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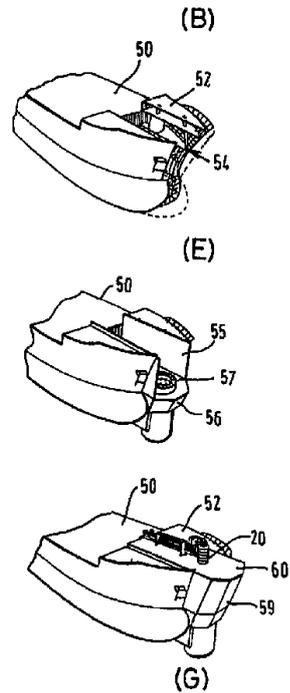
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(54) Title: VESSEL TURRET SYSTEMS

(57) Abstract

A turret system is installed on an existing vessel (50) such as an oil tanker. A portion of the existing structure, such as the centre splice, is removed (B) to leave an opening (54). A support structure (55) is attached (C) within the opening (54). The support structure includes (D) a turret support means (56). The turret structure (57) is assembled (E) within the turret support means (56). Fluid piping is installed between the turret structure (57) and the pipework of the vessel, including a manifold structure (58) and a fluid swivel (20). The turret assembly is cladded (G, H) for environmental protection. In one arrangement, the turret system is within the profile of the original vessel. In another arrangement (not shown), the turret system is external to the profile of the original vessel.



VESSEL TURRET SYSTEMS

This invention relates to vessel turret systems, that is systems that can be used in offshore terminals comprising dedicated vessels, for providing  
5 fluid couplings between the vessel and subsea risers/pipelines.

It has been previously proposed to convert a vessel such as an oil tanker into a floating production storage and offloading (FPSO) system by attaching a turret assembly to one end, generally the bow, of the vessel. The turret assembly includes a fluid swivel allowing relative rotation  
10 between, firstly, the seabed and associated production risers, mooring chains etc. and, secondly, the vessel itself while maintaining a continuous flow path for production fluids from the subsea well into the vessel. The previously-proposed mounting of the turret assembly has been significantly outboard of the end of the vessel, which has resulted in the turret assembly  
15 being exposed to adverse environmental effects, as well as requiring a complex structural mounting arrangement attached to suitable load-bearing portions of the vessel end. Accordingly, once the turret assembly had been fitted, the conversion was effectively permanent, or at least semi-permanent in that considerable work would be required to remove the turret assembly.

20 It is an aim of the invention to provide such a vessel turret system which is modular in design and which can accordingly be readily fitted to the deck of a tanker (or other suitable vessel), and also can be removed with minimum effort and cost, so that the vessel can then be used again for its original purpose.

25 According to a first aspect of the invention there is provided a method of installing a turret system on to an existing vessel, the method comprising the steps of:

removing a portion of the existing structure of the vessel at one end thereof, the removed portion including external plating;

30 attaching a support structure to an exposed portion of the vessel remaining after removal of the existing structure portion, the support

structure including turret support means and metal plating attached to the exposed portion;

attaching a turret assembly to the turret support means of the support structure;

5 installing fluid piping between the turret assembly and pipework of the vessel; and

cladding the turret assembly for environmental protection thereof.

According to a second aspect of the invention there is provided a floating production storage and offloading (FPSO) vessel, including a turret system installed on a converted vessel, the FPSO vessel comprising:

10

a support structure attached to an exposed portion of the vessel remaining after removal of a portion of the existing structure including external plating, the support structure including turret support means and metal plating attached to the exposed portion;

15 a turret assembly attached to the turret support means;

fluid piping between the turret assembly and pipework of the vessel; and

cladding around the turret assembly for environmental protection thereof.

20 In a preferred embodiment, a framework structure may be attached at the top of the turret assembly, to the weather deck of the vessel. In one arrangement, the turret system is mounted externally of the original end (bow) of the vessel wherein the support structure includes extension structures such as plates attached to the existing decks of the vessel,

25 forming deck extensions. Vertical extension plates may also be provided at each side of the deck extensions, and horizontal stringers may also be attached to the vessel at different levels to the deck extensions. The extension plates and stringers include respective apertures for accepting and retaining the turret assembly. In another arrangement, the turret system is

30 mounted at least partially, preferably at least substantially, within the profile of the original vessel. In this arrangement, the centre splice of the vessel is removed and longitudinal support structure plating is attached in its place.



