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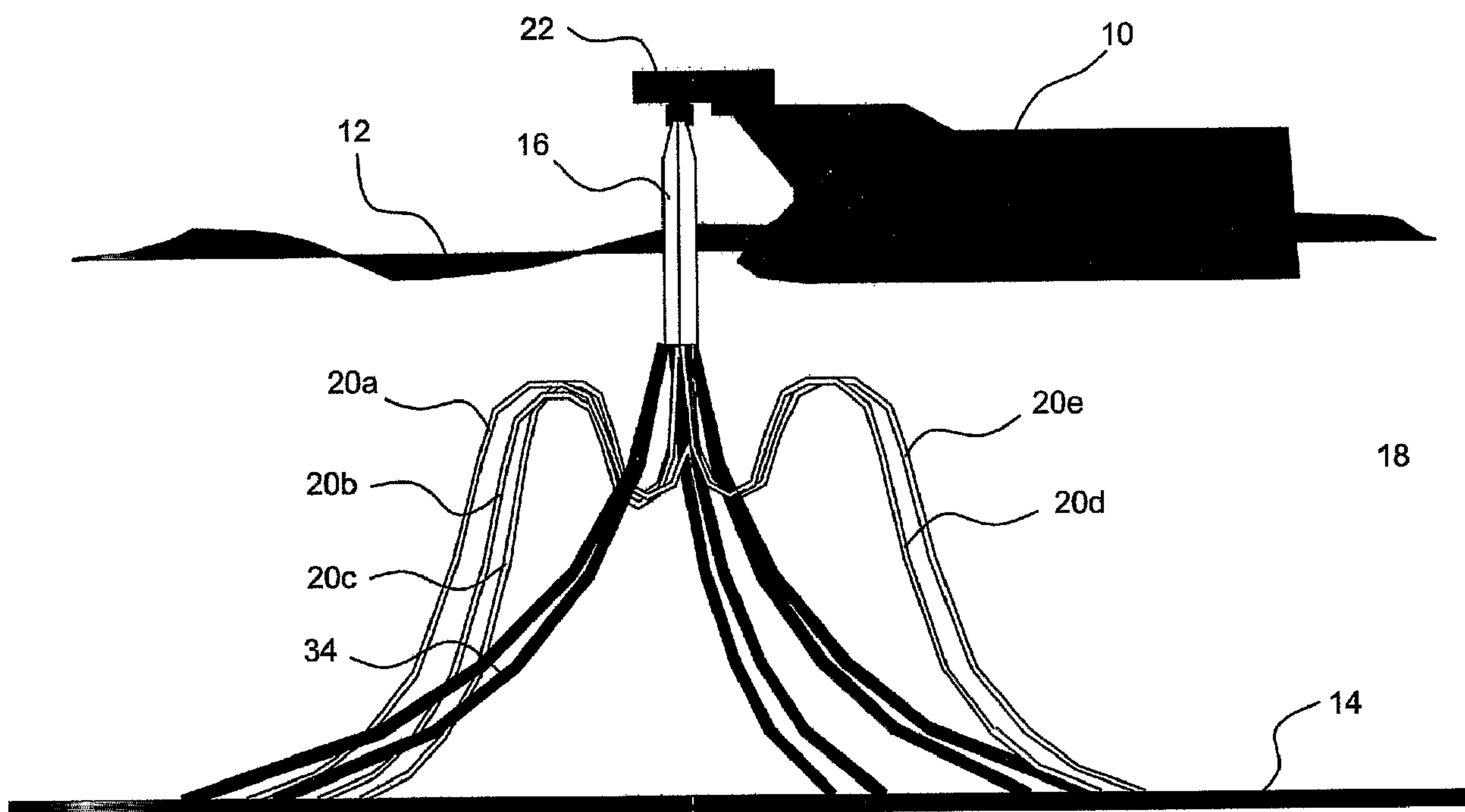
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(54) Titre : ANCRAGE DE NAVIRE DE HAUTE MER ET SYSTEME DE CHARGEMENT DE TUBE GOULOTTE

(54) Title: OFFSHORE VESSEL MOORING AND RISER INBOARDING SYSTEM



(57) Abrégé/Abstract:

There is disclosed an offshore vessel mooring and riser inboarding system (12) for a vessel (10) such as an FPSO or FSO. In one embodiment, the system comprises a first mooring element (16) adapted to be located in an offshore environment (18); a riser (20) adapted to be coupled to the first mooring element; a connector assembly (22) 11 adapted to be mounted on the vessel, the connector assembly comprising a second mooring element (28); and a transfer line (32) adapted to be coupled to the riser; wherein the first and second mooring elements are adapted to be connected to facilitate coupling of the riser and the transfer line; and wherein the connector assembly is adapted to permit relative rotation between the vessel and the first mooring element about three mutually perpendicular axes of rotation. This facilitates weathervaning of the vessel relative to the first mooring element, as well as pitch, roll, heave and surge, under applied wind, wave and/or tidal forces.

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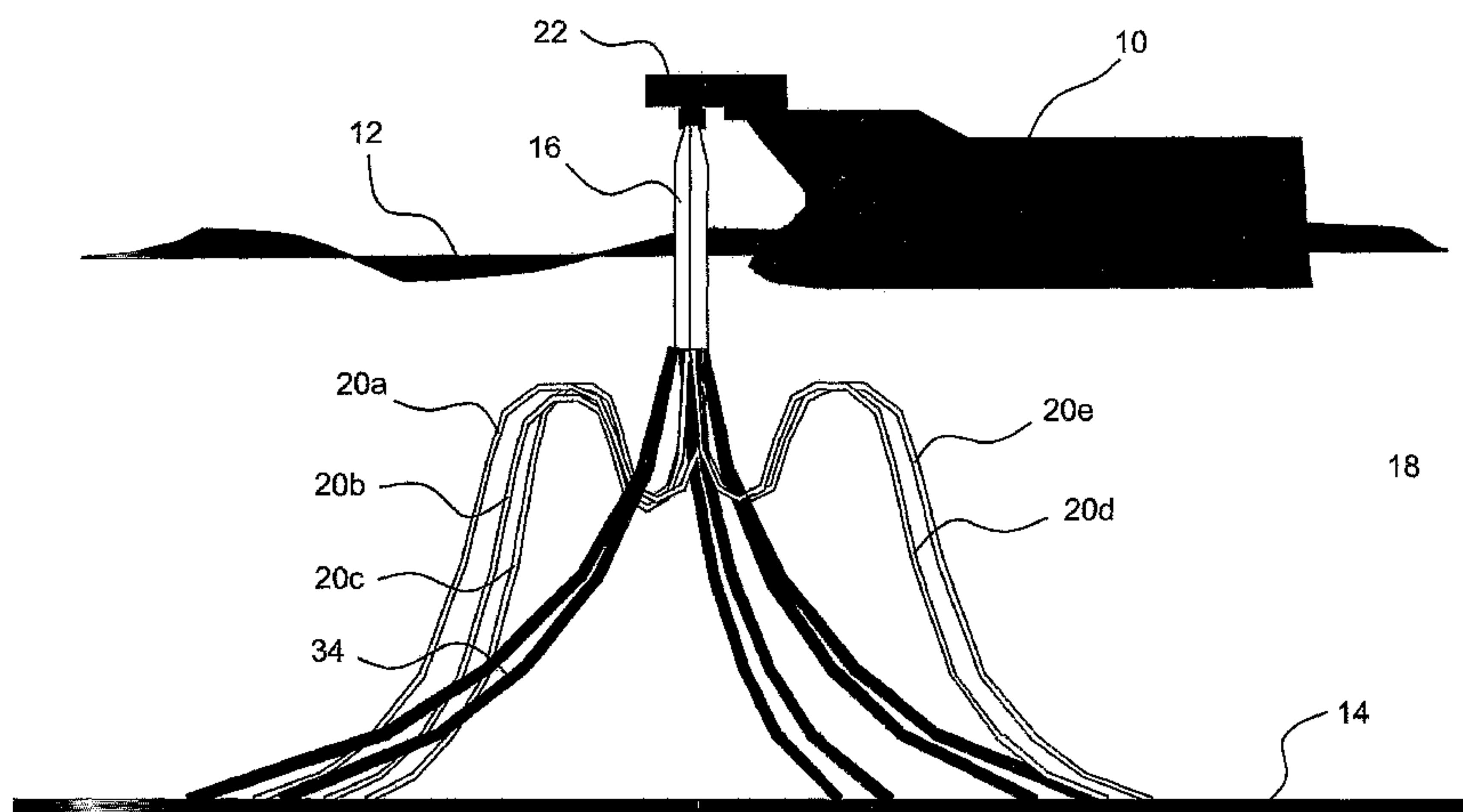
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(54) Title: OFFSHORE VESSEL MOORING AND RISER INBOARDING SYSTEM



(57) Abstract: There is disclosed an offshore vessel mooring and riser inboarding system (12) for a vessel (10) such as an FPSO or FSO. In one embodiment, the system comprises a first mooring element (16) adapted to be located in an offshore environment (18); a riser (20) adapted to be coupled to the first mooring element; a connector assembly (22) adapted to be mounted on the vessel, the connector assembly comprising a second mooring element (28); and a transfer line (32) adapted to be coupled to the riser; wherein the first and second mooring elements are adapted to be connected to facilitate coupling of the riser and the transfer line; and wherein the connector assembly is adapted to permit relative rotation between the vessel and the first mooring element about three mutually perpendicular axes of rotation. This facilitates weathervaning of the vessel relative to the first mooring element, as well as pitch, roll, heave and surge, under applied wind, wave and/or tidal forces.

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1 Offshore vessel mooring and riser inboarding system

2
3 The present invention relates to an offshore vessel
4 mooring and riser inboarding system, and to a method of
5 mooring a vessel in an offshore environment. In
6 particular, but not exclusively, the present invention
7 relates to an offshore mooring and riser inboarding
8 system for a vessel such as a Floating Production Storage
9 and Offloading Vessel (FPSO) or a Floating Storage and
10 Offloading Vessel (FSO), and to a method of mooring a
11 vessel in an offshore environment.

12
13 In the oil and gas exploration and production industry,
14 well fluids (oil and gas) from offshore oil wells can be
15 transported to shore by submarine pipelines, laid on the
16 seabed. However, installing submarine pipelines involves
17 the use of dedicated pipelaying vessels, with a very
18 large associated capital expenditure, and the use of such
19 pipelines is therefore only commercially viable in
20 limited circumstances. As a result, the exploitation of
21 oil and gas fields in certain areas, particularly those
22 far offshore or in deep water locations, has been shown

1 in the past to be of such marginal value that it has not
2 been worth extracting the available oil and gas reserves.

3
4 To address this problem, there have been movements in the
5 industry towards the exploitation of offshore oil and gas
6 fields by the use of FPSOs or FSOs. An FPSO is moored in
7 an offshore location and is typically coupled to a number
8 of producing wells, for the temporary storage of produced
9 well fluids, which are periodically exported to shore by
10 tankers. FPSOs typically include facilities for
11 separating recovered well fluids into different
12 constituents (oil, gas and water), so as to stabilise the
13 crude oil for onward transport by tanker. FSOs are
14 similarly moored and allow for the storage of recovered
15 well fluids, and may either be disconnected from their
16 moorings for travel to an offloading location, or the
17 recovered fluids may similarly be exported by tanker. In
18 contrast to FPSOs, however, FSOs do not have the facility
19 for separating the well fluids into different
20 constituents, and are therefore used in more limited
21 circumstances, typically for storage of stabilised, low
22 pressure crude.

23
24 Whilst some vessels are constructed and designed for
25 these purposes, many FPSOs and FSOs are conversions of
26 existing trading tankers. Converted vessels of this type
27 have usually functioned adequately, but there is a
28 continuing need for a substantial reduction in costs in
29 order to improve the economics of prospective development
30 and production of oil and gas fields, particularly those
31 which are currently deemed to be marginal.

1 Tankers used hitherto have often required extensive
2 conversion work to enable them to operate as an FPSO or
3 FSO. The extent of conversion work required depends upon
4 factors including the particular circumstances under
5 which the vessel is to be moored offshore.

6
7 A number of different systems have been developed for
8 mooring vessels such as FPSOs and FSOs. For example, in
9 one system, flowlines extend from the seabed to a mooring
10 assembly which includes a buoyant mooring node, which is
11 located just below the sea surface. The node is moored
12 to the seabed by a number of mooring chains, and the
13 flowlines extend from the seabed to the node. A vessel
14 such as an FPSO is coupled to the node by a chafe chain
15 anchored on the vessel forecastle, and the chafe chain
16 and the flowlines extend over a ramp on to the bow of the
17 vessel. Whilst the FPSO can weathervane around the sea
18 surface in the prevailing wind/tide, the degree of
19 movement permitted is limited (by the chafe chain and the
20 flowlines) to around one-and-a half rotations of the
21 vessel relative to the node in either rotational
22 direction; the vessel must then be either disconnected
23 and reset with the chain and flowlines in their original
24 positions, or rotated back to its median heading with the
25 aid of another vessel. Additional problems include that
26 the bow must be strengthened to accommodate loads
27 imparted by the chains and the flowlines, and that the
28 chain and the flowlines wear over time due to
29 scrubbing/chafing movement on the bow of the vessel.

30
31 In an alternative system, a buoyant canister is located
32 with a part above and a part below the sea surface. The
33 canister is moored to the seabed by a number of mooring

1 chains, which are connected to the canister, and the
2 canister is connected to a vessel such as an FPSO by a
3 cantilever frame on the FPSO. The frame is coupled to
4 the canister by a swivel, to permit weathervaning of the
5 vessel in the wind/tide, but is not free about the two
6 orthogonal axes. In use, the canister requires to be
7 maintained in a vertical orientation, to maintain
8 connection with the frame and to permit weathervaning.
9 Wind, wave and tidal loads on the FPSO are transmitted to
10 the canister through the frame, and can be extremely
11 large. For example, in the event of a storm surge force
12 acting on the vessel tending to move the vessel astern, a
13 large bending moment is generated at the canister head.
14 This is due to the distance between the location at which
15 the mooring chains are connected to the canister and the
16 location where the connecting frame is coupled to the
17 canister; this distance is dictated by a requirement to
18 ensure that the FPSO does not strike the mooring lines.
19 As a result, the connecting frame experiences large
20 forces and is therefore a relatively heavy, bulky
21 structure, adding to the complexity of a tanker
22 conversion for use as an FPSO, and to the overall weight
23 of the structure at the vessel bow. The canister
24 likewise has to be robust and heavy to sustain the large
25 bending moment.

26

27 Further systems involve the introduction of a rotating
28 turret into the hull of a vessel, which permits
29 engagement with a subsea buoy initially located below
30 surface. Installation of systems of this type involves
31 deep invasion into the structure of the vessel,
32 necessitating a substantial period in drydock. Such
33 systems are therefore relatively time-consuming and

1 costly to install. Furthermore, it is harder to achieve
2 connection of the vessel to systems of this type, as the
3 buoy must be below surface during approach of the vessel
4 on station above it.

5
6 All of the systems developed to date have therefore
7 suffered from a number of disadvantages, including: that
8 they do not allow the vessel to weathervane continuously
9 without restriction; that they have been difficult to
10 install and hook up in the field; that they have had an
11 uncertain ability to allow the vessel to disconnect
12 rapidly, reliably and safely from the risers; and that
13 they have had a relatively restricted seastate
14 capability. Systems employing a chafe chain coupled to a
15 subsea node have also been prone to the risk of local
16 combined tension-bending fatigue in the upper mooring
17 chain where it traverses a ramp or fairlead on its route
18 to a forecastle deck anchorage.

19
20 These problems apply in relation to the bringing inboard
21 of flow risers or lines (conduits for hydrocarbons or
22 other fluids), as well as to other risers or lines such
23 as power/control cables (for example, electrical lines
24 and hydraulic lines), and umbilicals.

25
26 It is amongst the objects of embodiments of the present
27 invention to obviate or mitigate at least one of the
28 foregoing disadvantages.

29

30

31

1 According to a first aspect of the present invention,
2 there is provided an offshore vessel mooring and riser
3 inboarding system, the system comprising:
4 a first mooring element adapted to be located in an
5 offshore environment;
6 a riser adapted to be coupled to the first mooring
7 element;
8 a connector assembly adapted to be mounted on a vessel,
9 the connector assembly comprising a second mooring
10 element; and
11 a transfer line adapted to be coupled to the riser;
12 wherein the first and second mooring elements are adapted
13 to be connected to facilitate coupling of the riser and
14 the transfer line;
15 and wherein the connector assembly is adapted to permit
16 relative rotation between the vessel and the first
17 mooring element about three mutually perpendicular axes
18 of rotation.
19

20 By permitting such relative rotation between the vessel
21 and the first mooring element, the present invention
22 facilitates movement of the vessel under external
23 loading, in use, and reduces forces transmitted to/borne
24 by the vessel and the mooring and riser system
25 components. Accordingly, the connector assembly of the
26 present invention may not be required to support the
27 relatively large loads found in prior art systems. In
28 addition, the system permits all likely ranges of
29 movement of the vessel relative to the first mooring
30 element without excessive wear or damage to components
31 either of the system or to the vessel itself. In
32 particular, the vessel is able to weathervane (that is,
33 to move in response to applied wind, wave and/or tidal

1 loads, to face a direction of the prevailing wind, waves
2 and/or tide), and to heave, pitch, roll, surge, sway and
3 yaw.

