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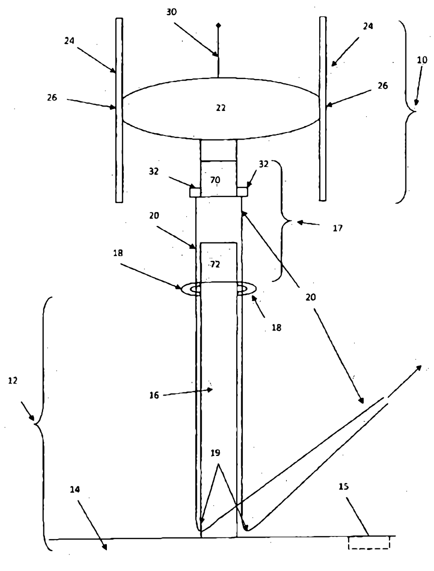

Fig. 1

(57) **Abstract**: A connector (17) is provided to mount a power generation unit of an underwater power generator to a base assembly. The connector comprises (17) a lower connector portion (72) having a stem (62) projecting upwardly and having a tapering profile and an upper connector portion (70) having an inwardly and upwardly extending recess (60). At least one generally cylindrical pin (61) extends radially inwardly into the recess (60) and at least one groove (64) is formed in the stem (62). The groove (64) is configured to allow the pin (61) to travel along the groove (64) as the stem (62) is axially inserted into the recess (60).

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Underwater Power Generator

Field of the Invention

The present invention relates generally to underwater power generators for generating power from water flows, such as marine currents and tidal or river flows, and method and apparatus for their deployment.

Background of the Invention

Known underwater power generators harness the power of marine currents and tidal flows to drive the rotation of turbine blades, which in turn drives a generator to generate power.

Optimum locations for operation of underwater power generators with suitable marine current and tidal flows are often less than optimum environments for deployment of the underwater power generators.

Many locations have strong currents making accurate deployment of underwater power generators difficult. As the generators need to undergo maintenance from time to time, the main generation unit typically needs to be raised above water for maintenance operations. Accordingly, the generation units must be disconnected from any base assembly and then reconnected once maintenance operations are complete.

Accurate deployment of the generation unit onto the base assembly is often difficult due to rugged floor terrain, wave movements when deploying from floating barges and underwater currents. Achieving correct alignment of the generation unit on the base assembly can be very difficult.

Summary of the Invention

In a first aspect, the present invention provides a connector adapted to mount a power generation unit of an underwater power generator to a base assembly, the connector comprising:

a lower connector portion adapted to be secured to the base assembly, the lower connector portion having a stem projecting upwardly from a base to a tip and having a tapering profile;

an upper connector portion adapted to be secured to the generation unit, the upper connector portion having an inwardly and upwardly extending recess;

at least one generally cylindrical pin extending radially inwardly into the recess; and

at least one groove formed in the stem, the groove being configured to allow the pin to travel along the groove as the stem is axially inserted into the recess.

In a preferred embodiment, the connector includes a plurality of the pins and a corresponding plurality of the grooves.

Preferably, each groove extends from an upper opening to an end seat and wherein the pins are adapted to rest in the end seat when the upper connector portion is lowered onto the lower connector portion.

Preferably, the upper and lower edges have complementary undulating profiles that inhibit axial rotation of the upper connector portion. Further preferably, the upper and lower edges are formed with a plurality of teeth.

In a preferred embodiment, the stem is provided with a plurality of radially outwardly projecting splines and the recess is provided with corresponding radially inwardly projecting splines, wherein the splines of the stem are adapted to engage the splines of the recess to inhibit axial rotation of the upper connector portion.

Preferably, the stem is provided with at least one bearing surface and the recess is provided with a corresponding bearing surface, wherein the bearing surface of the recess bears on the bearing surface of the stem when the upper connector portion is lowered onto the lower connector portion.

In a preferred embodiment, the connector further comprises a services connector adapted to connect service cabling between the lower and upper connector portions, the services connector comprising:

a first services table having one or more cable connectors; and

a second services table having one or more corresponding cable connectors;

wherein at least one of the services tables is a turntable adapted to rotate relative to the other table to allow alignment of the corresponding cable connectors, prior to the tables being pressed together to join the corresponding cable connectors.

Preferably, at least one of the tables is provided with positioning pins and the other table is provided with positioning apertures arranged to receive the positioning pins when the tables are pressed together.

The services connector may be arranged internally of the connector or alternatively, the services connector may be arranged externally of the connector.
Preferably, the positioning pins and apertures are arranged asymmetrically on the turntables to ensure that the turntables can only be connected in a single orientation.

In a third aspect, the present invention provides an underwater power generator comprising:

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a base assembly;

a generation unit adapted to be mounted on the base assembly; and

a connector according to either the first or second aspect above.

Brief Description of the Drawings

A preferred embodiment of the invention will now be described by way of specific example with reference to the accompanying drawings, in which:

Fig. 1 depicts an underwater power generator during deployment;

Fig. 2 depicts an underwater power generator after deployment;

Fig. 3 depicts a first connector portion of an underwater power generator;

Fig. 4 depicts a second connector portion of an underwater power generator;

Fig. 5 depicts an alternate embodiment of a second connector portion;

Fig. 6 is a cross sectional view of the second connector portion of Fig. 5;

Fig. 7 depicts an alternate embodiment of a first connector portion;

Fig. 8 is a cross sectional view of the first connector portion of Fig. 7;

Figs. 9A to 9D depict stages of connection of a services connector of an underwater power generator;

Fig. 10 is a side elevation view of an alignment system for aligning a generation unit and a base assembly; and

Fig. 11 is a cross-sectional view of an alignment tool for an underwater power generator.

