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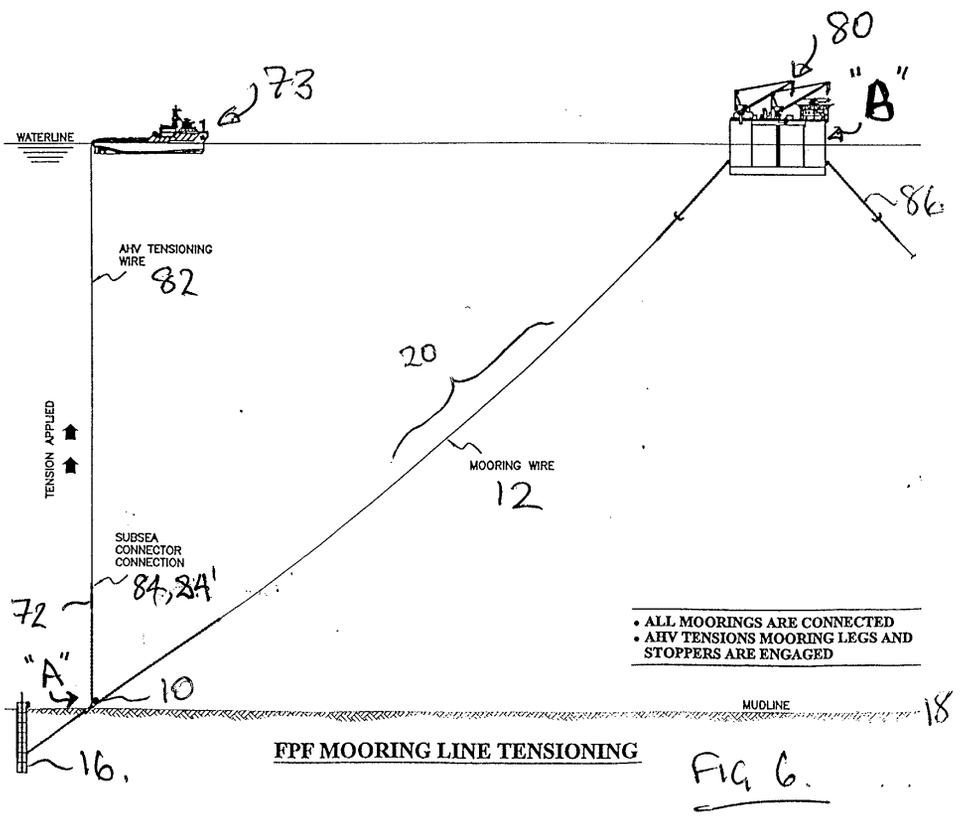
(54) Mooring systems

(57) A floating platform (80) has a mooring line (12) which passes through coupling apparatus (10) tethered to suction anchor (16). The coupling apparatus (10) allows the effective length (20) of the mooring line (12) between the platform (80) and the anchor (16) to be adjusted using a vessel (73) independent of the platform (80). The vessel (73) pulls the mooring line (12) through the coupling apparatus (10), reducing the effective length (20) of mooring line (12), until the floating platform (80) is in a desired position. The coupling apparatus (10) includes a locking device to prevent the effective length (20) of the mooring line (12) from changing once the floating platform (80) is in the desired position.



EP 1 318 072 A2

Description

FIELD OF THE INVENTION

[0001] This invention relates to offshore mooring systems, particularly methods of mooring buoyant structures at sea, such as floating platforms or mid-water buoys, which may be used in the oil and gas industry or other marine exploitation activities.

BACKGROUND TO THE INVENTION

[0002] Offshore floating structures are typically moored by a plurality of mooring lines, often as many as 8 to 16 lines for any one structure. Conventionally these mooring lines are set up and controlled by equipment on the floating structure.

[0003] Such equipment requires machinery to pay out and haul in mooring lines, for example rotary winches for spooling steel wire and rotary windlasses or linear jacks for hauling chain, devices to brake or stop the lines, a power supply for example an electricity generator, and a control and monitoring system. For example, European patent application EP-A-0 831 053 describes a ram winch of the kind used in deep water mooring projects and which is mounted on the deck or hull of floating vessel for controlling mooring lines and their tensions. Equipment of this kind is costly to supply and install; it tends to be cumbersome and heavy and occupy a substantial amount of area on the deck and so reduces the available area and capacity of the structure for more productive equipment. This is a particular drawback for smaller floating structures, such as are being proposed more frequently for exploitation, e.g. oil prospecting and extraction, in very deep water, and for early designs of mobile offshore drilling units (MODUs) which were designed to operate in relatively shallow waters and for which the cost of upgrading the MODU's mooring system may be un-economic.

[0004] A device known as the "Steadfast Gipsy Tensioner" has been available since about 1987, and has been used to apply tension to cable extending between two or more anchors. In this way, drag anchors can be used even where the tension in the mooring line is aligned more in a vertical direction than a horizontal direction.

[0005] Similarly, US Patent 4,889,065 (Van den Haak) describes a method of tensioning anchor line, in particular for testing an anchor, and a device for carrying out the method, and such devices have been proposed to embed opposing drag anchors by applying vertical load at the centre of a taut cable arrangement joining the two anchors, and by virtue of the mechanical advantage gained converting the applied vertical load to horizontal load suitable to embed the drag anchors.

[0006] US Patent 6,158,093 (Bergeron) describes a mechanism for remotely connecting and disconnecting mooring components together, and has been widely used, particularly in the Gulf of Mexico, for the setting of suction anchors and mooring systems in very deep water in advance of the arrival of the floating structure, thus improving economic efficiencies and the utilisation of the floating structures involved.