4
5 It will be understood that the three mutually
6 perpendicular axes of rotation may be taken about or with
7 reference to the first mooring element and may be taken
8 when the vessel is in a neutral or unloaded position.
9 Thus the first mooring element has three degrees of
10 freedom in its movement.

11
12 The riser may comprise or may take the form of a fluid
13 flow riser or flowline, which may be a conduit for
14 hydrocarbon containing fluids or other fluids.

15 Alternatively, the riser may comprise or may take the
16 form of a power and/or control cable, such as an
17 electrical and/or hydraulic cable. The riser may be an
18 umbilical comprising a flowline and one or more power
19 and/or control cable. The system may therefore permit
20 inboarding of any desired type of riser on to a vessel.
21 References herein to inboarding of a riser and to a riser
22 inboarding system are to the bringing inboard or onboard
23 of a riser to a vessel and to such a system.

24
25 Where the riser comprises or takes the form of a fluid
26 flow riser or flowline, the transfer line may be a
27 transfer flowline, and connection of the first and second
28 mooring elements may facilitate flow of fluid between the
29 fluid flow riser, the transfer flowline and the vessel.
30 The transfer flowline may be for the passage of fluid
31 from the fluid flow riser into the transfer flowline and
32 to the vessel, or vice-versa.

33

1 Where the riser comprises or takes the form of a power
2 and/or control cable, the transfer line may provide an
3 electrical and/or hydraulic and/or other connection to
4 the riser. This may facilitate power supply, data
5 transmission and/or supply of hydraulic control fluid.
6

7 Preferably, the connector assembly further comprises a
8 support adapted to be mounted on the vessel, and the
9 second mooring element may be adapted to be mounted for
10 movement relative to the support. The support may be a
11 cantilever support and may be a support frame or the
12 like. The support may be located extending beyond a bow
13 or stern of the vessel, or from the side of the vessel.
14 This may provide clearance for alignment and connection
15 of the first and second mooring elements.
16

17 Preferably also, the connector assembly further comprises
18 an outer gimbal member, which may be mounted for rotation
19 relative to a part of the connector assembly, in
20 particular, the support. The assembly may also comprise
21 an inner gimbal member mounted for rotation relative to
22 the outer gimbal member. Additionally, the assembly may
23 comprise a rotatable coupling for facilitating rotation
24 of the inner gimbal member relative to the first mooring
25 element. The rotatable coupling, inner gimbal member and
26 outer gimbal member together permit relative rotation
27 between the vessel and the first mooring element about
28 said axes of rotation.
29

30 The inner gimbal member may be rotatable about an inner
31 gimbal axis and the outer gimbal member about an outer

1 gimbal axis. The inner and outer gimbal member axes may
2 be disposed substantially perpendicular to one another.
3 This may facilitate relative rotation between the vessel
4 and the first mooring element about two of the three
5 mutually perpendicular axes of rotation.

6
7 The rotatable coupling may facilitate rotation between
8 the inner gimbal member and the second mooring element,
9 to thereby permit relative rotation between the vessel
10 and the first mooring element about one of the three axes
11 of rotation. The rotatable coupling may therefore be
12 provided between the inner gimbal member and the second
13 mooring element. Alternatively, the rotatable coupling
14 may facilitate rotation between the second mooring
15 element and the first mooring element, to permit such
16 rotation. The rotatable coupling may thus be provided
17 between the first and second mooring elements and may be
18 coupled to one of said elements. The rotatable coupling
19 may be a swivel and may comprise a rotary bearing, such
20 as a needle or roller bearing or a journal bearing of
21 special marine bearing material.

22
23 The inner and outer gimbal members may be annular rings
24 and the inner gimbal ring may be located within the outer
25 gimbal ring. In preferred embodiments, where the
26 connector assembly comprises a support adapted to be
27 mounted on the vessel, the outer gimbal member may be
28 rotatably mounted to the support and the inner gimbal
29 member may be rotatably mounted to the outer gimbal
30 member. Where the inner and outer gimbal members
31 comprise annular rings, the inner

1 gimbal ring may be mounted to the outer gimbal ring by
2 inner trunnions and the outer gimbal ring may be mounted
3 to the support by outer trunnions, the trunnions of the
4 inner gimbal ring disposed perpendicular to those of the
5 outer gimbal ring.

6
7 The connector assembly, in particular the support (which
8 may be a cantilever structure), may be releasably
9 mountable on the vessel. This may facilitate removal of
10 the connector assembly if required. This may be desired,
11 for example, where the connector assembly is provided on
12 a vessel such as a tanker converted for use as an FPSO or
13 FSO and it is desired to convert the vessel back for use
14 as a standard tanker.

15
16 Preferably, the first mooring element is buoyant and may
17 comprise or define a buoyant member. Alternatively, the
18 system may comprise a separate buoyant member, and the
19 first mounting element may be coupled indirectly to the
20 buoyant member by a chain or the like. The first mooring
21 element or the buoyant member may be generally tubular,
22 and may optionally be a cylindrical tubular, and may
23 define an internal passage for receiving the main riser.
24 This may serve both to guide the riser into engagement
25 with the first mooring element, and may also protect the
26 riser from damage, for example, by contact with the
27 vessel in storm conditions.

28
29 The first mooring element and/or the buoyant member may
30 be adapted to be located at surface prior to connection
31 of the first and second mooring elements together.
32 Accordingly, at least part of the first mooring element
33 may protrude above a sea surface level. Alternatively,

1 the entire first mooring element may be adapted to be
2 located below sea surface level. This may protect the
3 first mooring element and the riser from loading, such as
4 wind and wave loading. In this situation, the location
5 of the first mooring element/buoyant member may be
6 indicated by a marker buoy or the like.

7

8 The first mooring element may be adapted to be moored to
9 or relative to a seabed in the offshore environment by a
10 plurality of mooring lines. The mooring lines may be
11 catenary chains, mooring cables of wire or polymer rope
12 or other material, or a combination thereof. The mooring
13 lines may be adapted to bear loading of the vessel on the
14 first mooring element, to maintain the element on station
15 and/or to prevent or minimise transmission of loads to
16 the riser. The mooring lines may be coupled to or
17 adjacent to a lower end or portion of the first mooring
18 element. This may provide sufficient clearance between
19 the mooring lines and the hull of the vessel, in use,
20 when the first and second mooring elements are connected.

21

22 In embodiments of the invention, the system may be a
23 mooring and riser inboarding system for a dynamically
24 positionable vessel. As is known in the industry,
25 dynamically positioned (DP) vessels are capable of
26 maintaining their geographical position through a control
27 system which includes a number of thrusters spaced around
28 the hull of the vessel. Where the system is designed for
29 use with such a vessel, it may not be necessary to moor
30 the first mooring element to or relative to the seabed,
31 as the mooring element does not require to maintain the
32 vessel on station. In these circumstances, the riser may
33 bear the relatively minor loading experienced by the

1 first mooring element due to, for example, wind, wave and
2 tidal forces.

3

4 The first and second mooring elements may comprise or may
5 define first and second connector elements, respectively,
6 and may be adapted to be coupled together in a quick-
7 connect and disconnect arrangement. This may facilitate
8 alignment, connection and disconnection of the first and
9 second connector elements, in use. One of the first and
10 second mooring elements may comprise a male member and
11 the other a female member, the female member adapted to
12 receive the male member for engagement of the elements.
13 The connector assembly may comprise a locking arrangement
14 for locking the first and second mooring elements
15 together. The locking arrangement may comprise at least
16 one latch, locking dog or pin, which may be adapted to
17 provide a releasable locking engagement between the first
18 and second mooring elements.

19

20 The connector assembly may comprise an intermediate
21 connector for coupling the first and second mooring
22 elements together. The intermediate connector may be
23 secured to the first mooring element and thus may be
24 provided as part of the first mooring element, and may be
25 adapted to be releasably coupled to the second mooring
26 element. However, the intermediate connector may also be
27 releasably connected to the first mooring element. The
28 intermediate connector may also be adapted to support the
29 riser, and may define a riser hang-off unit. Releasably
30 securing the riser hang-off unit to the first mooring
31 element may facilitate access to the risers for
32 maintenance. The connector assembly may comprise a

1 jacking assembly or device, for selectively separating
2 the first and second mooring elements by a desired or
3 suitable distance.

4
5 Preferably, the system comprises a plurality of risers
6 and a corresponding plurality of transfer lines. Each
7 transfer line may be associated with a corresponding
8 riser. Alternatively, a single transfer line may be
9 associated with a plurality of risers. Where the riser
10 is a fluid flow riser, each riser may be coupled to or
11 associated with a separate well, for the flow of well
12 fluids comprising oil and/or gas to the vessel.

13
14 The/each transfer line may be coupled to the/each
15 respective riser through a rotatable line coupling such
16 as a swivel or the like, which may be provided as part of
17 or coupled to the second mooring element. This may
18 facilitate weathervaning of the vessel whilst maintaining
19 connection between the riser and the transfer line.

20
21 Preferably, the connector assembly permits unlimited
22 rotation between the vessel and the first mooring element
23 about one of said axes of rotation, which may be a
24 vertical or Y-axis. This may facilitate full
25 weathervaning of the vessel around the first mooring
26 element. Rotation between the vessel and the first
27 mooring element about the other two of said axes of
28 rotation may be restricted depending upon dimensions of
29 the connector assembly, and in particular, by dimensions
30 of the inner and outer gimbal member. However, rotation
31 of at least up to 60 degrees from a neutral position
32 about the other two of said axes may be permitted,
33 providing up to 120 degrees total permissible rotation.

1 The system may comprise a device for adjusting a position
2 or orientation of the second mooring element relative to
3 the first mooring element, to facilitate connection of
4 the first and second mooring elements. In particular,
5 where the connector assembly comprises a rotatable
6 coupling and inner and outer gimbal members, the system
7 may comprise a device for adjusting a rotational position
8 of the outer gimbal member relative to the support;
9 and/or of the inner gimbal member relative to the outer
10 gimbal member; and/or a rotational orientation of the
11 first and second mooring elements.

12

13 The present invention may facilitate flow of well fluids
14 from a riser in the form of a fluid flowline through a
15 transfer flowline to a vessel. Additionally or
16 alternatively, the invention may be utilised in
17 circumstances where it is desired to offload fluid from
18 the vessel through the transfer flowline and into the
19 main flowline. This may facilitate discharge of fluid
20 carried by the vessel into a well, such as in order to
21 stimulate production, and/or to supply well fluids from
22 the vessel into a storage or transfer system, for
23 subsequent transfer to an alternative location.

24 References herein to transfer of fluid between the main
25 flowline, the transfer flowline and the vessel should
26 therefore be interpreted accordingly.

27

28 According to a second aspect of the present invention,
29 there is provided a method of mooring a vessel in an
30 offshore environment, the method comprising the steps of:
31 locating a first mooring element in an offshore
32 environment;
33 coupling a riser to the first mooring element;

1 connecting a second mooring element of a connector
2 assembly mounted on a vessel to the first mooring
3 element, such that relative rotation between the vessel
4 and the first mooring element about three mutually
5 perpendicular axes of rotation is permitted;
6 coupling a transfer line between the vessel and the
7 second mooring element; and
8 connecting the transfer line to the riser.

9
10 The method may comprise coupling a fluid flow riser to
11 the first mooring element, and coupling a transfer
12 flowline to the second mooring element. Following
13 connection of the transfer flowline to the fluid flow
14 riser, the method may comprise transferring fluid between
15 the fluid flow riser, the transfer flowline and the
16 vessel.

17
18 Further features of the method are defined above in
19 relation to the first aspect of the invention.

20
21 According to a third aspect of the present invention,
22 there is provided an offshore vessel mooring and riser
23 inboarding system, the system comprising:
24 a first mooring element adapted to be located in an
25 offshore environment;
26 at least one riser adapted to be coupled to the first
27 mooring element;
28 a support adapted to be mounted on a vessel;
29 an outer gimbal member mounted for rotation relative to
30 the support;
31 an inner gimbal member mounted for rotation relative to
32 the outer gimbal member;

1 a second mooring element adapted for connection to the
2 first mooring element;
3 a rotatable coupling for facilitating rotation of the
4 inner gimbal member relative to the first mooring
5 element; and
6 at least one transfer line adapted to be coupled between
7 the vessel and the second mooring element;
8 wherein, in use, the first and second mooring elements
9 are adapted to be connected to couple the transfer line
10 to the riser;
11 and wherein the rotatable coupling, the inner gimbal
12 member and the outer gimbal member together permit
13 rotation of the vessel relative to the first mooring
14 element.
15
16 There may be three degrees of freedom in movement of the
17 vessel relative to the first mooring element provided by
18 the inner and outer gimbal members and the rotatable
19 coupling.
20
21 According to a fourth aspect of the present invention,
22 there is provided a freely weathervaning bow or stern or
23 side mooring and riser inboarding system comprising:
24
25 means for mooring an offtake tanker or buffer tanker or
26 FPSO to the seabed and one or more fluid flowline and/or
27 well control umbilical or electrical umbilical risers
28 connecting seabed facilities to the tanker or FPSO;
29
30 the mooring system comprising at least three chain or
31 rope or hybrid mooring lines with or without anchors,
32 each line being attached to padeyes at the lower end of a
33 cylindrical annular flotation canister, the upper end of

1 which is latched into a specially designed mooring swivel
2 suspended within a gimbal in a structural cantilever
3 projecting forward from the bow of the vessel at focsle
4 deck level or at the stern or other position off the
5 vessel's gunwale and being additionally supported by
6 structural members springing from the vessel hull
7 typically at focsle deck level or below;

8
9 the gimbal being so designed as to be capable of
10 accommodating an angular deviation of the flotation
11 canister axis relative to the intersection of the
12 sagittal and transom planes of the ship of plus or minus
13 60 degrees in any direction arising as a result of the
14 first and second order motions of the ship subject only
15 to the constraint of avoidance of interference with the
16 bulbous bow;

17
18 each fluid flowline and umbilical running from the
19 direction of the seabed well or subsea facility and
20 ascending as a riser in the configuration of a Lazy Wave
21 or other suitable shape and entering the lower end of the
22 annular flotation canister through polymer bend-
23 stiffeners attached to the lower end of the canister and
24 projecting below the canister and each flowline and
25 umbilical then ascending through the canister and through
26 the mooring swivel and gimbal to a hangoff frame above
27 and thence upwards via double-valved quick disconnects to
28 a multiple path swivel stack with its inner (geodetically
29 fixed azimuth) part standing on the upper part of the
30 quick disconnect assembly and riser hangoff unit within
31 the inner ring of the special mooring swivel and the
32 outer part of the multiple path swivel stack following
33 the azimuth of the vessel (the swivel stack may consist

1 of one single path swivel alone in applications where
2 there is only one fluid conduit riser and no umbilical);
3

4 the fluid and electrical conduits from the outer part of
5 the swivel stack passing down between the middle and
6 inner gimbal rings in the form of catenary jumpers
7 terminating at the vessel's pipework and cabling at a
8 hangoff location on the stem of the vessel typically
9 between main deck and focsle deck level whence the fluid
10 conduits proceed to Emergency Shutdown Valves (ESDs) and
11 a manifold inboard;
12

13 the multiple path swivel stack being shielded from the
14 weather within a protective housing mounted on the outer
15 ring of the mooring swivel so as to enable servicing and
16 maintenance work on the stack to be performed
17 conveniently and safely;
18

19 the riser hangoff frame being an integral part of a
20 specially designed Riser Hangoff Unit (RHU) incorporating
21 at its upper end the lower part of the multiple path
22 fluid conduit and electrical conduit quick disconnect
23 assembly (QDC) including the lower valve set and
24 incorporating at its lower end a specially designed
25 Latching Can (LC) containing the two sets of latches
26 which respectively lock the RHU into the flotation
27 canister and lock the whole of the RHU-cum-flotation-
28 canister assembly into the inner ring of the mooring
29 swivel;
30

31 the RHU being capable of being broken (unbolted) just
32 above the LC and the upper part of it together with QDC
33 and swivel stack being jacked up so as to provide access

1 above the LC for work in connection with initial pull-in
2 and attachment of the risers and any subsequent changeout
3 of the risers;

4
5 the vessel being able to abandon the mooring by
6 activating the QDC and then releasing the flotation
7 canister with the RHU still locked into it and the
8 buoyancy of the flotation canister being such as to
9 ensure that the head of the canister and the RHU remain
10 above water level all abandonment functions being
11 controlled remotely from the bridge of the vessel without
12 any requirement for crew members to be present on or near
13 the devices comprising the invention or the focus area
14 as a whole;

15
16 the mooring swivel incorporating a rotational indexing
17 motor or device to enable the inner part of the mooring
18 swivel together with the QDC assembly and the inner part
19 of the multiple path swivel stack to be rotated to the
20 appropriate geodetic azimuth for recovery of the canister
21 and RHU regardless of the azimuth of the vessel;

22
23 a pair of winches being mounted in the cylindrical space
24 between the upper part of the QDC and the swivel stack
25 with the winch lines running down through the QDC for
26 attachment to the head of the RHU on the floating
27 canister (by crew standing on the structure hanging from
28 the inner ring of the mooring swivel) as the vessel
29 approaches for pickup and reconnection so that the
30 canister can then be pulled towards the vessel and the
31 vessel towards the canister with the gimbal automatically
32 coming into appropriate alignment for mating and
33 latching;

1

2 the hydraulic supply to the QDC and to the latches in the
3 LC being routed from the vessel via fluid path swivels in
4 the swivel stack and the locks and hydraulic circuitry
5 and controls being designed so as to provide appropriate
6 functional interlocks and fail-safe behaviour.

