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(54) IMPROVEMENTS IN OR RELATING TO TANKS FOR INSTALLATION ON BOARD SHIPS

(71) We, SENER, Tecnica Industrial y Naval, S.A., a Spanish company, of Avd. del Triunfi, 46, Las Arenas, Vizcaya, Spain, 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:—

This invention relates to improvements in the mounting of self-strengthened tanks in the shape of a vertical axis solid or body of revolution on board ships and other buoyant marine structures and designed to transmit to the resistant member or structure of the ship or buoyant marine structure concerned the weight of the tank without in practice producing bending moments in the shell or wall of the tank.

These tanks can take any vertical axis solid-of-revolution shape, e.g. they may be spherical, cylindrical with spherical or ellipsoidal tops, or else formed by a combination of these geometrical shapes.

In accordance with any of the shapes indicated, such tanks are particularly suitable for the storage and/or carriage of pressurized liquid gas due to their low ratio of surface area to volume and to the fact that their walls are predominantly working under membrane stressing without major bending moments or shear stresses being introduced. All this contributes to tank weights being relatively low according to the shapes described, this having considerable bearing on their cost.

In the case of liquids or liquefied gas stored and/or carried at a pressure close to atmospheric, tanks of the above mentioned shapes of the advantage of their low surface-to-volume ratio and also to a lesser degree the advantage that they are fundamentally working as membranes. The fact that the bending moments and shear stresses may be relatively more important when the pressure is of atmospheric order does not cause major difficulties inasmuch as, due precisely to the relatively simple geometric shape and the absence of

stiffeners interrupting homogeneity of the tank shell, it is possible to calculate very accurately the status of stresses on each point of the tank for any cargo-load situation.

All this gives greater reliability in the design of tanks, to a point where for solid revolution tanks designed on the basis of a very accurate analysis of the stress condition at each point, the appropriate authorities permit their installation on board ships or in other buoyant marine structures without requiring the installation of a full secondary barrier to contain contingent leaks from the main tank, which barriers are becoming obligatory with other types of tank.

The possibility of wholly or partially eliminating the secondary barrier aforementioned and the economy in material that can be achieved, makes the adoption of tanks in the form of a body of revolution particularly attractive in harmony with the shapes above mentioned, for marine transport of natural liquid gas, ethylene, propane, propylene, butane, butadiene, isobutane, ammonia, chlorine, and other liquid products carried under pressure not very much above atmospheric, particularly in those cases where the boiling point at atmospheric pressure is very low. Such is the case for liquid natural gas carried at less than -162°C ., for ethylene at less than -105°C ., and other liquid petroleum gases carried between -45°C and -50°C . In all these cases of low-temperature carriage the tanks are insulated to prevent excessive evaporation of the product.

The geometrical configuration and the materials to be used in the cargo tanks, their support systems and the ship's supporting structure, must be such that at no point are temperatures reached below those at which brittle fracture may occur, at the same time allowing thermal contraction of the tanks, which occurs when the temperature drops

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below ambient to that of the individual product carried.

One of the most important problems that the use of the vertical axis body of revolution type tank gives rise to on board ship is that of mounting, due to the ship's movement at sea which sets up inertia pressure not only in the direction parallel to the axis of revolution of each tank but also in directions parallel to the longitudinal and transverse axes of the ship or other buoyant marine structure. The problem becomes particularly acute in the case of large ships designed for the carriage of natural liquid gas because of the large dimensions of the tanks, which are associated with large inertia.

Several working forms for mounting tanks on board ship are already known. As examples, Norwegian Patents Nos. 4145/69 and 4146/69 can be quoted, as also Spanish Patent No. 368,210 which claims priority from French Applications Nos. 157299 of 28 June 1968 and 180260 of 24 December 1968.

The first of these patents describes an arrangement for carrying tanks on board ship, consisting of cylindrical plates welded directly to the ship's structure and to the tank shell, where these plates can be continuous between tank and the mounting structure or else non-continuous with an intermediate supporting wing fitted with coupling devices preventing the relative movement between upper and lower parts of the support. In such patents there is also disclosed the provision of an equatorial or middle ring or collar forming an integral part of the tank, this having an outer foot attached to the skirt or flange to form part of the support.

The tank is thus held non-concentrically on a line of circumference, causing major bending moments to be induced in the tank shell by the action of stresses parallel to the axis of revolution.

The bending moments induced and the dimensions of the middle or equatorial part, according to the preferred working method of the aforesaid patents, result in the system being impracticable for large dimension tanks.

In Spanish Patent No. 368,210, the tanks are held by means of a relatively large number of discrete members preferably arranged along the middle-line or equator and perpendicular meridians.

Although no bending moments of importance are induced in the shell with this method, strong concentrations of stresses in fact originate in the link areas between the shell and the discrete members, which also makes this method impracticable for large-dimension tanks.