AMENDED SHEET

A turret casing is assembled to the support structure plating. Once the turret assembly has been fitted in the turret casing, a manifold structure is attached at the top of the turret casing, and then a fluid swivel is installed over the manifold structure.

5 Conversion of a vessel such as an oil tanker can be effected readily using these techniques. The resulting vessel turret systems are strong and well-protected against environmental effects. Moreover, the modular nature of conversion designs means that, as well as simplifying the installation process, the turret systems can be readily removed, allowing the vessel to  
10 be used once more for its original purpose.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

15 Figure 1 is a schematic side sectional view of an external mounted bow turret according to one embodiment of the invention;

Figures 2A and 2B are respectively schematic side sectional and plan views of an integrated bow mounted turret according to another embodiment of the invention;

20 Figure 3 is a general view of the vessel and turret of Figure 1 with details of subsea pipework and mooring structure; and

Figure 4 shows the construction steps in a method of converting a vessel into one equipped with a turret as shown in Figures 2A and 2B.

Referring to Figure 1, there is shown an external bow-mounted turret which consists of two cylinders with concentric vertical axes, an outer  
25 cylinder 1 and an inner cylinder 2. The inner cylinder 2, which remains geostationary and is watertight, supports mooring chains 15 and risers 16. Each chain 15 is held by a respective chain stopper 21 which is positioned just below the top of the inner turret cylinder 2. In order to accommodate  
30 varying chain angles, each chain 15 passes through a specially designed fairlead 17, which protrudes below the bottom of the turret. The centre of the turret is designed to be fully accessible by ladder (not shown) for



AMENDED SHEET

maintenance and inspection. The integrated bow-mounted turret of Figures 2A and 2B is broadly similar in respect of the configuration of the turret assembly.

In the arrangement of Figure 1, the turret centreline is arranged  
5 forward of the tanker's Forward Perpendicular (FP) and is attached to the existing vessel's structure, as will be described. In the arrangement of Figures 2A and 2B, the turret centreline is marginally aft of the tanker's FP. In both cases, the turret manifold 3 is accessed at the level of the bearing deck 4 which is an extension of the vessel's second deck. The fore-end  
10 extension is open from the bearing deck level to the level of the weather deck 5. The weather deck 5 supports a framework structure 6 for environmental protection of the turret swivel assembly. This structure 6 is clad with plating, suitably reinforced to resist wave slam.

The upper structure of the inner tube or cylinder 2 is stiffened to resist  
15 the axial forces applied by the upper bearing 18.

An upper structure flange 7 supports the outer ring of the upper bearing 18, as can be seen in the enlarged detail of Figure 1.

A support ring for the lower bearing 8 is designed to resist the forces applied by the chains 15 to the fairleads 17 and the bearing reactions.

20 A bottom end closure 9 of the turret is a stiffened plate designed to resist the maximum hydrostatic head imposed by the ship motions. It is also designed to support the forces imposed by riser shrouds 10. The riser shrouds 10 are connected to the upper decks to form an integrated structure.

25 The top deck is designed to be watertight against flooding of the lower space.

As can be seen in Figure 1, the turret is cantilevered forward of the bow of the vessel. The turret forms a cylinder hub around which the vessel rotates by means of a bearing system. The bearing system is formed by a  
30 three roller upper bearing 18 which is positioned at the top of the turret, and the lower bearing 8 towards the bottom of the turret. The deflections of the

turret due to mooring loads are an order of magnitude lower than the clearance between the inner cylinder 2 and the outer cylinder 1 so jamming will not occur.

5 The basic turret is preferably positioned between a spread of twelve catenary anchor lines or chains 15, and has an earth-bound orientation. The turret and vessel's relative position effects a passive weathervaning in extreme conditions so that vessel behaviour is not dependent on power supply or thruster operation.

10 The flexible flow lines or risers 16, which transfer the fluids from the seabed to the floating production storage and offloading (FPSO) turret, enter the turret structure through the bottom and continue to the top of the turret through the individual riser shrouds 10. Swivels 20, well known in this art, provide the fluid transfer link between the piping on the fixed turret and the weathervaning vessel.

15 The turret contains equipment to hook-up the anchoring chains 15, to fix them in stoppers and to hook-up the flexible risers 16.

