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(54) Tension leg platform production system

(57) A production system includes a small tension leg platform (24, Fig. 1) connected to the sea floor by vertical tendons (50) and connected to sea floor wells by vertical risers (52), which avoids over or under tensioning of the tendons and risers. A restraint structure (66, Fig. 7) that is mounted on a lower portion of the platform, prevents horizontal movement of the tendons and risers relative to each other, which assures that all risers and tendons extend parallel to each other when the platform drifts in a severe storm.

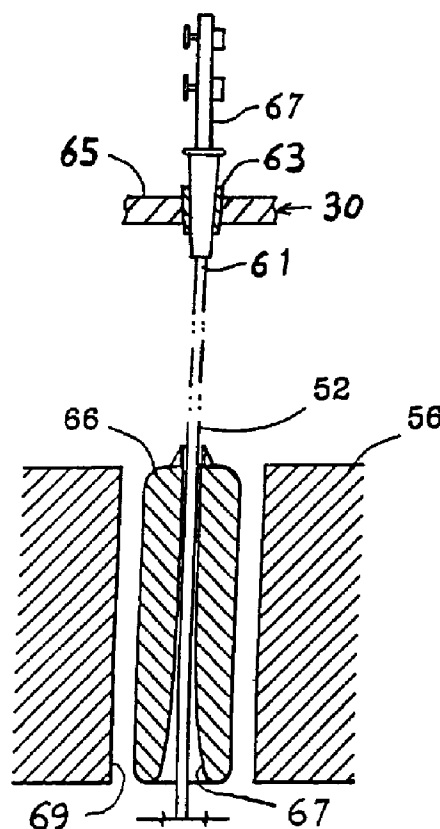


Fig. 7

EP 0 716 011 A1

Description

The present invention relates to floating offshore petroleum, drill and production systems, and to a TLP (tension leg platform) thereof.

In recent years, there has been a continuing effort to produce crude oil and gas from subterranean formations located in ever increasing water depths. One approach is to use a TLP (tension leg platform) that floats at the sea surface and that is anchored by a plurality of tendons that extend substantially vertically to the sea floor. Vertical risers extend down from the platform to sea floor wells to carry hydrocarbons up to trees on the platform. The trees include outlets and valves that control flow. The platform includes a deck structure with one or more decks lying at or above the sea surface, and a hull which has a highly buoyant undersea lower hull portion that supports the deck structure and that keeps the tendons and risers under tension. Large tensioning of the tendons by excess buoyancy of the hull, virtually eliminates heave, roll and pitch motions. The TLP is a stable, heave-resistant platform which provides trees connected to sea floor wells, with the trees lying substantially at and preferably above the sea surface, with all of the operational benefits thereof.

Conventional TLP structures must be able to withstand the effects of extreme environmental events such as a hurricane or other storm while remaining in place. The response of the platform to severe winds, waves and currents can be minimized by using a small platform that is permanently anchored by the vertical tendons and connected through the vertical risers, and by using a semisubmersible platform that carries a derrick and production equipment and that can sail away when a storm approaches. The tendons and risers should experience proportional increases in tension (so they experience equal increases in length) in a storm so none are over tensioned, and should experience proportional decreases in tension after a storm so each has sufficient tension to prevent it from hitting another tendon or riser.

In a first aspect the present invention provides an offshore hydrocarbon production system for use in a sea of known sea depth, to produce hydrocarbons from at least one subsea well at the sea floor, comprising:

a platform which comprises a deck structure that includes at least one deck positioned substantially above the sea surface, and a buoyant hull which supports said deck structure and which includes a below-sea lower hull portion that extends more than three meters below the sea surface but which lies closer to the sea surface than the sea floor;

a plurality of primarily vertical tendons having upper ends connected to said platform and having lower ends connected to the sea floor;

at least one riser having an upper end connected to said deck structure and a lower end connected to the sea floor;

a lateral restraint structure which is mounted on said lower hull portion and which horizontally restrains

each of said tendons and said risers against substantial horizontal movement relative to said hull, at locations which are more than three meters below the sea surface.

In a second aspect the present invention provides an offshore hydrocarbon production system for use in a sea, to produce hydrocarbons from sea bed wells, comprising:

a platform that floats at the sea surface and that can drift by up to about 8° from a quiescent position, said platform having a lower portion with a hull bottom that lies below the sea surface and an upper portion that lies above the sea surface;

a plurality of trees each mounted on said platform with a lower end lying at a height of a plurality of meters above said hull bottom;

a plurality of primarily vertical tendons that extend to the sea floor, said tendons having lower ends anchored to the sea floor and having upper ends attached to said platform;

a plurality of primarily vertical risers having lower ends attached to the sea floor and coupled to said wells, and having upper ends attached to said lower ends of said trees on said platform;

said platform having lateral guide structure that confines each of said risers to bending at a location that lies a plurality of meters below said tree lower ends when the vessel drifts up to about 8° from said quiescent position;

said tendons also being confined to pivoting at a location that lies a plurality of meters below the level of said tree lower ends and that is chosen so said risers and tendons extend substantially parallel to each other when said platform drifts by up to about 8° from said quiescent position.