An object of the present invention is to achieve the installation of body-of-

revolution type tanks on board ship without the danger of bending moments or major stress concentrations being induced in the shell, thus permitting erection of the tank without practical restriction on dimensions, and with greater safety.

According to the present invention, there is provided a tank arrangement for installation on board a ship or other buoyant marine structure and comprising a tank shell shaped as a vertical axis solid of revolution, a continuous peripheral structure arranged around the tank shell in the equatorial area thereof, and two support and coupling elements extending from the continuous peripheral structure and encircling the tank shell, each element being coupled by one of its ends to the continuous peripheral structure and, in use, by the other end to the ship or other buoyant marine structure so that forces perpendicular to the axis of revolution of the tank shell can be absorbed by at least one of the elements while forces parallel to the axis of revolution of the tank shell can be absorbed by the two elements of which one will be subject to tension and the other to compression, so that whatever the spacing between elements and the tank shell may be, bending moments will not be induced in the latter, said peripheral structure being coupled to the tank so that at least the inner part thereof forms part of the tank shell.

Coupling of the support and coupling elements to the ship's structure or carrying arrangement can be effected below the equatorial or middle area of the tank, close to the double bottom of the ship, or above the middle area close to the upper deck. In the first case the tank will be supported on the carrying arrangement and in the second suspended from it.

By employing this invention, stresses perpendicular to the axis-of-revolution of the tank, i.e. those directed on planes parallel to the base plane of the ship, are transmitted in the form of shear stresses through the peripheral structure, passing from it to one or both of support and coupling members or elements, also in the form of shear stresses. Thus, mutual action between the peripheral structure and the tank shell, derived from the action of forces perpendicular to the axis-of-revolution, does not in practise induce bending moments in the tank shell. Transmission of shear stresses from the peripheral structure to the carrying arrangement is effected through one or both support and coupling elements which has or have circumferential continuity throughout the whole of the web.

In so far forces parallel to the tank's axis-of-revolution are concerned, also transmitted through the peripheral

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structure, those forces are absorbed and transmitted to the structure of the ship by the assembly comprising the two support and coupling elements, one of which will work under compression, while the other will be doing so by tension. Due to this joint form of working of the two elements, the mutual action between the peripheral structure and the tank shell as derived from the action of forces parallel to the axis-of-revolution, does not in practice induce bending moments in the tank shell, as distinct from what would occur if only a single element were employed, in which event major bending moments would appear due to non-concentricity of the line of reaction application in respect of the shell half surface.

Thermal contraction of the tank, appreciably similar to that in the peripheral structure which is at the same temperature as the tank shell, is possible thanks to the existence of a temperature gradient in the two support and coupling elements, the temperature of which rises from the end or edge coupled to the peripheral structure to that joined to the ship's structure. However, the support and coupling elements lack stiffeners in the area closest to the tank peripheral structure, resulting in low rigidity in comparison with the peripheral structure, the whole of the support system becoming thermally deformed so that the peripheral structure can follow the tank shell, keeping it appreciably parallel to itself. This implies both the normal forces on the tank as also the bending moments induced by thermal contraction being of low magnitude, hence the oversize or allowances of the tank shell in the vicinity of the middle or equatorial line are of moderate magnitude.

The two support and coupling elements are desirably peripherally continuous in the area of coupling with the continuous peripheral structure, one of the elements furthermore being continuous throughout its height, preferably the one subject to compression.

Between the two support and coupling elements there may be stiffeners contained on meridian planes of the tank, these being defined between the carrier structure and a diaphragm or ring located close to the peripheral structure, in an area where both elements are continuous. Between this carrier structure and the ring or diaphragm one or more rings can be fitted, these running between the support and coupling elements, which together with the aforementioned stiffener give stability to these support and coupling elements.

The peripheral structure may consist of at least one open profiled section having the general configuration of a continuous web, preferably horizontal, from which extend

four continuous projections, three from one side of the web and the fourth from the other and at least the radially inner and radially outer projections on said one side extending from the free edges of the web, the fourth and one of the other three projections serving to couple the peripheral structure of the tank shell and the remaining two projections serving to couple the structure to the support and coupling elements.

The projections from the sections to which the tank shell is attached become a part of it, the other projections encircling the tank being for coupling to the support and coupling elements. The web of the peripheral structure lies preferably in the radial direction, perpendicular to the tank axis-of-revolution, i.e. in a horizontal plane.

The stubs or projections attached to the tank shell to form part of it may be the inner projection of the three located on one side, together with the stub emerging from the other side of the web.

The projection emerging alone from one side of the web can occupy different positions in relation to the web, so that only the projections attached to the tank shell become part of the shell or alternatively these projections together with part or whole of the web become part of the tank shell.

