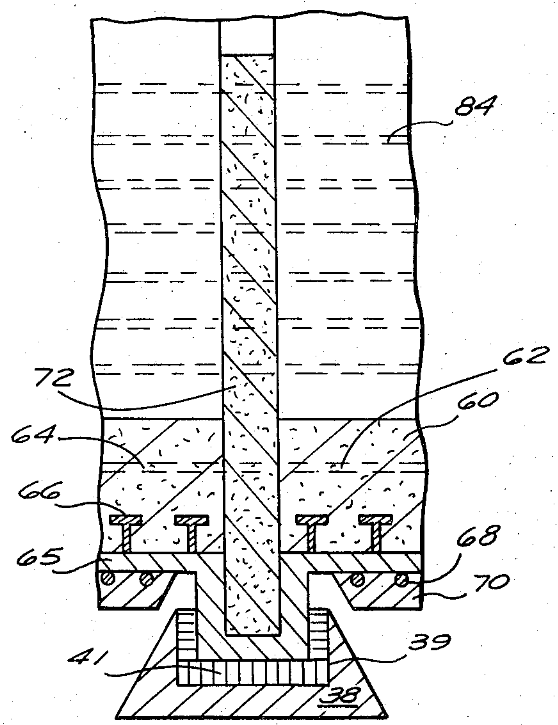
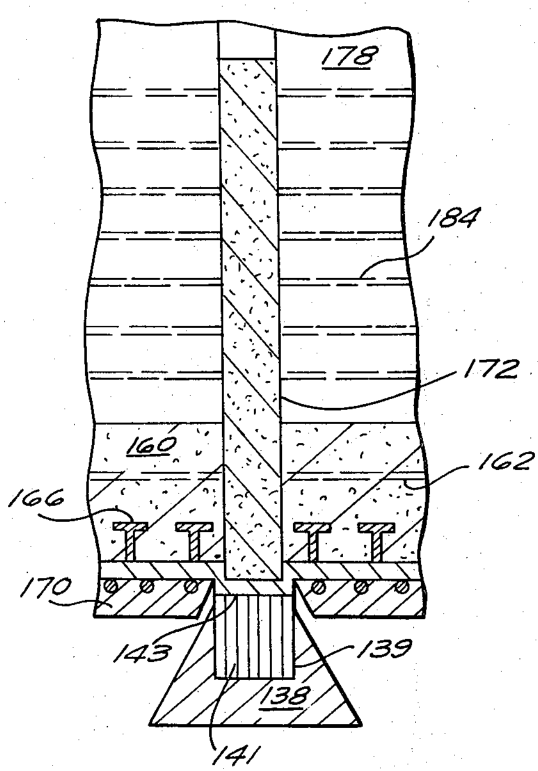

84
72
62
60
64
66
68
65
70
41
39
38

FIG. 9


178
184
172
160
162
166
170
143
139
138
141

PRESTRESSED CONCRETE TANKS FOR LIQUID NATURAL GAS TANKERS

This invention relates broadly to the transport of cryogenic liquids in marine vessels. More specifically, this invention relates to use of inexpensive prestressed concrete tanks in steel or concrete barges and ships for carrying liquefied natural gas. Even more specifically, this invention relates to a modular tank configuration for liquid natural gas tanks which provides exceptional safety features and economies in the design, construction and operation of marine transport vessels.

The art of transporting cryogenic liquids in ships and barges has developed rapidly in the past several years. The accelerating world-wide demand for liquid natural gas has resulted in development of ever larger barges and tankers and has given rise to several different types of cargo containment systems. World wide fuel shortages have now been foreseen and in view of the ecological acceptability of natural gas as a fuel, the demand for it will certainly increase. Thus, the art is faced with a need to develop safe and economical systems for liquid natural gas containment and transport.

BACKGROUND OF INVENTION AND PRIOR ART

Liquid natural gas is comprised of a mixture of primarily methane, with lesser amounts of ethane, propane and butane. Although the actual composition may vary according to source and with the degree of processing during liquefication, typical liquefied natural gas products have a boiling point, at atmospheric pressure of approximately −250°F. The natural gas is transported at these temperatures and at atmospheric pressures and the cargo containment systems must be designed for service at these temperatures as well as for cool-down and warm-up cycles.

