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(54) DOCKING RISER BARGE FOR FPSO

(57) A floating production storage and offloading vessel (FPSO, 1) is formed with a recess (2) inside of its hull for receiving and connecting to a buoy (10) therein. A spread moored buoy (10) is adapted to be received in said recess, as well as a FPSO assembly (10) comprising such a spread moored buoy connected to the FPSO in the recess thereof. A method of installing such a FPSO assembly.

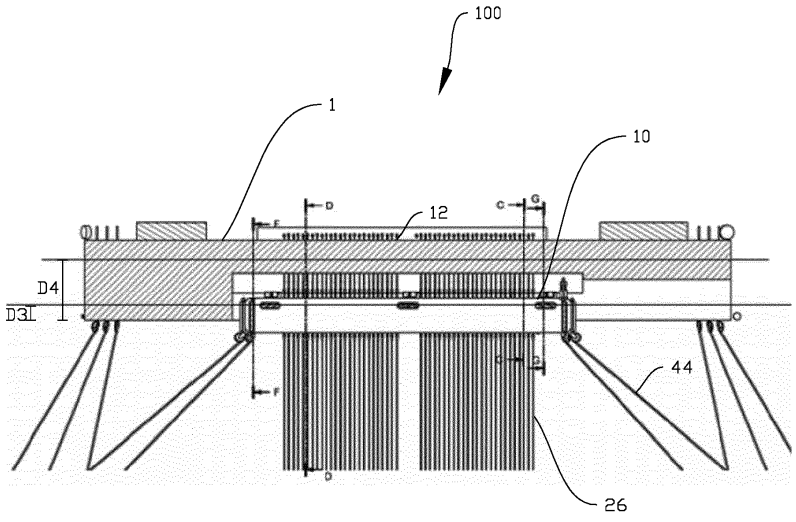

Fig. 16

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Description

[0001] The present invention relates to a buoy with hang-off for a plurality of risers. The invention also relates to a floating production, storing and offloading (FPSO) vessel adapted to receive and connect to said buoy in a recess of said FPSO. The invention further relates to a FPSO assembly comprising such a buoy connected to the FPSO. Finally, the invention relates to a method for establishing such a FPSO assembly.

[0002] Offshore hydrocarbon drilling and production systems require a fluid connection between the subsea production system and the floating production storage and offloading vessel (FPSO). Upon arrival at the offshore wellsite, the FPSO can be secured to the seabed or dynamically positioned using an onboard propulsion system. A mooring system is used to couple the FPSO to the seabed. A spread mooring of the FPSO can ensure position control and a fixed heading of the FPSO at the sea surface. Various mechanisms and apparatus are used to connect the subsea production or manifold system to the FPSO for transferring hydrocarbons. A spread mooring connection will physically connect to the FPSO. A riser connection or hook-up will fluidly connect the subsea production system to the FPSO. For example, the fluid connection between the subsea system and the FPSO can be used for hydrocarbon production, water injection, gas injection, chemical injection, control lines, and the like.

[0003] Typically, risers and spread mooring are located at the outside of the hull of the FPSO, such as at the port and/or starboard side, and are installed after the FPSO has arrived at the operation wellsite. The spread mooring system is typically installed in four mooring clusters from four locations on the vessel. The mooring lines can be made from chains and neutrally buoyant polyester rope. Piles or suction anchors can be used to fix the mooring and are typically preinstalled before FPSO arrival. The connection of the mooring lines is done after FPSO arrival at the wellsite with the help of construction vessels and positioning tug boats. After the mooring lines are handed over to the FPSO, they are pre-tensioned using an onboard mooring tension system.

A riser balcony at a side of the FPSO is configured to receive and connect to the risers. The risers may be free hanging. The riser balcony typically includes a lower balcony, an upper balcony, and a pull-in balcony and extends a substantial portion of the vessel's length. The lower balcony is used to fix the risers laterally to the vessel through a riser bend restrictor. The upper balcony is used to fix the risers vertically and laterally. The pull-in balcony often includes a skidding rail or similar structure to allow the pull-in device and/or sheave to travel longitudinally to pull in/out each riser. The risers are pulled in individually with a handover from a flex lay vessel. The commissioning of the wells can start after the risers are pulled in and connected. The pull-in of risers is performed after all mooring lines are installed.

Deep waters with large quantities of risers routed directly to the FPSO result in high loads on the side of the FPSO hull. Consequently, the balconies are getting strong and heavy to support the large riser loads, and represent thus a substantial heeling moment to the vessel. Normally risers are routed to only one side of the hull to allow safe approach for supply vessels at the opposite side. In order to maintain stability and buoyancy, extra ballast tanks and/or buoyancy are required. However, extra ballast or void tanks will reduce the available cargo capacity or increase the required steel material needed. Alternative ways to reduce riser loads include using separate buoyancy solutions to support the riser weights, or reducing the quantity of risers through subsea manifolding. However, both of these options are costly and reduce operational flexibility.

[0004] In addition to the reduction of cargo capacity in the FPSO, having the risers suspended from the side of the vessel also has a negative impact on the riser fatigue life. The lines that the risers are hung from are away from the vessel center, thereby creating a lever arm on the vessel and amplifying the vessel motions in the risers. The FPSO is subjected to rolling motion from the sea water, and wave slamming motion at the FPSO hull side where the risers are suspended. These two factors, vessel motion and wave slamming, introduce high load on the risers thereby decreasing riser fatigue life.

[0005] Furthermore, the flexible risers need to be suspended from the balcony high above the sea surface to maintain air gap in all sea states. The combination of the substantial motion envelope of the flexible risers and the large vessel roll motion, particularly a spread moored vessel in beam seas, require the riser suspension points to be located far off the vessel sides to avoid chafing between the sensitive flexible risers with the sharp bilge keel. Hence, the balcony structures grow very heavy since it represents a long cantilever exposed to high static and dynamic weight and submarine riser loads.

[0006] US 8,904,949 discloses a system for mooring a large FPSO vessel. The mooring system includes two or more floating spread-moored docks, each dock with a riser hang-off and termination system, and each dock connectable and rigidly lockable to the sides of the FPSO. The system further comprises a fluid transfer system in fluid communication, when the FPSO and docks are connected, with a corresponding fluid transfer system on the FPSO. The system solves some of the above-mentioned drawbacks as it allows for pre-installation and pre-mooring before arrival of the FPSO.

[0007] However, the placement of the docks on the sides of the FPSO still entails several drawbacks relating to the mentioned lever arm leading to riser fatigue and mooring line fatigue. Suspending the risers from the sides of the FPSO may also lead to the risers chafing against the bilge keel of the FPSO, further increasing wear on the risers as well as the hull of the FPSO itself. Connecting the docks on the sides of the FPSO does not allow for a full and concentrated transfer of loads between the

dock mooring and the hull of the FPSO. The riser suspensions in the docks according to the prior art, are located above the splash zone during use, i.e. after connecting and locking to the FPSO, leading to substantial forces acting on the risers and mooring.

[0008] The invention has for its object to remedy or to reduce at least one of the drawbacks of the prior art, or at least provide a useful alternative to prior art.

[0009] The object is achieved through features, which are specified in the description below and in the claims that follow.

[0010] In a first aspect, the invention relates to a floating production storage and offloading vessel (FPSO) formed with a recess/trunk inside its hull for receiving and connecting to a buoy therein.

[0011] In a second aspect, the invention relates to a buoy, said buoy being provided with a plurality of riser suspensions and said buoy being adapted to be received and connected to the FPSO according to the first aspect of the invention in the recess thereof.

[0012] In a third aspect, the invention relates to a FPSO assembly comprising a FPSO according to the first aspect of the invention and a buoy according to the second aspect of the invention, wherein said buoy is connected to the FPSO in said recess, and wherein a plurality of risers are connected to riser reception pipes on said FPSO via said buoy.

[0013] In a fourth aspect, the invention relates to a method for connecting a FPSO assembly according the third aspect of the invention, the method comprising the steps of:

- hauling FPSO relative to said buoy so that said buoy is slid into the recess of said hull of the FPSO, connecting said buoy mechanically to the hull of said FPSO; and
- connecting said plurality of risers, suspended on the buoy, to a riser reception unit on the FPSO.

[0014] The buoy will in the following mostly be referred to as a spread-moored buoy (SMB). For most applications, the buoy will be a SMB but in sheltered waters the buoy may stay positioned even without mooring lines or any mooring system to keep it positioned. The risers may then have sufficient capacity to keep the buoy on location without mooring lines. The configuration of the buoy and the FPSO will then remain the same, except that all the mooring of the FPSO assembly after mating will be provided by the FPSO mooring system as will be explained below.

[0015] The invention is defined by the independent patent claims. The dependent claims define advantageous embodiments of the invention.

[0016] In the following examples are described of preferred embodiments illustrated in the accompanying drawings, wherein:

Fig. 1	shows, in an upside-down isometric view, a first embodiment of a FPSO according to the invention;
Fig. 2	shows, in a side-view; a spread-moored buoy according to the invention;
Fig. 3	shows, in a cross-sectional view, the spread-moored buoy from Fig.2 as seen through section B-B;
Fig. 4	shows, in a cross-sectional view, the spread-moored buoy from Fig.2 as seen through section C-C;
Fig. 5	shows, in a top view, the spread-moored buoy from Fig. 2;
Fig. 6	shows, in a side view, a FPSO assembly according to the invention;
Fig. 7	shows, in a side view, an installation stage of the FPSO assembly;
Figs. 8-10	show, in different cross-sections, another installation stage of the FPSO assembly;
Figs. 11-13a, b	show, in different cross-sections, a further installation stage of the FPSO assembly;
Figs. 14-15a-c	show, in different cross-sections, an even further installation stage of the FPSO assembly;
Figs. 16-19	show, in different cross-sections, the final installation stages of the FPSO assembly; and
Fig. 20	shows, in a longitudinal cross-section, an FPSO assembly with a FPSO according to a second embodiment.

[0017] In the following, the reference numeral 1 will be used to denote a FPSO vessel according to the first aspect of the invention, while the reference numerals 10 and 100 will be denoting a spread-moored buoy (SMB) according to the second aspect of the invention and a FPSO assembly according to the third aspect of the invention, respectively. Like reference numerals will be used to identify identical or similar feature in the drawings. The drawings are shown schematically and highly simplified, and various features shown therein are not necessarily drawn to scale.

[0018] Any reference to prepositions, such as "over", "under", "in front of", "behind" etc., or directions, such as "up", "down", "forward", "backward" etc., will refer to the

normal orientation and direction of the features in the drawings in their normal position of use.

[0019] Fig. 1 shows, in an upside-down isometric view, a FPSO vessel 1 according to the invention. The FPSO 1 has a recess, in the form of a trunk 2, extending from the stern 4 of the FPSO, along an axial/longitudinal centreline C inside the hull 3 of the FPSO 1 and to a position substantially amidship 8. In an alternative, not shown embodiment, the trunk 2 may be provided inside the hull 3 of the FPSO but off the centreline. In yet an alternative, not shown embodiment, the trunk 2 may be extending from the bow 5 of the FPSO 1 and into the inside of the hull 3. The trunk 2 may even, in alternative ,not shown embodiments, be extending from the sides of the FPSO 1 and into a docking area inside the hull 3. In that regard it should be noted that the seaworthiness of a FPSO 1 in transit is of little importance, as the FPSO 1 will typically be moored and stationary at the wellsite for several years, sometimes for decades. The shown FPSO 1 includes a plurality of riser reception pipes 12, the riser reception pipes 12 constituting a part of a riser reception unit on the FPSO 1. The trunk 2 allows for the reception of the spread-moored buoy 10, as shown in in Fig. 2, and as will be described in further detail below with reference to the drawings in the following figures. The FPSO 1 is moored by means of plurality of mooring lines 14 to the seabed 21, as shown e.g. in Fig. 6. The mooring lines 14 are connected to the FPSO 1 at the stern 4 and bow 5 both at the starboard side 16 and port side 18 thereof, in a spread-mooring arrangement. The trunk 2 is closable by means of a hatch 82, which may be beneficial for protecting equipment provided in the trunk 2 from waves, wind etc. The hatch 82 may, in alternative, not shown embodiments, be located near the bow 5 or one the sides 16, 18 of the FPSO 1.

[0020] The trunk 2 may, as indicated in Fig. 16, be formed with low and narrow aft portion and a wider and deeper portion forward for docking area for the SMB 10, the docking area incorporating equipment for warping, locking and flow line make-up etc., as will be explained in the following. In this, embodiment, the SMB 10 may need to be brought to a deeper draft in order to pass the low portion of the trunk 1, before docking.

