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(54) **Title:** BUOYANCY DEVICE FOR MARINE STRUCTURES

(57) **Abstract:** Disclosed is a buoyancy device for tensioning an elongate vertical (or quasi vertical) subsea structure at a point below the sea surface, anchored at its bottom. The device comprises as its main buoyancy elements a plurality of hollow elongate objects, and further comprises at least one auxiliary buoyancy element comprising a solid buoyant material. Ideally, the solid buoyant material provides enough uplift to maintain the device afloat should the main buoyancy elements be flooded. A riser apparatus comprising such a buoyancy device is also described.

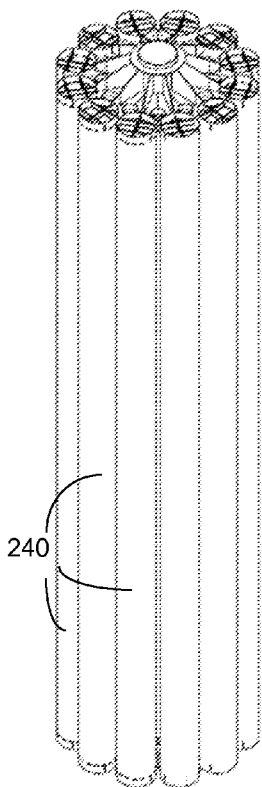


Fig. 2i



WO 2010/041229 A2



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Buoyancy Device for Marine Structures

The present invention relates to a marine riser tower, of the type used in the
5 transport of hydrocarbon fluids (gas and/or oil) from offshore wells. The riser tower
typically includes a number of conduits for the transport of fluids. In particular it
relates to apparatus for buoyancy tensioning of offshore deepwater structures. It
finds particular application in tensioning a slender, vertical or near-vertical, bottom-
anchored, submarine structure, such as a riser or a bundle of risers (which may, or
10 may not, include a structural member) or an umbilical.

Tensioning is the act of ensuring that a marine structure doesn't experience
excursions from its nominal upright position that would fall outside the acceptable
limits, even in extreme environmental conditions, the said limits being possibly
15 defined with reference to the occurring current profile and sea state. There should
always be sufficient tension to ensure stability, no matter the weight of the structure
and the weight of the pipelines/risers hanging off the structure.

The structure may form part of the so-called hybrid riser, having an upper portions
20 ("jumpers") made of flexible conduit and suitable for deep and ultra-deep water field
development. US-A-6082391 (Stolt/Doris) proposes a particular Hybrid Riser Tower
(HRT) consisting of an empty central core, supporting a bundle of (usually rigid)
riser pipes, some used for oil production some used for injection of water, gas
and/or other fluids, some others for oil and gas export. This type of tower has been
25 developed and deployed for example in the Girassol field off Angola. Further
background has been published in paper "Hybrid Riser Tower: from Functional
Specification to Cost per Unit Length" by J-F Saint-Marcoux and M Rochereau,
DOT XIII Rio de Janeiro, 18 October 2001. Updated versions of such risers have
been proposed in WO 02/053869 A1. The contents of all these documents are
30 incorporated herein by reference, as background to the present disclosure.

Buoyancy tensioning conventionally requires a large hollow buoyancy tank including a number of compartments, which, when filled with air or specific gas as nitrogen and submerged, provides the required tensioning force to the top of the riser tower. However, manufacture of such a large tank is expensive. Furthermore, there is a risk of losing the tank or the whole riser tower, should it leak when a number of the compartments are water flooded, this being done on purpose during the installation process to submerge it when attaching it to the top of the tower or after it is attached. It is an aim of the invention to address one or more of these issues.

10

In a first aspect of the invention there is provided a buoyancy device for tensioning an elongate vertical (or quasi vertical) subsea structure at a point below the sea surface, anchored at its bottom, wherein said device comprises as its main buoyancy elements a plurality of hollow elongate objects, and further comprises at least one auxiliary buoyancy element, said at least one auxiliary buoyancy element substantially comprising a solid buoyant material.

15

20

Vertical (or quasi vertical) is to be taken to mean that the structure is of the vertical tower type of riser structures (as opposed to catenary or other curved form of structure), particularly taking into regard its length. It is not to be interpreted as a structure that must be literally vertical, and in reality, it very rarely will be, due to the actions of sea currents and other forces.

