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Glasfeld et al.

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[54] LIQUIFIED-GAS SHIP

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[51] Int. Cl. **B63b 25/16**

[58] Field of Search 114/74 A; 220/9, 15

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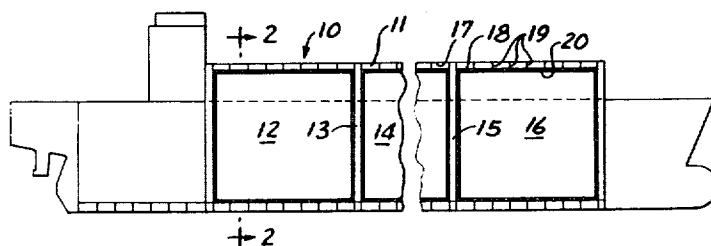
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[57] ABSTRACT

A ship for the transporation of liquified gases at pressures approximately equal to atmospheric pressure and at temperatures substantially below ambient temperature has a double-hull structure with both the inner and outer portions of the hull made from an aluminum alloy having high strength and ductility at cryogenic temperatures. A layer of insulation is provided on the interior wall of the inner hull for thermally insulating the liquid gas cargo from the ambient temperature. A layer of an impermeable material, preferably in the form of a laminate, is disposed on the interior surface of the insulation layer to prevent gas/liquid leaks.

9 Claims, 5 Drawing Figures



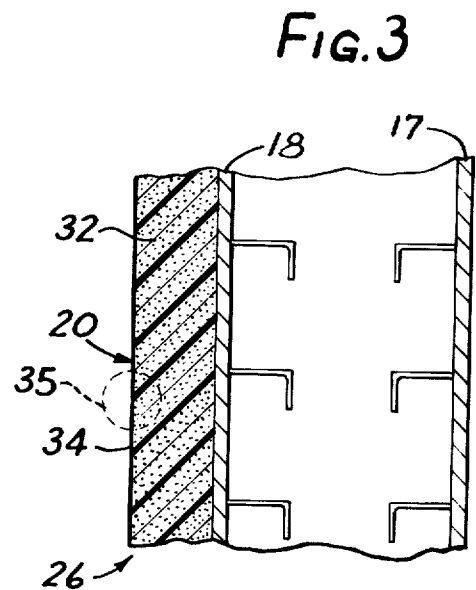
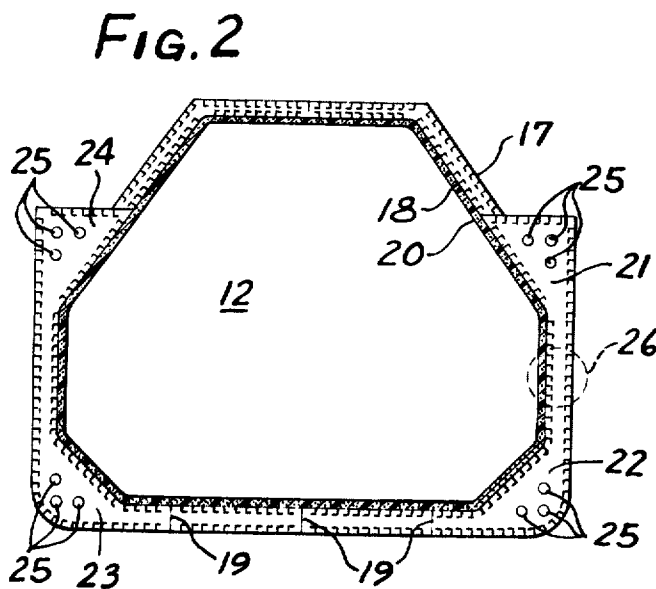
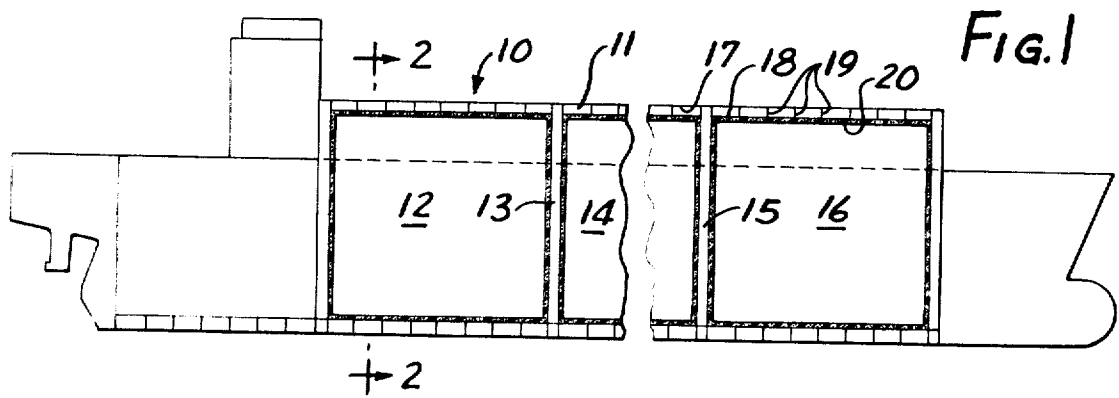
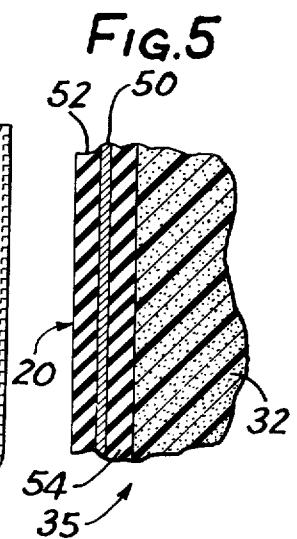
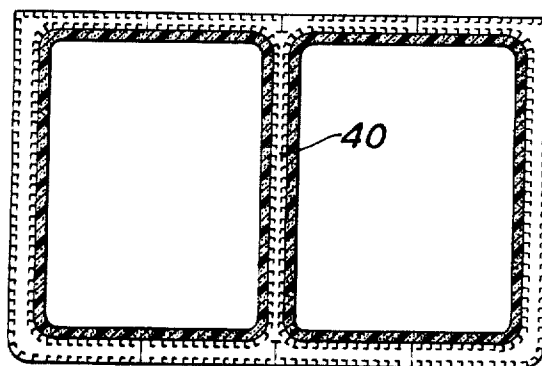