[0021] Reference is now made to Figs. 2-5, showing the spread-moored buoy (SMB) 10 floating in the sea 20. Figs. 2 and 5 show the SMB 10 in a side and top view, respectively, while Figs. 3 and 4 show cross-sections B-B and C-C, respectively, as indicated in Fig. 2. The distance D1 between the sea surface 22 and the bottom 24 of the SMB 10 represents the draft of the SMB 10 in the shown position. A plurality of risers 26 extend from a not shown well head, pipe line or subsea manifold and up to the SMB 10. Each riser 26 enters the bottom 24 of the SMB via a riser bend restrictor/stiffener 28 protecting the risers 26 from static loads that could otherwise have led to bending and buckling during installation and operation. From the bend restrictors 28, the risers 26 extend through guide pipes/caissons 30 in the SMB body, as shown in Figs. 3 and 4, and therein protected through the splash zone to be hung off on the upper surface/weather deck 32 of the SMB 10 in a riser hang off 34 with end fittings 33, flanges for isolation valves 35 and riser isolation valves 36 connected thereto shown extending above the hang-offs. The isolation valves 36, together with emergency shut down valves 37, as shown in Fig. 17, may be important for safety if the risers 26 are already connected to live subsea wells. The risers 26 are hung off in two parallel rows on the SMB 10. A plurality of fenders 38 are provided on each side of the SMB 10 for gentle docking in the trunk 2 inside the hull 3 of the FPSO 1 as will be explained below with reference to the following drawings. The SMB 10 is provided with locking means 40, here shown in the form of locking dogs/arms 43 that are extendible to engage with complementary fitting cradles 42, see e.g. Figs. 12 and 13, in the trunk 2 of the FPSO 1 as will explained below. The cradles 42 may be lined with an elastomer sheet to reduce the effects of the impacts during the docking/mating operations of the SMB 10 within the hull 3 of the FPSO 1. The two bodies of the locking means 40 will have different motion characteristics during the docking sequence, and means for reducing the load response caused by the impacts during such mating may be beneficial. The locking arms 43 complementary fit with the cradles 42. The locking means 40 includes a stationary sleeve part 41 and a linearly extendable arm part 43 as will be described in further detail below. In alternative, not shown embodiment, the locking dogs 43 may be mounted to the FPSO 1 while the cradles 42 are located on the SMB 10. The SMB 10 is moored to the seabed 21, as shown in Figs. 5 and 6, by a plurality of SMB mooring lines 44 connected to the aft 46 and front 48 of the SMB 10 on both starboard side 50 and port side 52 thereof, in a spread mooring arrangement, hence the name "spread-moored buoy". Mooring fairleads 54, with lower swivelling members 56 and vertical stationary members 58, extending along the height of the hull of the SMB 10 acting a hawse pipes and supporting the lower swivelling members 56, guide the mooring lines 44 from the sea to the SMB weather deck 32, where in the mooring lines 44 are hung off in mooring line hang-offs 60, here shown in the form of chain stoppers. The vertical, stationary parts 58 of the fairleads 54 are protected by means of vertically extending fenders 62. To tension the mooring of the SMB 10, prior to arrival of the FPSO 1, the SMB 10 mooring lines 44 on the SMB 10 may be tensioned by a means of a not shown installation vessel carrying the necessary winches and equipment to establish the desired tension, as will be understood by a person skilled in the art. The installation vessel will normally be the same vessel installing the risers 26 and connecting them to the SMB 10. This full installation process does not require the presence of a FPSO. In an alternative embodiment, as indicated in Fig. 17, the SMB 10 itself may be provided with one or more mooring line tensioning members, here in the form of linear winches 64, adapted to tension the mooring lines 44 to the desired tension. The draft D1 of

the SMB 10 indicated in Figs. 2-4 is representative for the typical draft of a fully loaded, moored SMB 10 waiting for the FPSO 1 to arrive. The SMB 10 is during and after installation, before connection to a FPSO 1, made as a barge for surface operations. However, after connection and installation to the FPSO 1, the SMB 10 is designed to be able to be fully submerged when the FPSO 1 shifts to a fully loaded draft, as will be explained below.

[0022] In the following, with reference to Figs. 6 - 20, the FPSO 1 and SMB 10 will be shown together, both before, during and after connection and installation, and the combined FPSO 1 and SMB 10 will, as already described herein, be referred to as a FPSO assembly 100.

[0023] Fig. 6 shows, in small scale, the FPSO assembly 100, including the FPSO 1 and the SMB 10, installed and spread-moored to the seabed 21 by means of the FPSO mooring lines 14 and the SMB mooring lines 44. In another, not shown embodiment it is envisioned that the SMB 10 may carry a larger part or even all of the mooring, implying that the FPSO 1, when mechanically connected to the SMB 10, may not need to be moored, potentially simplifying the process of connecting the FPSO assembly 100. In still another, not shown embodiment, the mooring lines 44 suspended in the SMB 10 may be idle or dismounted, leaving all the station keeping duties to the mooring system mounted onto the hull 3 of the FPSO 1.

[0024] The mooring system for the SMB 10 disclosed herein is just one exemplary embodiment out of a variety of different, possible mooring systems, as will be understood by a person skilled in the art. The SMB 10 may be provided with mooring suspension means as is well known for ordinary moored vessels including mooring systems connected by means of lugs to the SMB. Other alternative mooring systems may include dual axis supported chain stoppers located at the bilge.

[0025] In the following, with reference to Figs. 7-21, different stages of the process of connecting and installing the FPSO assembly 100 are shown. In the various stages, different steps where the SMB 10 and FPSO 1 are moved relative to each other are i n-volved; first horizontally by hauling/warping one relative to the other in order to dock the SMB 10 in the trunk 2 inside the hull 3 of the FPSO 1, and then subsequently vertically by ballasting or de-ballasting one relative to the other in order to make up the mechanical connection between the FPSO 1 and SMB 10. It should be noted that in the method according to the invention, it is sufficient that there is relative movement between the FPSO 1 and SMB 10, and that instead of hauling the FPSO 1 in over the SMB 10, the SMB 10 may instead be hauled into the trunk 2 of the FPSO 1. Similarly, steps relating to ballasting and de-ballasting of the SMB 10 could equally well be achieved by de-ballasting and ballasting, respectively, of the FPSO 1.

[0026] Fig. 7 shows the SMB 10 moored and positioned at its final position, while the FPSO 1 is located with its stern 4 adjacent the front 48 of the SMB 10. The FPSO 1 may now be hauled into a position over the SMB 10 by increasing the tension in the mooring lines 14 connected to the stern 4 of the FPSO 1, while simultaneously reducing the tension in the mooring lines 14 connected to the bow 5 of the FPSO, as will be understood by a person skilled in the art. In an alternative, not shown embodiment, tug boats may be used in addition or as an alternative to haul the FPSO 1 into position over the SMB 10. Not shown propulsion equipment on the FPSO 1 may also be used to assist in the hauling process.

[0027] Fig. 8 shows a longitudinal cross-section through the FPSO assembly 100 in a stage where the SMB 10 is half-way into the trunk 2 within the hull 3 of the FPSO 1. The relative movement of the FPSO 1 to SMB 10 is, in the shown embodiment, enabled by re-tensioning of the FPSO mooring lines 14 as described above. During hauling/warping, both the FPSO 1 and the SMB 10 is at a light draft, as will be explained in further detail below.

[0028] Fig. 9 shows cross-sections through sections C-C and D-D from Fig. 8 in the upper and lower parts of the figure, respectively. Section C-C in the upper part of the figure clearly shows the SMB 10 in the trunk 2 of the FPSO 1, while the SMB 10 has not yet reached section D-D, hence the seemingly empty trunk 2. In the shown embodiment, the FPSO 1 is at light ship draft and the SMB 10 is at a deep draft when moving through the aft portion of the trunk 2 for minimum height of the trunk 2. Similarly, Fig. 10 shows cross-sections through sections F-F and G-G from Fig. 8 in the upper and lower parts of the figure, respectively. Section C-C is taken vertically through the front 48 of the SMB 10 just rear of the amidship portion 8 of the FPSO 1. Section G-G is taken substantially amidship of the SMB 10 towards the stern 4 of the FPSO 1. Section D-D is taken just in front of the amidship portion 8 of the FPSO 1, while F-F is taken in front of the trunk 2, between the bow 5 and the amidship portion 8 of the FPSO 1. As can be seen clearly in sections C-C and G-G, the locking arms 43 of the locking means 40 are in their retracted position, whereby the FPSO 1 can be moved freely, linearly relative to the SMB 10. Fig. 8 and sections D-D and F-F in Figs. 9-10 also show riser connections in the form of riser reception pipes 12 on the FPSO 1. Each reception pipe 12 extends from the trunk 2 through an upper part of the trunk 23 in the hull 3 and to the deck 11 of the FPSO 1. The SMB 10 has not yet been mechanically connected to the FPSO 1 and no installation of risers 26 has been made. Process modules 66, to which the riser reception pipes 12 fluidly connect (not shown), are only schematically indicated on deck 11 of the FPSO. Each riser reception pipe 12 is provided with its own valve 68, defining the top of the riser reception pipe 12. Winches 70, as shown in sections D-D and F-F, provided on deck 11 of the FPSO 1 may be used to tension the SMB mooring lines 44 if needed.

[0029] Fig. 8 shows a warping line 75 extending longitudinally from the SMB to either a winch 70 on deck 11 via the hawse pipe 78 (fig 10) or preferably from a smaller

winch in the forward end of the trunk 2 to the SMB 10. A corresponding warping line from the aft portion of the wide portion of the trunk to the SMB is established as the SMB is entering the trunk. These two warping lines will keep the relative position of the two floating bodies in control relative to one another.

[0030] Alternatively, as mentioned previously and shown in Fig. 17, the SMB 10 may carry its own winch 64 for the tensioning up its mooring lines. Winches 71 are connected to the FPSO mooring lines 14 for tensioning of the mooring lines 14. The mooring lines 14 extend from the seabed 21, as shown in Fig. 6, to deck 11 of the FPSO 1 through fairleads 67, which are of similar construction as the fairleads 54 on the SMB 10, discussed in relation to Figs. 3 and 4 above. Chain stoppers 69 are used to hang-off the FPSO mooring lines 14 on deck. 11. The winches 71 will normally be used in order to haul/warp the FPSO 1 in over the SMB 1 in the installation process. A winch 72, adapted to pull in risers 26 by means of a pull-in rope 73, is provided on a carriage 74, linearly movable on rails 76 extending longitudinally in the upper trunk 23. This carriage 74 may thus be placed at any longitudinal position over the risers 26 once the SMB 10 is installed to make up connection with any of the risers 26. The process of pulling in risers 26 in order to make up the connection between the risers 26, hung off at the SMB 10, and the riser receptions pipes 12 will be described in further detail below. Section F-F further shows hawse pipes 78 extending through the hull 3 of the FPSO 1. When installed, the mooring lines 44 from the SMB 10 may extend through these hawse pipes 78 for connection to the tensioning winches 70 on deck 11 of the FPSO. The cradles 42, into which the locking arms 43 will be extending to make up the mechanical connections between the SMB 10 and FPSO 1, is shown in sections C-C, D-D and F-F. The process of making the mechanical connection will be described in further detail below.

[0031] Reference is now made to Figs. 11-13a, b, where Fig. 11 shows the SMB 10 docked into the trunk 2 of the FPSO 1 in the final horizontal position of the FPSO 1, while Fig. 12 shows the cross-sections F-F and D-D from Fig. 11, and Fig. 13a shows the cross-sections G-G from Fig. 11 and the detail M from the cross-section G-G. The SMB 10 is still at the same draft D1 as shown in Figs. 2-4, where the waterline/sea surface 22 is at the level of the fenders 38. In this relatively light draft D1 of the SMB 10, the locking arms 43 are at a higher vertical position than the corresponding cradles 42 in the trunk 2 of the FPSO 1, and may be extended horizontally into a vertical position above the cradles 42, as best seen in Fig. 13a and in particular in detail M. Each locking arm 43 is formed with an inclined end/engagement portion 45 adapted to be received by a complementary inclined receiving portion 47 in the cradle 43 in order to position the SMB 10 sideways relative to the FPSO 1. The extension of the arms 43 is actuated by means of not shown linear actuators, which may be operated hydraulically, pneumatically, electrically or manually-mechanically as will be understood by a person skilled in the art. In the shown position, the SMB 10 is now ready to be mechanically connected to the FPSO 1.