25

Said hollow elongate objects may be cylindrical. They may comprise sections of pipe, capped at both ends.

30

Said hollow elongate objects may be arranged evenly and vertically around a central core, such that they are parallel with the buoyancy device's vertical axis. Said buoyancy device may comprise a supporting structure to support said hollow elongate objects around said core.

Said plurality of hollow elongate objects preferably should be floodable. Said at least one solid buoyancy element may comprise a foam element. Said solid buoyancy element should preferably provide sufficient uplift to keep the buoyancy device afloat when all of said hollow elongate objects are flooded. Said plurality of
5 hollow elongate objects may be arranged around the periphery of said solid buoyancy element.

Said elongate subsea structure may comprise one or more rigid conduits. Said conduits may be arranged around a structural core. Alternatively some conduits
10 may be located inside a tubular core. Alternatively the tubular core may be used as a conduit, which may be the sole conduit, or the structure may comprise further conduits arranged therearound. Preferably there is also provided the same number of flexible conduits as rigid conduits such that a flexible conduit connects each rigid conduit to a surface structure.

15

In a further aspect of the invention there is provided an elongate subsea structure, having anchoring means at its bottom and a buoyancy device for tensioning said elongate subsea structure attached at, or near its top wherein said buoyancy device comprises as its main buoyancy elements a plurality of hollow elongate objects, and
20 further comprises at least one auxiliary buoyancy element, said at least one auxiliary buoyancy element substantially comprising a solid buoyant material.

Said buoyancy device may include any of the variations described with reference to the first aspect of the invention above.

25

Said elongate subsea structure may comprise one or more rigid conduits arranged around a structural core. Alternatively some conduits may be located inside a tubular core. Alternatively the tubular core may be used as a conduit, which may be the sole conduit, or the structure may comprise further conduits arranged
30 therearound. Preferably there is also provided the same number of flexible conduits as rigid conduits such that a flexible conduit connects each rigid conduit to a surface structure.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, by
5 reference to the accompanying drawings, in which:

Fig. 1 shows a known type of riser structure in an offshore oil production system;

Figs. 2a to 2i show the buoyancy tank according to an embodiment of the invention
10 in different stages of fabrication;

Figs. 3a to 3c show in closer detail the top and bottom of the buoyancy tank of Fig.
2 with one, six and twelve buoyancy tubes attached; and

15 Fig. 4 shows the buoyancy tank of Fig. 2 in cross section.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to Figure 1, the person skilled in the art will recognise a cut-away view of
20 a seabed installation comprising a number of well heads, manifolds and other
pipeline equipment 100 to 108. These are located in an oil field on the seabed 110.

Vertical riser towers are provided at 112 and 114, for conveying production fluids to
the surface, and for conveying lifting gas, injection water, gas and treatment
25 chemicals such as methanol from the surface to the seabed. The foot of each riser,
112, 114, is connected to a number of well heads/injection sites 100 to 108 by
horizontal pipelines 116 etc.

Further pipelines 118, 120 may link to other well sites at a remote part of the
30 seabed. At the sea surface 122, the top of each riser tower is supported by a buoy
124, 126. These towers are pre-fabricated at shore facilities, towed to their

operating location and then installed to the seabed with anchors at the bottom and buoyancy at the top.

5 A floating production unit (FPU) 128 is moored by means not shown, or otherwise held in place at the surface. FPU 128 provides production facilities, storage and accommodation for the fluids from and to the wells 100 to 108. FPU 128 is connected to the risers by flexible flow lines 132 etc arranged in a catenary configuration, for the transfer of fluids between the FPU and the seabed, via riser towers 112 and 114.

10

Individual pipelines may be required not only for hydrocarbons produced from the seabed wells, but also for various auxiliary fluids, which assist in the production and/or maintenance of the seabed installation. For the sake of convenience, a number of pipes carrying either the same or a number of different types of fluid are grouped in "bundles", and the riser towers 112, and 114 in this embodiment comprise each one a bundle of conduits for production fluids, lifting gas, water and gas injection, oil and gas export, and treatment chemicals, e.g. methanol. All the component conduits of each bundle are arranged around a central core, and are often held in place relative to each other (in the two lateral dimensions, longitudinal movement not being prevented) by guide frames attached to the central core.