Detailed Description of the Preferred Embodiments

Fig. 1 depicts an underwater power generator during deployment of a generation unit 10 for installation on a base assembly 12 comprising a base 14 and a pylon 16. Alternatively, the pylon 16 can be installed directly in the sea bed. Fig. 2 depicts the underwater power generator after deployment of the generation unit 10 on the base assembly 12.

The base 14 includes recesses 15 for receiving solid or fluid masses, such as for example concrete or spoil to improve stability. The support pylon 16 includes a pair of upper guides 18 and a pair of lower guides 19, which during deployment guide alignment cables 20. The alignment cables 20 during deployment help to align a connector 17 that comprises a first upper connector portion 70 and a second lower connector portion 72.

The generation unit 10 includes blades 24 mounted on a rotor 26 that allows the blades 24 to rotate in response to flowing water currents. The rotor 26 is mounted to a nacelle 22 which houses a generator. The generation unit 10 also includes a lobe 29 for lifting or lowering the generation unit 10 via a deployment cable. Attachment points 32 for the alignment cables 20 are provided on the upper connector portion 70 for alignment by the alignment cables 20 with the upper guides 18.

As shown in Figs. 3 and 4, the connector 17 comprises upper and lower connector portions 70, 72 that are designed to be coupled together and held in location by gravity and interference fit.

The upper connector portion 70 includes an inwardly and upwardly extending recess 60 and radially inwardly projecting cylindrical pins 61. The lower connector portion 72 includes a stem 62 projecting upwardly from a base 67 to a tip 69 and having a generally tapering profile. A series of tapered grooves 64 are formed in the stem 62.

When the upper connector portion 70 is lowered axially over the lower connector portion 72 to couple the connector 17, the inwardly projecting cylindrical pins 61 in the recess 60 are received in, and travel along, the grooves 64 of the stem 62. Rotation is inhibited by the interference of the pins 61 in the grooves 64 when the connector 17 is coupled together.

Each groove 64 extends from an upper opening to an end seat 65 and the pins 61 rest in the end seats 65 when the upper connector portion 70 is lowered onto the lower connector portion 72.

An alternate embodiment of the connector is shown in Figs. 5 to 8. The connector comprises upper and lower connector portions 270, 272 that are designed to be coupled together similar to the embodiment described above. Figs. 5 and 6 depict the lower connector portion 272 and Figs. 7 and 8 depict the upper connector portion 270.

The lower connector portion 272 comprises a stem 262 that projects upwardly and has a intermittently tapering profile narrowing from a base 274 towards a tip 276. An upper bearing surface 275 and a lower bearing surface 277 are provided between the base 274 and the tip 276. The outer surface of the stem 262 is provided with a series of splines 264 that are spaced circumferentially around the stem 262. An upwardly projecting flange ring 278 is bolted to stem 262 adjacent to the base 274 and comprises an upright ring spaced outwardly from the base 274 of the stem 262 and having an undulating upper edge 280.

The upper connector portion 270 comprises a recess 260 extending inwardly and upwardly into the body of the upper connector portion 270. The recess 260 has an intermittently tapering profile narrowing from a lower rim 282 into the upper connector portion 270. An upper bearing surface 285 and a lower bearing surface 287 are provided between the rim 282 and the inner end of the recess 260. The inner surface of the recess 260 is provided with a series of radially inwardly projecting splines 261 that are spaced circumferentially around the recess 260. The rim 282 includes a skirt ring 286 that depends downwardly from the upper connector portion 270 and has an undulating lower edge 288, which is complementary to the undulating upper edge 280 of the flange ring 278.

The lower connector portion 272 is typically bolted to the top of a pylon in an upright presentation, while the upper connector portion 270 is typically bolted to the lower end of a generation unit of the underwater power generator. As the upper connector portion 270 is lowered onto the lower connector portion 272, the portions align axially due to the tapering profile. As the connector portions 270, 272 come together, the undulating lower edge 288 of the skirt ring 286 meshes with the complementary undulating upper edge 280 of the flange ring 278. As the flange ring 278 and the skirt ring 286 mesh together, the bearing surfaces 285, 287 of the upper connector portion 270 engage and bear on the bearing surfaces 275, 277 of the lower connector portion 272. The upper and lower edges 280, 288 are effectively formed with complementary teeth that are adapted to mesh together. The meshed upper and lower edges 280, 288 engage one another and inhibit axial rotation of the upper connector portion 270. Further, the inwardly projecting splines 261 of the upper connector portion 270 inhibit axial rotation by engaging the outwardly projecting splines 264 of the lower connector portion 272.

In this way, weight and torsional forces are transmitted through the connector without needing to clamp or latch the two portions 270, 272 together. The upper connector portion 270 is retained on the lower connector portion 272 merely by gravity and interference forces.

No locking mechanism, clamping or other fastening mechanism is required to retain the generation unit 10 on the base assembly 12 as gravity holds the generation unit 10 in place. This allows the generation unit 10 to be raised for maintenance simply by lifting the generation unit 10, which disengages the upper connector portion 70 from the lower connector portion 72.

In some embodiments, the upper connector portion 70 includes a mechanical restraint to augment the gravity connection, while still allowing disengagement from the lower connector portion 72 by simply lifting the generation unit 10. This provides an additional factor of safety for occasional impact loads.