[0007] US Patent 5,845,893 (Groves) describes an underwater self-aligning fairlead latch device for mooring a structure at sea, and has been proposed for use together with tensioning and control equipment mounted on a floating structure.

[0008] US Patent 5,441,008 (Lange) describes a submerged swivelling mooring line fairlead device for use on a structure at sea, and such devices have been used together with tensioning and control equipment mounted on a floating structure.

[0009] It is an object of the present invention to provide an improved method of mooring offshore a buoyant structure, particularly a buoyant structure where provision of tensioning and control equipment on the buoyant structure is not possible, is not preferred or is uneconomic.

SUMMARY OF THE INVENTION

[0010] According to a first aspect of the present invention, there is provided a method of mooring a buoyant structure, comprising: providing a coupling apparatus comprising a body defining a channel for receiving a mooring line and a releasable locking device for engaging the mooring line received in the channel, the coupling apparatus being fixed relative to a first reference point; attaching one end of the mooring line to a second reference point, with one reference point being associated with the buoyant structure and the other being associated with an anchored structure; pulling the mooring line through the channel in the body of the coupling apparatus to reduce a length of the mooring line between the two reference points; and securing the mooring line with the locking device to maintain a desired length of mooring line between the first and second reference points, wherein the mooring line is pulled through the channel by means spaced from and independent of the first and second reference points.

[0011] The buoyant structure may be water borne (*e.g.* deployed off shore), the coupling apparatus may be deployed subsea, and the anchored structure may be secured to an underwater substrate such as a seabed. The mooring line may be attached to the second reference point by a shackle and padeye connection, or other simple structural connection. Thus, the operative length of the mooring line (*i.e.* the length of mooring line between the coupling apparatus and the second reference point) may be adjusted at the coupling apparatus by the device, rather than by means provided on the buoyant structure or on the anchored structure. This obviates the need for any arrangement for adjusting the mooring line to be provided on the buoyant or the anchored structure.

[0012] In a first embodiment, the first reference point

is associated with the anchored structure and the second reference point is associated with the buoyant structure. For example, the coupling apparatus may be attached to the anchored structure by a tether, possibly a length of chain. The anchored structure may be an underwater anchor, possibly a suction anchor or drag anchor for use in deep sea applications. The method may further comprise as an initial step, threading the coupling apparatus onto the mooring line prior to attaching or tethering the coupling apparatus to the anchored structure. Thereafter, as an intermediate step, the end of the mooring line for attachment to the buoyant structure may be laid out upon the seabed or attached temporarily to a mooring buoy. The mooring buoy may be used to position the said end of the mooring line above the anchored structure e.g. near sea level.

[0013] In a second embodiment, the first reference point is associated with the buoyant structure, and the second reference point is associated with the anchored structure. For example, the coupling apparatus may be mounted on the buoyant structure. The anchored structure may be an underwater anchor, possibly a suction anchor for use in deep-sea applications in a relatively soft substrate.

[0014] In one embodiment, the buoyant structure may float on water, and may be a floating platform or the like. In another embodiment, the buoyant structure may (at least in use) be submerged in water, and may be configured to be a mid-water buoy, (*i.e*. buoys that are tethered to the seabed and maintained at a certain depth below the water surface). At least in the case of a submerged buoyant structure, the method may further comprise releasing the locking device, adjusting the length of the mooring line between the two reference points, and relocking the locking device to maintain a different desired length of mooring line between the first and second reference points. In this way, the depth below the surface at which the submerged buoyant structure is deployed may be varied.

[0015] The pulling means used to reduce the length of missing line between the two reference points may comprise a vessel, possibly a surface vessel with a motor such as an anchor handling tug (AHT). Such a vessel may be operated to apply tension to the mooring line (*e.g.* steered and moved in a direction away from the buoyant structure). Use of the vessel in this way may be preferred when the coupling apparatus is positioned such that the mooring line extending therefrom to the vessel is substantially horizontal. The device may further comprise a winch mounted on the vessel, the winch being configured to apply tension to the mooring line. Use of the winch in this way may be preferred when the coupling apparatus is positioned such that the mooring line extending therefrom to the vessel is more vertical than horizontal.

[0016] The locking device may be actuated automatically by remote control, *e.g.* by a remote control vehicle such as a remote operated underwater vehicle (ROV). An automatically actuated locking device may comprise a chain stopper. The chain stopper may comprise at least one flap biased towards mooring line in the channel and configured to ride over the mooring line when the latter is pulled in one direction through the channel, but to wedge against it when pulled in the opposite direction.

[0017] According to a second aspect of the present invention, there is provided apparatus for adjustably coupling a mooring line to a structure, comprising: a body defining a channel for slidably receiving a mooring line when the body is threaded thereon; a locking device for preventing movement of the mooring line in at least one direction through the channel; and a mounting for attaching the body to a structure. The structure may be one of an anchored structure and a buoyant structure.

[0018] The apparatus allows the operative length of the mooring line to be varied whilst allowing the mooring line to be coupled simply to the structure being moored. The apparatus may be configured for use under water *e.g.* adjacent an anchor embedded in the seabed.

[0019] The body may comprise a curved member for guiding the mooring line through a bend in the channel. A curved member may comprise a wheel rotatably mounted on a shaft. The wheel may comprise teeth for engaging links in a chain-type mooring line. The locking device may comprise a ratchet mechanism for resisting one direction of rotation of the wheel on the shaft. Alternatively or in addition, the locking device may comprise a chain stopper for engaging links in a chain-type mooring line. The chain stopper may comprise at least one flap member biased towards mooring line in the channel and configured to ride over the mooring line when the latter is pulled in one direction through the channel, but to wedge against it when pulled in the opposite direction. The or each flap member may be pivotally coupled to the body. The chain stopper may be releasable (*e.g.* by hydraulic or mechanic means) whereby the mooring line is freed to move in both directions.