20

An embodiment of the invention will now be described with reference to the remaining figures. Figures 2a to 2i show the buoyancy device according to an embodiment of the invention in different stages of fabrication. Figures 3a to 3c also show in closer detail the top and bottom of the buoyancy device according to an embodiment of the invention with one, six and all buoyancy tubes attached. Figure 4 shows the buoyancy device in cross section (with only one buoyancy tube shown for clarity).

25

30 The buoyancy device comprises a central core 200, with top and bottom flanges 210 which support the main tube supports 220. Extensions 220a are then added to the main tube supports 220, so as to provide a plurality of insets 230 for the placing

therein of the buoyancy tubes 240. Buoyancy foam (syntactic foam) 250 is placed around the core 200. Around this are placed the buoyancy tubes 240 such that they are held in place by main supports 220, such that their top and bottom rest in the insets 230. One of said buoyancy tubes 240 is shown in Figure 2f with closed ends
5 shown in close-up. Figures 2g-2i show the buoyancy tank with 1, 6 and all 12 buoyancy tubes 240 attached.

Each buoyancy tube 240 is closed and hollow and therefore produces uplift when submerged. The combined uplift from all the buoyancy tubes (and buoyancy foam,
10 if present) is sufficient for tensioning a riser tower structure. However, it is much cheaper to produce a plurality of buoyancy tubes than a conventional buoyancy tank. This is especially so, when it is recognised that the buoyancy tubes 240 can be made of pipe (with the ends sealed) manufactured by a pipe mill rather than by a structure fabrication yard. This pipe may be the same sort of pipe as that which is
15 supported by the riser tower structure, for manufacture of the riser conduits etc. Ideally, each buoyancy tube 240 should be made floodable, for ballasting purposes.

The buoyancy foam 250 results in, in one embodiment, sufficient uplift to keep the entire buoyancy device afloat, even when all buoyancy tubes 240 are
20 flooded/ballasted. Therefore, it is not possible to accidentally lose this buoyancy device to the bottom of the sea.

As each pipe is a separate buoyancy tank, overall buoyancy is also more controllable than with a conventional buoyancy tank, as flooding/ballasting may be
25 done selectively, to only one or a portion of the buoyancy tubes 240. Therefore, it may be possible (assuming less foam than in the embodiment described in the previous paragraph), to balance forces resultant from the empty buoyancy tubes 240, buoyancy foam 250, and the weight of the device including ballasted tubes, so to make the device neutrally buoyant (or near so), making it easier to manoeuvre.

30

The buoyancy device is suitable for any type of essentially vertical riser tower structure, including those that comprise a single riser conduit or a bundle of riser

conduits, and those that have a central core, or not. Any central core, where present, may additionally act as a riser conduit, and in such a case, may comprise the whole riser structure, having no other conduits. The buoyancy device may be rigidly connected to the top of the riser structure, or connected via a mechanical articulation (such as a double pivot joint, or universal joint with two degrees of freedom), or flexible joint, or tether.

The above embodiments are for illustration only and other embodiments and variations are possible and envisaged without departing from the spirit and scope of the invention. For example, the buoyancy tube arrangement depicted is simply for illustration and may be varied, including provision of less or more than the twelve buoyancy tubes shown. Furthermore, the buoyancy foam (or other material) may take different forms to that shown.

Claims

1. A buoyancy device for tensioning an elongate vertical (or quasi vertical) subsea structure at a point below the sea surface, anchored at its bottom, wherein
5 said device comprises as its main buoyancy elements a plurality of hollow elongate objects, and further comprises at least one auxiliary buoyancy element, said at least one auxiliary buoyancy element substantially comprising a solid buoyant material.
2. A buoyancy device as claimed in claim 1 wherein said hollow elongate
10 objects are cylindrical.
3. A buoyancy device as claimed in claim 1 or 2 wherein said hollow elongate objects comprise sections of pipe, capped at both ends.
- 15 4. A buoyancy device as claimed in any preceding claim wherein said hollow elongate objects are arranged evenly and vertically around a central core, such that they are parallel with the buoyancy device's vertical axis.
5. A buoyancy device as claimed claim 4 comprising a supporting structure to
20 support said hollow elongate objects around said core.
6. A buoyancy device as claimed in any preceding claim wherein said each of said plurality of hollow elongate objects is floodable.
- 25 7. A buoyancy device as claimed in any preceding claim wherein said at least one auxiliary buoyancy element comprises syntactic foam.
8. A buoyancy device as claimed in any preceding claim wherein said auxiliary
30 buoyancy element provides sufficient uplift to keep the buoyancy device afloat when all of said hollow elongate objects are flooded.