Thus, for example, the projection directed in the opposite sense to the other three can extend from the inner end of the web, becoming in effect an extension of a projection of the other three also extending out from that end, both becoming part of the tank shell, while the other two outer projections serve for coupling to the support and coupling elements.

On the other hand, the projection directed in the opposite sense to the other three can emerge from the outer end of the web to come together with the one of the other three emerging from the inner end of the web and, with this web, form part of the tank shell, the other two projections as in the previous case remaining for fixing to the support and coupling elements.

Between these two positions, the projection directed in the sense opposite to the other three can root out from an intermediate point of the web to form part of the tank shell together with the opposite projection rooting out from the inner end of the web and with the part of the web running between these two inner and intermediate opposite projections, the other two projections serving as in the previous cases for securement to the support and coupling elements. In this event, the projection directed in the opposite sense to the other three will preferably emerge from a point opposite to the centre one of the

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opposite three projections to become in effect an extension of it.

When the peripheral structure, as it may be, is made up of two or more open profiled sections, the end of the section furthest away from the carrier structure has a continuous web from which the four continuous projections extend, while the or each remaining section consists of a continuous web from which six also continuous projections extend.

Of the end section projections farthest away from the carrier structure, three are turned towards the adjacent section and the fourth in the opposite direction, to become part of the tank shell together with the inner projection of the other three opposite.

Of the six stubs on the remaining sections, three are located on each side, preferably as extensions, the inner stubs (one on each side) being used to form part of the tank shell.

The other four stubs of the remaining sections, two on each side, face the intermediate—or end—section projections, these not forming part of the tank shell, for coupling to them by means of intermediate coupling elements.

Lastly, the end section projections closest to the carrier structure, turned towards that structure, abut the support and coupling elements for coupling to them.

Here, as when the continuous peripheral structure is formed by a single open profiled section, the projection directed in the opposite sense to the other three, on the section furthest away from the carrier structure, can be positioned at the inner end of the web, on the outer end or at an intermediate position, only the two opposite intermediate projections or also the whole or part of the web then becoming part of the tank in this case.

The peripheral structure can instead be composed of three profiled sections following horizontal and parallel circumference of different diameters, which sections in radial cross-section define the vertices of a triangle, and interconnecting these sections three intermediate elements of revolution each forming a respective side of said triangle and connecting a respective pair of the sections together, the sections having continuous projections for coupling them to the intermediate elements, to the support and coupling elements, and to the tank shell.

Within this arrangement, the circumference followed by the inner and outer of the sections will preferably be coplanar and the intermediate element coupling them will comprise a horizontal ring.

Preferably, the intermediate section of the three forming part of the continuous

peripheral structure is generally Y-shaped, each of the two inclined arms thereof being directed towards a respective one of the other two sections and being coupled thereto by a respective one of the intermediate elements of the peripheral structure the edges of which are coupled to the inclined arms, while the remaining arm is directed towards the support and coupling element closer to the tank shell and coupled to an edge of such element.

Of the other two sections, one of these may have three continuous stubs or projections and the other four, while the outer section can be the one fitted with four stubs and the inner with three, or vice versa.

In this case, when it is the outer section which is fitted with four continuous projections or stubs, the arrangement is such that parts of the tank on each side of the continuous peripheral structure have different diameters, the rim of the part of the shell having the larger diameter being coupled to the outer section of the peripheral structure and the rim of the part of the shell having the lesser diameter being coupled to the inner section, and wherein the inner and outer sections of the peripheral structure each have a first continuous projection directed towards the part of the tank shell to which it is coupled, a second directed towards the other of the inner and outer sections, and a third directed towards a respective continuous projection of the intermediate section; the outer section also having a fourth continuous projection directed towards and connecting it to the outer support and coupling element.

In the second case, the inner section has four continuous projections, two of which extend in opposite directions and are coupled to the rims of two parts of the tank shell to form part of the shell, while the other two projections are directed one towards the outer section and the other towards a continuous projection from the intermediate section, and wherein the outer section has three continuous projections respectively directed towards the inner section, one of the support and coupling elements, and a continuous projection from the intermediate section.

In the first case, the two end section stubs and also the intermediate element joining them become part of the tank shell, whilst in the second case only the two inner section stubs directed for coupling to the tank shell form part of the tank shell.