In a third aspect the present invention provides a method for installing an offshore wellhead platform for hydrocarbon production in a sea, comprising:

drilling at least one well into the sea floor;

installing a small tension leg wellhead platform having a deck structure and a hull having an undersea lower hull portion that supports said deck structure, with said platform floating near the sea surface, by anchoring lower ends of each of a plurality of tendons to the sea floor and connecting upper ends of the tendons to said platform;

installing at least one riser, including coupling a lower end of said riser to said well and connecting an upper end of said riser to said deck structure of said platform;

restraining said riser and said tendons from substantial horizontal movement relative to each other, at about the same undersea level as said lower hull structure.

In a fourth aspect the present invention provides a method for installing an offshore wellhead platform to produce from an offshore reservoir that lies under a sea floor comprising,

anchoring lower ends of each of a plurality of tendons to the sea floor in proximity to said offshore reser-

voir, and attaching at least one buoy to upper ends of said tendons;

after attaching said at least one buoy to said tendons, moving a small tension leg wellhead platform that floats at the sea surface, to said tendons, wherein said platform has a deck structure lying at least about as high as said sea surface and has a lower hull portion that lies below the sea surface and below said deck structure, and picking up said upper ends of said tendons and attaching said upper ends of said tendons to location spaced about said platform, including tensioning said tendons;

drilling at least one well into said offshore reservoir, and installing at least one riser including connecting a lower end of said riser to a well that connects to said reservoir and connecting an upper end of said riser to said deck structure;

restraining said riser and said tendons from substantial horizontal movement relative to each other, at about the same level as said lower hull portion.

In accordance with one embodiment of the present invention, a hydrocarbon production system is provided which includes a TLP, which is a wellhead platform that floats at the sea surface and that is held in position by tension legs. The platform has a deck structure lying at or above the sea surface, with wellhead equipment, primarily production trees, on the platform connected to the upper ends of risers that extend substantially vertically to wells at the sea floor. The platform is held above the drill site, or wells, by a plurality of substantially vertical tendons that extend to the sea floor and that are anchored thereat. The platform maintains the tendons and risers in tension, to prevent them from striking each other. The platform has a hull structure that lies largely underwater and that supports the deck structure at or above the sea surface.

In order to assure that the tendons and risers experience proportional changes in tension due to wave action and platform offsets (drift), the platform is provided with a lateral restraint structure which allows bending of the tendons and risers at about the same underwater depth, which is near the bottom of the platform. As a result, when the platform moves horizontally and vertically under wave action in a storm, the risers and tendons will remain parallel and will all undergo the same percentage increase in tension. Over tensioning of the tendons and risers in a severe storm is avoided because they share the increased load, and yet the tendons and risers are adequately tensioned in the quiescent position (zero platform drift).

The production system can be an interruptive one which combines the advantages of a laterally (catenary) moored semisubmersible with some of the advantages of a tension leg wellhead platform, at a greatly reduced cost and with improved safety. In that case, the system includes a small tension leg platform that is left on site in advance of a storm, and a semisubmersible production support vessel that is removed in advance of a storm.

The novel features of the invention are set forth with particularity in the appended claims. The invention will be best understood from the following description, when read in conjunction with the accompanying drawings, which describes, by way of example only, embodiments of the present invention.

FIG. 1 is an elevational view of an offshore platform system, showing the semisubmersible production structure and the small tension leg wellhead platform.

FIG. 2 is an isometric view of the platform of FIG. 1.

FIG. 3 is an illustration of the lateral movement of the small platform, wherein a parallelogram configuration is formed by the tendons and risers.

FIG. 4 is a plan view taken on line 4-4 of FIG. 1, showing a means for connecting the semisubmersible structure to the platform, using a cross springs mooring system.

FIG. 5 is a plan view of a lower hull structure of the platform, of another embodiment of the invention.

FIG. 6A is a plan view of the deck structure of the platform, in an embodiment having twenty risers.

FIG. 6B is a plan view of the deck structure of the platform, in an embodiment having twelve risers.

FIG. 7 is a sectional view of a lateral restraining structure which is restraining a riser.

FIG. 8 is a sectional view of a lateral restraining structure of another embodiment of the invention.

Fig. 1 shows an interruptive mobile production system 10 which includes a floating semisubmersible production structure or unit 20 that floats on a body of water at the sea surface 22, and that is connected to a small tension leg wellhead platform, or TLP 24. The semisubmersible unit 20 contains equipment 26 for the production of hydrocarbons, and has a working deck 34 lying above the small TLP 24. This permits direct access between the deck 34 and the platform 24 as by means of a ramp. The platform is generally centered over a seabed template and well site 28. The platform deck structure 30, with wellhead equipment 32 (principally trees at the upper ends of risers), preferably lies above the sea surface, and should lie within 3 meters of the sea surface so valves and openings in the trees lie within 1.5 meters of the sea surface and can be accessed without diving equipment.