It has long been recognized that carbon steels, which are used commonly in ship building are relatively weak at cryogenic temperatures. For this reason, the tanks are typically made of nickel steel or aluminum alloys which have superior strength characteristics at low temperatures and serve to safely contain the liquid natural gas cargo, protecting the hull of the vessel from exposure to extremely low temperatures. Several configurations of tanks, in ships and barges, have been developed, many of which provide a double barrier between the cargo and the external steel hull to protect the hull from exposure to low temperatures in the event of a rupture of the cargo containment system; and numerous intricate configurations have been developed for insulating the outer hull from the cryogenic temperatures. Configurations have also been developed to protect the cargo containment systems from rupture in the event of a collision which damages the external hull of the vessel.

Conventional liquid natural gas containment systems heretofore have fallen within three general catgeories: prismatic free-standing tanks, spherical free-standing tanks and membrane tanks. Although each of the several types of tanks and the several design variants thereof have been used with success in the past, and although each type of tank has certain advantages peculiar to it, each likewise has certain disadvantages. In evaluating each of the several alternative designs, many factors must be taken into consideration including the initial cost of the containment systems, the overall life of the system, operational safety, ease and time of con-

struction, unit cost per cargo-mile and many other factors.

The prismatic free-standing tank has been used more than the others. Generally, they are comprised of 9% nickel steel, stainless steel or aluminum alloy and their configuration roughly follows the interior configuration of the vessel. They include a secondary barrier between the tank and the steel hull of the vessel. Among the advantages of such tanks is that they are relatively efficient in terms of utilizing the internal volume (cubic) of the vessel. The center of gravity of such tanks is generally fairly low so that the amount of ballast required to trim the vessel is not excessive.

A very substantial disadvantage of prismatic, free-standing tanks stems from their configuration. To follow the shape of the hull structure, three corner systems are used, and although such structures are analyzable, design problems are more difficult than in tanks of more simple configuration. The many structural details and welded connections involved and the unknown stresses which develop due to thermal contraction of the steel, torsion of the hull, impact on the hull, motion of the vessel in a seaway and movement of the liquid within the tank, lead to a variety of structural problems. If simpler configurations, such as vertical cylinders are used, there is an attendant sacrifice in the efficiency of space usage within the vessel. Due to these problems, prismatic free-standing tanks tend to have a relatively higher weight and cost than do other types of tanks now in use.

Spherical, free-standing tanks have a salient advantage in that they are most easily analyzed for stresses, and accordingly spherical tank systems can be constructed having no secondary barrier or only a partial secondary barrier. A related advantage is that the spherical tanks can be relatively easily fabricated; there is no necessity for internal structural members to ensure the integrity of the tank; and there are no unforeseen problems of metal fatigue due to unforeseen stresses.

On the other hand, spherical tanks have certain disadvantages primary among which is their inefficiency in regard to use of the internal cubic of the marine vessel. There is a greater amount of waste space within the hull although this is partially offset by a greater availability of hull volume for carriage of ballast. They are also relatively difficult to support, have a relatively high vertical center of gravity and extend above the deck level causing operational problems.

Membrane tanks, which generally include two thin, flexible membranes comprised of, for example, stainless steel, and at least two layers of insulation separating the barriers from one another and the outer barrier from the steel hull of the vessel, have certain very significant advantages. Their primary advantage is that their configuration most closely follows that of the outer steel hull of the vessel and they therefore are most efficient with respect to use of the internal cubic of the vessel. The construction cost of membrane tanks is relatively less than that of free-standing systems because the thickness of the membranes is considerably less than that of the steel plate used in prismatic tanks. Thus, the total material cost is drastically lower than for prismatic tanks although the unit cost for the membrane material may be slightly higher. The smaller mass of the membranes also results in a substantially shorter cool-down time as compared with prismatic tanks. Installation costs for membrane tanks tend to be somewhat less than for prismatic tanks largely because the weight of the materials used is less.