Fig. 4



LIQUIFIED-GAS SHIP

The present invention relates to cargo ships and, more particularly, to ships or "tankers" adapted to transport liquified gases at atmospheric pressures and cryogenic temperatures.

The advantages and problems involved in marine transportation of cargoes of liquified gases such as natural gas, hydrogen, oxygen, methane, and the like at atmospheric pressures are generally well-known. In the liquid state (at approximately atmospheric pressure), such gases typically have temperatures of several hundred degrees below zero degree Fahrenheit. Consequently, a primary consideration in building such a ship is that of insulating the cargo from the ambient temperature sufficiently to maintain its temperature generally below the vaporization point. In addition to providing adequate insulation for the liquified-gas cargo, the ship must also be constructed so that the extremely cold liquified gas does not escape and interfere with the operation of the ship or destroy the integrity of its hull. Moreover, gas leaks should be detected and prevented so that an inadvertent explosion or poisoning does not occur.

The hull and major structural components of conventional ships, liquified-gas tankers or otherwise, are generally constructed from mild steel which has sufficient strength to withstand the stresses normally encountered by a ship on the seas. When subjected to extremely cold temperatures such as those of liquified gases, however, mild steel often becomes so brittle that it loses its strength and ductility to such an extent that it becomes subject to cracking and disintegration. Thus, even a small leak in the cargo-containing portion of the ship, though not large enough to permit substantial heat transfer to the cargo, might permit enough liquified gas to escape and damage the hull to cause a catastrophic failure. Consequently, the construction of a liquified-gas ship should be such that it minimizes the amount of heat transfer and gas/liquid leakage through the cargo-containing portion of the ship, it being generally recognized that these two objectives are neither necessarily achieved concomitantly, (i.e., a material that is a good insulator may not necessarily be a good gas/liquid sealer and vice versa) nor, as a practical matter, achieved completely (i.e., it is rather difficult to obtain zero heat transfer or insure zero possibility of a gas/liquid leak). This recognition stems from the fact that perfect heat insulators are not commercially available and that there is usually the possibility that some gas/liquid leaks may occur due to normal stresses after some indefinite period of use or as a result of structural damage caused by a minor collision with some object.

