(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 August 2008 (28.08.2008)

PCT

(10) International Publication Number
WO 2008/103053 A1

(51) International Patent Classification:
F17C 1/02 (2006.01) *B65D 90/02* (2006.01)
B63B 25/16 (2006.01)

(21) International Application Number:
PCT/NO2008/000065

(22) International Filing Date:
20 February 2008 (20.02.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20070958 20 February 2007 (20.02.2007) NO

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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,

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(54) Title: A TANK STRUCTURE

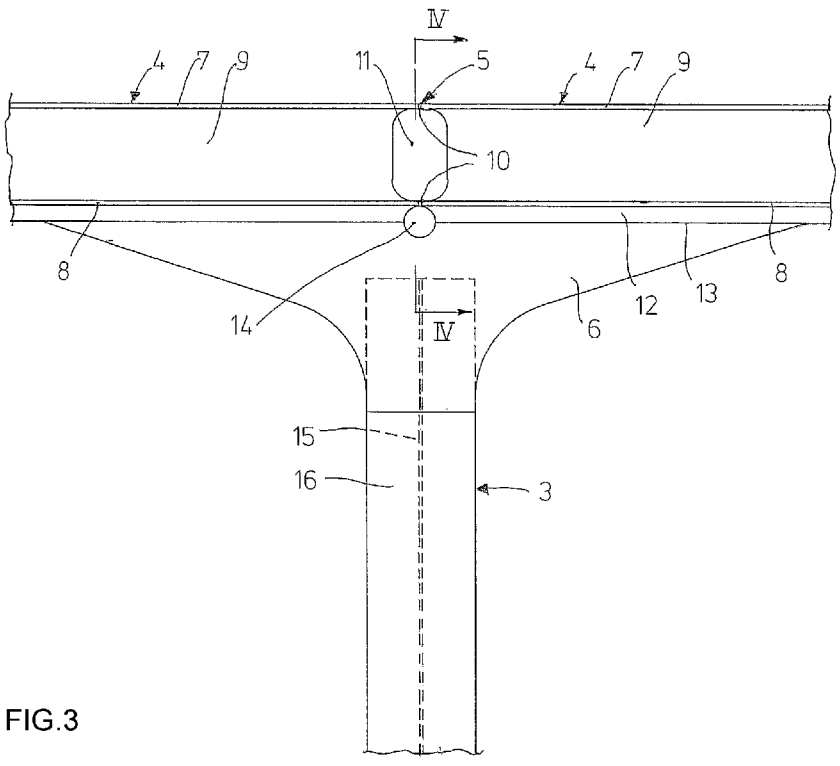

FIG.3

(57) Abstract: A double containment prismatic tank has outer and inner walls (1, 2) made by stacking H-beam sections on top of each other and joining them along their longitudinal flange edges and at their abutting end faces in joints (5). In the joint areas internal stays (tension beams) (3) are connected to the inner wall (2) to improve the structural efficiency of the tank. The stays (3) are connected to the inner wall (2) by means of brackets (6) which extend in a smooth and tapering manner to the sides of the joint (5) area. In the joint (5) the outer and inner flanges (7, 8) of the beams (4) are joined by welds (10). However, the webs (9) of the beams (4) are not welded together in the joint, but are instead recessed and terminated in a smooth curve so as to form an opening (11), thus avoiding any contact between the outer and inner walls (7, 8) that are not base metal and thereby avoiding a risk of fatigue crack propagation from the inner wall (2) to the outer wall (1). The inner flange (8) of the beam sections (4) is provided with a rib (12) being an external extension of the web (9) between the flanges (7, 8). The bracket (6) is attached to the rib (12) through a weld (13), and a second hole (14) is made through the bracket (6) and rib (12) adjacent to the inner weld (10) between abutting inner flanges (8) in order to avoid stress concentrations and crack propagation in this area.

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NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report*

A TANK STRUCTURE

Field of the invention

The present invention relates to tanks for storage and transportation of fluids such as hydrocarbons, including low temperature liquefied natural gas. This includes tanks for ships, for gravity base and floating offshore structures, and for land-based installations.

Background of the invention

Tanks may be designed in many different configurations, such as spheres, cylinders, cones and shells in general, as well as prismatic shapes. The principle advantage of prismatic shapes is that they nest close to each other, minimising the volume taken up by such tanks. Simple prismatic tanks are far less efficient structurally as they rely on bending action for mobilisation of strength. Shells develop strength through direct tension in the plane of the shell. This develops greater strength for the same amount of material.