The peripheral structure can also be composed of four profiled sections following horizontal and parallel circumferences, which sections in radial cross-section define the vertices of a quadrilateral, the sections forming two

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opposite vertices (the upper and the lower) each being generally Y-shaped and each having each of their inclined arms directed towards a respective one of the other two sections, whilst the remaining arm of one is directed for coupling to the rim of an adjacent part of the tank shell and the remaining arm of the other is directed for coupling to an end of the inner support and coupling element, the sections forming the other two opposite vertices each having three continuous projections extending therefrom of which two are directed towards the sections forming the first-mentioned two opposite vertices and the third projection is directed towards an edge of part of the tank shell for coupling to it, on the inner section, while on the outer section the third projection is directed towards the outer support and coupling element for coupling to an end thereof, each section of one of the two pairs of sections forming opposite vertices also having a fourth inner continuous projection directed towards the opposite section, the four consecutive sections and the two opposite ones having the fourth projections being interconnected by intermediate elements of revolution joined by their edges to the projections.

In this case, the outer projection of one of the Y-sections and one of the inner section projections become part of the tank shell, apart from the intermediate elements of revolution coupling the two aforementioned sections.

Preferably, the pair of sections forming opposite vertices and having the fourth continuous projections are the second-mentioned such pair of sections.

The aforementioned diaphragm or ring, located next to the peripheral structure, together with the peripheral structure and with the continuous part of the two support and coupling elements between the aforementioned diaphragm and peripheral structure may be arranged to define a conduit in which a coolant can be introduced at an intermediate temperature between ambient and that of the cargo to be carried, for the purpose of pre-cooling the peripheral structure and the middle or equatorial-area of the tank before loading, allowing carrying out the loading operation with greater speed without the danger of thereby inducing excessive thermal stresses in the tank and bearer.

This pre-cooling feature is particularly attractive in the case of carrying liquid natural-gas at -162°C ., a coolant consisting of nitrogen-gas being possible at a temperature in the order of -80°C inasmuch as its availability in liquid form at -196° is normal in this type of vessel.

If the peripheral structure consists of two or more sections, one or more conduits can

be formed between these and the intermediate coupling elements, to be similarly used for the introduction of coolant.

The coolant fluid can be introduced at one or more points, and also removed at one or more points, so that a uniform flow is in any event obtained, whereby a substantially uniform circumferential distribution is achieved.

The nature of the invention and of the characteristics and structure of various forms thereof broadly described above will become more readily apparent from the following more detailed description given by way of example only and with reference to the accompanying drawings, wherein:

Fig. 1 is a diametrical schematic sectional view of a spherical tank arrangement suitable for installation on board ship;

Fig. 2 is a detailed view of part of Fig. 1 showing how the peripheral structure is coupled to the tank shell and to the support and coupling elements;

Figs. 3 and 4 are views corresponding to Figs. 1 and 2 of a different form of tank arrangement;

Figs. 5 and 6 are views corresponding to Figs. 1 and 2 of another form of tank arrangement;

Fig. 7 is a diametrical section of a peripheral structure generally similar to those shown in Figs. 2, 4 and 6, but showing a variation in which the peripheral structure is made up of at least two open profiled sections;

Figs. 8 and 9 are views corresponding to Figs. 1 and 2 of yet another different form of tank arrangement; and

Figs. 10, 11 and 12 are views corresponding to Fig. 8 of three further tank arrangements.

As can be seen from Figs. 1 and 2, a spherical tank 1 is mounted on a support system comprising a peripheral structure 2 and two support and coupling elements or members 3 & 4. The peripheral structure 2 is continuous and extends around the middle or equatorial area of the tank 1. The members 3 & 4 encircle the tank and are separated in a radial direction. These members are each coupled to the peripheral structure 2 by one of their edges and are coupled to a carrier structure 5 by the other. The peripheral structure 2 is in turn joined to the shell of the tank 1 so that at least the inner peripheral part of that structure forms part of the tank shell.

With the arrangement described, the forces perpendicular to the vertical axis of revolution of the tank are absorbed by at least one of the elements 3 or 4, while the forces parallel to the vertical axis of revolution will be absorbed by the two elements, one of which will be subject to

tension and the other to compression, bending moments not being induced on the tank shell.

The support and coupling elements 3 & 4 are peripherally continuous at least in the area of coupling to the peripheral structure 2, so that said coupling can also be continuous. Moreover, at least one of these elements, preferably the one working under compression, is continuous throughout its height.

Two vertical stiffeners 30 are fitted between both support and coupling elements 3 & 4 in meridian or longitudinal planes of the tank 1 and extend from a respective ring or diaphragm 31 and 32, which connects said elements 3 and 4 to each other, towards the carrier structure 5, to provide stability to the elements.

Both stiffeners and rings are shown only in Fig. 1 and partially in Fig. 2, their arrangement being the same *mutatis mutandis* in the tank arrangements shown in the other figures.

