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Water current turbine pitch control

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ABSTRACT

A turbine water actuatable turbine system, wherein turbine system is mounted for operational co-operation with water current by means of an upstanding column in such manner as to be axially displaceable length ways of the column. The turbine system is preferably arranged to be rotatably about the longitudinal axis of the column. Flotation means can be provided for operationally supporting the turbines which can include blade pitch control. Arrangements are provided to enable selective control of the operational pitch of the turbines with respect to the direction of water flow.

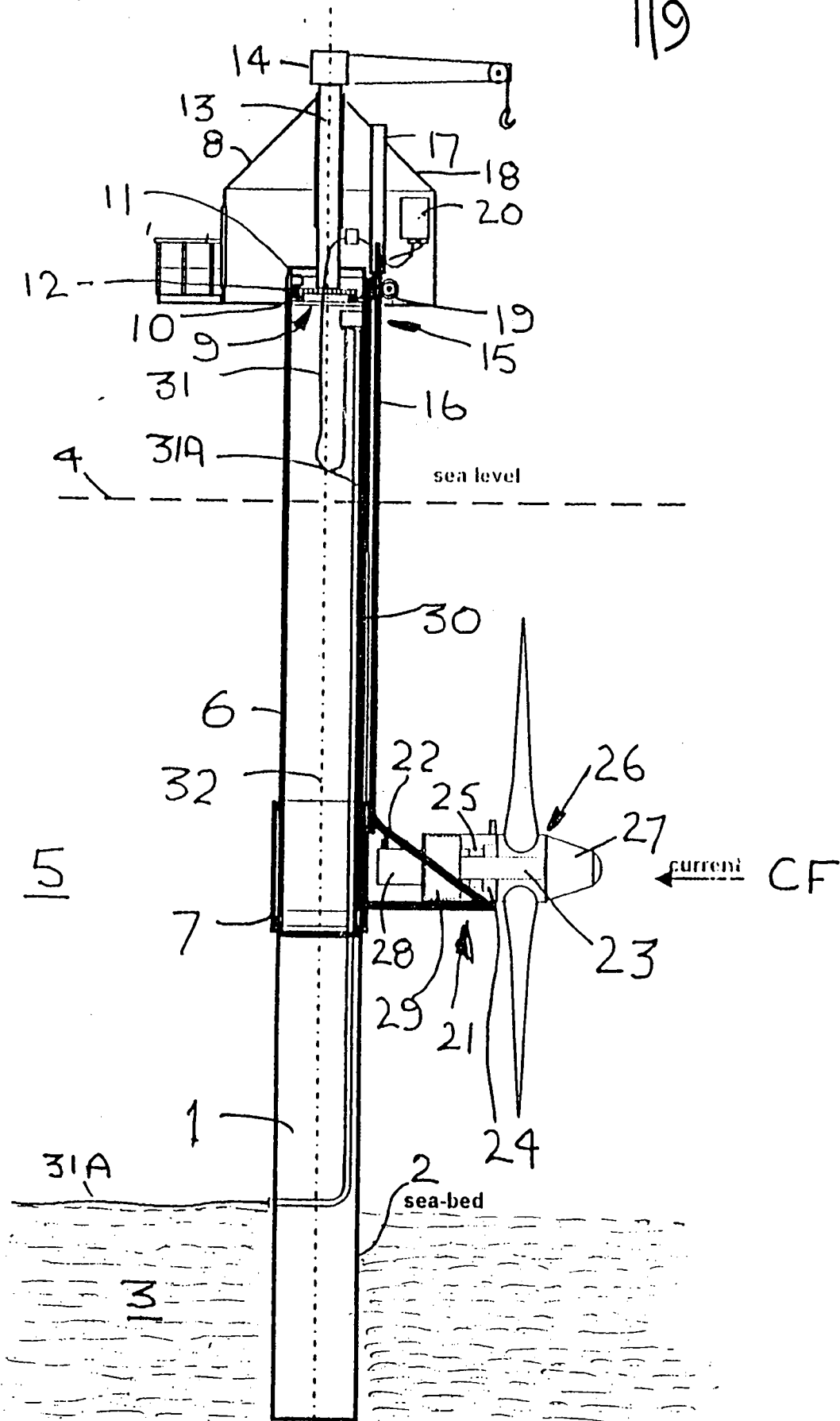


FIG 1

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MARINE CURRENT TURBINES LIMITED

COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title:

Water current turbine pitch control

The following statement is a full description of this invention including the best method of performing it known to us:-

WATER CURRENT TURBINE SLEEVE MOUNTING

This invention relates to water turbines and more particularly to turbines arranged to be driven by the action of a flow of water.

5 In our British Patent No 2311566 and in our British Patent No 2256011 B we have disclosed constructions of water drivable turbines.

As has been previously mentioned flowing water is a characteristic of tidal, marine, estuarial or river currents.

10 Bearing this in mind the present invention relates in particular to the use of turbines for to produce either electricity directly or to produce rotation of a shaft for utilisation for a required purpose.

15 A known turbine arrangement intended for extracting kinetic energy from water currents, whether in a river or at sea, generally includes a rotor capable of interacting with the flow of water in such a way that some of the energy motion of the passing mass of water produces forces on the blades of a rotor thereby producing rotation of the rotor. The rotation of the shaft is utilised to perform some useful function such as to generate electricity. Such a device is analogous in principle to the better known concept of a windmill or wind turbine which extracts kinetic energy from flowing air, except that due to the much greater density of water as compared with that of air, lower fluid flow
20 velocities (by a factor of approximately 9) are needed to give the same power density (power per unit area of flow) so that water moving at 1m/s has a similar power density (e.g., watts per square metre) as air moving at 7.5 metres/second.

It is also to be noted that although the basic principles involved in extracting kinetic energy from water currents are similar to those involved in the better

known art of extracting kinetic energy from the wind, the actual forces involved and the practical engineering requirements for the formation of suitable installation are in most respects totally different. In practice, tidal, marine and river currents generally have their maximum velocity near to the surface so that any device intended efficiently to intercept the kinetic energy of the currents needs to have its rotor set so that its active plane or cross section is perpendicular to the direction of water flow and as near as possible to the surface. Any such device also needs to be securely positioned in such manner as to resist the considerable drag forces and reaction forces associated with any interaction with large masses of moving water. In practice, the main drag force is an axial thrust in the direction of current flow due to the momentum deficit in the flow, which thrust is proportional to the area of the active rotor and the velocity squared. There is also a significant torque reaction to be resisted when a load is applied to the turbine rotor drive shaft. Furthermore, means has to be provided to convert slow rotational rotor movement produced by the water flow into a useful energy form that can be effectively transmitted from the generation location to a location at which it can be gainfully employed.

Such transmission of energy can be in the form of electricity by way of a marine cable along the sea or river bed (or by way of overhead cables supported by pylons or poles if the installation is close to the shore or river bank), there is also the option to use the energy "on site" for the production of some portable product such as fresh water, ice, minerals extracted from the sea or hydrogen and oxygen produced by electrolysis or any other products that can be generated from energy and the local environment, any such products can be stored and collected by an appropriate vessel, or transmitted to shore by pipeline.

For a practical installation there are other important factors that need to be addressed. In the case of marine applications such factors include the need to resist damage from large waves during storms, the need to make the device visible to minimise it as a marine hazard to shipping and the need to be able to

service and repair as well as to deploy the device at sea both safely and at a minimum cost

Any discussion of documents, acts, materials, devices, articles or the like which has
5 been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed before the priority date of each claim of this application.

10

According to a first aspect of the invention, there is provided a water current flow actuatable turbine installation including a turbine and associated bladed rotor, wherein in order to accommodate change of the direction of water flow with respect to the water current turbine(s) the installation further including means for enabling selective control
15 of the operational pitch of the blades of the rotor of each turbine with respect to the direction of water flow with respect to such turbine(s).

Preferably, the range of pitch change is such that each turbine rotor is operationally settable to a reversed position as to be able operate with a reversed water flow
20 direction.

In a preferred arrangement the control of the pitch of the blades of each turbine is such that the angle of attack of the turbine blades is arranged to be effected automatically in accordance with an operation optimisation function.

25

Preferably said optimisation function is arranged to allow the turbine rotor to run at constant speed for all current flow values within an operational spectrum of velocities.

In a preferred aspect, the optimisation function is arranged to act as a means of limiting
30 turbine operational overload or over speed at velocities above a rated velocity and as a means for also bringing the associated turbine to a halt under such conditions by reducing the effective angle of attack of the rotor blades effectively to zero.

Typically, the optimisation function is arranged to allow the associated turbine to run at
35 variable speeds in such a manner as to obtain optimum efficiency and optimum energy capture across the velocity spectrum of the water current.

Means may be provided for controlling the operational pitch of the blades electrically or hydraulically.

- 5 Typically, a servo motor is arranged to effect the control of the operational pitch of the rotor blades.

