June 20, 1972 F. J. IAROSSI 3,671,315

THERMAL TRANSITION DESIGN FOR VESSELS CARRYING LIQUID CARGOES AT NONAMBIENT TEMPERATURES

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Fig. 1.

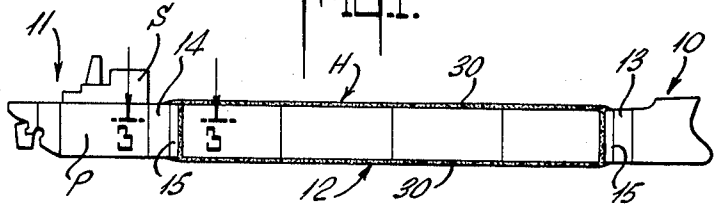


Fig. 2.

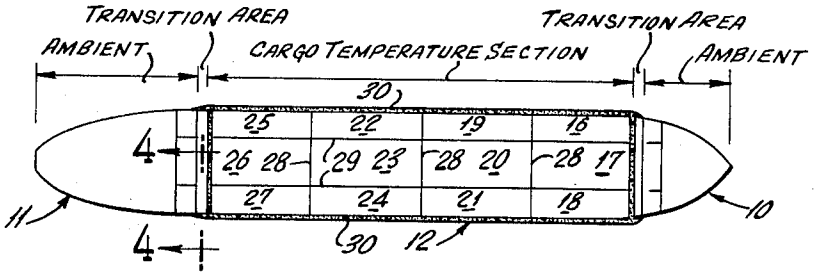


Fig. 3.

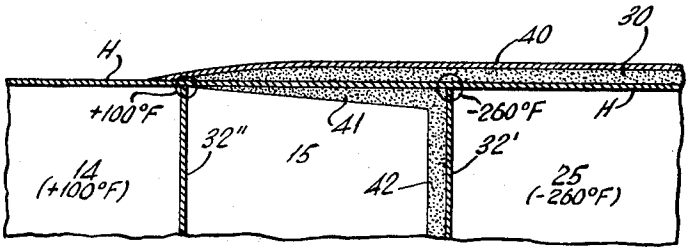


Fig. 4.

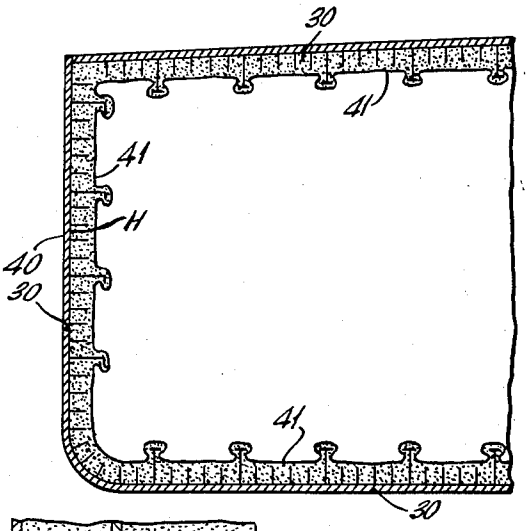
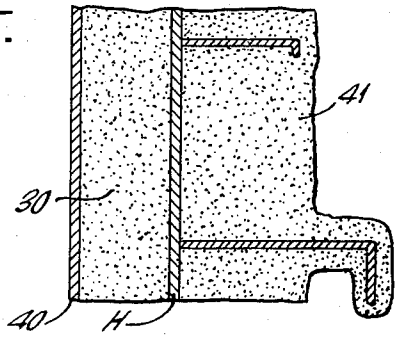


Fig. 5.



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THERMAL TRANSITION DESIGN FOR VESSELS CARRYING LIQUID CARGOES AT NONAMBIENT TEMPERATURES

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U.S. Cl. 114—74 A 2 Claims

ABSTRACT OF THE DISCLOSURE

An externally insulated integral tanker vessel intended especially for the transport of liquid cargoes at temperatures differing from ambient temperature, including bow and stern sections, joined to the cargo midbody, which is at the temperature of the cargo, in such a manner as to maintain substantially ambient temperatures throughout the end portions of the tanker hull. Toward this end there is provided a temperature transition area or compartment at each end of the cargo midbody section to minimize the thermal stresses that normally would occur between the cold hull of the midbody and the relatively warm hull at either end of the tanker. The entire hull is constructed as a continuous shell similar to that of a conventional vessel. The shell plating in the transition area is insulated internally and externally in such a manner as to reduce the temperature gradient between the cold hull steel of the midbody and the warm steel at the end. The insulation gradually is tapered along the shell so as to control the heat input to the plating as a function of the distance away from the cold midbody steel. This acts to extend the length of the thermal transition, thereby reducing the thermal gradient and resulting thermal stresses in the vessel's hull.

