

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 May 2007 (10.05.2007)

PCT

(10) International Publication Number
WO 2007/053377 A2

(51) International Patent Classification:
B63B 3/10 (2006.01)

(21) International Application Number:
PCT/US2006/041546

(22) International Filing Date: 24 October 2006 (24.10.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/261,678 28 October 2005 (28.10.2005) US

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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS,
JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS,
LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY,
MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS,
RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

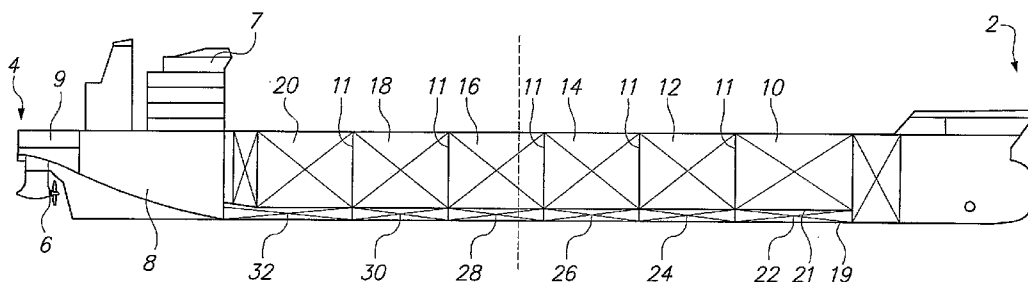
(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT,
RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished
upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: CONCRETE DOUBLE-HULLED TANK SHIP



(57) Abstract: A double-hulled tanker of not less than of not less than about 2,000 metric tons deadweight in size which is suitable for the transportation of liquid hydrocarbons and meeting the requirements for the United States Pollution Act of 1990 and similar international regulations, said tanker comprising an inner hull and an outer hull separated by a void, said inner and outer hulls being constructed of high strength, light weight, reinforced and prestressed concrete.



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CONCRETE DOUBLE-HULLED TANK SHIP

FIELD OF THE INVENTION

- 5 The present invention is directed to the field of double-hulled tank vessels for over-water transport of liquid hydrocarbons, particularly, petroleum and petroleum products.

BACKGROUND OF THE INVENTION

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- Ships having concrete hulls were being built as early as the late nineteenth century, and cargo ships having concrete hulls were built and used during World War I and World War II when steel was in short supply. See for example U.S. Patent Nos. 1,297,143; 1,313,592; 1,314,069; and 1,377,153. Two major disadvantages of concrete hulled ships which have limited their utility are the weight and the thickness of the hull when compared to other materials. The greater thickness of the hull necessary for a ship fabricated of concrete translates into a larger "footprint" in the water when compared to a conventional steel hulled ship of comparable cargo volume. Consequently, concrete hulled ships in the past have had significantly greater wavemaking resistance than conventional ships. The greater weight of the hull arising from a ship fabricated of concrete made each ship sink deeper in the water than conventional ships. Consequently, concrete ships in the past have also had significantly greater hull friction resistance than conventional ships. The greater wave making resistance and hull friction resistance resulted in poor fuel efficiency. Finally, the greater hull thickness and deeper underwater displacement combined to restrict navigation of concrete ships (in terms of draft limits, beam limits and length limits at sea, in ports, canals and drydocks, etc.) compared to the smaller, lighter conventional ships. Following World War I and World War II when steel again became readily available, interest in concrete hulled ships waned, and, with the possible exception of a few experimental designs, few commercial concrete hulled ships have been built since the 1940's. No ships having hydrodynamically faired concrete hulls comparable to modern tank ships in size have ever been built.
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As used in this disclosure, the term "vessel" refers to a ship or a barge. A ship is a self propelled vessel, and a barge is a non-self propelled vessel, i.e., a vessel which must either be towed or pushed. A "tanker" as used herein refers to either a ship or barge intended for the over water transport of liquid hydrocarbons. The term "tank ship" refers to a ship intended for the over water transport of liquid hydrocarbons.