In a preferred embodiment, the root ends of the rotor blades are provided with spiral teeth adapted for meshing with drive wheels, the arrangement being such that rotation
10 of the drive wheels produces corresponding rotation of the blades and thus the pitch thereof.

Preferably, a drive shaft rotatably couples with the root end of each blade the rotor, and wherein means are provided for rotating the shaft by an amount related to the blade
15 pitch required.

In a preferred embodiment, the blades are arranged to be controllably rotatable to positions in which the blades are edge on to a water flow.

- 20 Preferably, the operational setting of the pitch of the blades is selectively settable in either direction throughout a range of 180 degrees of rotation.

Conveniently the turbine is mounted on a column/pile to be bodily displaceable length ways of the column/pile.
25

Conveniently, the installation includes load handling means for bodily displacing the turbine following its separation from its operational connection with the column/pile

Preferably, the control of the operational pitch is arranged to be effected by way of a
30 powered drive.

For a better understanding of the invention and to show how it may be carried into effect, reference will now be made to the accompanying drawings in which:

- 35 Figure 1 schematically illustrates a first embodiment of a marine turbine, the turbine being shown in its operational position;

Figure 2, schematically illustrates the turbine of Figure 1 when it has been raised location above the surface of the water;

- 5 Figure 3 illustrates the embodiment of Figures 1 and 2 when the associated turbine has been removed from its connection with the mounting column/pile.

Figure 4 is a schematic sectional view of an embodiment of a pitch control mechanism for a two bladed turbine rotor; taken on the line A -A of Figure 6;;

10

Figure 5 is a schematic sectional view of the mechanism of Figure 4, taken on the line B-B of Figure 4,

- 15 Figure 6 is a schematic view of a pitch control mechanism for a three bladed turbine rotor,

Figure 7 is an enlarged view of the pitch control mechanism associated with one of the blades of Figure 6,

- 20 Figure 8 schematically illustrates a still further embodiment of the mounting of a turbine to an upstanding column,

Figure 9 is a plan view of a double turbine installation carried from a column,

- 25 Figure 10 is a side elevation of the installation of Figure 9,

Figure 11 is an end on view of a further embodiment of a turbine installation involving two turbines;

Figure 12 is a side view of the installation of Figure 11;

Figure 13 is a schematic view of a turbine installation involving a water current flow turbine and an air driven turbine.

Referring now to Figures 1 and 2 these Figures illustrate a column 1 upon which it is proposed to mount a water driven turbine. As will be noted, the column stands in an appropriately formed hole 2 in the seabed 3. The height of the column 1 can be such that it is tall enough to project about the surface 4 of the surrounding water 5 what ever the state of tides or flood levels of a river. A sleeve 6 fits closely around the column and is supported on thrust pads 6A (not shown in detail). These pads are formed from a sea water compatible low friction material generally attached to the inside surface of the lower part of the sleeve. A rubbing ring (not shown) having non-corrodable finish is provided on the surface of the column.

A housing 8 is provided at the upper end of the column. The housing incorporates a slewing mechanism 9 schematically shown as including a main gear 10 which connects with the sleeve 6. A worm wheel 11 meshes with the main gear 10. The worm wheel receives drive from a suitable drive arrangement such as a servo motor 12. A smaller diameter extension 13 is provided at the upper end of the column. This extension 13 serves as a support for a crane or other lifting device/mechanism 14 the purpose of which will be discussed herein after.

The vertical setting or position of an outer sleeve 7 mounted on the sleeve 6 is controlled by a rack and pinion mechanism 15. The rack 16 thereof is mounted to the sleeve 6 and extends vertically upwards parallel to the vertical axis of the sleeve with its upper engaging within an open-ended guide tube 17. which

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projects upwardly through the roof 18 of the housing. The pinion 19 of the mechanism 15 is suitably mounted within the housing 8 that it is effectively positionally constrained against displacement lengthways of the column 1. An electrical control box is schematically indicated at 20.

- 5 A water current turbine unit 21 is mounted by way of a support frame 22 carried by the outer sleeve 7 whereby displacement of the outer sleeve 7 lengthways of the sleeve 6 will produce corresponding lengthways displacement of the turbine. Figure 2 illustrates the turbine unit and associated outer sleeve 7 when in their raised positions. As will be seen the upper end of the rack 16 is
10 then projecting out from the upper end of the guide tube 17.

The turbine unit 21 includes a main shaft 23 and associated bearings 24 which are journaled in the body/nacelle 25 of the turbine. A rotor assembly 26 is mounted on the main shaft 23.

- 15 The rotor can incorporate two, three, four or more blades according to operational design requirements and expected mode of use. For the purposes of Figures 1 and 2 it will be presumed that the rotor assembly is provided with two blades equiangularly spaced about the axis of the main shaft 23 and of the rotor assembly 26. A faring 27 is provided to offer streamlining to water flow through the rotor assembly. The main shaft 23 is arranged to drive an electrical
20 generator 28 through a suitable speed increasing gear box 29. Electrical output from the generator is fed by way of an output cable 30 which is guided upwards, conveniently, adjacent to the rack 16. The cable connects with the control box 20. The output from the control box feeds into a marine cable 31 which by way of a conduit 32 extending axially of the column leads
25 downwardly of the column 1 to exit therefrom at the river or sea bed, the conduit leading to a shore or river bank location (not shown)

The arrangement of the slewing mechanism on the rotatable sleeve 6 allows the turbine unit 21 to be yawed through a full 180 degrees to face the current

flow CF when the tide changes direction. Thus, the rotor assembly 26 can thus be always operationally faced into the current and can if desired be disabled.

Referring to Figure 3, it will be noted that in this Figure that the turbine unit 21 has
5 been released from the support cradle 22 and lifted using the crane 14. This arrangement makes it possible to service and/or remove and replace turbine units without it being necessary to employ a so-called jack-up barge for this purpose.

In practice it is possible to slew the crane 14 so as to facilitate the handling of any load
10 being carried by the crane 14. It will be understood that normally the turbine unit would be released from its cradle 22 by removal of retaining bolts after the sleeve 7 had been raised to position the sleeve 6 and turbine unit 26 above water level.

It will be appreciated that the arrangements shown in the Figures 1 to 3 and as so far
15 described in relation to these Figures represent a particular typical embodiment of water turbine installation. Various variations may be made whilst achieving essentially a similar if not the same result. For example, a direct drive multi-pole generator may eventually be developed capable of rotating at the same speed as the rotor and therefore not needing a gearbox. The gearbox may be replaced by a hydraulic transmission
20 system (using either suitable hydraulic oils or fluids or even sea water) and the generator may then be driven by a hydraulic motor either in the nacelle or even located remotely, such as above the column, in the housing on top, or even remote from the installation with hydraulic transmissions pipes running along the seabed. The gearbox can incorporate the shaft bearings in some cases or it can be driven from a separately
25 supported shaft via a coupling. The generator can be external to the nacelle for the purposes of cooling (using submersible rotor/pump technology) and it may be filled with water or some other fluid to help avoid ingress of sea water.

Furthermore, it is convenient to note that a faring (not shown) could be provided on the side of the outer sleeve 7 remote from the turbine support frame, the faring being so shaped that it not only serves to streamline the column and thus serve to reduce drag forces thereupon, but also, when the turbine is in the yawed position with its
5 rotor edge facing on to the direction of water current flow CF, the drag of the faring counterbalances the drag of the rotor and the nacelle thereby to reduce torsional loads on the sleeve slewing mechanism.

Whilst the construction as above so far discussed allows for the rotation of the sleeve
10 6 it is possible for the need to be able to rotate the sleeve to be avoided by so constructing the rotor assembly of the turbine installation according to the invention so that the rotor assembly thereof incorporates pitch control such as is used in relation to aeroplanes' propeller blades, for adjusting the angle of set of the blades with respect to the flowing water direction.

15

Referring now to Figures 4 and 5 which illustrate a two bladed rotor assembly 26 incorporating pitch control. As is shown in these Figures, the root 33n of a blade 34 of the rotor assembly 26 is bolted or otherwise attached in an appropriate manner to a cylindrical body 35. The body 35 cooperates with bearings 36 set into a rotor hub 37
20 which is mounted to the rotor shaft 23.

The external cylindrical face of the body 35 runs in a bush 38 and emerges at the circumference of the hub 37 through seals 39 designed to prevent ingress of sea water into the hub. The bodies 35 are machined with spiral teeth 40 to be able to mesh with
25 a worm drive 41 driven via gears 42 by a servo motor 43. Said servo motor 43 can cause the pair or worm drives 41 to rotate the same distance in opposite directions, thereby causing the rotor blades to move differentially by identical amounts.

Profiles of a rotor blade 34 outboard of the roots of the blades are shown in broken lines in Figure 5 to illustrate how the blades 34 may be positioned to face the current in either direction or to lie with little or no effective angle of attack to the current in order to disable the turbine.