A more efficient design of prismatic shapes is to incorporate internal stays (tension beams). By developing tension as the main means of restraining the internal load or pressure, such prismatic staid tanks are comparable to shell shapes in structural efficiency. WO 2006/001711 A2 discloses such tanks and is hereby incorporated by reference. This publication also forms the basis for the preamble of claim 1.

Apart from having sufficient strength to restrain yielding, the tank structure must also be designed to prevent crack propagation as a consequence of fatigue. The principle concern of such structures is crack propagation at weld locations, as opposed to locations in base metal where crack propagation will progress very slowly or even be arrested.

Object of the invention

The object of the present invention is to design a double barrier tank such that all connections between the two barriers are base metal without local stress raisers, to ensure that fatigue cracks do not propagate from one liquid barrier to the other.

Summary of the invention

The object of the present invention is obtained by a prismatic tank as defined in the independent claim 1. Advantageous embodiments of the tank are defined in the dependent claims.

The more common way of joining a continuity of beam sections to form a tank wall is to place the joints between the beams close to the inflection points where the axial stresses in the flanges are zero and the shear load is modest. However, in the present invention the joints between the beam sections are placed at the connecting points of the internal stays. In the beam joints, only the flanges of the beams are connected to each other and not the webs. Instead, the webs are recessed in a smooth curve, so that the end faces of the recessed webs form an opening with a rounded contour. Thus, there will be no weld or other connection between the end faces of the webs, thereby avoiding stress concentrations and material changes susceptible to fatigue crack propagation. The reduction in shear strength caused by the opening may be counteracted by a stiffening bracket applied to the inner wall of the tank generally in the plane of the web. These brackets may suitably be made to attach the internal stays of the tank to the double wall.

Brief description of the drawings

Further details of the invention will be described below with reference to the exemplifying embodiments shown schematically in the appended drawings, wherein:

Figure 1 shows a plan view of a prismatic double-walled tank with the roof removed;

Figure 2 show a sectional view taken along the line II-II in Figure 1;

Figure 3 shows at a larger scale the detail indicated by III in Figure 1;

Figure 4 shows at a larger scale a sectional view along the line IV-IV in Figure 3;

Figure 5 shows an end view of two beam sections before being joined to a connecting piece as shown in the bottom left corner of Figure 2;

Figure 6 shows an end view of the beam sections of Figure 5 joined together;

Figure 7 shows schematically the connecting piece of Figure 6 in forming the corner between a wall of the tank and its roof; and

Figure 8 illustrates schematically how a corner between two walls of the tank may be formed.

Detailed description of the drawings

Figure 1 shows a plan view of a double containment having an outer wall 1, an inner wall 2, and internal stays 3 connecting opposite walls of the tank. The tank walls are established by welding together horizontal beam sections 4 having a cross-section in the shape of an H, the beam sections 5 being stacked one on top of the other and joined together along their adjoining longitudinal edges and at their end faces abutting other end faces of beam sections 4 or connecting pieces, as indicated by 5 in Figure 1. The stays 3 are connected to the respective walls at the joint 5 locations by means of brackets 6. It will be understood that the stays 3 substantially reduce bulging of the tank walls when subjected to internal pressure from the fluid contained therein. Additionally, the stays 3 in effect form perforated "bulkheads" reducing cargo movement, known as sloshing, when the tank is a cargo tank in a ship which is rolling and pitching on its journey.

Figure 2 shows a cross-section through part of the bottom and a side wall of the tank in Figure 1. Figure 2 shows how H-beam sections 4 are stacked one on top of the other, their parallel flanges 7, 8 forming the outer and inner walls 1, 2 of the double-walled tank. The flanges 7, 8 of the beam sections are joined by a horizontal web 9, as will be more clearly seen in Figure 4. The brackets 6 connecting the stays 3 to the inner wall 2 are aligned with the web 9 so as to form an extension of the web on the inner side of the tank, thus transferring the tensile load from the respective stay 3 in the area of the beam section 4 where it can best handle such a load.

Figure 3 shows an enlargement of the area circled and labelled III in Figure 1. This plan view shows two beam sections 4 welded together at their outer and inner flanges 7, 8 by welds 10. In this area, the webs 9 of the beam sections have been recessed so as to form a first opening 11 having a smooth and rounded contour. Thus, there is no weld extending between the flanges 7, 8 in the area of the joint 5.