As depicted in Figs 9A to 9D, the connector 17 also includes a services connector 80 for connecting service cabling such as electrical power and optical fibre lines between the upper and lower connector portions 70, 72. The services connector 80 includes a first turntable housing 82, having a first turntable 93 with male cable connectors 83, and a second turntable housing 84, having a second turntable 95 with female cable connectors 85 corresponding to the male cable connectors 83. The first and second turntable housings 82, 84 are connected during deployment by pressing the two turntable housings 82, 84 together, usually after coupling the upper and lower connector portions 70, 72 together. Positioning pins 86 and corresponding positioning apertures 87 are also provided to ensure correct alignment and by being asymmetrically offset only allow the turntable housings 82, 84 to be connected in a single orientation.

The turntables 93, 95 are rotatable relative to one another to allow the positioning pins 86 to be aligned with the positioning apertures 87, thereby aligning the male and female cable connectors 83, 85 before the turntable housings 82, 84 are pressed together, typically using hydraulic actuators. This connects the male and female cable connectors 83, 85 together and provides a services connection between the upper and lower connector portions 70, 72.

The services connector 80 can be provided internally of the connector 17 or alternatively, externally of the connector 17.

Returning to Figs. 1 and 2, during deployment, the base assembly 12 is first lowered by cables to a sea bed. The alignment cables 20 extend through the lower and upper guides 19, 18 during the deployment. Spoil or other mass may be provided in the recesses 15 of the base 14 to improve stability. Alternatively, the pylon 16 can be installed directly in the sea bed. The pylon 16 is installed generally upright with the lower connector portion 72 attached to the top of the pylon 16.

The deployment cable 30 is then attached to generation unit 10 at the lobe 29 and the ends of the alignment cables 20, which already extend through the lower and upper guides 19, 18, are attached to the attachment points 32 of the upper connector portion

70. The other ends of the alignment cables 20 are attached to a take-up winch which could be arranged on a deployment barge or another platform or on the base 14 or sea bed.

The generation unit 10 is lowered by letting out the deployment cable 30. With the alignment cables 20 attached to the attachment points 32 and extending through the upper and lower guides 18, 19, a winch is used to draw in the alignment cables 20, which guides the generation unit 10 towards the base assembly 12.

With the generation unit 10 aligned over the base assembly 12, the upper connector portion 70 is lowered over the lower connector portion 72, so that the stem 62 is received in the recess 60. The pins 61 in the recess 60 of the upper connector portion 70 are received in, and travel along, the corresponding grooves 64 on the stem 62 of the lower connector portion 72. The generation unit 10 is lowered until the pins 61 sit in the end seats 65 of the grooves 64. When fully coupled, the upper connector portion 70 overlaps the lower connector portion 72 by approximately 2 metres in length.

The cable tension, cable playout length and speed are all monitored by sensors arranged adjacent to the winches. Communications networks communicate this data to a control system which controls the deployment of the generation unit 10 from the standby position shown in Fig. 1 to the deployed position shown in Fig. 2.

The connector 17 can be provided with the connector portions reversed such that the stem is on the upper portion and the recess is on the lower portion. However, the arrangement described is preferred because when disengaged from the upper portion, the recess if located on the lower portion would be vulnerable to being clogged with silt and marine growth.

A separate rotation device may be disposed in the pylon 16 or in the upper connector portion 70 to rotate the generation unit 10 to align with prevailing current flows.

The upper connector portion 70 can be aligned with the lower connector portion 72 in any of the multiple alignments determined by the number of pins 61 and corresponding grooves 64. By using different pairs of attachment points 32, the generation unit 10 can be lowered in any of the multiple alignments. A rotatable flange connection 76 between the upper connector portion 70 and the generation unit 10 also allows selective orientation of the generation unit 10 relative to the upper connector portion 70. These features are employed to correctly align the generation unit 10 with the prevailing current flow.

The blades 24 may be provided in one or two rotor sets and may be bi-directional or mono-directional. In the latter case of one rotor set, a rotation device will be desirable to provide efficient harnessing of the flow.

Once full deployment has been achieved, the deployment cable 30 is detached from the generation unit 10. The ends of the alignment cables 20 that are attached to the take-up winch are detached and reattached to an anchor 75 or mooring block. Some chain may be attached to provide absorption of movement.

As depicted in Figs. 9A to 9D, hydraulic power is then used to join the turntable housings 82, 84 of the services connector 80. In order to ensure that like services are connected to like services, the positioning pins 86 must be correctly aligned with the positioning apertures 87 in order to allow the turntable housings 82, 84 to be joined. To ensure the exact alignment and integrity of the services connector 80, cameras and other recording instruments are utilised.

The second turntable housing 84 includes a void of square cross section with chamfered corners. The first turntable housing 82 includes posts disposed at spaced apart corners so as to inhibit rotation between the first and second turntable housings 82, 84.

Alignment facilitators are depicted on the first and second turntable housings 82, 84 to facilitate alignment and these are in the form of chamfers or lead-in portions.

Figs. 10 and 11 depict an alternative method for guiding the connector portions 70, 72 together using auxiliary alignment cables 102 acting as a guide. Anchors 100 are lowered at the end of associated guidance cables 102 that are kept taught from a surface vessel, preferably the same device that is providing the lift/lower function. Various holes are provided in the base 14 for receiving the anchors 100 to allow for different alignment of the nacelle 22 of the generation unit 10.