In accordance with the above considerations, conventional liquified-gas tankers may generally comprise a mild steel double hull which holds a separate tank system to contain the cargo. Such tank systems are commonly divided into two classes: self-supporting and membrane. Self-supporting tanks are independent of the ship structure and only incidentally contribute to ship strength whereas membrane tanks derive their structural support almost entirely from the ship structure.

One of the first types of such tankers put into commercial operation and presently being used, commonly employs a self-supporting or "free-standing" tank sys-

tem comprising a plurality of separate tanks of different sizes to conform to the lines of the ship. Each tank is fabricated from an aluminum alloy which, although relatively more expensive than mild steel, establishes a primary barrier to contain the liquified gas and yet maintains its strength and ductility even at the extremely cold temperatures associated therewith. Laminated balsa wood insulation is typically employed under the tanks, and provides insulative support therefor. An additional layer of hardwood plywood is generally included under the tanks to form a secondary barrier to prevent any leakage of liquified gas from contacting the mild steel hull. On the sides of the tanks polyurethane foam is used as a combination secondary barrier and insulation, while the tops of the tanks are insulated with mineral wool or glass fiber. The hull is of the commonly used "double-shell" or "double-hull" configuration which is usually made from mild or low-carbon steel. Throughout many years of extensive service this type of hull construction has demonstrated its superior ability to withstand the substantial stresses to which a ship is subjected on the high seas.

Except for the particular way in which the tank portion is supported, commercial membrane tankers are constructed very similarly to the self-supporting tankers; that is, employing a tank structure having a primary barrier of stainless steel or Invar which maintains its strength and ductility at extremely low temperatures (although the use of aluminum for the membrane has also been proposed); a secondary barrier of plywood, Invar, reinforced polyurethane with an impermeable covering; a layer of insulation comprising balsa wood, mineral wool, polyurethane, or perlite; and a mild steel, double-shell outer hull.

These conventional approaches to the problem of building a liquified-gas tanker require a substantial amount of labor and material, both of which tend to increase the cost of the ship. Moreover, since the possibility of leaks is generally present and the consequences thereof are often quite serious, relatively elaborate detection and warning systems, piping networks, and pumps are often provided for sensing and removing any liquified gas that may leak. Notwithstanding these elaborate safeguards, it is still possible for such a leak to cause serious damage to the hull before it is detected and the leakage removed. Consequently, there have been numerous proposals for improving conventional liquified gas tankers. Heretofore, the thought of using a cryogenically non-embrittling metallic material for all or most of the ship's main structure has been quickly discarded as being far too expensive and impracticable. Moreover, relative to double hull structures, the prior art has taught against the use of special metals for the outer hull which do not lose their ductility when reduced to low temperatures. For example, in U.S. Pat. No. 3,085,538 it is said that such an approach "would result in a material increase in the cost of the ship from the standpoint of the metals employed and their assembly, and it would possibly result in reduction of stability of the ship from the standpoint of the strength of the metals employed in its construction."

One prior proposal involves merely using a substantial amount of insulation on the inner hull of a conventional mild steel double hull ship; but, of course, this gives rise to the very problems mentioned above. Other proposals that have been advanced include the making of the tank portion out of concrete and providing an in-

terior liner made of a material which is both gas-tight and liquid-tight at cryogenic temperatures, with an outer hull formed in the conventional manner of mild steel or the like, or even making an entire single-hull structure out of prestressed concrete lined on the inside with a layer of an insulating material, such as polyethylene. The practical aspects (i.e., manufacturing feasibility, stability, maneuverability, and floatation characteristics) of a liquified-gas ship constructed in accordance with these proposals, however, are not believed to be commonly known and may well give rise to other significant problems.