Several recent developments have made large commercial concrete tankers viable for transporting liquid hydrocarbons, such as petroleum and petroleum derived products. These include the availability of new concrete materials, especially high-strength lightweight concrete; modern methods of concrete fabrication; and regulations which require the replacement of single hulled tankers with double-hulled tankers. Significant advances in both concrete materials and methods for construction have been made since World War II. Modern concrete technology has made it possible to efficiently build large, exceptionally strong, and relatively light weight structures as may be seen in modern bridges, causeways, and office buildings.

With the enactment of the U.S. Oil Pollution Act of 1990 (OPA 90) and similar international regulations mandating the replacement of single-hulled tankers with double-hulled ones, major disadvantages of concrete hulled vessels also have been removed. Double hulled steel tankers are heavier and have a larger footprint in the water compared to their single-hulled predecessors. In addition, the thicker walls of a double hulled concrete vessel may now extend into the void space between the inner and outer hulls, further decreasing the overall footprint of the hull without encroaching on the cargo space.

A concrete hulled tank ship intended for the transportation of liquefied gas is described in U.S. Patent No. 3,977,350. See also U.S. Patent Nos. 6,655,155 and 6,584,781 which describe a tank ship for carrying liquefied natural gas having a concrete midsection with a steel bow and stern section. See also U.S. Patent No. 6,009,821 which describes a method for retrofitting a steel hulled ship with a concrete bottom inside of the hull.

- The tank vessel of the present invention is intended for the transportation of liquid hydrocarbons, i.e., hydrocarbons which are normally liquid at ambient temperature and pressure; as well as hydrocarbons which may require heating to become/remain in liquid form. Examples of liquid hydrocarbons include petroleum and petroleum
5 derived products, such as crude oil, petroleum derived gasoline and diesel fuel, and synthetic hydrocarbons, such as those derived from the Fischer-Tropsch process. Examples of hydrocarbons which may require heating include heavy fuel oils, bunker oils, asphalt, high pour point crude oils, and the like.
- 10 As used in this disclosure the words "comprises" or "comprising" are intended as open-ended transitions meaning the inclusion of the named elements, but not necessarily excluding other unnamed elements. The phrases "consists essentially of" or "consisting essentially of" are intended to mean the exclusion of other elements of any essential significance to the composition. The phrases "consisting of" or
15 "consists of" are intended as a transition meaning the exclusion of all but the recited elements with the exception of only minor traces of impurities.

SUMMARY OF THE INVENTION

- 20 In its broadest aspect, the present invention may be described as a double-hulled tanker of not less than about 2,000 metric tons deadweight in size which is suitable for the transportation of liquid hydrocarbons and meeting the requirements for the United States Oil Pollution Act of 1990 and similar international regulations, said tanker comprising an inner hull and an outer hull separated by a void, said inner and
25 outer hulls being constructed of high strength, light weight, reinforced and prestressed concrete. The present invention is particularly useful in the fabrication of tank ships, especially tank ships of not less than about 30,000 metric tons deadweight. Unlike earlier concrete hulled cargo ships, the double-hulled tankers of the invention use reinforced/prestressed high-strength lightweight concrete. The reinforcing may be
30 conventional steel rebar, either coated or uncoated for corrosion resistance, stainless steel, or recently developed reinforcing materials such as MMFX steel, fiberglass and carbon fiber. Both the inner and outer hulls are reinforced and prestressed. Preferably,

the hulls will be prestressed in at least two directions as will be described in greater detail below.

5 In addition to the inner and outer hulls of the vessel, internal structural elements, such as bulkheads and frames also may be fabricated of high strength, light weight, reinforced and prestressed concrete.