An alignment tool 110 which has a snug interference fit with the nacelle 22 is arranged on the nacelle 22 and held in place by gravity. The alignment tool 110 has a pair of laterally extending arms 105 and is arranged on the nacelle 22 in an appropriate alignment. The alignment cables 102 run through guide apertures 112 at the end of each laterally extending arm 105. The guide apertures 112 have a large enough diameter to accept the guide cable 102 but are smaller than the anchors 100. Once the nacelle 22 is in place on the pylon 16, the anchors 100 are released from the base 14 and winched up. The anchors 100 can not pass through the guide apertures 112 so the alignment tool 110 is caught by the anchors 100 and lifted off the nacelle 22 and back to the surface. The lifting force imposed on the arms 105 of the alignment tool 110 also releases the snug gravity fit of the alignment tool 110 on the nacelle 22.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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The claims defining the present invention are as follows:

1. A connector adapted to mount a power generation unit of an underwater power generator to a base assembly, the connector comprising:

a lower connector portion adapted to be secured to the base assembly, the lower connector portion having a stem projecting upwardly from a base to a tip and having a tapering profile;

an upper connector portion adapted to be secured to the generation unit, the upper connector portion having an inwardly and upwardly extending recess;

at least one generally cylindrical pin extending radially inwardly into the recess; and

at least one groove formed in the stem, the groove being configured to allow the pin to travel along the groove as the stem is axially inserted into the recess.

2. The connector of claim 1, including a plurality of the pins and a corresponding plurality of the grooves.

3. The connector of any one of the preceding claims, wherein each groove extends from an upper opening to an end seat and wherein the pins are adapted to rest in the end seat when the upper connector portion is lowered onto the lower connector portion.

4. The connector of any one of the preceding claims, wherein the stem is provided with a plurality of radially outwardly projecting splines and the recess is provided with corresponding radially inwardly projecting splines, wherein the splines of the stem are adapted to engage the splines of the recess to inhibit axial rotation of the upper connector portion.

5. The connector of any one of the preceding claims, wherein the stem is provided with at least one bearing surface and the recess is provided with a corresponding bearing surface, wherein the bearing surface of the recess bears on the bearing surface of the stem when the upper connector portion is lowered onto the lower connector portion.

6. The connector of any one of the preceding claims, further comprising a services connector adapted to connect service cabling between the lower and upper connector portions, the services connector comprising:

a first services table having one or more cable connectors; and a second services table having one or more corresponding cable connectors;

wherein at least one of the services tables is a turntable adapted to rotate relative to the other table to allow alignment of the corresponding cable connectors, prior to the tables being pressed together to join the corresponding cable connectors.

7. The connector of claim 6, wherein at least one of the tables is provided with positioning pins and the other table is provided with positioning apertures arranged to receive the positioning pins when the tables are pressed together.

8. The connector of claim 6 or 7, wherein the services connector is arranged internally of the connector.

9. The connector of claim 6 or 7, wherein the services connector is arranged externally of the connector.

10. The connector of claim 7, wherein the positioning pins and apertures are arranged asymmetrically on the turntables to ensure that the turntables can only be connected in a single orientation.

11. An underwater power generator comprising:

a base assembly;

a generation unit adapted to be mounted on the base assembly; and

a connector according to any one of the preceding claims.