The working deck 34 of the unit 20 is supported by buoyancy chambers 36 that is held in place by a mooring system 40. Equipment on the working deck 34 may include a drilling rig 42 and production facilities 26. The buoyancy chambers 36 support one or more vertical columns 38 which support the deck 34. The unit 20 can be floated to the well site and the buoyancy chambers 36 partially flooded so the vertical columns 38 will come to rest partially under the sea surface 22, while maintaining the working deck 34 above the platform 24.

The catenary mooring system 40 which holds the unit 20 in place, includes several mooring lines 44 and buoys 46 (about eight) attached at different locations about the unit and extending in different directions to and along the sea floor 48. The area below the working deck

34 is substantially unobstructed to allow the small platform 24 to be situated underneath the working deck.

The small tension leg wellhead platform 24 with the deck structure 30 thereon that is preferably positioned above the sea surface 22, lies above a sea floor, or sea bed, template 28. The template 28 is situated on the sea floor 48 above the wellbore 58 and in proximity to the offshore reservoir from which hydrocarbons are produced. Sea bed template 28 is constructed and then anchored to the sea floor 48 in such a manner as to provide sufficient anchorage for the platform to withstand forces arising from the response of the platform to wave and tide movements. A plurality of tendons 50, have upper ends connected to the platform, as by connection to the deck structure 30 of the platform. The tendons extend substantially vertically to the sea bed template 28. The deck structure 30 has one or more decks that are each preferably positioned above the sea surface, and has a hull 51 that includes a plurality of corner columns 54 connecting the deck structure 30 to a buoyant pontoon means 56 which is positioned below the sea surface. The lower portion 53 of the hull 51, which always lies underwater, may include the lower ends of the columns as well as the pontoon means. At least one riser 52 extends from the deck structure 30 to the sea bed template and connects a subsea well to the deck structure.

The production system is designed to function continuously under normal weather conditions. However, in extreme weather conditions such as when a hurricane approaches, the semisubmersible vessel or unit 20 suspends operations and moves away.

The semisubmersible unit 20 is connected to the small platform 24 in such a way as to be conveniently and quickly disconnected from the platform 24 and from the mooring system 40. The catenary mooring system 40 includes mooring lines 44 which are conveniently disconnected at the mooring buoys 46 and secured to the working deck 34 of the semisubmersible unit 20.

As shown in Fig. 4, the system for connecting the semisubmersible unit 20 to the platform 24 is a cross springs mooring system 72. Cables are used in the system 72 which allow the unit 20 to be disconnected by releasing the cable from the platform 24 and securing the cable 74 on the unit 20. Both the catenary mooring and cross springs mooring systems may use standard quick release couplings or the like, which are standard for mooring systems, pipelines and umbilicals.

In one embodiment of the invention shown in Fig. 5, the risers 52 extend through holes in the lower hull portion 53. The lower hull portion may include a moonpool and a template 60 at the center of the lower hull portion. The moonpool is also illustrated in Fig. 2. The risers in Fig. 5 extend through holes in the moonpool template 60. Also, the corner columns 54 are hollow and contain tubes 62 through which the tendons 50 pass.

Figs. 6A and 6B are plan views illustrating different deck structures 30 of the wellhead platform 24. The deck structure 30 is approximately thirty meters square

(twenty to forty meters square), with Fig. 6A showing an arrangement for up to about twenty-one wells and Fig. 6B showing an arrangement for about thirteen wells. The platform 24 is capable of carrying up to thirty-three risers that each have a diameter (inside) of 24.5 centimeters. Each tendon may be a thick-walled steel tube having a diameter somewhat greater than that of the risers.

The platform 24 includes means for laterally (horizontally) restraining the tendons 50 and the risers 52 at or near the level of the lower hull portion 56. As illustrated in Fig. 3, applicant constructs the system so the tendons 50 and risers 52 form a parallelogram configuration wherein all tendons and risers remain parallel under all weather conditions. In other words, the lateral (horizontal) distance between the tendons 50 and risers 52 does not substantially vary anywhere between the bottom of the platform 24 and the sea floor 48, as the platform 24 moves laterally and downwardly into the water in a severe storm. This assures that the percent increase in tension of all tendons and risers will be the same in a severe storm, and the percent decrease in tension when the storm has passed will be the same. The result is that none of the tendons or risers will be over or under tensioned. An under tensioned tendon or riser is more likely to "whip around" and hit other tendons or risers and damage them.

The deck structure 30 of the platform 24 may include a single deck, or may include two or more decks. The tendon tops preferably are connected to one of the decks, but do not have to be since there is seldom need for access to the tendons. For a minimum size platform with a deck that is twenty meters square and where the platform has a height of twenty-five meters, the bottom of the platform lies about fifteen meters below the sea surface in the quiescent position, and the tendons and risers are restrained at a level at least 10 meters below the sea surface. The tops of the risers (at the trees) always lie far above the bottom of the platform.