[0032] Figs. 14-15a-c show the SMB 10 after it has been mechanically connected to the FPSO 1. Fig. 14 shows a longitudinal cross-section through the FPSO assembly 100, Fig. 15a shows a cross-section G-G from Fig. 14 and a detail M from G-G, while Fig. 15b shows the cross-section X-X from Fig. 15a. The actual connection is made by changing the relative vertical position between the SMB 10 and FPSO 1, here by ballasting the SMB 10 to a deeper draft D2, where the waterline 22 is closer to the weather deck 32 of the SMB 10.

[0033] Referring again to Figs. 13a, b, the vertical clearance/distance between the locking arms 43 and the cradles 32 is reduced as ballast water is pumped into the SMB 10 until the underside 83 of the arm 43 comes into contact with the liner 84 in bottom of the cradle 42. The inclined portion 45 of the arm 43 eventually ensures centralizing effects on the SMB 10 as it comes into engagement with the complementary inclined receiving portion 47 in the cradle 42, whereby the remaining portion of the difference between submerged buoyancy of the SMB 10 and the weight of the SMB 10 with all mooring and riser loads carried by it becomes carried by the FPSO 1. Section X-X in Fig .13b similarly shows the principles for longitudinal positioning of the SMB 10 versus the FPSO 1, wherein the inclined sidewalls of the cradle 42, provided with liner 85, ensure gentle docking and longitudinal positioning of the arms 43 into the cradles 42.

[0034] A large draft during the connect-up operation of the SMB 10 to the FPSO 1 may be beneficial for minimizing the reserve buoyancy of the SMB 10. (The reserve buoyancy is the difference between the SMB 10 total buoyancy less the total weights and loads on the SMB 10.) The locking means 40 will thus be exposed to less loads when the FPSO 1 is at loaded drafts and the SMB 10 is fully submerged. The most beneficial reserve buoyancy will be the one resulting in net load reaction between the locking means 40 and the cradle 42 just a little larger than the double amplitude of the dynamic vertical loads between the SMB 10 and the FPSO 1. Then alternative loads passing zero in the locking device 40 connections represented by Fig. 15a, b is avoided.

[0035] The locking means 40 will be subjected to a static force corresponding with the reserve buoyancy at the draft at connect-up of the SMB barge 10 to the FPSO vessel 1 hull 3. This draft will in most cases correspond with a reserve buoyancy which will be too small for a free-floating barge in open sea.

[0036] Ballast water is filled into the ballast water tanks in the SMB 10 sufficiently to keep it calmly in the cradles 42. The docking operation is completed by engaging uplift preventers 86 to the cradle 42, by means of not shown fixing means, as indicated in the cross-section shown in Fig. 15c.

[0037] The design of the SMB 10 and the FPSO 1 may, as mentioned above, be inversely designed so that the

FPSO 1 play the active role in the shifting of the relative draft between the SMB 10 and the FPSO 1 during the mating operation, implying that when the vertical distance/clearance between the locking dogs 43 and the cradles 42 are to be closed/reduced, the FPSO 1 may be de-ballasted to a lighter draft, in contrast to the shown embodiment where the SMB 10 is ballasted to a heavier draft.

[0038] The connection of the risers 26 to the riser connection pipes 12 may then commence as well as adjustment of the tension in mooring lines suspended by the SMB 10.

[0039] Reference is now made to Figs. 16-19, showing the process of connecting the risers 26 on the SMB 10 to the riser reception pipes 12 on the FPSO 1. The FPSO 1 is shown with two different drafts in the figures, a first draft D3 indicating the relatively light draft maintained by the FPSO 1 during the whole installation and connection phase, and a second, deeper draft D4 which will be the draft of the FPSO assembly 100 after installation and connection has been finalized. When the FPSO assembly 100 is in the final, deep draft D4, the SMB 10 will be fully submerged, which will significantly reduce the hydrodynamic forces acting on then the submerged SMB 10, and the risers 26 are now protected through the splash zone. Fig. 16 is a longitudinal cross-section through the FPSO assembly 100, while Figs. 17-19 show vertical cross-sections through C-C, D-D and F-F, respectively, from Fig. 16. As mentioned above, the embodiment shown in Fig. 17 also includes a winch 64 that may be used to tension the SMB mooring lines 44. The winch 64 may be used in addition to or as an alternative to the winches 70 on deck 11 of the FPSO 1, as e.g. shown in section D-D of Fig. 9. The riser pull in winch 72 is available for pulling in additional risers 26 through the guide tubes in the SMB 10 after docking, and for later riser installation/demobilization operations. Chain hoists or similar, or riser pull in winch 72 as shown in Fig. 18 may be used for mounting the spool piece 80 for establishing the final connection between one of the risers 26 on the SMB 10 and one of the riser reception pipes 12, whereby hydrocarbons extracted from a not shown subsea reservoir may be transported from the reservoir, through a not shown wellhead at the seabed, through the risers 26, up to the SMB 10, and further through the riser reception pipes 12 on the riser reception unit into the process modules 66. Emergency shut-down valves 37 are either mounted onto the isolation valve 36 on the SMB 10 or provided on the riser reception pipe side (topside) of the spool pieces 80. The actual processing of hydrocarbons in the processing units 66 will not be described in any detail herein. When all the risers 26 have been connected to their respective riser reception pipes 12, the installation process in finished. The FPSO 1 may then be ballasted to the full/deep draft D4. In order to secure the mechanical connection between the SMB 10 and the FPSO 1, the locking means 40 may be provided with means to prevent the SMB 10 from disengage from the FPSO 1 due to negative load, locking the locking arms in the cradles 42. The negative load prevention means may be provided as a roof/superstructure above the cradle 42. It should be noted that the locking means 40 disclosed herein is only one of multiple possible embodiments. In one alternative embodiment, the locking means 40 may be based on not shown tongues on one of the SMB 10 and the FPSO 1 and complementary fitting grooves on the other of the SMB 10 and the FPSO 1. The tongues may be provided on the SMB 10, whereby a similar ballasting and de-ballasting process discussed above may also be used in the alternative embodiment. The preferred location of the SMB as regards the effects on both the riser loads and the vessel motions is at longitudinal centreline midship.

[0040] Fig. 20 shows, in a longitudinal cross-section, an alternative embodiment of a FPSO assembly 100 according to the present invention. The trunk 2 of the FPSO 1 is, in this alternative embodiment, shorter than in the embodiment shown in the previous figures, whereby the SMB 10 connects to the FPSO 1 at the stern/aft end 4 thereof rather than amidship 8. The SMB 10 is still provided along the axial centreline of the FPSO 1, though this positioning is not visible in the shown cross-section, which is beneficial for reducing the previous mentioned roll effects due to the lever arm resulting from riser connections on the sides of the FPSOs according to the prior art and reduced vertically imparted motion on the flexible risers. The shorter trunk 2 represents a smaller insection in the hull 3 of the FPSO 1, whereby more of the hull's 3 structural integrity may be maintained. The SMB 10 may carry all of the stern mooring of the FPSO 1, though in the figure, also the stern of the FPSO 1 is shown moored by means of mooring lines 14. The shorter trunk 2 may simplify the actual installation process, since the FPSO 1 and SMB 10 may need to be moved a shorter distance relative to each other in order to make the final connection. The quick connection may also result in a quick deconnection, which may be useful e.g. in an emergency situation. In the figure, the SMB 10 is shown after it has been mechanically connected to the FPSO 1, but before final connection of the risers 26 to the riser reception pipes 12. In an alternative, not shown embodiment, an even shorter trunk 2 than the one shown in Fig. 20 may extend the full height over the hull 3 of the FPSO 1 at the aft 4 thereof, whereby the SMB 10 may fill the whole trunk 2 through the whole height of the FPSO 1. The SMB 10 may thus carry all of the aft mooring of the FPSO assembly 100.

[0041] A (SMB) buoy 10 may, as also mentioned above, especially in sheltered waters stay positioned even without mooring lines 44 or any mooring system to keep it positioned.

[0042] The risers 26 may then have sufficient capacity to keep the buoy 10 on location without mooring lines 44. The configuration of the buoy 10 and the FPSO 1 will then remain the same, except that all the mooring of the FPSO assembly 100 after mating will be provided by the

FPSO mooring system 14.

[0043] Not shown in the figures or discussed in detail herein are the ballast systems provided on both the FPSO 1 and the SMB 10. The ballast systems typically comprise pumps, pipes, valves etc., as will be known to a person skilled in the art, for changing the draft/draught of the FPSO 1 and the SMB 10 by pumping water into or out from the SMB/FPSO for controlling the weight and thereby buoyancy of the SMB/FPSO.

[0044] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

[0045] The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. Floating production storage and offloading vessel (FPSO) formed with a recess inside its hull for receiving and connecting to a buoy therein.

2. FPSO according to claim 1, wherein said recess extends from the stern or from the bow of said FPSO along an axial centerline thereof.

3. FPSO according to claim 1 or 2, wherein said recess extends from the stern or bow of said hull and substantially amidship.

4. FPSO according to any of the preceding claims, wherein the FPSO is provided with a plurality of riser reception pipes located substantially at said axial centerline of the FPSO.

5. FPSO according to claim 4, wherein said plurality of riser reception pipes also are located substantially amidship of the FPSO.

6. FPSO according to any of the preceding claims, wherein said FPSO is moored by means of a plurality of mooring lines.

7. FPSO according to any of the preceding claims, wherein the hull of said FPSO is provided with a closable hatch for closing the entrance of said recess in the hull.

8. Buoy, said buoy being provided with a plurality of riser suspensions and said buoy being adapted to be received and connected to a FPSO in a recess thereof inside the hull of the FPSO.

9. Buoy according to claim 8, wherein said buoy is provided with ballasting means for shifting the draft of the buoy in water.

10. Buoy according to any of the claims 7-9, wherein the buoy is provided with locking means for mechanically locking the buoy to the FPSO.

11. FPSO assembly comprising a FPSO according to any of the claims 1-7 and a buoy according to any of the claims 8-10, wherein said buoy is connected to the FPSO in said recess, and wherein a plurality a risers are connected to riser reception pipes on said FPSO via said buoy.

12. Method for establishing an FPSO assembly according to claim 11, the method comprising the steps of:

    - hauling said FPSO relative to said buoy so that said buoy is slid horizontally into the recess of said hull of the FPSO;
    connecting said buoy mechanically to the hull of said FPSO; and
    - connecting said plurality of risers, suspended on the buoy, to the FPSO.

13. Method according to claim 12, wherein the hauling of the FPSO relative to the SMB includes hauling the FPSO in over the SMB while the position of the buoy is substantially fixed.

14. Method according to claim 12 or 13, wherein the method further comprises the step of pre-installing and suspending said plurality of risers to the buoy prior to arrival of the FPSO.

15. Method according any of the claims 12-14, wherein the method further comprises the step of ballasting the FPSO assembly to a final draft, after connecting the risers to the FPSO, where the buoy is fully submerged.