The primary disadvantage of membrane tanks, is that they are virtually impossible to analyze structurally. Unknown problems of fatigue and stress concentration lead to increased risks, including the risk of damage to the primary barrier in the event of a ship collision. The free-standing tanks, particularly the spherical tanks are less subject to damage in the event of collision because they have greater structural integrity and are separated from the hull by additional space. The relatively weak membrane is also subject to damage during construction and during maintenance operations. Membranes can be damaged by overpressurization of the vapor space behind the primary barrier, by movement of liquid within the tank and by development of fatigue cracks or stresses within the hull of the vessel. For these reasons, construction of membrane tanks is more closely supervised by the authorities and must be attended with more care than with free-standing tanks.

In view of the many, and often conflicting, design, construction and operational factors which must be considered in the development of tanks for cryogenic liquids in marine vessels, there is considerable room for improvement over conventional containment systems. Several, but by no means all of the objectives facing the art are hereinafter set forth.

OBJECTIVES

It is the primary object of this invention to provide a tank construction for marine transport vessels having a configuration which makes maximum use of the internal volume of the marine vessel.

It is another primary object of this invention to provide a construction for such tanks which requires relatively inexpensive materials and is relatively easy to fabricate and erect within a conventional concrete or steel ship or barge.

It is still a further primary object of this invention to provide a tank having a substantial structural integrity to protect the outer vessel from the cryogenic cargo and to protect the cargo from damage in the event the outer vessel is ruptured due to collision.

It is a further and important object of this invention to provide a fully determinate tank system wherein the stresses can be readily analyzed without excessive design or testing work and wherein excessive safety factors and redundant structural systems need not be employed.

It is a further related object of this invention to provide a tank configuration which does not require the structural and operational complexities of a double barrier system.

It is still a further object to provide a tank which because of its structural simplicity and reliability will enjoy the benefit of relaxed design requirements of the authorities having jurisdiction over the design and erection of these tanks.

It is still a further object of this invention to provide economies in construction and specifically to reduce or eliminate the use of expensive alloy steels in the construction of cryogenic tanks in marine vessels.

It is a further object of this invention to provide a tank which is simple to erect in a ship yard and whose construction does not grossly disturb other operations within that yard.

It is a further object of this invention to provide a modular construction for such tanks which simplifies the tank construction and reduces the time required to complete such construction.

It is still a further object of this invention to provide a simple method for constructing the modular components of the tank.

It is another object of this invention to provide compartments within the tank to reduce movement of the cryogenic liquid contained therein during ship movement.

It is another object of this invention to provide a tank in which the weight of both the tank and its contents are distributed along the tank so as to reduce the concentrated loads normally encountered at the ends of horizontal cylindrical tanks;

It is another and related object of this invention to provide a tank structure which cooperates with the ship structure to reduce the requirements of the ship structure.

It is yet another object of this invention to provide a tank which has a low vertical center of gravity.

SUMMARY OF THE INVENTION

These and many other objectives of the invention are achieved in a tank for containment of cryogenic liquid, for placement within a marine transportation vessel which comprises a cylindrical tank wall, of any suitable curved cross-section for tank service but preferably of circular or elliptical cross-section comprised of prestressed concrete, and end closure means such as heads attached thereto. In order to withstand, the very considerable hydrostatic and vapor pressures which are developed within the tank, the cylindrical tank wall is prestressed by steel tendons positioned essentially circumferentially about its exterior surface and by other steel tendons, positioned within the tank wall itself, and oriented essentially parallel to the axis of the tank. To provide stiffness, one or more annular stiffening disks are positioned coaxially within the wall of the tank and are attached thereto. The stiffening disks are formed from steel or concrete and a portion thereof may extend past the exterior surface of the tank wall to provide support or retainer posts for the tank. Desirably a plurality of these stiffening disks are attached at intermediate locations between the heads of the tank. A series of planar stiffening plates (or ribs) are positioned in a radial-axial orientation with respect to the tank wall and are connected to the stiffening disks and to the interior of the tank wall. Desirably, the stiffening plates are flat, prestressed concrete plates and they, as well as the cylindrical tank wall have essentially axially positioned prestressing tendons therein. To provide a "secondary" barrier, a steel sheath may be anchored to the outer surface of the cylindrical wall. This sheath may be of carbon steel since it acts compositely with the prestressed concrete, and thus is not subject to tensile stresses when subjected to the low temperatures of the cryogenic liquid within the concrete container.