5 The embodiment shown in Figures 4 and 5 illustrates one mode of enabling the requisite change of pitch. It will be appreciated that other modes of enabling pitch change can be used.

Thus, referring now to Figures 6 and 7, these Figures schematically illustrating the root portions of the blades 34 of a three bladed turbine rotor and associated hub 50. Three equiangularly spaced blade roots 51 are mounted in the hub 50 for rotation with the hub. In each case the root 51 engages with a cylindrical housing 52 that is secured to the hub 50. In each case the blade root 51 is engaged with a opposed taper main roller bearing 53. To prevent the ingress of water, main seals 54 are provided adjacent the join between the root 51 and the housing 52. The main bearings 53 are held in place at a required pressure by a clamping plate 55 held in place by bolts 56. The inner end of the housing 52 terminates in an outwardly directed flange 57 which co-operates with an annular plate 58 which serves to support and position the rear bearing 59 for the blade root. A secondary housing 61 with a mounting flange 62 is secured to the opposite side of the plate 58. This secondary housing 61 provides support for a gearbox 63 whose output shaft 64 (shown dotted) is spindled into the end of the blade root 51. The input to the gear box is by way of a shaft 65 which is the output shaft of a servo motor (not shown). It will be understood that operation of the servo motor rotates its output shaft, and in so doing causes the gearbox output shaft 64 to rotate the associated blade root 51 through an angle related to the extent of operation of the servo motor the latter being controlled by way of a control system such as a computer system (not shown). Thus in accordance with the concepts of this aspect of the invention it will be appreciated that the arrangement provides up to 180 degrees of pitch variation for each rotor blade 34, as applied in the context of a water current turbine

installed upon a fixed column or pile. With this pitch change possibility the turbine unit 21 can be operationally set to receive water flow from either direction or to be disabled without the need to yaw the rotors.

5 Hence it follows that for the purpose of this form of variable pitch hub is to remove the need to move the nacelle 25 with respect to the flow of water in any direction where the water either flows continuously in the same direction or where it flows in opposite directions 180 degrees opposed, namely the situation that pertains in most marine and riverine current applications. The rotor blades 34 can be rotated to the optimum pitch angle to function with the
10 current flowing one way. The rotors can be rotated to be edge on to the current or feathered in the same way as with variable pitch aircraft propellers in order to stop or disable the turbine even when the water is flowing fast and they can be rotated to face the other way and operate efficiently with the flow direction reversed.

15 A further advantage of this arrangement is that the angle of attack of the blades can be automatically adjusted so as to perform some optimisation function such as allowing the rotor to run at constant speed yet at maximum efficiency for all current velocities in the operational spectrum of velocities (from cut-in velocity to rated velocity). It can then be used as a means of limiting either
20 overload or over speed in velocities above the rated velocity and as a means also for bringing the turbine to a halt under such conditions by reducing the effective angle of attack to zero. Another optimisation is to run the turbine at variable speeds so as to obtain maximum efficiency and hence maximum energy capture across the velocity spectrum.

25 Lastly it should be noted that when the pitch is reversed the shaft will rotate in the reverse direction too, so that the generator, hydraulic pump or other means of extracting the energy of rotation needs to be capable of functioning effectively when run in either direction.

Referring now to Figure 8 this Figure illustrates a further alternative way of using a turbine unit 21 with a variable pitch rotor. In this case the column (shown in part section) has a slot 74 cut vertically in the side where the turbine unit 21 to be placed. Inside the column is a close fitting closed cylindrical body 75 attached to the turbine unit 21 by a mounting bracket member 76 which projects through and can slide in the slot 2 and which carries the turbine nacelle and rotor assembly 26.

The cylindrical body 75 is in the form of a tank which is internally sea water compatible and which can be filled with sea water while in operational mode with the rotor shown as positioned with solid lines. If the water in the body 75 is pumped out by displacing it with air from an air compressor, then buoyancy of body 75 causes it and the attached bracket member 76 and the turbine mounted therefrom to rise to the position shown in ghosted lines, from where the nacelle can be removed or replaced.

Although the use of buoyancy is one method for raising the nacelle, 25 said nacelle could also be raised using appropriate more conventional and well-known lifting devices such as hydraulic jacks or an electric rack and pinion drive, an electric winch or any other appropriate lifting method. It is to noted that in accordance with the features of the invention the nacelle is mounted to the body 75 internal to the column through a vertical slot 74 in such manner that the nacelle can be raised above the water level for access by applying the requisite lifting force to the body internally of the column.

Referring now to Figures 9 and 10, these Figures show a further embodiment of a twin turbine assembly arrangement including turbines 21 with rotors incorporating pitch control. In this arrangement the turbines, nacelles and the rotors are attached to a cross arm 80 via a torque tube 81, which runs through the cross arm 80 and past one side of the column 1. Said torque tube 81 is sufficiently strong to hold the turbines in place under operational conditions and is also capable of being driven by a slow high torque actuator such as an

electric motor with a worm gearbox assembly 82 so as to be able to rotate the turbines and rotors through 180 degrees about the axis of the torque tube 81 such that after a 90 degree rotation the turbines are moved into a vertical plane of rotation (as shown ghosted in Figure 9 By rotating the turbine units 21 so that they point vertically upwards the rotor assemblies 26 can be disabled even in full flow.

Furthermore, to be able to effect a rotation of 180 degrees the rotor assemblies 26 can be positioned to face in either direction depending on whether the tide is ebbing or flowing. Since with this arrangement it is not necessary for the sleeve to be able to rotate about a vertical axis, a faring such as the faring 83 can optionally be fitted on both the upstream and downstream sides of the pile.

The advantages of this arrangement are saving of costs in some situations combined with the probable performance enhancement gained from a greater blockage to the flow of water as compared with that achieved by a single turbine unit. Generally, but not necessarily, the rotor assemblies 26 are arranged so as to rotate in opposite directions, thereby cancelling out the torque reaction on the column and also in producing contra rotating swirl components in their wakes which will rapidly cancel each other out thereby leading to less turbulence downstream of the rotors. It is considered that this arrangement would be of importance when installing as many as possible turbine installations into a particular area of the sea by allowing closer spacing in the directions of flow through the several turbine installations.

For this proposal a servicing vessel would manoeuvre alongside so that the vessel can remove either the complete cross arm and nacelle assembly as a single unit or the individual nacelles from the cross arm.

Referring now to Figures 11 and 12 these Figures schematically show a still further embodiment of a twin rotor arrangement. It will be appreciated that the concepts utilised in relation to these Figures can be used in conjunction with a

single rotor installation or with a four rotor installation. The purpose of this embodiment shown in Figures 11 and 12 is to incorporate arrangements for facilitating the installation of and the removal of the turbine units 21 and nacelles 25 by having them mounted below a floating structure which is in turn held in position by the column. Thus in the Figures 11 and 12 embodiment the turbine assemblies 21 are carried from vertically arranged support structures 96 which are carried from a horizontal further support structure 97 mounted to the upper part of a rotatable ring/sleeve 98 provided upon the column 1. A hull 99 is connected with the outermost part of the support structure 97. These hulls 99 provide the requisite flotation to the turbine assemblies and associated support structures. The vertical supports 96 have associated therewith struts 100 as shown in Figure 12 much like keels, the latter being streamlined.

The lower ends of the support structures 96 connect with a strut 101 which is secured to a ring 102 rotatable about the column 1. Electrical connections from the generators associated with the turbine assemblies are taken from the assemblies at a point above the water surface 4 to another ring 103 that is constrained to turn in unison with the ring 98.

The installation shown in Figures 11 and 12 always operates downstream of the column, since it is oriented by the considerable drag force of the supporting hulls 99 and the rotor assemblies 26. In situations, where the water flows are tidal, the entire floating component can swing around through the freedom of rings 98, 102 and 103 to turn with respect to the column when the direction of the flow of the tide periodically changes. To avoid the cable connection from the ring 103 becoming increasingly wound up as a result of such rotation, the load on the rotor assemblies 26 can be differentially adjusted under control of a computer system so as to bias the entire unit always to follow a 180 degree movement backwards and forwards rather than a full 360 degree movement. This control is achieved by loading the generators differently in such a way that the drag on one rotor is less than the drag on the other.

An advantage of this system is that the floating component can readily be removed and replaced and also it has the benefit of a positive mooring from direct attachment to a column. In practice this embodiment is best suited for use in unidirectional currents such as in rivers, where there is no need to yaw the system through 180 degrees. Moreover, the system shown in Figures 11 and 12 has the advantage in major rivers with great seasonal changes in level that the flotation component can move up or down according to changes of surface level, always maintaining the turbine rotors at optimum depth for maximum power.