10 International regulations similar to the United States Oil Pollution Act of 1990 include the United Nations International Maritime Organization's "International Convention for the Prevention of Pollution from Ships, 1973", as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), and further amended in 1992 which mandates the phase out of single hulled tankers.

BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1 is a side elevation view of a concrete double-hulled tank ship of approximately 38,000 metric tons deadweight showing the location of the internal bulkheads.

20 Figure 2 is the same tanker as Figure 1 viewed from above.

Figure 3 is a midships cross section taken through the cargo section of the same tank ship showing the double-hulled construction.

25 Figure 4 is an enlargement of a cross section of the double-hull showing the position of the tensioning cables and the internal members and haunches.

DETAILED DESCRIPTION OF THE INVENTION

30 Recent advances in materials and construction methods have made it possible to efficiently construct very large, strong, relatively lightweight, hollow, concrete structures. The present invention is directed to the application of this recent concrete technology in the construction of double-hulled tank vessels, especially double hulled

tank ships. Modern methods for concrete fabrication allow a double-hulled concrete tanker to be optimized in order to minimize hull size and weight. Hull resistance is reduced (fuel efficiency is improved), and the tankers can safely navigate with fewer draft, beam and length restrictions.

5

The present invention may be more clearly understood by reference to the drawings which illustrate a representative concrete double-hulled tank ship falling within the scope of the invention which is intended as a non-limiting embodiment of the invention. Figures 1, 2, and 3 show different views of a 632 foot long double-hulled
10 concrete tank ship of about 38,000 metric tons deadweight, propelled by two Azipod® units aft. Figure 1 is a side elevation view. Figure 2 is a top view taken from above the deck. Figure 3 is a midships cross sectional view taken through cargo tank number 4.

15 Referring to Figure 1, the tank ship has a bow 2 and a stern 4. The stern section contains the propeller 6, the accommodations block 7, the pod room 9 containing machinery, and the engine room 8. Six cargo tanks designed for holding liquid hydrocarbons, shown as 10, 12, 14, 16, 18, and 20, respectively, are arranged midships separated by a series of bulkheads 11. Below the cargo tanks, between the
20 outer hull 19 and the inner hull 21 are void spaces, 22, 24, 26, 28, 30, and 32, respectively.

Figure 2 shows the starboard engine room 8s and the port engine room 8p, as well as the starboard pod room 9s and the port pod room 9p. The cargo tanks 10, 12, 14, 16,
25 18, and 20 are also divided into starboard and port sections which are separated by a centerline bulkhead 34. The starboard and port void spaces between the outer and inner hulls in this embodiment serve as water ballast tanks. This is shown more clearly in Figure 3.

30 Figure 3 is a cross sectional view of the ship taken through cargo tank 4 shown as a dotted line in Figures 1 and 2. In Figure 3, the outer hull is shown as divided into the outer starboard side hull 102, the outer port side hull 104, and the outer bottom hull 106. The inner hull is also divided into the inner starboard side hull 108, the inner port

side hull 110, and the inner bottom hull 112. The void spaces 114s and 114p located between the inner and outer hulls on both the starboard and port sides, respectively, are used as water ballast tanks in this embodiment. The deck 118 is shown as supported by a concrete support beam 120. Cargo tanks 16s and 16p are separated by centerline bulkhead 34. Tensioning cables 122 are shown passing fore and aft horizontally along the swash bulkhead 34 and along the deck 118. Horizontal tensioning cables are also shown passing fore and aft through the inner and outer hulls on the starboard side. Although not shown on the port side of the diagram, tensioning cables would be present there as well. A tensioning cable is also shown running across the midships through deck support beam 120 on the starboard side. A tensioning cable 124 is shown running around the inner hull from the starboard side of the deck, down through the side of the inner hull, and across the bottom of the inner hull. Although not shown in the figure, this tensioning cable would run up through the side of the inner hull on the port side of the ship. A corresponding tensioning cable 126 is shown running around the outer hull as well. It will be seen that the tensioning cables run through the inner and outer hulls in two directions perpendicular to each other.