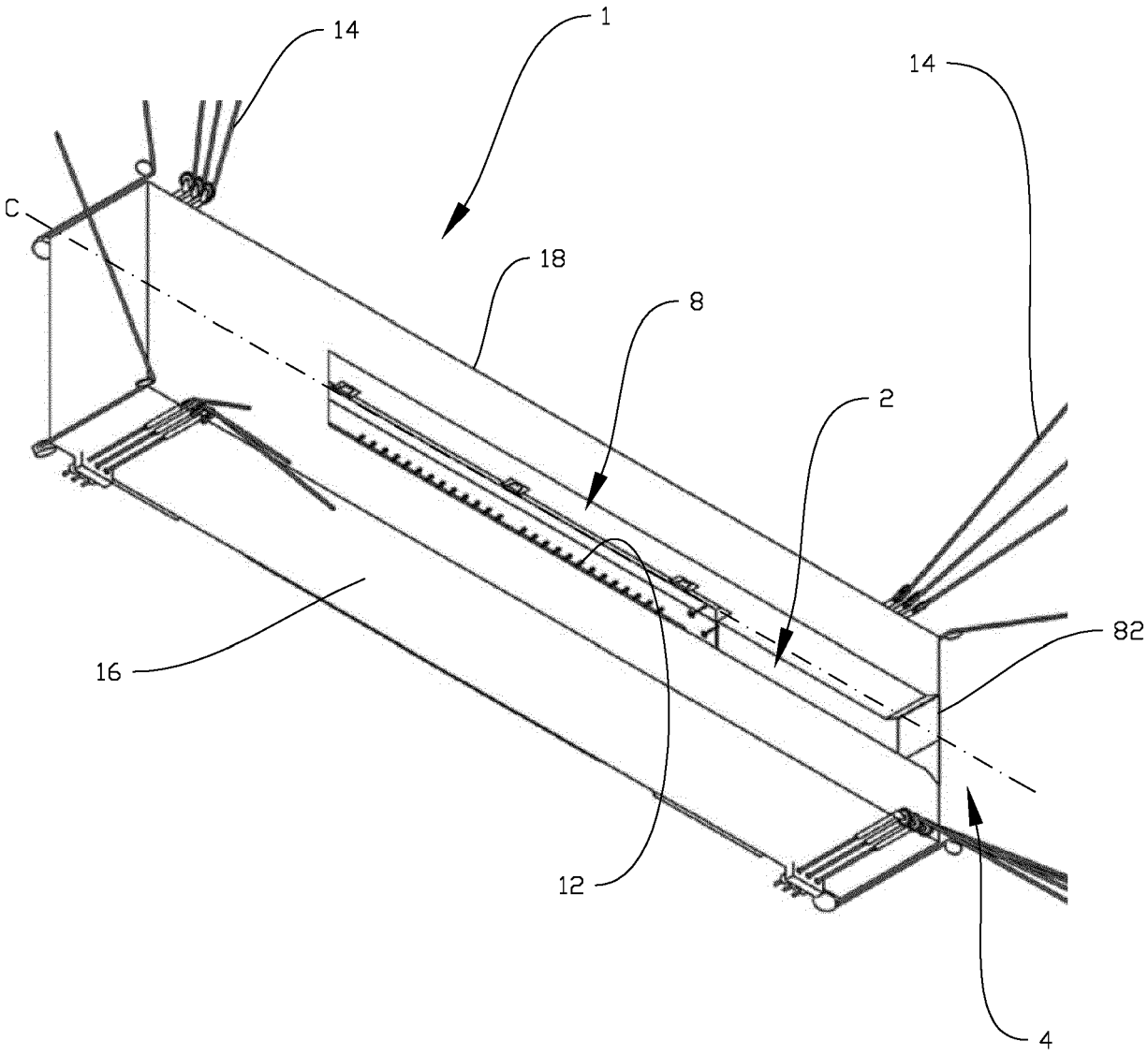


Fig. 1

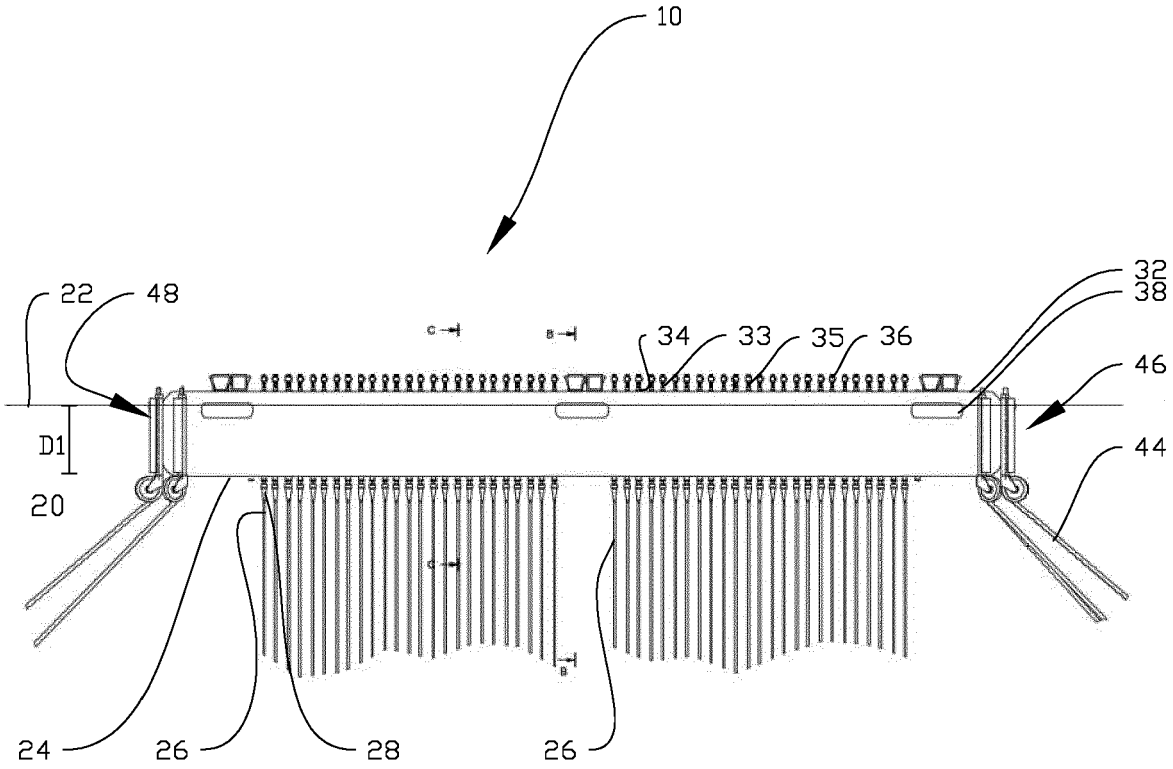


Fig. 2

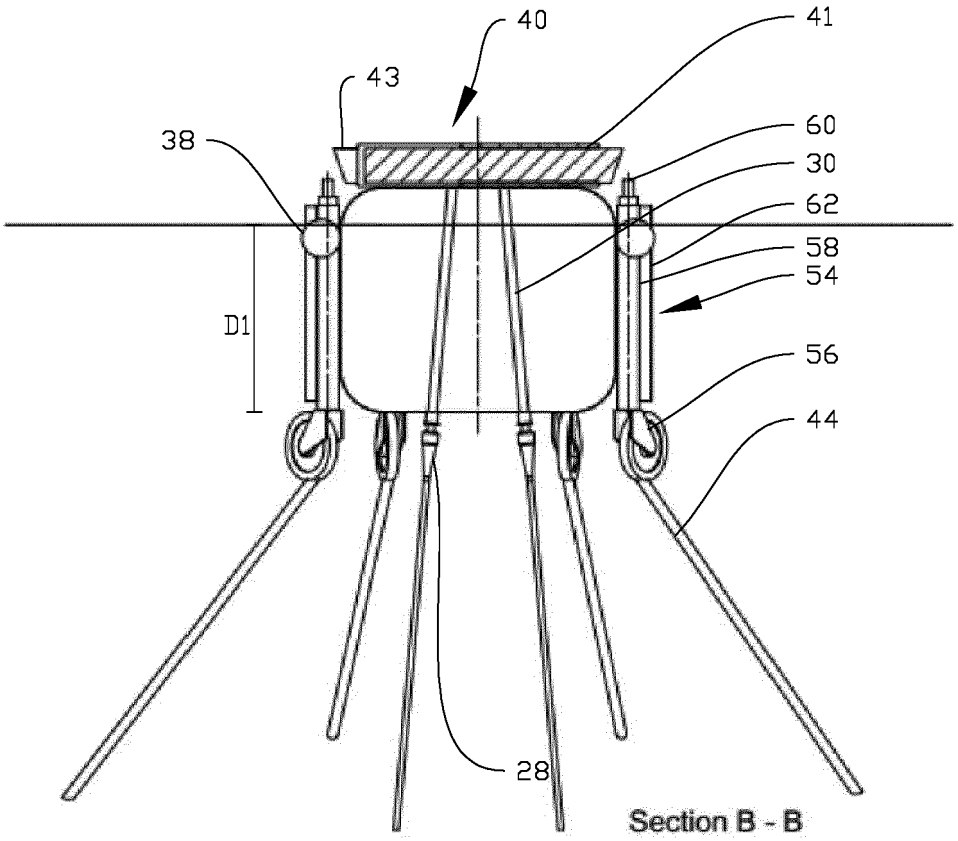
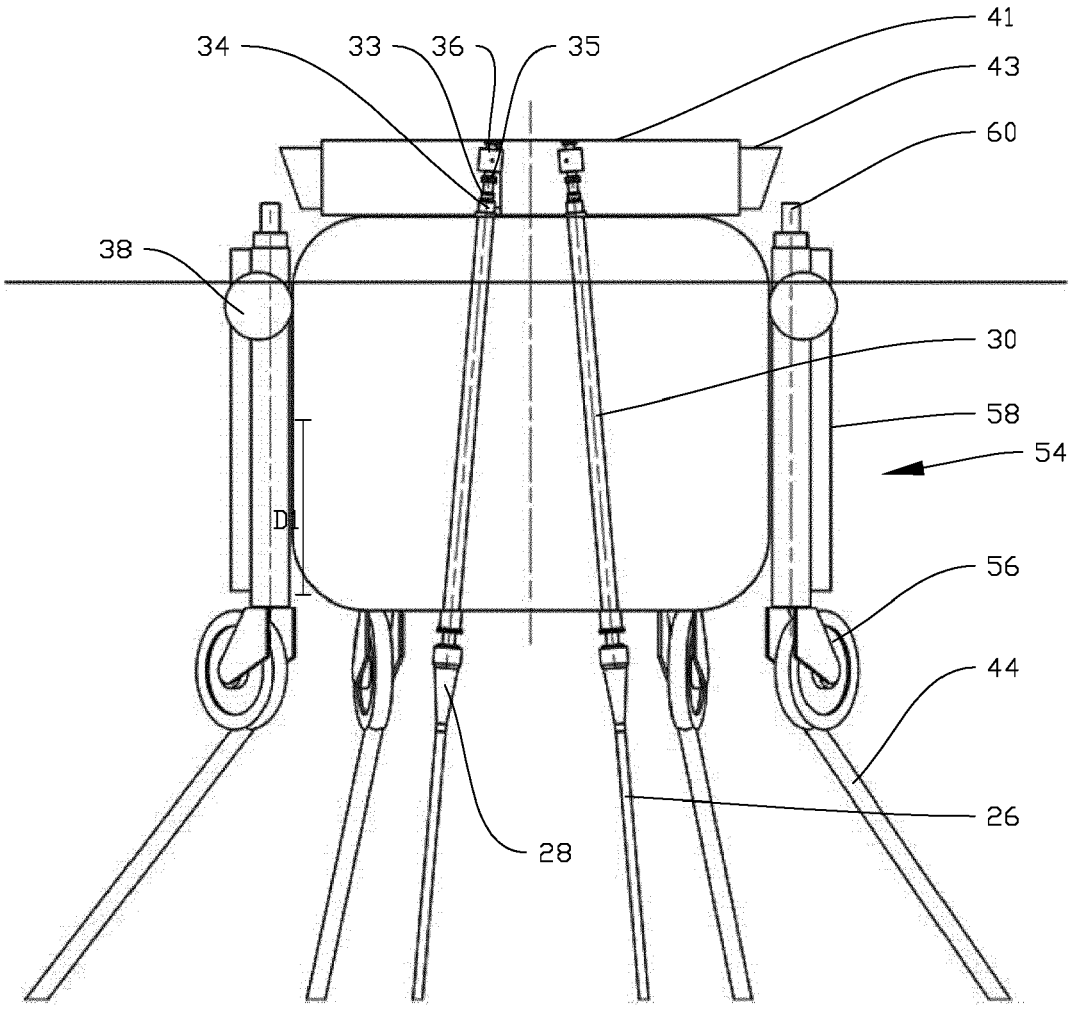