10 If desired two columns similar to that of the above discussed Figures may be installed in such manner that they support a much wider horizontal arm that can carry as many as for example, five variable pitch rotor assemblies. Thus two columns are arranged side by side and then linked together with an appropriately long cross arm carrying five turbine assemblies. The lifting
15 mechanisms would be driven in unison to ensure that the turbines can be raised smoothly with their supporting arm remaining horizontal at all times. Since these turbines are of the variable pitch type they can accept the flow from either direction and also they can be disabled by setting the rotor blades at a pitch such that no effective torque is produced. The reason for a system of this
20 kind is for use in shallow water where lack of depth requires the use of a number of small rotors to gain the required power rather than the use of one or two larger rotors

Referring now to Figure 13, this Figure illustrates schematically a turbine support column which has been adapted or modified to provide support for a
25 water driven turbine unit 21 and an air driven i.e., wind turbine 115. As will be noted the overall height of the column 1 has been increased by effectively providing an extension 116 to the upper part of the column 1. This extension column 116 serves to support the wind turbine 115. As is shown in the Figure 13 the housing 8 takes a different form and position on the column to allow for
30 the extension column 116, The housing 8 as with the previously discussed

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housing construction incorporates arrangements for controlling the positioning of a sleeve 117 that carries the water current turbine. In the Figure 13 the construction of the sleeve 117 is such that it carries the turbine unit 21 from an associated support frame 22. In addition, the length of the sleeve is such that the housing 8 is always above the water level 4 what ever the state of a tide and river level. With this arrangement in order to avoid the need to provided for rotation of the sleeve the rotor 26 of the turbine unit 21 would incorporate the facility of pitch control such as that discussed above in relation to Figures 2 and 3. If desired depending upon the number of blades on the rotors the blade pitch control disclosed in our copending Application No 0004144.2 Publication No 2347976 Water Current Turbine with Pitch Control can be adopted. In addition the turbine could be mounted to a vertically displaceable outer sleeve such as disclosed in Figure 1. As will be apparent from Figure 2 relationship between the column 1 and the extension 8 thereof is such that the sleeve on the column can be raised sufficiently to position the water driven turbine above the water level, for example, the purposes of maintenance and or replacement.

The arrangement of the water current turbine unit 21 and the wind driven turbine 115 provides a hybrid combination of wind and water powered equipment (not shown) for utilising the energy obtained by the respective turbines. An advantage of installing a wind driven turbine on the column is that the overheads involved in installing a column and connecting it to an electricity grid on the shore are high, so by adding a air current driven turbine significantly more energy can be captured from a single/common installation. This requires the use of a stronger column having thicker walls to handle the increased bending moment caused by the wind driven turbine. However, it is considered that the extra energy gained would outweigh the extra installation costs. In a variation the air current driven turbine is mounted from a tower provided at the top of the column.

In the Figure 13 embodiment the wind is shown blowing from the same direction as the water current. However, the wind driven turbine 115 would be

of the kind, which can orient its rotor automatically to face in the direction from which the wind blows so that the wind turbine rotor may face in any direction. That is to say the support arrangements for the wind driven turbine would be such as to enable such rotation.

- 5 The water current turbine will either be of the kind mounted upon a sleeve which can be yawed through 180 degrees to face the current from either direction or it can have a variable pitch rotor in which the rotor blades can be pitched through as much as 180 degrees to take energy efficiently from flow in either direction. In the Figure 4 both turbines are shown in their operational
10 positions.

- It will be understood that if desired the installation could incorporate two water current flow turbines carried from the associated common support column. Also it is possible to provide multiple turbine installations in which a turbine carrying cross bar for water current flow turbines is provided between two
15 spaced columns Similarly a corresponding number of air flow turbines could be provided upon a cross bar arranged above water level.

- As a further aspect of the invention where the column is of such length as to project well above the water surface a wind turbine can be mounted at the top of the column of any one of the arrangements previously considered to provide
20 a hybrid combination of wind and water powered equipment (not shown) for utilising the energy obtained by the respective turbines. An advantage of installing a wind turbine on the column is that the overheads involved in installing a column and connecting it to an electricity grid on the shore are high, so by adding a wind driven turbine significantly more energy can be
25 captured from a single/common installation. This requires the use of a stronger column having thicker walls to handle the increased bending moment caused by the wind turbine. However, it is considered that the extra energy gained would outweigh the extra installation costs. In a variation the wind turbine is mounted from a tower provided at the top of the column.

Preferably the wind turbine is of the kind, which can orient its rotor automatically to face in the direction from which the wind blows so that the wind turbine rotor may face in any direction.

5

As has been mentioned, the water current turbine will have a variable pitch rotor in which the rotor blades can be pitched through as much as 180 degrees to take energy efficiently from flow in either direction.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A water current flow actuatable turbine installation including a turbine and associated bladed rotor, wherein in order to accommodate change of the direction of water flow with respect to the rotor the blades of the rotor of the turbine are arranged to
5 be responsive to means for enabling selective control of the operational pitch of the blades with respect to the direction of water flow through the rotor.
2. A water current flow actuatable turbine installation as claimed in claim 1, wherein the range of pitch change for the blades is such that each blade of the rotor is operationally settable to a reversed position as to be able to operate with a reversed
10 water flow direction.
3. A water current flow actuatable turbine installation as claimed in claim 1 or 2, wherein the control of the pitch of the blades of the rotor is such that the angle of attack of the turbine blades is arranged to effected automatically in accordance with an operation optimisation function.
- 15 4. A water current flow actuatable turbine installation as claimed in claim 3, wherein said optimisation function is arranged to allow the turbine rotor to run at constant speed for all current flow values within an operational spectrum of velocities.
5. A water current flow actuatable turbine installation as claimed in claim 3, wherein said optimisation function is arranged to act as a means of limiting turbine
20 operational overload or over speed at velocities above a rated velocity and as a means for also bringing the associated turbine to a halt under such conditions by reducing the effective angle of attach of the rotor blades effectively to zero.
6. A water current flow actuatable turbine installation as claimed in claim 3, wherein optimisation function is arranged to allow the associated turbine to run at
25 variable speeds in such a manner as to obtain optimum efficiency and optimum energy capture across the velocity spectrum of the water current.
7. A water current flow actuatable turbine installation as claimed in any one of the preceding claims 1 to 6, wherein the control of the operational pitch is arranged to be effected by way of a powered drive.
- 30 8. A water current flow actuatable turbine installation as claimed in any one of claims 1 to 7, wherein means may be provided for controlling the operational pitch of the blades electrically or hydraulically.
9. A water current flow actuatable turbine installation as claimed in claim 8, and wherein a servo motor is arranged to effect the control of the operational pitch of the
35 rotor blades.

10. A water current flow actuatable turbine installation as claimed in claim 9, wherein the root ends of the rotor blades are provided with spiral teeth adapted for meshing with drive wheels, the arrangement being such that rotation of the drive wheels produces corresponding rotation of the blades and thus the pitch thereof.
- 5 11. A water current flow actuatable turbine installation as claimed in claim 10, wherein a drive shaft rotatably couples with the root end of each blade the rotor, and wherein means are provided for rotating the shaft by an amount related to the blade pitch required.
12. A water current flow actuatable turbine installation as claimed in any one of
10 claims 1 to 11, wherein the blades are arranged to be controllably rotatable to positions in which the blades are edge on to a water flow.
13. A water current flow actuatable turbine installation as claimed in claim 1, and wherein the operational setting of the pitch of the blades is selectively settable in either direction throughout a range of 180 degrees of rotation.