Figure 4 is a detail of the transverse ribs or frames which extend continuously between the inner and outer hulls for strength. In the figure, the inner hull 21 and the outer hull 19 are separated by the transverse rib 202 and the void space 22. The outer and inner hull plates are haunched 204 between the rib frames as shown in the figure. The haunches in the hull plates facilitate the load transfer within the hull structure and minimize any tensile stresses induced in the hull. This configuration strengthens the hull and results in a significant reduction in the hull weight. Tensioning cables 206 are shown passing through the center of the ribs and in the haunch area.

The concrete used in the fabrication of the hull, decks, frames, and bulkheads is one or more types of high strength, light weight concrete. Concrete suitable for use in fabricating the hulls of tank ships typically will contain between 550 kg/m³ to about 400 kg/m³ of Portland cement. Lightweight concrete generally will have a higher void volume than conventional concrete by use of suitable lightweight aggregates in the concrete mixture. Typically, lightweight concrete will have a nominal air content

of between about 3% and about 10% by volume. Notwithstanding the void spaces in the aggregate, lightweight concrete has excellent strength and can be made relatively impermeable to water. Pozzolans (amorphous silica which reacts with the calcium hydroxide from the Portland Cement paste) may be added to the mixture to

5 moderately increase long-term strength, significantly decrease the permeability, decrease the heat of hydration, and reduce the material cost. Pozzolans include microsilica fume, fly ash, and granulated blast furnace slag. Depending on a number of factors (such as workability, rate of strength gain, batch plant setup, heat of hydration, cost of materials, material availability, design strength, exposure

10 conditions, etc.) typical pozzolan addition rates range from 0%-10% by weight for microsilica fume, 0%-25% by weight (up to 50% in extreme cases) for fly ash, and 0% -60% by weight (up to 80% in extreme cases) for granulated blast furnace slag.

Prestressing (whether by pre-tensioning or post-tensioning) may be achieved by use

15 of stress-relieved wire strands such as is widely used in modern concrete construction. Seven-wire assemblies conforming to ATSM A416/A416M Grade 270 are one example. Local prestressing may be applied using high strength bars, for example conforming to ASTM A722/A722M. Prestressing routed through prestressing ducts would normally be grouted and all anchorages protected from corrosion. All

20 prestressing steel would normally be bare steel, without epoxy coating, checked for electrical continuity and properly grounded.

In addition to the prestressing steel, reinforcing is also present in the concrete. The reinforcing may be steel rebar such as is widely used in steel reinforced concrete.

25 ASTM A615 Grade 520 (Grade 75) is one example. The rebar may also be coated, as for example, with an epoxy resin, to improve its resistance to oxidation in order to increase the overall life of the hull. MMFX steel which is particularly resistant to oxidation may also be used as reinforcing. Fiberglass or carbon fiber reinforcing also may be advantageously employed as reinforcing for the concrete where both

30 oxidation and weight are factors for concern.

Although not required for protection, it is expected that generally, the exposed concrete surfaces will have a coating of some sort. On the exterior surface of the outer

hull, the coating would be designed to improve water impermeability and prevent the growth of marine organisms on the underwater portion of the hull. On the interior surface of the inner hull, the coating would be intended to protect the concrete from the cargo and to improve impermeability. If the void spaces between the inner and
5 outer hulls are used as ballast tanks, the surfaces which contact the sea water could also be coated in manner similar to the outer surface of the hull. Protection by use of sacrificial anodes is another alternative. Obviously, the type of cargo will be a factor on the choice of coating selected for the inner surface of the cargo tanks. Typical coatings that may be applied to the concrete surface may include of polyurethane,
10 epoxy, and polyurea coatings.