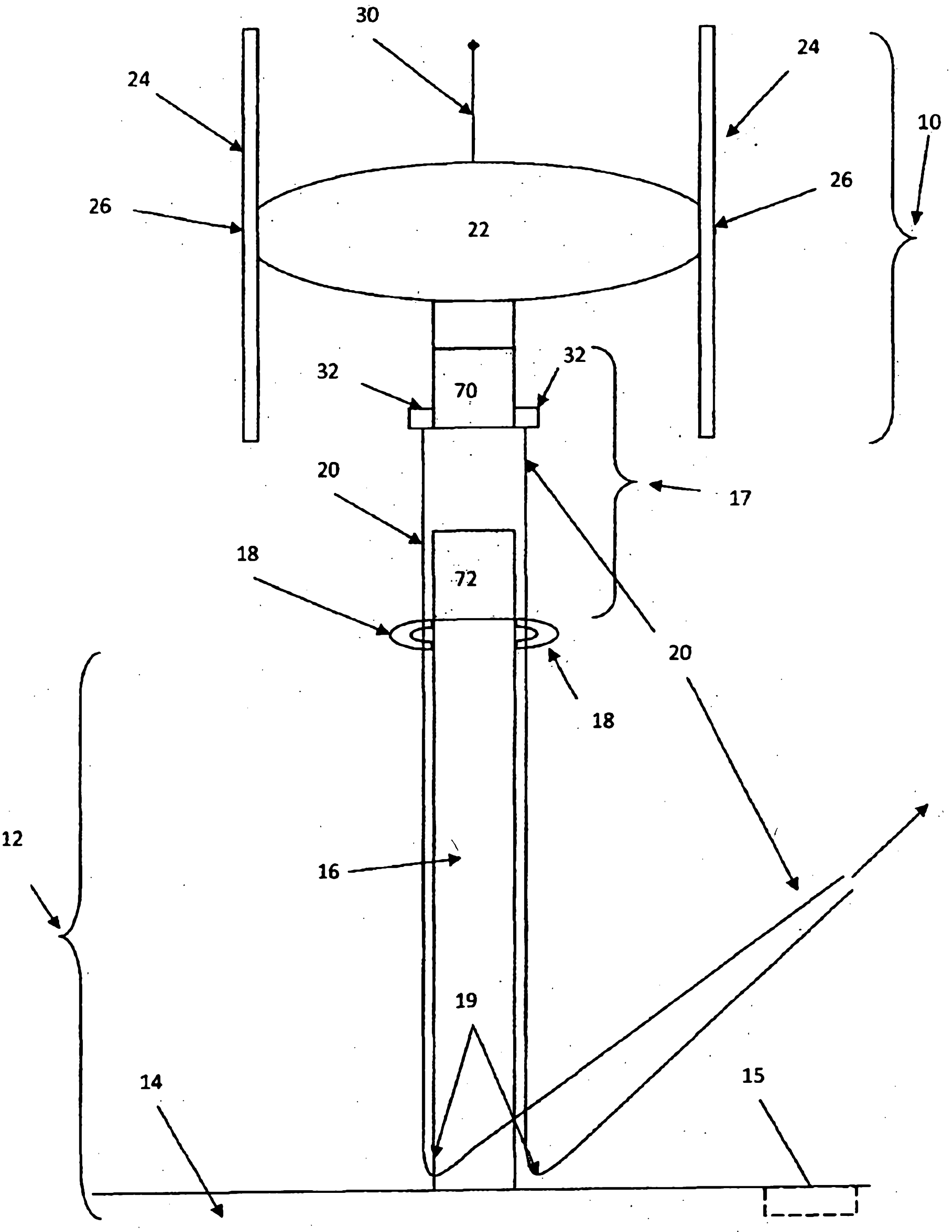

Fig. 1

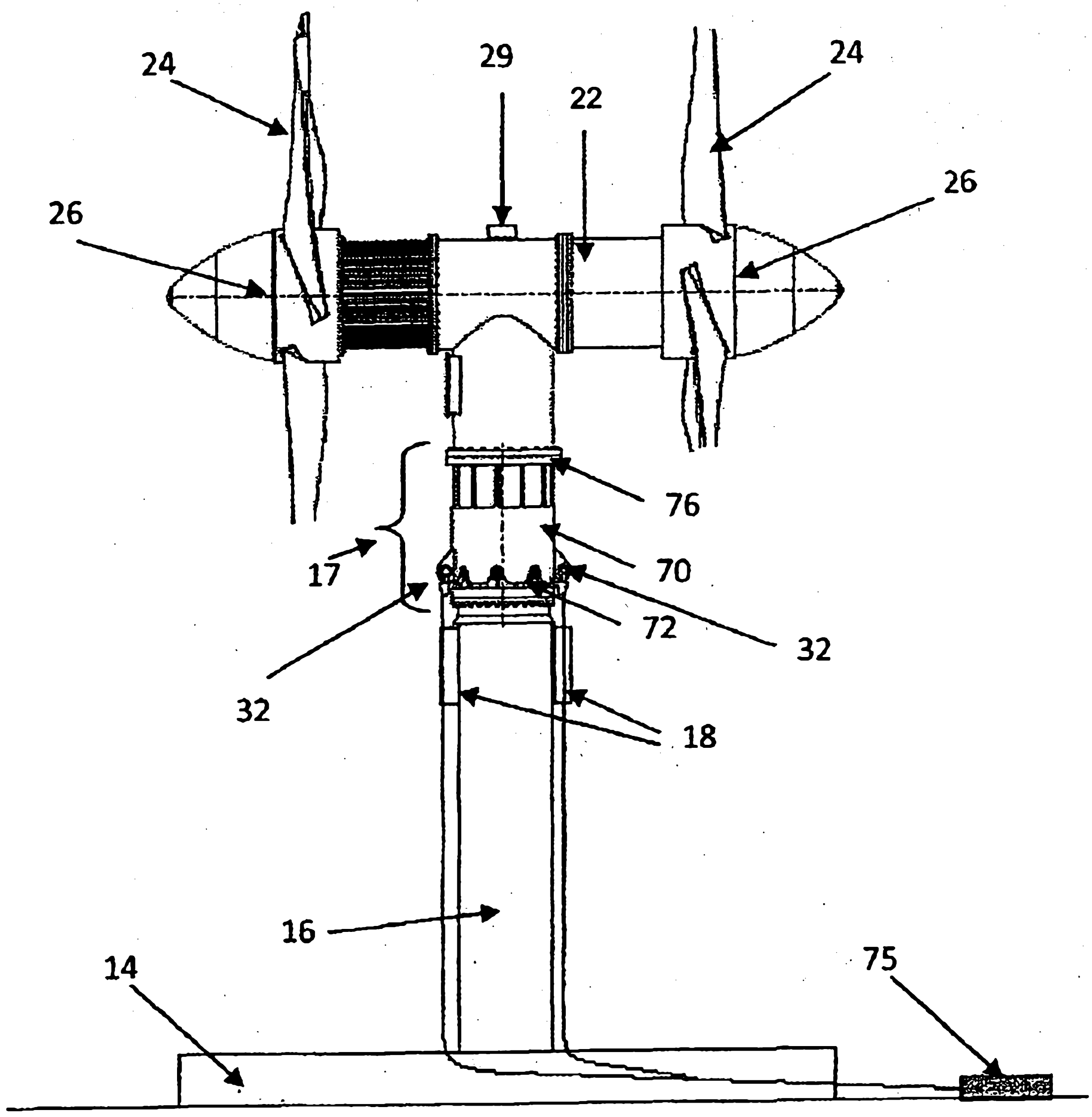

Fig. 2

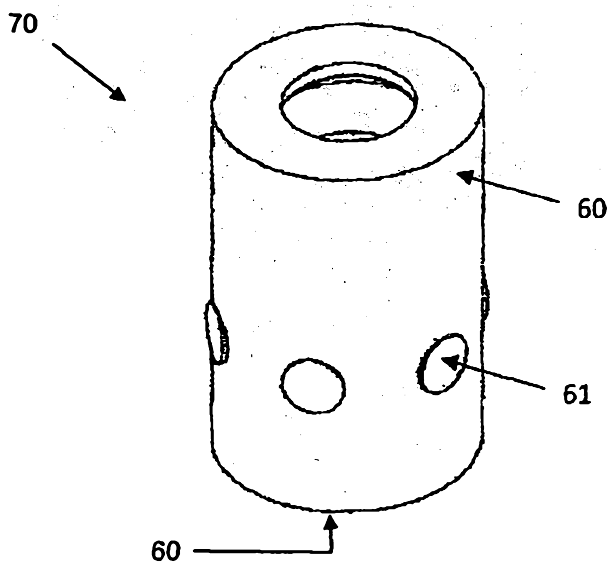

Fig. 3

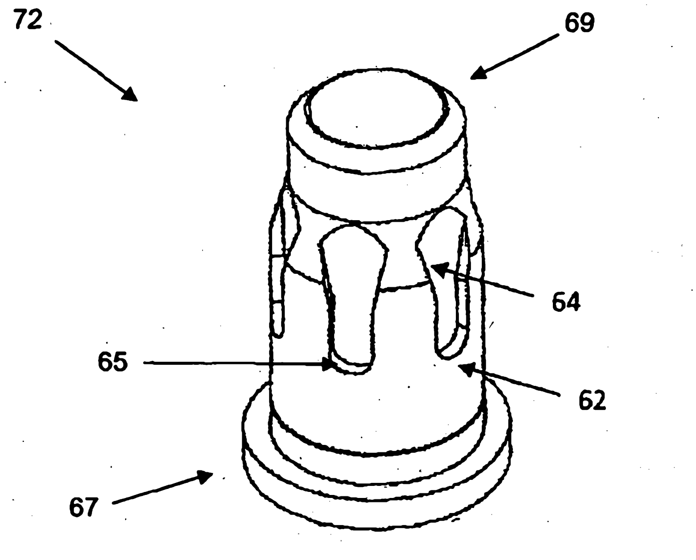

Fig. 4