Fig. 3



Section C-C

Fig. 4

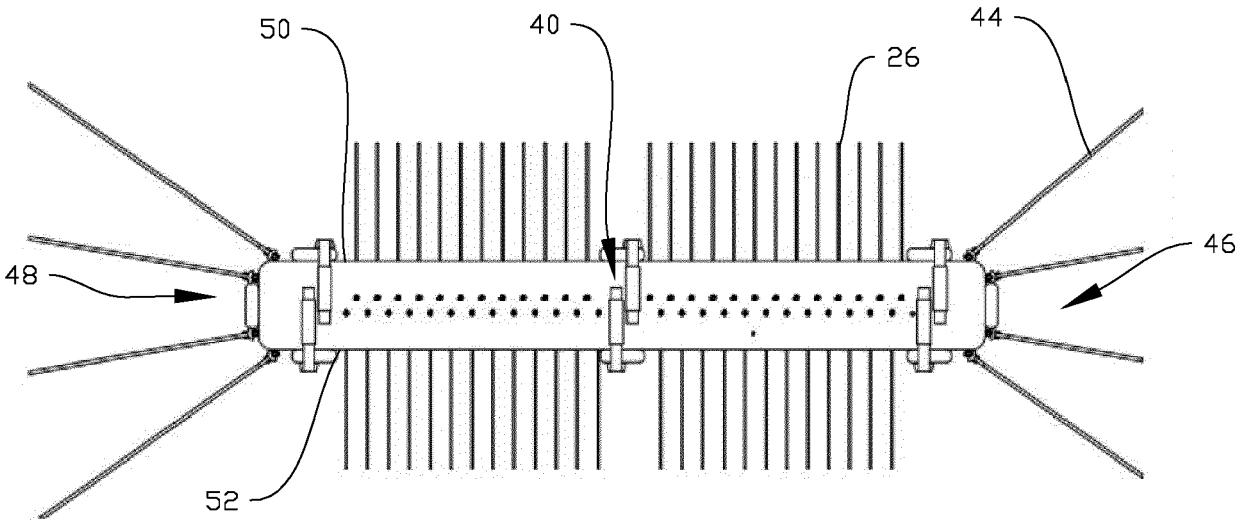


Fig. 5

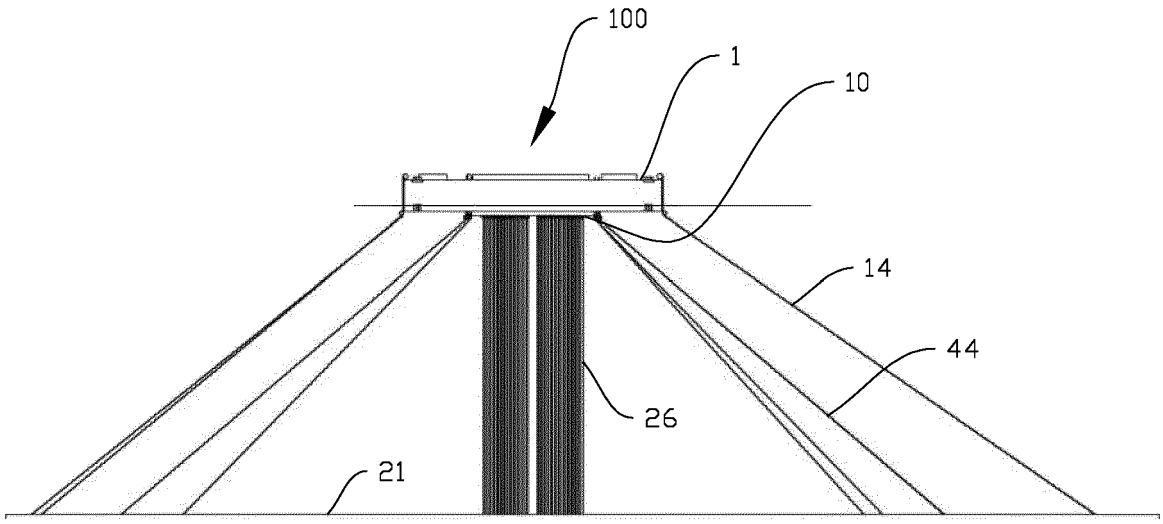


Fig. 6

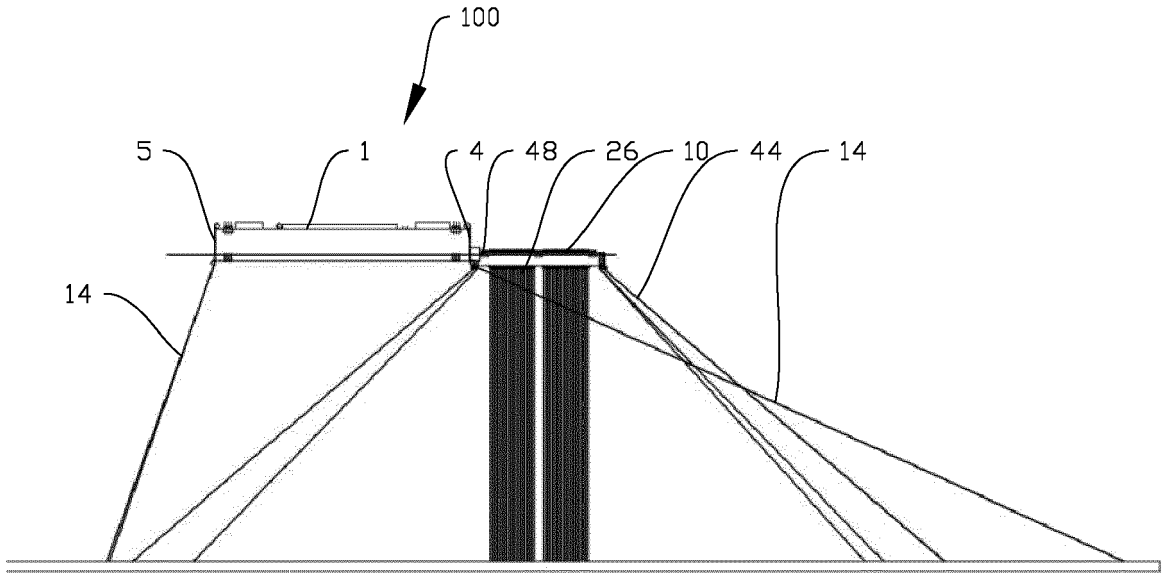


Fig. 7

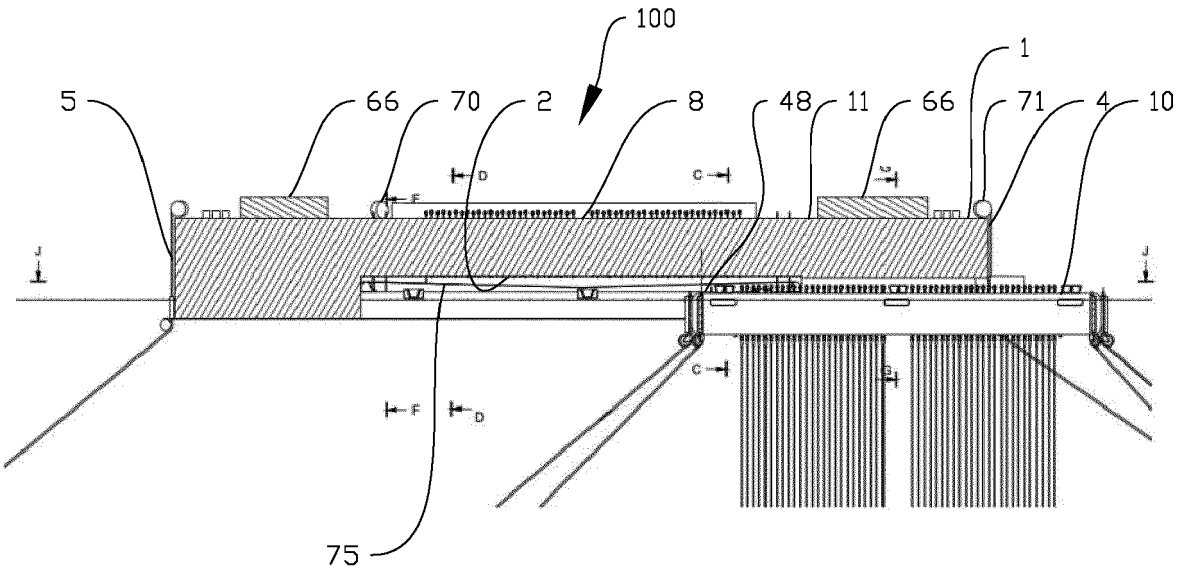
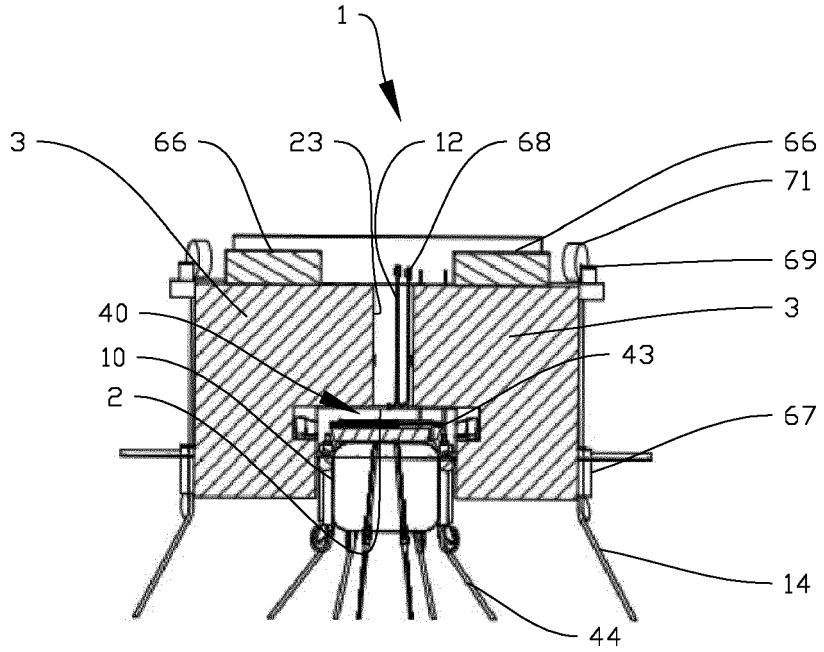


Fig. 8



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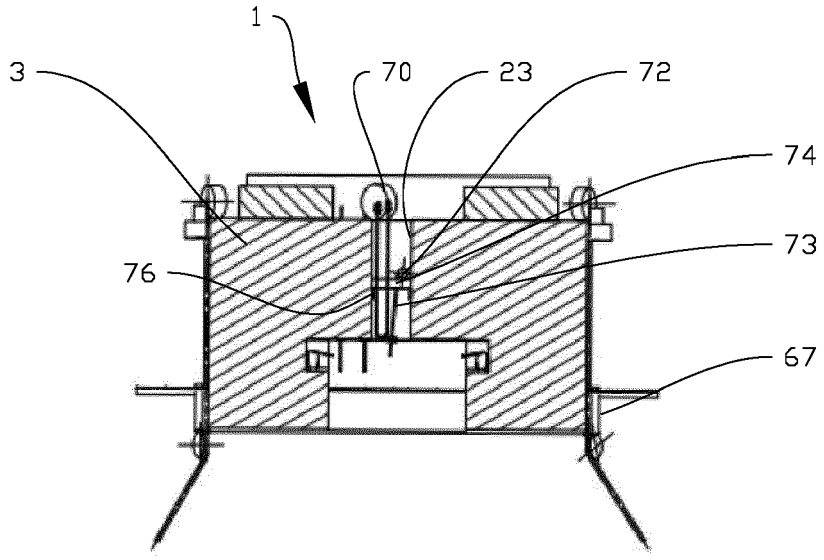