[0020] The curved member may be disposed to one side of a notional line linking the mounting and a channel opening in the body and extending substantially parallel to a direction along which, in use, mooring forces are transmitted through the body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1 is a schematic illustration showing use of coupling apparatus used in embodiments of the present invention;

Figure 2 is a schematic illustration showing detail of the coupling apparatus of Figure 1;

Figure 3 illustrates schematically deployment of coupling apparatus of Figure 1 with mooring line in

accordance with one embodiment of the invention;

Figure 4 illustrates schematically an intermediate step of attaching mooring line of Figure 3 to mooring buoy;

Figure 5 illustrates schematically attachment of mooring line of Figures 3 and 4 to a floating platform;

Figure 6 illustrates schematically application of tension in mooring line to moor floating platform of Figure 5; and

Figure 7 illustrates schematically deployment of coupling apparatus of Figure 1 in accordance with an alternative embodiment of the invention to that of Figure 3 to 6.

DESCRIPTION OF SPECIFIC EMBODIMENTS

[0022] Figure 1 shows schematically the use of coupling apparatus (10) in mooring a buoyant structure, such as a floating platform (not shown) or a mid-water buoy (not shown) to an underwater substrate *via* a mooring line (12). The coupling apparatus (10) may be mounted on the buoyant structure or attached to an anchored structure (13) as shown in Figure 1. In the latter case, the coupling apparatus (10) is tethered *via* forerunner chain (14) to a suction anchor (16) embedded in the seabed indicated at (18). The mooring line (12) engages the coupling apparatus (10) in a manner which, as explained hereinafter, enables the effective length of the mooring line - that is, the part (20) of the mooring line (12) extending between the coupling apparatus (10) and the floating platform - to be varied in order to help control the position of the buoyant structure.

[0023] The coupling apparatus (10) comprises a body (30) which defines a channel (32) through which the mooring line (12) is a sliding fit. The channel (32) has an inlet (34) and an outlet (36), with a bend (38) (e.g. of about 90°) formed therebetween. A wheel (40) is rotatably mounted on a shaft (42) and housed, at least in part, in the body (30) on the radially inner side of the bend (38). The wheel (40 has a drum-like peripheral surface (44) configured to engage one or more chain links (48) of the mooring line (12) as the mooring line rides on the wheel (40). In this way, the wheel (40) rotates in a clockwise direction as the mooring line is pulled through the coupling apparatus (10) in the direction of arrow P. A releasable chain stopper (52) is provided in channel (32).

[0024] The releasable chain stopper (52) comprises a pair of flap members, each biased towards opposing sides of mooring line in the channel (32). The flap members are configured to ride over the mooring line when the latter is pulled in direction of force P through the channel, but wedge against links of a chain-type mooring line when pulled in the opposite direction. When engaged, the releasable chain stopper (52) prevents movement of the mooring line in a direction through the channel (32) which would extend the effective length of the mooring line. End flanges (54) are provided on wheel (40) to further guide movement of the chain (12) around the wheel (40).

[0025] The body (30) of coupling apparatus (10) further comprises a mounting (60) which is pivotably engaged by connector (62) for attachment to the forerunner cable (14) tethered to anchor (60). The mounting (60) is positioned such that it is in line with the direction in which the mooring line (12) enters channel (32) through inlet (34); the wheel (40) being positioned to one side of a notional line extending between the mounting (60) and the channel inlet (34).

[0026] One method of deploying and using the coupling apparatus (10) will now be described with reference to Figures 3 to 6. The suction anchor (16) is embedded in the seabed (18) and includes the forerunner cable (14) with an accessible connector (62') for mating with pivotal connector (62) mounted on coupling apparatus (10). The coupling apparatus (10) is threaded onto one end of (70) the mooring line (12) which is then fitted with a floatation collar (72). A surface support vessel (73) (such as an anchor handling tug, AHT) lowers the coupling apparatus (10) on the mooring (12) towards the suction anchor (16), until the connectors (62,62') are interconnected with the assistance from a remote operated underwater vehicle (ROV). The mooring line (12) is laid out on the seabed (18) and at the surface a buoy (74) is attached to the other end (76) of the mooring line (12) before the surface support vehicle (73) releases the mooring line (12). Buoy (74) holds the end (76) of the mooring line (12) near the surface until it is ready to be used, whilst part of the mooring line (12) which exceeds the lift generated by the buoy (74) rests on the seabed (18).

[0027] When a floating platform (80) is ready to be moored, the buoy (74) is collected and raised by the surface support vessel (73) and the end (76) of the mooring line (12) is secured to the floating platform (80) *via* a straightforward mechanical link, *e.g*. shackle and padeye. One way of performing this operation is for the floating structure to have lengths of chain already attached to the shackle and padeye arrangement. A free end of one such chain is passed to the surface support vessel (73) and a connection is made between the chain and the end (76) of the mooring line (12).

[0028] The surface support vessel (73) then manoeuvres to a position spaced from the platform (80), above the suction anchor (16). The surface support vessel (73) constitutes a device for pulling the mooring line (12) through the apparatus (10), which is spaced from and independent of the anchor (16) and platform (80). The surface support vessel (73) lowers a cable (82) which includes a connection (84) which docks with a corresponding connection (84') on floating collar (72). The surface support vessel (73) pulls on cable (82) *via* an onboard winch (not shown). Resulting tension in the cable (82) is transmitted to mooring line (12) which is consequently pulled through the coupling apparatus (10),

turning wheel (40) in a clockwise direction. As it is pulled through the coupling apparatus (10), slack in the effective or operative part (20) of the mooring line (12) is taken up and the floating platform (80) is pulled into the desired position (and optionally stabilised with other mooring lines (86)). If the floating platform (80) is to be submerged, the operative part (20) of the mooring line is reduced to a length which will maintain the submerged floating platform below the sea surface.