Another consideration of the building of such ships is that of size. In order to obtain a useful-sized cargo area, after providing the necessary insulating layers, tanks, and supporting structures, a relatively large outer hull structure is normally required. Typical dimensions for a conventional liquified-gas tanker of about 120,000 cubic meter capacity are a length of 900 feet, beam of 135 feet, and a depth of 85 feet. Conventional "double-shell" hull structures of low-carbon or mild steel are rather heavy in and of themselves, often weighing in excess of 23,000 tons, and contribute substantially to the total lightship displacement which may be about 27,000 tons. This relatively large size and weight substantially limits the ship itself, in terms of increased power and draft requirements, as well as restricting the manufacture thereof to only the very largest shipyards. Also, as compared to conventional oil tankers of a given size where the cargo is relatively heavy (i.e., dense), the hull weight of a liquified-gas ship represents a much larger percentage of the total displacement; and thus it will generally be a more significant factor in the overall design of tankers for liquified gas than for conventional oil cargoes.

It is therefore an object of the invention to provide an improved ship for the transportation of liquified gases at pressures approximately equal to atmospheric pressure and at temperatures substantially below ambient temperature.

It is another object of the invention to provide such a ship which is relatively inexpensive to construct, lightweight, and efficient to operate.

Other objects and advantages of the invention are more particularly set forth in the following detailed description and in the accompanying drawing, of which:

FIG. 1 is a schematic side elevational view of a ship constructed in accordance with the invention;

FIG. 2 is an enlarged sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is an enlarged cross-sectional view of the encircled portion of FIG. 2;

FIG. 4 is a cross-sectional view of an alternative embodiment of the invention; and

FIG. 5 is an enlarged cross-sectional view of the encircled portion of FIG. 3.

With reference to FIG. 1, there is generally shown a raised-deck, double-hull ship 10 having a cargo-containing portion 11 for the transportation of a liquified gas at pressures approximately equal to atmospheric pressure and at temperatures substantially below ambient temperature. Cargo-containing portion 11 may be subdivided as shown into separate tank portions 12, 14, and 16 by transverse bulkheads or cofferdams 13 and 15, respectively. Such subdivisions may be employed to reduce sloshing forces and to comply with the requirements of regulatory agencies. Moreover,

each subdivision or tank may be tapered at the top (see FIG. 2) or otherwise divided (see FIG. 4) to reduce free-surface effects. The details of the non-cargo-containing portion of the ship form no part of the invention and are therefore only shown schematically.

In accordance with the present embodiment of the invention, ship 10 comprises an outer hull portion 17 made from a cryogenically non-embrittling metallic material and preferably extending, as shown, substantially around the sides and deck of the ship, and an inner hull portion 18 also made from a cryogenically non-embrittling metallic material and disposed within and at least substantially co-extensive with the outer hull portion. If desired, of course, the inner hull and/or outer hull portions may extend essentially the entire length of the ship. The cryogenically non-embrittling metallic material (i.e., one that does not lose its strength and ductility at extremely low temperatures) is preferably an aluminum alloy. One such alloy is 5083 aluminum alloy (having a chemical composition, in percent by weight, of approximately 93 percent aluminum, 4.5 percent magnesium, 0.6 percent manganese, 0.25 percent zinc, 0.15 percent chromium, 0.15 percent titanium, 0.10 percent copper, and a maximum of 1.25 percent impurities) although any other similar material may be used. A suitable aluminum alloy having the highest possible resistance to fire and heat is, of course, desirable.

Framing shown as support members 19, which may be also made from an aluminum alloy, are provided for supporting inner hull 18 within outer hull 17 and in a spaced relation to each other. Framing 19 may be formed by typical or conventional ship framing structural arrangements. Insulating means shown as an insulating layer 20 is coupled to inner hull portion 18 on the interior surface thereof for preventing substantial heat transfer through the inner hull.