20 The turret consists of two cylinders with vertical axes, the outer cylinder 1 and the inner cylinder 2, 6m. o/d and 5.040m. o/d respectively in one specific design. The outer cylinder 1 is 15.140m. long and is stiffened internally with ring stiffeners. The inner cylinder 2, which remains geostationary and is watertight, supports the twelve mooring chains 15 and the six risers 16.

25 The turret centreline is located forward of the tanker's FP for the external bow-mounted turret of Figure 1 and marginally behind the FP for the integrated turret of Figures 2A and 2B. In both cases, the turret is attached to the existing vessel's structure using typical ship's reinforced plating. All vertical and horizontal plating marries up with existing structure.

30 The upper structure flange 7, which supports the outer ring of the upper bearing 18, is preferably welded to the inner tube shell plating by full penetration weld.

The lower bearing 8 support ring, which is designed to resist the

forces applied by the fairleads 17 and the bearing reactions, is preferably a forging. It may instead be possible to use a fabricated beam of I-section. The ring is welded into the shell plating using full penetration girth welds.

Chain boxes, which accommodate the chains 15, utilise the existing  
5 stiffeners on the shell plating. These are plated on the inside to form "boxes" which extend upwards from the fairleads 17 to the chain stoppers 18.

The chain stoppers 18 are formed from two cylindrical castings bolted to the chain. Each stopper 18 sits in a seat.

10 Provision is made for seals between the chain stoppers 18 preventing water leaking into the compartment during storms.

The riser shrouds 10 are of solid drawn steel pipe. In addition to their function of protecting the risers 16 and the compartments within the turret during blowout, their structural strength allows them to be integrated with  
15 the inner cylinder structure. This integration reduces the weight for the same strength. The bottom of each riser shroud 10 is flared to protect the riser 16 and assist in pull in.

The fairleads 17 are of the bend shoe type. This transfers the load from the chain 15 via the line of contact to the bend shoe support bracket.  
20 This shoe can be released by a diver and recovered to the surface for inspection.

The bend shoe of each fairlead 17 is provided with collars (not shown) to support slack chain; these avoid damage to the plate. The upper structure of the inner cylinder 2 is stiffened to resist the axial forces applied  
25 by the upper bearing 18.

At the turret/vessel interface of the external turret of Figure 1, minimal stiffening needs to be added within the bow of the vessel. The modifications may involve the installation of columns, gussets and vertical plates; these will be chiefly located forward of the collision bulkhead.

30 The turret cylinders 1, 2 may be fabricated in several units, dictated by the fabricator's facility and equipment. The units in way of the bearings

8, 18 at either end of the turret will be stress relieved. After installation of the turret structure to the vessel, the top and bottom bearing support structure will be lined up and machined to a flat surface, to receive the bearings 8, 18. The inner and outer cylinders 2, 1 can then be assembled and mated. The choice of construction facility and availability of the vessel, will determine the procedure for fabrication. The vessel bow extension can either be installed on the vessel as subassemblies or in one piece.

The two bearings 8, 18 incorporated into the design of the turret are designed to take all the expected loads and to ensure an easy rotation of the vessel around the moorings and risers 16.

The upper bearing 18 is fitted at the top of the primary turret tubes. It is preferably a three-roller type, a variation of a standard commercially available design. The diameter may be approximately 5.81 metres.

The upper bearing 18 is bolted to ring forgings which, in turn, are welded to the turret structure. To ensure that there are no induced stresses in the structure, due to geometric variations, the bearing faces will be carefully machined after local structural welding and stress relieving, before final erection of the turret.

The lower bearing 8 is located at the bottom of the inner, fixed turret cylinder 2. The lower bearing 8 itself is preferably a composite material fitted in twelve segments to the cylinder 2 by bolts and slotted 'T' plates. The bearing faces will be designed to transfer all the loads to a hard-faced reaction forging, incorporated into the outer turret cylinder 1. These loads will be the radial components of all those loads described for the upper bearing 18.

The composite bearing material for the lower bearing 8 is preferably fabricated from hot laminated sheets and suitably cured. The resulting material can be machined, is extremely dense, and has a very good compressive strength, typically 414 N/mm<sup>2</sup>. It also has the distinct advantage that it is self-lubricating in sea water. In these conditions the coefficient of friction is virtually zero.

The design of the lower bearing 8 may be such that each segment can be separately removed for survey and/or replacement.

Typical moorings and risers for the system can be seen in Figure 3.