In particular case of Fig. 1, the peripheral structure 2 consists of a continuous open profiled section which, as best can be appreciated from Fig. 2, comprises a continuous web 6, preferably lying in a horizontal plane, and a series of continuous projections, stubs or wings 7, 8, 9 and 10 extending from the web. Of these continuous stubs or projections, those designated numbers 7, 8 & 9 project from one side of the web, while that designated 10 projects from the opposite side, the stubs 9 & 10 rooting out of the inner end of the web 6 in an inter-continue manner abutting the rims of two half-parts 11 & 12 of the tank shell 1 for welding to them. For their part, the stubs or projections 7 & 8 abut the upper edges of the support and coupling elements for welding to them.

The continuous stub or projection 10 can assume different positions. Thus for example, it can be located opposite the outer stub 7 as shown in Figs. 3 & 4.

In the arrangement of Figs. 3 & 4, as in the case of Figs. 1 & 2, stubs 9 & 10 are those coupled to the rims of the tank half-parts 11 & 12, while the continuous projections or shoulders 7 & 8 are coupled to the support and coupling elements 3 and 4. In this case, not only do stubs 9 & 10 become part of the tank shell but also the web 6 of the peripheral structure, the upper part 12 of the tank therefore being of greater than that of the lower half-part 11, as can clearly be seen.

The continuous shoulder or projection 10 can also take an intermediate position between these two end positions, preferably opposite the projection 8 as shown in Figs. 5 & 6.

In this case, as well as stubs 9 & 10, the

part of the web 6 between these stubs also becomes part of the tank shell.

The working arrangement shown in Figs. 3 & 4 can be utilized for the carriage of fluid at low pressure close to atmospheric. The working arrangement shown in Figs. 5 & 6 can serve for the carriage of fluids at low or medium pressures, the arrangement shown in Figs. 1 & 2 serving for low, medium or high pressures.

Fig. 7 shows a peripheral structure consisting of two profiled sections of configuration similar to those shown in Figs. 1 to 6.

In this case, two open contour profiled sections are arranged in parallel, the structure consisting of continuous webs 6', 6'', the first of these having four projections 7', 8', 9' and 10' and the second having six projections 7'', 8'', 9'', 10'', 13 and 14.

The inner projections 9'—10' and 9''—10'' are joined to the tank shell, on which there is an intermediate strip 15 defined between the projections 9' and 10'.

Stubs 7' and 8' are linked to the support and coupling elements 3 & 4, intermediate coupling elements 16 & 17 being fitted between projections 7'—14 and 8'—13 to ensure continuity of the support and coupling elements from the profiled section having the web 6'.

The stub 10' can occupy either of the positions shown in Figs. 4 and 6, instead of that shown in Fig. 7.

As will be readily understood, the peripheral structure can consist of more than two profiled sections similar to those described.

Fig. 8 shows the same tank 1 equipped with a peripheral structure of different composition resting on the same support and coupling elements 3 and 4, these being secured at the bottom to the carrier structure 5.

The peripheral structure of Fig. 8, as can be seen from Fig. 9, comprises three continuous profiled sections 18, 19 and 20 each following a respective coaxial circumference, of which those associated with sections 18 and 19 are coplanar, while that associated with the section 20 is positioned on the side of the support and coupling elements.

These sections have a number of continuous projections or stubs, section 20 assuming a general Y-shaped configuration, the inclined arms of which are directed towards the other two sections 18 & 19, while remaining arm is directed towards the inner support and coupling element 4.

Of the other sections, that marked 19 has three stubs, one directed towards section 18, another towards section 20 and another in the case of Fig. 8 towards the outer support and coupling element 3. For its part, section

18 has stubs, one of which is directed towards section 19, another towards section 20, while the other two stubs appearing in sequence are directed towards the upper part 12 and lower part 11 of the tank, for coupling to rim of the shell of those half-parts. The sections are interconnected by planar members 21 of which the one that runs between sections 18 and 19 comprises a horizontal annulus when the top surfaces of the sections are coplanar, while the others jointly define a shape that is frustoconical in cross-section.

In Fig. 10 there is shown a format similar to that of Fig. 8, with the difference that the circumference of the sections 18 and 19 are not coplanar and that the support and coupling elements 3 and 4 are constituted by the combination of cylindrical and frustoconical parts.

Fig. 11 shows a tank made up of two different radius halves or parts, the one positioned towards the side of the support and coupling elements 3 & 4 being of lesser radius. The peripheral structure in this case has the same configuration as in Fig. 8, with the sole difference that section 18 is the outer so that one of its projections is secured to the edge or rim of the upper tank part 12, while the opposite section is linked to the outer support and coupling element 3, its other two projections being directed towards sections 19 and 20. On the other hand, the inner section will be section 19 fitted with three projections directed two towards sections 18 & 20 and the third towards the rim of the tank lower half 11.

In this Fig. 11 working arrangement, apart from the sections 18 & 19, the intermediate coupling element 21 between these sections becomes part of the tank shell.

