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(56) Documents Cited:
GB 2473354 A **WO 2005/057006 A1**
JP 620267577 A **US 20100164230 A1**

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INT CL **F03B**
Other: **EPODOC, TXTE, WPI**

(54) Title of the Invention: **Water turbine assembly**
Abstract Title: **Water turbine assembly**

(57) A water turbine assembly for generating useful energy, such as electricity, from a flow of water in a tidal or other wet environment has an energy converting turbine 16, 116 and anchoring means for anchoring the water turbine assembly to a water bed such as a sea or river bed. A pair of rigid tether members 18A and 18B, 118A and 118B connect the electricity generating turbine to the anchoring means. One tether member is provided upstream of the other to form a parallelogram arrangement whereby the tether members are pivotable around horizontal axes which are perpendicular to the flow of water. This allows the electricity generating turbine to move between upper and lower depths depending upon the magnitude of the flow of water, whilst maintaining the electricity generating turbine level with the anchoring means. One or more turbines 16 may be mounted by a horizontal wing 14 on each side of a central faired flotation unit 12. The length of each tether may be actively adjustable.

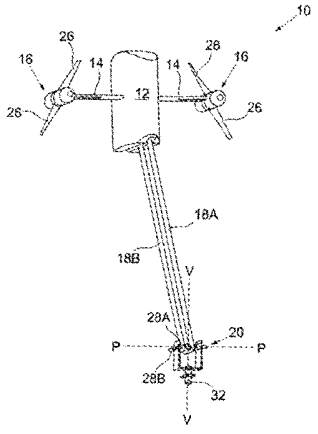

Fig. 1

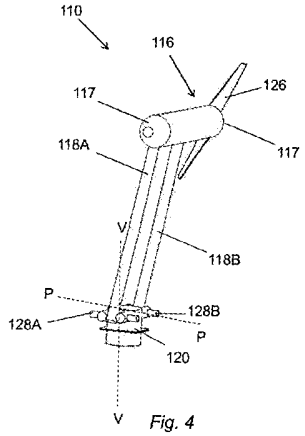

Fig. 4

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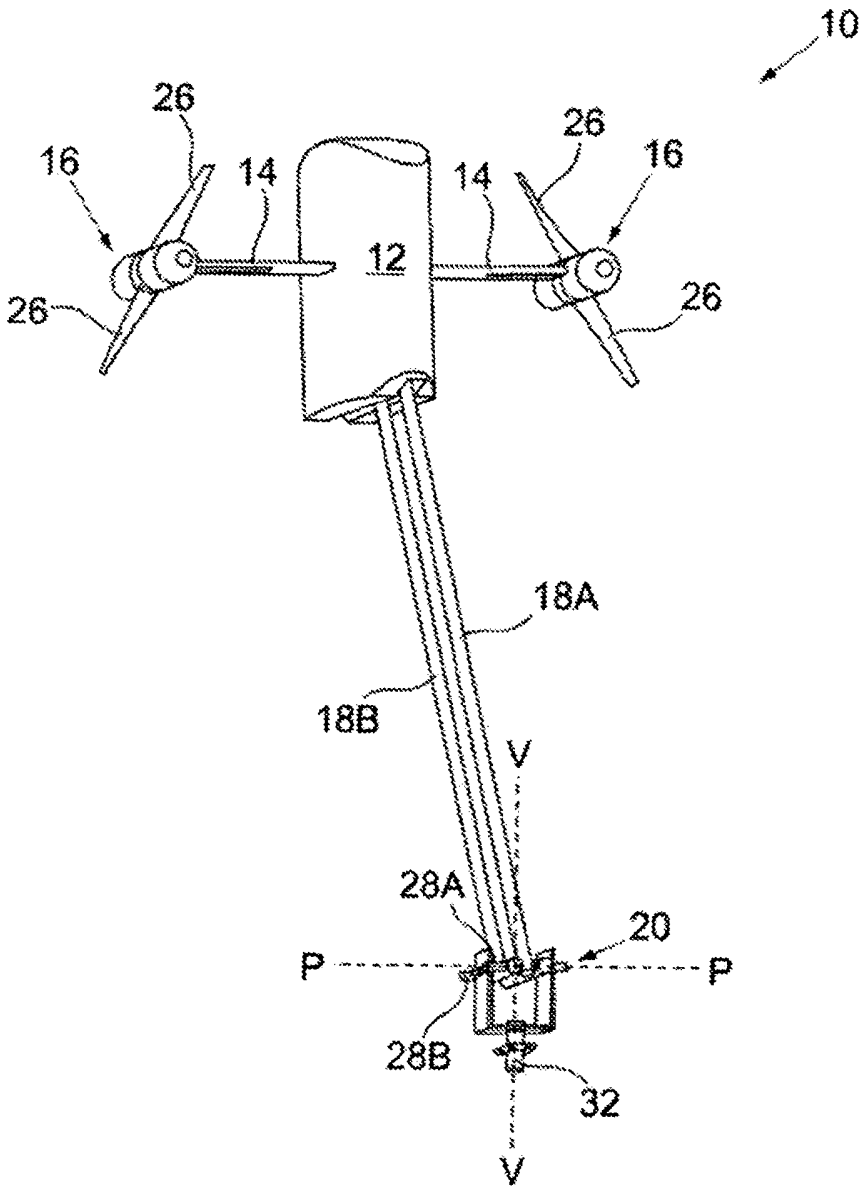
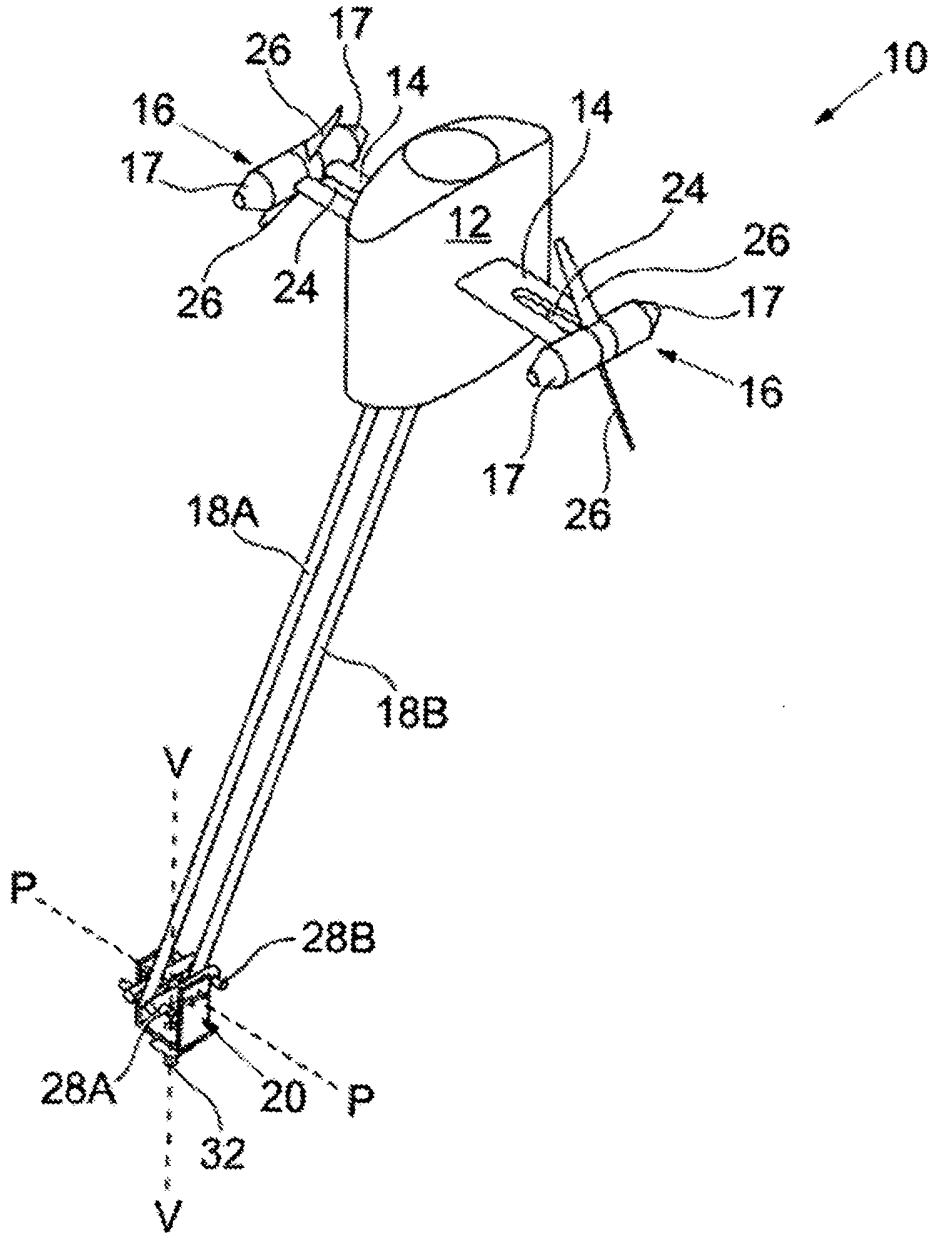