[0029] When the desired length of mooring line between the coupling apparatus (10) and the platform (80) is achieved, the mooring line (12) is locked in position in the body (30) of coupling apparatus (10) by the locking device, *e.g.* the chain stopper (52). The connection (84,84') may then be released and the cable (82) winched onto the surface support vessel (73).

[0030] The mooring line (12) may be subsequently slackened with the aid of the surface support vessel (73). The cable (82) is once again lowered and connectors (84,84') reconnected. The surface support vessel (73) applies tension to cable (82) to counteract that in the effective part (20) of the mooring line (12). The chain stopper (52) is then released by remote control (*e.g.* using a ROV), enabling the surface support vessel (73) to slacken the mooring of platform (80) by lowering cable (82) as required. As cable (82) is lowered, the mooring line (12) is dragged through the channel (32) in the body (30) of coupling apparatus (10) by the tension in the effective part (20) of the mooring line (12).

[0031] In the method described with reference to Figures 3 to 6, the coupling apparatus (10) is attached to the suction anchor (16) which acts as a first reference point ("A") and the mooring line is attached to the floating platform (80) which acts as a second reference point ("B"). By pulling the mooring line (12) through the coupling apparatus (10) the length of the mooring line between the two reference points can be controlled, and hence so can the spacing between the two reference points.

[0032] In the alternative configuration illustrated schematically in Figure 7, the coupling apparatus (10') is attached to the buoyant structure (80'), and the mooring line is attached to the anchor (16'). Thus, the buoyant structure (80') is acting as the first reference point ("A") and the anchor (16') is acting as the second reference point ("B"). The mooring line (12') is pulled through the coupling apparatus (10') by movement of the surface support vessel (73') in direction of arrow M, away from the buoyant structure (80'). The movement of the vessel (73') reduces the length of the mooring line (12') between the two reference points, and hence the spacing between the two reference points is likewise reduced.

Claims

1. A method of mooring a buoyant structure, comprising:

providing a coupling apparatus comprising a body defining a channel for receiving a mooring line and a releasable locking device for engaging the mooring line received in the channel, the coupling apparatus being fixed relative to a first reference point;

attaching one end of the mooring line to a second reference point, with one reference point being associated with the buoyant structure and the other being associated with an anchored structure;

pulling the mooring line through the channel in the body of the coupling apparatus to reduce a length of the mooring line between the two reference points;

and securing the mooring line with the locking device to maintain a desired length of mooring line between the first and second reference points, wherein the mooring line is pulled through the channel by means spaced from and independent of the first and second reference points.

2. A method according to claim 1, in which the first reference point is associated with the anchored structure, and the second reference point is associated with the buoyant structure.

3. A method according to claim 2, in which the coupling apparatus is attached to the anchored structure by a tether.

4. A method according to claim 3, further comprising: threading the coupling apparatus onto the mooring line before attaching the coupling apparatus to the anchored structure.

5. A method according to claim 4, further comprising: resting the threaded mooring line on an underwater substrate prior to attaching said one end to the second reference point.

6. A method according to claim 1, in which the first reference point is associated with the buoyant structure, and a second reference point is associated with the anchored structure.

7. A method according to claim 1, in which the buoyant structure is floating on water.

8. A method according to claim 1, in which the buoyant structure is submerged in water, at least when the desired length of mooring line between the first and second reference points is secured.

9. A method according to claim 1, in which the means for pulling the mooring line through the channel comprises a floating vessel.

10. A method according to claim 9, further comprising: moving the floating vessel away from the first reference point to pull the mooring line through the channel in the body of the coupling apparatus.

11. A method according to claim 9, in which the device further comprises a winch, mounted on the floating vessel and configured to pull the mooring line through the channel in the body of the coupling apparatus.

