PATENT SPECIFICATION (11) 1 586 228

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(21) Application No. 39620/77 (22) Filed 22 Sept. 1977 (19)
(31) Convention Application No. 2 644 856
(32) Filed 5 Oct. 1976 in
(33) Fed. Rep. of Germany (DE)
(44) Complete Specification published 18 March 1981
(51) INT. CL.[3] B63B 5/16
(52) Index at acceptance
B7A DT

(54) TANKER VESSEL MADE OF REINFORCED CONCRETE, IN PARTICULAR FOR SHIPPING LIQUID GAS

(71) We, DYCKERHOFF & WIDMAN AKTIENGESELLSCHAFT, a German Body Corporate, of Sapporobogen 6, 8000 Munich 40, German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a tanker vessel, in particular for shipping liquid gas, having a monolithic ship's hull made of reinforced concrete, which vessel has side-by-side in the cross section of the hull at least two separate tank rooms extending longitudinally, subdivided by transverse bulkheads and joined together by deck and bottom.

Tankers for shipping liquid gas, if they are made of steel, have to be provided for safety reasons with special containers for the liquid gas, which containers consist of cold-resisting steel and mostly take the form of spherical tanks. Apart from the fact that in such tankers the available tank space can only be inadequately utilised, they are inordinately expensive to build and to maintain. At the same time, tankers made of reinforced concrete are already known, which can be built more easily and cheaply than steel ships.

In a known tanker the hull comprises two cylindrical bodies which intersect in the region of the longitudinal axis, so that in cross-section three spaces obtained, of which the two outer ones are used as tank rooms and the central space, formed by the intersection, is used as an operating room. The tank rooms are braced by flat transverse bulkheads. The deck, bottom and outer side walls of the hull are conventionally reinforced longitudinally and transversely.

When using reinforced concrete for the outer skin of tankers for shipping liquid gas, it is possible to omit the safety zone which in steel tankers necessitates the provision of special containers. As a building material, concrete does not suffer any reduction in strength if it happens to come in contact with the cold liquid in the event of a disaster, but instead undergoes an increase in strength. The main problem in a hull made of reinforced or prestressed concrete, in relation to a building construction on land, lies in the fact that the cross-section of the hull is subjected, while in service, to stress of extremely variable nature due to external loads, such as wave motion.

The invention provides a tanker vessel, in particular for shipping liquid gas, having a monolithic hull made of reinforced concrete and prestressed at least in part in the longitudinal direction, which hull has side-by-side in the cross-section of the hull at least two separate tanks extending lengthwise of the hull, sub-divided by transverse bulkheads and joined together by a deck and a bottom for the hull, the cross-sectional shape of the outer skin of the hull comprising the deck, bottom and outer side walls of the tanks extending between the deck and the bottom, which side walls have a continuous convex curvature facing outwardly of the hull over a major proportion of each wall between the deck and bottom.

In the tanker according to the invention, the load-bearing outer skin of the hull, viewed statically, consists, in the transverse direction, of two three-dimensional half-frames symmetrical to the longitudinal axis and comprising deck, outer side walls and bottom, which are subjected to extremely variable stress by the presence of the cargo acting from the inside outwards and by the pressure of the wave motion acting from the outside inwards. In longitudinal direction the hull represents a box girder whose length corresponds to the entire length of the ship.

A further and preferred feature of the invention is that the cross-sectional design of the hull is so chosen that the bending moments in transverse direction, which are caused, on the one hand, by water pressure and, on the other hand, by the cargo, are very small. The cross-sectional shape corresponds approximately to a pressure or thrust axis. It is also preferred that tensioning members for effecting a prestressing are provided, in addition to the normal conventional reinforcement and that the prestressing in longitudinal direction is so chosen that the maximum positive and negative bending moments are approximately equal in longitudinal direction. The conventional reinforcement thus acts alternately under compression and under tension, which has the advantage, in conjunction with the prestressing that the thickness of the solid slabs can be so dimensioned that the reinforced-concrete building material is optimally utilised throughout in a three-dimensional state of stress and the outlay on materials, and therefore, on weight is kept to a minimum.

The continuous curvature of the hull in cross-section has the advantage, in addition to the utilisation of an arch support action by avoiding corners, that the conventional reinforcing rods and the tensioning members do have to be previously bent, but can be bent elastically into the round configuration. Likewise, no corners are present against which the reinforcing rods have to be abutted, whereby the dynamic strength of the reinforcement is impaired. For the same reason, the longitudinal reinforcement is also arranged substantially unjointed over the entire length of the hull.

In a tanker according to the invention, the slab forming the deck can be widened laterally beyond the tangentially joining outer side walls. The widened portions can be supported towards the outer side walls and it is possible for additional tank rooms to be formed in the region of these widened portions.

These widened portions of the deck surface also have advantages for the operation of the ship, since the utilisable deck surface is increased thereby. Moreover, the widened portions can so alter the moment of inertia of the static cross-section of the hull that the zero line of the cross-section is located approximately in the centre and the stresses in the deck and bottom are approximately of equal magnitude. This also contributes to optimum utilisation of the reinforced-concrete building material.