9. A buoyancy device as claimed in any preceding claim wherein said plurality of hollow elongate objects are arranged around the periphery of said auxiliary buoyancy element.
- 5 10. An elongate subsea structure, having anchoring means at its bottom and a buoyancy device for tensioning said elongate subsea structure attached at, or near its top wherein said buoyancy device comprises as its main buoyancy elements a plurality of hollow elongate objects, and further comprises at least one auxiliary buoyancy element, said at least one auxiliary buoyancy element substantially
10 comprising a solid buoyant material.
11. An elongate subsea structure wherein said buoyancy device is as claimed in any of claims 1 to 9.
- 15 12. An elongate subsea structure as claimed in claim 10 or 11 comprising one or more rigid conduits.
13. An elongate subsea structure as claimed in claim 12 comprising a structural
20 core.
14. An elongate subsea structure as claimed in claim 13 wherein said one or more rigid conduits are arranged around said structural core.
15. An elongate subsea structure as claimed in claim 13 wherein some or all of
25 said one or more rigid conduits are located inside said tubular core.
16. An elongate subsea structure as claimed in claim 13 or 14 wherein said tubular core is used as a conduit.
- 30 17. An elongate subsea structure as claimed in any of claims 10 to 16 further comprising the same number of flexible conduits as rigid conduits such that a flexible conduit connects each rigid conduit to a surface structure.

18. An elongate subsea structure as herein before described with reference to the accompanying figures 2 to 4.

5 19. A buoyancy device as herein before described with reference to the accompanying figures 2 to 4.