Fig. 12 shows another working arrangement in which the peripheral structure comprises four continuous sections 22, 23, 24 & 25 following coaxial circumferences and sectionally defining the vertices of a quadrilateral.

Two of these circumferences will be coplanar, preferably those associated with sections 22 and 24, while the other two circumferences associated with sections 23 and 25 may or may not be on the same vertical.

The sections 23 and 25 are generally Y-shaped, with their inclined arms directed towards the adjacent associated sections 22 & 24, while the remaining arm is directed outwardly for coupling, on section 25; to the inner support and coupling element 4 and on section 23 to the rim of the tank part or half 12. Of the three projections from section 24, two are directed towards sections 23 and 25, while the other is directed towards the rim of the tank part 11

for coupling to it. The four sections are interconnected as in the case of Figs. 8, 9, 10 and 11, by means of intermediate elements of revolution 21.

Here sections 23 and 24 and the intermediate elements of revolution 21 linking these sections become part of the tank shell.

Apart from this, two of the opposed sections, preferably sections 22 and 23, have another inner facing wing projection 21' designated to strengthen the peripheral structure.

In all the cases described, coupling of the support and coupling elements 3 & 4 to the carrier structure 5 has been shown as taking place underneath the middle or equatorial area of the tank, meaning that the tank rests on the carrier structure. However, this coupling area could instead be located above the equatorial area, the tank then being suspended from the carrier detail by means of the same support and coupling elements and with the same peripheral structures. These working arrangements can be seen by simply inverting the figures.

Making the support and coupling elements 3 & 4 continuous, at least between the peripheral structure 2 and the ring 31 (Figs. 1 & 2) as also the ring 32, a conduit 26 is formed between these elements in which a coolant fluid can be introduced for precooling the tank and peripheral structure.

In the case of Fig. 7, this conduit 26 can be formed between the web 6'', the corresponding ring (not shown) and the elements 3 & 4, or else, preferably, between the webs 6' and 6'' and the intermediate coupling elements 16 & 17.

Lastly, in the case of Fig. 8 and the following figures the conduit 26 can be defined by the ring mentioned (not shown), the elements 3 & 4 and the intermediate element coupling the peripheral structure sections to the elements 3 & 4; or else preferably by the peripheral structure itself or part of it.

In all cases, the conduit 26 will be provided with coolant inlet and outlet apertures, these openings being cut in any one of the elements circumscribing the assembly.

WHAT WE CLAIM IS:—

1. A tank arrangement for installation on board a ship or other buoyant marine structure and comprising a tank shell shaped as a vertical axis solid of revolution, a continuous peripheral structure arranged around the tank shell in the equatorial area thereof, and two support and coupling elements extending from the continuous peripheral structure and encircling the tank shell, each element being coupled by one of



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18 has stubs, one of which is directed towards section 19, another towards section 20, while the other two stubs appearing in sequence are directed towards the upper part 12 and lower part 11 of the tank, for coupling to rim of the shell of those half-parts. The sections are interconnected by planar members 21 of which the one that runs between sections 18 and 19 comprises a horizontal annulus when the top surfaces of the sections are coplanar, while the others jointly define a shape that is frustoconical in cross-section.

In Fig. 10 there is shown a format similar to that of Fig. 8, with the difference that the circumference of the sections 18 and 19 are not coplanar and that the support and coupling elements 3 and 4 are constituted by the combination of cylindrical and frustoconical parts.

Fig. 11 shows a tank made up of two different radius halves or parts, the one positioned towards the side of the support and coupling elements 3 & 4 being of lesser radius. The peripheral structure in this case has the same configuration as in Fig. 8, with the sole difference that section 18 is the outer so that one of its projections is secured to the edge or rim of the upper tank part 12, while the opposite section is linked to the outer support and coupling element 3, its other two projections being directed towards sections 19 and 20. On the other hand, the inner section will be section 19 fitted with three projections directed two towards sections 18 & 20 and the third towards the rim of the tank lower half 11.

In this Fig. 11 working arrangement, apart from the sections 18 & 19, the intermediate coupling element 21 between these sections becomes part of the tank shell.

Fig. 12 shows another working arrangement in which the peripheral structure comprises four continuous sections 22, 23, 24 & 25 following coaxial circumferences and sectionally defining the vertices of a quadrilateral.

Two of these circumferences will be coplanar, preferably those associated with sections 22 and 24, while the other two circumferences associated with sections 23 and 25 may or may not be on the same vertical.

The sections 23 and 25 are generally Y-shaped, with their inclined arms directed towards the adjacent associated sections 22 & 24, while the remaining arm is directed outwardly for coupling, on section 25, to the inner support and coupling element 4 and on section 23 to the rim of the tank part or half 12. Of the three projections from section 24, two are directed towards sections 23 and 25, while the other is directed towards the rim of the tank part 11

for coupling to it. The four sections are interconnected as in the case of Figs. 8, 9, 10 and 11, by means of intermediate elements of revolution 21.