In fabricating the hulls of the ship, the bow section, cargo section and stern section may be cast or molded separately. The type of concrete used in the fabrication of different parts of the hull may vary from one part of the ship to another. For example
15 the portion of the hull containing the cargo may contain concrete having the greatest structural strength, since a rupture would have the greatest consequences in that area. The concrete at the stern of the ship may be made from a lighter weight concrete, since it is the least likely part of the ship to be damaged in an accident. The bow section may be fabricated from a concrete of intermediate strength. Strength of the
20 concrete used in the fabrication of the hull will depend on a number of factors well understood by one skilled in the art. Such factors include the volume percent of air, the percent of Portland cement in the aggregate, the presence of additives, thickness of the concrete, quality and quantity of the reinforcing material, the presence of internal supports, and the like.

25 Various methods for fabricating large concrete structures, such as bridge sections and the like, have been developed and are known to those skilled in the art. Slipforming is a modern method used for the manufacture of such structures and would be suitable for fabricating double hulled tanker within the scope of the invention. Slipforming is a
30 high productivity concrete construction method that utilizes a form which moves, usually continuously, during the placing of the concrete. Movement may be either horizontal or vertical. Slipforming is similar to an extrusion process with the forms acting as moving dies to shape the concrete. The depth of the form and the rate of

form slipping are set such that the fresh concrete placed at one end of the form has time to harden before exiting the other end of the form.

5 The type of propulsion system employed is not critical to the invention. Conventional engines operating on fuels such as, for example, diesel, gasoline, coal, and bunker oil would be suitable. Less conventional propulsion systems such as nuclear reactors could also be used if desired.

WHAT IS CLAIMED IS:

1. A double-hulled tanker of not less than about 2,000 metric tons deadweight in size which is suitable for the transportation of liquid hydrocarbons and
5 meeting the requirements for the United States Oil Pollution Act of 1990 and similar international regulations, said tanker comprising an inner hull and an outer hull separated by a void, said inner and outer hulls being constructed of high strength, light weight, reinforced and prestressed concrete.
- 10 2. The double-hulled tanker of claim 1 wherein the inner and outer hulls are prestressed in at least two directions.
3. The double-hulled tanker of claim 1 having bulkheads, frames and hull stiffening and strengthening members are comprised of high strength, light
15 weight, reinforced and prestressed concrete.
4. The double-hulled tanker of claim 1 wherein the inner and outer hulls are strengthened by longitudinal and/or transverse concrete frames (ribs) which are disposed in the void between the outer surface of the inner hull and the
20 inner surface of the outer hull.
5. The double-hulled tanker of claim 4 wherein the transverse and/or longitudinal concrete ribs are haunched.
- 25 6. The double-hulled tanker of claim 1 wherein at least one of the two concrete hulls is reinforced with embedded steel.
7. The double-hulled tanker of claim 6 wherein the embedded steel is stainless steel.
- 30 8. The double-hulled tanker of claim 6 wherein the embedded steel is epoxy-coated steel.

9. The double-hulled tanker of claim 6 wherein the embedded steel is MMFX steel.
- 5 10. The double-hulled tanker of claim 1 wherein at least one of the two concrete hulls is reinforced with fiberglass.
- 10 11. The double-hulled tanker of claim 1 wherein at least one of the two concrete hulls is reinforced with carbon fiber.
12. The double-hulled tanker of claim 1 wherein the light weight concrete also contains pozzolans.
- 15 13. The double-hulled tanker of claim 12 wherein the light weight concrete contains fly ash.
14. The double-hulled tanker of claim 12 wherein the light weight concrete contains silica fume.
- 20 15. The double-hulled tanker of claim 12 wherein the light weight concrete contains granulated blast furnace slag.
- 25 16. The double-hulled tanker of claim 1 wherein at least one of the two hulls have a nominal air content between about 3 vol.% and about 10 vol.%.
17. The double-hulled tanker of claim 1 wherein parts of the concrete hull and /or structure are fabricated utilizing concrete slip form construction technology.
18. The tanker of claim 1 which is a tank ship.
- 30 19. The tank ship of claim 18 of not less than about 30,000 metric tons dead weight.