In the preferred tank configuration, the tank wall is concrete and of circular cross-section. A series of axial holes are located within the tank wall through which steel prestressing tendons are passed. A carbon steel sheath is anchored to the exterior of the tank wall by studs and external to the sheath are prestressing tendons wrapped essentially circumferentially. Either one continuous tendon in a helical wind or a series of individual tendons can be used. Annular concrete stiffening disks are positioned coaxially within the tank wall and are attached to the steel sheath. The disks have holes along an outer circle and along certain radii, for through-passage of axially oriented prestressing tendons. Between the several stiffening disks and abutting their surfaces are a plurality of flat, concrete, stiffening plates which are positioned radially-axially with respect to the tank. These stiffening plates abut the interior of the tank wall at their radial outermost extension. Located within these stiffening plates are axially oriented holes for prestressing tendons. Defining the remainder of the tank structure are steel heads which are attached to the end-most stiffening disks. Inlet and outlet means are provided for the cryogenic liquid.

In its erected configuration, the tank is prestressed both circumferentially and axially, the circumferential prestressing is by means of the tendons positioned around the circumference of the tank and the axial prestressing is by means of the tendons passing through the holes in the tank wall. The stiffening plates are also prestressed by tendons which pass through an axial series of plates located between adjacent stiffening disks, the tendons passing through the radially located holes in those disks. Where the tank is of large diameter, it may be desirable to form the steel head from a central dome and a surrounding torus, in order to limit the amount of steel which is required. The head is attached to the end stiffening disks and the toroidal section of the head is further anchored to the cylindrical wall by the axial prestressing tendons and by tendons external to the tank which are oriented diagonally of the tank axis.

The advantages of the tank configuration of this invention are many. The circular or elliptical cross-section, particularly in a horizontal orientation, makes very efficient use of the internal cubic of conventional ships or barges. Prestressed concrete is markedly more economical than the expensive alloy plates of free-standing, prismatic tanks or the even more expensive materials and complicated construction techniques associated with membrane tanks. Since the configuration of the tank is relatively simple, the structure is a fully determinant one, and does not require a secondary barrier to protect the ship hull and the cargo from one another. With the steel sheath a measure of secondary barrier is provided, nonetheless. Thus, the tank configuration of the invention provides all of the advantages of a two barrier system while being fully determinant and thus subject to the less rigid design controls promulgated for determinant systems. The structural integrity of the system, by virtue of its circumferential and axial prestressing, provides a very substantial measure of safety for tank and cargo, should the vessel be involved in a collision and lends a stiffness to the ship structure. The compartments which are formed within the tank, due to the presence of stiffening disks and stiffening plates, reduce sloshing of the cargo within the tank and make the overall operation more safe. The relatively high weight of the concrete, is an advantage insofar as it substantially reduces the ballast requirements of the vessel and lowers the center of gravity. Still a further advantage of the tank configuration, is that it is relatively easily positioned within a supporting cradle in the ship structure and can be firmly positioned therein without requiring elaborate support systems.

To facilitate construction of the tank, a modular wall component is fabricated. The component is comprised of a length of concrete, cylindrical tank wall of suitable curved cross-section having axially oriented holes passing through its length, a steel sheath anchored to its exterior surface and prestressing tendons wrapped essentially circumferentially about the exterior of the steel sheath. The concrete stiffening plates are integrally cast with the modular tank wall, and axial holes are provided therein. To erect the tank, from the modular components, it is necessary only to combine several of the wall modules, end to end and position, between them, annular, steel or concrete stiffening disks. The assembled tank is then prestressed axially as described above and the steel heads are attached to the end disks.

By providing a number of the modular components, together with the annular disks, a tank having the configuration described above can be relatively easily constructed within a conventional steel or concrete vessel. Desirably, the vessel will include a grid-like cradle which comprises transverse and axial structural members positioned in registration with the lower stiffening disks and the lower stiffening plates respectively. The transverse members are provided with a balsa wood support upon which the exterior portion of a stiffening disk is mounted. The axial structural members are positioned beneath the lower stiffening plates within the tank. Desirably, the tank is fixed to its cradle at only one position along the axis of the tank, i.e., at one transverse structural member and is slidably supported on several other structural members. The purpose of the fixed support is to preclude axial movement of the tank within the vessel and the purpose of the sliding supports is to permit axial contraction and expansion of the tank during cool-down and warm-up. Chocks may be provided at the sides and top of the tank to prevent it from rotating. However, the chocks should permit axial expansion and contraction of the tank.