12. A method according to claim 1, in which the anchored

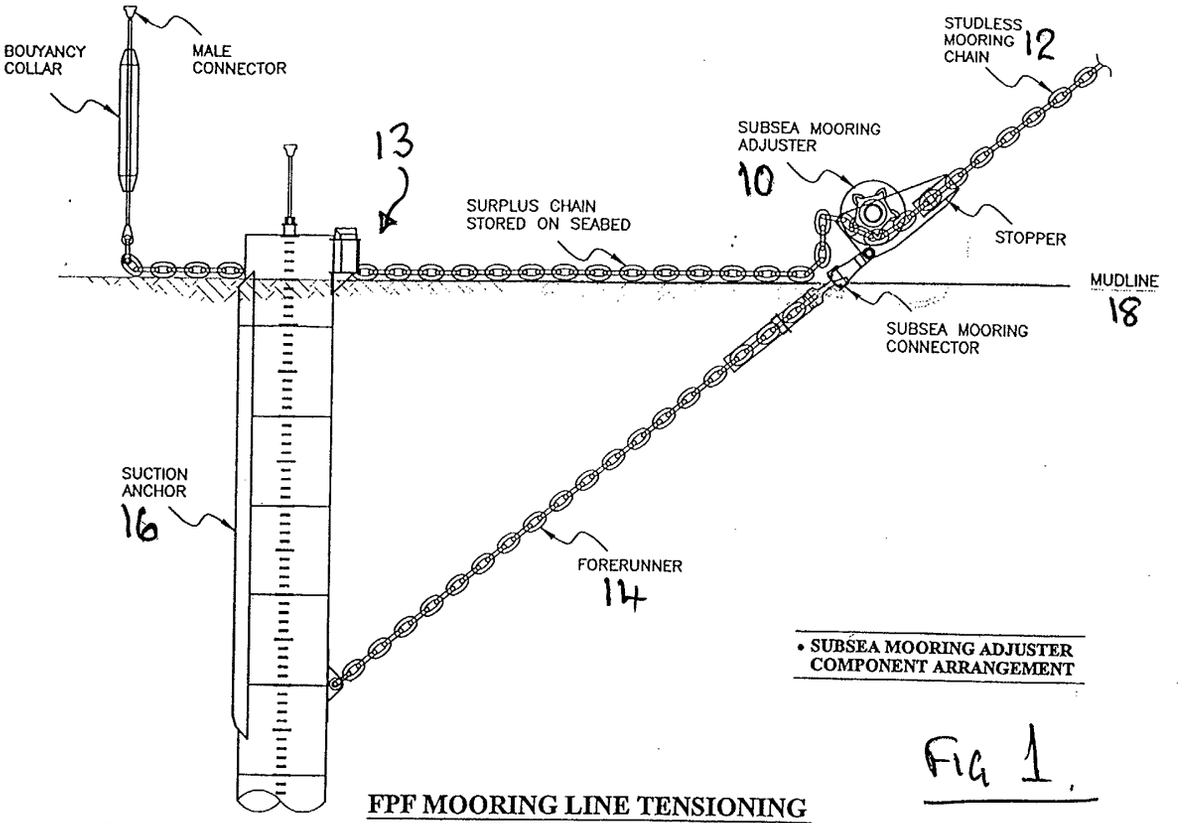
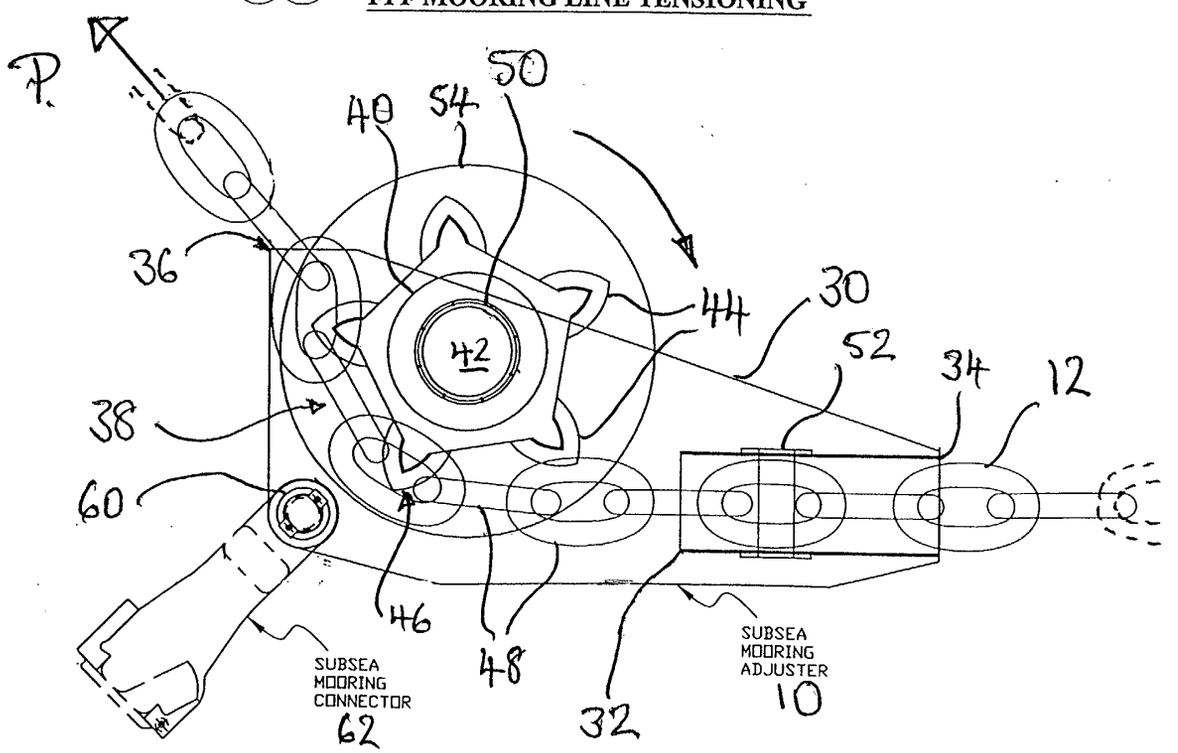