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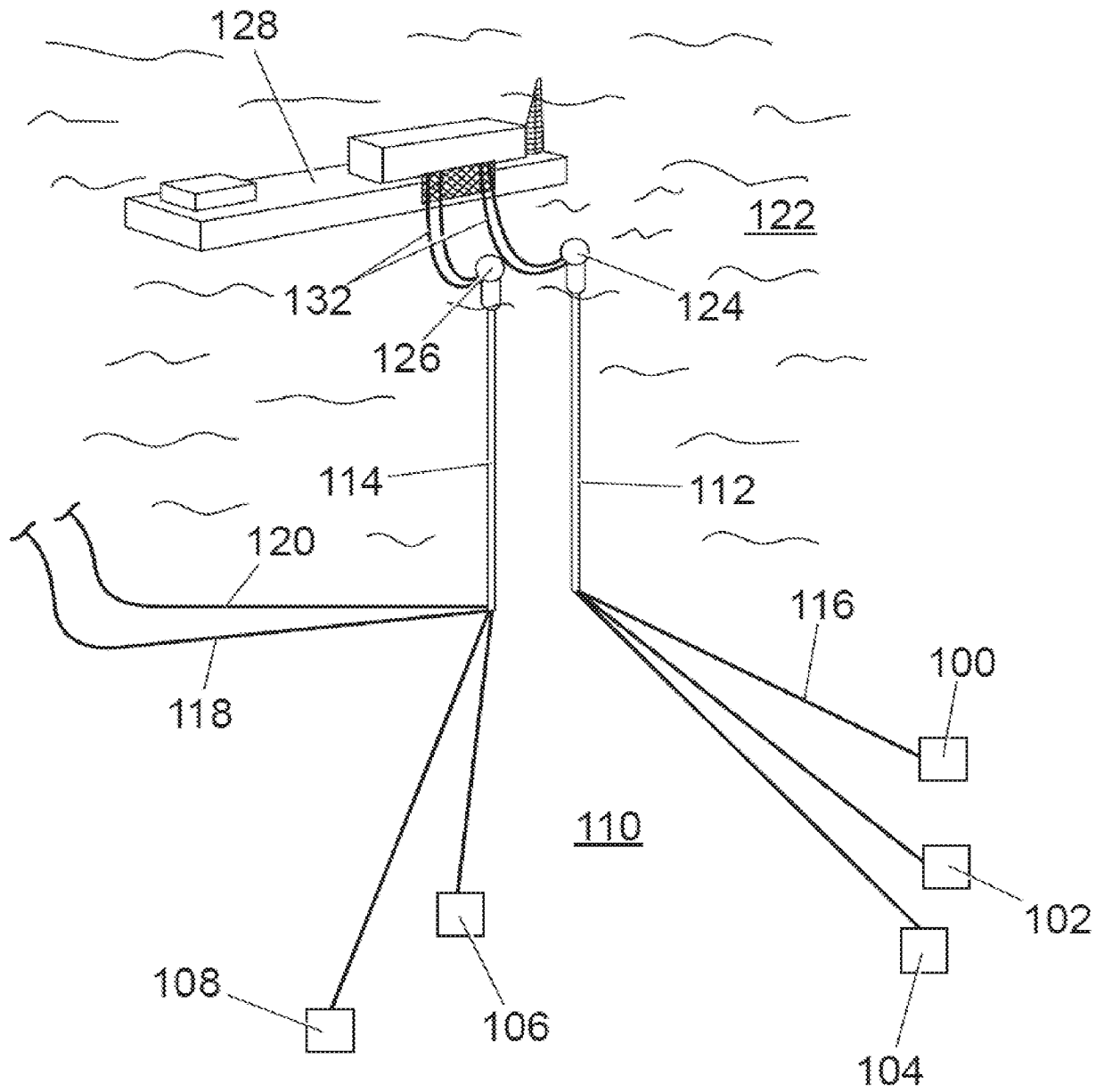
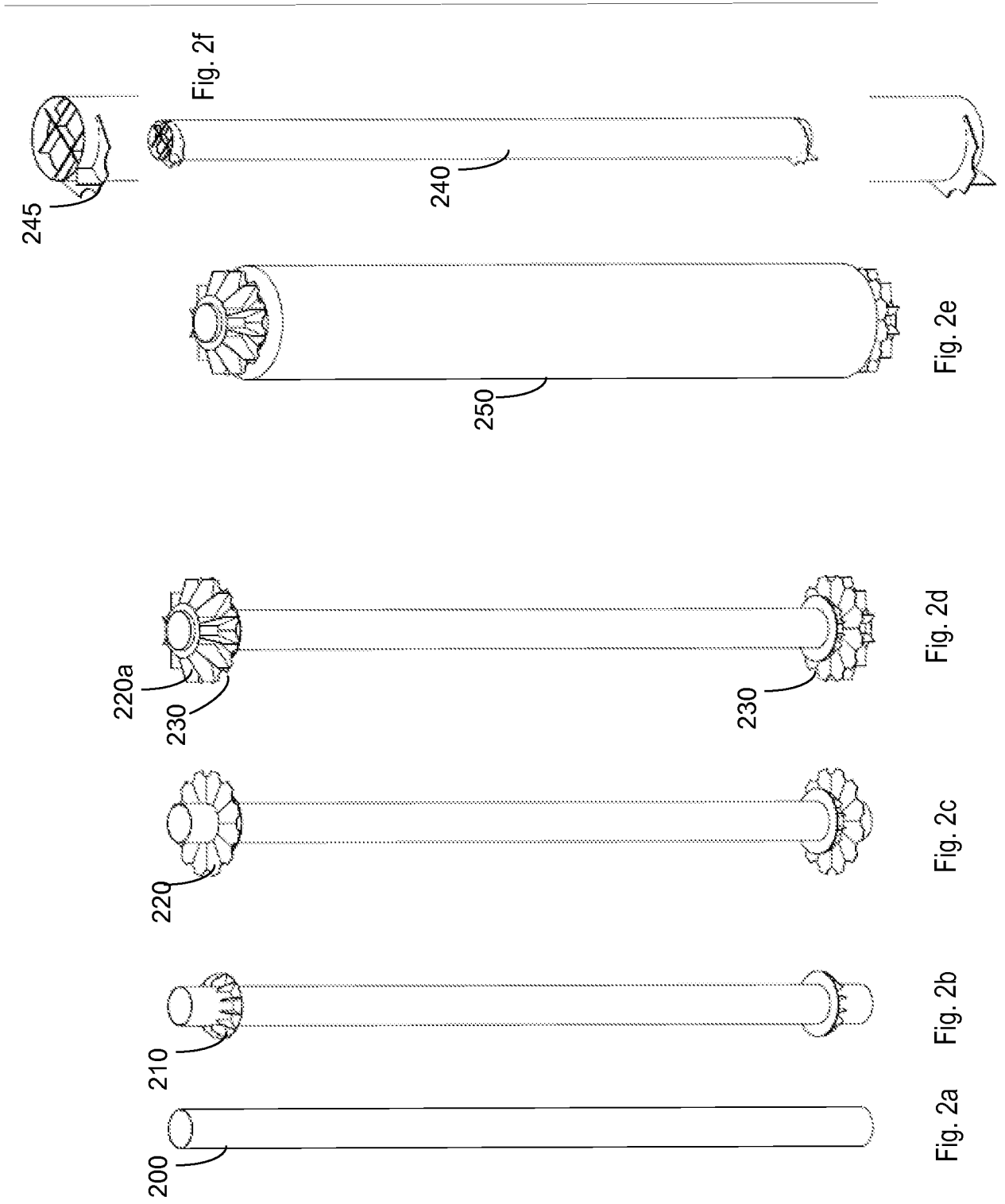