The invention also embraces the method for forming the modular component for the cryogenic tank. A length of concrete, cylindrical tank wall of circular or elliptical cross-section is cast with axially oriented holes extending through it and radial-axial stiffening plates extending inwardly from its inner surface at spaced locations. A steel sheath is anchored to its exterior surface. The steel sheath may be studded to the concrete, as it is poured, according to conventional techniques. After the concrete has set, the tank wall is prestressed by wrapping one or more steel tendons, in tension, about the outer surface of the steel sheath. The latter step may be carried out by mounting the cast wall on a turntable and rotating the turntable while tendons are wrapped about the tank wall. Alternatively, a carriage may be supported from the tank wall and moved about the circumference thereof while wrapping a tendon thereabout, as is conventional procedure in the construction of stationary tanks. A group of components positioned one above the other may be prestressed in a single operation.

The advantages in the methods of this invention are numerous. Modular components may be formed by conventional techniques in the shipyard, but at a distance from the site of the ship construction, or at a remote location. The erection of the tank is simplified because the modular components should be sized so as to be of such weight as will be within the lifting capacity of available lifting apparatus at ship building sites. The axial tensioning of the modules and stiffening plates is performed with suitable jacks.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified, side elevation view of a steel tanker containing five liquid natural gas tanks according to the present invention;

FIG. 2 is a side elevation view of one of the tanks shown in FIG. 1;

FIG. 3 is a fore and aft elevation view, in section, of the tank of FIG. 2 taken along lines 3—3 of FIG. 2;

FIG. 4 is a partial section view of the tank shown in FIG. 2, showing details of the modular wall construction;

FIG. 5 is a partial fore and aft elevation view of the portion of the modular wall construction of FIG. 4 taken along lines 5—5 of FIG. 4;

FIG. 6 is a simplified, exploded, view of the modular components of the tank, showing their juxtaposition prior to assembly;

FIG. 7 is a view of the tank in partially assembled state;

FIG. 8 is a detailed view of a fixed support pedestal for the tank of FIG. 2; and

FIG. 9 is a detailed elevation view of a sliding support pedestal for the tank of FIG. 2.

With reference to FIG. 1, reference numeral **10** refers generally to a conventional tanker. Reference numeral **12** refers to a hull and reference numeral **14** to a tanker super structure. Reference numerals **16, 18, 20, 22** and **24** refer to five, horizontally oriented tanks for containment of cryogenic liquid having the configuration more fully described below.

With reference to FIGS. **2, 3, 4** and **5**, it can be seen that tank **16** is comprised of a cylindrical tank wall of circular cross-section **26** and includes heads **28** and **30.** Head **28** comprises a central dome **32** and a torus **34.** However, this head design is optional and may be employed in large tanks to reduce the amount of expensive alloy metal required. In smaller tanks, the heads may be elliptical or hemispherical. Inlet and outlet means for the cryogenic liquid are not shown, however, they may be provided at suitable locations in the top of the tank or through the steel heads.

As shown in FIG. **3**, cylindrical tank **16** is supported within hull **12** on a cradle **36** which includes several parallel, transverse, partially circular support members **38** and three parallel, axial support members **40, 42** and **44.** The entire tank is surrounded by insulation **46** which may be minneral wool, perlite or other suitable insulating material. The tank **16** is prevented from rotating within hull **12** by means of a chock **48** which includes a bracket **50** attached to the top of the tank having a recess section **52** in which is placed restraining member **54** attached to the hull or deck structure. Chocks may also be attached to the sides of the tank.