BACKGROUND OF THE INVENTION

The present invention relates to liquid-carrying tankers and, more particularly, to an externally insulated LNG tanker wherein the vessel comprises, preferably, a single shell internally stiffened both longitudinally and transversely and wherein the cargo sections are subdivided into tank spaces by longitudinal and transverse bulkheads with the vessel's shell forming the outer tank boundary.

It is well known that the waterborne transportation of liquefield natural gas at or near atmospheric pressure has required radical departures from conventional tanker design. Since at cryogenic temperatures the steels normally employed in ship construction become so brittle that they no longer provide structural integrity, the major design effort has been directed toward the development of satisfactory tank systems to contain the cryogenic cargo apart from the ship's structure.

To cope with the problem of low temperature embrittlement of mild steel, a variety of designs have been provided for independent or self-supporting and integrated or membrane tanks. However, these prior art solutions have proven to be relatively unsatisfactory in that not only do they provide an LNG ship which is three to four times more expensive than a conventional tanker of similar capacity, but the ship is dependent upon the integrity of a multiple of barriers and warning systems for structural security, and in the case of membrane tanks, there is raised the question of long-term durability.

The novel construction and arrangement of the present invention is employed in conjunction with the utilization of low temperature, nickel alloy steel or a like material for the hull structure throughout the cargo section or midbody of the vessel. Since at cryogenic temperatures nickel steel possesses mechanical properties far superior

to those of ordinary structural steel, many of the problems which have greatly complicated previous LNG ships are bypassed. A 9% nickel steel hull would be resistant to brittle fracture at temperatures as low as −320° F. and would itself provide a suitable container for the liquefied natural gas cargo. This would remove the necessity for independent tanks or membrane liners, access spaces, cofferdams and secondary barriers. A typical vessel construction employing an externally insulated nickel steel hull is disclosed in the U.S. Gorman Pat. No. 3,283,734 assigned to the assignee of the present invention. Structurally, the vessel previously disclosed may comprise a single shell, internally framed with intermittent deep web transverses. The cargo section is subdivided into tank spaces by longitudinal and transverse bulkheads with the ship's shell forming the outer tank boundary. The bow and stern sections, maintained at ambient temperature, are joined to the cargo midbody which is at the temperature of the cargo. In so joining the body, stern, and cargo midbody sections, it is critical that these sections be joined so that substantially ambient temperatures are maintained throughout the end portions of the tanker hull. The Gorman patent does not disclose the means whereby this connection is accomplished. Thus, if the shell plating is contained between the warm and cold sections without provision for limiting the thermal gradient, the resulting thermal stresses would exceed the design load of the vessel structure and cause undesirable damage, e.g., buckling, etc.

The present invention discloses a construction and arrangement whereby the entire hull is constructed as a continuous shell similar to a conventional vessel, but with temperature transition areas or cofferdams arranged at each end of the tank section. To limit the thermally induced stresses created between the cold hull of the midbody and the warm hull at each end of the vessel, the shell plating in the transition area is insulated internally and externally so as to reduce the thermal gradient and the structure is reinforced to accept the resulting stresses. This temperature transition area is necessitaed by the fact that by employing the aforedescribed vessel construction the shell in way of the cargo carrying portion of the ship no longer is at ambient temperature as was true with prior art structures, since the hull itself forms the outer boundary for the cargo carrying portion of the ship.

It clearly is apparent that the foregoing construction and arrangement has numerous advantages over prior art arrangements presently in use for the transportation of methane, ethylene, LPG, molten sulfur or other materials at temperatures higher or lower than ambient temperature. The use of a temperature transition area as contemplated by the present invention provides for the carriage of very low and very high temperature cargoes in a manner similar to the carriage of ambient temperature cargoes. This novel construction and arrangement provides up to substantially forty percent greater cargo capacity for given ship dimensions than does present known technologies. Also, a vessel constructed in accordance with the present invention provides an intrinsically safe ship's hull free from structural failures that might be induced by high thermal stresses.

Accordingly, it is an object of the present invention to provide a liquid cargo-carrying vessel with a novel construction and arrangement for maintaining ambient temperatures throughout the bow and stern sections and cargo temperatures throughout the midbody section of the vessel's hull.

Another object of the present invention is to provide an externally insulated tanker vessel having a hull forming the outer boundary of the cargo section with temperature transition areas at the forward and after extremities of the cargo carrying midbody in order to re-

duce thermally induced stresses at the junction to the bow and stern sections.