Figure 3 also shows that the beam section 4 is provided with a longitudinal rib 12 which, as will be better seen in Figure 4, is located on the inner flange 8 as an extension

of the web 9. The plate 6 is welded at 13 to the rib 12 and extends in a smoothly tapering form at a substantial distance on either side of the area of the joint 5. The bracket 6 will therefore ensure that the discontinuity of the webs 9 in the joint 5 area does not impair the strength of the joint. The shape of the bracket 6 also ensures that cracks will not form at its free edge when cyclic loads are transferred from the stay 3. Also, to avoid crack formation and propagation in the area of the inner weld 10, a second opening 14 is made in the rib 12 and bracket 6 adjacent to this weld.

The bracket 6 is preferably welded to the rib 12 before the stay 3 is attached to the bracket. Furthermore, if expedient from a manufacturing point of view, the bracket 6 may be divided into two symmetrical parts, each being welded to the respective beam section 4 before the beam sections are joined at the joint 5, whereupon the bracket parts are welded together before being attached to the stay 3. The stay may be attached to the bracket 6 by means (not shown), e.g. for both on either side of the web 15 of the stay. This will cause the force between the stay 3 and bracket 6 to be taken up mainly as a friction force created in the contact area between the bracket 6 and the respective flange 16 of the stay 3 (Figure 2 will show that the stays 3 are I-beams).

An enlarged cross-section taken along line IV-IV in Figure 3 is shown in Figure 4. This view may also be taken as an enlargement of the upper left hand corner of the tank shown in Figure 2.

The figure shows two beam sections 4 joined together along adjoining longitudinal edges of the outer and inner flanges 7, 8 by welds 17. The webs 9 extending between the flanges 7, 8 will be recognised, as also the openings 11 made in the webs. On the inner side of the inner flange 8, the rib 12 will be seen as an extension of the respective web 9, as will the weld 13 between the rib 12 and respective bracket 6. Furthermore, the second opening 14 is also shown.

Figure 4 further shows the end of the stay 3 fixed between two brackets 6 by means of bolts, hear indicated only by their centre line. It is noted that the stay 3 is terminated at a distance from the inner flanges 8 which is about five times the width of the rib 12, while the radius of the second opening 14 is about equal to the width of the rib. Thus, this opening 14 also avoids a stress concentration in the weld 13.

Figure 4 shows the relative dimensions of the various component parts taken from an actual LNG ship tank about 30 metres high. The thickness of the flanges, webs and ribs both for the beam sections 4 and stay 3 is 10-12 mm, the width of the flanges 7, 8 is 400

mm and the span between them is 270 mm. The web is located eccentrically between the edges of the flanges 7, 8, the shorter distance from the web 9 to the nearest flange edge being about half the longer distance to the other flange edge. This will place the weld 17 near an inflection point in the inner wall 2 when it is subjected to a hydrostatic pressure from the cargo. From this point of view, the eccentricity of the flange could have been even larger, but the present shorter distance between the web 9 and weld 17 has been chosen in this manner in order to provide sufficient room for performing the weld 17, which preferably is made by friction stir welding.

According to the purpose of the present invention, it is also important to avoid stress concentrations and fatigue crack propagation at the corners of the tank. A simple mitre joint where the flanges and webs of the beam sections are welded together, would therefore not be satisfactory. Consequently, the invention suggests special connection pieces or beams for such purposes. Figure 5 shows two identical beam sections 18 placed so as to form a symmetrical arrangement before being welded together to form the transition piece 19 shown in Figure 6. The parts 18 are made of extruded aluminium material, and the reason for welding two such beams together instead of extruding the beam 19 directly, is that extruding a beam having a hollow portion 20, here shaped like a right-angled triangle, is very difficult. The small sides of the triangular portion 20 have parallel legs 21, 22 extending therefrom, the spacing between said legs being equal to the width of the web 9 of the beam sections 4.

Figure 7 shows how the transition piece 19 enters into a corner between a side wall and the roof 23 of the tank. Here, the roof is made up by beam sections identical to the beam sections 4 of the walls of the tank. Again, the web 9 is recessed away from the weld area.