Fig. 1



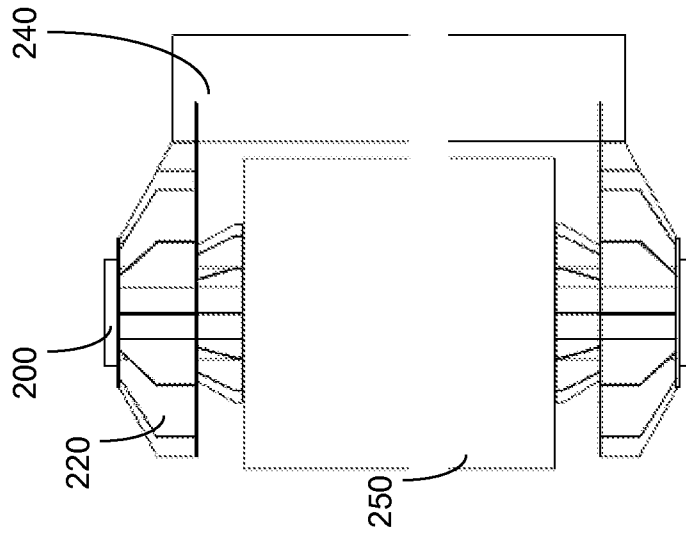


Fig. 4

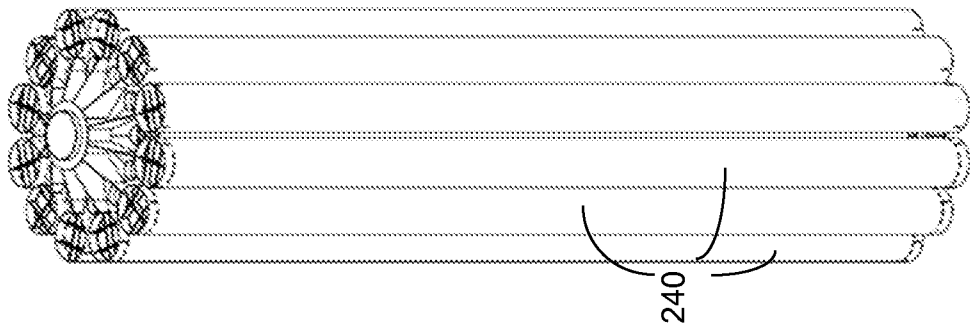


Fig. 2i

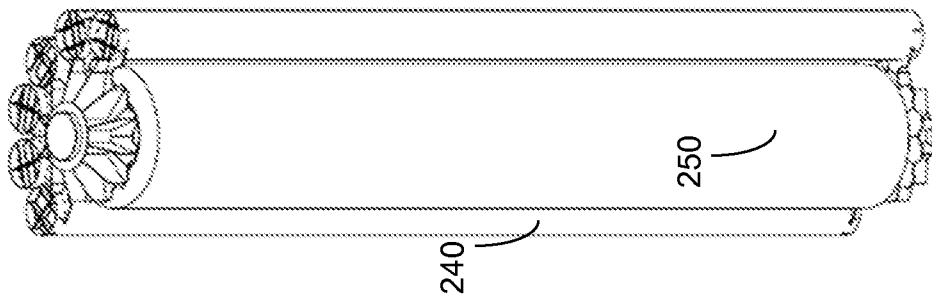


Fig. 2h