Tank **16** is comprised of a plurality of modular, concrete wall components **60***a*, **60***b*, **60***c*, etc. Each of these modular wall components is cylindrical and of circular cross-section and has a plurality of axial holes passing therethrough designated by reference numeral **62.** Located within axial holes **62** are prestressing tendons **64.** Located externally of modular components **60***a*, **60***b*, **60***c*, etc. are steel sheaths **65***a*, **65***b* and **65***c*, etc. which pass circumferentially around the exterior surface of the concrete. The steel sheaths are anchored to the concrete wall by means of studs **66.** Located on the outer surface of steel sheaths **65** are prestressing tendons **68** which pass circumferentially about the sheaths and are in tension causing the concrete and steel sheath to act compositely. A series of discrete tendons may be used or helically wound tendons may be employed. A layer of gunnite or other suitable bitumastic material or plastic coating such as epoxy serves as protective overcover for the circumferential prestressing tendons as designated by reference numeral **70.** Positioned at the right end of modular tank component **60***a* and between each of components **60***a* and **60***b*, **60***b* and **60***c*, etc. are annular, concrete stiffening disks **72***a*, **72***b*, **72***c*, etc. Each of these stiffening disks are positioned coaxially with respect to the tank. Head **28** is attached, by suitable connection to endmost stiffening disk **72***a*.

As seen best in FIGS. **4** and **5**, a series of flat, concrete stiffening plates **74** are provided. Each of these stiffening plates are positioned both radially and axially with respect to tank **16.** They are integral with the inner surface of the cylindrical tank wall at their radial outermost extension **76** and abut, at their axial extensions **78** and **80**, the two stiffening disks between which they are located, i.e., in FIG. **4**, disks **72***a* and **72***b*. These stiffening plates have essentially axially oriented holes therein designated by reference numeral **82** through which prestressing tendons **84** are passed. Suitable holes are provided in stiffening disks **72** for through-passage of tendons **64** through the holes **62** in modular wall components **60**, and through an axial series of stiffening plates **74.** Prestressing tendons **84** terminate in suitable tensioning heads **86** on the end most stiffening disk, **72**a.

Desirably, stiffening disks **72** are spaced from one another by uniform modular wall components **60** and the rows of stiffening plates **74** are positioned at a uniform angular distance from one another around the inner circumference of the tank. These outer extensions of the disks may form support posts or positioning rails for the tank, and as seen in FIG. **3**, these posts are received in cradle **36** in transverse structural member **38.**

As shown in FIGS. **6** and **7**, the tank configuration of this invention is most easily assembled by positioning modular wall components **100**, comprised of cast concrete wall sections of circular cross-section having holes **102** therein and circumferential prestressing tendons **104**, alternately with stiffening disks **106** which have circumferential holes **108** and radial holes **110** for through-passage of prestressing tendons. The axial prestressing tendons which pass through the wall of the concrete tank are designated by reference numerals **120** and the prestressing tendons which pass through the series of stiffening plates are designated by reference numerals **122.** As seen best in FIG. **7**, the interior of the assembled tank has a partially compartmentalized configuration, which is of advantage in reducing sloshing when the tank is filled. To complete the overall tank structure, heads are fixed to either end of the assembled cylindrical structure as shown in FIG. **2.** As further shown in FIG. **2**, where the heads are toroidal, the torus may be further anchored to the assembled cylindrical wall by prestressing tendons **125** and **127** which are oriented diagonally of the tank volume enclosed by the torus.

FIG. **8** shows a fixed support for the tank. Reference numeral **38** represents a transverse support member for the tank. Within support member **38** is a recess **39** containing balsa wood **41** which provides a support for the tank. The lower extension of stiffening disk **72** on one end of the tank is thus fuxed with respect to the axis of the tank and accordingly the tank cannot move when affected by impacts due to waves or other disturbances encountered by the vessel.

In FIG. **9**, reference numeral **138** refers to a transverse, cradle support member, of partial circular shape, having a recess at **139** filled with balsa **141.** As shown, the lower extension of the stiffening disk **172** sits on the upper surface **143** of balsa **141** and can slide across that surface under the influence of contraction and expansion forces encountered in the cool-down and warm-up of the tank.

What is claimed is:

1. A tank for cryogenic adapted for placement within a marine transportation vessel comprising:

a. a concrete, cylindrical tank wall having a plurality of steel prestressing tendons located therein in axial orientation;

b. a steel sheath anchored to the exterior surface of said wall;

c. a prestressing tendon wrapped essentially circumferentially about the exterior of said steel sheath;

d. at least two, annular stiffening disks positioned coaxially within the said wall said disks having holes therein for through-passage of axially oriented prestressing tendons;

e. a plurality of stiffening plates positioned radially-axially with respect to said tank and abutting at both axial extensions thereof, said stiffening disks and at their radial outermost extension, the said cylindrical tank wall, said stiffening plates having essentially axially oriented prestressing tendons therein;

f. steel heads defining the ends of said cylindrical tank and attached to said stiffening disks; and

g. inlet and outlet means for said cryogenic liquid.