Here sections 23 and 24 and the intermediate elements of revolution 21 linking these sections become part of the tank shell.

Apart from this, two of the opposed sections, preferably sections 22 and 23, have another inner facing wing projection 21' designated to strengthen the peripheral structure.

In all the cases described, coupling of the support and coupling elements 3 & 4 to the carrier structure 5 has been shown as taking place underneath the middle or equatorial area of the tank, meaning that the tank rests on the carrier structure. However, this coupling area could instead be located above the equatorial area, the tank then being suspended from the carrier detail by means of the same support and coupling elements and with the same peripheral structures. These working arrangements can be seen by simply inverting the figures.

Making the support and coupling elements 3 & 4 continuous, at least between the peripheral structure 2 and the ring 31 (Figs. 1 & 2) as also the ring 32, a conduit 26 is formed between these elements in which a coolant fluid can be introduced for precooling the tank and peripheral structure.

In the case of Fig. 7, this conduit 26 can be formed between the web 6'', the corresponding ring (not shown) and the elements 3 & 4, or else, preferably, between the webs 6' and 6'' and the intermediate coupling elements 16 & 17.

Lastly, in the case of Fig. 8 and the following figures the conduit 26 can be defined by the ring mentioned (not shown), the elements 3 & 4 and the intermediate element coupling the peripheral structure sections to the elements 3 & 4; or else preferably by the peripheral structure itself or part of it.

In all cases, the conduit 26 will be provided with coolant inlet and outlet apertures, these openings being cut in any one of the elements circumscribing the assembly.

WHAT WE CLAIM IS:—

1. A tank arrangement for installation on board a ship or other buoyant marine structure and comprising a tank shell shaped as a vertical axis solid of revolution, a continuous peripheral structure arranged around the tank shell in the equatorial area thereof, and two support and coupling elements extending from the continuous peripheral structure and encircling the tank shell, each element being coupled by one of



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its ends to the continuous peripheral structure and, in use, by the other end to the ship or other buoyant marine structure so that forces perpendicular to the axis of revolution of the tank shell can be absorbed by at least one of the elements while forces parallel to the axis or revolution of the tank shell can be absorbed by the two elements of which one will be subject to tension and the other to compression, so that whatever the spacing between elements and tank shell may be, bending moments will not be induced in the latter, said peripheral structure being coupled to the tank so that at least the inner part thereof forms part of the tank shell.

2. A tank arrangement as claimed in claim 1, wherein the two support and coupling elements are peripherally continuous in the area of coupling with the continuous peripheral structure, at least one of the elements also being continuous throughout its height.

3. A tank arrangement as claimed in claim 2, wherein said one element is that subject to compression.

4. A tank arrangement as claimed in claim 1, 2 or 3, wherein the continuous peripheral structure comprises an open profiled section in the form of a continuous web from which extend four continuous projections, three from one side of the web and the fourth from the other and at least the radially inner and radially outer projections on said one side extending from the free edges of the web, the fourth one of the other three projections serving to couple the peripheral structure to the tank shell and the remaining two projections serving to couple the structure to the support and coupling elements.

5. A tank arrangement as claimed in claim 4, wherein the web lies in a horizontal plane.

6. A tank arrangement as claimed in claim 4 or 5, wherein the continuous peripheral structure comprises at least one further open profiled section disposed nearer to the support and coupling elements than the said open section, each further section also being in the form of a continuous web from which extend six continuous projections, three from each side of the web, the projections located between the webs of the two sections or the two end sections serving to couple the sections together by means of intermediate coupling elements also serving to couple the sections to the tank shell, while the projections outside the webs of the two sections or the two end sections serve to couple the sections to the tank shell and to the support and coupling elements.

7. A tank arrangement as claimed in claim 6, wherein the web of the or each further open section lies in a horizontal plane.

8. A tank arrangement as claimed in claim 4, 5, 6 or 7, wherein said fourth projection from the section provided with four projections extends from the inner end of the web and one of the three projections from the opposite side of the web also extends from the inner end of the web whereby both such projections form part of the tank shell.

9. A tank arrangement as claimed in any of claims 4, 5, 6 or 7, wherein said fourth projection from the section provided with four projections extends from the outer end of the web and is coupled to part of the tank shell and one of the three projections from the opposite side of the web extends from the inner end of the web and is coupled to a second part of the tank shell, whereby such two projections together with the web form part of the tank shell, which therefore has a different diameter on each side of the continuous peripheral structure.

10. A tank arrangement as claimed in claim 4, 5, 6 or 7, wherein said fourth projection from the section provided with four projections extends from an intermediate position along the web and is coupled to part of the tank shell and one of the three projections from the opposite side of the web extends from the inner end of the web and is coupled to a second part of the tank shell, whereby such two projections together with the part of the web between them form part of the tank shell.