Having in mind the above and other objects that will be evident from an understanding of this disclosure, the invention comprises the combinations and arrangements as illustrated in the presently preferred embodiment of the invention which is hereinafter set forth in such detail as to enable those skilled in the art readily to understand the function, operation, construction and advantages of it when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic elevational view of an externally insulated tanker incorporating the present invention;

FIG. 2 is a schematic plan view of the tanker of FIG. 1;

FIG. 3 is an enlarged sectional view of the novel and improved tanker construction taken substantially along the line 3—3 of FIG. 1 illustrating details of the temperature transition area;

FIG. 4 is an enlarged cross-section view taken through the transition area substantially along the line 4—4 of FIG. 2;

FIG. 5 is an enlarged view of a portion of FIG. 4 illustrating the details of the external insulation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Having reference to the drawings the present invention is illustrated in FIG. 1 as embodied in an externally insulated tanker having a nickel steel plate hull at its mid-body, reference being made to the U.S. Gorman Pat. No. 3,283,734 for a more complete and detailed explanation thereof.

The tanker generally includes a hull H, a power plant P, and a superstructure S, arranged as shown. The forward hull portion or bow **10** and the after hull portion or stern **11** are conventionally fabricated from mild steel plate and mild steel strengthening members. As shown in FIG. 1, the forward and after hull portions **10** and **11** each typically may include ballast tanks **13** and **14**, respectively.

In accordance with the teachings of the previous invention as disclosed in the Gorman patent the midbody **12** of the ship is fabricaed from a metal plate possessing physical and mechanical properties compatible with the particular cargo to be carried. Since the primary requirement for a cryogenic container is suitable notch toughness at the service temperature, the midbody plate material may advantageously comprise a nickel steel containing substantially nine percent nickel such as disclosed in the heretofore mentioned Gorman patent. The cargo hold or midbody of the ship may be subdivided into a plurality of individual cargo holds **16–27** by transverse bulkheads **28** and a longitudinal bulkhead **29**, and is completely enveloped or clad externally with a suitable thermal insulation material **30**. It should be noted that although the ship's midbody structure has been disclosed as comprising a material such as nine percent nickel steel for cryogenic products such as methane and the like, in the case of other low temperature products such as LPG, usual tank quality steel would be sufficient while ordinary hull quality steel would suffice for high temperature products.

The present invention discloses an arrangement for joining the bow and stern, **10** and **11** respectively, to the midbody or cargo carrying portion of the hull, designated **12**, in such a manner as to limit the resulting thermal stresses. As illustrated in FIGS. 1 and 2, a specially designed cofferdam or temperature transition area **15** of the hull, which is likewise fabricated from specially suitable metal plate, is interspaced between the forward and after portions and the midbody. An external insulation **30** is fixed to the exterior of the midbody **12** and extends over the plating in the transition areas **15**. As best shown

in FIG. 3, the insulation **30** is reduced in thickness moving fore and aft of the midbody **12** until it terminates at the extreme ends of the transition areas **15**. The shell in way of the transition areas also is insulated internally as shown at **41** in a manner similar to that described heretofore, namely with diminishing thickness. The forwardmost and aftermost transverse bulkheads of the cargo section also are insulated as shown at **42** within the transition area. FIG. 3 illustrates the details of the insulation arrangement at the transition area located in the vessel's stern and a similar construction is provided in the transition area located in the bow of the vessel.

The thermal insulation **30**, **41** and **42** comprise a low density, organic, foam-type material containing a cellular structure of separate or interconnecting voids, such as polyurethane. The external insulation is protected by an outer covering **40** comprising a material or combination of materials possessing suitable qualities of elasticity, toughness, permeability and fire resistance disposed over said foam. FIGS. 4 and 5 further illustrate in sectional view the aforementioned details of the insulation. The outer protective coating **40** may be sprayed on by conventional techniques and may comprise a suitable rubber compound such as butyl or neoprene. Also, vinyl and polyurethane are suitable. Alternatively, the coating may comprise a sheet material such as a nylon/phenolic laminate, fiberglass reinforced laminate or a reinforced rubber compound such as neoprene mentioned heretofore.