Section D-D

Fig. 9

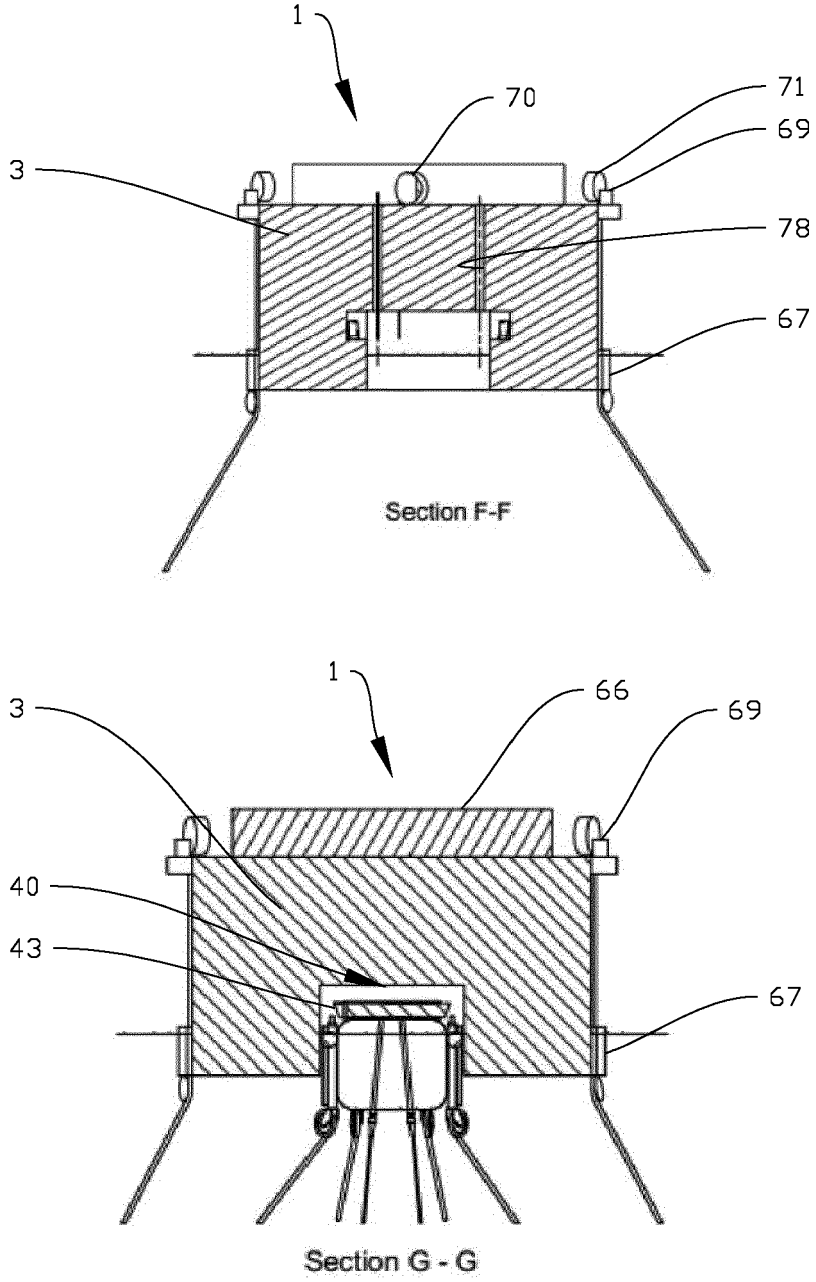


Fig. 10

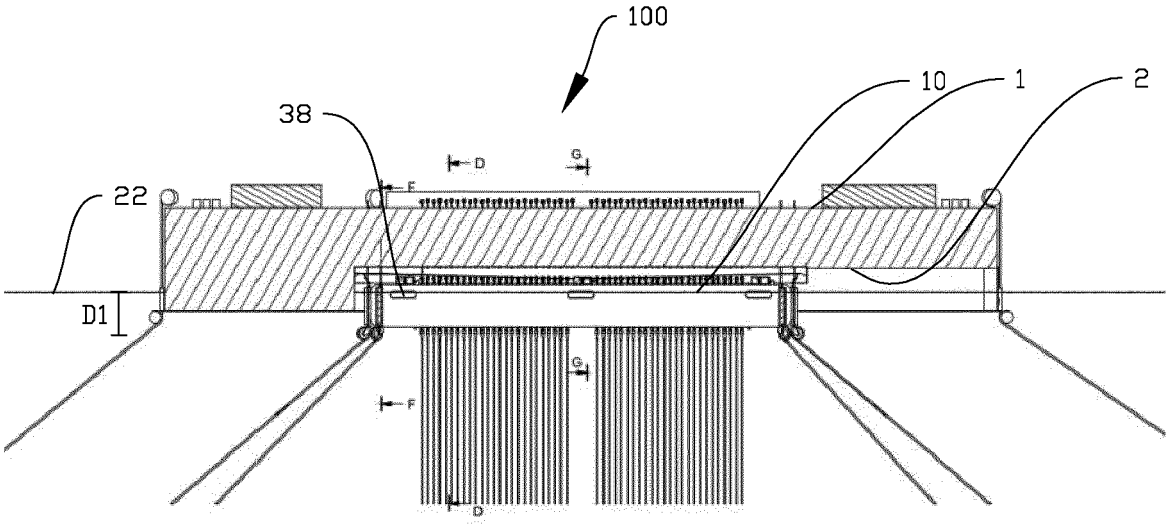
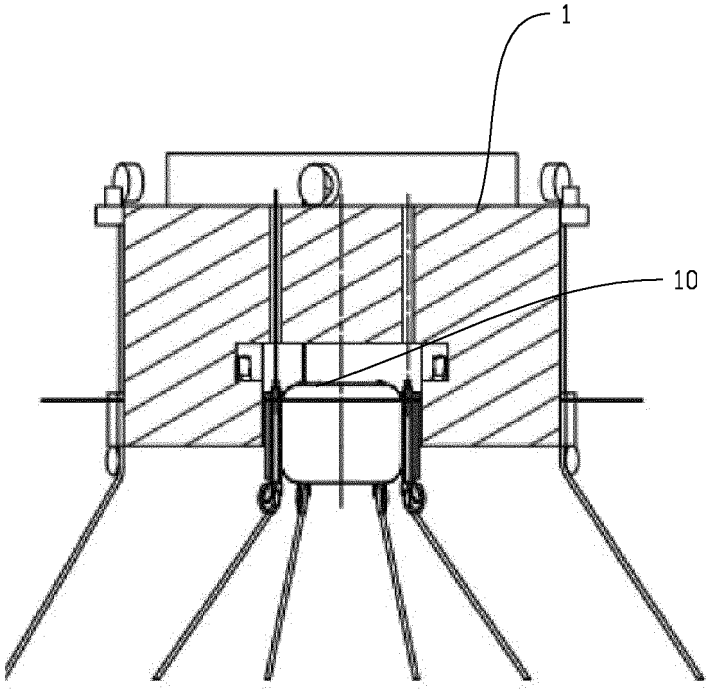
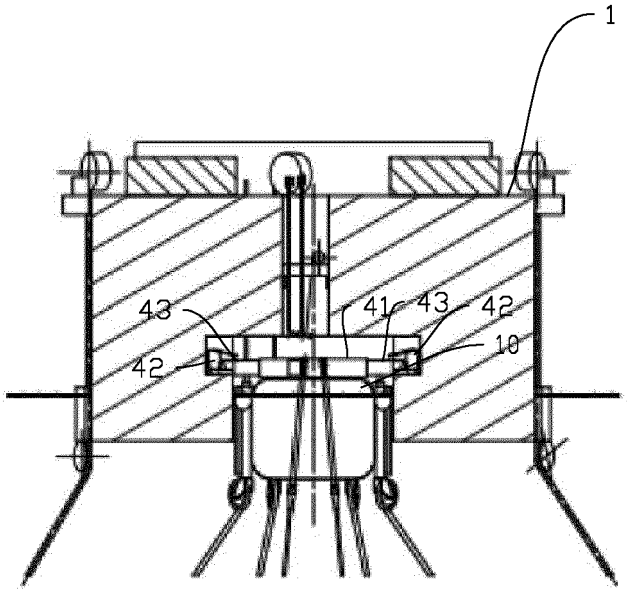


Fig. 11

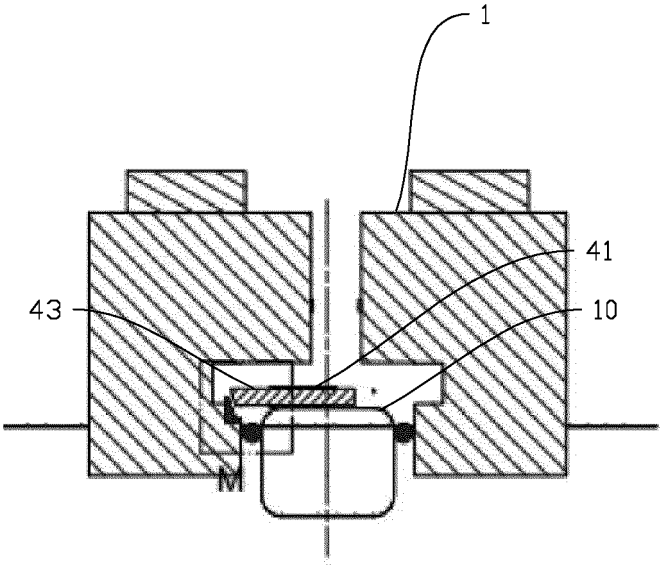


Section F-F



D-D

Fig. 12



Section G - G

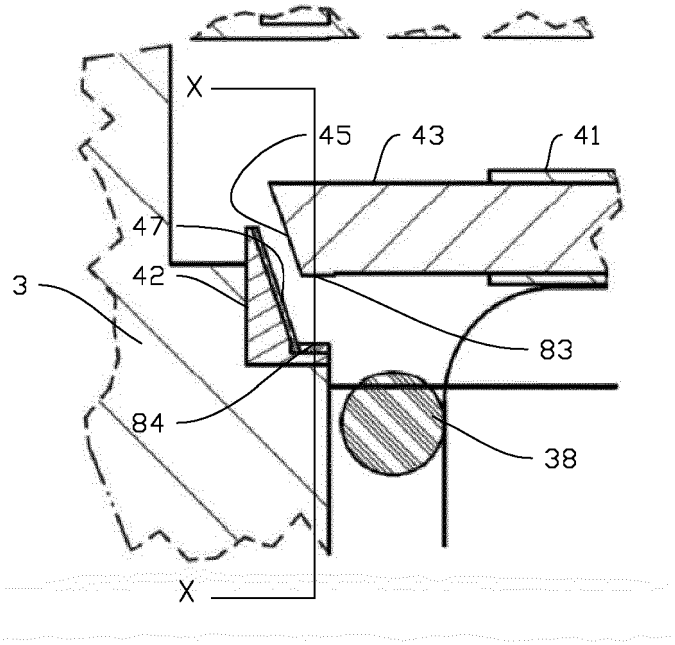
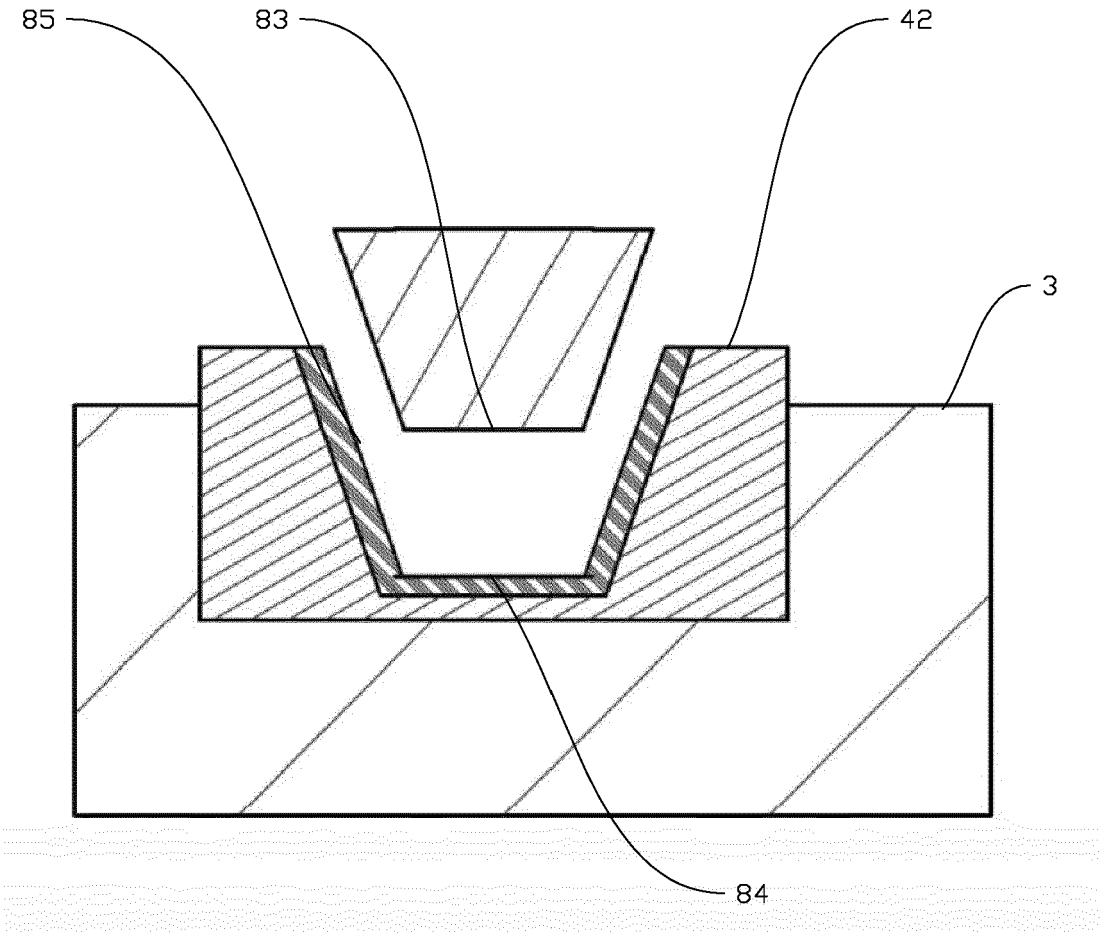