The fluid transfer system has been designed to satisfy the following  
5 principal requirements:

- (i) the turret will be bow-mounted, external to the vessel structure in the case of the Figure 1 arrangement;
- (ii) the arrangement will enable the vessel to weathervane through 360°;
- 10 (iii) the turret is to be moored with 12 off, 152 mm diameter chain mooring lines located in six pairs; and
- iv) the arrangement will provide suitable riser paths and maximise riser clearances.

Taking due account of these requirements, the preferred turret  
15 incorporates the following features.

The mooring chains 15 are brought up into the turret via the fairleads 17 passing through individual hawse pipes which form the principal vertical stiffening of the turret's inner cylinder 2. The chain ends are secured by the internal chain stoppers 18 located in the turret. Chain installation and  
20 tensioning is performed using a wire rope passing over a fairlead sheave (not shown) mounted on the upper section of the process deck, leading aft to a 150 tonne winch. This feature allows a simple installation procedure.

During installation, the FPSO vessel will be rotated onto the mooring heading and located on position using a series of tugs. The turret will be  
25 rotated and locked in position against the ship to maintain alignment of winch and hawse pipe.

The geostationary cylindrical manifold structure 3 is mounted on a slewing ring; this houses the process equipment, consisting of the riser ESD valves, block valves and non-return valves, carrying produced oil, export  
30 gas, lift gas and injection water to the production facility. In order to reduce the number of swivel flow paths, the three production risers may terminate

in a production header piped into the swivel base.

Infield pigging is via temporary pigging stubs located upstream of the production riser ESD valves. Pigging will take place during suitable sea states with the turret locked off and the pigging jumper hoses connected  
5 back to the pigging system.

The production fluids are transferred to the vessel through the swivel assembly 20.

The three path swivel assembly 20 is mounted on the geometric centre of the turret providing the flow path between the geo-fixed and the  
10 ship-fixed flow lines. Control ESD and electrical systems (not shown) are linked through a series of slip rings to a central control room (CCR).

The complete turret assembly is weather protected by the deckhouse including the framework structure 6; this may be open at the rear to provide free air ventilation.

15 Access to the top of the turret, the swivel assembly 20 and the riser shut off valves is via the weather deck 5 of the tanker.

The manner in which an existing vessel such as an oil tanker is converted into an FPSO as shown in Figure 1 will now be described. Initially, the bow area of the vessel is cleared of all fittings. Parts of the  
20 vessel's plating are removed in the areas where the mounting structure is to be attached to the vessel. A number of extension structures are then fitted to the existing vessel decks to provide part of the mounting structure. For example, as shown in Figure 1, the bearing deck 4 is an extension of the vessel's second deck. Typically, further generally horizontal extensions can  
25 be attached to other decks such as the upper deck. These extensions are provided with apertures for accepting and retaining the turret assembly. The mounting structure can also include generally vertical extension structures on each side of the assembly, as well as generally horizontal stringers extending from the original bow profile 30 of the vessel. These extension  
30 structures may be fabricated from 25 mm steel plate. Plating is then attached to the extension structures where required and, once the turret

assembly, the manifold assembly 3, the swivel assembly 20 and piping as well as electrical connectors have been installed, the top framework structure 6 forming the deckhouse may be fitted.

5 Figures 2A and 2B show an integrated bow-mounted turret FPSO in which the turret assembly is similar to that of Figure 1 and hence will not be described in detail. As will be explained below, the turret assembly is mounted generally at least partially within the existing bow structure of the vessel, in contrast with the Figure 1 arrangement in which an extension structure is provided for the entire turret assembly. As can be seen in Figure 10 2A, the turret centreline C is just aft of the tanker's FP.

Figure 3 shows a typical arrangement for an FPSO vessel 40 including mooring and riser deployment. Although the vessel 40 is shown as being equipped with a turret structure according to Figure 1, a similar arrangement would apply to one having a turret structure according to Figures 2A and 2B. 15 It can be seen from Figure 3 that the anchor chains 15 take up a catenary configuration when anchored to the sea bed. Some of the flexible risers 16 may have their static configuration determined by a number of buoyancy modules 42 attached to the risers 16. In other cases a midwater buoy 44 retained on the sea bed by a piled base frame 46 may be used, the midwater 20 buoy 44 supporting the riser 16.

Figure 4 shows the steps in converting a vessel 40 such as an oil tanker into an FPSO turret vessel as shown in Figures 2A and 2B.