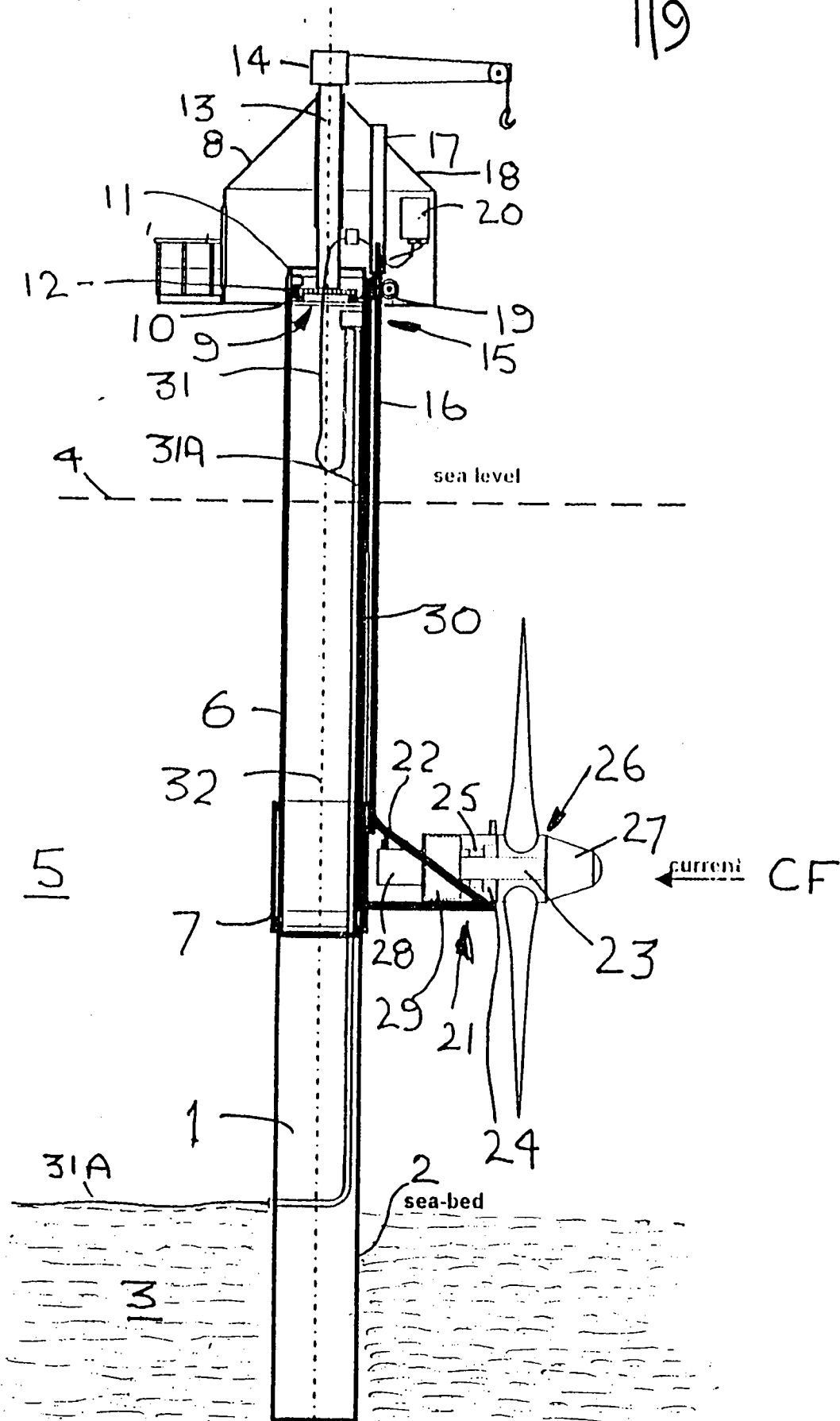


FIG 1

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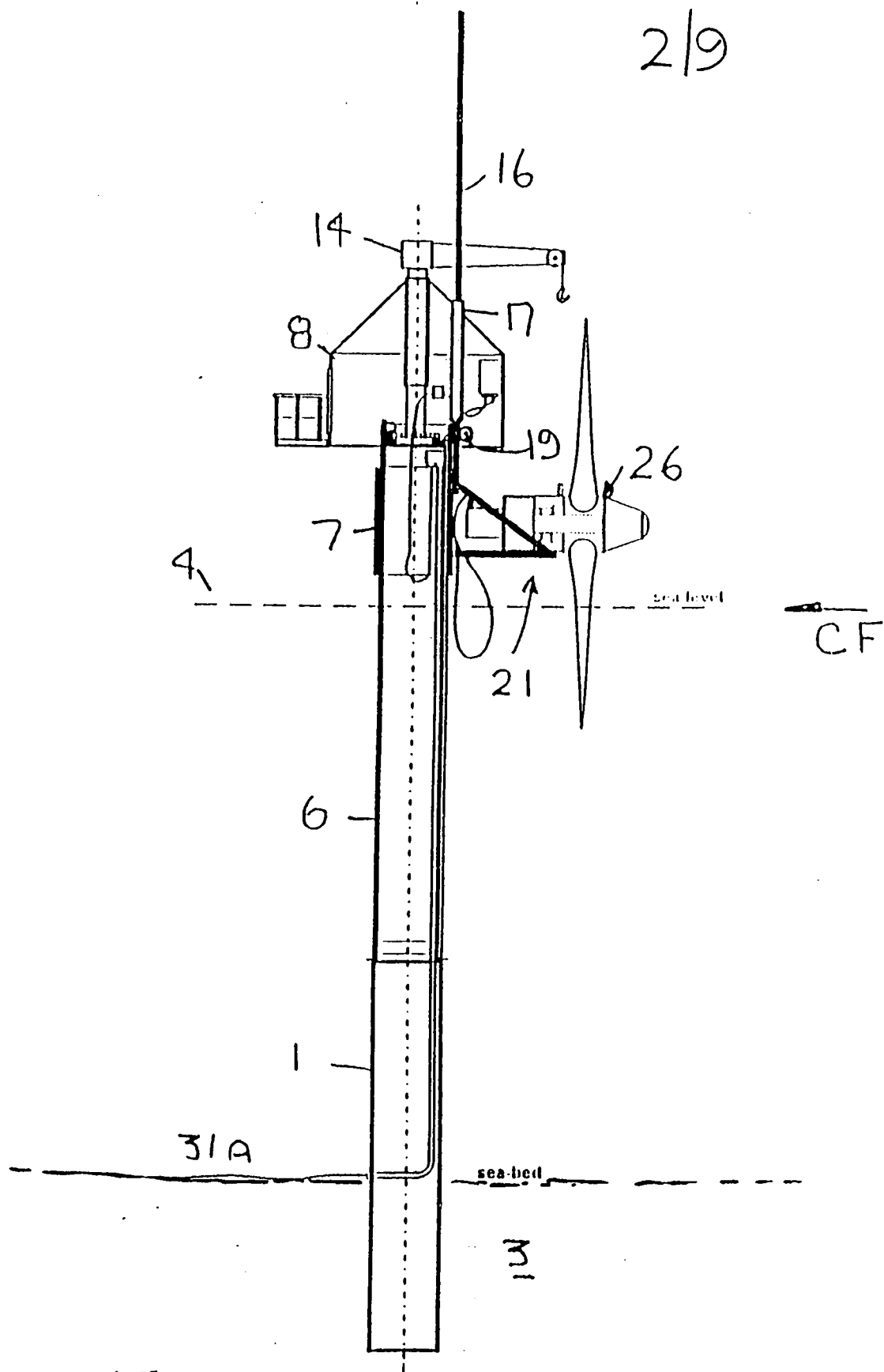