More particularly, and with reference to FIG. 2, the enlarged cross-sectional view taken along line 2—2 of FIG. 1, shows the construction of the cargo-containing portion 11 (i.e., tank 12) in greater detail. The trapezoidal shape of the top portion of the inner hull structure reduces free-surface effects to improve the stability of the ship. Alternatively, it should be noted that this may be obtained by longitudinally subdividing the tanks, such as with a longitudinal bulkhead 40 of the alternative embodiment illustrated in FIG. 4, which is a cross-sectional view of a flat-deck, double-hull ship constructed in accordance with the principles of the present invention. The space between the hulls, including the four triangular-shaped spaces 21, 22, 23, and 24, may be used for ballast purposes to further improve the stability and maneuverability of the ship, especially on return voyages without cargo. Moreover, these spaces may be used to house pipes, symbolically represented at 25, for cargo-handling purposes as well as to provide a place for monitoring devices to sense any leakage from the inner hull. Moreover, some of pipes 25 may be utilized for controlling any leakage that may occur. In addition, these spaces may be filled with an inert gas to increase the safety of the ship during a loaded voyage. The contained and controllable nature of this interhull space makes it well-suited for these purposes without requiring additional structural components, while still providing the advantages of the present invention.

With reference to FIG. 3, there is shown an enlarged view of the hull and insulation structure of the embodiment of the invention illustrated in FIG. 1, and, in particular, the portion encircled by dotted line 26 in FIG. 2. Insulating layer 20 comprises a relatively thick layer 32 of a foamed plastic insulating material and a thin solid barrier layer or liner 34 applied thereto. Insulating material 32 may be conventional polyurethane foam, for example, applied directly to the interior surface of inner hull 18. The liner 34, as shown in detail by the encircled portion 35 in FIG. 5, is preferably a laminate of organic and metallic films or layers, such as a metal foil 50 (e.g., of aluminum) sandwiched between two strength-providing polymer sheets 52 and 54 (e.g., of Mylar, Dacron or other suitable polyester). One such laminate which may desirably be employed comprises an aluminum foil between a sheet of Mylar and a sheet of Dacron to provide a primary barrier against gas and/or liquid leakage. Of course any other suitable material may be alternatively used for this purpose. Also, of course, the insulation may conceivably be applied to the exterior surface of inner hull 18, but less advantageously.

By making both outer hull 17 and inner hull 18 out of a cryogenically non-embrittling metallic material, such as an aluminum alloy, it can be seen from FIG. 3 that inner hull 18 thus forms a secondary barrier and outer hull 17 forms a tertiary (or second secondary) barrier which (unlike prior art liquified-gas ships) will withstand contact with, and even successfully contain, any liquified gas which might foreseeably leak through both the primary and secondary barriers. In other words, the hull structure provides two complete secondary barriers. Furthermore, although at first glance it may merely seem costlier to make the outer hull portion 17 from a cryogenically non-embrittling metallic material, this is not believed to be the actual case. While the cost of the outer hull portion of the ship may be increased, the total cost for the ship of the same cargo capacity will actually be reduced. Also, additional advantages are obtained as will be discussed below.

One such advantage is the substantial reduction in weight of the hull structure and, consequently, the total displacement of the ship. A ship constructed in accordance with the invention and of a size comparable to a conventional liquified-gas ship having a separate tank structure has a lightship displacement up to approximately 50 percent less than the conventional ship. This results primarily from the reduction in weight provided by the non-embrittling metallic material used for the hull (e.g., in going from mild steel to 5083 aluminum alloy, the corresponding weight reduction is from 10,000 tons or more to approximately 7,000 tons). It also results from the elimination of separate tanks and access space to such tanks, the amount of which varies depending upon the particular design of the ship. This substantial reduction in weight provides for real economies in terms of reduced power requirements for a given-sized ship. The substantially lighter weight also reduces the draft of a ship constructed in accordance with the invention to such an extent that it may call at ports which are too shallow for conventional tankers of the same or even less cargo capacity. The draft of such a ship is especially important in view of the general desire to have liquified-gas cargoes delivered as close to shore as possible. Alternatively, the full draft allowed

for conventional ships may be utilized to thereby reduce the ship's depth and freeboard which decreases windage and thus decreases ballast requirements and the wasted space occupied thereby. Similarly, the full power provided for conventional liquified-gas ships may be used for a ship constructed in accordance with the invention to permit a greater cruising speed.