In step A, the forecastle deck 52 of the vessel is cleared of all existing machinery and fittings. In step B, the centre splice of the bow is removed 25 leaving an opening 54 which is generally rectangular on the forecastle deck 52 when seen in plan. In step C, steel plating is attached within the opening 54, including at the sides, forming a longitudinal turret support structure 55. In step D, a turret casing 56, which is to include a turret assembly as previously described, is brought within the opening 54 and attached to the 30 lower decks of the vessel 50. In step E, the turret assembly 57 is constructed by installation of the internal turret (or cylinder) and its bearings

within the turret casing 56. In step F, a manifold structure 58 (including a manifold assembly 3 as previously described) is placed over and secured to the turret casing 56 and assembly 57. In step G, the swivel assembly 20 is installed over the manifold structure 58, as also are the necessary piping, 5 electrics and subsea connections. Cladding 59 is added to enclose the upper turret structure including the manifold structure 58, and a weather deck 60 is added to the top, slightly raised relative to the forecastle deck 52. In step H, turret cladding, hook-up and commission is completed, including the addition of an upper framework structure 6' enclosing the swivel 10 assembly 20.

Although the FPSO turret structures of Figure 1 and Figures 2A and 2B have been described as being bow-mounted, this being the preferred configuration, they could instead be stern-mounted. Also, although conversion of an oil tanker is advantageous, since much of the existing 15 infrastructure (tanks, piping etc.) can be used with little or no modification for FPSO purposes, any other vessel (self-powered or towed) could be used instead.

Thus, while specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the 20 invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

CLAIMS

1. A method of installing a turret system on to an existing vessel, the method comprising the steps of:
  - 5 removing a portion of the existing structure of the vessel at one end thereof, the removed portion including external plating;  
attaching a support structure to an exposed portion of the vessel remaining after removal of the existing structure portion, the support structure including turret support means and metal plating attached to the
  - 10 exposed portion;  
attaching a turret assembly to the turret support means of the support structure;  
installing fluid piping between the turret assembly and pipework of the vessel; and
  - 15 cladding the turret assembly for environmental protection thereof.
2. A method according to claim 1, including the step of attaching a framework structure at the top of the turret assembly.
- 20 3. A method according to claim 2, wherein the framework structure is attached to a weather deck of the vessel.
4. A method according to claim 1, claim 2 or claim 3, wherein the turret system is mounted externally of the original end of the vessel.
- 25 5. A method according to claim 4, wherein external plating at the end of the vessel is removed, and wherein said support structure comprises a plurality of extension structures attached to respective existing decks of the vessel thereby forming deck extensions.
- 30 6. A method according to claim 5, wherein generally vertical extension structures are attached to the vessel, on each side of the deck extensions.



AMENDED SHEET

7. A method according to claim 5 or claim 6, wherein generally horizontal stringers are attached to the vessel at different levels to the deck extensions.
- 5 8. A method according to claim 5, claim 6 or claim 7, wherein the turret support means includes respective apertures for accepting and retaining the turret assembly.
9. A method according to claim 1, claim 2, or claim 3, wherein the turret  
10 system is mounted at least partially within the existing vessel.
10. A method according to claim 9, wherein the turret system is mounted at least substantially within the existing vessel.
- 15 11. A method according to claim 9 or claim 10, wherein the portion removing step comprises removing the centre splice of the vessel to a predetermined distance from the end thereof.
12. A method according to claim 11, wherein removal of the centre splice  
20 leaves a substantially rectangular opening when seen in plan on the topmost deck.
13. A method according to claim 11 or claim 12, wherein the metal  
25 plating is attached to the exposed portion remaining after removal of the centre splice.
14. A method according to claim 13, wherein the support structure further includes a turret casing which is assembled to the support structure plating.
- 30 15. A method according to claim 14, wherein, after the turret assembly has been fitted in the turret casing, a manifold structure is attached at the top of the turret casing.