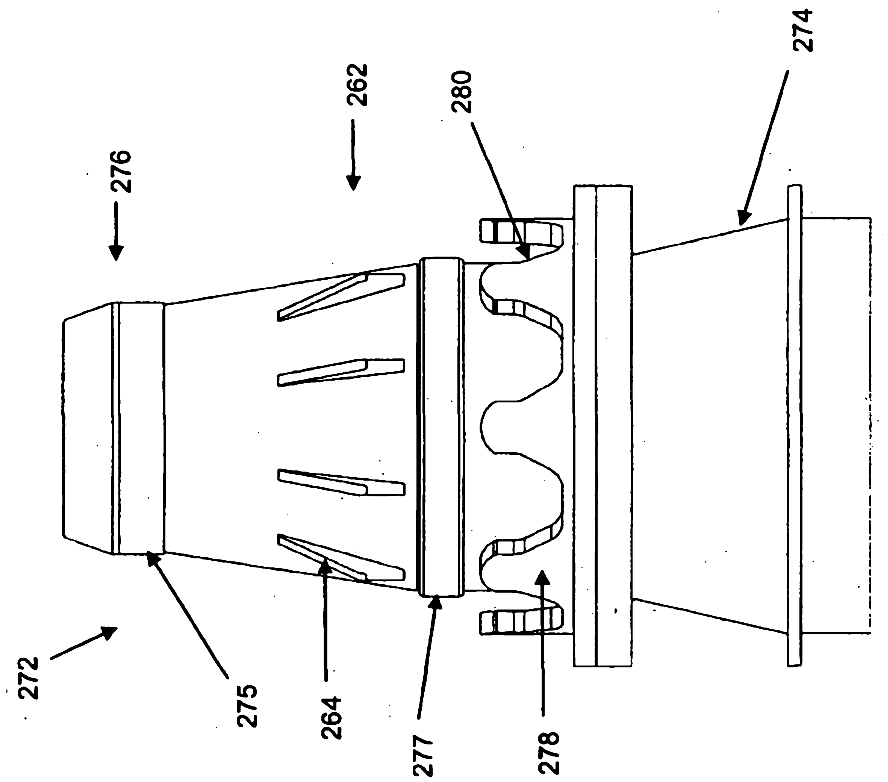
276
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Fig. 5

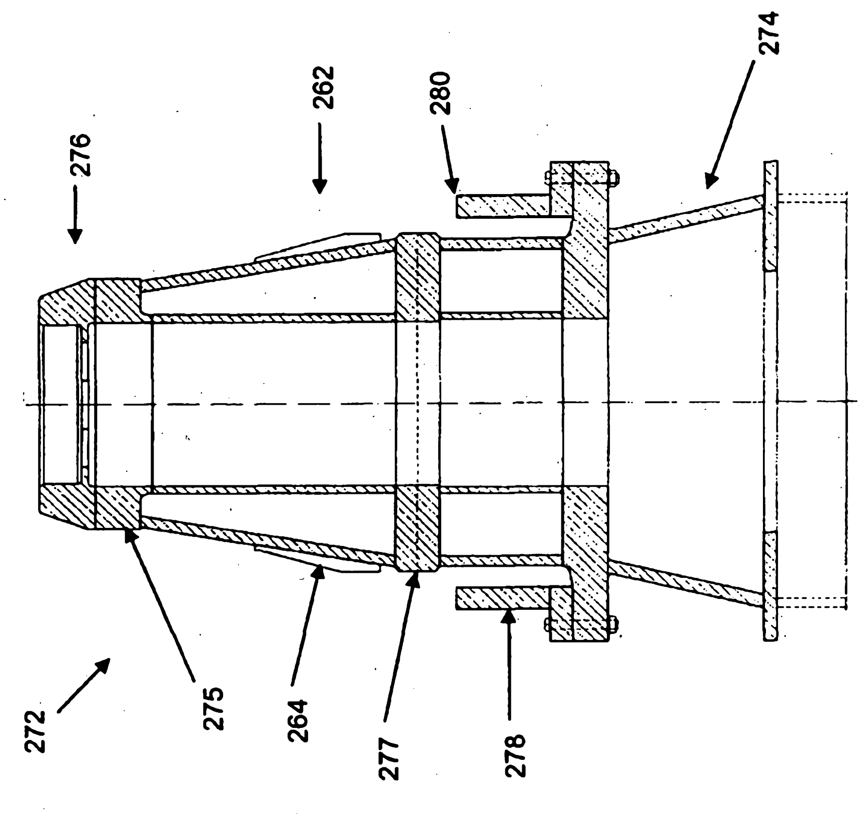
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Fig. 6