Figure 8 suggests a simpler corner solution, which is particularly suited for vertical corners between side walls of the tank. This is basically a mitre joint, but the webs 9 of the beam sections 4 have been recessed as in other joints between the beams, and the weakening caused by such recessing is counteracted by placing a flat plate 24 between the end faces of the flanges 7, 8 to be joined together.

It will be understood that the invention is not limited to the exemplifying embodiments shown in the drawings and described above, but that it may be modified and varied within the scope of the appended claims. Thus, means of joining tank element other than welding and bolting may be used, such as gluing or riveting. Furthermore, to reduce the detrimental effect of minor dimensional differences or slight warping of the

beam sections at their end faces to be joined, a transition piece, e.g. in the form of an I-beam section, may in inserted between said faces. In such cases, a second opening should be introduced in the weld areas on either side of the I-beam section.

Claims

1. A prismatic tank having outer and inner walls (1, 2) and internal horizontal stays (3) restraining the force exerted on said walls by fluid contained in the tank, said walls (1, 2) being made up of horizontal beam sections (4) having two parallel flanges (7, 8) interconnected by a web (9), the beam sections (4) being stacked one on top of the other and joined together along their adjoining longitudinal edges of the flanges (7, 8) and at their end faces abutting other end faces of beam sections (4) or connecting pieces (19, 24),
characterised in that the end face of the web (9) of a beam section (4) abutting another beam section (4) or connecting piece (19, 24) is recessed so as to leave a first opening (11) between said end face and the abutting beam section (4) or connecting piece (19, 24).

2. A tank according to claim 1, wherein said first opening (11) has a rounded contour.

3. A tank according to claim 1 or 2, wherein at least a plurality of said stays (3) are connected to the respective inner wall (2) at the location of the joint (5) between abutting beam sections (4) by means of at least one bracket extending to the sides of said joint (5).

4. A tank according to claim 3, wherein a second opening (14) is formed in the bracket (6) adjacent to said joint (5).

5. A tank according to claim 4, wherein at least some of said beam sections (4) have a rib (12) arranged as an external extension of their web (9), said bracket (6) being connected to said rib (12) and said second opening (11) extending into said rib (12).

6. A tank according to claim 3, 4 or 5, said stay (3) being connected to said at least one bracket (6) at a distance from said inner wall (2), the connection preferably comprising pre-stressed bolts (16).

7. A tank according to claim 1, 2 or 3, wherein the web (9) of at least some of said beam sections (4) is located eccentrically with respect to the longitudinal edges of the flanges (7, 8) of the beam sections, preferably near the deflection point of the inner flange (8) when subjected to a hydrostatic pressure from fluid contained in the tank.

8. A tank according to any one of the preceding claims, wherein an I-beam section forms a connecting piece between the end faces of beam sections (4) to be joined.

9. A tank according to any one of the preceding claims, wherein corners of the tank comprises connecting pieces (19, 24) transferring forces and bending moments while permitting the web (9) of a beam section (4) connected thereto to have a discontinuity.

10. A tank according to claim 9, wherein the connecting piece (19) comprises a hollow portion (20) shaped like a right-angled triangle and parallel legs (21, 22) extending perpendicularly from the ends of the small sides of the triangle.

11. A tank according to claim 10, wherein the connecting piece (19) is formed by two symmetrical parts (18) welded together at the apex and the middle of the base of the triangle.

12. A tank according to claim 9, wherein beam sections (4) are joined in a corner in a mitre joint, the connecting piece being a flat plate (24) to which the flanges (7, 8) of the beam sections (4) are welded, the webs (9) of the beam sections (4) being recessed away from said flat plate (24).