FIG 2

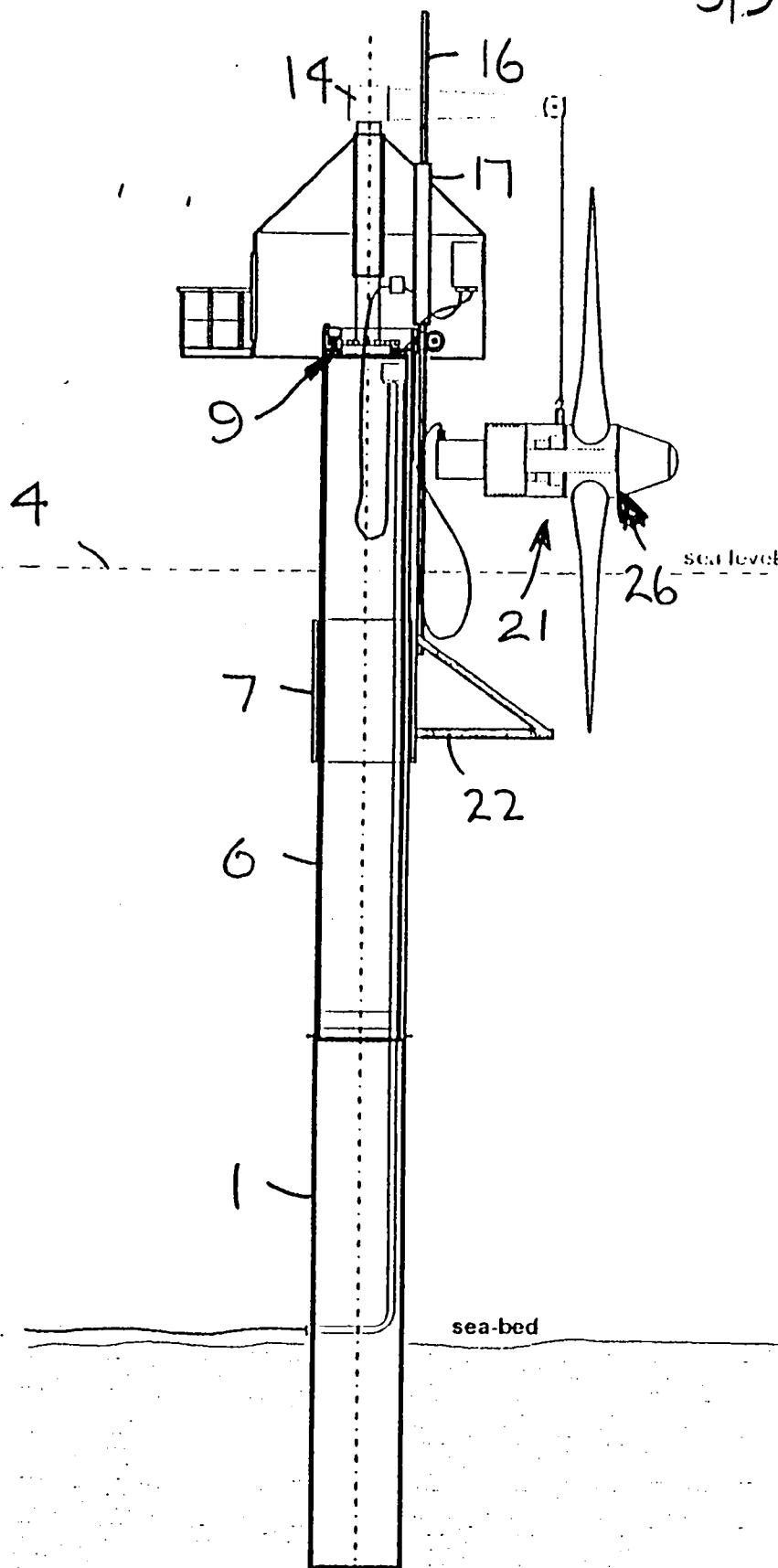
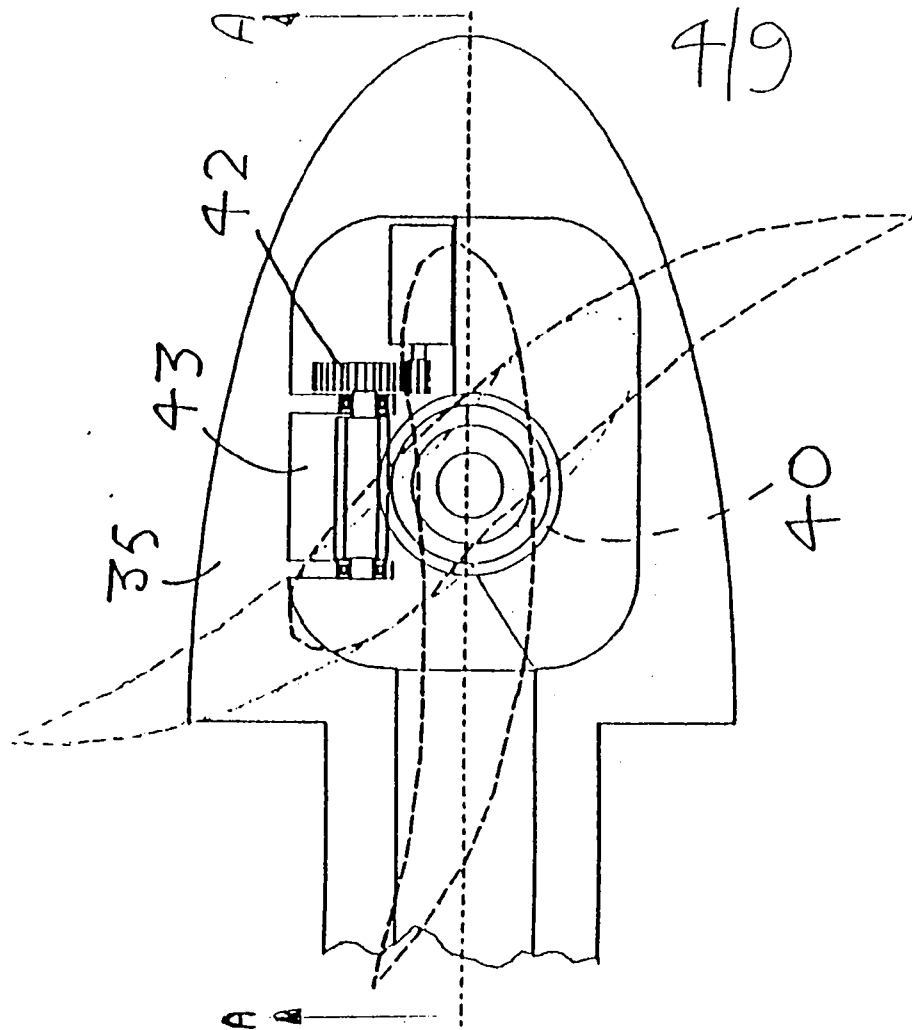
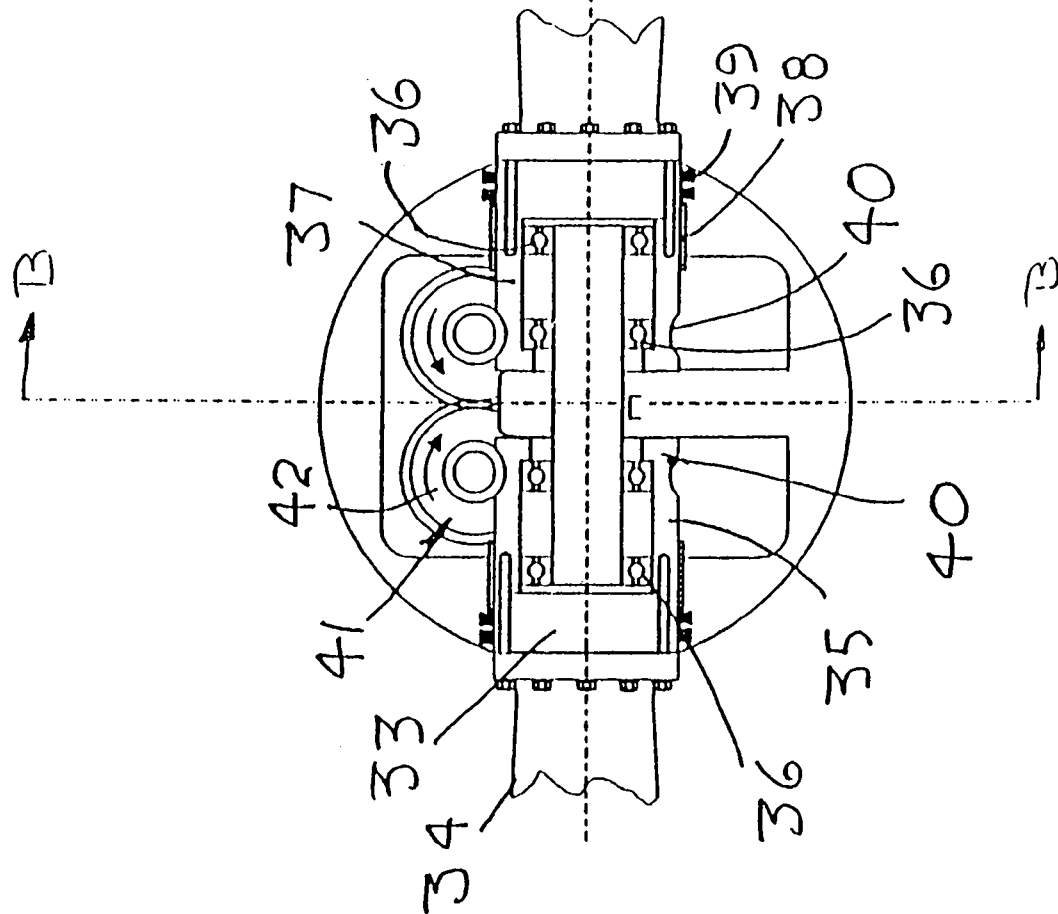


FIG 3



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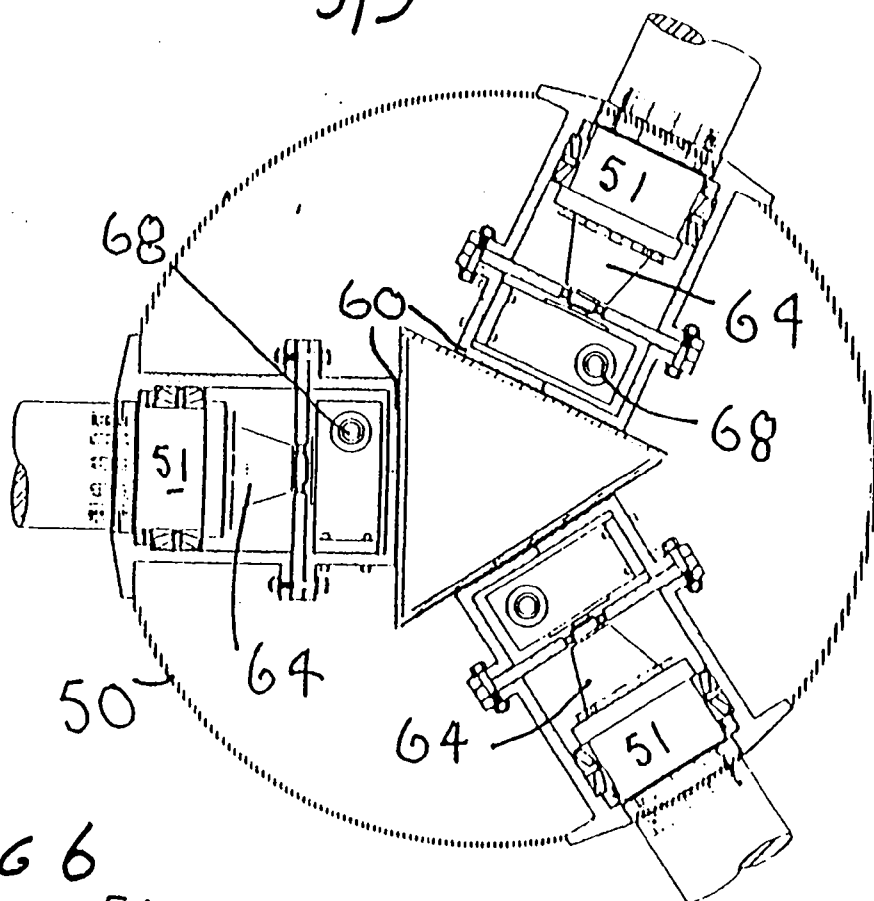