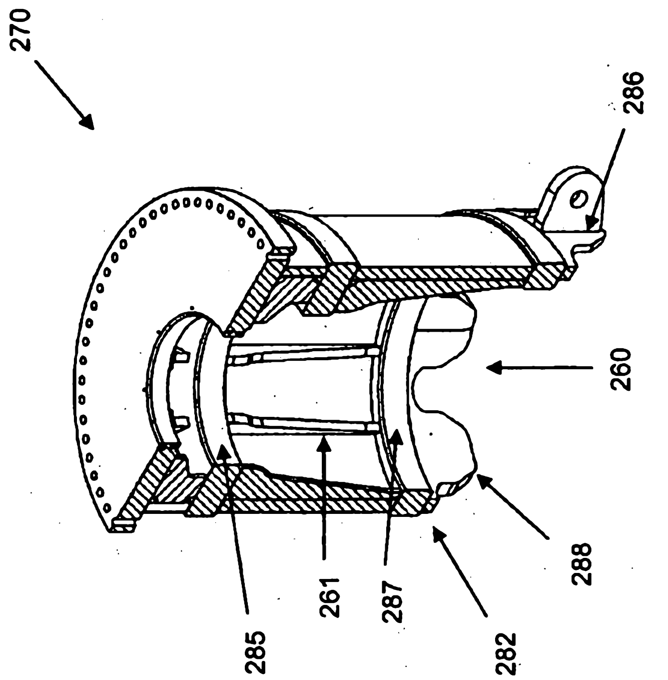

Fig. 8

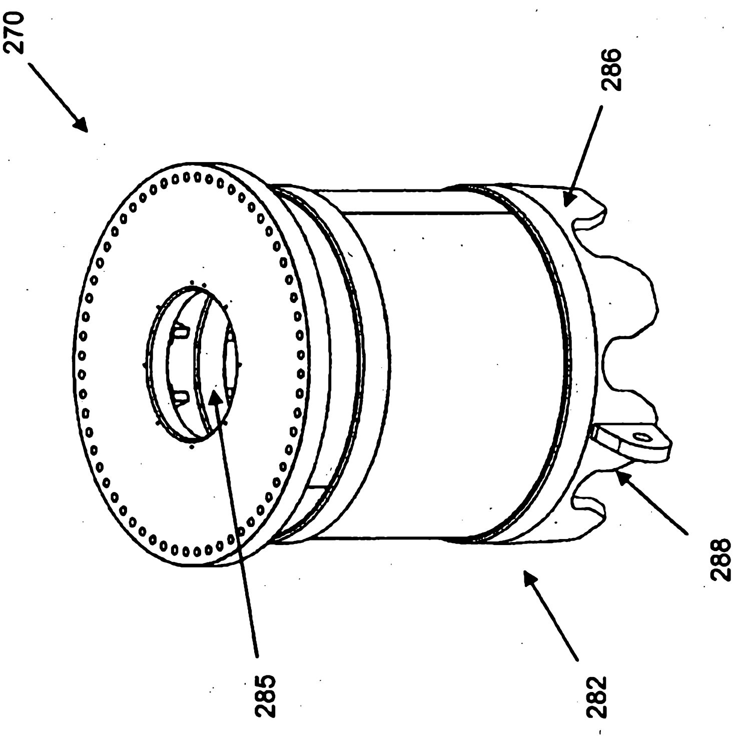

Fig. 7

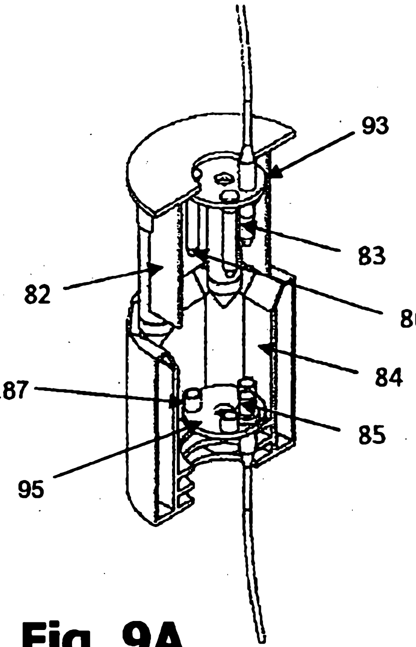

Fig. 9A

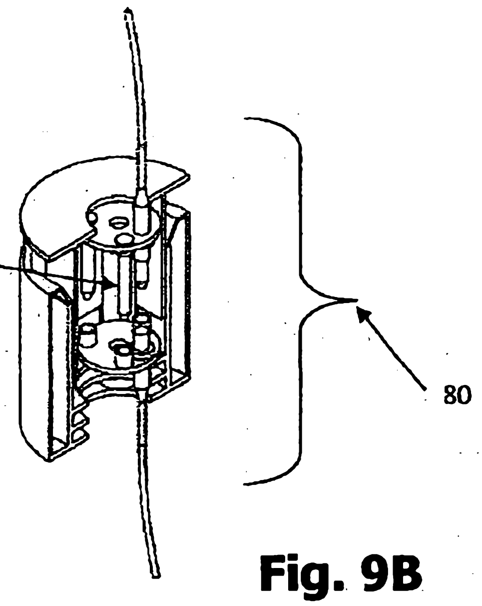

Fig. 9B