Fig. 13a



X-X

Fig. 13b

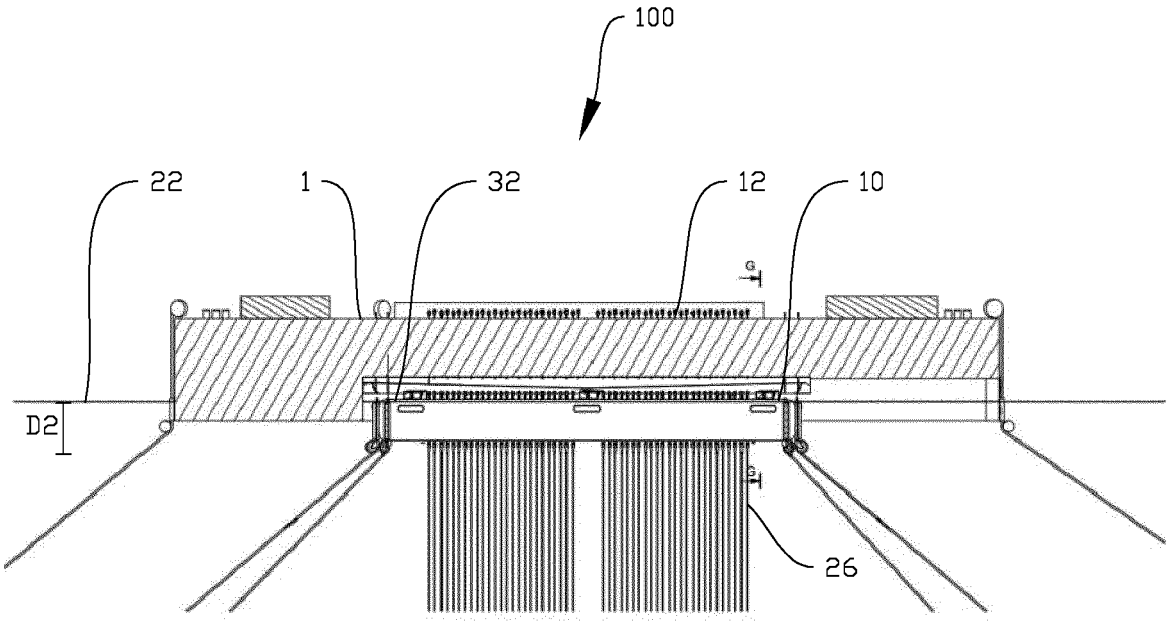
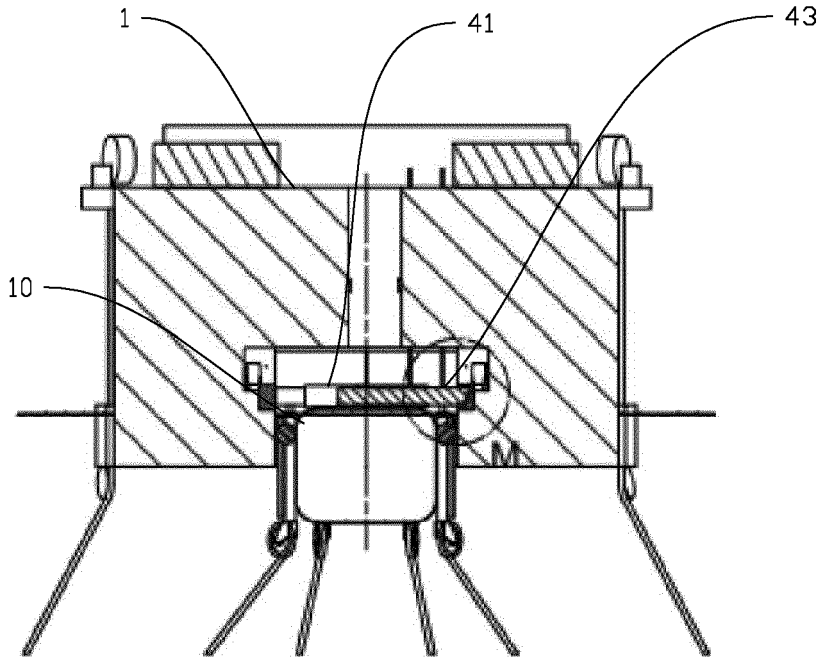
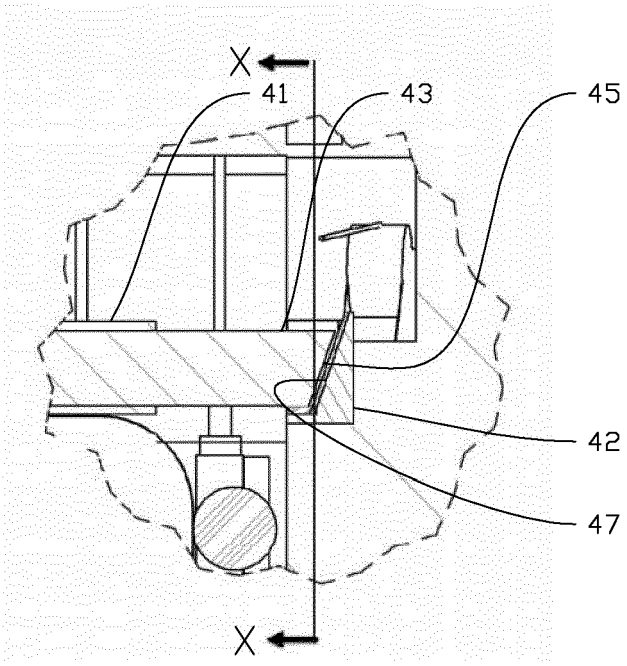