Figs. 7 and 8 show two mechanisms for laterally restraining the tendons and risers at or near the horizontal level of the lower hull portion 56, with the figures showing the case for a riser 52. Fig. 7 shows a lateral restraint structure formed by an element 66 with a horn-shaped passage 67 that surrounds and is fixed to the riser 52. The element 66 can move laterally by a small amount within a hole 69 in the lower hull portion for small platform drift. For larger platform drift, the walls of the passage 67 allow the riser 52 to bend by a small angle (up to about 8°) about a large radius of curvature as the platform 24 moves laterally in difficult weather conditions. The top 61 of the riser is held by a mount 63 to a deck 65 of the deck structure 30, and the tree 67 extends above that deck. The guide passage 67 confines the riser to bending about a radius of curvature of more than ten times the outside diameter of the riser, and preferably more than twenty times. It is possible to fix the element 66 to the hull.

Fig. 8 shows a lateral restraint structure formed by a series of rings 68 affixed to the walls 64 of the lower

hull portion 56 such as in hollow tubes (62 in Fig. 5) in the columns 54. Progressively lower rings 68 are of progressively increasing inside diameter. The rings allow the riser 52 to bend (up to about 8°) as the wellhead platform moves laterally.

In prior art designs, any drift of the platform was accounted for by allowing pivoting at the tree mount, such as 63 in Fig. 7, which required a large hole in the lower hull portion 56. With the tendons pivoting at a much lower level, tension in the riser was maintained by a hydraulic activator. The present invention which guides riser bending at the lower hull portion, well below the riser mount 63, avoids the need for such hydraulic activators and associated equipment.

For each tendon, lateral restraint which allows bending at or near the level of the lower hull portion, can be accomplished by the devices of Figs. 7 or 8 or by a pivot joint. An elastomeric pivot joint which allows for limited pivoting in any direction, allows sharp bending, and can be used for a tendon because a tendon does not carry fluid, but generally cannot be used for a riser which carries fluid (as through tubes within the riser). However, applicant may prefer to use the devices of Figs. 7 or 8 to bend the tendons, and avoid the expense of a pivot joint and match the bending of the risers.

It is noted that in a severe storm the platform 24 drifts only a small amount, so the angle of the risers and tendons from the vertical is no more than about 8°. The small platform 24 has virtually no wind load, which is a major factor that limits its drift in a severe storm.

Applicant provides a method for installing the production system, which includes setting a sea bed template on the sea floor 48 in proximity to the offshore reservoir, as illustrated in Fig. 1. The sea bed template 28 is anchored to the sea floor. Tendons are installed by anchoring them to the template, and buoys are temporarily attached to upper ends of the tendons. Then, the platform 24 is towed to a position over the template, and the upper ends of the tendons are attached to the platform and tensioned. At least one well 58 is drilled into the offshore reservoir through the sea bed template 28, using the drill rig 52. Risers are installed to connect trees on the platform structure to the wells. The tendons and risers are restrained from substantial horizontal movement relative to each other at the lower hull portion at a level below the deck structure.

The production system has been designed so that all installation activities can be executed without resort to an expensive heavy lift crane vessel. The platform 24 is installed over the sea bed template 28 by connecting the upper ends of the tendons 50 to the platform, preferably to the deck structure 30 of the platform. The semi-submersible unit 20 has direct vertical access to the platform 24 and the well site at 28. The unit 20 is connected to the platform with a cross springs mooring system 72 using cables 74. The risers 52 are then installed from the semisubmersible unit 20 through the platform 24 and extend to the sea bed template 28. The risers 52 are attached to the deck structure 30 of the platform. At

least one flexible flow line 70 is installed that extends from the upper deck structure 30 to production facilities 26 on the working deck 34 of the unit 20, for the transfer of hydrocarbons from the offshore reservoir to the semi-submersible unit 20. The flexible flowline 70 can include a plurality of lines for the flow of oil and gas, and can include one or more controlled umbilicals for wellhead controls.

Thus, the present invention provides a deep water drilling and production facility of reduced complexity and cost. Risers that extend from near the sea floor to trees on a small tension leg platform, and tendons that extend from the sea floor to the platform, extend through a lateral guide structure at the bottom of the platform at the below sea lower hull portion. The lateral guide structure prevents substantial lateral (horizontal) movement of the risers and tendons relative to one another at the bottom of the platform, to assure that they extend parallel to each other between the bottom of the platform and the locations where they terminate near the sea floor. The lateral guide structure for the risers comprise guides that guide the risers in large radius bends at the bottom of the platform.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art.