AMENDED SHEET

16. A method according to claim 15, wherein, after the manifold structure has been attached to the turret casing, a fluid swivel is installed over the manifold structure.
- 5 17. A method according to any one of the preceding claims, wherein the turret assembly is installed at the bow end of the vessel.
18. A floating production storage and offloading (FPSO) vessel, including a turret system installed on a converted vessel, the FPSO vessel comprising:
- 10 a support structure attached to an exposed portion of the vessel remaining after removal of a portion of the existing structure including external plating, the support structure including turret support means and metal plating attached to the exposed portion;
- 15 a turret assembly attached to the turret support means;
- fluid piping between the turret assembly and pipework of the vessel;
- and
- cladding around the turret assembly for environmental protection thereof.
- 20 19. An FPSO vessel according to claim 18, comprising a framework structure attached at the top of the turret assembly.
20. An FPSO vessel according to claim 19, wherein the framework structure is attached to a weather deck of the vessel.
- 25 21. An FPSO vessel according to claim 18, claim 19 or claim 20, wherein the turret system is mounted externally of the original end of the vessel.
22. An FPSO vessel according to claim 21, wherein said support structure
- 30 comprises a plurality of extension structures attached to respective decks of the vessel thereby forming deck extensions.



AMENDED SHEET

23. An FPSO vessel according to claim 22, wherein said support structure further comprises generally vertical extension structures attached to the vessel on each side of the deck extensions.
- 5 24. An FPSO vessel according to claim 22 or claim 23, wherein said support structure further comprises generally horizontal stringers attached to the vessel at different levels to the deck extensions.
25. An FPSO vessel according to claim 22, claim 23 or claim 24, wherein  
10 the turret support means includes respective apertures for accepting and retaining the turret assembly.
26. An FPSO vessel according to claim 18, claim 19 or claim 20, wherein  
15 the turret system is mounted at least partially within the profile of the unconverted vessel.
27. An FPSO vessel according to claim 26, wherein the turret system is mounted at least substantially within the existing vessel.
- 20 28. An FPSO vessel according to claim 26 or claim 27, wherein the turret system is mounted within a removed centre splice of the vessel.
29. An FPSO vessel according to claim 28, wherein the metal plating is attached to the exposed portion of the vessel remaining after removal of the  
25 centre splice.
30. An FPSO vessel according to claim 29, wherein the support structure further includes a turret casing assembled to the support structure plating.