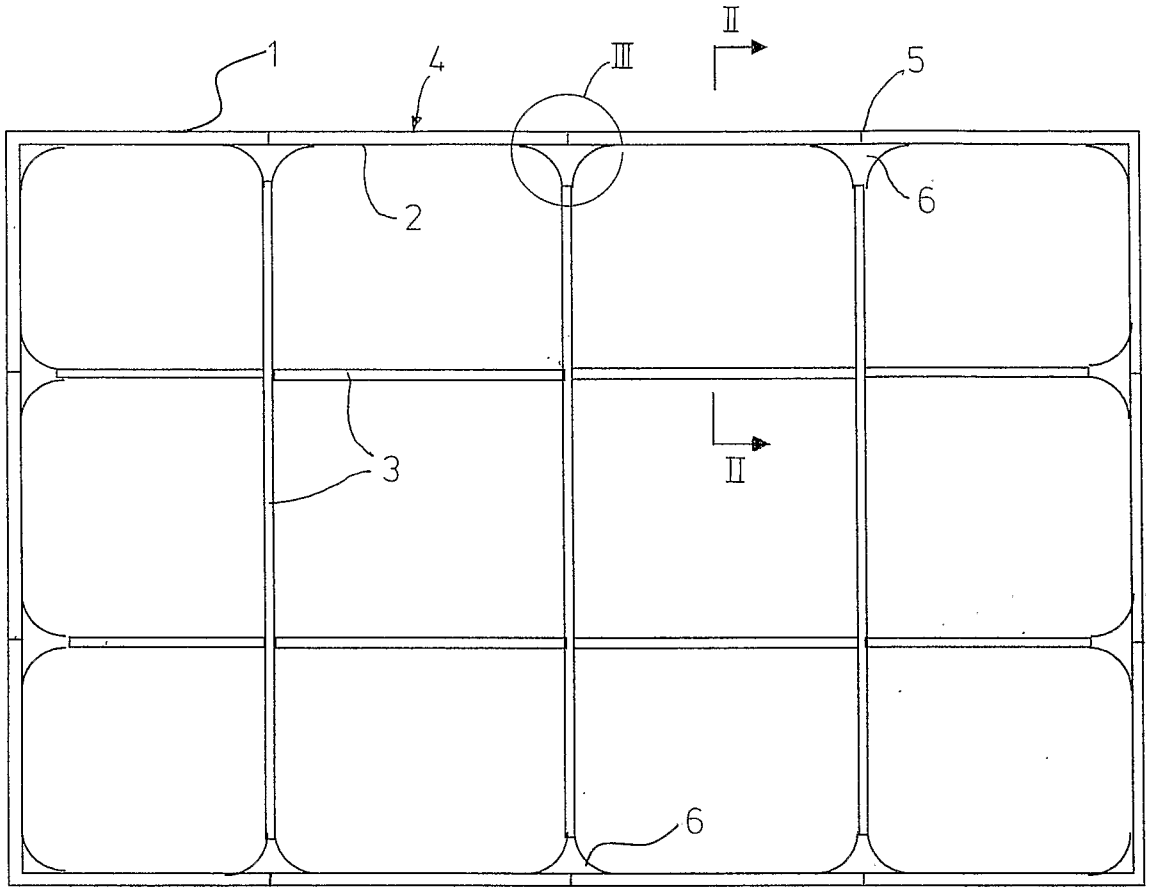

Fig. 1

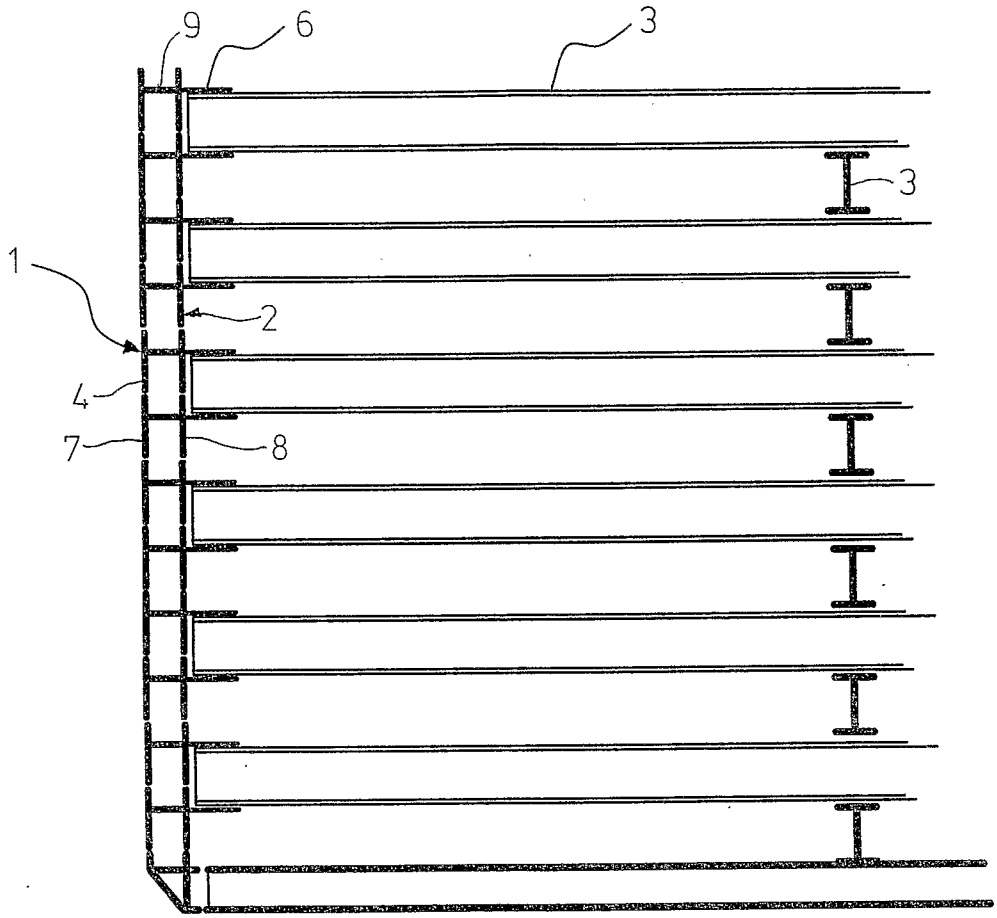

Fig. 2

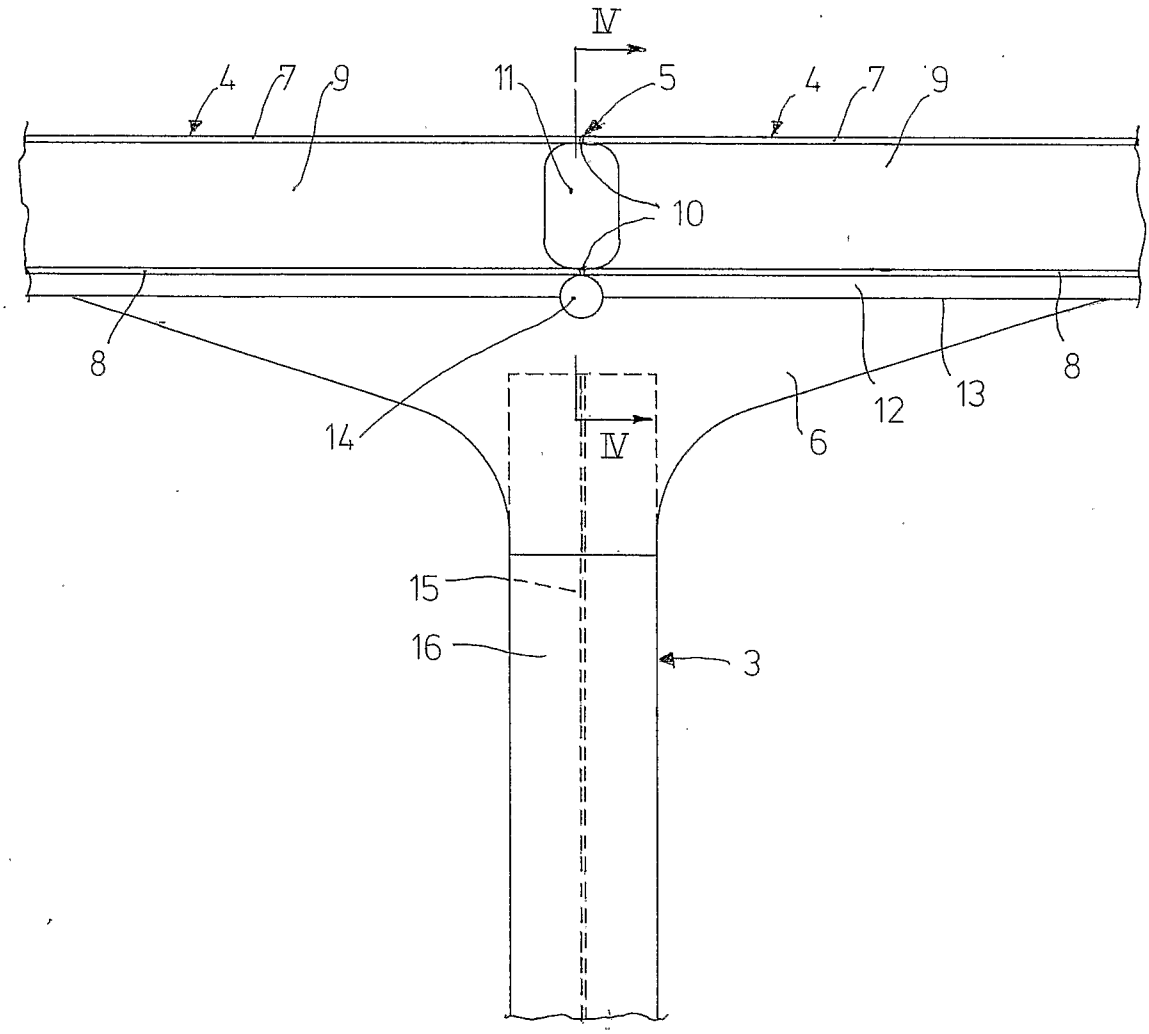

Fig. 3

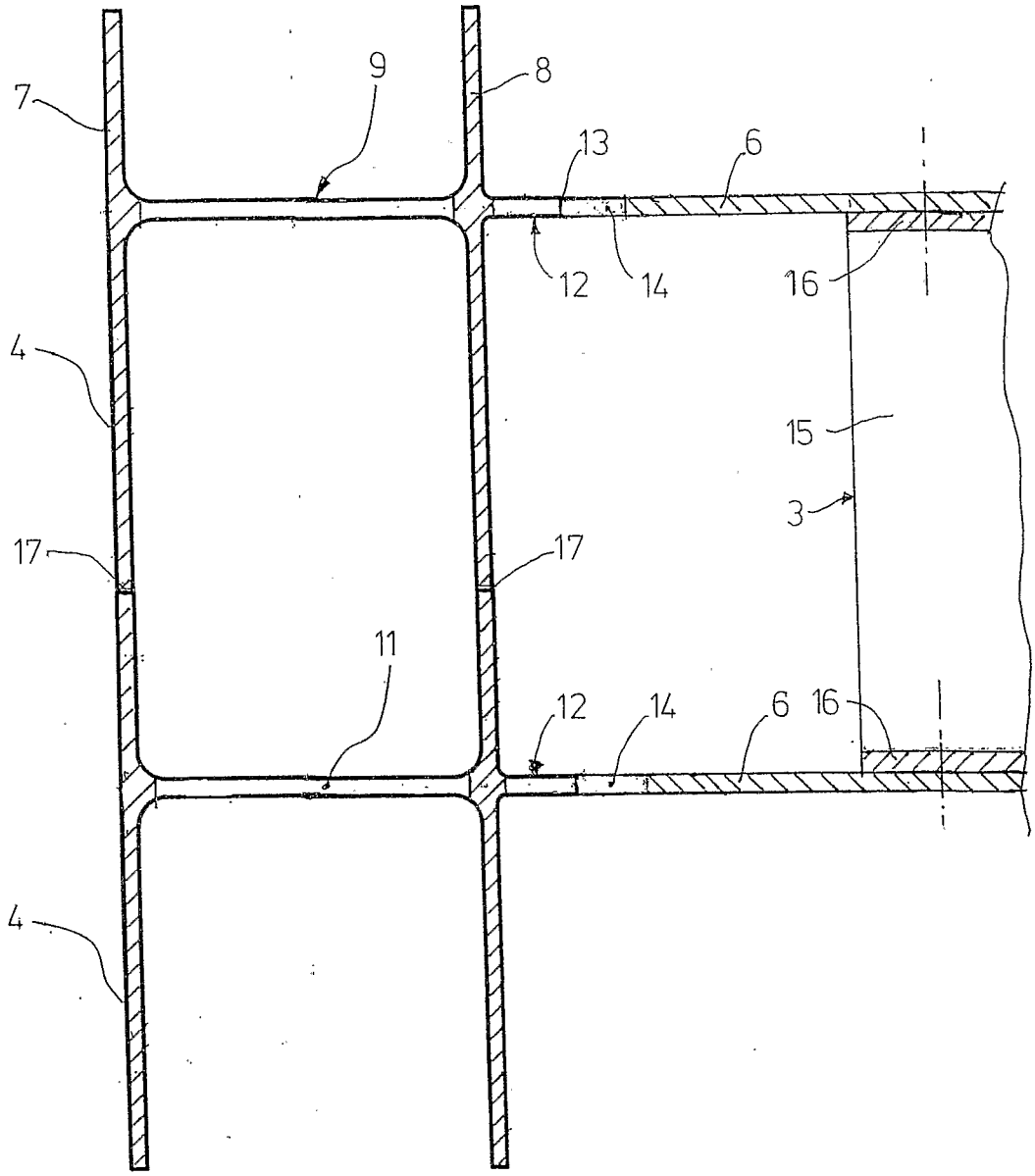

Fig. 4

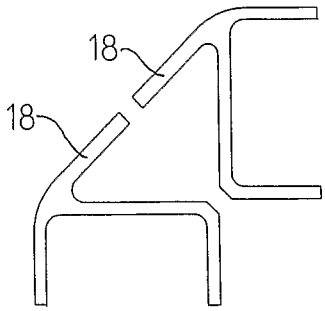

Fig. 5

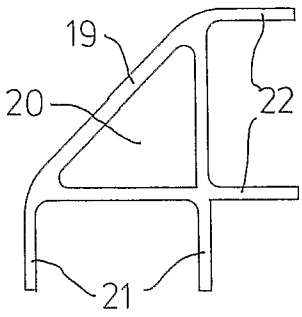

Fig. 6