Claims

1. An offshore hydrocarbon production system for use in a sea of known sea depth, to produce hydrocarbons from at least one subsea well at the sea floor, comprising:
 - a platform which comprises a deck structure that includes at least one deck positioned substantially above the sea surface, and a buoyant hull which supports said deck structure and which includes a below-sea lower hull portion that extends more than three meters below the sea surface but which lies closer to the sea surface than the sea floor;
 - a plurality of primarily vertical tendons having upper ends connected to said platform and having lower ends connected to the sea floor;
 - at least one riser having an upper end connected to said deck structure and a lower end connected to the sea floor;
 - a lateral restraint structure which is mounted on said lower hull portion and which horizontally restrains each of said tendons and said risers against substantial horizontal movement relative to said hull, at locations which are more than three meters below the sea surface.
2. The offshore system described in claim 1 wherein:
 - said lateral restraint structure comprises a guide which confines said riser to bending up to

about 8° at a radius of curvature which is more than ten times the diameter of said riser.

3. The offshore system described in claim 1, wherein:
said restraint structure includes an element 5
with a passage that is of progressively greater width at progressively lower locations, with said riser extending through said passage.
4. The offshore system described in claim 3, wherein: 10
said restraint structure includes a plurality of horn-like guides, and each of said tendons extends through one of said guides.
5. The offshore system described in claim 3, wherein: 15
said restraint structure includes a series of rings of different inside diameters mounted on said lower hull structure, with said rings arranged so rings of progressively greater inside diameters lie progressively lower. 20
6. The system described in claim 1, wherein:
the upper end of said riser is connected to a tree that lies above the sea surface, and said lateral restraint structure lies at least three meters below 25 the sea surface.
7. An offshore hydrocarbon production system for use in a sea, to produce hydrocarbons from sea bed wells, comprising: 30
a platform that floats at the sea surface and that can drift by up to about 8° from a quiescent position, said platform having a lower portion with a hull bottom that lies below the sea surface and an upper portion that lies above the sea surface; 35
a plurality of trees each mounted on said platform with a lower end lying at a height of a plurality of meters above said hull bottom;
a plurality of primarily vertical tendons that extend to the sea floor, said tendons having lower ends anchored to the sea floor and having upper ends attached to said platform; 40
a plurality of primarily vertical risers having lower ends attached to the sea floor and coupled to said wells, and having upper ends attached to said lower ends of said trees on said platform; 45
said platform having a lateral guide structure that confines each of said risers to bending at a location that lies a plurality of meters below said tree lower ends when the vessel drifts up to about 8° from said quiescent position; 50
said tendons also being confined to pivoting at a location that lies a plurality of meters below the level of said tree lower ends and that is chosen so said risers and tendons extend substantially parallel to each other when said platform drifts by up to about 8° from said quiescent position. 55

8. The system described in claim 7 wherein:
said lateral guide structure comprises a plurality of guide which each confines one of said risers to bending about a radius of curvature that is more than twenty times the diameter of the riser for platform drift of up to about 8° from said quiescent position.
9. A method for installing an offshore wellhead platform for hydrocarbon production in a sea, comprising:
drilling at least one well into the sea floor;
installing a small tension leg wellhead platform having a deck structure and a hull having an undersea lower hull portion that supports said deck structure, with said platform floating near the sea surface, by anchoring lower ends of each of a plurality of tendons to the sea floor and connecting upper ends of the tendons to said platform;
installing at least one riser, including coupling a lower end of said riser to said well and connecting an upper end of said riser to said deck structure of said platform;
restraining said riser and said tendons from substantial horizontal movement relative to each other, at about the same undersea level as said lower hull structure.
10. The method described in claim 9 wherein:
said step of restraining said riser includes guiding it to bend about a radius of curvature of more than ten times the diameter of said riser, when said platform drifts.
11. A method for installing an offshore wellhead platform to produce from an offshore reservoir that lies under a sea floor comprising,
anchoring lower ends of each of a plurality of tendons to the sea floor in proximity to said offshore reservoir, and attaching at least one buoy to upper ends of said tendons;
after attaching said at least one buoy to said tendons, moving a small tension leg wellhead platform that floats at the sea surface, to said tendons, wherein said platform has a deck structure lying at least about as high as said sea surface and has a lower hull portion that lies below the sea surface and below said deck structure, and picking up said upper ends of said tendons and attaching said upper ends of said tendons to location spaced about said platform, including tensioning said tendons;
drilling at least one well into said offshore reservoir, and installing at least one riser including connecting a lower end of said riser to a well that connects to said reservoir and connecting an upper end of said riser to said deck structure;
restraining said riser and said tendons from substantial horizontal movement relative to each other, at about the same level as said lower hull portion.