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FIG. 1

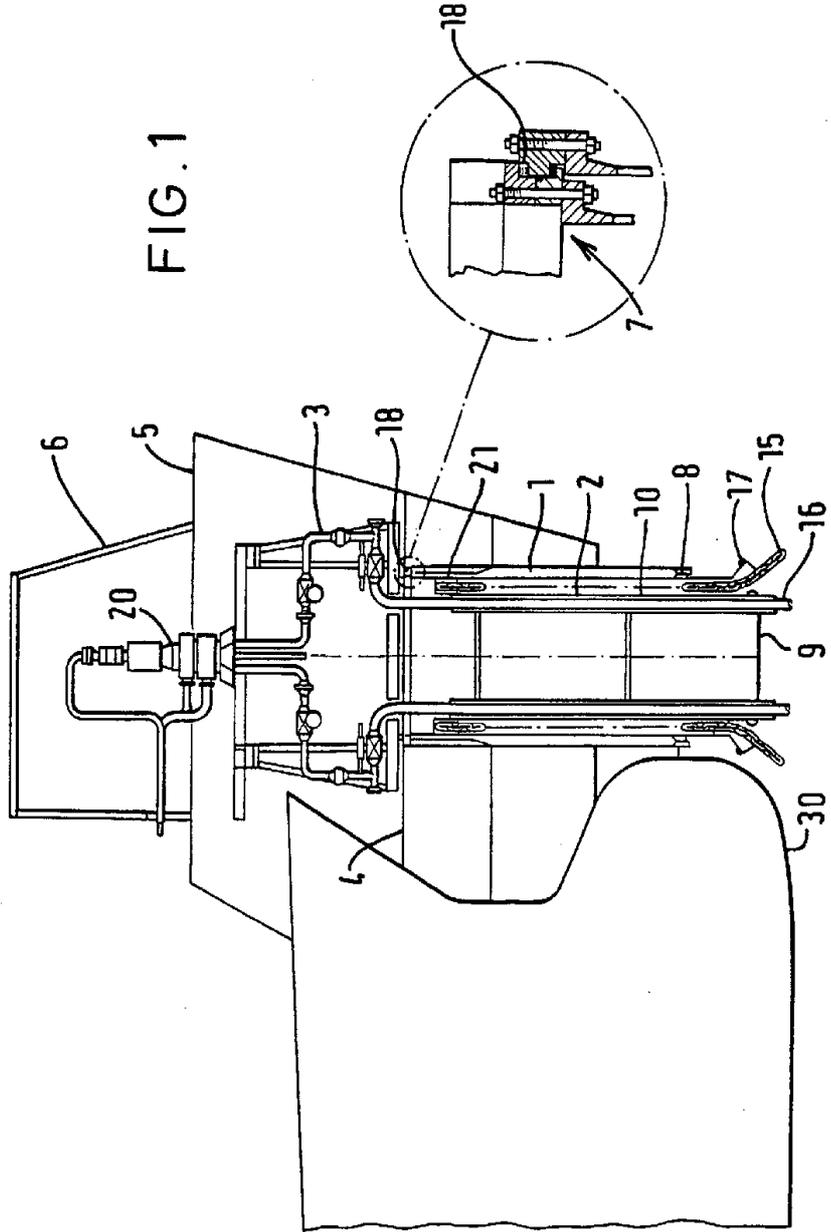


FIG. 2A

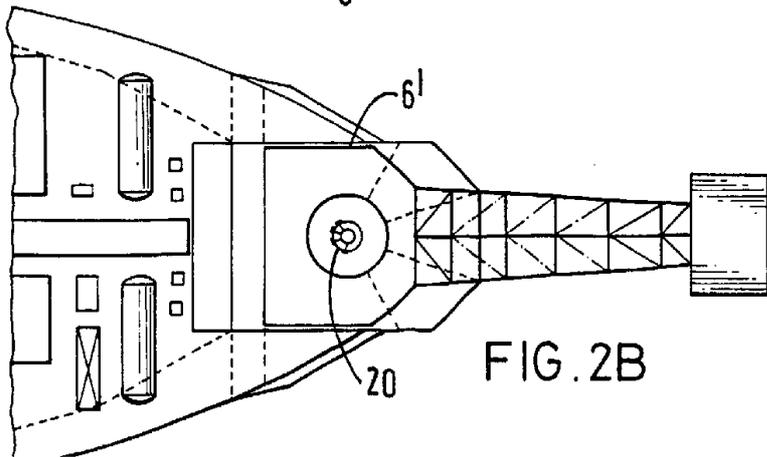
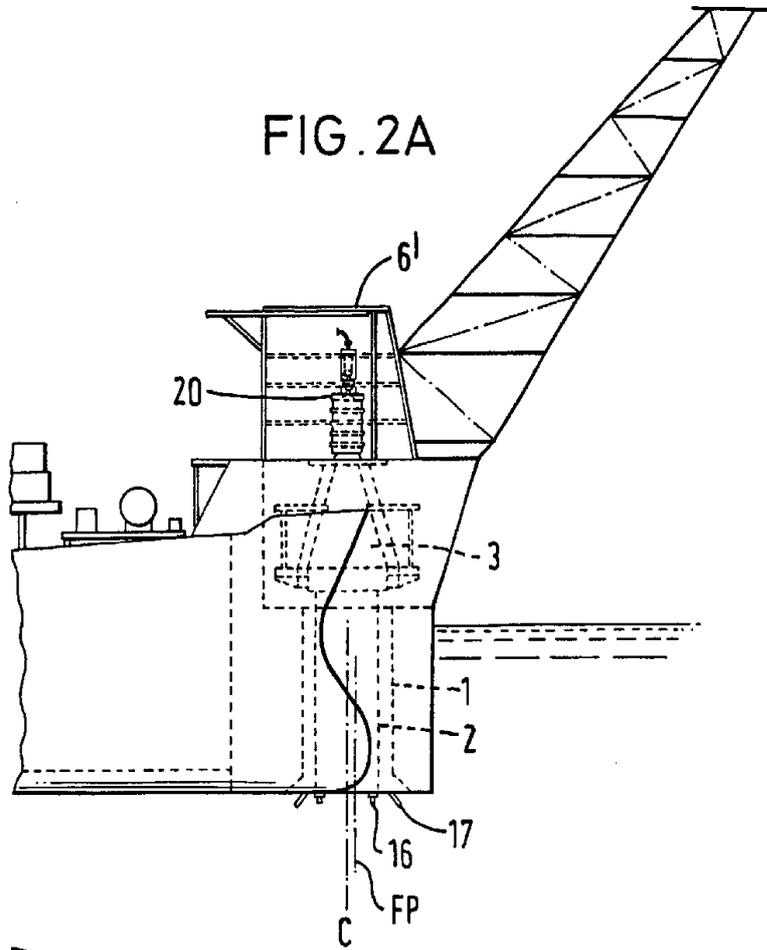