7

8 In a further aspect of the present invention, there is
9 provided a connector assembly as defined in the attached
10 claims. Further features of the connector assembly are
11 defined above.

12

13 Embodiments of the present invention will now be
14 described, by way of example only, with reference to the
15 accompanying drawings, in which:

16

17 Fig 1 is a schematic side view of a vessel shown
18 moored to an offshore mooring and riser inboarding
19 system in accordance with a preferred embodiment of
20 the present invention;

21

22 Fig 2 is an enlarged, perspective view of the system
23 and a bow of the vessel shown in Fig 1;

24

25 Fig 3 is an enlarged, partial cross-sectional view
26 of part of a first mooring element, and part of a
27 connector assembly comprising a second mooring
28 element, of the system shown in Fig 1;

29

30 Fig 4 is a view of the complete first mooring
31 element of the system shown in Fig 1;

32

1 Fig 5 is a cross-sectional view of the first mooring
2 element taking about the line A-A of Fig 4;

3
4 Fig 6 is an enlarged view of part of the system
5 shown in Fig 1, taken from the other side, and
6 illustrated when the vessel experiences a large
7 surge force in an astern direction;

8
9 Fig 7 is an enlarged front view of part of the
10 system shown in Fig 1, illustrated when the vessel
11 experiences a large force in a thwartship direction;

12
13 Fig 8 is an enlarged view of part of a locking
14 assembly and a riser take-off unit of the system
15 shown in Fig 1;

16
17 Fig 9 is a schematic cross-sectional view of the
18 first mooring element of the system shown in Fig 1,
19 taken at a location where it abuts a riser hang-off
20 of the system;

21
22 Figs 10 to 13 are views illustrating the steps in a
23 method of connecting the first and second mooring
24 elements of the system shown in Fig 1 together;

25
26 Fig 14 is an enlarged view of a bottom part of the
27 first mooring element shown in Fig 4;

28
29 Fig 15 is a view illustrating part of the system of
30 Fig 1 during riser installation, changeout, or
31 inspection and maintenance;

32

1 Fig 16 is a view illustrating part of the system
2 during a maintenance procedure;

3
4 Fig 17 is a perspective view of a vessel shown
5 moored to an offshore mooring and flowline system in
6 accordance with an alternative embodiment of the
7 present invention;

8
9 Fig 18 is a side view of a bow of a vessel shown
10 moored to an offshore mooring and flowline system in
11 accordance with a further alternative embodiment of
12 the present invention;

13
14 Fig 19 is a view of the system of Fig 18 prior to
15 connection of first and second mooring elements of
16 the system together or after disconnection;

17
18 Fig 20 is a side view of a bow of a vessel shown
19 moored to an offshore mooring and flowline system in
20 accordance with a still further alternative
21 embodiment of the present invention; and

22
23 Fig 21 is a view of the system of Fig 20 prior to
24 connection of first and second mooring elements of
25 the system together.

26
27 Turning firstly to Fig 1, there is shown a schematic side
28 view of a vessel 10, the vessel 10 shown moored to an
29 offshore mooring and riser inboarding system in
30 accordance with a preferred embodiment of the present
31 invention, the system indicated generally by reference
32 numeral 12. The system 12 is shown in more detail in the
33 enlarged, perspective view of Fig 2 and in Fig 3, which

1 is an enlarged, partial cross-sectional view of part of
2 the system 12 shown in Fig 1.
3
4 The vessel 10 may take the form of an FPSO, FSO, an
5 off-take tanker or a buffer tanker, and is shown in the
6 figures moored to a seabed 14 by the system 12, for the
7 transfer of well fluids such as oil or gas to the vessel
8 10. The system 12 comprises a first mooring element in
9 the form of a flotation canister 16, which is shown
10 separately in Fig 4 and in the cross-sectional view of
11 Fig 5, which is taken about line A-A of Fig 4. As shown
12 in Fig 1, the flotation canister 16 is located in an
13 offshore environment 18, such as a sea or ocean. The
14 system 12 also comprises at least one and, in the
15 illustrated, preferred embodiment, a number of risers,
16 five of which are shown in Fig 1 and given the reference
17 numerals 20a to 20e. The risers 20a to 20e take the form
18 of fluid flow risers or flowlines and extend from the
19 seabed 14 into the flotation canister 16. The inherent
20 buoyancy of the main fluid flowlines 20a to 20e is
21 utilised to arrange the lines in a "lazy wave"
22 configuration, which reduces loading on the flowlines and
23 allows for movement of the flotation canister 16 without
24 transferring excessive loading on to the flow lines 20a
25 to 20e. However, the canister 16 includes buoyancy
26 chambers 17 and is thus inherently buoyant, to support
27 the risers 20. It will be understood that any other
28 alternative configuration of the flowlines 20a to 20e may
29 be employed. Each of the main fluid flowlines 20a to 20e
30 extend from a respective subsea wellhead (not shown) or
31 pumping facility provided on the seabed 14 (not shown),
32 for supplying well fluids through the respective main
33 flowline 20 to the vessel 10.

1
2 The system also comprises a connector assembly 22 which
3 includes a support in the form of a frame 24 which is
4 mounted on a bow 26 of the vessel 10 on the forecastle 27
5 as best shown in Fig 2. The connector assembly includes
6 a second mooring element of the system 12, which is
7 indicated generally by reference numeral 28. The second
8 mooring element 28 forms a second connector for coupling
9 to a first connector defined by a neck 30 of the
10 flotation canister 16.

11
12 The system 12 also comprises at least one and, in the
13 illustrated, preferred embodiment, a number of transfer
14 lines, six of which are shown and given the reference
15 numerals 32a to 32e, each of which corresponds to a
16 respective riser 20. The transfer flowlines are provided
17 as catenary jumpers 32a to 32e, and are each coupled
18 between the vessel 10 and the second connector 28, and
19 serve for transfer of fluid through the respective riser
20 20 to the vessel 10 when the second connector 28 is
21 coupled to the flotation canister 16, as will be
22 described in more detail below.

23
24 The flotation canister 16 is moored in the offshore
25 environment 18 by a number of mooring lines 34, which are
26 coupled to padeyes on the canister 16. As shown in Fig
27 2, there may be three such mooring lines 34a to 34c and
28 the mooring lines may be catenary chains, cables, wires
29 or a combination thereof. As will be understood by
30 persons skilled in the art, selection of the appropriate
31 mooring line 34 depends upon factors including water
32 depth in the offshore environment 18. In the illustrated
33 embodiment, however, catenary chains 34a to 34c are

1 employed, which are anchored to the seabed 14 and serve
2 for maintaining position of the flotation canister 16
3 within accepted tolerances, and for supporting loading
4 transmitted to the canister 16 by the vessel 10, in use.

5
6 As will be described in more detail below, the connector
7 assembly 22 permits a relative rotation between the
8 vessel 10 and the flotation canister 16 about three
9 mutually perpendicular axes of rotation X, Y and Z, as
10 shown in Fig 2. The axes X and Z are in a horizontal
11 plane and are perpendicular to one another. The Y axis
12 is in a vertical plane and is perpendicular to both the X
13 and Z axes. In a neutral position of the system 12,
14 where the flotation canister 16 is vertically oriented
15 and assuming no external loading on the vessel 10, the X
16 axis is parallel to a main, longitudinal or sagittal axis
17 of the vessel 10; the Y axis is parallel to a main,
18 longitudinal axis of the flotation canister 16; and the Z
19 axis is parallel to a transom or transverse plane of the
20 vessel 10.

21
22 By this arrangement, the vessel 10 may weathervane
23 according to the prevailing wind, wave and/or tide where
24 the vessel is turned to face the direction of applied
25 loading, by rotation about the Y axis. Additionally, the
26 connector assembly 22 permits an angular deviation
27 between the vessel 10 and the flotation canister 16 of up
28 to 60 degrees astern and 15 degrees forward from the
29 neutral position of Fig 2 about the Z axis, as shown in
30 Fig 6, which is an enlarged view of the system 12 shown
31 when the vessel 10 experiences a large surge force in an
32 astern direction. It will be noted that certain
33 components of the system 12 have been omitted from Fig 6,

1 for ease of illustration. Relative rotation between the
2 vessel 10 and the flotation canister 16 about the X axis
3 is shown in Fig 7, where the vessel 10 is experiencing a
4 large thwartship force derived from the combination of,
5 for example, low frequency yaw and sway and wave
6 frequency roll. The relative dimensions of the system 12
7 and in particular of the connector assembly 22 are such
8 that unlimited rotation of the vessel 10 in a path around
9 a circumference of the flotation canister 16 is possible
10 (about the Y axis). Additionally, these dimensions are
11 such that an angular misalignment of up to 60 degrees
12 from the vertical is possible in any other direction, as
13 shown in Figs 6 and 7, subject only to the constraint of
14 avoiding interference with the bulbous bow. Thus a total
15 relative movement of up to about 75 degrees about the Z
16 axis is possible (60 degrees during surge astern and
17 about 15 degrees during surge forward) and of up to 120
18 degrees about the X axis. The canister 16 includes
19 bumper strips 21 which prevent damage to the canister
20 through accidental contact with the vessel bow 26.

21

22 The system 12 therefore facilitates vessel mooring and
23 riser inboarding even where the vessel experiences
24 extremes of loading due to wind, wave and/or tidal
25 forces.

26

27 The structure and method of operation of the system 12
28 will now be described in more detail, with reference also
29 to Figs 8 to 17.

30

31 As best shown in Figs 2 and 3, the support frame 24
32 includes outer support arms 36 and 38 by which the second
33 connector 28 is suspended from the vessel 10. The

1 connector assembly 22 includes an outer gimbal member in
2 the form of an outer gimbal ring 40, which is rotatably
3 mounted between the outer support arms 36 and 38 by
4 trunnions 42. The connector assembly 22 also includes an
5 inner gimbal member in the form of an inner gimbal ring
6 44, which is rotatably mounted to the outer gimbal ring
7 40 by trunnions 46, which are best shown in Fig 6. The
8 trunnions 42 and 46 are disposed on axes which are
9 perpendicular to one another, such that respective axes
10 of rotation of the outer and inner gimbal rings 40 and 44
11 are also perpendicular.
12

13 An inner flanged swivel ring 48 is mounted and suspended
14 from the inner gimbal ring 44, and the inner gimbal ring
15 44 and inner swivel ring 48 together define a swivel 50.
16 This facilitates rotation between the inner gimbal ring
17 44 and the inner swivel ring 48, via suitable bearings
18 (not shown). An integral structure in the form of a
19 lower housing 52 is coupled to and extends downwardly
20 from the inner swivel ring 48, and the second connector
21 28 is coupled to the inner swivel ring 48 and extends
22 along the lower housing 52 and is thus suspended from the
23 inner gimbal ring 44.
24

25 The outer gimbal ring 40 facilitates angular displacement
26 between the vessel 10 and the flotation canister 16 in
27 the fore and aft directions, as illustrated in Fig 6, by
28 rotation about the outer support arms 36 and 38 on the
29 trunnions 42. In a similar fashion, the inner gimbal
30 ring 44 permits annular displacement between the vessel
31 10 and the flotation canister 16 in the thwartship
32 direction of Fig 7, by rotation of the inner gimbal ring

1 44 relative to the outer gimbal ring 40 on the trunnions
2 46.

3
4 The second connector 28 includes a housing 54 which is
5 located within and secured relative to the inner swivel
6 ring 48. The second connector 28 includes a locking
7 mechanism 56 which forms an upper part of a quick
8 disconnect (QDC) 58, which is also shown in Fig 8. A
9 lower part 63 of the QDC 58 forms part of a riser hang
10 off unit (RHU) 60, which also includes a latching can 61
11 that is secured to the canister neck 30 by latches 62a.
12 The RHU 60 supports the risers 20, which extend upwardly
13 through a central shaft 64 of the canister 16, and
14 includes a latching can. The RHU 60 is normally
15 permanently latched into the head or neck 30 of the
16 canister 16 and constitutes an integral part of the
17 canister.

18
19 Fig 9 illustrates flow risers 20a to 20f in cross-section
20 at the interface between the canister 16 and the QDC 58.
21 Fig 9 also illustrates hydraulic and electrical umbilical
22 cores 66 and shows QDC valve and latch actuator hydraulic
23 cores 68, which are used to control operation of the QDC
24 58.

25
26 As shown in Fig 8, the housing 54 of the second connector
27 28 carries a multiple path swivel stack 70, which
28 includes a number of primary fluid swivels 72a to 72f,
29 each associated with a respective riser 20 and jumper 32.
30 The primary fluid swivels 72 provide fluid connection
31 between a riser 20 and the respective jumper 32, and
32 facilitates unlimited rotation of the vessel 10 about the
33 canister 16 whilst maintaining fluid flow. Connectors

1 may extend between the swivels 72 and the risers 20. A
2 secondary swivel assembly 74 is provided above or below
3 the primary fluid swivels 72, and provides for canister
4 to mooring swivel latch actuation; QDC valve actuation;
5 QDC release actuation; umbilical hydraulic line
6 connection; hydraulic core 68 connection; and connection
7 to other ancillary equipment. An optional methanol line
8 76 and electrical slipring box 78, for handling the
9 umbilical power and signal cores 68, is also shown in Fig
10 8. The housing 54 contains piping extending from the QDC
11 58 to the swivel stack 70 and pull-in winches (not
12 shown), which are used during connection, as will be
13 described below.

14
15 Turning now to Figs 10 to 13, the method of connection of
16 the second connector 28 to the flotation canister 16 will
17 now be described. In Fig 10, the vessel 10 is shown
18 approaching the canister 16, which is shown with the RHU
19 60 latched to the canister neck 30 by latches 62b. A
20 protective cover 80 is also shown in place on the RHU 60.
21 A connector line 82 is coupled to the cap 80 and is
22 marked by a buoy 84. When it is desired to mate the
23 second connector 28 with the flotation canister 16, a
24 winch line 86 is hooked on to the connector line 82, as
25 shown in Fig 10. The connector line 82 is then reeled-
26 in, as shown in Fig 11, and bears against a lower end of
27 the lower housing 52, rotating the connector assembly 22
28 about the support arms 36 and 38 by the outer gimbal ring
29 40. Automatic alignment of the swivel 50 and the
30 canister head of the RHU 60 is assured during pull-in by
31 the two angular degrees of freedom of the gimbals 40, 44
32 and two degrees of freedom of the canister 16.

1 When the canister 16 is picked up, it is important that
2 the azimuth of the riser array and lower part of the QDC
3 assembly 58 around the central axis of the stack match
4 with the azimuth of riser connections on the underside of
5 the upper part of the QDC assembly 58. Final adjustment
6 can be achieved with the aid of simple mechanical
7 guides(not shown), but the azimuths must first be brought
8 into approximate alignment using an indexing system (not
9 shown). This is done by fitting a gear ring in the
10 around the stack at a convenient level, such as in the
11 swivel 50, with an associated hydraulic motor and
12 gearbox. An operator with a remote (wandering lead)
13 control box stands in a position where he can observe the
14 RHU 60 and canister 16 approaching and turns the stack so
15 as to match the azimuths of the upper and lower parts.

16
17 Accordingly, the second connector 28 is rotated to align
18 it with the RHU 60, by rotating the swivel 50 the
19 indexing system. Further reeling-in then draws the RHU
20 60 into an internal passage 88 defined by the lower
21 housing 52, as shown in Fig 12, and the vessel 10 is then
22 moved forwards to position on station with the canister
23 16 in a vertical orientation, as shown in Fig 13. The
24 canister 16 is supported and the cap 80 removed,
25 following which the canister 16 is drawn up and the
26 locking mechanism 56 is operated to engage an upper ring
27 90 of the RHU, as shown in Fig 3. The lower latches 62a
28 are also actuated to engage the lower housing 52, and the
29 canister 16 is locked and supported 16 within the housing
30 28 and is ready for operation.

31
32 Following connection and appropriate testing of integrity
33 of the system 12, fluid communication between the risers

1 20 and the vessel 10, through the primary fluid swivels
2 72 and jumpers 32, may commence. The outer gimbal ring
3 40, inner gimbal ring 44 and swivel 50 permit a full
4 range of motion of the vessel under wind, wave and tidal
5 loading, including any combination of pitch, heave, roll,
6 surge, sway and yaw and also weathervaning (a particular
7 manifestation of yaw), without requiring disconnect from
8 the flotation canister 16. Movement of the canister 16
9 under load, as illustrated for example in Figs 6 and 7,
10 causes a degree of flexing in the risers 20 where they
11 enter the canister 16. Accordingly, as shown in Fig 14,
12 which is an enlarged view of a lower part of the
13 flotation canister 16, bend stiffeners 92 are provided
14 around the risers 20; two such bend stiffeners 92a and
15 92b are shown on the risers 20a and 20b. These provide
16 protection for the risers 20 against damage through
17 contact with the canister 16.

18
19 When it is desired to abandon connection with the
20 flotation canister 16, a controlled abandonment may be
21 carried out in fair weather. This is achieved by
22 releasing the locking mechanism 56 and the latches 62a
23 and lowering the canister 16 to the position of Fig 13.
24 This provides a space 94 facilitating access to re-secure
25 the protective cover 80 and connector line. The RHU 60
26 is then lowered out of the lower housing 52. The
27 connector line 86 can then be disconnected and the vessel
28 10 may move away from the location of the canister 16,
29 for example, for passage to discharge location or if it
30 is desired to abandon the oil/gas field. However, in
31 certain circumstances, such as in an emergency
32 abandonment or in a heavy seaway, no crew are allowed in

1 the vicinity and the RHU 60 may be released without a
2 protective cover.