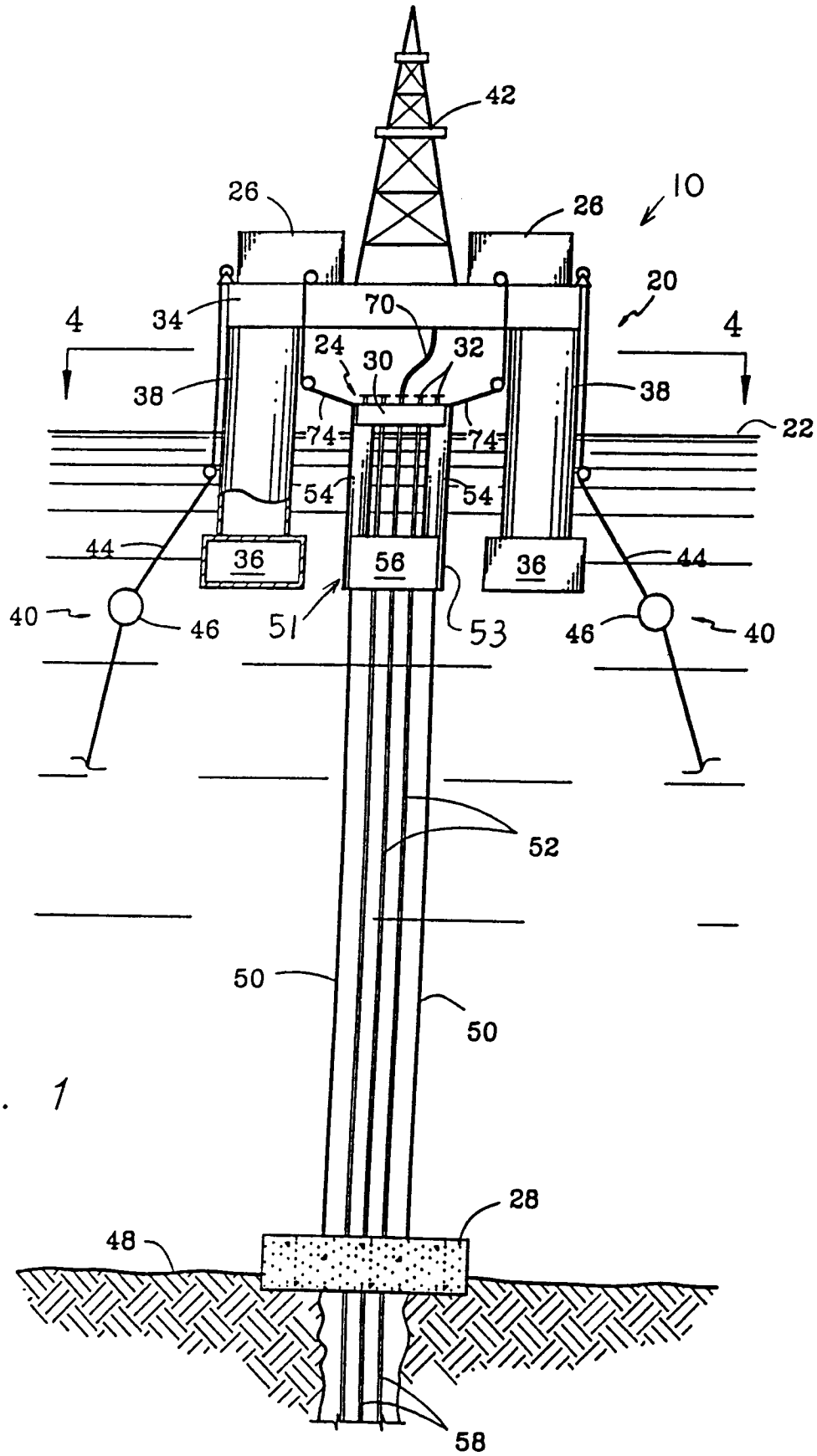


Fig. 1

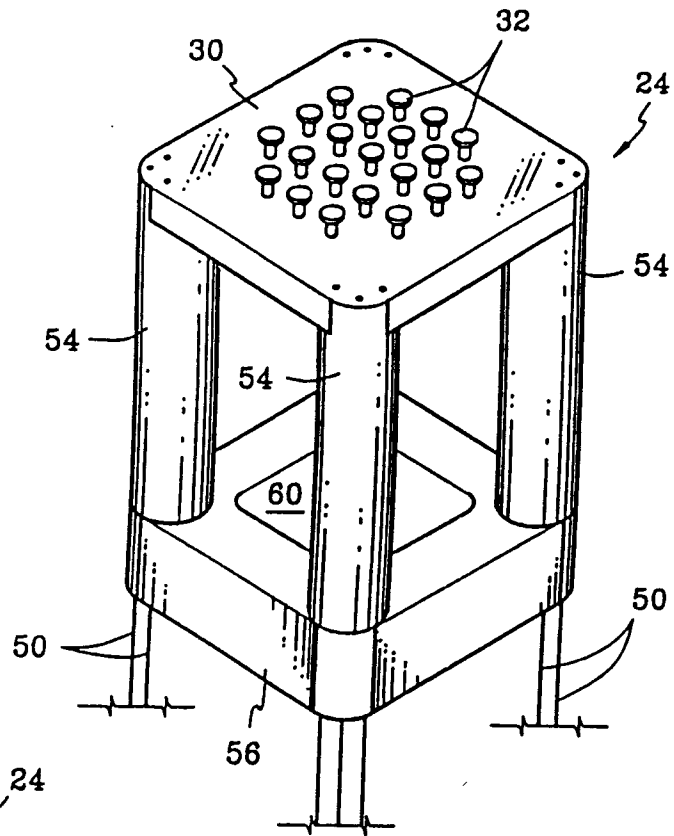


Fig. 2

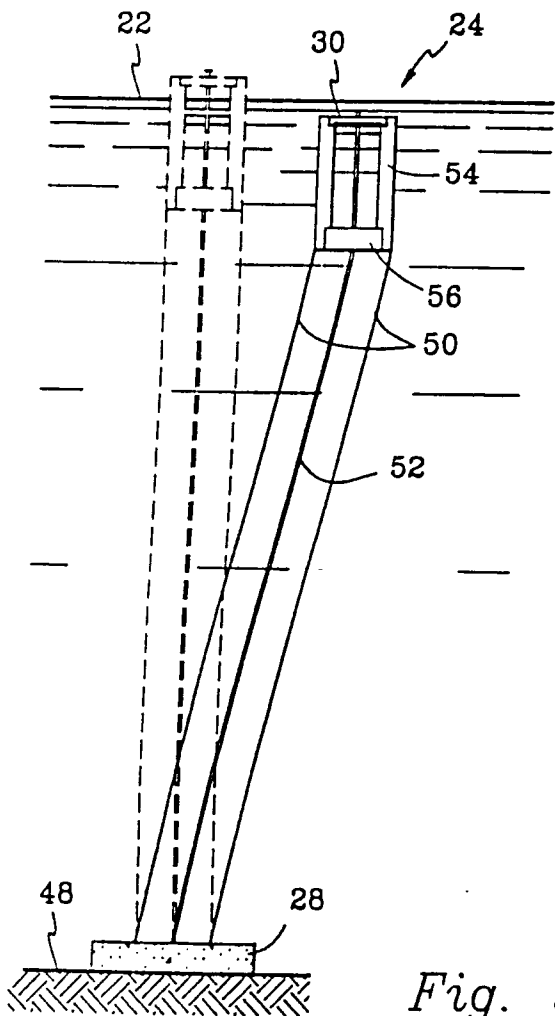


Fig. 3

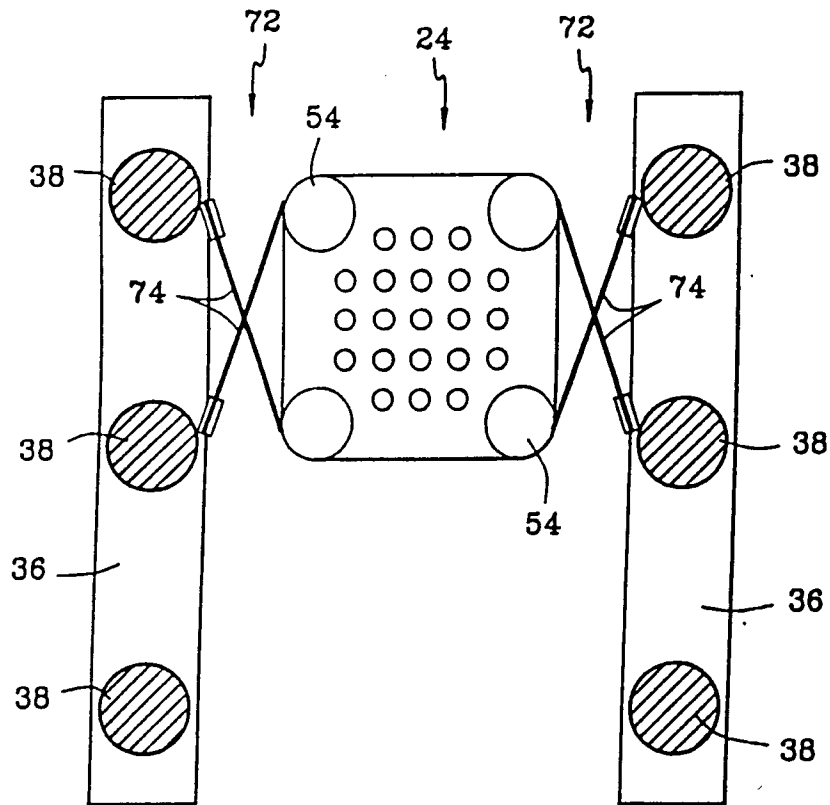


Fig. 4

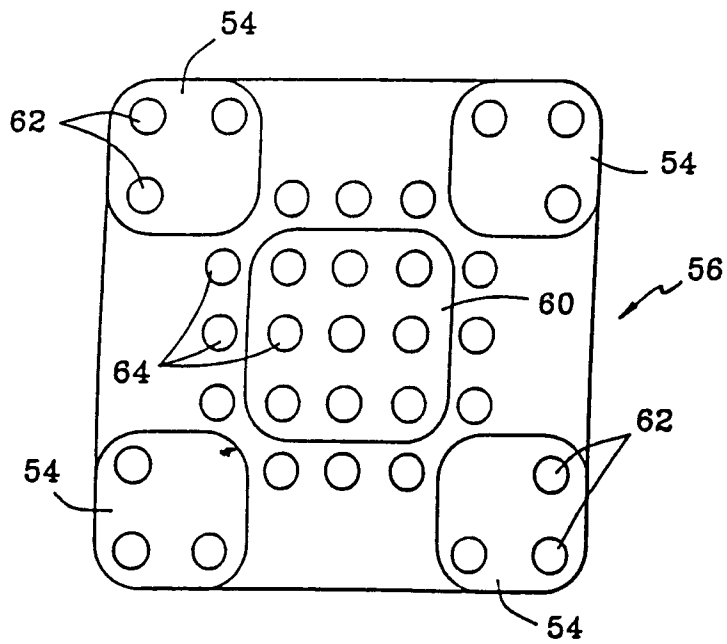


Fig. 5

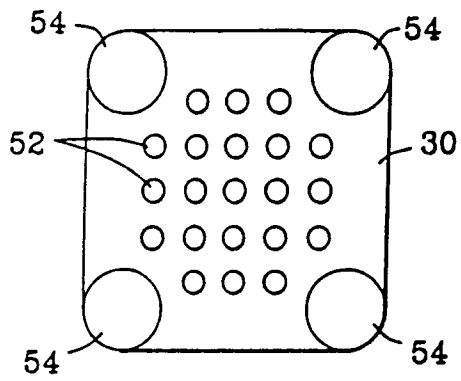


Fig. 6a

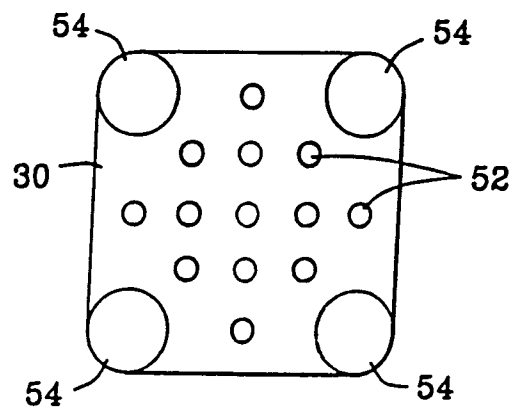


Fig. 6b

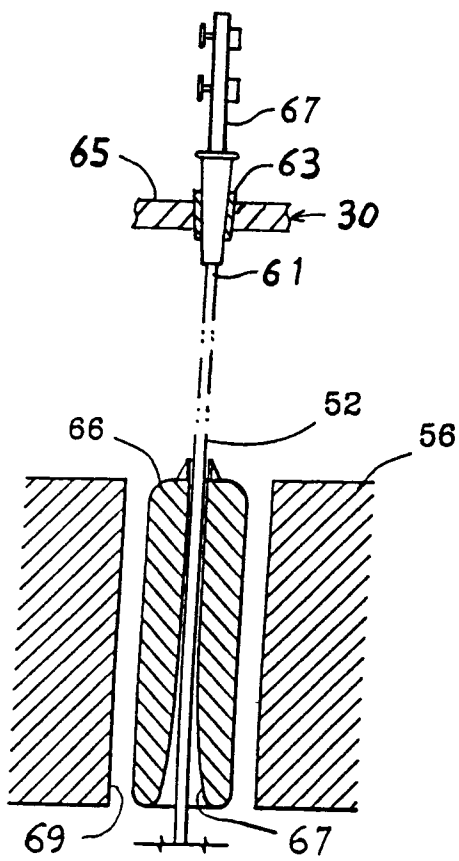


Fig. 7