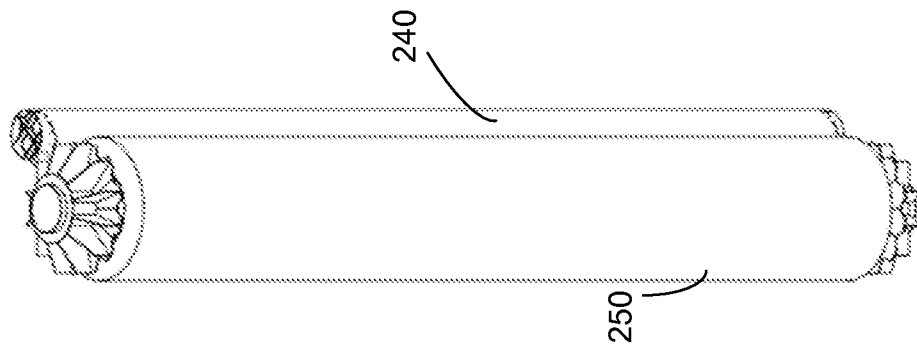


Fig. 2g

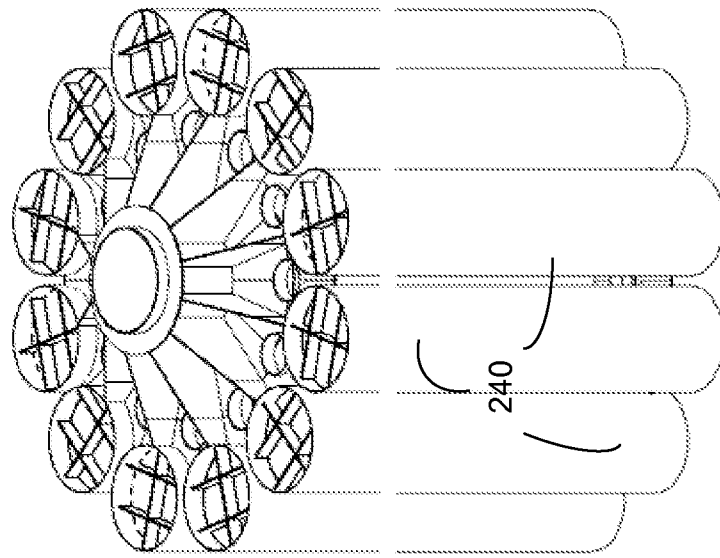


Fig. 3c

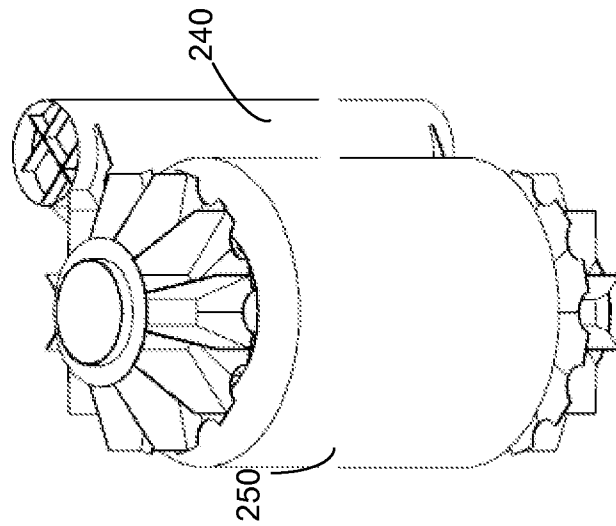


Fig. 3b

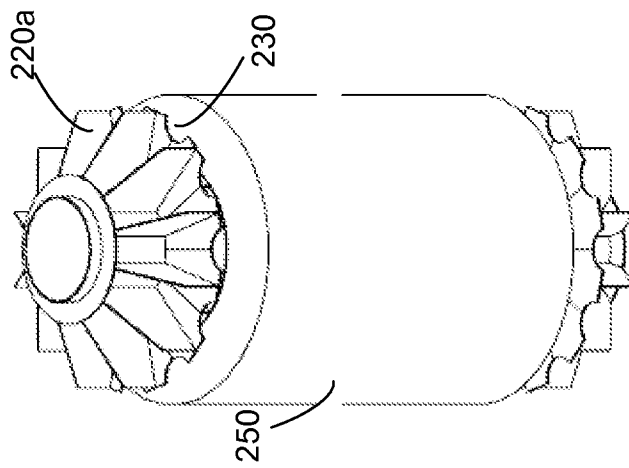


Fig. 3a