3
4 Fig 15 illustrates an optional maintenance procedure,
5 where the locking mechanism 56 is released and a jack
6 assembly 89 actuated. This carries the housing 54
7 upwardly, to provide a space 94 for access to the RHU 60.

8
9 In other circumstances, it may be desired or required to
10 access the RHU 60, to carry out maintenance work, such as
11 on supports for the risers 20 or to carry out riser
12 installation/changeout. To enable this, the latch
13 elements 62a are operated to release a lower ring 96 of
14 the RHU 60, and the jack assembly 89 is actuated to carry
15 the second connector housing 54 and the RHU 60 upwardly,
16 to provide a space 98 for access to the inside of the RHU
17 60 and the risers 20, as shown in Fig 16.

18
19 Indeed, Fig 16 also illustrates first connection of the
20 FPSO 10 to the canister 16; the canister 16 (without the
21 RHU 60) and its moorings 34 are installed before the FPSO
22 10 arrives at the field. The risers 20 are likewise
23 installed before FPSO 10 arrival and are buoyed off.
24 The RHU is installed on the FPSO 10 at the dockyard.
25 The upper part of the RHU 60 is the lower part of the QDC
26 58 and the QDC 58 is locked in a connected mode. When
27 the FPSO 10 arrives on site, the canister 16 is picked up
28 and latched in, the bottom of the RHU 60 is latched into
29 it, the RHU 60 unbolted at the intermediate level, and
30 the whole stack from this unbolted level upwards is
31 jacked up to give access for riser connection to riser
32 hangoff flanges. A pickup winch line 82 (or the line of
33 a temporary small service crane) is deployed, taken down

1 through the canister 16 core, brought backup to the
2 surface, and connected to the first riser 20a, which will
3 have been raised to the surface and disconnected from the
4 temporary buoy. This activity requires the assistance of
5 another vessel; riser installation and replacement are
6 rare events. The assisting vessel then lowers the top of
7 the riser 20a until it is below the canister 16 and the
8 weight of the riser 20a is transferred to the pull-in
9 line 82. The riser 20a is then pulled up and the
10 hangoff flange is bolted up. This requires good access
11 for Hydratight(TM) bolting equipment and the operators,
12 hence the need to break the RHU 60 and jack it apart.
13 This process is repeated for each of the risers 20.

14

15 Turning now to Fig 17, there is shown a perspective view
16 of a vessel 110 shown moored to an offshore mooring and
17 flowline system in accordance with an alternative
18 embodiment of the present invention, the system indicated
19 generally by reference numeral 112. The system 112 is
20 essentially similar to the system 12 shown in Figs 1 to
21 16, and like components share the same reference numerals
22 incremented by 100. The vessel 110 may be a similar
23 vessel to that described above in relation to Figs 1 to
24 16, but will typically be an FSO. The system 112 differs
25 from the system 12 in that it includes only a single
26 riser 120 and associated jumper 132, and therefore does
27 not require the multiple path swivel stack 70 of the
28 system 12. Additionally, with only a single riser 20, an
29 indexing system may not be required.

30

31 Turning now to Fig 18, there is shown a side view of a
32 bow 226 of a vessel 210 shown moored to an offshore
33 mooring and riser inboarding system in accordance with a

1 further alternative embodiment of the present invention,
2 the system indicated generally by reference numeral 212.
3 The system 212 is essentially similar to the system 12
4 shown in Figs 1 to 16, and like components share the same
5 reference numerals incremented by 200. The vessel 210
6 shown in Fig 18 is a DP vessel such as an FPSO, and
7 includes thrusters (not shown) for maintaining the vessel
8 in a fixed geographical location. This enables the
9 vessel 210 to remain on station, that is, in the vicinity
10 of a buoy 216 forming a first mooring element of the
11 system 212. As the vessel 210 is dynamically positioned,
12 it is not necessary for the buoy 216 to be moored
13 relative to the seabed 14 by heavy mooring lines such as
14 the catenaries 34; this is because the buoy 216 does not
15 need to transmit loads experienced by the vessel 210 due
16 to the prevailing wind, wave or tide to the seabed 14.
17 Accordingly, risers 220 are able to maintain the buoy 216
18 approximately on station. However, the indexing system
19 may be utilised to account for friction in a swivel of
20 the system 212; the indexing system may be activated to
21 maintain a rotational position (about the Y axis) of the
22 buoy 216. This ensures that the lower assembly does not
23 turn with the weathervaning FPSO 210, which could result
24 in the risers 220 twisting about each other and the
25 individual risers 220 being subjected to excessive,
26 detrimental twist. The risers 220 are thus maintained on
27 a constant geodetic azimuth. In this situation, the
28 indexing motor will be controlled automatically by a
29 system of gyrocompasses and a computer (not shown), with
30 a manual override for emergency situations.

31

32 As shown in Fig 19, which is a view prior to connection
33 of a second connector 218 to the buoy 216, the inherent

1 buoyancy of the buoy 216 is such that the buoy is
2 initially below the sea surface 19, and a marker buoy 284
3 indicates the location of the primary buoy 216. By
4 locating the buoy 216 below the sea surface 19, the buoy
5 is shielded from external loads at surface. The system
6 212 is otherwise of similar construction and operation to
7 the system 12 of Figs 1 to 16.

8

9 Turning now to Fig 20, there is shown a side view of a
10 bow 326 of a vessel 310 shown moored to an offshore
11 mooring and riser inboarding system in accordance with a
12 still further alternative embodiment of the present
13 invention, the system indicated generally by reference
14 numeral 312. The system 312 is essentially similar to
15 the system 12 shown in Figs 1 to 16, and like components
16 share the same reference numerals incremented by 300.
17 However, in a similar fashion to the system 212 of Figs
18 18 and 19, the vessel 310 is a DP vessel. Accordingly,
19 the first mooring element of the system 312, which takes
20 the form of a canister 316 (similar to the canister 16 of
21 the system 12) does not need to be moored relative to the
22 seabed 14 by heavy mooring lines; the risers 320 are able
23 to maintain the canister 316 approximately on station.

24

25 As shown in Fig 21, which is a view prior to connection
26 of a second connector 318 to the canister 316, the
27 inherent buoyancy of the canister 316 is such that the
28 canister is initially at a similar level to the canister
29 16. However, the canister 316 may be initially below sea
30 surface 19, in a similar fashion to the buoy 216 of the
31 system 212, if desired.

32

1 Various modifications may be made to the foregoing
2 without departing from the spirit and the scope of the
3 present invention.
4

5 For example, the above described embodiments of the
6 invention include adjustable couplings in the form of
7 inner and outer gimbal members which facilitate relative
8 rotation between the vessel and the first mooring element
9 about two axes of rotation. However, the system may
10 include any suitable, alternative adjustable couplings in
11 place of the gimbals.
12

13 The system may comprise any suitable riser found in the
14 offshore environment, used in the oil and gas exploration
15 and production industry, for bringing the riser onboard
16 or inboard to a vessel.
17

18 In the embodiments of the invention where a DP vessel is
19 moored using the system, the vessel may weathervane
20 around the first mooring element, rotating about a
21 vertical or Y axis, with little or minimal rotation about
22 the other axes of rotation. By allowing the vessel to
23 weathervane, loads on the vessel may be reduced.
24

25 The first and second mooring elements may be coupled
26 together using any, suitable alternative coupling/locking
27 mechanism.

Claims

1. An offshore vessel mooring and riser inboarding system, the system comprising:
- a first mooring element for locating in an offshore environment and coupled to a fluid flow riser, the first mooring element defining an internal passage for receiving the riser;
 - a connector assembly comprising:
 - a cantilever support for mounting on a vessel;
 - a second mooring element suspended from the cantilever support and which can be connected to the first mooring element, to thereby suspend the first mooring element from the cantilever support,
 - an outer gimbal member mounted for rotation relative to the cantilever support,
 - an inner gimbal member mounted within and for rotation relative to the outer gimbal member, and
 - a rotatable coupling for facilitating rotation of the inner gimbal member relative to the first mooring element;
 - a transfer flowline adapted to be coupled to the fluid flow riser; and
 - a swivel, the transfer flowline coupled to the fluid flow riser through the swivel;
- wherein in use:
- the first and second mooring elements are connected to facilitate coupling of the fluid flow riser and the transfer flowline;
 - the outer gimbal member, the inner gimbal member and the rotatable coupling together permit relative rotation between the vessel and the first

mooring element about three mutually perpendicular axes of rotation;

the fluid flow riser ascends through the internal passage in the first mooring element, through the rotatable coupling and the inner and outer gimbals to the swivel; and

the rotatable coupling and the swivel facilitate unlimited rotation of the vessel about a longitudinal axis of the first mooring element while maintaining fluid flow.

2. A system as claimed in claim 1, wherein the fluid flow riser and the transfer flowline, when coupled together, extend through an aperture in the inner gimbal member.

3. A system as claimed in claim 1 or 2, wherein the three mutually perpendicular axes of rotation are taken with reference to the first mooring element in a neutral position.

4. A system as claimed in any one of claims 1 to 3, wherein the riser is a conduit for hydrocarbon containing fluids.

5. A system as claimed in claim 1, 2 or 3, further comprising at least one further riser, wherein the further riser comprises one or more cables selected from the group consisting of a power cable and a control cable.

6. A system as claimed in claim 1, 2 or 3, further comprising at least one further riser, wherein the

further riser comprises one or more cables selected from the group consisting of an electrical cable and a hydraulic cable.

7. A system as claimed in any one of claims 1 to 4, further comprising at least one further riser, wherein the further riser is an umbilical.

8. A system as claimed in claim 1, wherein connection of the first and second mooring elements facilitates flow of fluid between the fluid flow riser, the transfer flowline and the vessel.

9. A system as claimed in claim 8, wherein the transfer flowline is for the passage of fluid from the fluid flow riser into the transfer flowline and to the vessel, or vice-versa.

10. A system as claimed in claim 5 or 6, further comprising a transfer line, which provides one or more connections selected from the group consisting of an electrical connection and a hydraulic connection to the riser.

11. A system as claimed in claim 10, wherein the transfer line facilitates one or more of power supply, data transmission, and supply of hydraulic control fluid.

12. A system as claimed in any one of claims 1 to 11, wherein the second mooring element is adapted to be mounted for movement relative to the cantilever support.

13. A system as claimed in claim 12, wherein the cantilever support is located extending beyond a bow of the vessel.

14. A system as claimed in any one of claims 1 to 13, wherein the inner gimbal member is rotatable about an inner gimbal axis and the outer gimbal member about an outer gimbal axis.

15. A system as claimed in claim 14, wherein the inner and outer gimbal member axes are disposed substantially perpendicular to one another.

16. A system as claimed in any one of claims 1 to 15, wherein the rotatable coupling facilitates rotation between the inner gimbal member and the second mooring element, to thereby permit relative rotation between the vessel and the first mooring element about one of the three axes of rotation.

17. A system as claimed in claim 16, wherein the rotatable coupling is provided between the inner gimbal member and the second mooring element.

18. A system as claimed in any one of claims 1 to 17, wherein the rotatable coupling facilitates rotation between the second mooring element and the first mooring element, thereby permitting relative rotation between the vessel and the first mooring element about one of the three axes of rotation.

19. A system as claimed in claim 18, wherein the rotatable coupling is provided between the first and second mooring elements.

20. A system as claimed in any one of claims 1 to 19, wherein the rotatable coupling is a swivel.

21. A system as claimed in any one of claims 1 to 20, wherein the inner and outer gimbal members are annular rings.

22. A system as claimed in any one of claims 1 to 21, wherein the inner gimbal member is mounted to the outer gimbal member by inner trunnions, and wherein the outer gimbal member is mounted to the cantilever support by outer trunnions, the trunnions of the inner gimbal member disposed perpendicular to those of the outer gimbal member.

23. A system as claimed in any one of claims 1 to 22, wherein the connector assembly is releasably mountable on the vessel.

24. A system as claimed in any one of claims 1 to 23, wherein the first mooring element is buoyant.

25. A system as claimed in any one of claims 1 to 24, wherein the system comprises a buoyant member, and wherein the first mooring element is indirectly coupled to the buoyant member.

26. A system as claimed in any one of claims 1 to 25, wherein the first mooring element is tubular.

27. A system as claimed in any one of claims 1 to 26, wherein the first mooring element is adapted to be located at surface prior to connection of the first and second mooring elements together.

28. A system as claimed in any one of claims 1 to 26, wherein the entire first mooring element is adapted to be located below sea surface level prior to connection of the first and second mooring elements together.

29. A system as claimed in claim 28, wherein a location of the first mooring element prior to connection is indicated by a marker buoy.

30. A system as claimed in claim 25, wherein the buoyant member is adapted to be located at sea surface prior to connection of the first and second mooring elements together.

31. A system as claimed in any one of claims 1 to 30, wherein the first mooring element is adapted to be moored to a seabed in the offshore environment by a plurality of mooring lines, the mooring lines adapted to bear loading of the vessel on the first mooring element, to maintain the element on station and to minimise transmission of loads to the main flowline.

32. A system as claimed in claim 31, wherein the mooring lines are coupled to a lower portion of the first mooring element.

33. A system as claimed in any one of claims 1 to 30, wherein the system is for a dynamically positionable vessel.

34. A system as claimed in any one of claims 1 to 33, wherein the first and second mooring elements define respective first and second connector elements.

35. A system as claimed in claim 34, wherein the first and second mooring elements are adapted to be coupled together in a quick-connect and disconnect arrangement.

36. A system as claimed in any one of claims 1 to 35, wherein one of the first and second mooring elements comprises a male member and the other a female member, the female member adapted to receive the male member for engagement of the elements.

37. A system as claimed in any one of claims 1 to 36, wherein the connector assembly comprises a locking arrangement for locking the first and second mooring elements together.

38. A system as claimed in claim 37, wherein the locking arrangement comprises at least one latch adapted to provide a releasable locking engagement between the first and second mooring elements.

39. A system as claimed in any one of claims 1 to 38, wherein the connector assembly comprises an intermediate connector for coupling the first and second mooring elements together.

40. A system as claimed in claim 39, wherein the intermediate connector is secured to the first mooring element and thus provided as part of the first mooring element, and is adapted to be releasably coupled to the second mooring element.

41. A system as claimed in claim 40, wherein the intermediate connector is also adapted to be releasably connected to the first mooring element.

42. A system as claimed in any one of claims 39 to 41, wherein the intermediate connector is adapted to support the riser, and defines a riser hang-off unit.

43. A system as claimed in claim 42, wherein the connector assembly comprises a jacking device for raising part of the connector assembly to provide access space for connection of the riser to the riser hang-off unit.

44. A system as claimed in any one of claims 1 to 43, comprising a plurality of fluid flow risers and a corresponding plurality of transfer flowlines, each transfer flowline associated with a corresponding fluid flow riser.

45. A system as claimed in claim 44, wherein each riser is associated with a separate well, for the flow of well fluids to the vessel.

46. A system as claimed in any one of claims 1 to 45, wherein the swivel is coupled to the second mooring element.

47. A system as claimed in any one of claims 1 to 46, wherein rotation between the vessel and the first mooring element about at least one of the other two of said axes of up to 60° from a neutral position is permitted, providing up to 120° total permissible rotation.

48. A system as claimed in any one of claims 1 to 47, comprising a device for adjusting an orientation of the second mooring element relative to the first mooring element, to facilitate connection of the elements.

49. A system as claimed in claim 48, wherein the connector assembly comprises an indexing device for adjusting a rotational orientation of the first and second mooring elements.

50. A system as claimed in claim 49, wherein the device is for adjusting at least one of a rotational position of the outer gimbal member relative to the support; and of the inner gimbal member relative to the outer gimbal member.

51. A method of mooring a vessel in an offshore environment, the method comprising the steps of:

- locating a first mooring element in an offshore environment;
- coupling a fluid flow riser to the first mooring element;
- suspending a second mooring element of a connector assembly from a cantilever support mounted on a vessel;

raising the first mooring element and connecting it to the second mooring element to thereby suspend the first mooring element from the cantilever support, the second mooring element being connected to the first mooring element such that relative rotation between the vessel and the first mooring element about three mutually perpendicular axes of rotation is permitted, said relative rotation being permitted by means of an outer gimbal member mounted for rotation relative to the cantilever support, an inner gimbal member mounted within and for rotation relative to the outer gimbal member, and a rotatable coupling which facilitates rotation of the inner gimbal member relative to the first mooring element;

locating the fluid flow riser such that it ascends through an internal passage in the first mooring element, through the rotatable coupling and the inner and outer gimbals to a swivel coupled to the second mooring element; and connecting a transfer flowline to the fluid flow riser through the swivel;

wherein the rotatable coupling and the swivel facilitate unlimited rotation of the vessel about a longitudinal axis of the first mooring element while maintaining fluid flow.

52. A method as claimed in claim 51, comprising transferring fluid between the fluid flow riser, the transfer flowline and the vessel.

53. A connector assembly for an offshore vessel mooring and riser inboarding system of a type comprising: a first mooring element located in an offshore environment and coupled to a fluid flow riser, the first mooring element defining an internal passage for receiving the riser; and a transfer flowline adapted to be coupled to the fluid flow riser;

the connector assembly comprising:

a cantilever support for mounting on a vessel;

a second mooring element suspended from the cantilever support for connecting to the first mooring element, to thereby facilitate coupling of the riser and the transfer line and suspension of the first mooring element from the cantilever support;

an outer gimbal member mounted for rotation relative to the cantilever support;

an inner gimbal member mounted within and for rotation relative to the outer gimbal member;

a rotatable coupling for facilitating rotation of the inner gimbal member relative to the first mooring element; and

a swivel through which the transfer flowline is couplable to the fluid flow riser;

wherein, in use:

the first and second mooring elements are connected to facilitate coupling of the fluid flow riser and the transfer flowline;

the outer gimbal member, the inner gimbal member and the rotatable coupling together

permit relative rotation between the vessel and the first mooring element about three mutually perpendicular axes of rotation;

the fluid flow riser ascends through the internal passage in the first mooring element, through the rotatable coupling and the inner and outer gimbals to the swivel; and

the rotatable coupling and the swivel facilitate unlimited rotation of the vessel about a longitudinal axis of the first mooring element while maintaining fluid flow.