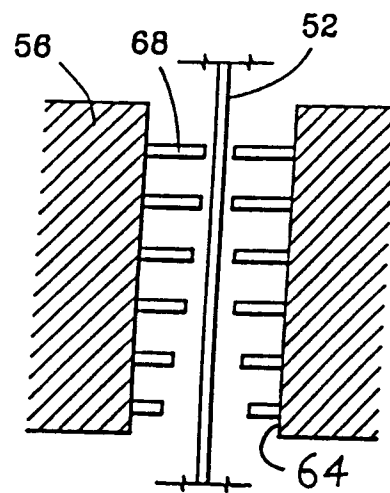


Fig. 8



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 94 30 9127

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 287 243 (CONOCO)	1-4,6-10	B63B21/50
Y	* column 9, line 36 - line 53; figure 6 * ---	11	
Y	US-A-4 365 912 (R.BURNS) * column 5, line 67 - column 6, line 8; figure 2 * ---	11	
X	EP-A-0 087 922 (STANDARD OIL COMPANY) * abstract; figures * * page 2 * ---	1,2,6-10	
A	US-A-3 934 528 (E.HORTON) * figure 6 * ---	1,3,4	
A	US-A-4 913 238 (M.DANAZCKO) * abstract; figures * -----	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B63B
Place of search		Date of completion of the search	Examiner
THE HAGUE		15 May 1995	Stierman, E
CATEGORY OF CITED DOCUMENTS T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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