Fig. 14

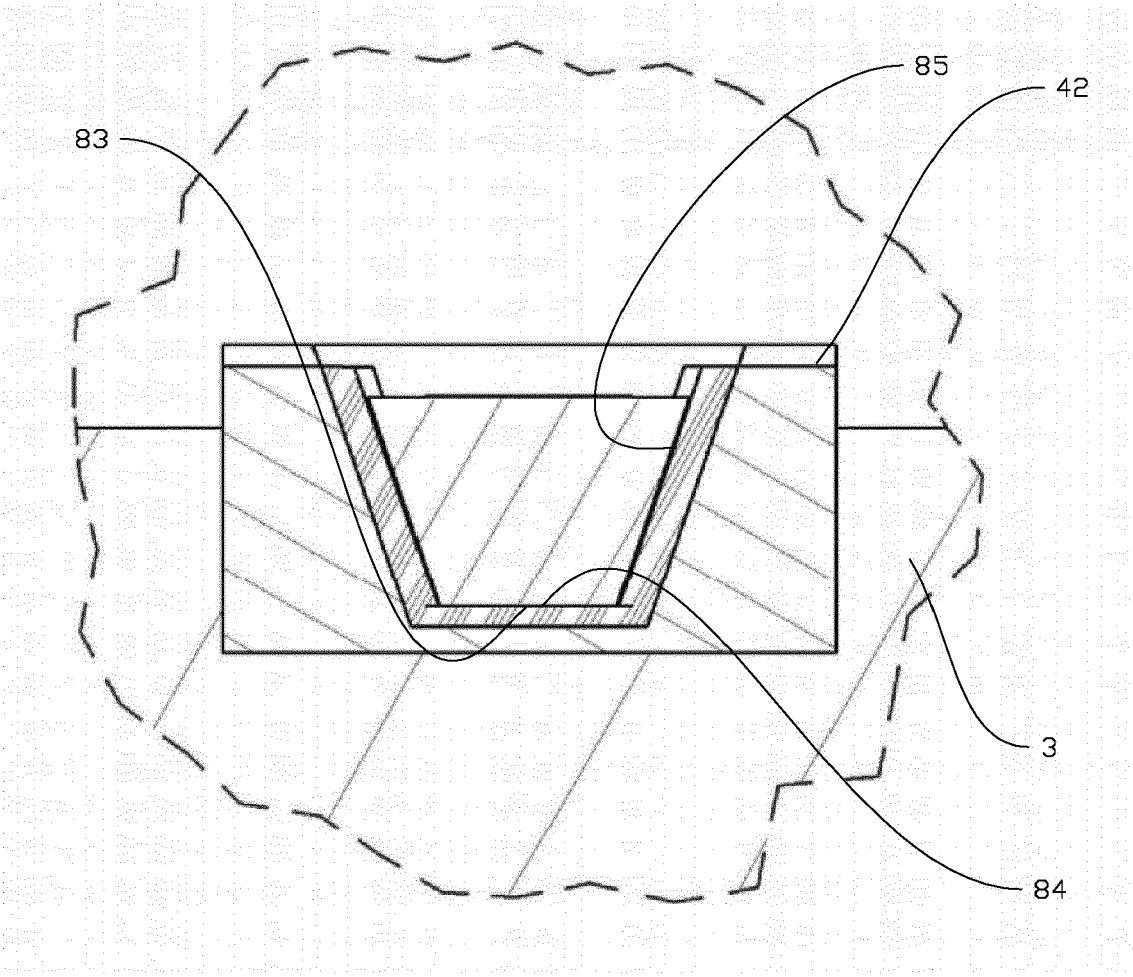


Section G - G



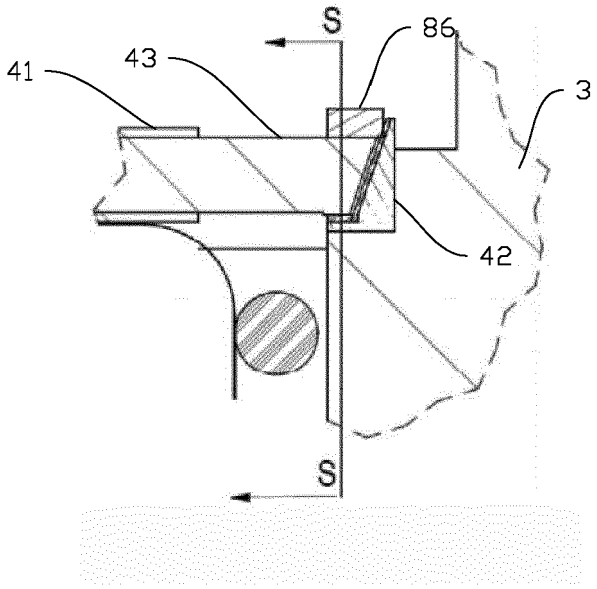
Detail M

Fig. 15a



X–X

Fig. 15b



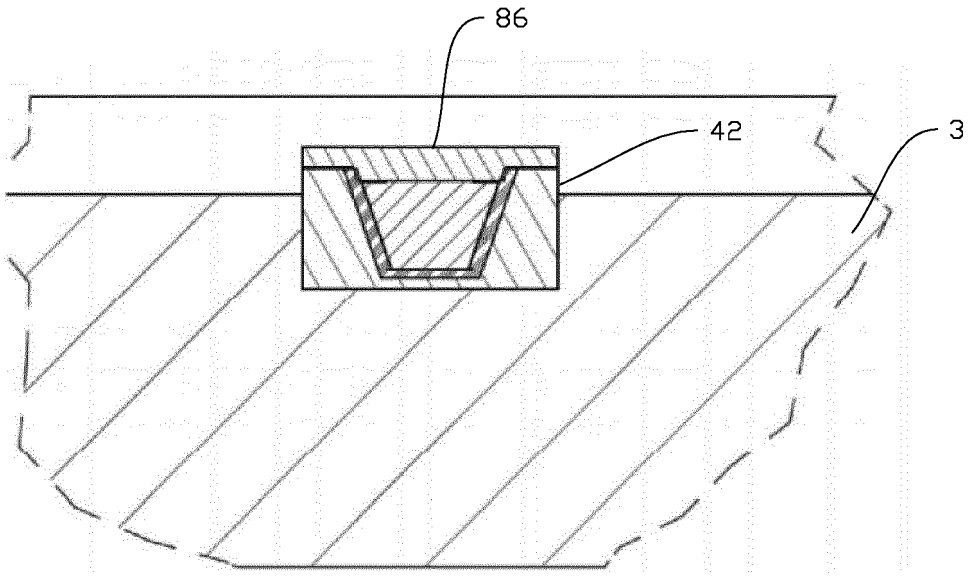


Fig. 15c

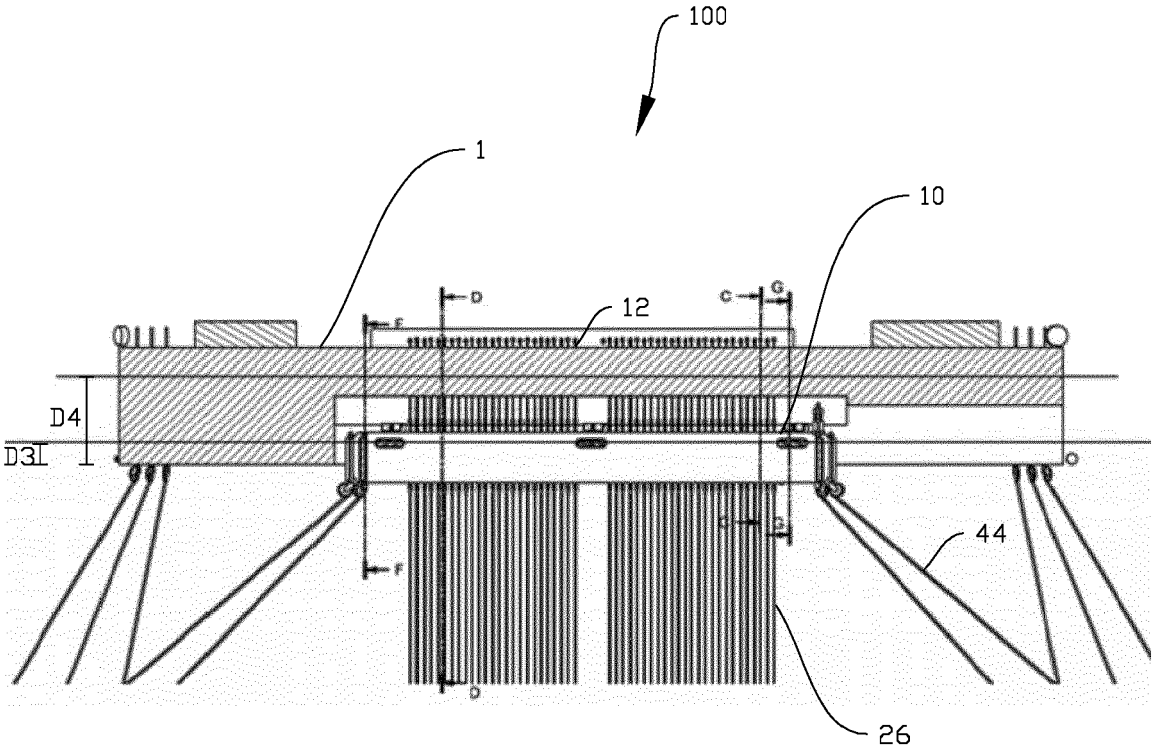
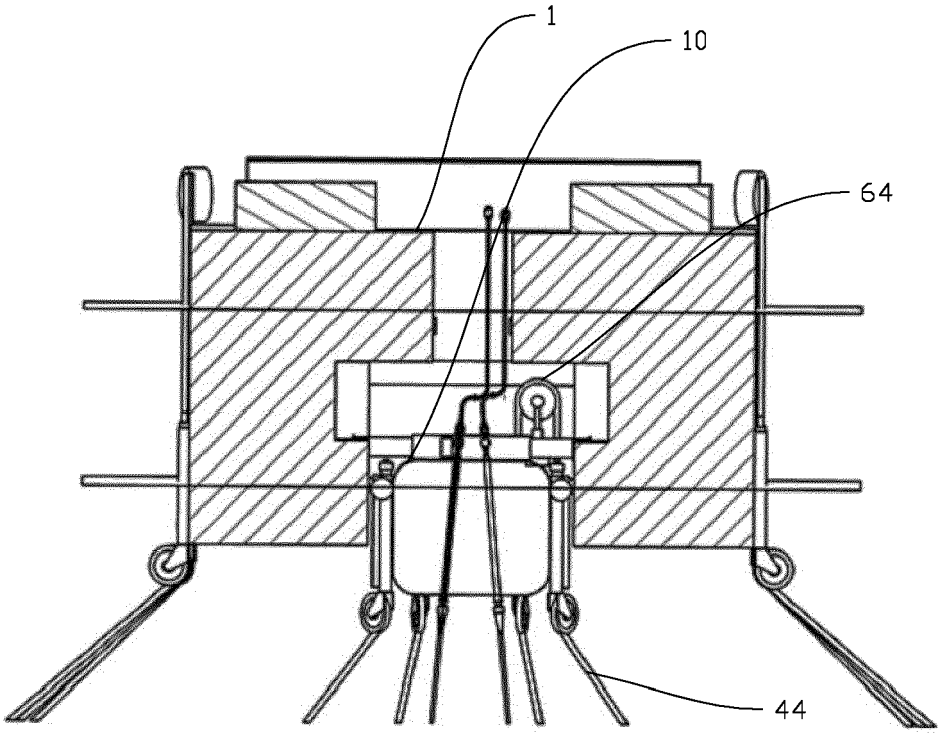
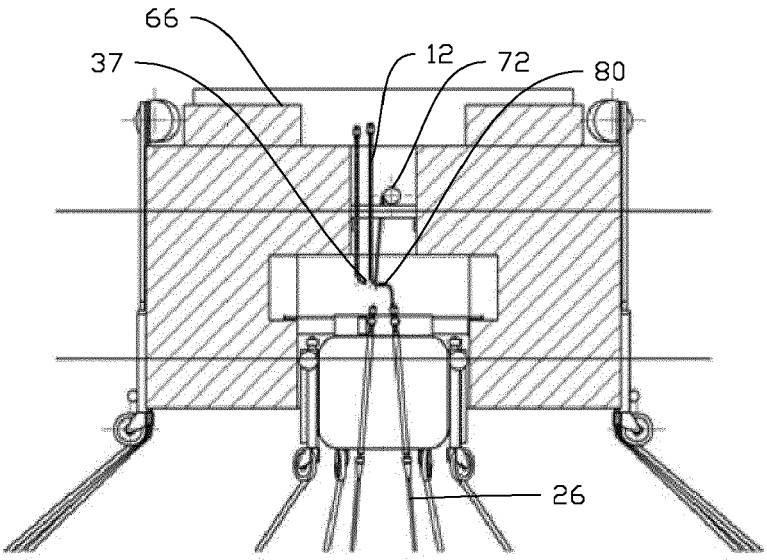


Fig. 16



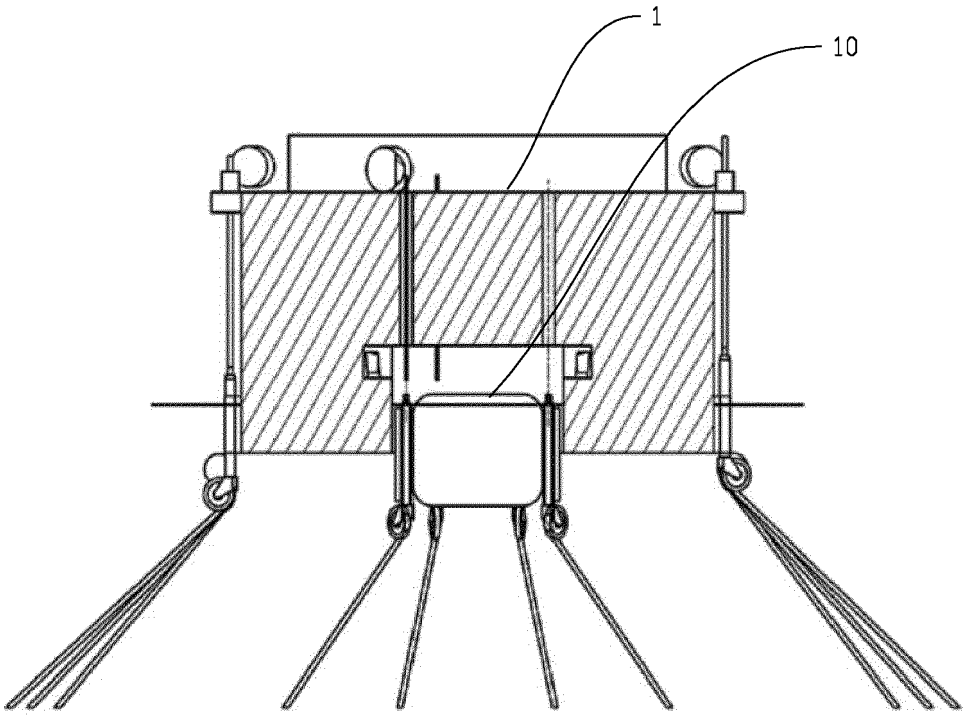
C — C

Fig. 17



D – D

Fig. 18



F — F

Fig. 19

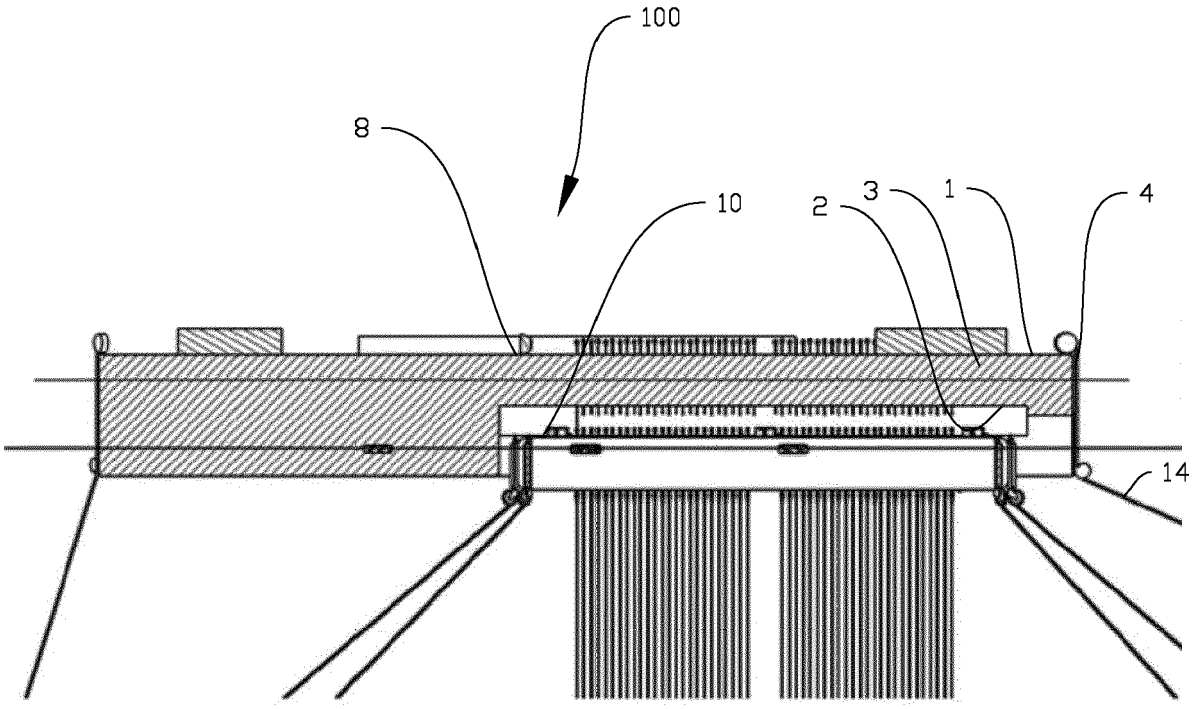


Fig. 20

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 4088

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2012/032163 A1 (SINGLE BUOY MOORINGS [CH]; LAVAGNA PHILIPPE [MC]) 15 March 2012 (2012-03-15) * page 1, line 21 - line 25; figures 1,2,4a,4b * -----	1,4-6,8, 10,11 2,3	INV. B63B21/50 B63B22/02 B63B35/44
X Y A	GB 2 160 166 A (EXXON PRODUCTION RESEARCH CO) 18 December 1985 (1985-12-18) * line 86 - page 5, line 88; figures 7-10 * * line 129 - page 5, line 130 * -----	12,13 2,3 9	
A	WO 2006/006852 A1 (HEEREMA MARINE CONTRACTORS NL [NL]; SALOME PETER [NL]; NAROLD ROBERT R) 19 January 2006 (2006-01-19) * page 11, line 19 - line 26; figures 18-20 * * page 16, line 28 - line 2 * -----	6,11,12, 14	

TECHNICAL FIELDS SEARCHED (IPC)

B63B
E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 January 2018	Székely, Zsolt

CATEGORY OF CITED DOCUMENTS

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16-01-2018

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