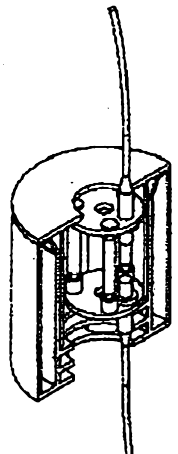

Fig. 9C

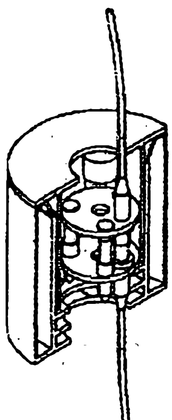

Fig. 9D

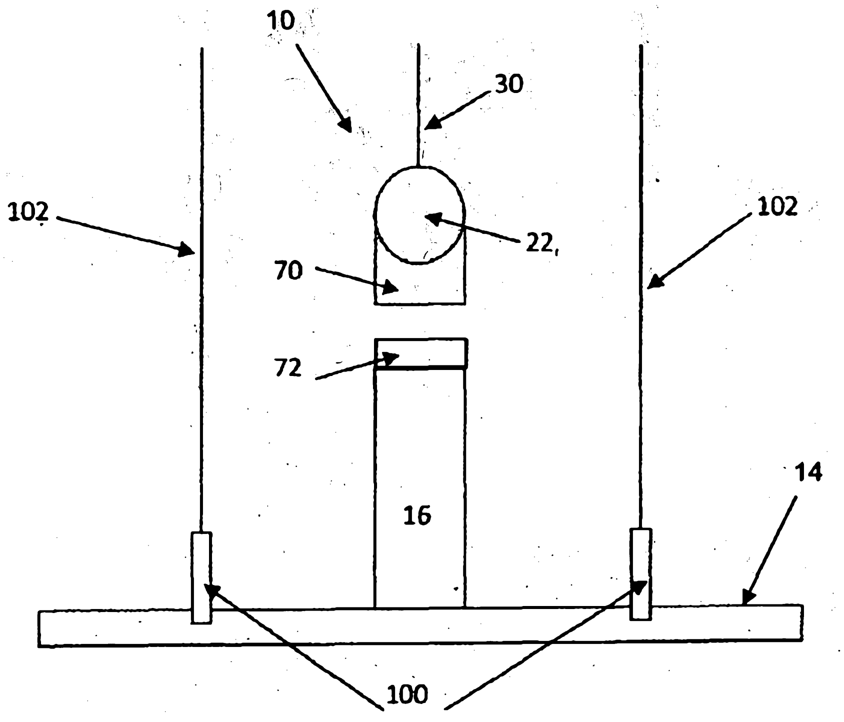

Fig. 10

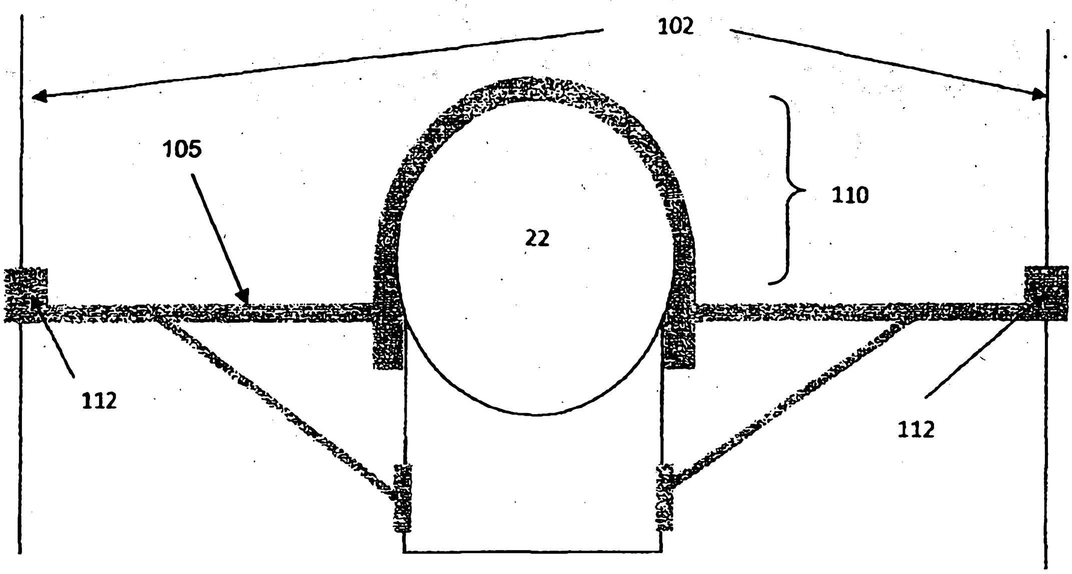

Fig. 11