FIG. 4(A)

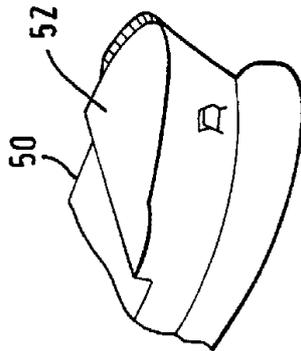


FIG. 4(B)

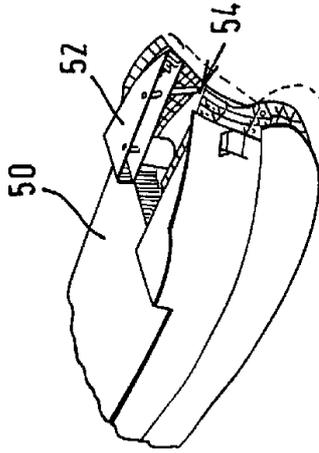


FIG. 4(C)

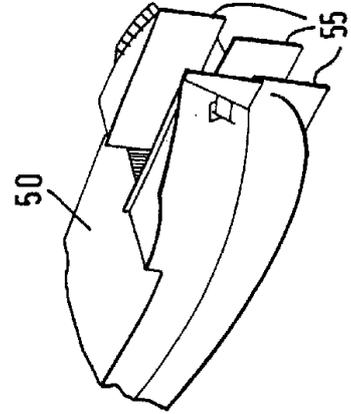


FIG. 4(D)

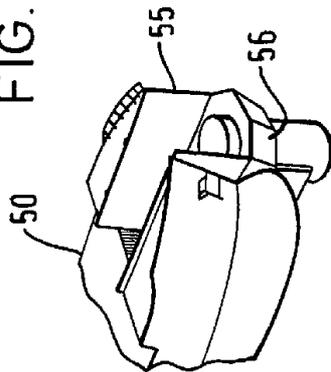


FIG. 4(E)

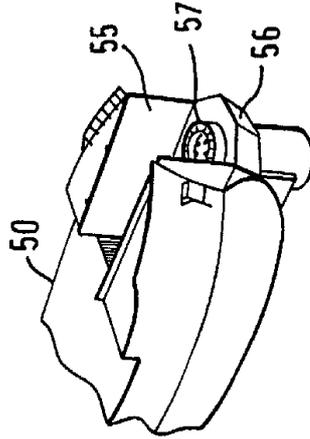
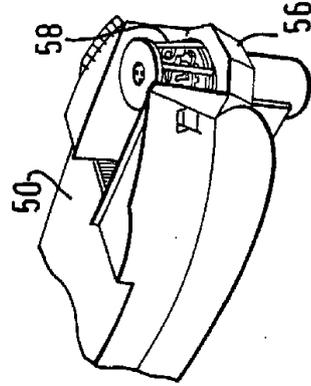


FIG. 4(F)



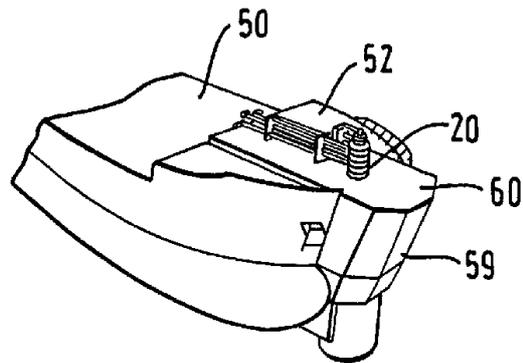


FIG. 4(G)

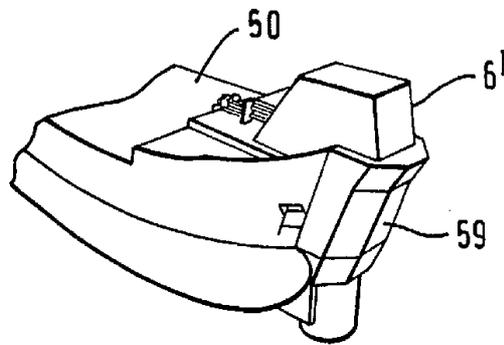


FIG. 4(H)