2. A tank for cryogenic liquids as recited in claim **1** wherein said tank includes a series of stiffening disks spaced along the axis of said tank and a series of stiffening plates spaced around the circumference of said tank, between each of said disks, the axial prestressing tendons associated with each of said stiffening plates passing through mating holes in said disks and linking an axial series of stiffening plates.

3. A tank as recited in claim **2** wherein at least a portion of said stiffening disks extends past the exterior surface of the said steel sheath the protruding edge thereof forming a post for retention of said tank.

4. A tank as recited in claim **2** wherein said steel head comprises a central dome and torus attached to a said end stiffening disk, said torus being further anchored to said cylindrical wall by external prestressing tendons oriented diagonally of the tank volume enclosed by said torus.

5. A modular component for construction of a tank for cryogenic liquids for placement within a marine transportation vessel comprising:

a. a length of concrete, cylindrical tank wall having a plurality of axially oriented holes passing through the length thereof;

b. a plurality of radial-axial stiffening members, integral with the internal surface of said cylindrical tank wall and extending inwardly thereof in order to act as compartmental walls within said tank for reduction of liquid movement within said tank;

c. a steel sheath anchored to the exterior surface of said wall; and

d. a prestressing tendon wrapped essentially circumferentially about the exterior of said steel sheath.

6. A tank, of modular construction, for cryogenic liquids, adapted for placement within a marine transportation vessel, comprising:

a. a plurality of prestressed concrete wall modules comprising:

1. a length of concrete, cylindrical tank wall and a plurality of radial-axial stiffening members integral with the internal surface thereof, said walls and stiffening members having a plurality of axially oriented prestressing tendons passing through the lengths thereof;
2. a steel sheath anchored to the exterior surface of said wall;
3. a prestressing tendon wrapped essentially circumferentially about the exterior of said steel sheath, said wall modules being laid end to end;

b. annular stiffening disks positioned between adjacent wall modules, said disks having holes therein for through-passage of said axially oriented prestressing tendons;

c. steel heads defining the ends of said cylindrical tank; and

d. inlet and outlet means for said cryogenic liquid.

7. A tank for cryogenic liquids comprising:

a. a cylindrical tank wall comprised of prestressed concrete;

b. end closure means attached to said cylindrical tank wall;

c. at least one annular stiffening disk positioned coaxially within the said cylindrical tank wall intermediate the said end closures, said stiffening disk being attached to said wall and extending into said tank, in order to compartmentalize said tank and reduce movement of liquid therein; and

d. inlet and outlet means for said cryogenic liquids.

8. A tank as recited in claim **7** having a plurality of said stiffening disks attached intermediate to said end closures of said tank.

9. A tank as recited in claim **7** wherein at least a portion of the said disk extends past an exterior surface of said wall, the protruding edge thereof forming a longitudinal restraint for said tank.

10. A tank as recited in claim **7** wherein said end closure means comprises a steel head.

11. A tank as recited in claim **7** wherein said end closure means comprises a steel head comprising a central dome and torus.

12. A tank as recited in claim **7** having a steel sheath anchored to the outer surface of said cylindrical wall.

13. A tank for cryogenic liquids comprising:

a. a cylindrical tank wall comprised of prestressed concrete;

b. end closure means attached to said cylindrical tank wall;

c. at least one annular stiffening disk positioned coaxially within the said cylindrical tank wall intermediate the said end closures and attached to said wall.

d. at least one stiffening member positioned radially-axially with respect to said tank, the axial extension of said stiffening member abutting said stiffening disk and the radial outermost extension of said stiffening member abutting the said cylindrical tank wall.

14. A tank as recited in claim **13** wherein said stiffening member comprises a flat, prestressed concrete plate having essentially axially positioned prestressing tendons therein.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,863,408 Dated February 4, 1975

Inventor(s) John J. Closner, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

IN THE CLAIMS:

Column 9, line 14, after "cryogenic" insert -- liquids --.

Signed and Sealed this

second Day of *September 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks