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DESCRIPTION

[0001] The present invention relates to a wet mateable connection assembly for undersea applications.

[0002] In particular the present invention especially refers to a wet mateable connection assembly for electrical and/or optical cables.

[0003] In particular, the present invention especially refers to a wet mateable connection assembly for medium and high voltage electrical cables. Typically, by medium voltage cables we mean cables suitable for more than 1 kV and up to about 30 kV, and for high voltage cables we mean cables suitable for operating above about 30 kV.

[0004] The oceanic/undersea energy generation is growing at a fast speed and in this field the technologies used to generate energy are dominantly "wind mills" but wave and tidal generators are showing some promising results.

[0005] The wind mills are generally built with fixed bottom structures and inter array cables are used to go from one turbine to the next.

[0006] In order to connect the wind mills or similar apparatus to an electric network, cables may be used, wherein the cable connections are "dry mate", i.e. the ends of the cables coming from the wind mills and of the cables of the electric network or of intermediate stations are connected together (i.e. are mated, or unmated, by means of appropriate connectors) in a dry environment, to avoid the presence of water at the connector interface, which may produce partial discharges and the consequent cable faults in the presence of electrical field and subsequently laid down underwater.

[0007] Cable hubs and/or cable substations can be used for connecting two or more underwater cables of an electric network. In these cases, and especially in places where water depths exceed 40 m depth, the dry mating is more cumbersome because it implies retrieving from underwater, for example to a ship, a sunken hub or substation having a significant weight.

[0008] The dry mating is often unpractical and generally economically disadvantageous.

[0009] In offshore windmills and other submarine applications, wet mateable connection assemblies are known.

[0010] The wet mateable connection assemblies are configured to allow the cable connection to be realized directly undersea.

[0011] Known wet mateable connection assemblies utilize an insulating liquid, such as oil, and sealing arrangements between male and female connector elements to exclude seawater from

the connector interfaces. As disclosed, for example, by US 6,736,545, such connectors generally comprise a plug unit containing one or more contact probes and a receptacle unit containing an equivalent number of contacts or junctions for engagement with the contact probes, which extend into the receptacle unit when the units are connected to each other. Typically, the contacts or junctions are contained in a sealed chamber containing dielectric fluid, and the probes enter the container via one or more openings which are sealed when the units are separated.

[0012] One major problem in designing such units is the provision of seals which will adequately exclude seawater from the phase connectors even after repeated mating and unmating, and also prevent dielectric fluid from leaking out of the chamber.

[0013] WO 96/22554 relates to underwater mateable connectors suitable for high-pressure applications and provided with a connector sealing mechanism for opening and closing a passage through a connector unit.

[0014] This mechanism comprises a moveable gate body. The gate body is moveable in a lateral direction within the connector.

[0015] The connector according to WO 96/22554 is also provided with two or dual elastomer seals, and also with an intervening chamber of dielectric fluid. In each unit, the elements to be joined are enclosed in the chamber, which is a sealed fluid-filled cavity, pressure balanced to the outside environment.

[0016] US 4,203,640 relates to an improved electrical cable coupler which incorporates a rotatable protective cover on each coupler section to protect the electrical contacts and insulation against contamination when the coupler sections are disconnected and to allow the contacts to be electrically engaged when the coupler sections are connected together. Each protective cover includes one or more openings which correspond in number and location to the electrical contacts on its coupler section. Each disc is rotatable between a protective position in which its openings are out of alignment with the respective contacts to provide protection against contamination and an operative position in which the openings are in registration with the respective contacts to expose the contacts for electrical engagement.

[0017] The Applicant recognized the need for an improved wet mateable connection assembly which has a less complex construction and which provides reliable connection and disconnection, especially in harsh subsea environments.

[0018] In particular, the applicant has found that the presence of insulating fluids requires a complex arrangement to store and manage the insulating fluid and the use of such insulating fluid may not be as effective as required in case of multiple mating and unmating actions.

[0019] The Applicant found that a wet mateable connection assembly ensuring a water-free electric connection for submarine cables and allowing repeated mating and unmating actions

can be made by providing an assembly in which an electric connector attached to a submersible cable is housed in a water-tight submersible case having a first closing gate, and an electric connector attached to a submersed cable is housed in a water-tight submersed case having a second closing gate, in which the first and second closing gates are arranged in complementary coupling interfaces such that, when the cases are coupled to each other, only a negligible amount of water may remain entrapped therebetween and in which the first closing gate is movable inside the submersed case to open communication between the submersible and submersed cases. Preferably, the submersed case is active (i.e. has self-operating equipments, activated by an external power supply) and the submersible case is passive (i.e. its components have no operating means) and the connection of the electric connectors housed in the cases is actuated by the equipment arranged in the submersed case. This contributes to reduce the weight of the submersible case, simplifying the installation operations.

[0020] Within the present description, by submersed case we mean a case, connected with a relevant cable, intended to be laid on the seabed or in general in a submersed location, where it can remain during the life of the apparatus and relevant network to which it is attached; conversely, by submersible case we mean a case connected with a relevant cable which is sunken for mating or retrieved from underwater after unmating when the relevant cable is to be detached from the submersed fixed network.

[0021] In one aspect, the present invention concerns a wet mateable connection assembly according to claim 1. Preferred embodiments are defined by the dependent claims 2 to 20. In another aspect the present invention provides a method according to claim 21. As "to operatively couple" it is meant to establish an electrical or optical connection between phase connectors.

[0022] The characteristics and advantages of a wet mateable connection assembly according to the present invention will become more apparent from the following by way of example and non-limiting description, with reference to the attached schematic drawings wherein:

- Figure 1 is a perspective view of a wet mateable connection assembly according to the present invention;
- Figure 2 is a sectional view of a wet mateable connection assembly of figure 1;
- Figures 3-5 are sectional views of a wet mateable connection assembly of figure 1 showing the movements of the gates;
- Figure 6 is a sectional view of the mating between first and second phase connectors in a wet mateable connection assembly according to the invention;
- Figures 7-9 are views of securing fittings associated with the gates of the wet mateable connection assembly according to the invention;
- Figures 10-12 are perspective views of the steps of the placing method of the wet mateable connection assembly according to the present invention.

[0023] With reference to the figures, an embodiment of a wet-mateable connector according to the present invention is shown with 10.

[0024] With reference to the figure 1, the wet mateable connection assembly 10 comprises a first watertight case 11 with a cable 1 exiting therefrom and a second watertight case 12 with a cable 2 exiting therefrom, cases 11 and 12 being mated to each other in a watertight manner along a common longitudinal connecting axis A.

[0025] Each first and second case 11, 12 comprises respective first and second coupling ends 13, 14 which are intended to be adjoined to each other when the two cases are mated together as shown in fig. 1. The first and second coupling ends 13, 14 comprise respective substantially circular apertures perpendicular to the connecting axis A.

[0026] The first coupling end 13 of the first case 11 has a flange 25 having an axial aperture.

[0027] Each case 11, 12 comprises a respective first and second opposite end 13', 14' opposite to the first and second coupling end 13, 14.

[0028] The second coupling end 14 of the second case 12 has a flange 35 having an aperture. The flange 35 has preferably a straight side on its lower portion, so as to provide the second case 12 with a foothold for the positioning on, for example, the seabed.

[0029] The second opposite end 14' opposite to the second coupling end 14 comprises a foothold 36 or the like for the positioning on the seabed.

[0030] The first coupling end 13 of the first case 11 comprises a guide handle 26 associable with a seat 27 provided on the second coupling end 14 of the second case 12.

[0031] The first case 11 comprises a bend stiffener 24 fixed to the first opposite end 13', providing a smooth connection between the rigid first case 11 and the cable 1 connected thereinto.

[0032] As shown in figure 2, the first case 11 houses first phase connectors 16, supported by a relevant cage 37 arranged inside the first case 11 and immersed in an epoxy resin; the first phase connectors 16 are coupled to corresponding cables or to corresponding cable phases of a three phases cable 1.

[0033] The second case 12 houses second phase connectors 17 supported by a relevant movable cage 38. The second phase connectors 17 are coupled to respective cables or cable phases of a three phase cable 2.

[0034] The portion of the three phase cable 2 water-tightly housed in the case 12 has a length - for example 1-1.5 m - suitable to enable the movement of the second phase connectors 17 from a distal position to a connecting position, as explained in detail hereafter. Alternatively, the

cables, or at least one or some of the cables, can be optical cables, and the connecting arrangement is configured accordingly.

[0035] The first phase connectors 16 are fixed with respect to the first case 11 to face the first coupling end 13, while the second phase connectors 17 are movable from a distal position, where the second phase connectors 17 are spaced from the second coupling end 14, to a connecting position where the second phase connectors 17 extend through coupling end 14 toward the first phase connectors 16 so as to connect thereto, as shown in figure 6.

[0036] With reference to the figures 2-6, both first and second coupling ends 13, 14 of the first and second cases 11, 12 are provided with relevant gates 18, 19. The first gate 18 is abutting against the flange 25 and is shaped to close the aperture of the first coupling end 13. Sealing rings 28 provide water tightness between the first gate 18 and the flange 25.

[0037] Preferably, the first gate 18 is arranged in an axially external position with respect to the first case 11.

[0038] The first gate 18 is connected to the first coupling end 13 of the first case 11 by means of a first hinge 15a and is kept closed by a securing fitting 20, hereinafter described.

[0039] The second gate 19 is arranged in an internal position with respect to the second flange 35 and sealing rings 29 provide water tightness between the second gate 19 and the flange 35. The second gate 19 is connected to the second coupling end 14 of the second case 12 by means of a second hinge 15b and is kept closed by securing fittings 21, hereinafter described and shown in figures 7-9).

[0040] The first gate 18 has a shape similar to that of the aperture of the flange 35 of the second coupling end 14 - preferably circular - and dimension smaller than that of said aperture so that, when the first and second coupling ends 13, 14 are adjoined, the first gate 18 and its securing fitting 20 and first hinge 15a are housed within the aperture of the second flange 35 of the second coupling end 14.

[0041] Upon coupling of the first and second cases 11 and 12, the projection of the first gate 18 into the aperture of the second flange 35 brings first gate 18 as close to the second gate 19 as permitted by the securing fitting 20, so as to leave a narrow hollow space between the first and second gates 18 and 19.

[0042] Consequently, when the two first and second cases 11 and 12 are coupled together, only a small amount of water remains entrapped in the hollow space between the gates 18 and 19.

[0043] The amount of water entrapped between first and second gates 18 and 19 can be further reduced by covering the outer surface of one or both the gates 18, 19 with a spongy layer or with bubble wrap or bubble pack or the like.

[0044] As shown, for example, in figures 4 and 5, both the first and the second gates 18, 19 are pivotable around pivoting axes B, C orthogonal to the longitudinal axis A of the connection assembly 10. Both the first and second gates 18, 19 pivot in the same direction, moving inside the second case 12.

[0045] Both the first and the second gates 18, 19 are movable from closing positions, in which the first and second cases 11 and 12 are watertight closed, to an opening position, where the connecting interface is open for allowing the connection of the first and second phase connectors 16, 17.

[0046] The wet mateable connection assembly 10 comprises operable securing fittings 20, 21 for keeping the gates 18, 19 watertight closed and, when released, allowing opening of the relevant first and second gates 18, 19.

[0047] In particular, the securing fitting 20, associated with the first gate 18, comprises a pivoting clip, hinged to the first flange 25, urged against the first gate 18 by means of a spring or the like (not shown).

[0048] The securing fittings 21, associated with the second gate 19, are arranged around the second gate perimeter and are described in better detail in the following, in connection with fig. 7, 8 and 9.

[0049] The second case 12 comprises a pushing actuator 22, acting on the pivoting clip of the securing fitting 20 associated with the first gate 18. The pushing actuator 22 is movable from a non-working position, shown in figs. 3, 4, to a working position urging against the pivoting clip, causing it to disengage from the first gate 18, allowing its opening, for example by effect of its weight, as shown in figs. 5, 6 when the second gate 19 has been opened.

[0050] The opening of the first gate 18 can be eased by the presence of a spring (not illustrated) provided in position diametrically opposed to the pivoting axis B and compressed between the inner surface of the first gate 18 and the outer surface of the first coupling end 13 so that it provides a thrust to the gate 18 following the pressing on the pivoting clip of the securing fitting 20 by the pushing actuator 22. The presence of said spring is particularly advantageous when the first case 11 is in a position other than substantially horizontal.

[0051] The second case 12 comprises a lifting actuator 39 acting on the second gate 19 and, indirectly, on the first gate 18 to bring them in vertical position for closing after unmating.

[0052] The securing fittings 21, shown in figure 7, 8, 9, are arranged inside the second case 12 and comprise each a pusher lever 31 associated with a spring 32.

[0053] In particular, the pusher lever 31 is movable from a first position acting against the second gate 19 (figure 8), to a second position allowing the pivoting of the second gate 19,

(figure 9). The movement of the pusher lever 31 is enabled by a relevant spring actuator 32a, acting on the pusher lever 31 through a couple of articulated rods 32b.

[0054] When second watertight case 12 is not mated, its second gate 19 is exposed to water pressure acting in its opening direction. Accordingly a suitable number of securing fittings 21 is provided for bearing such pressure and provide the required tightness.

[0055] The articulated rods 32b ensure that the sealing of the second gate 19 is maintained in the presence of outer pressure even with a limited load applied by the spring actuator 32a.

[0056] Vice versa, when watertight case 11 is not mated, its first gate 18 is urged against the flange 25 by the water pressure; consequently, only one securing fitting 20 may be sufficient for providing the required tightness.

[0057] The second phase connectors 17 are arranged in the movable cage 38, sliding on the bearing structure 23 acted by the coupling actuator 23a. The guide handle 26 of the first case 11 has a U or V shape or any other shape suitable for guiding the case in suspension along a rope for installation.

[0058] As from figure 10, during installation, the first case 11 slides along a guiding rope 40 connected to the seat 27 of the second case 12 at one end and attached to the installation vessel at its other end, until the first case 11 reaches the second case 12.

[0059] Upon engagement of guide handle 26 and seat 27, the seat 27 acts as pivoting point for the first case 11 with respect to the second case 12.

[0060] An auxiliary rope 40a can be advantageously provided, having one end connected, for example, at or in the vicinity of the first opposite end 13' of the first case 11, while the other end can be on the installation vessel. A suspender 42 can be provided, for example, at one end of the bend stiffener 24, to engage one or, preferably, both the guiding rope 40 and the auxiliary rope 40a, when the latter is present.

[0061] The pivoting movement of the first case 11 with respect to the second case 12 is shown on figures 11-12. Conveniently, the second flange 35 of the second case 12 comprises a plurality of conical centering studs 33, suitable to couple with corresponding stud seats 34 (shown in figure 5) of the first flange 25, and easing self-alignment of the first case 11 with respect to the second case 12.

[0062] The second flange 35 can further comprise a locking clip 41 positioned to engage the first flange 25 at its rim. In the case depicted in figures 1, 2, 11 and 12, the locking clip 41 is in a position opposite to the seat 27.

[0063] Once the alignment and coupling between first and second cases 11 and 12 has been obtained, the first and second cases 11, 12 are fixed to each other by bolts 30, tightened either

by operators or automatic actuators or robots, as hereinafter described.

[0064] When installing a power underwater link, for example for wind mills installation, power cable/s connected to the second case 12 are deployed on the seabed.

[0065] As from figure 10, the guiding rope 40 is connected to the seat 27 and its free end is kept reachable, for example, by means of a buoy. Alternatively, at the time of installation, one end of the guiding rope 40 is attached to the seat 27 by a remotely operated underwater vehicle (ROV) when mating is to be made, while the other end of the guiding rope 40 is kept at the water surface by means of a buoy or on the installation vessel.

[0066] The guiding rope 40 acts as a guide for the first case 11 until, as shown in figures 11 and 12, it reaches a position close the second case 12 and the guide handle 26 engages with the seat 27 without intervention of any remotely operated vehicle.

[0067] Starting from this engaged position the first case 11 pivots around the seat 27, as from figure 12, until the two first and second cases 11, 12 are aligned along the connecting axis A and the two first and second coupling ends 13, 14 are in reciprocal contact, with the help of conical centering studs 33 and stud seat 34. The locking clip 41 engages the lower rim of the first flange 25 securing the adherence of the first case 11 to the second case 12, before the fixing by bolts 30.

[0068] After that, the two aligned first and second cases 11, 12 are fixed to each other to realize a watertight connection. The first and second cases 11, 12 are not permitted to move reciprocally. Such operation can be made by a remotely operated underwater vehicle (ROV) bearing a suitably arranged robot, or by an operator when the laying depth so permits.

[0069] When watertight connection has been performed, the securing fittings 21, associated with the second gate 19, are remotely operated, for example by a low voltage power feed line brought by the ROV, for opening the second gate 19 that rotates inward within the second case 12. The small volume of water remained entrapped between first and second gates 18, 19 during the fixing of the first and second cases 11, 12 flows down on the second gate 19 and/or the floor of the case 12, leaving the connecting interface substantially dry.

[0070] The pushing actuator 22 acts on the securing fittings 20 of the first gate 18 which pivots inside the second case 12.

[0071] The bearing structure 23 is remotely operated to move the second phase connectors 17 towards and after the connecting interface until engagement with the relevant first phase connectors 16. The length of cable 2 housed with the second case 12 allows such movement.

[0072] The various actuators of the second case 12 are preferably hydraulic actuators, powered by a hydraulic unit (not shown), powered by a low voltage (e.g. 220V) power supply, independently brought to the second case 12 for mating or unmating operation.

[0073] In case of unmating, the above outlined procedure is followed substantially on reverse, by sending a ROV to the connection 10 for bringing power to the system.

[0074] The closing of the first and the second gates 18, 19 is performed by the remotely operated lifting actuator 39 pushing up the second gates 19 that, in turn, pushes up the first gate 18. The two first and second gates 18, 19 get at reach of the respective securing fittings 20, 21 that suitably fasten them, restoring the independent water tightness of the first and second cases 11 and 12, which can then be detached after removal of the bolts 30 by a ROV or by an operator.

[0075] The wet mateable connection assembly as described allows a dry connection also in an undersea condition, with no need of insulating fluid. The wet mateable connection assembly according the present invention is simple, economical and functional.

[0076] The materials used, as well as their dimensions, may be of suitable type depending on the technical requirements of the specific installation.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- WO9622554A **[0013]** **[0015]**
- US4203640A **[0016]**

P a t e n t k r a v

1. Våd sammenpasbar forbindelsesenhed (10), der omfatter:

- mindst et første (11) og et andet (12) vandtæt hus, der kan sammenpasses med hinanden på en vandtæt måde, hvilket første og andet hus (11,12) har respektive første (18) anden (19) porte ved respektive første (13) og anden (14) koblingsender

- mindst en første faseforbinder (16) anbragt inden i det første hus (11);

- mindst en anden faseforbinder (17) anbragt inden i det andet hus (12);

hvor

den første port (18) er bevægelig indad til det andet hus (12), når den første og anden koblingsende (13, 14) støder op til hinanden.

2. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den første faseforbinder (16) er fastgjort, så den vender mod den første koblingsende (13), og den anden faseforbinder (17) er bevægelig fra en distal position, hvor den anden faseforbinder (17) er anbragt med afstand til den anden koblingsende (14), til en forbindelsesposition, hvor den anden faseforbinder (17) udstrækker sig gennem den anden koblingsende (14), så den når den første faseforbinder (16).

3. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den første koblingsende (13) er forsynet med den første port (18), der er bevægelig omkring en drejeakse (B), som i det væsentlige er vinkelret på en langsgående forbindelsesakse (A).

4. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 3, hvor både første og anden koblingsende (13, 14) er forsynet med henholdsvis den første port (18) og den anden port (19), der er bevægelige omkring en drejeakse (B,C), som i det væsentlige er vinkelret på den langsgående forbindelsesakse (A).

5. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den første port (18) er anbragt i en aksialt udvendig position i forhold til det første hus (11).

6. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 4, hvor den anden port (19) er anbragt i en aksialt indvendig position i forhold til det andet hus (12).

5 **7.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 4, hvor den første og anden port (18, 19) kan drejes i den samme aksiale retning, vinkelret på forbindelsesaksen (A).

10 **8.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor hvert første og andet hus (11, 12) omfatter henholdsvis første og anden sikrende fitting (20, 21), der holder portene (18, 19) vandtæt lukket og kan anvendes til at åbne portene (18, 19).

15 **9.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den omfatter en trykaktuator (22), som er anbragt inden i det andet hus (12).

20 **10.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den anden faseforbinder (17) er monteret på en bærende struktur (23) inden i det andet hus (12).

11. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor hver første og anden faseforbinder (16, 17) er mekanisk og elektrisk forbundet med et elektrisk eller optisk eller hybridkabel (1, 2).

25 **12.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den første faseforbinder (16) er dyppet i et hærdbart materiale.

30 **13.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den omfatter en bøjningsafstiver (24), der er fastgjort til en første modstående ende (13') af det første hus (11).

35 **14.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den første koblingsende (13) af det første hus (11) omfatter et føringsgreb (26), der rager frem i det væsentlige vinkelret på forbindelsesaksen (12).

15. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 14, hvor føringsgrebet (26) har en form, der er egnet til at føre det første hus (11) ophængt langs med et føringsreb (40).

5 **16.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den anden koblingsende (14) omfatter et sæde (27).

10 **17.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den anden koblingsende (14) omfatter en anden flange (35) med mindst to centreringsstudse (33), og den første koblingsende (13) omfatter en første flange (25) med mindst to studssæder (34).

15 **18.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den omfatter en flerhed af tætningsringe (28, 29) mellem den første og anden koblingsende (13, 14) og den første og anden port (18, 19).

19. Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor det første og andet hus (11, 12) er fastgjort til hinanden ved hjælp af bolte (30).

20 **20.** Våd sammenpasbar forbindelsesenhed (10) ifølge krav 1, hvor den anden koblingsende (14) omfatter en låseklemme (41).

21. Fremgangsmåde til at forbinde to kabelender under vandet, hvilken fremgangsmåde omfatter trinnene:

- 25 - at tilvejebringe mindst en første faseforbinder (16) i et første vandtæt hus (11), der indbefatter en første port (18) ved en første koblingsende (13);
- at tilvejebringe mindst en anden faseforbinder (17) i et andet vandtæt hus (12), der indbefatter en anden port (19) ved en anden koblingsende (14);
- 30 - at fæste det andet hus (12) til det første hus (11) på en vandtæt måde ved hjælp af respektive første og anden koblingsender (13, 14);
- at åbne den anden port (19), dernæst den første port (18), idet den første port (18) åbnes ved at bevæge den indad til det andet hus (12); og
- at bevæge den anden faseforbinder (17) aksialt, således at den går i indgreb med den første faseforbinder (16) og funktionsmæssigt sammenkobles
- 35 dermed.

DRAWINGS

Fig. 1

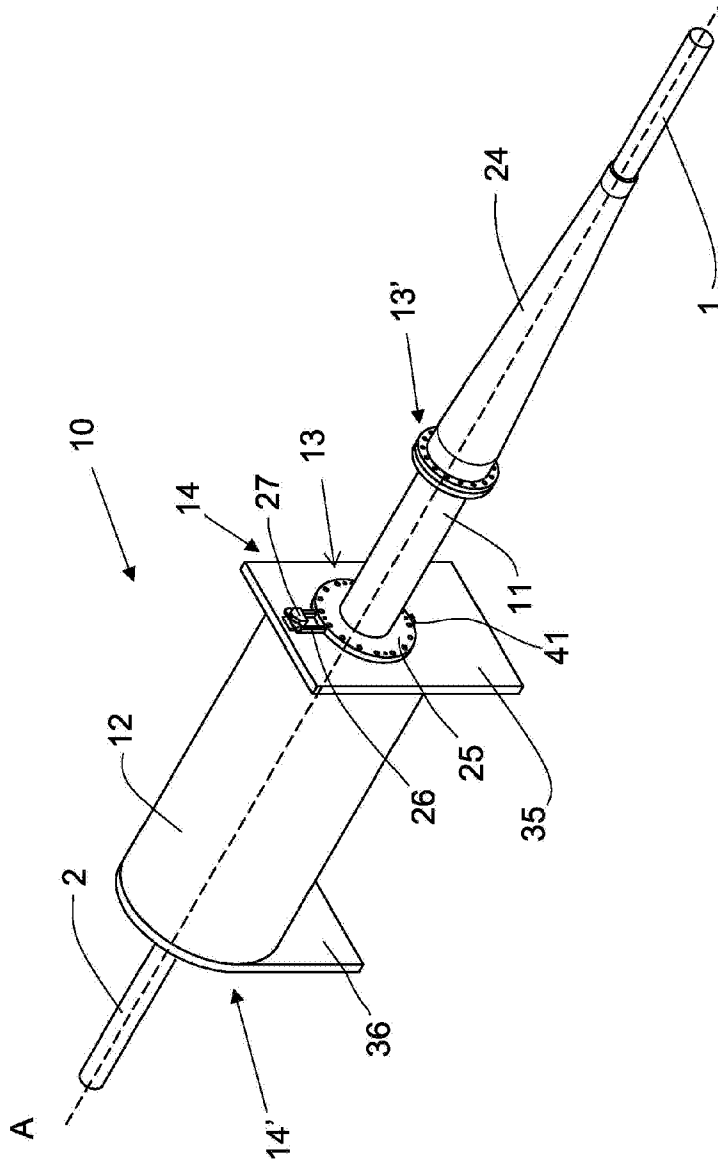
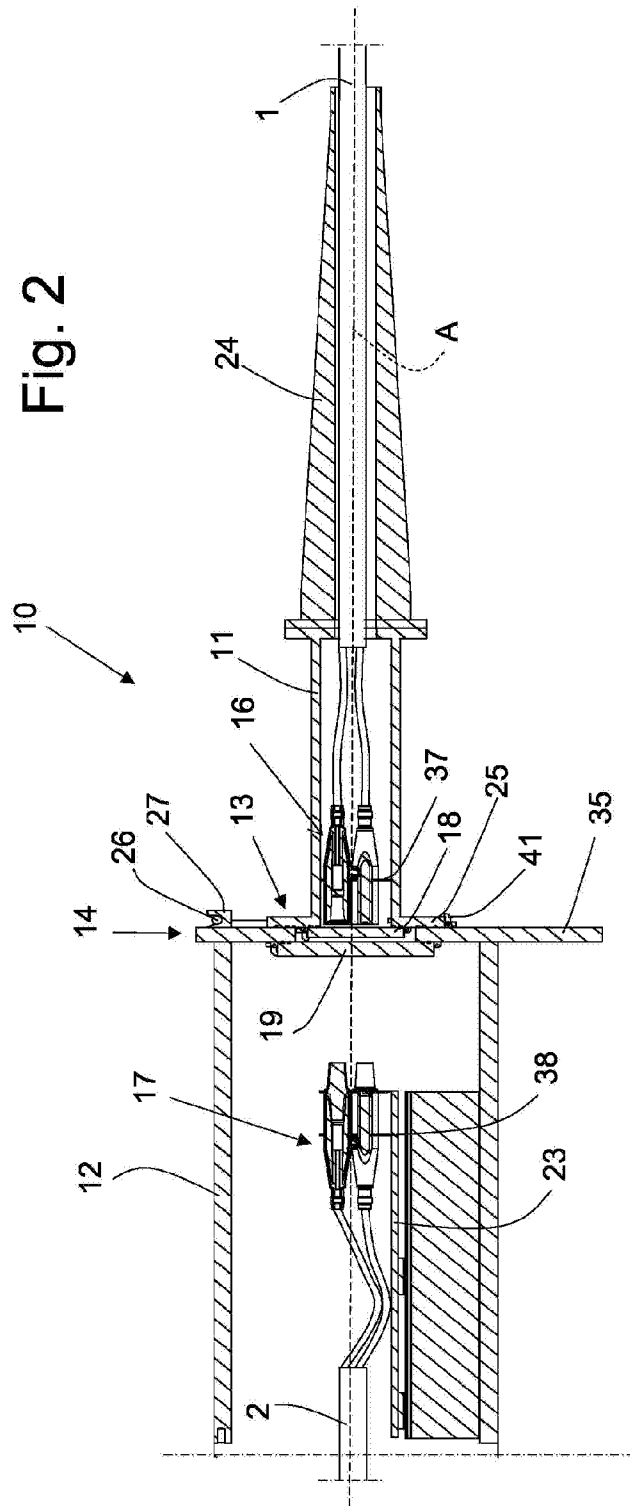


Fig. 2



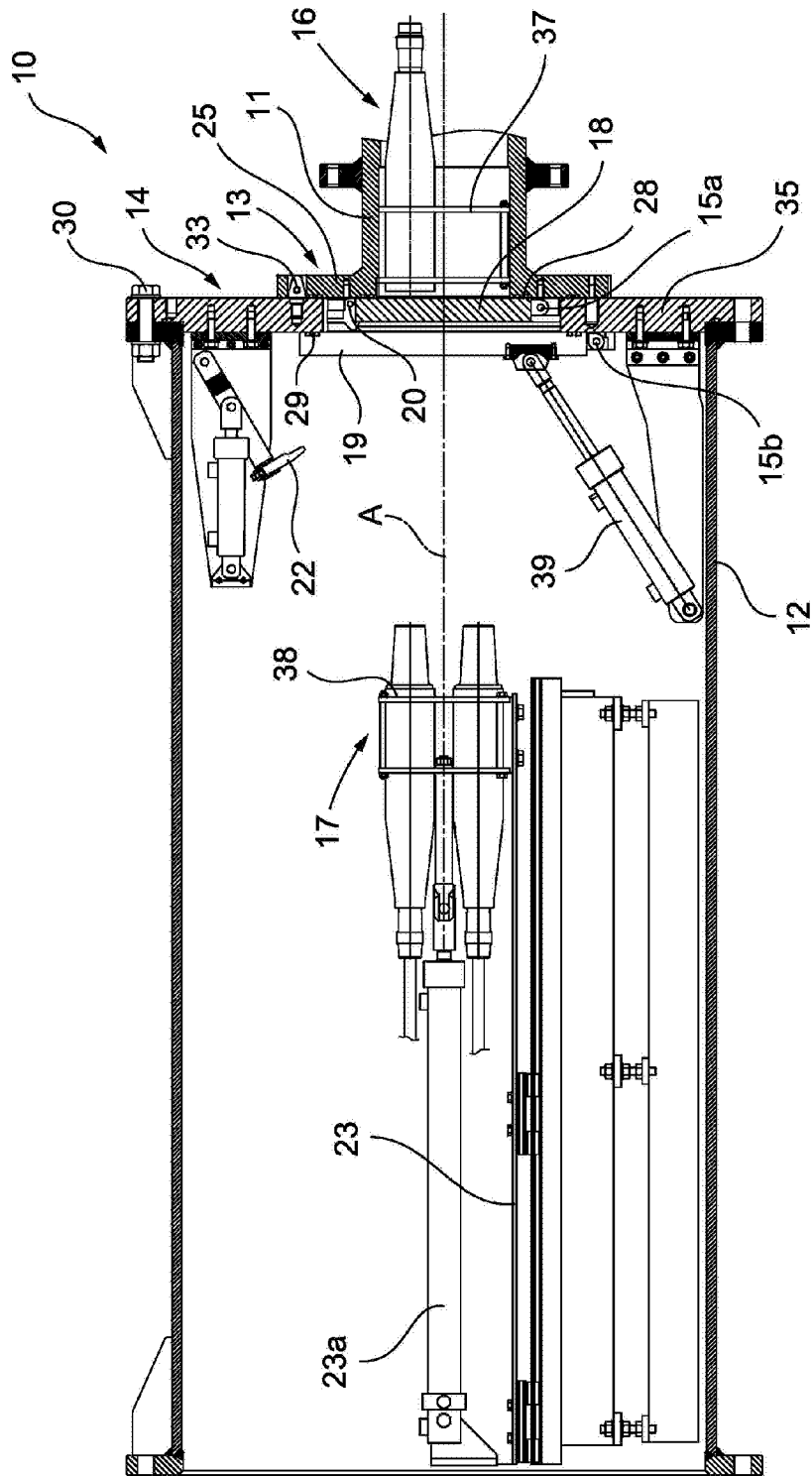


Fig. 3

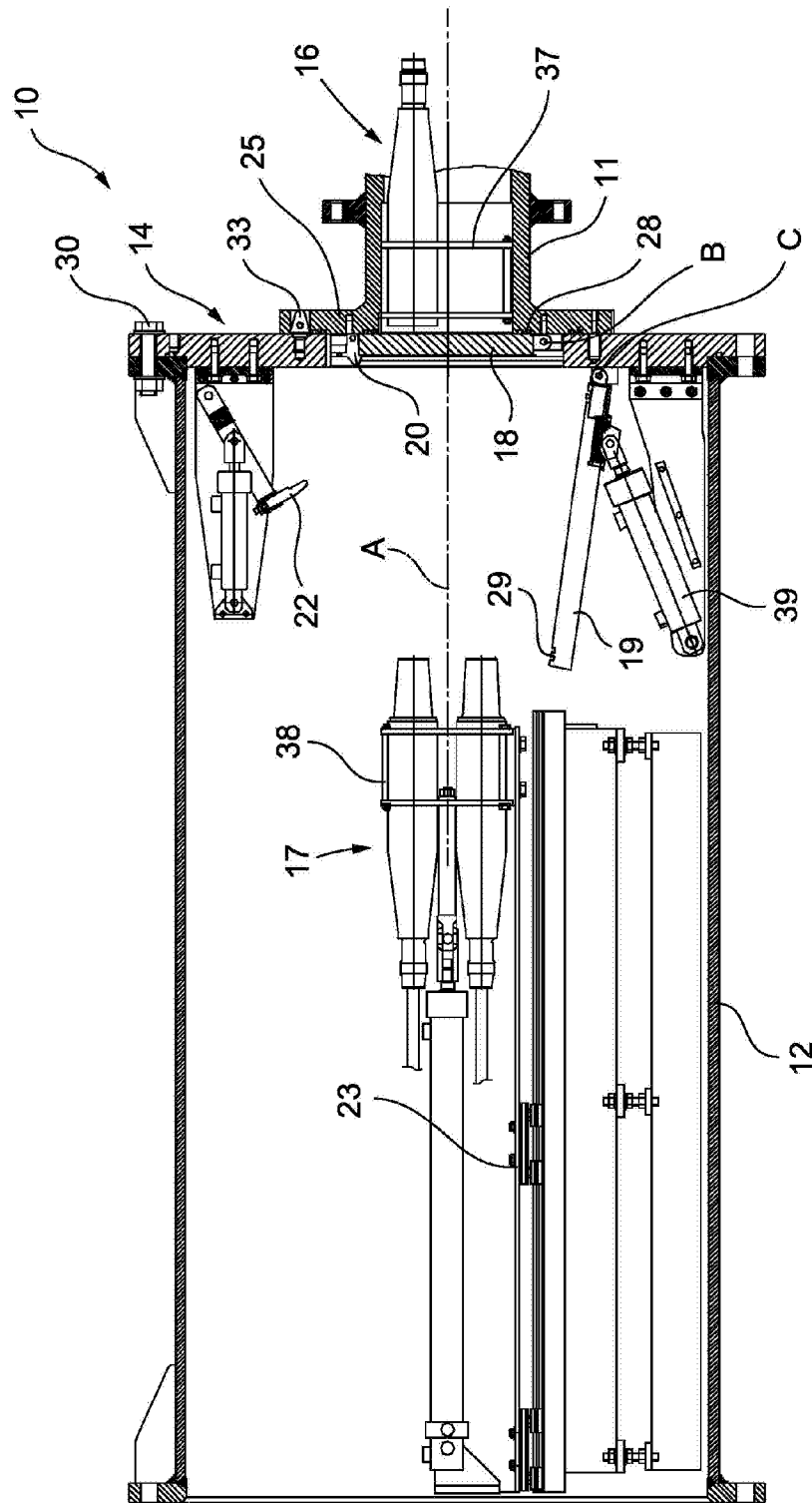


Fig. 4

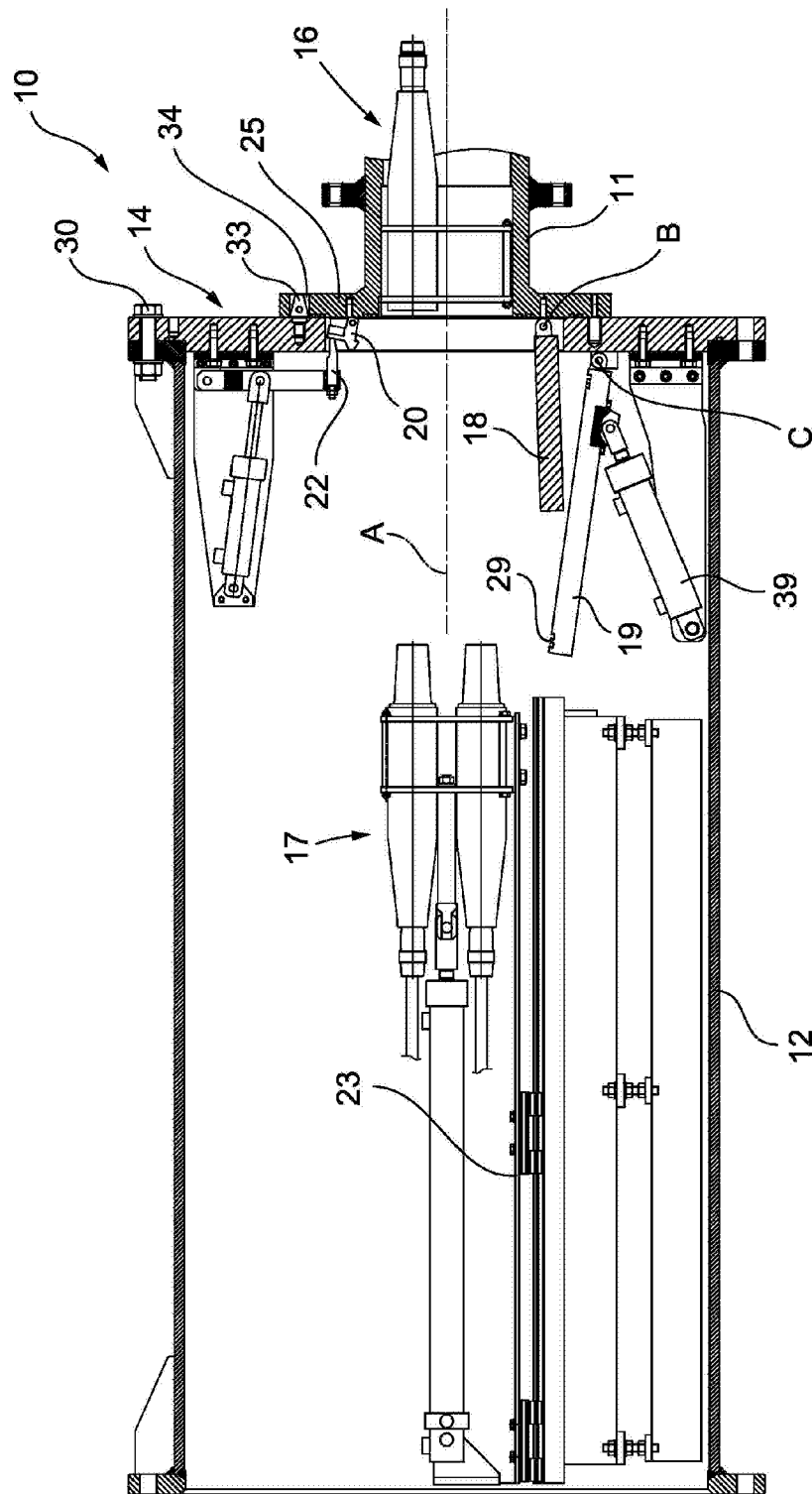


Fig. 5

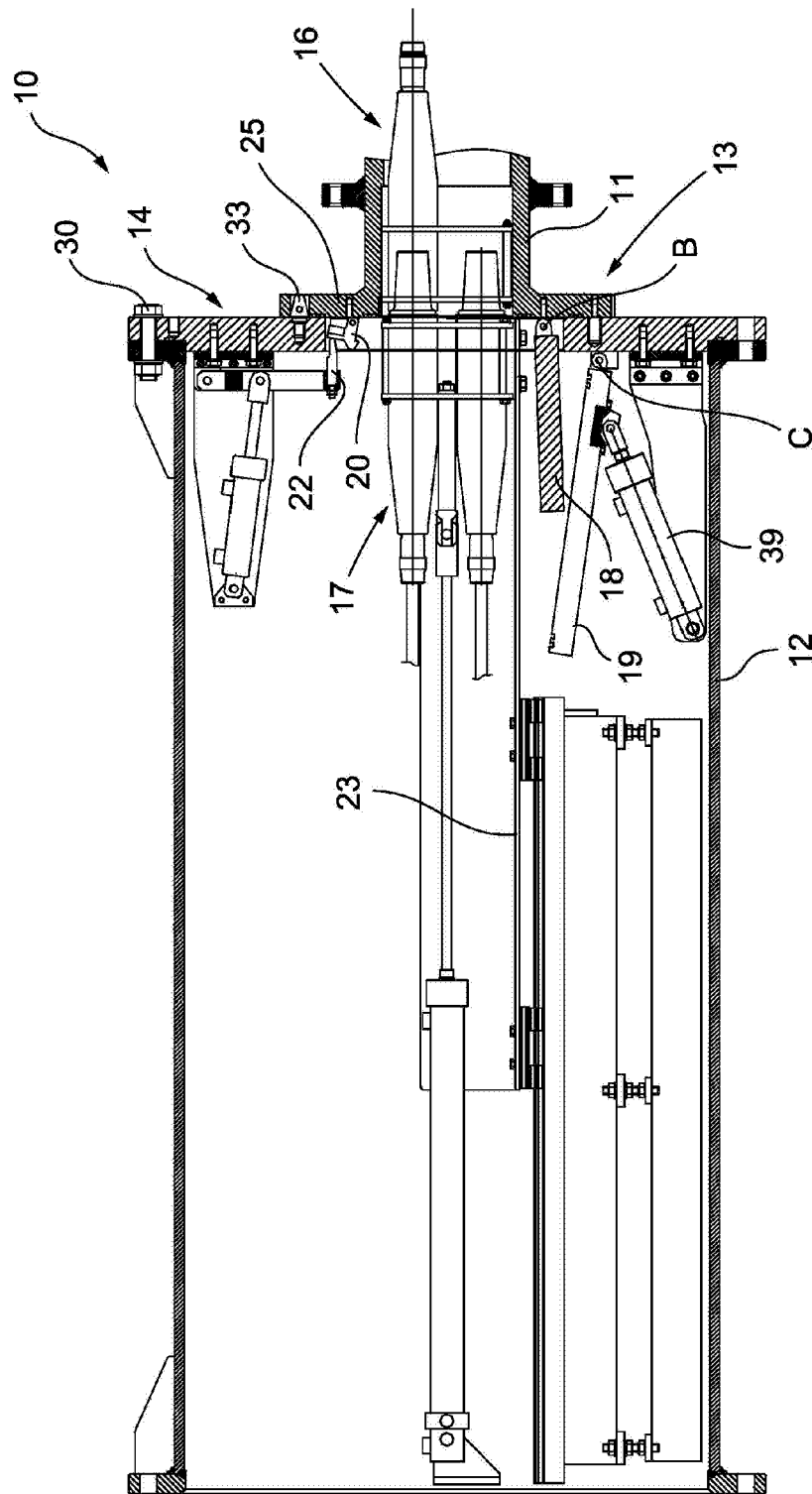
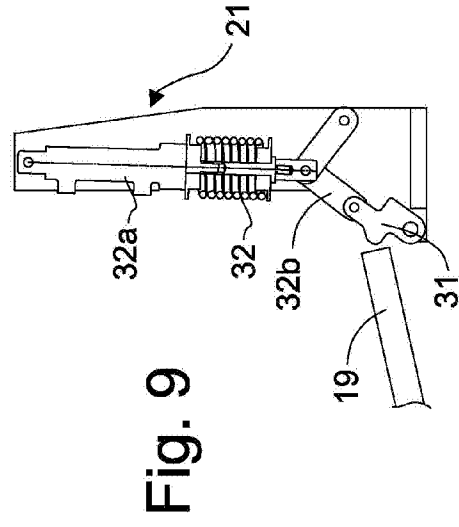
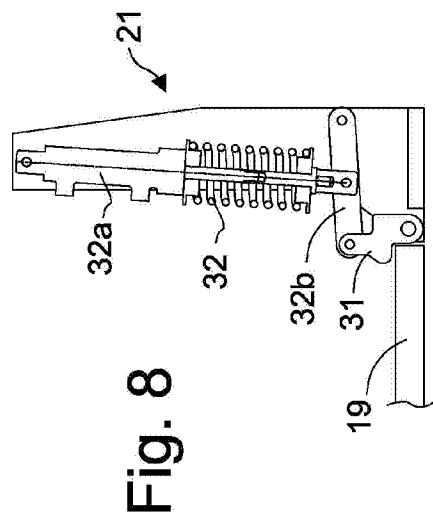
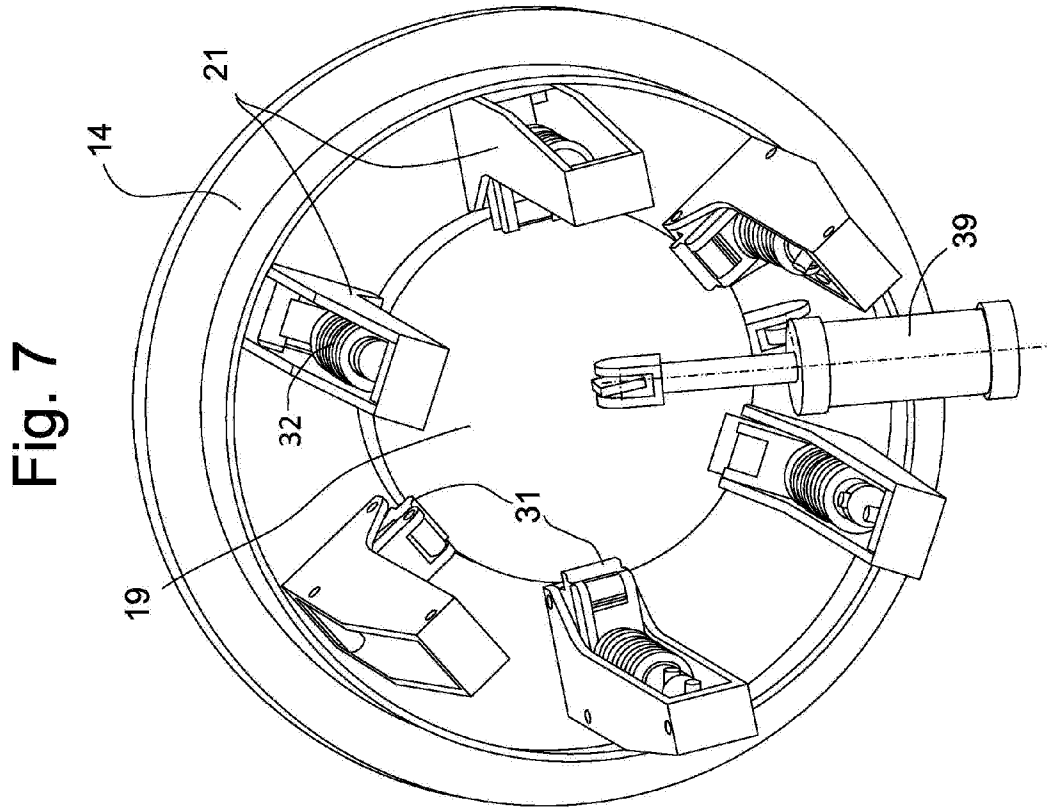


Fig. 6



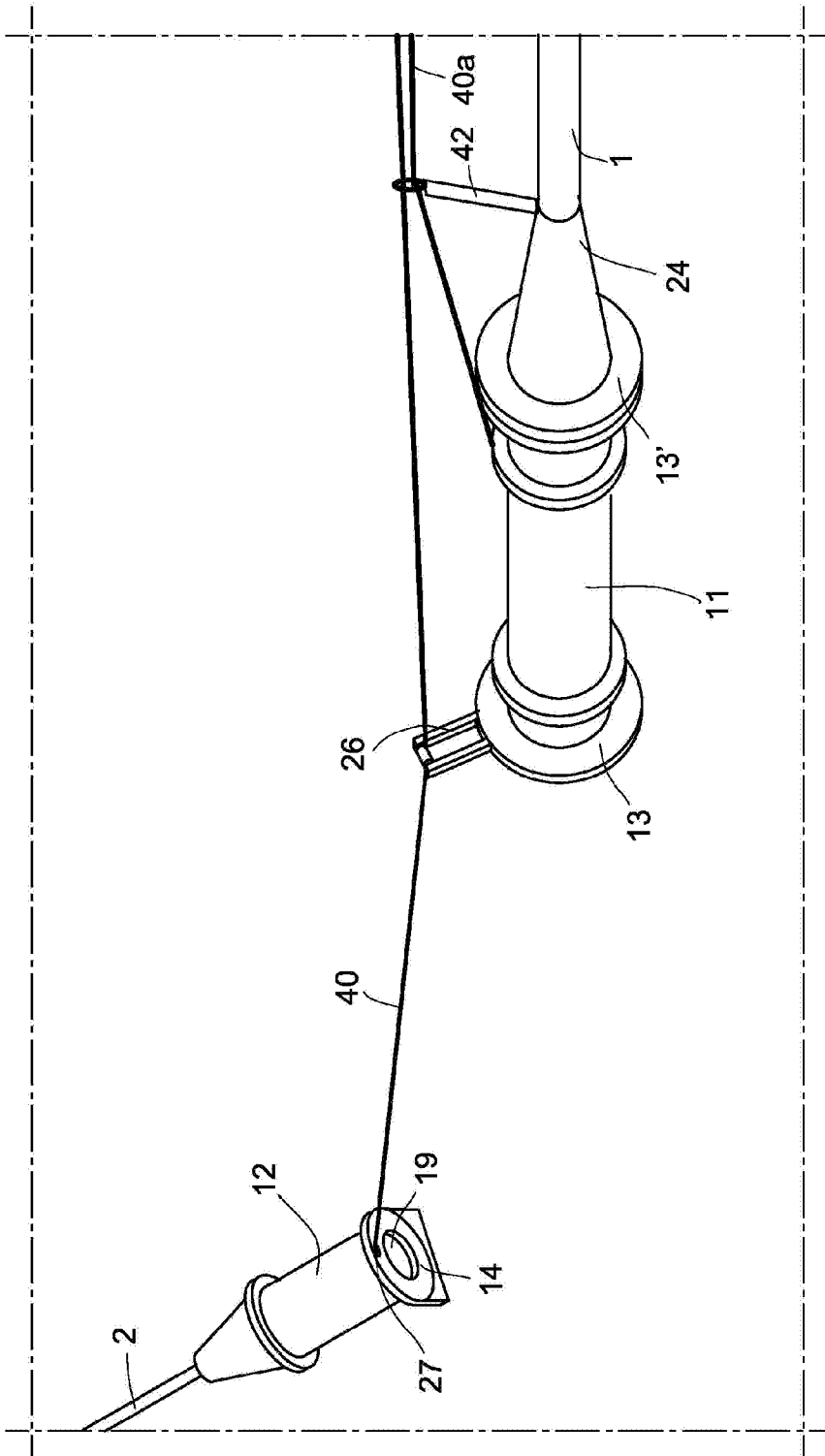
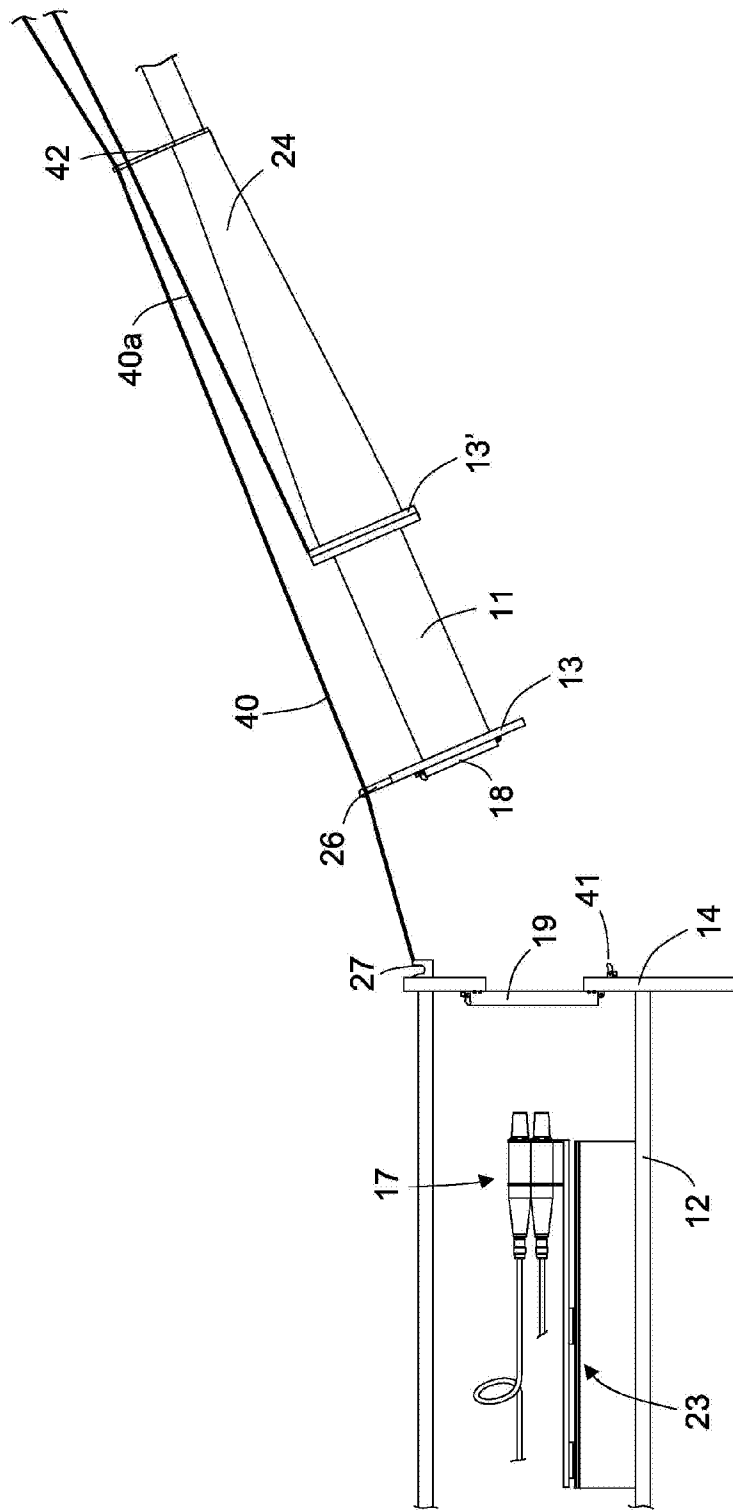


Fig. 10



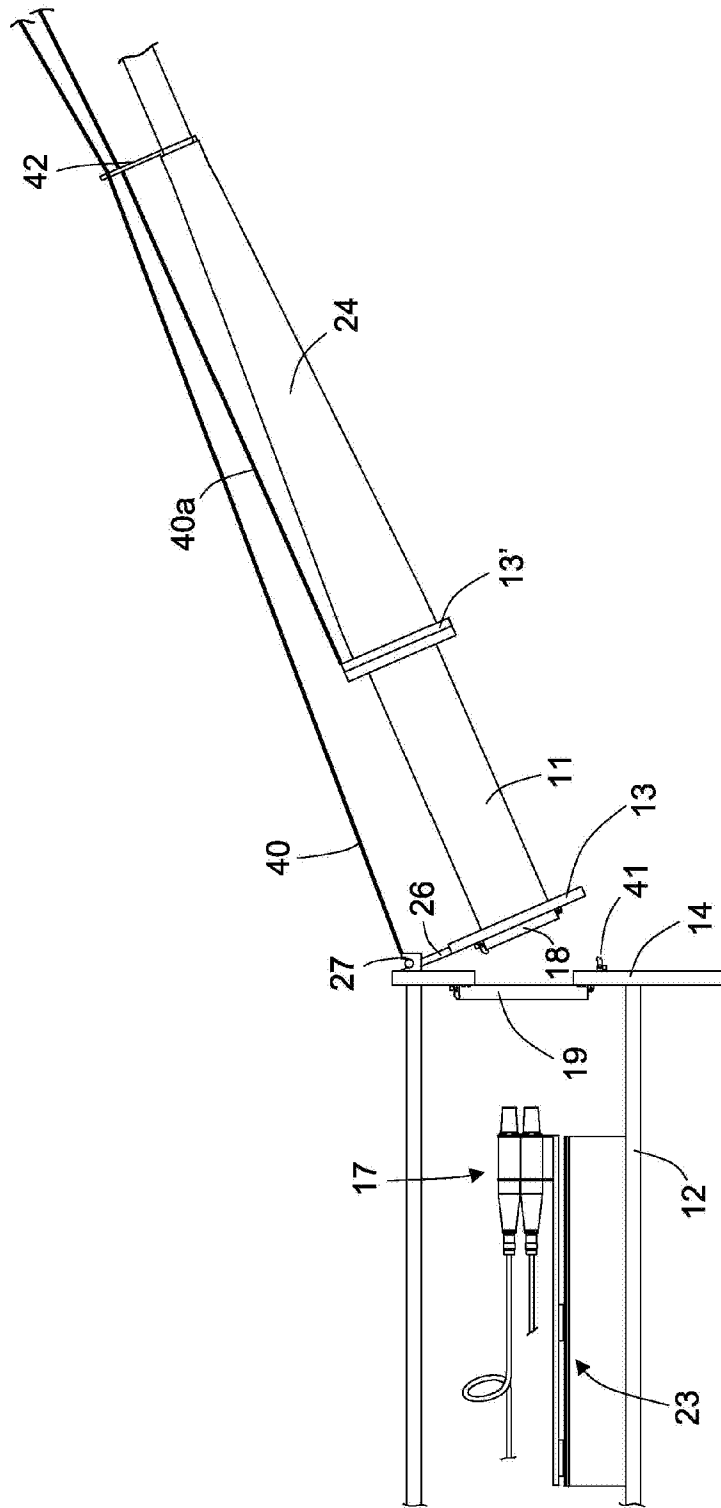


Fig. 12