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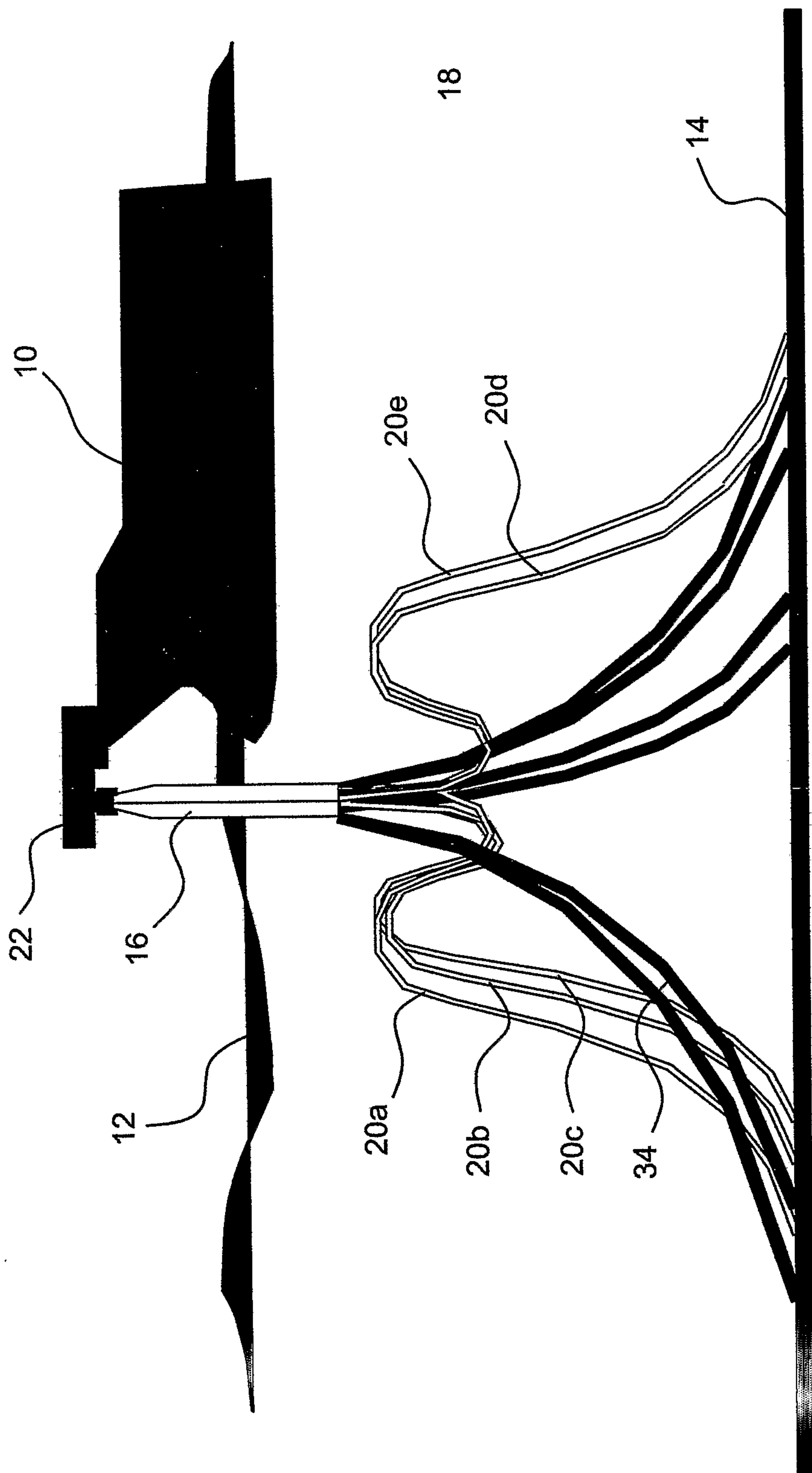


Figure 1.

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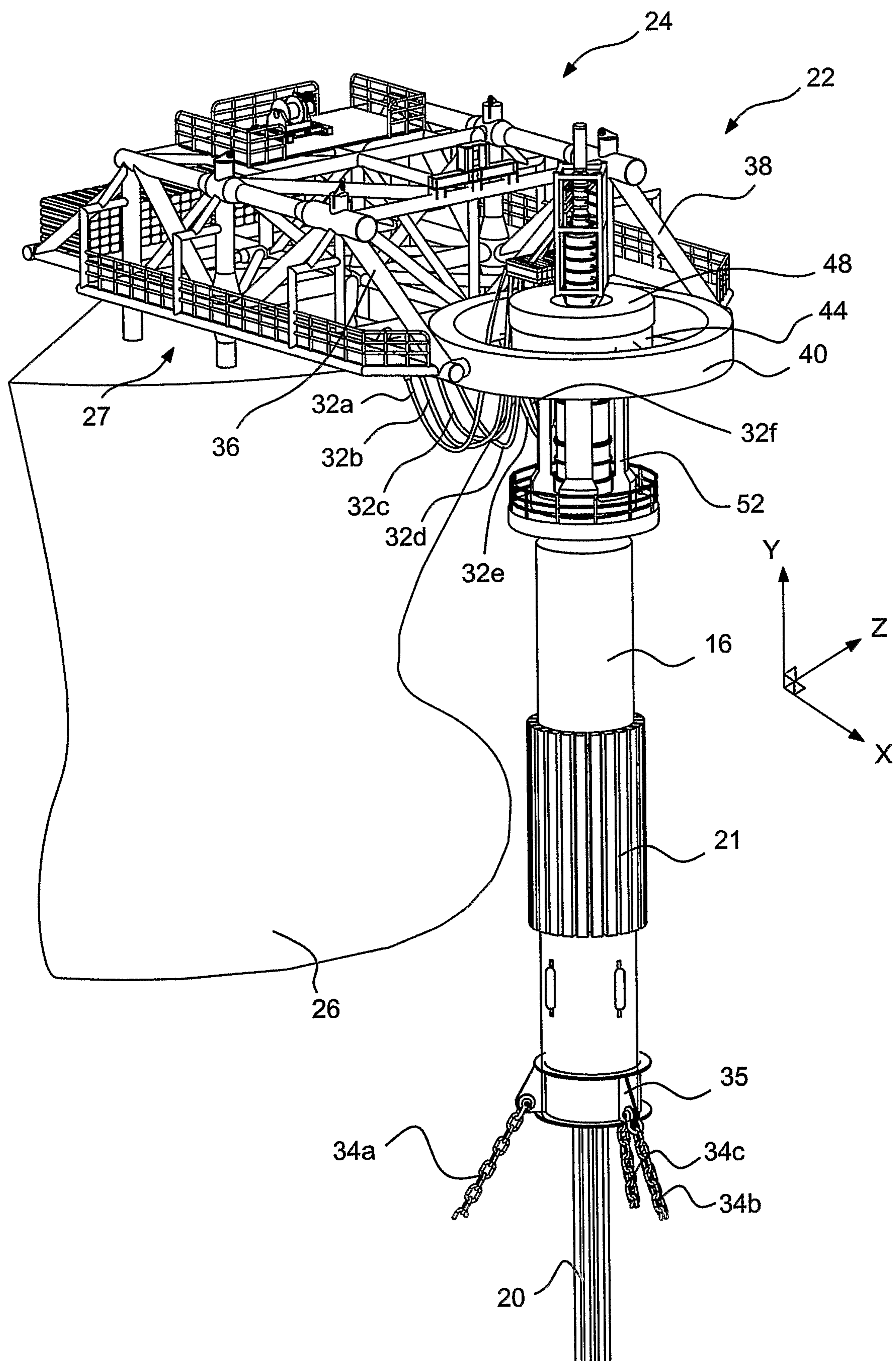


Figure 2.

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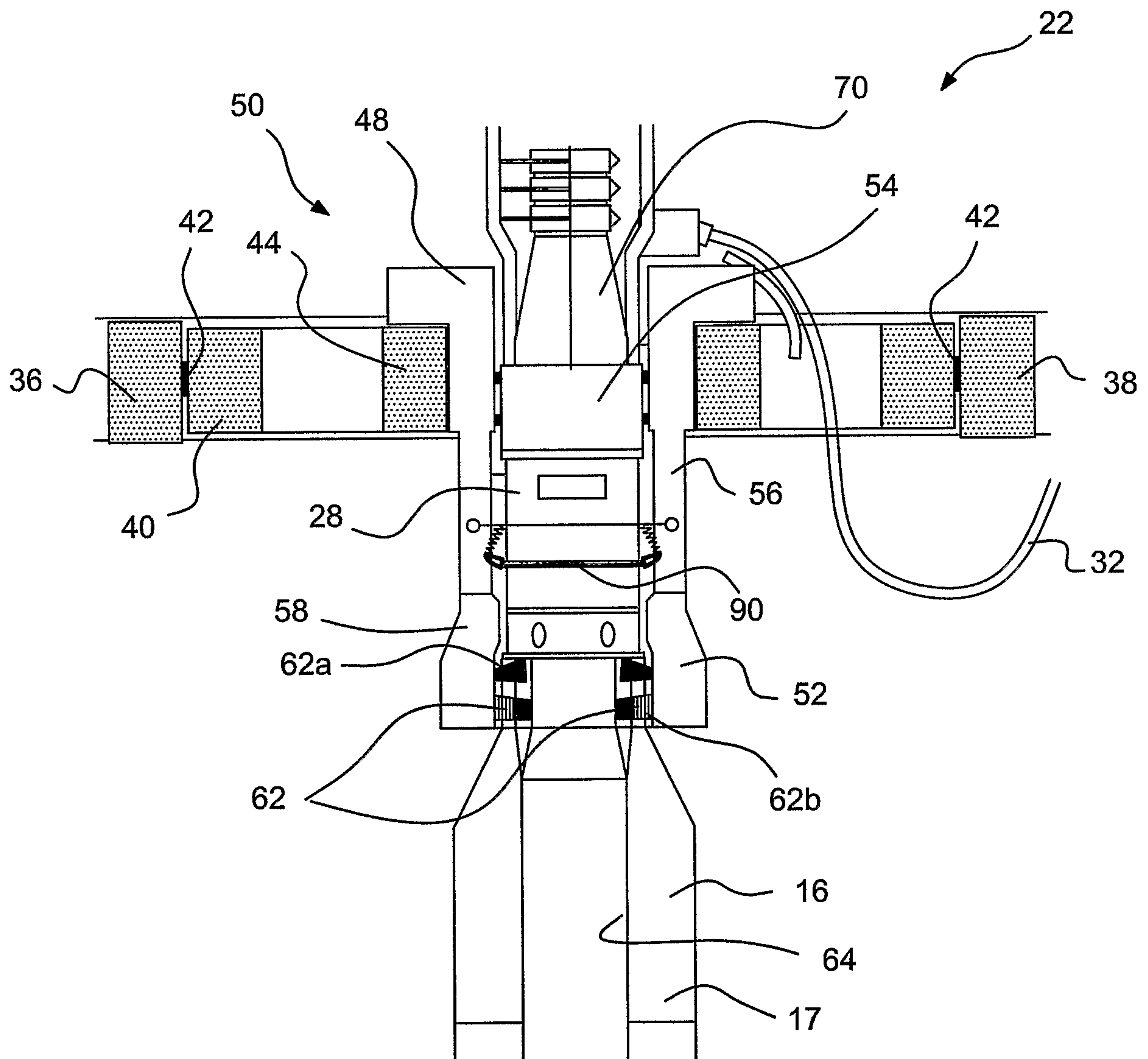


Figure 3.

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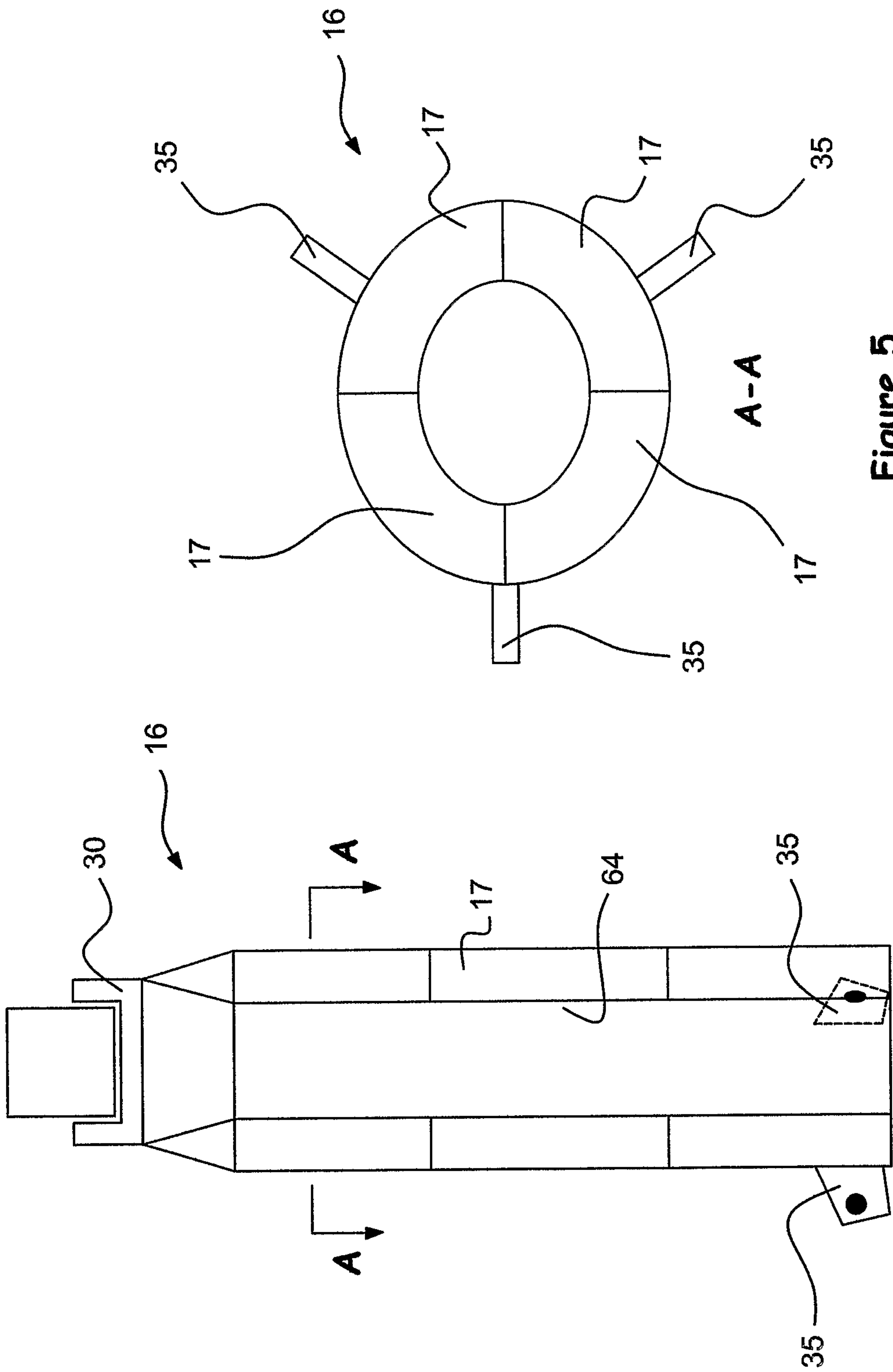


Figure 4.

Figure 5.