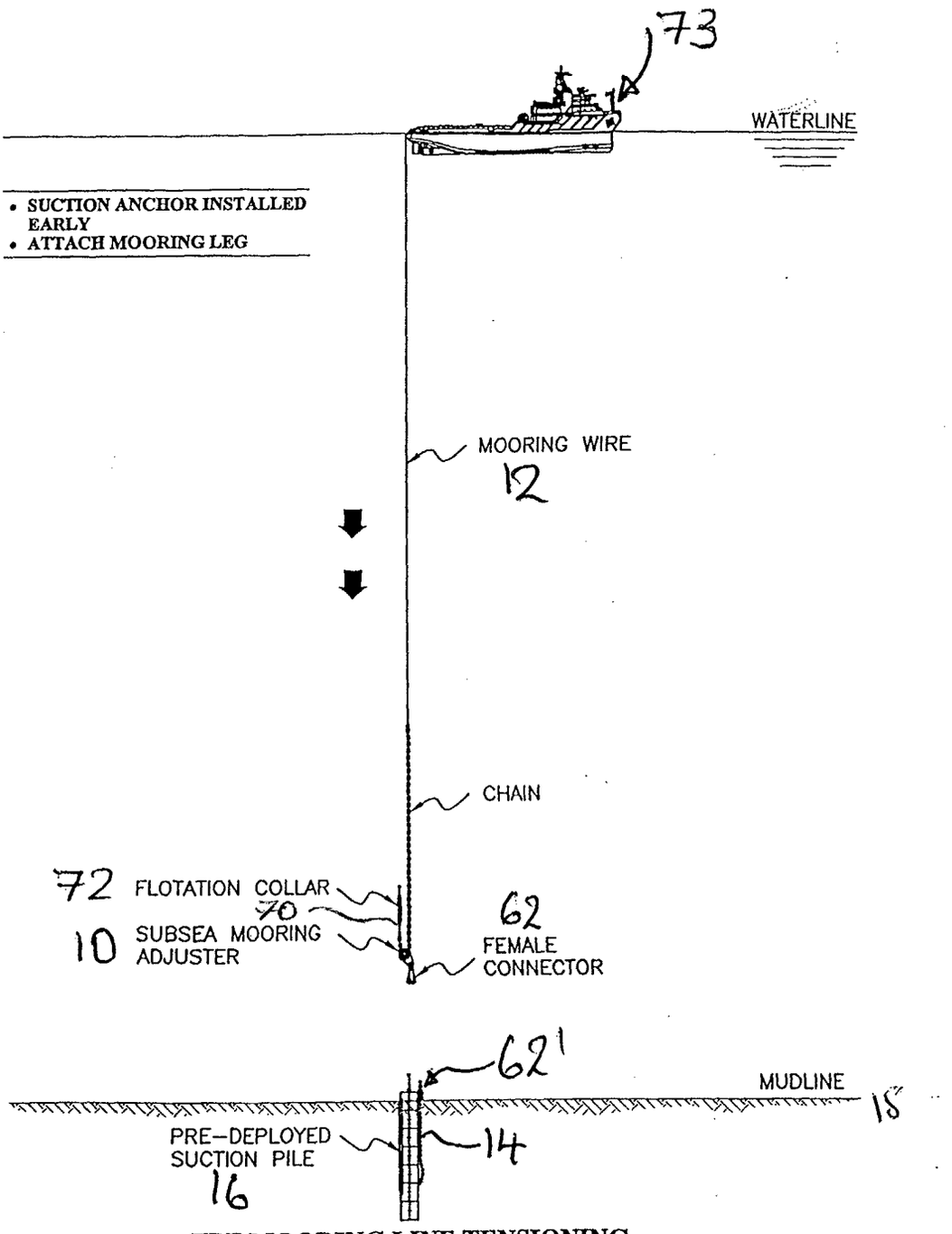
Fig 1.

FPF MOORING LINE TENSIONING



SUBSEA MOORING ADJUSTER / SUBSEA CONNECTOR ARRANGEMENT

Fig 2.