11. A tank arrangement as claimed in claim 10, wherein a second of said three projections extends from a position on the web opposite that from which the fourth projection extends.

12. A tank arrangement as claimed in claim 1, 2 or 3, wherein the continuous peripheral structure is composed of three profiled sections following horizontal and parallel circumferences of different diameters, which sections in radial cross-section define the vertices of a triangle, and interconnecting these sections three intermediate elements of revolution each forming a respective side of said triangle and connecting a respective pair of the sections together, the sections having continuous projections for coupling them to the intermediate elements, and to the tank shell.

13. A tank arrangement as claimed in claim 12, wherein the circumferences followed by the inner and outer of the sections are coplanar and the intermediate element coupling them comprises a horizontal ring.

14. A tank arrangement as claimed in claim 12 or 13, wherein the intermediate section of the three forming part of the continuous peripheral structure is generally Y-shaped, each of the two inclined arms

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thereof being directed towards a respective one of the other two sections and being coupled thereto by a respective one of the intermediate elements of the peripheral structure the edges of which are coupled to the inclined arms, while the remaining arm is directed towards the support and coupling element closer to the tank shell and coupled to an edge of such element.

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15. A tank arrangement as claimed in claim 12, 13 or 14, wherein parts of the tank on each side of the continuous peripheral structure have different diameters, the rim of the part of the shell having the larger diameter being coupled to the outer section of the peripheral structure and the rim of the part of the shell having the lesser diameter being coupled to the inner section, and wherein the inner and outer sections of the peripheral structure each have a first continuous projection directed towards the part of the tank shell to which it is coupled, a second directed towards the other of the inner and outer sections, and a third directed towards a respective continuous projection of the intermediate section; the outer section also having a fourth continuous projection directed towards and connecting it to the outer support and coupling element.

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16. A tank arrangement as claimed in claim 12, 13 or 14, wherein the inner section has four continuous projections, two of which extend in opposite directions and are coupled to the rims of two parts of the tank shell to form part of the shell, while the other two projections are directed one towards the outer section and the other towards a continuous projection from the intermediate section, and wherein the outer section has three continuous projections respectively directed towards the inner section, one of the support and coupling elements, and a continuous projection from the intermediate section.

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17. A tank arrangement as claimed in claim 1, 2 or 3, wherein the continuous peripheral structure is composed of four profiled sections, following horizontal and parallel circumferences, which sections in radial cross-section define the vertices of a quadrilateral, the sections forming two opposite vertices (the upper and the lower) each being generally Y-shaped and each having each of their inclined arms directed towards a respective one of the other two

sections, whilst the remaining arm of one is directed for coupling to the rim of an adjacent part of the tank shell and the remaining arm of the other is directed for coupling to an end of the inner support and coupling element, the sections forming the other two opposite vertices each having three continuous projections extending therefrom of which two are directed towards the sections forming the first-mentioned two opposite vertices and the third projection is directed towards an edge of part of the tank shell for coupling to it, on the inner section, while on the outer section the third projection is directed towards the outer support and coupling element for coupling to an end thereof, each section of one of the two parts of sections forming opposite vertices also having a fourth inner continuous projection directed towards the opposite section, the four consecutive sections and the two opposite one having the fourth projections being interconnected by intermediate elements of revolution joined by their edges to the projections.

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18. A tank arrangement as claimed in claim 17, wherein the pair of sections forming opposite vertices and having the fourth continuous projections are the second-mentioned such pair of sections.

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19. A tank arrangement as claimed in claim 6 or 7 or in any of claims 8 to 11 when dependent on claim 6 or 7, wherein a closed conduit is defined between a pair of open sections, the conduit being provided with apertures for the entry and exit of a coolant fluid.

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20. A tank arrangement as claimed in any of claims 12 to 18, wherein the sections and intermediate elements forming the continuous peripheral structure are arranged to define a closed conduit provided with apertures for the entry and exit of a coolant fluid.

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21. A tank arrangement as claimed in any of claims 1 to 18, including a closed conduit defined by the support and coupling elements, by the continuous peripheral structure and by a ring arranged between the support and coupling elements at a position close to the peripheral structure, the conduit being provided with apertures for the entry and exit of a coolant fluid.

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22. A tank arrangement substantially as herein described with reference to Figs. 1 and 2, Figs. 3 and 4, Figs. 5 and 6, Fig. 7,



Figs. 8 and 9, Fig. 10, Fig. 11 or Fig. 12 of the accompanying drawings.

- 5 23. A ship or other buoyant marine structure having installed thereaboard at least one tank arrangement as claimed in any preceding claim.

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