As mentioned hereinbefore, in a ship having a cargo storage area wherein the ship's hull comprises the outer boundaries of the storage tanks, the bow and stern sections **10** and **11**, although being of conventional tanker design and material, are joined to the cargo midbody **12** in such a manner as to maintain ambient temperatures throughout all portions of the ends. Exemplary temperatures of the cargo tank area (−260° F.) and the adjacent end sections (+100° F.) are illustrated in FIG. 3. Thus, it is shown that there may exist a temperature differential of approximately 360° F. between the transverse bulkheads **32'** and **32''** on either side of the temperature transition area **15**. Thus, while a temperature gradient will exist in the area denoted as the temperature transition area **15**, this area may be considered to be warm or at ambient conditions. The purpose is to limit the thermal stresses that normally would be induced as a result of the temperature differentials by reducing the thermal gradient between the cold tank and warm end sections of the vessel. The steeper the thermal gradient, the greater the possibility of excessive stress concentrations and resulting structural failure of the vessel's hull. By limiting the heat input to the shell at the transition zone, the gradient will be extended in length and thus reduced in magnitude. The preferred arrangement for accomplishing temperature transition from the cargo section to the ends of the vessel is illustrated in the drawings, FIG. 3 in particular. Thus, as shown, the entire hull H is constructed as a continuous shell similar to that of a conventional vessel, but in addition temperature transition areas or cofferdams **15** are provided at each end of the midbody cargo carrying section **12**. The hull structure in the transition area is insulated internally at **41** and externally in such a manner as to reduce the temperature gradient between the −260° F. cold hull steel of the midbody and the +100° F. relatively warm hull at the end sections. The internal insulation is arranged so as to extend longitudinally of the ship the full length of the transition area, that is, between the transverse bulkheads **32'** and **32''**. This arrangement provides for a controlled heat input to the shell as a function of distance from the cold midbody steel. By precluding a rapid temperature buildup in the hull structure, high thermal stresses, which would otherwise overstress the structure, are avoided. Thus, as shown, the longitudinally extending insulation, both externally and internally, terminates in a tapered fashion. The tapering begins at about the end of the midbody section **12** as defined by the trans-

verse bulkhead 32'. This tapered insulation arrangement allows the heat transition to occur gradually rather than abruptly, as would be the case if there were no taper present. Thus, it precludes adverse stress concentrations from occurring proximate the midbody or cargo carrying area of the vessel. Also, insulation 42 is disposed along the outer surface of the transverse bulkhead 32'. The hull structure is so designed that it is free of structural restraints, such as triaxial joints, so as to withstand the reduced thermal stresses in addition to stresses caused by longitudinal bending and local loading. The insulation may be secured to the hull and the transverse bulkheads by any suitable means, e.g., it may be bonded as a conventional spray-on a foam in-place process or alternately, the insulation may be of block form (e.g., balsa panels or foam blocks) and secured in place by a suitable adhesive.

It will be appreciated from the foregoing description that a new and improved tanker construction embodying the inventive concepts a described above enjoys significant construction advantages over conventional structures since the cryogenic liquefied natural gas cargo or the like may be carried directly by the ship structure itself rather than being separated therefrom by a plurality of barriers, independent tanks, cofferdams, access spaces and the like. One of the major advantages is a significant increase in cargo carrying capacity for specific ship dimensions. Further, as should be understood, significant savings are effected through the application of thermal insulation to the relatively smooth exterior surfaces of the ship hull rather than to internal surfaces which are interrupted by reinforcing ribs, pipe mountings, etc.

It should be understood that the specific construction and arrangement herein illustrated and described is intended to be representative of a preferred embodiment only and that certain changes may be made therein without departing from the clear teachings of the present disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

Having thus set forth the nature of the invention, what is claimed herein is:

1. A tanker for the transportation of liquid cargo at atmospheric pressure and cryogenic temperature comprising,

(a) a hull having a forward portion, an after portion, and an intermediate cargo-carrying portion including a first transverse bulkhead located at each end thereof,

(b) said forward and after portions being fabricated from mild steel plate,

(c) said cargo-carrying portion being fabricated from

plate material having physical and mechanical properties substantially characteristic of nine percent steel at extremely low temperatures,

(d) transverse cofferdams included in said forward and after portions adjoining said cargo-carrying portion to provide a thermal transition area between said cargo-carrying portion and said forward and after portions, said transverse cofferdams being defined lengthwise by said first transverse bulkhead and a second transverse bulkhead longitudinally spaced therefrom,

(e) thermal insulation means fixed to the outer hull surfaces of said intermediate cargo-carrying portion and extending to the outer extremity of said transverse cofferdams comprising said second transverse bulkhead,

(f) further thermal insulation means fixed to the interior hull surfaces of said transverse cofferdams and extending for the full length thereof between said first and second transverse bulkheads, said further thermal insulation means also being fixed to the surface of said first transverse bulkhead disposed externally of said cargo-carrying portion, and

(g) said thermal insulation means and said further thermal insulation means terminating adjacent said second transverse bulkheads in a tapered configuration with the insulation means tapering inwardly toward the hull fore and aft of said cargo-carrying portion, whereby the thermal gradient and resultant thermal stresses in the hull are substantially reduced.

2. A tanker in accordance with claim 1, wherein

(a) said thermal insulation means comprises a low density, organic, foam type insulation material, and further including

(b) insulation protection means comprising an outer covering possessing suitable qualities of elasticity, toughness, permeability and fire resistance overlying said foam material for protecting the latter from deleterious affects.

References Cited

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U.S. Cl. X.R.

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