FPF MOORING LINE TENSIONING

Fig 3

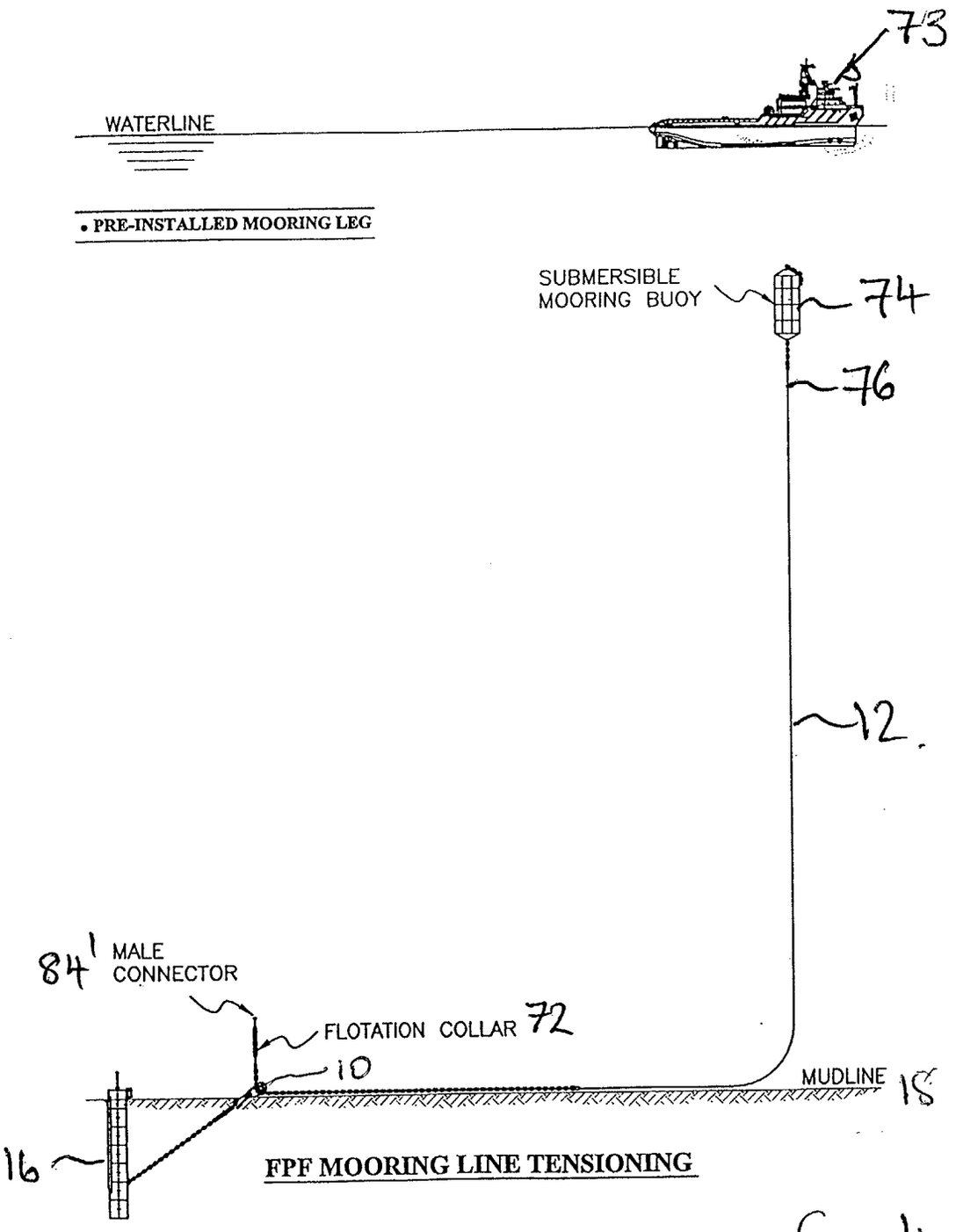
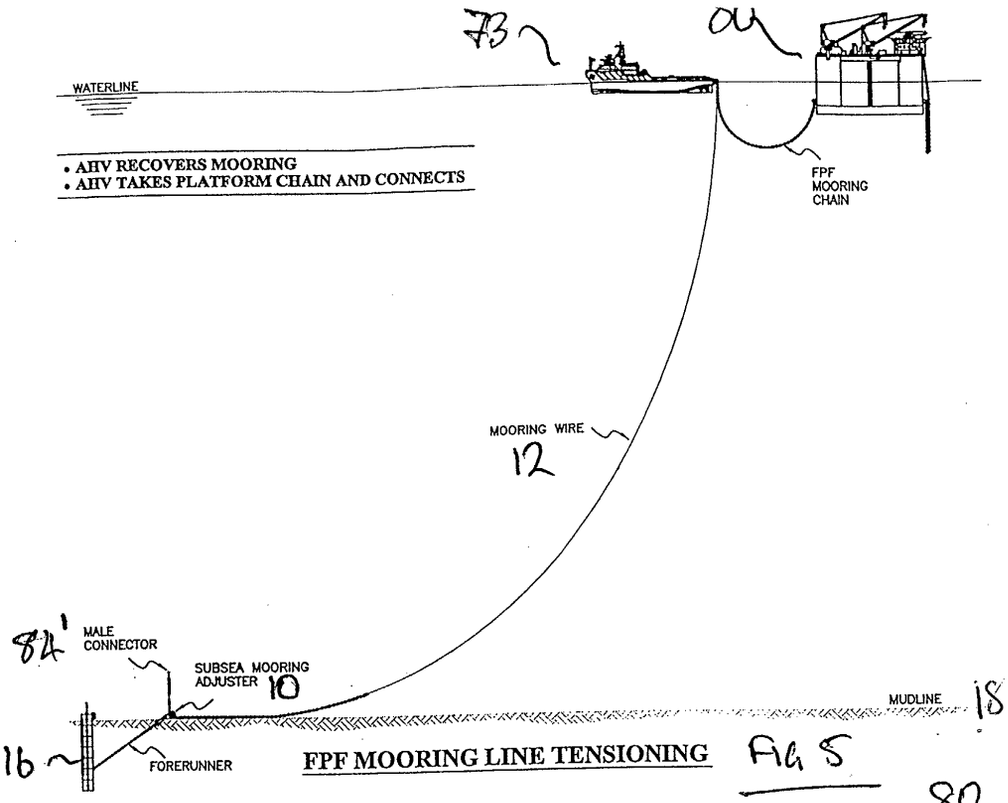
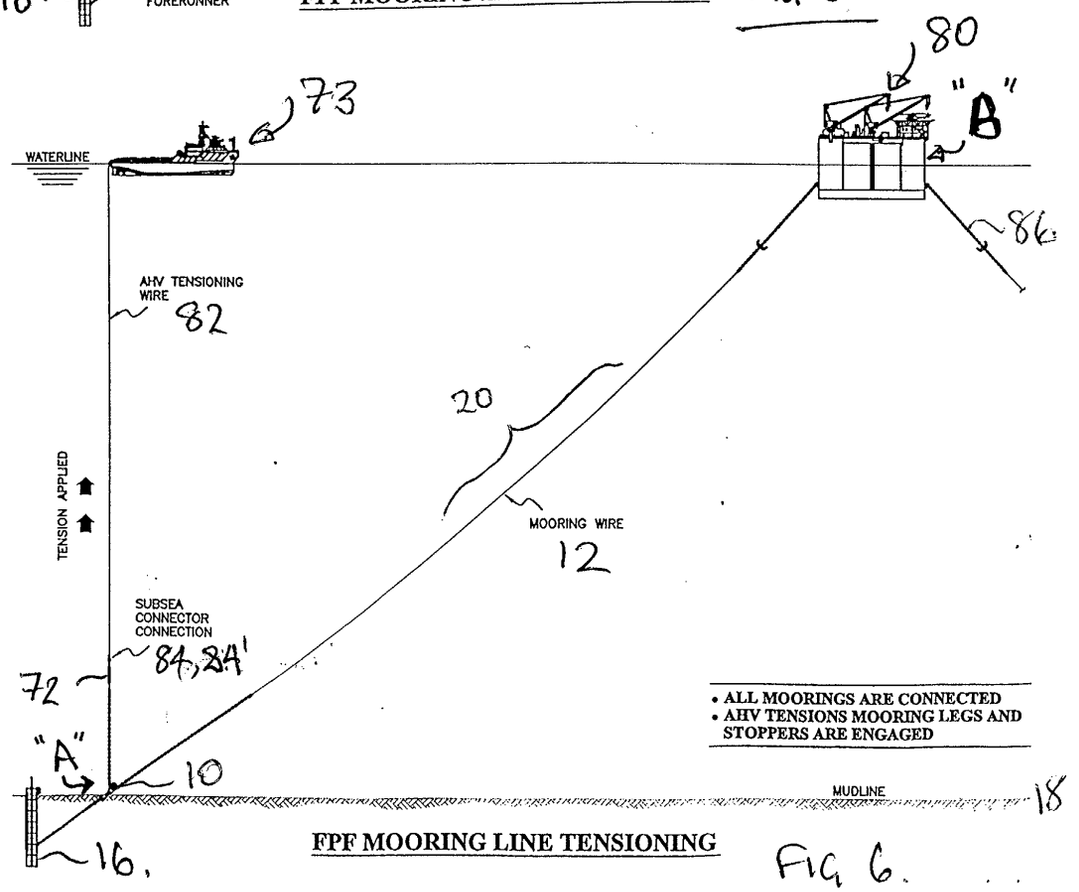