FIG 6

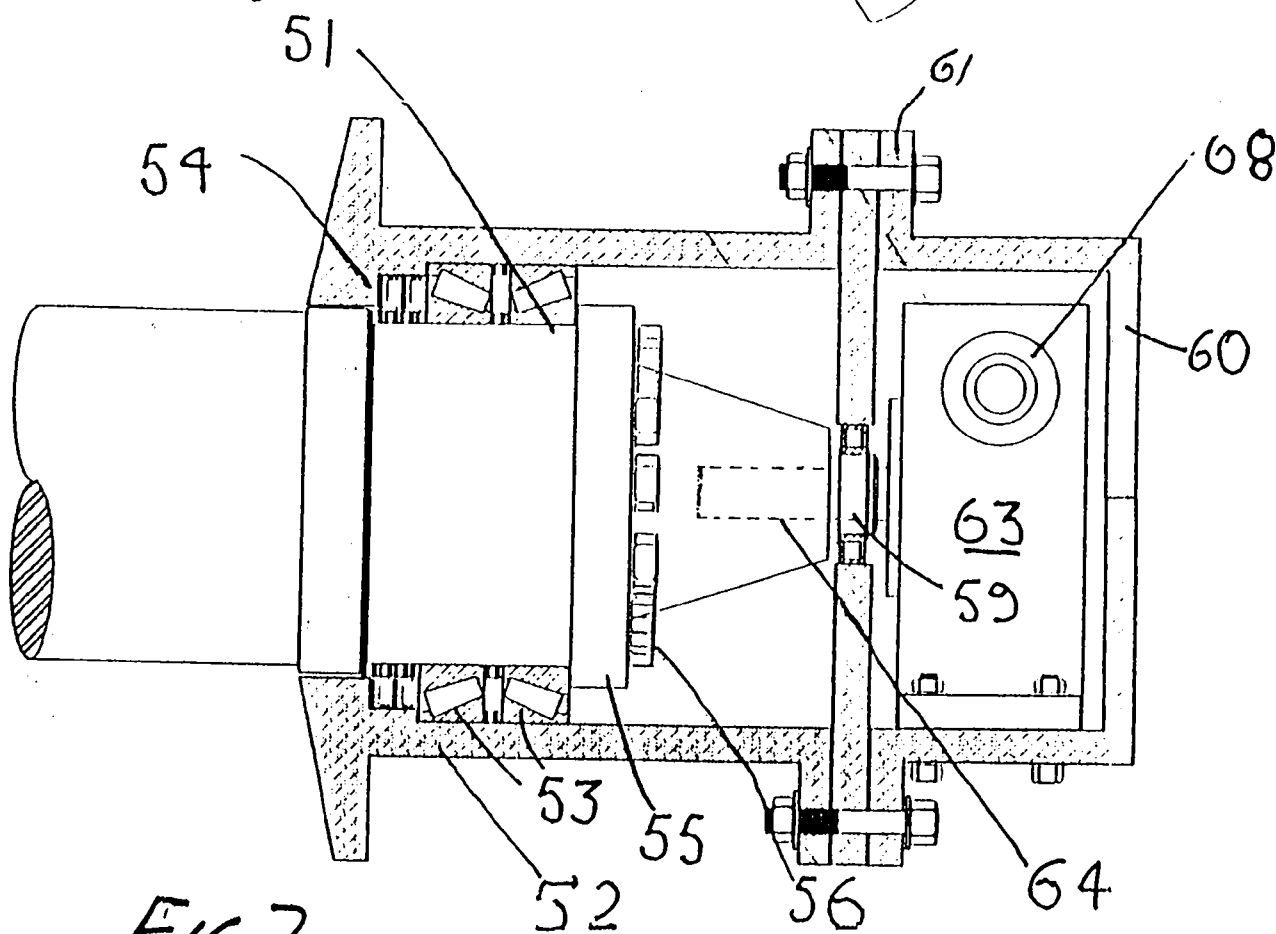


FIG 7

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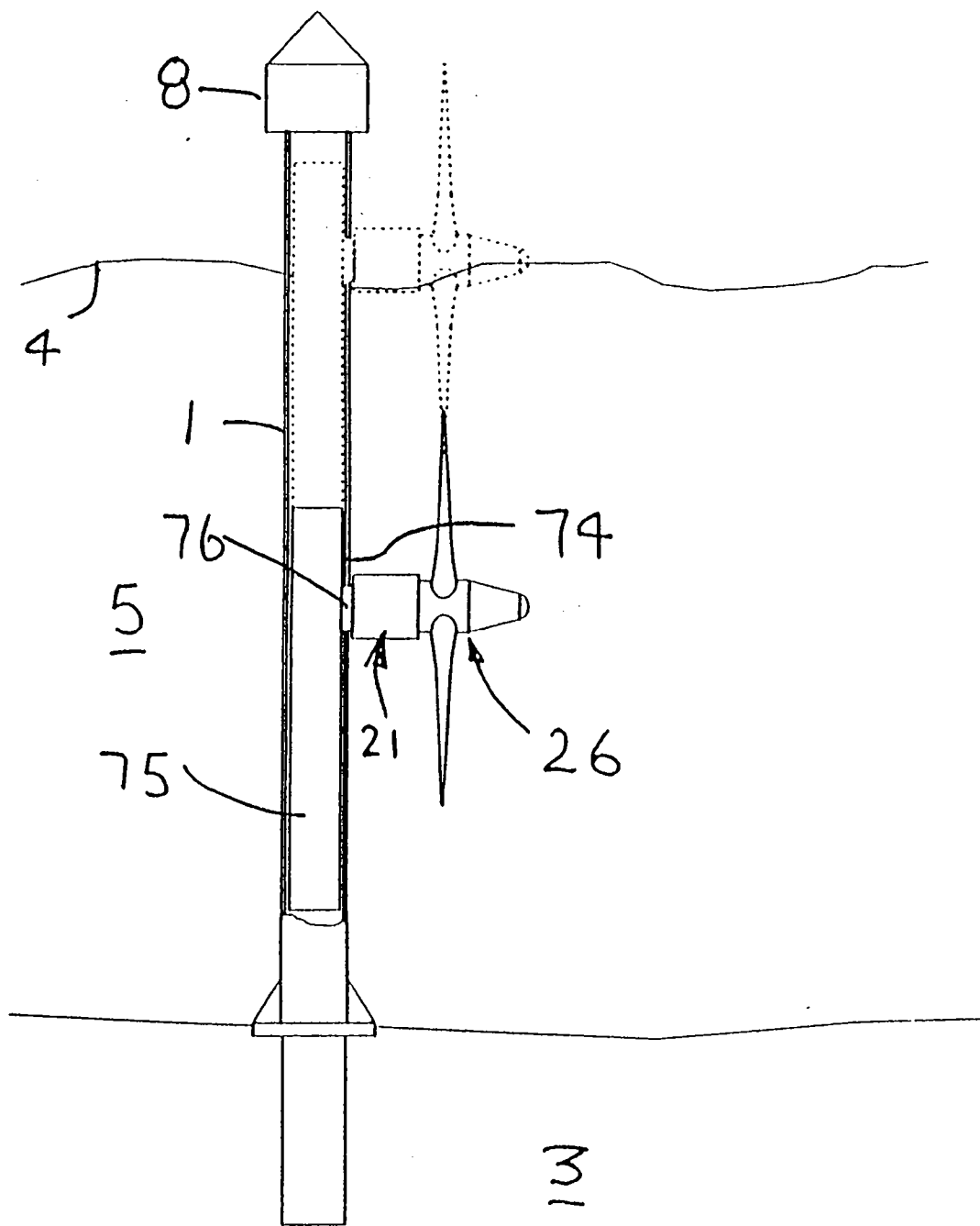
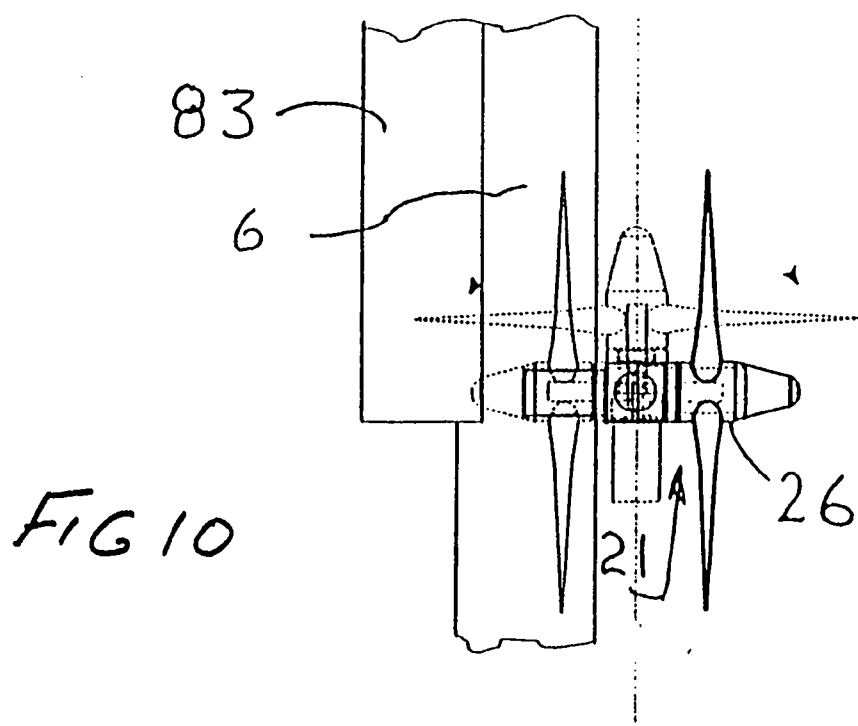