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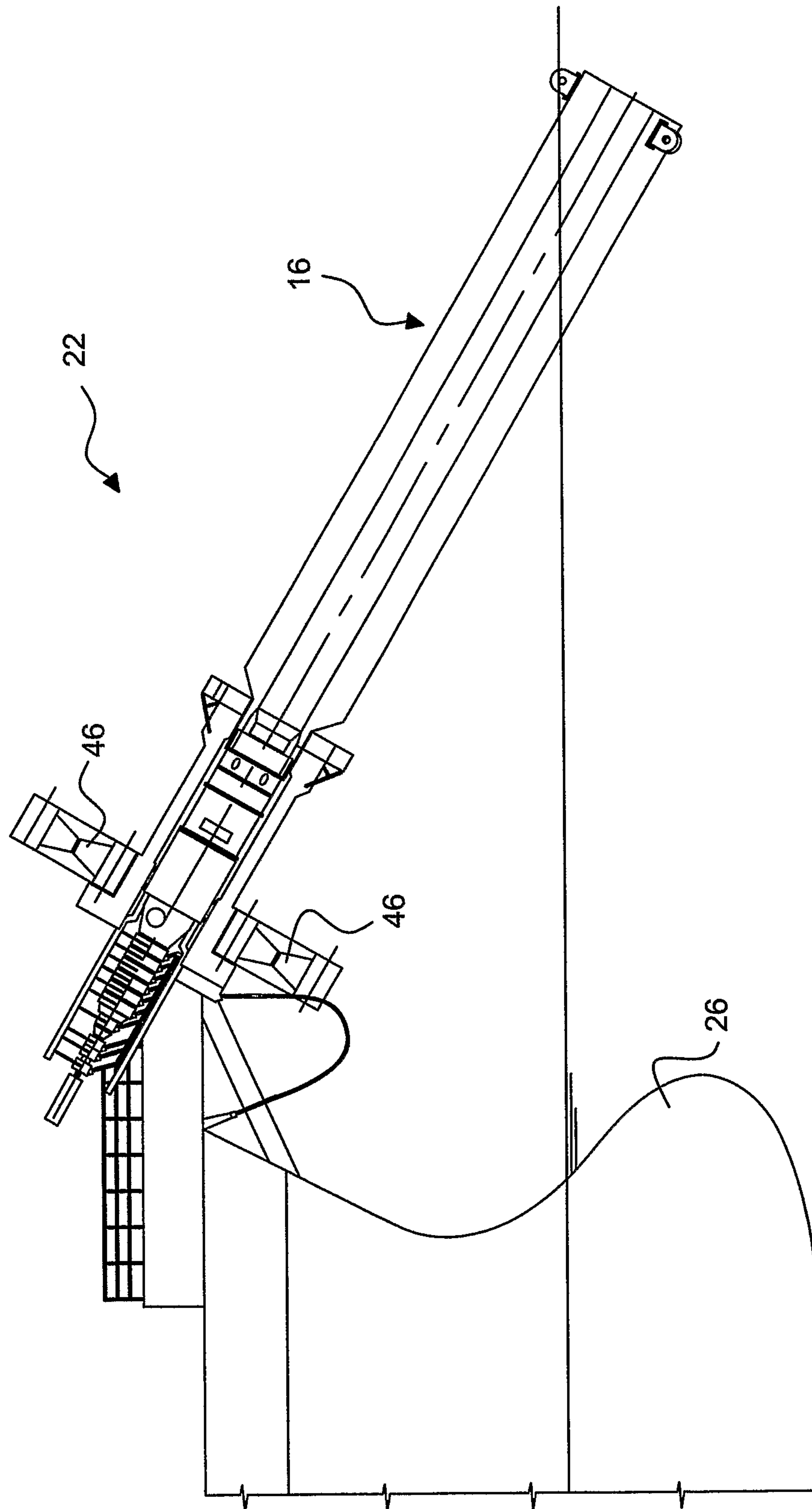


Figure 6.

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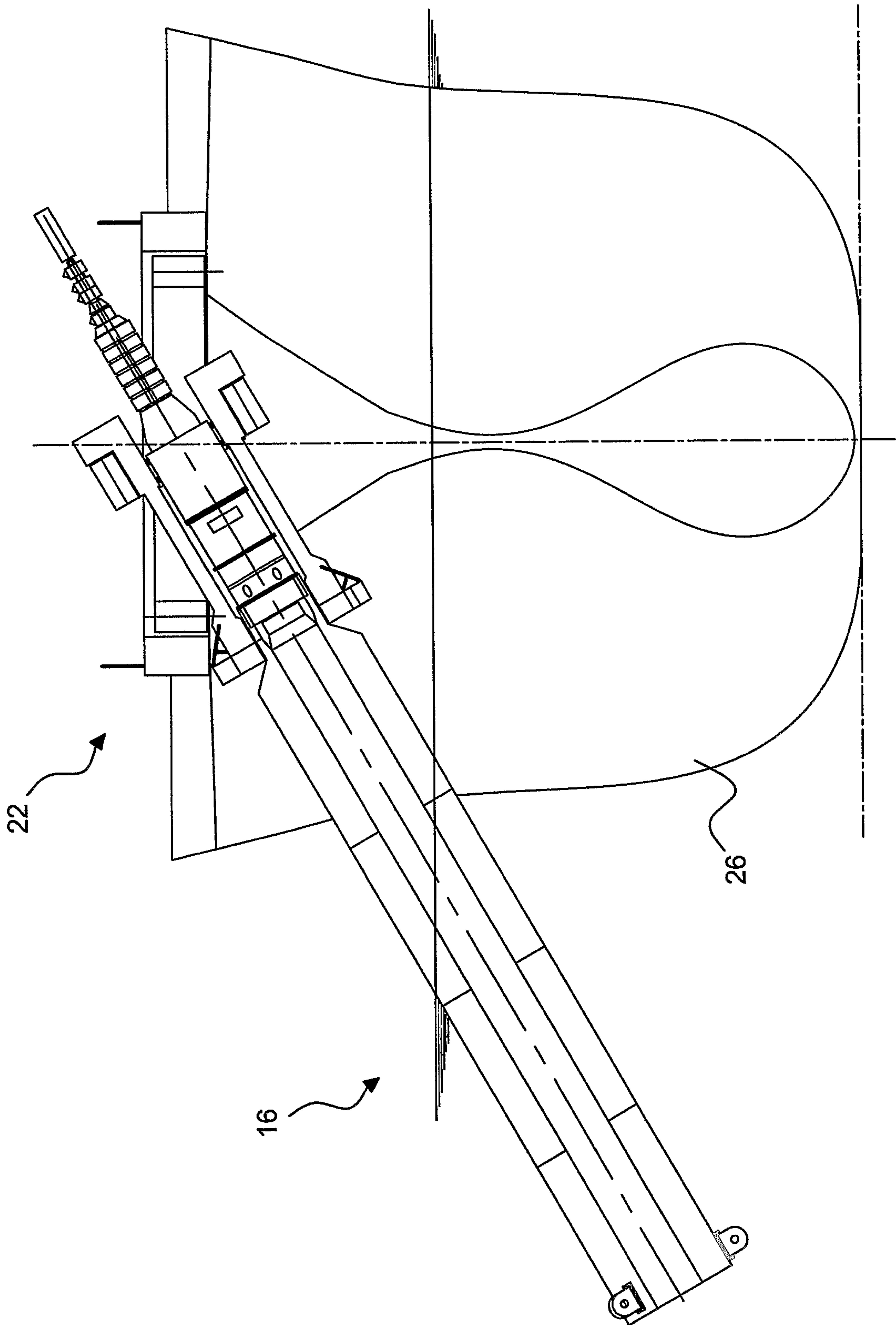


Figure 7.

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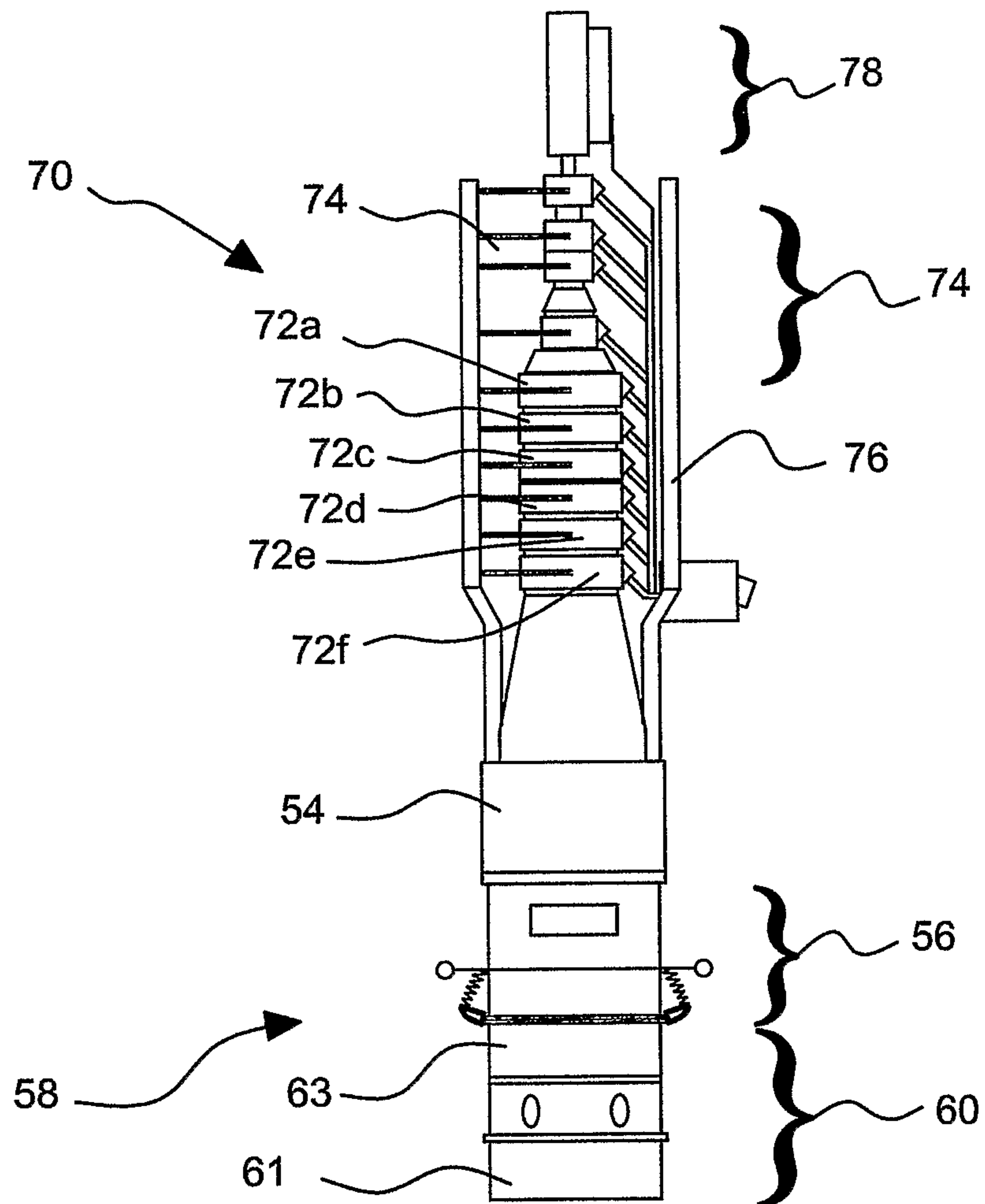


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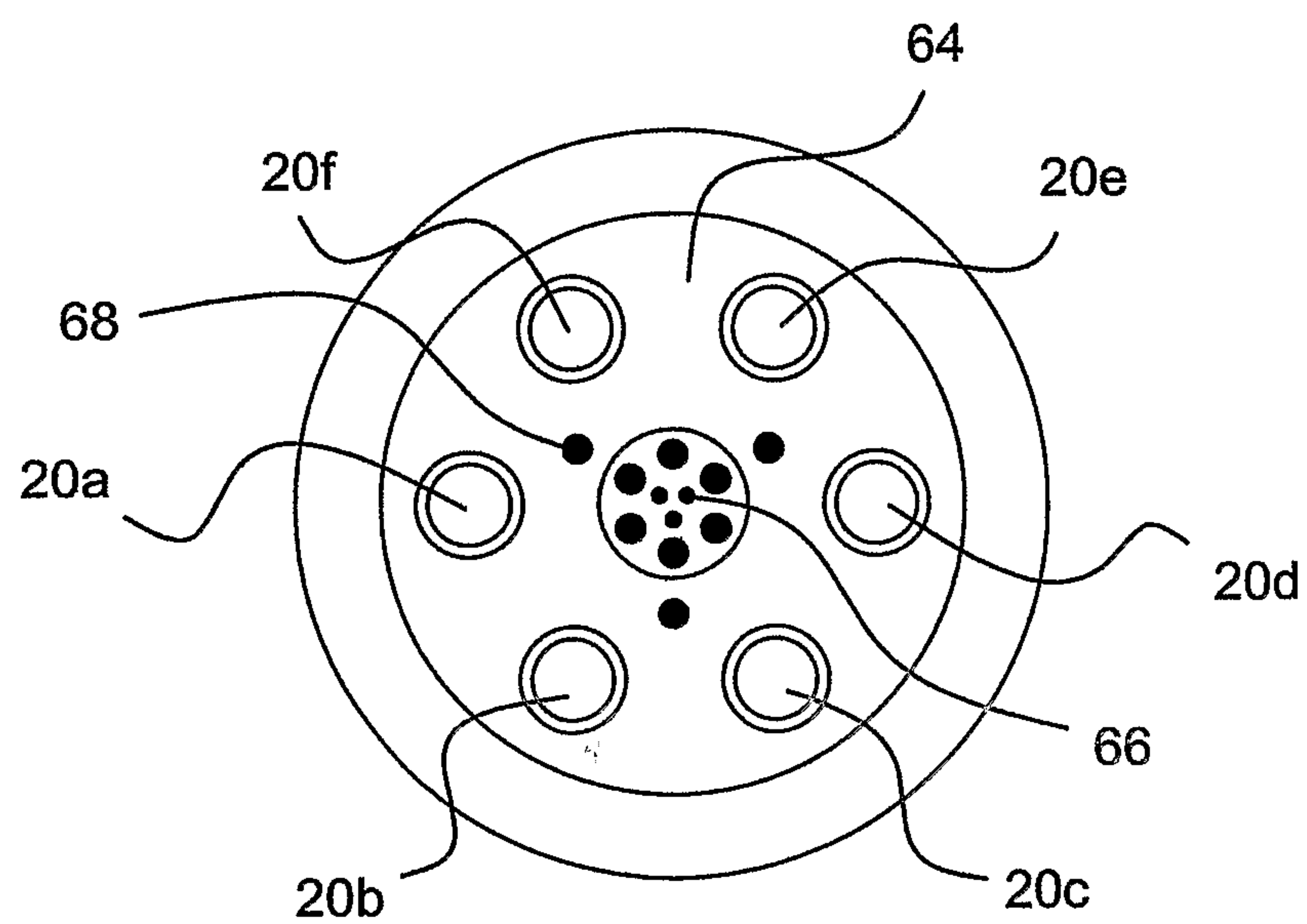


Figure 9.

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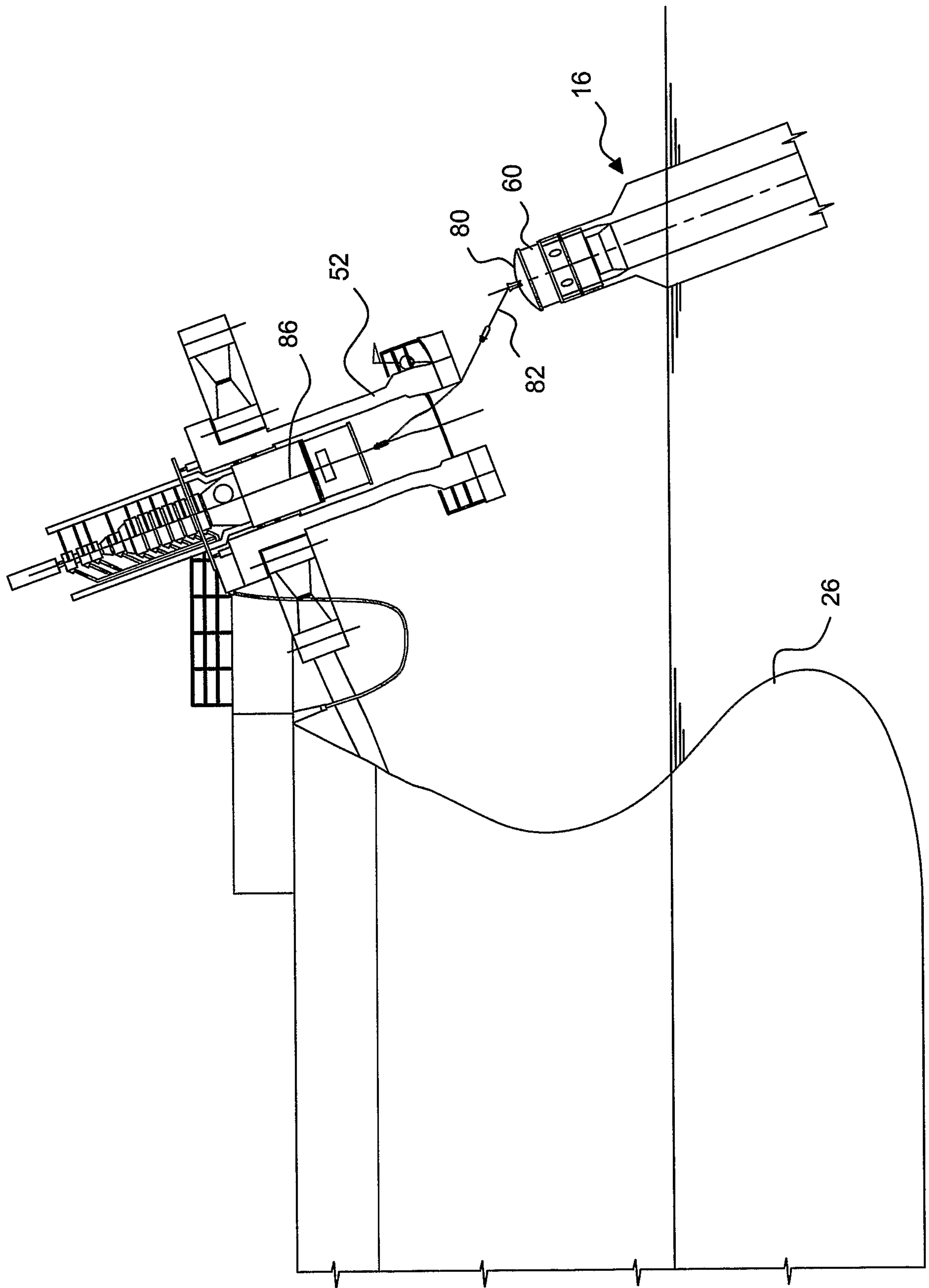


Figure 11.