73
WATERLINE
• PRE-INSTALLED MOORING LEG
SUBMERSIBLE
MOORING BUOY
74
76
12
84'
MALE
CONNECTOR
FLOTATION COLLAR 72
10
MUDLINE 18
16
FPF MOORING LINE TENSIONING

Fig 4



FPF MOORING LINE TENSIONING Fig 5



FPF MOORING LINE TENSIONING Fig 6.

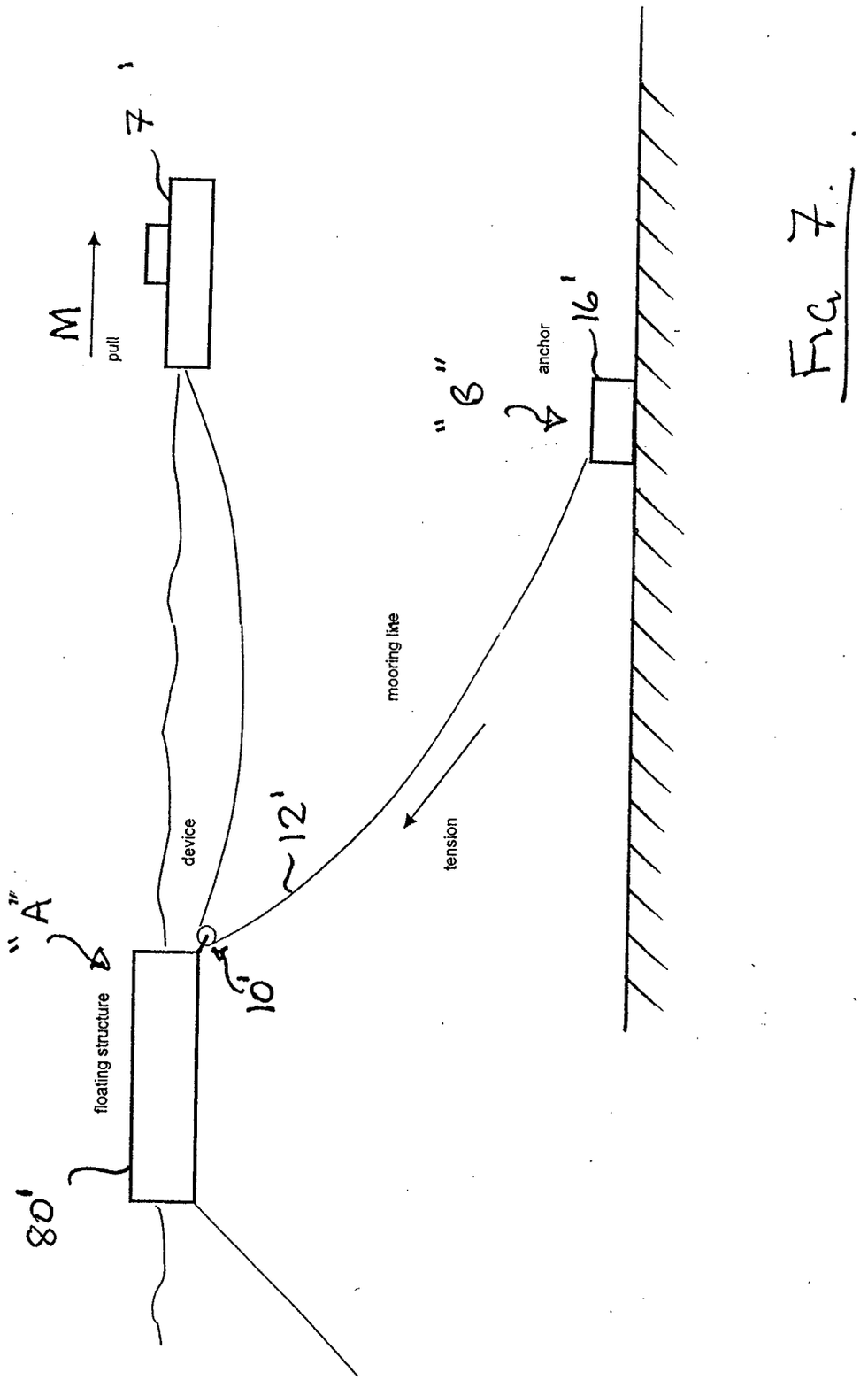

M
pull
floating structure
device
mooring line
tension
anchor
"A"
"B"
80'
10'
12'
14'
16'

Fig 7.