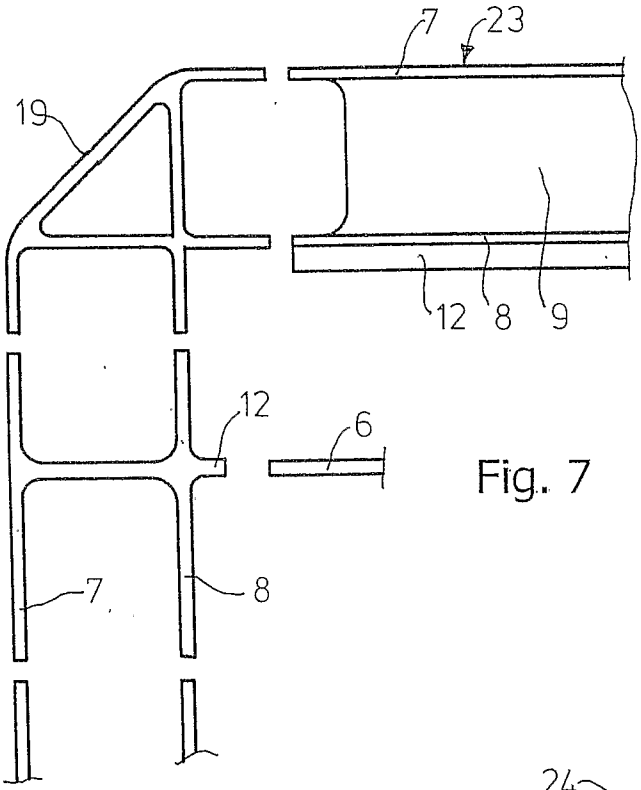

Fig. 7

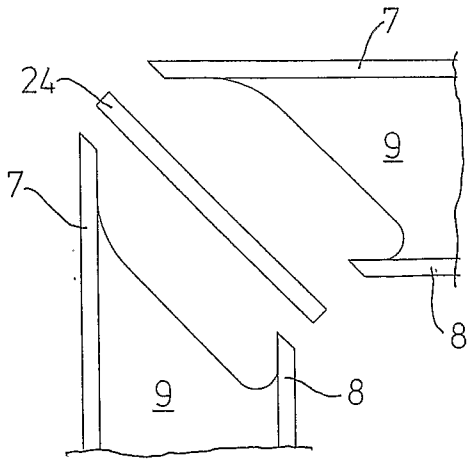

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2008/000065

A. CLASSIFICATION OF SUBJECT MATTER
F17C 1/02, B63B25/16, B65D90/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC:F17C, B63B, B65D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NO, DK, FI, SE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPOQUE: EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,D		1-12
A		1, 2
A		1-5, 8
A		1, 2, 8, 9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09. may 2008 (09.05.2008)	14 May 2008 (14.05.2008)
Name and mailing address of the ISA/ Nordic Patent Institute Helgeshov Allè 81, DK-2630 Taastrup, Denmark Facsimile No. (45) 53508008	Authorized officer Kanja Bah Telephone No. (47) 22387544

Form PCT/ISA/210 (second sheet) (April 2007)

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