FIG. 1

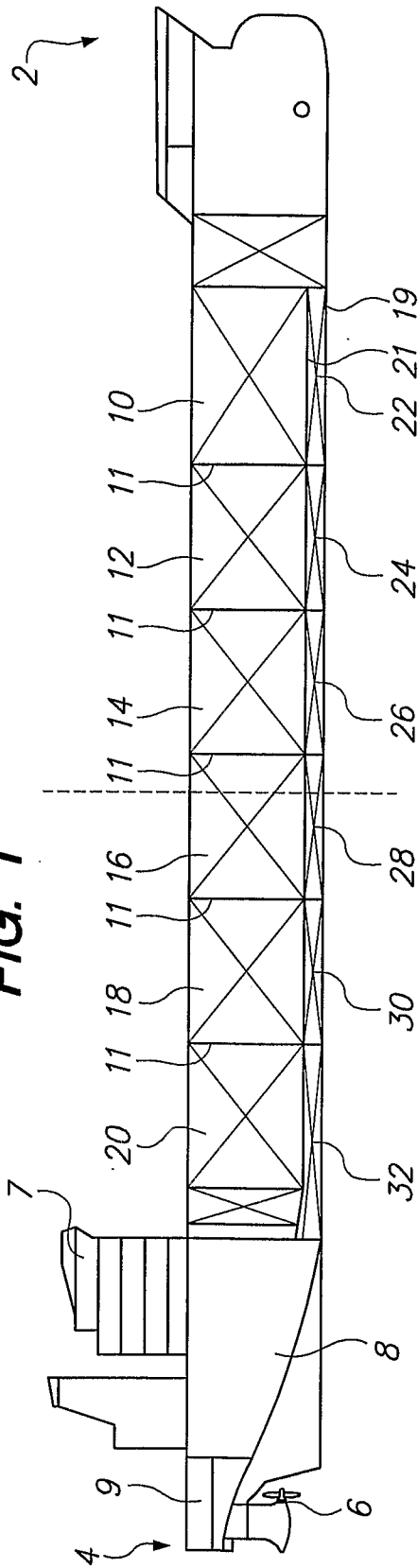
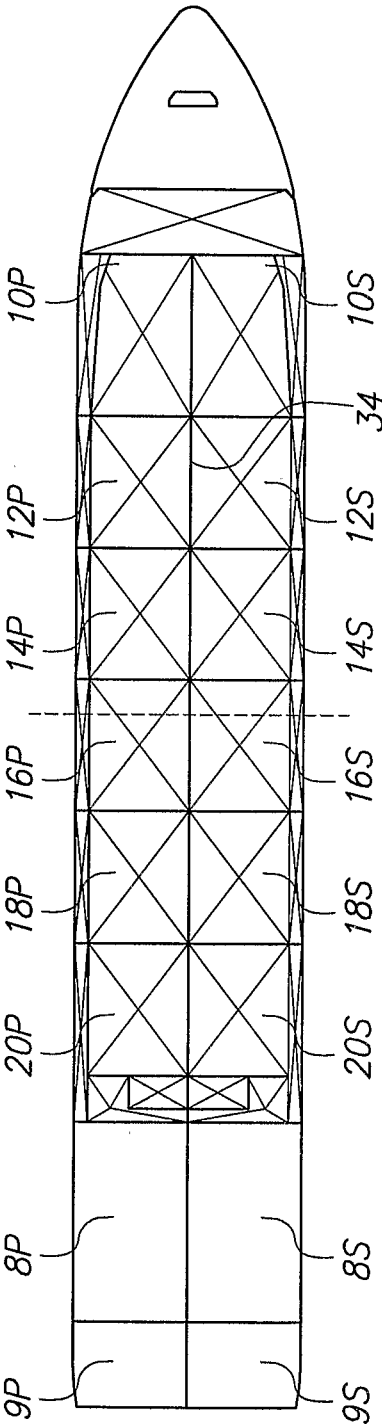