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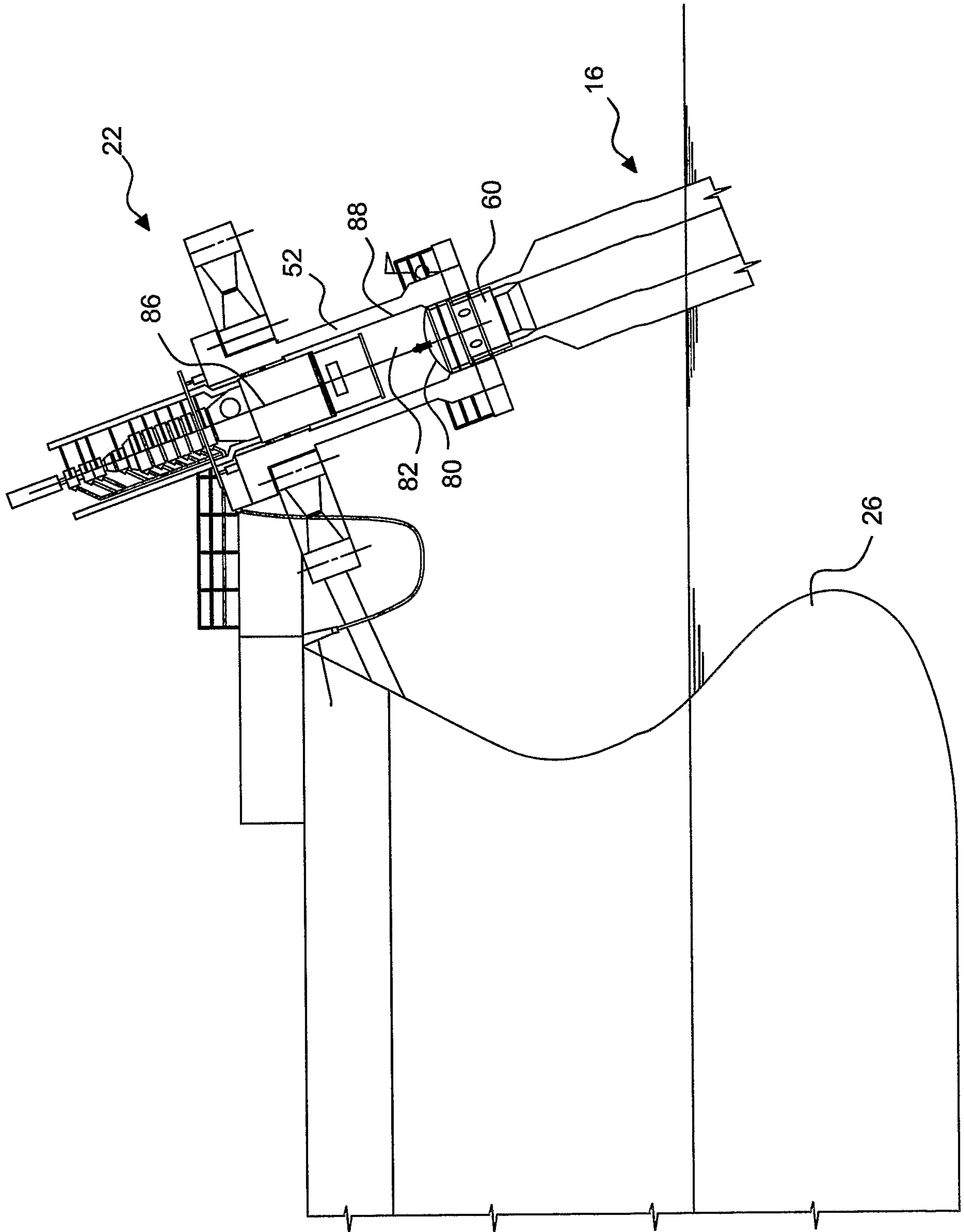


Figure 12.

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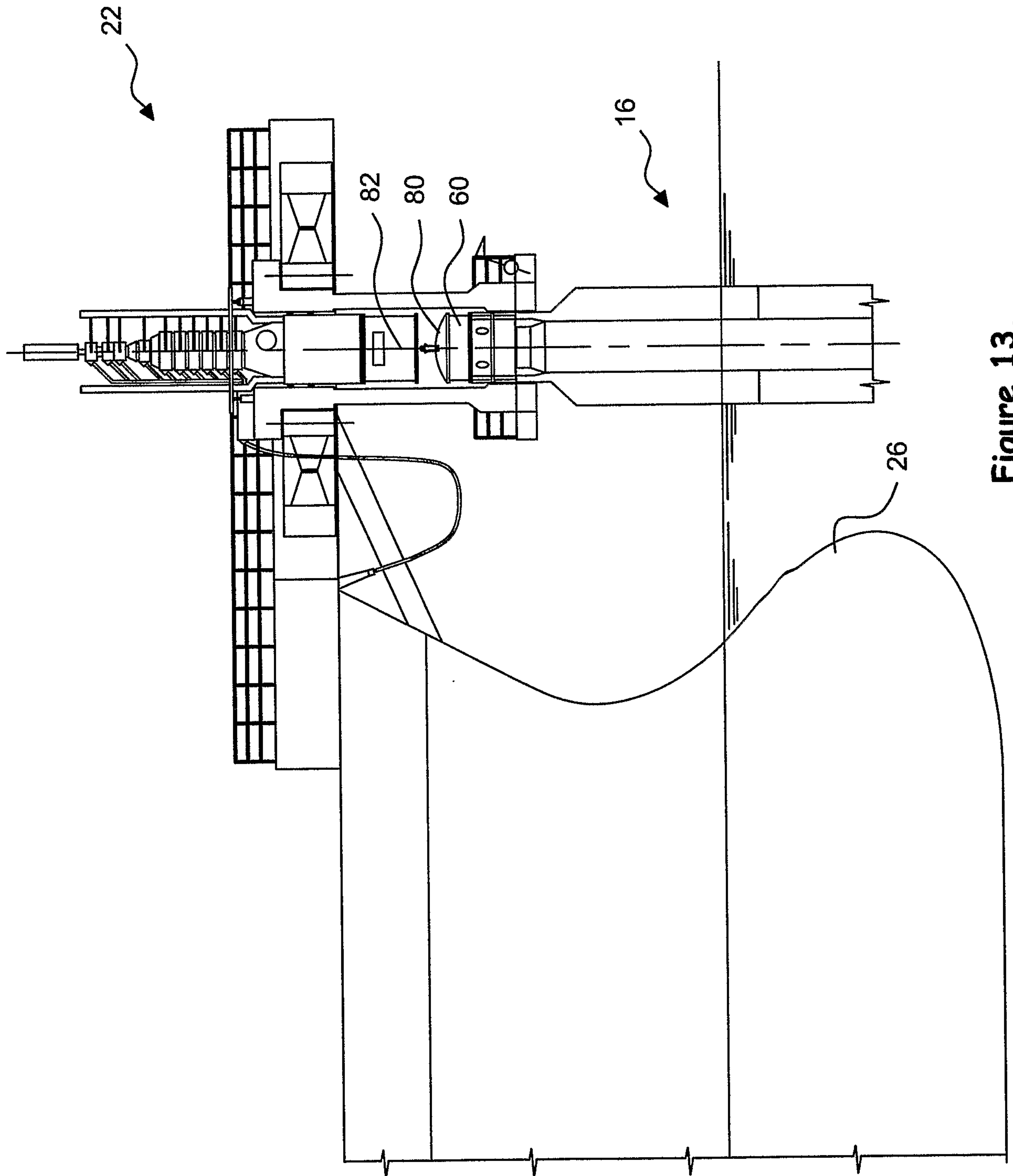


Figure 13.

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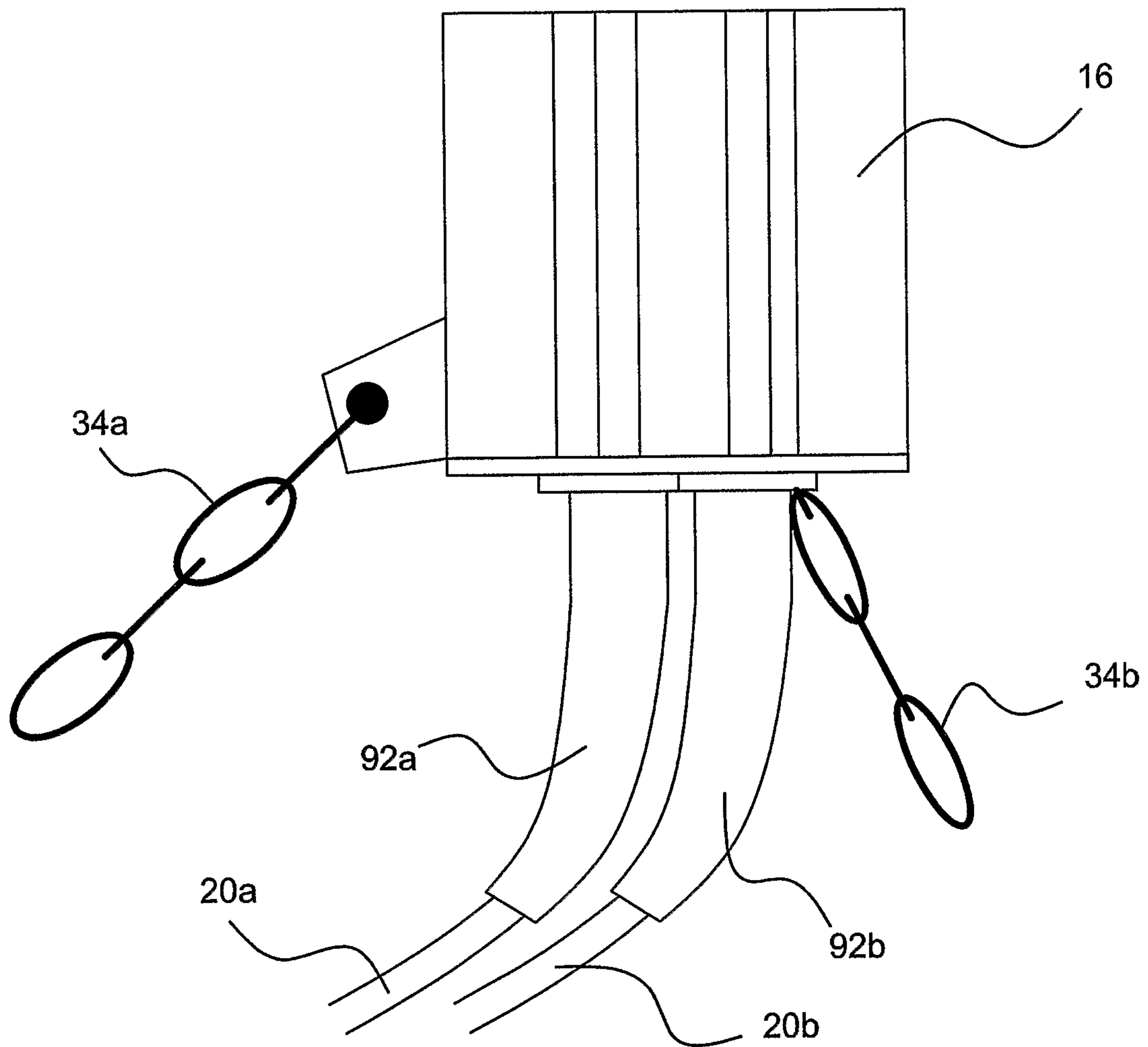


Figure 14.

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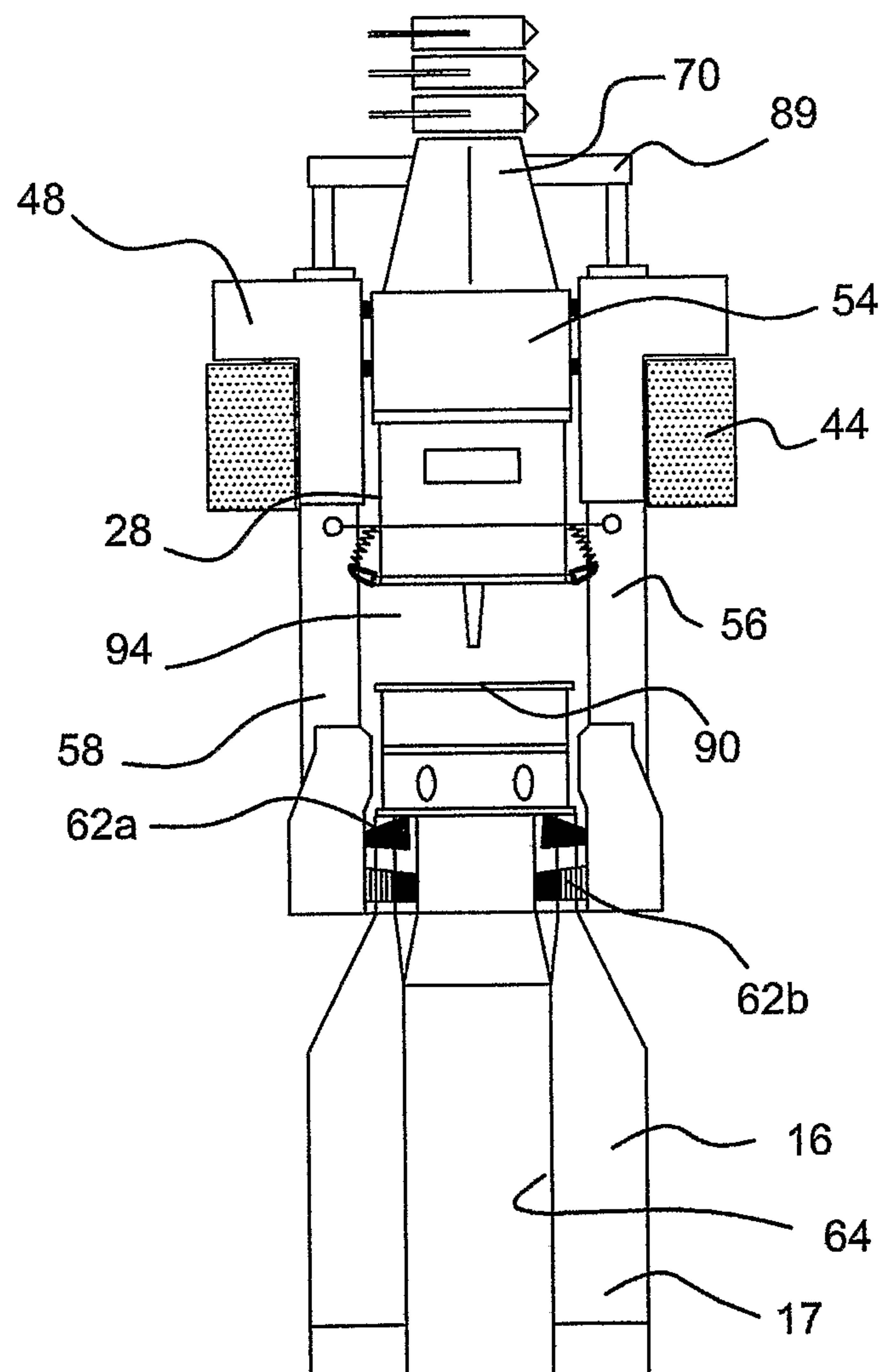


Figure 15.

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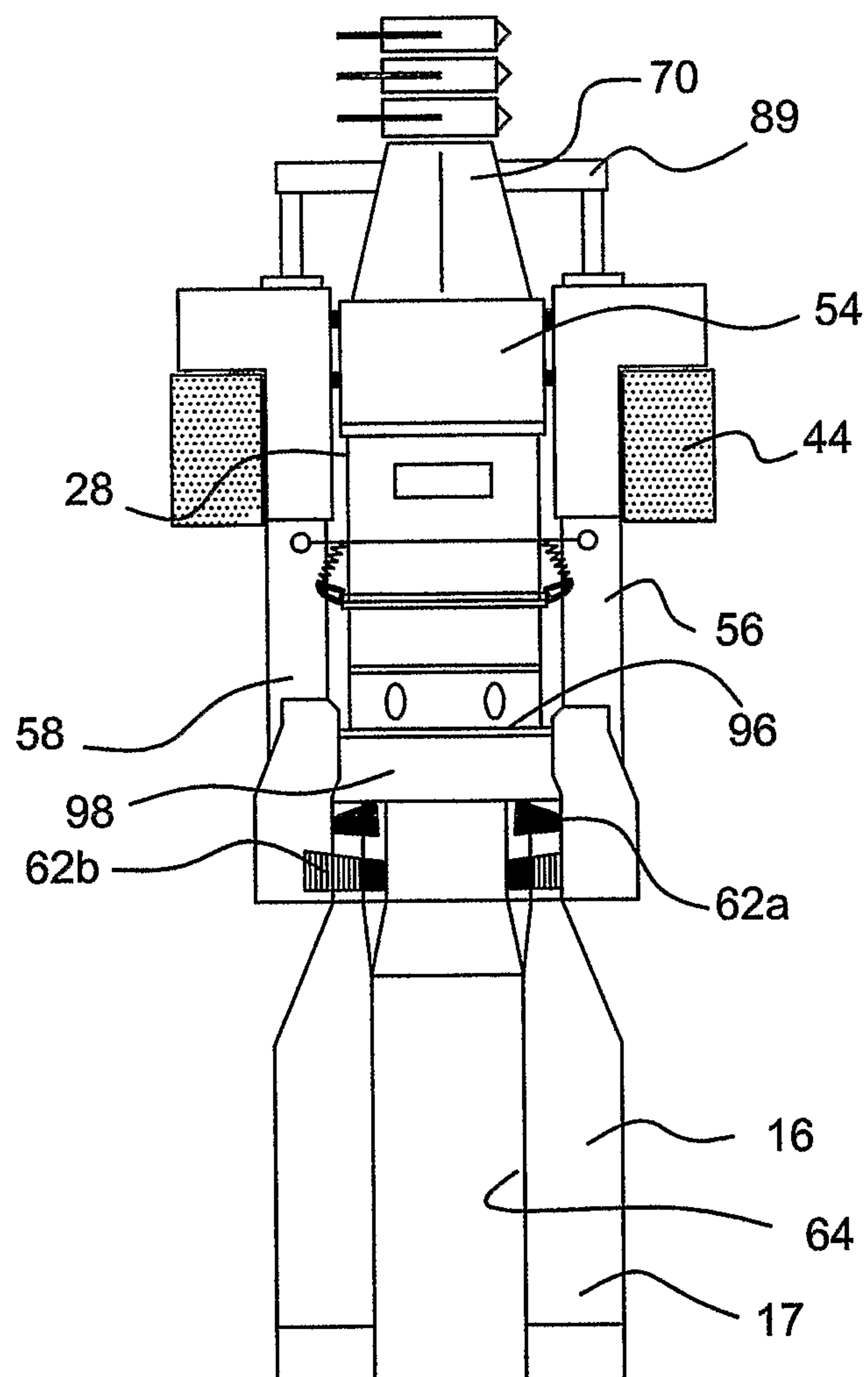


Figure 16.