Another substantial advantage is the elimination of the separate tank structure which thus permits an increase in cargo capacity of up to 10 percent and affords a smaller per-unit shipping cost. Alternatively, smaller ships may be constructed in accordance with the invention having greater capacity than tankers of an equivalent over-all size but of conventional construction, thus permitting shipyards too small for the conventional-sized tankers to participate in the growing liquified-gas transportation industry. Greater speed may also be obtained with the smaller and lighter ships. Furthermore, by providing practical liquified-gas ships in smaller sizes, in accordance with the invention, such ships may take advantage of existing hull designs which, because of their extensive actual use, are generally quite predictable in terms of safety, operating efficiency, maneuverability, stability, and floatability. The resulting increased maneuverability from the reduced size also eliminates some of the auxiliary navigational assistance (e.g., tugboats) normally required to move conventional liquified-gas tankers in and out of some ports.

All of these advantages are in addition to the very important advantage of increased safety. Unlike conventional tankers, no reasonable leak can cause a catastrophic failure in the hull structure. In addition, the aluminum alloy hull structure is far less susceptible to corrosion than is steel and therefore requires substantially less maintenance.

With respect to the manufacture of ships in accordance with the principles of the invention, the employment of aluminum permits the use of more efficient structural members because of the low cost of made-to-order aluminum extrusions. Furthermore, automation of hull construction may be facilitated by the use of coiled plate stock.

Various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawing. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. A ship for the transportation of liquified gases at pressures approximately equal to atmospheric pressure and at temperatures substantially below ambient temperature, having an outer hull portion and an inner hull portion, with a plurality of discrete cargo-containing portions integrally formed with said inner hull portion and separated by a rigid bulkhead having substantially the same structure as said inner hull portion:

said outer hull portion being made from a cryogenically non-embrittling metallic material;

said inner hull portion being made from a cryogenically non-embrittling metallic material and disposed within said outer hull portion;

means for supporting said inner hull portion within said outer hull portion and in a spaced relation thereto;

and thermal insulating means disposed on said inner hull portion and said rigid bulkhead to completely

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surround each of said cargo-containing portions, said inner hull portion and said insulating means defining each of said integrally formed cargo-containing portions of the ship.

2. A ship according to claim 1, in which said insulating means comprises a layer of insulation applied to the interior surface of said inner hull and having an impermeable liner on the interior surface of said insulation.

3. A ship according to claim 1, wherein said cryogenically non-embrittling metallic material is an aluminum alloy.

4. A ship according to claim 1, wherein said outer hull portion extends substantially around the sides and deck of the ship.

5. A ship having a plurality of discrete cargo-containing portions for the transportation of liquified gases at cryogenic temperatures, said cargo-containing portions comprising a primary barrier formed by an impermeable material completely enclosing and in contact with the liquified gas cargo, a secondary barrier formed by an inner hull portion of the ship composed

essentially of an aluminum alloy, a layer of foamed plastic thermal insulation disposed between said impermeable material and said inner hull each of said cargo containing portions being separated by a rigid bulkhead composed essentially of an aluminum alloy with other hull portion and in spaced apart relation thereto, said inner hull portion being at least substantially coextensive with said outer hull portion.

6. A ship according to claim 5 wherein said impermeable material comprises one or more layers of a polymer.

7. A ship according to claim 5 wherein said supporting means comprises metallic framing between the hulls.

8. A ship according to claim 5 wherein said impermeable material comprises one or more layers of a metal.

9. A ship according to claim 5 wherein said impermeable material comprises one or more layers of a mixed laminate of a polymer and a metal.

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