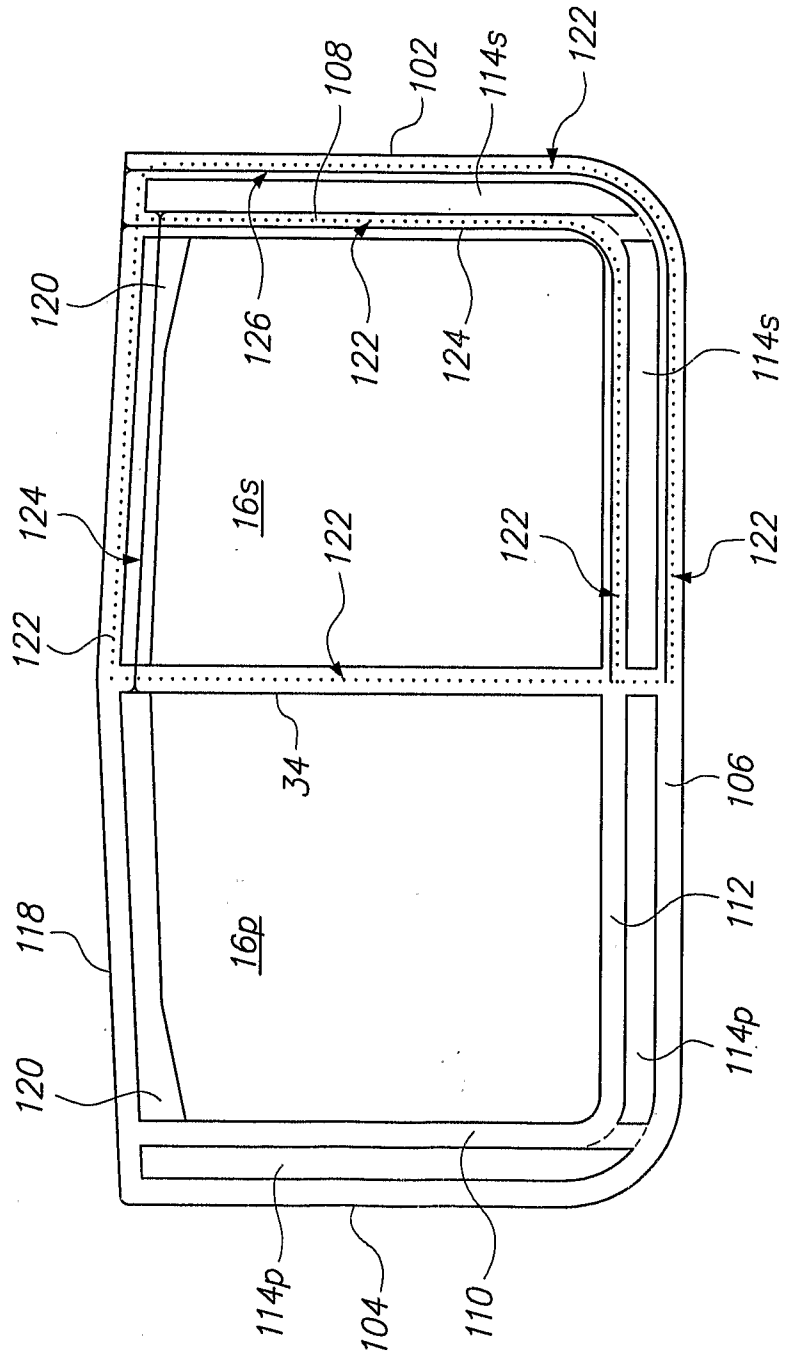


FIG. 2



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FIG. 3



3/3

FIG. 4