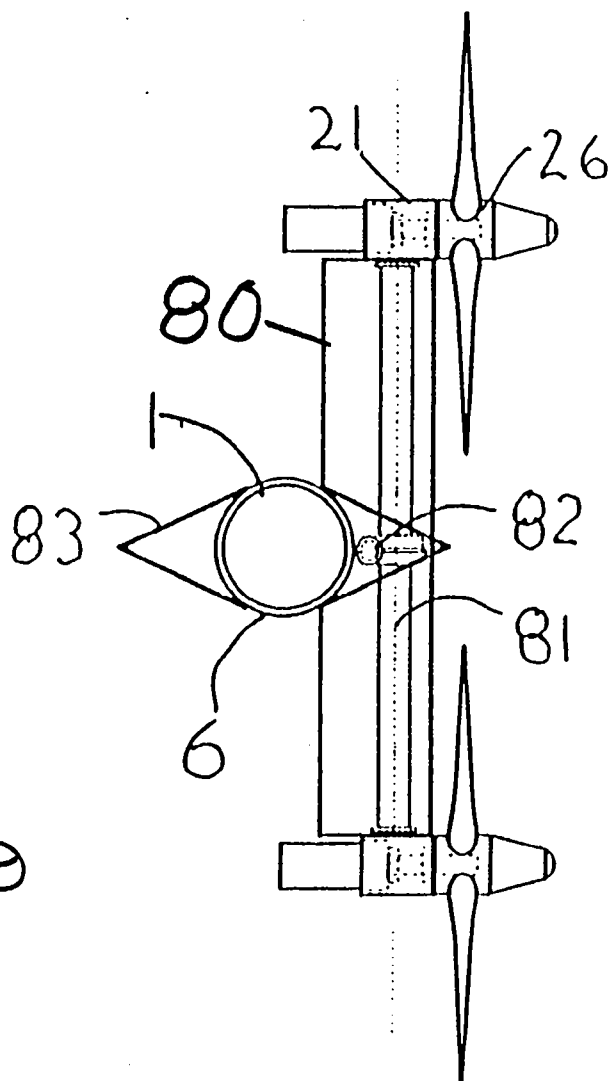


FIG 8

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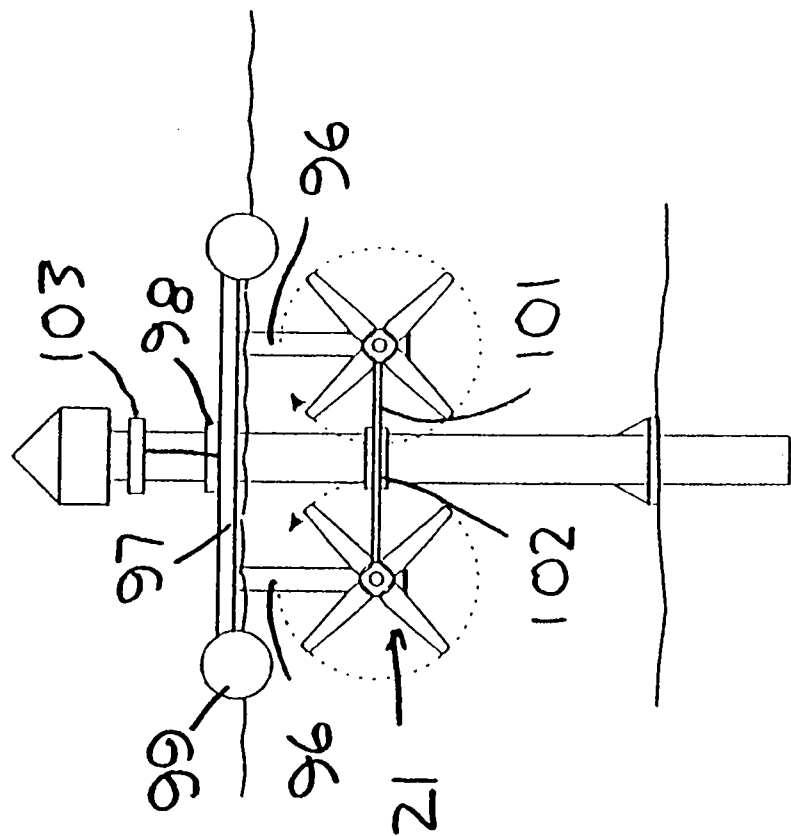


FIG 11

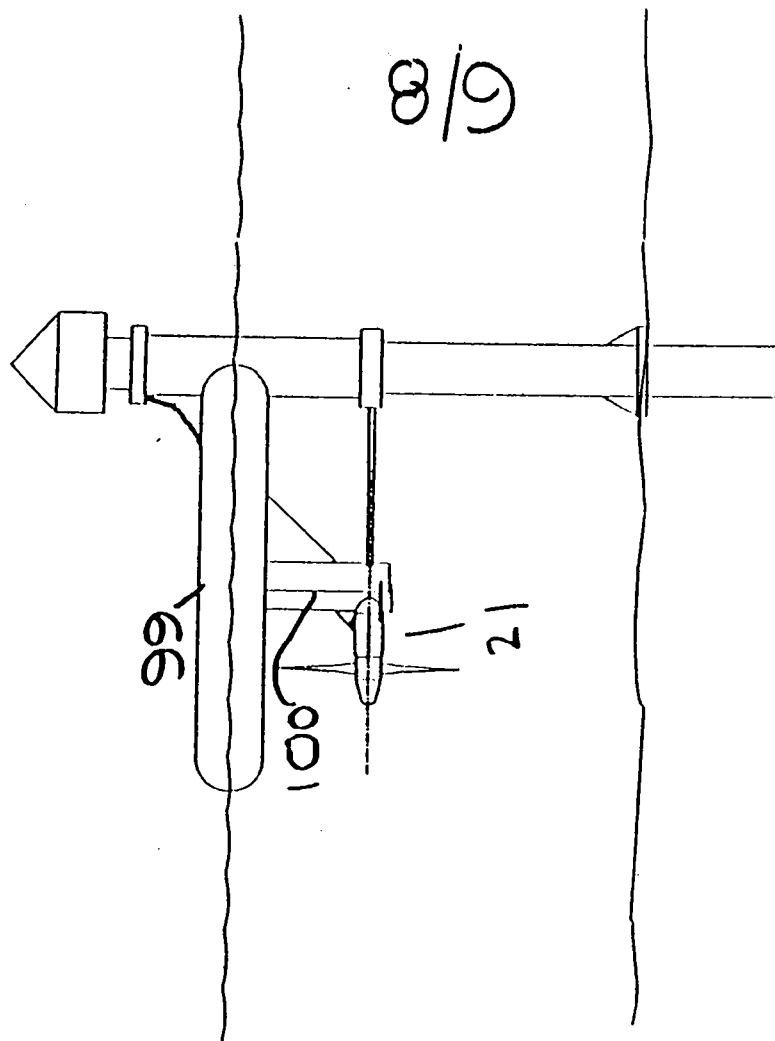


FIG 12