In the case where the transverse bulkheads are required to provide watertight integrity, then they are preferably formed as doubly-curved shell vaults.

The transverse bulkheads may only be of secondary importance for the static construction of the ship to resist unequal deflections of the outside and inside walls, which in any case are slight, along the length of the hull. They may also serve for the safety of the ship in the event of unusual incidents, such as touching the bottom, collisions or damage due to enemy action.

The design of the transverse bulkheads as a doubly-curved shell vault enables a light construction to be obtained. The shell vault forms together with those wall portions of the outer tank adjoining the shell rims a shell beam which, in the event of a leak, seals off the damaged location from further water intrusion and which transmits the water pressure acting in the longitudinal direction of the ship to the tank walls.

The design of the transverse bulkheads as shell vaults also meets the requirement that such a tanker can advantageously be used for shipping liquid gas which is conveyed at temperatures of minus 162°C.

For shipping liquid gas, the walls bounding the tank rooms are provided on their inside and the transverse bulkheads on both sides with insulation to prevent cold penetration. Whereas in the case of the outer side walls the temperature drop from the ambient temperature toward the cold interior space takes place almost entirely in the insulation, it is unavoidable that the bulkheads cool down despite the insulation. The temperature drop will take place constantly from the outer skin up to a trough in the centre of the respective bulkhead. A plane structure would undergo intolerable thermal stress as a result of this. A shell vault is, however, able to elastically avoid these stresses by reducing its rise.

Reference is now made to the accompanying drawings which illustrate, by way of example, one embodiment of the invention, and of which:

Figure 1 shows a partly cut away oblique view of a tanker in accordance with the invention;

Figure 2 shows a longitudinal section through the tanker along its longitudinal central axis;

Figure 3 shows a horizontal section slightly above the waterline; and

Figure 4 shows a cross-section on an enlarged scale.

In the drawings there is shown a tanker suitable for shipping liquid gas, in which the outer side walls 2, the bottom 3 and the deck of the hull 1 consist of solid slabs of reinforced concrete. In addition to conventional reinforcement, the slabs have, in the longitudinal and transverse directions tensioning members for producing prestressing. For greater clarity, the reinforcing elements have been omitted. Their particular disposition is also of secondary importance to the invention.

The outer skin of the hull 1 encloses two main tank rooms 5 and 6. In the central region of the hull 1, between the tank rooms 5 and 6, there is situated in the upper part a stowage space 7 which may be used for ballast water and, in the lower part, a tank room 8 for fuel. The partitions 9 for these two central tank rooms 7 and 8 are also in the form of slabs made of reinforced concrete; however, they may be thinner than the outer walls 2, since the interior space is braced at short intervals by transverse bulkheads 10 or ribs 11 and the forces are essentially taken up by the slabs of the outer skin.

All the reinforcing elements consist of high-strength steel, e.g. ST 135/150, diameter 16 mm, which is supplied wound on drums in lengths of 250 m or more, so that it can be installed unjointed in long lengths and is cold-resistant at temperatures down to —200°C. This steel can be used both for the conventional reinforcement and for the tensioning members owing to its strength and its surface conformation (its surface is provided with profiling in the shape of ribs which form a thread on to which the corresponding anchoring or connecting members can be screwed). It may also be used here both as individual rods, as for example in transverse tensioning members, and as individual elements in bundled tensioning members, e.g. in longitudinal tensioning members.

This steel exhibits a dynamic strength of 30 kp/mm², if the stress fluctuation goes from 0 to 30 kp/mm², but exhibits a dynamic strength of 24 kp/mm², if the basic stress caused by the prestressing of the steel amount to 70 kp/mm². This varying amplitude of vibration takes into consideration the fact that the conventional reinforcement is disposed on the outside of the reinforced-concrete slabs in each case. Where the largest variations in stress occur, whereas the prestressing steel is arranged in the inner region of the slabs, where the stress fluctuations are correspondingly lower.

The transverse bulkheads 12 in the vicinity of the outer tank rooms 5 and 6 take the form of doubly-curved shell vaults. They are connected at the outer edges (at the abutments) to the walls of the particular tank rooms.

The drawing illustrates a tanker suitable for shipping liquid gas. For this purpose the outer tank rooms 5 and 6 are provided on the inside and the transverse bulkheads formed as shell vaults on both sides with an insulation 13 (Figure 4). The insulation 13 advantageously consists of polyurethane foam sprayed on in layers. A vapour-tight layer e.g. of epoxy resin, is applied between the concrete surface and the insulation.

The ship's hull 1 is of streamlined design. In the stern it has rooms 14 for the driving machinery 15, for the equipment for maintaining the low temperatures etc. and has a screw 16 and a rudder 17. The usual superstructures 18 are provided on the deck 2, which have just a little significance for the invention as the pipe systems for filling and emptying the tank rooms, which are shown in Figure 1 but require no further explanation.

The slab forming the deck 4 has widened portions 4^1 on either side, which are supported by inclined walls 19 towards the curved outer side walls 2. According to the side of the widened portions 4^1, there is a possibility of adapting the statically effective cross-section of the deck 4 to that of the bottom 3 and thus adjusting the moments of resistance of the cross-section to each other. In addition, there are thereby formed in the cross-section further, approximately triangular tank rooms 20 which, for example, can be used for ballasting.