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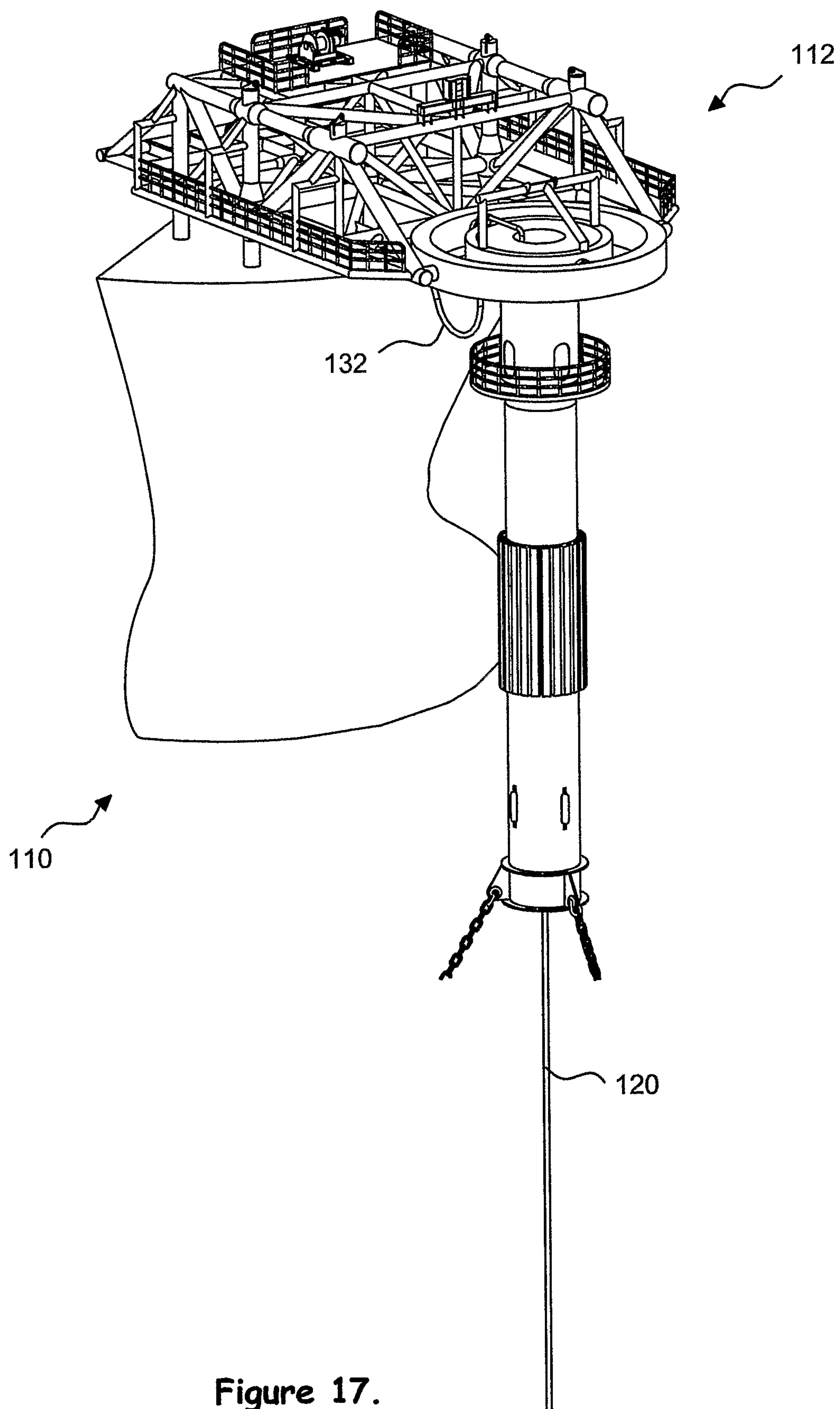


Figure 17.

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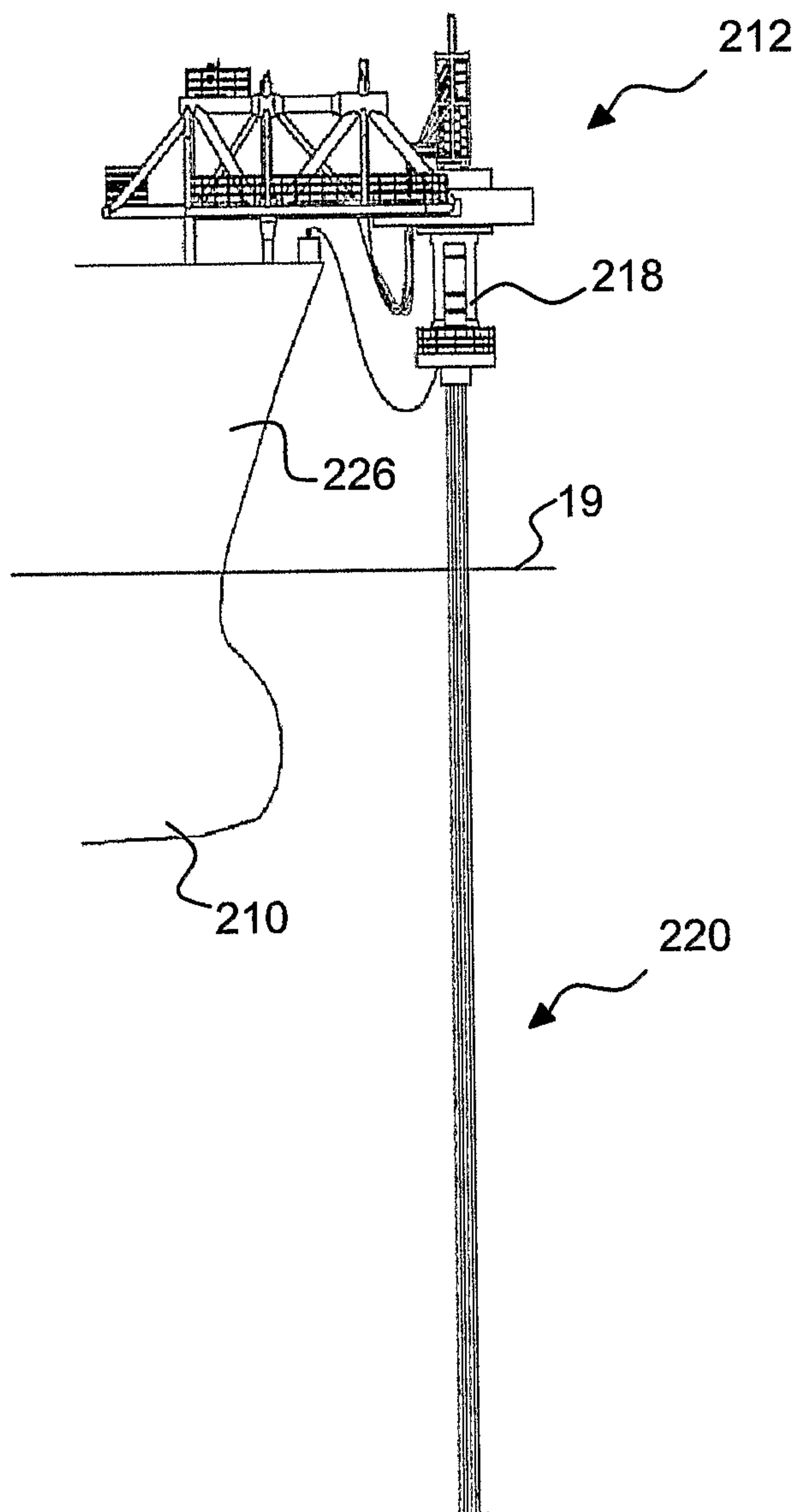


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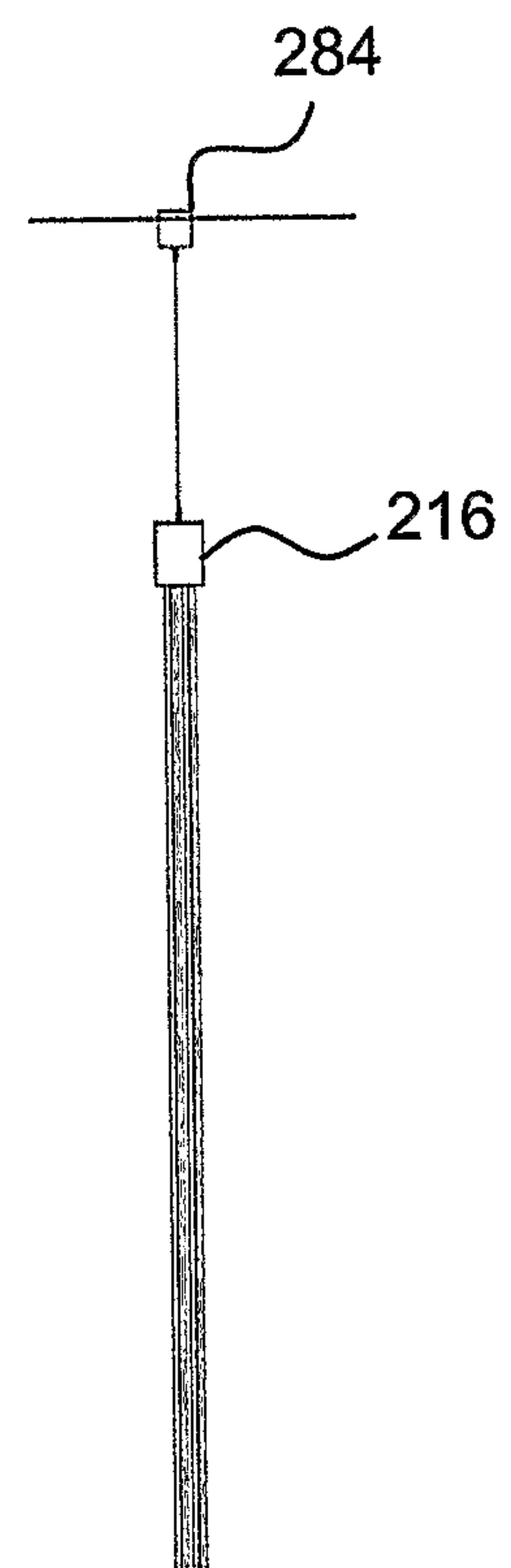


Figure 19.

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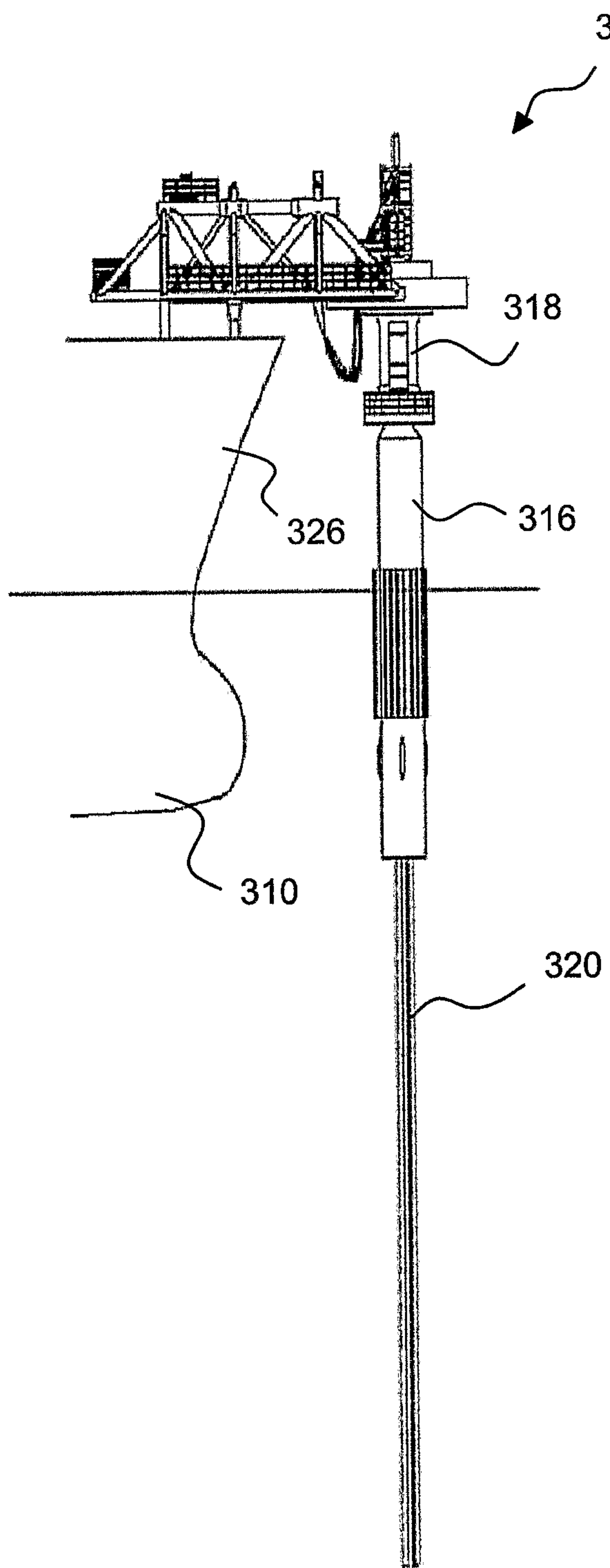


Figure 20.

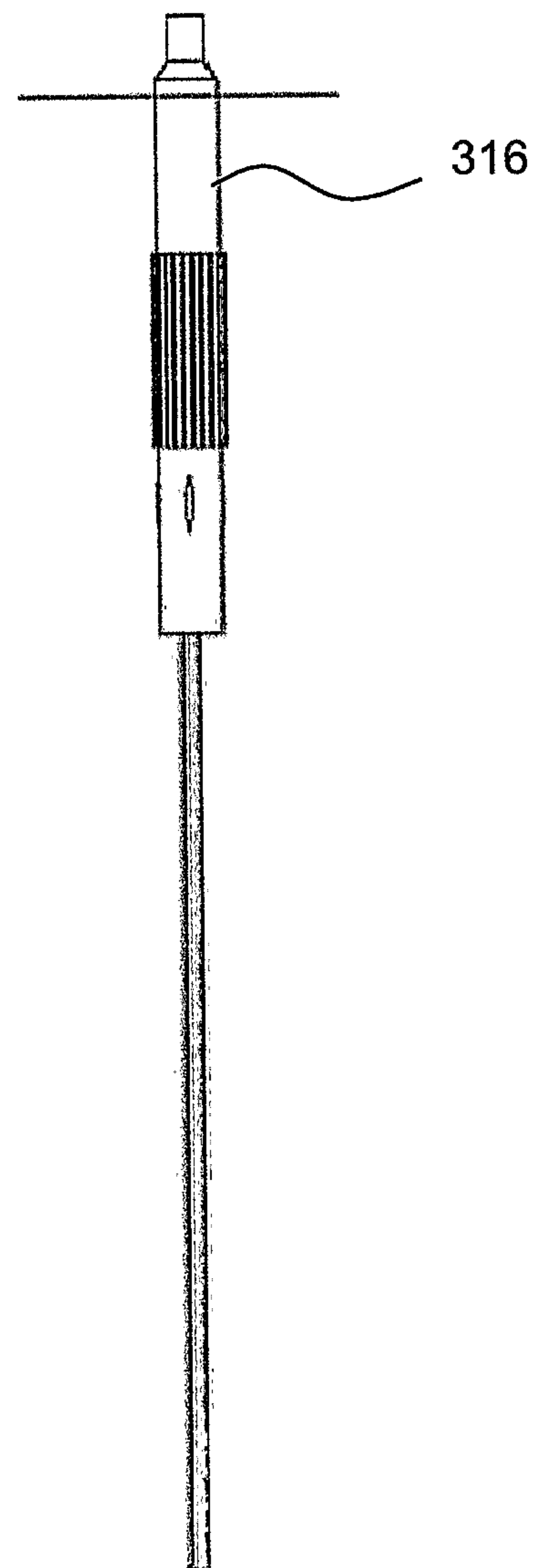


Figure 21.