WHAT WE CLAIM IS:—

1. A tanker vessel, in particular for shipping liquid gas, having a monolithic hull made of reinforced concrete and prestressed at least in part in the longitudinal direction, which hull has side-by-side in the cross-section of the hull at least two separate tanks extending lengthwise of the hull, subdivided by transverse bulkheads and joined together by a deck and a bottom for the hull, the cross-sectional shape of the outer skin of the hull comprising the deck, bottom and outer side walls of the tanks extending between the deck and the bottom, which side walls have a continuous convex curvature facing outwardly of the hull over a major proportion of each wall between the deck and bottom.

2. A tanker vessel according to claim 1, in which the slab forming the deck is widened laterally beyond the outer side walls which join the deck approximately tangentially.

3. A tanker vessel according to claim 2, in which the widened portions of the deck are supported against the outer side walls, there being formed, in the vicinity of these widened portions additional tank rooms.

4. A tanker vessel according to any of claims 1 to 3, in which the transverse bulkheads take the form of doubly-curved shell vaults.

5. A tanker vessel according to any of claims 1 to 4, in which, for shipping cold liquids, e.g. liquid gas, the walls delimiting the outer tanks are provided on their inside and the transverse bulkheads on both sides with insulation against cold penetration.

6. A tanker vessel substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1981.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 4

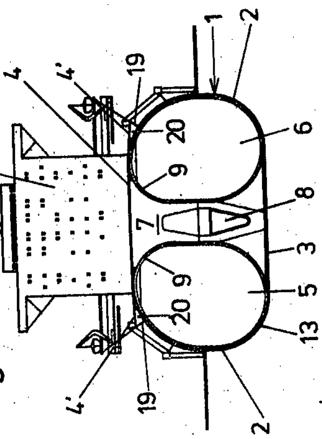
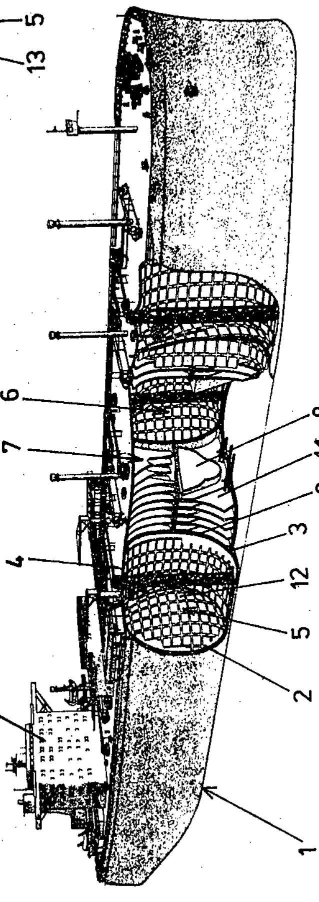


Fig.1



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Sheet 2

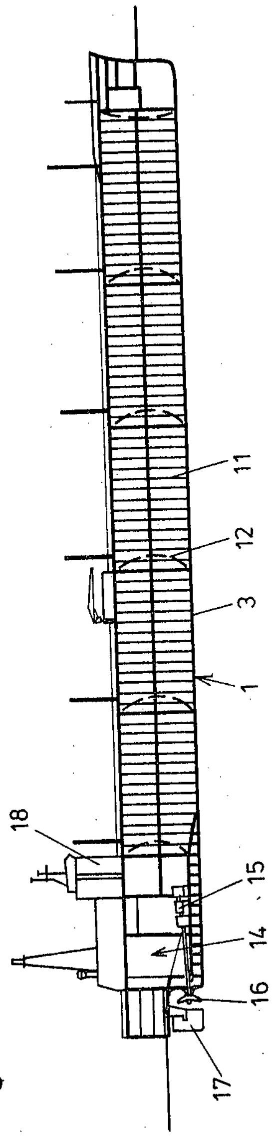

Fig.2

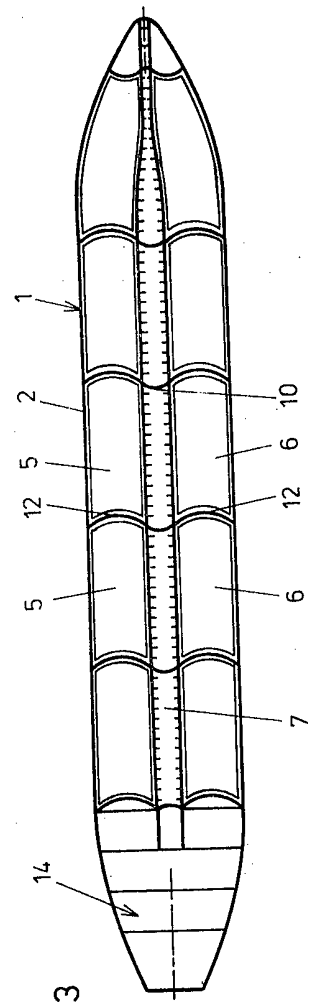

Fig.3