Fig. 1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17
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14
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12
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16
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18A
18B
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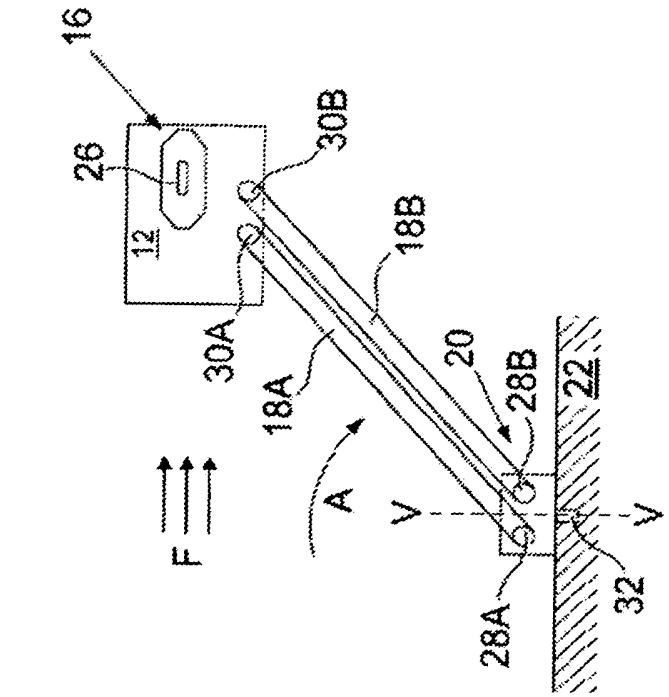
P
28B
28A
20
P
32
V

Fig. 2


16
26
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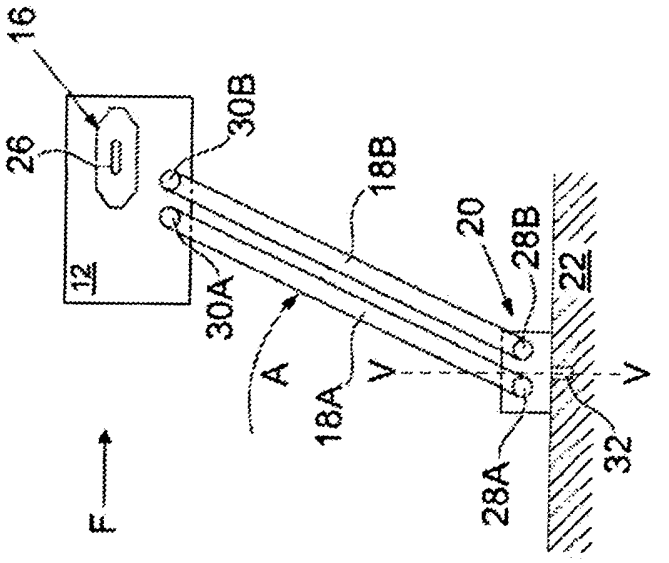
30B
18B
20
28B
22
30A
18A
A
V
V
F
28A
32

Fig. 3B


16
26
12
30B
18B
20
28B
22
30A
A
18A
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V
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28A
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Fig. 3A

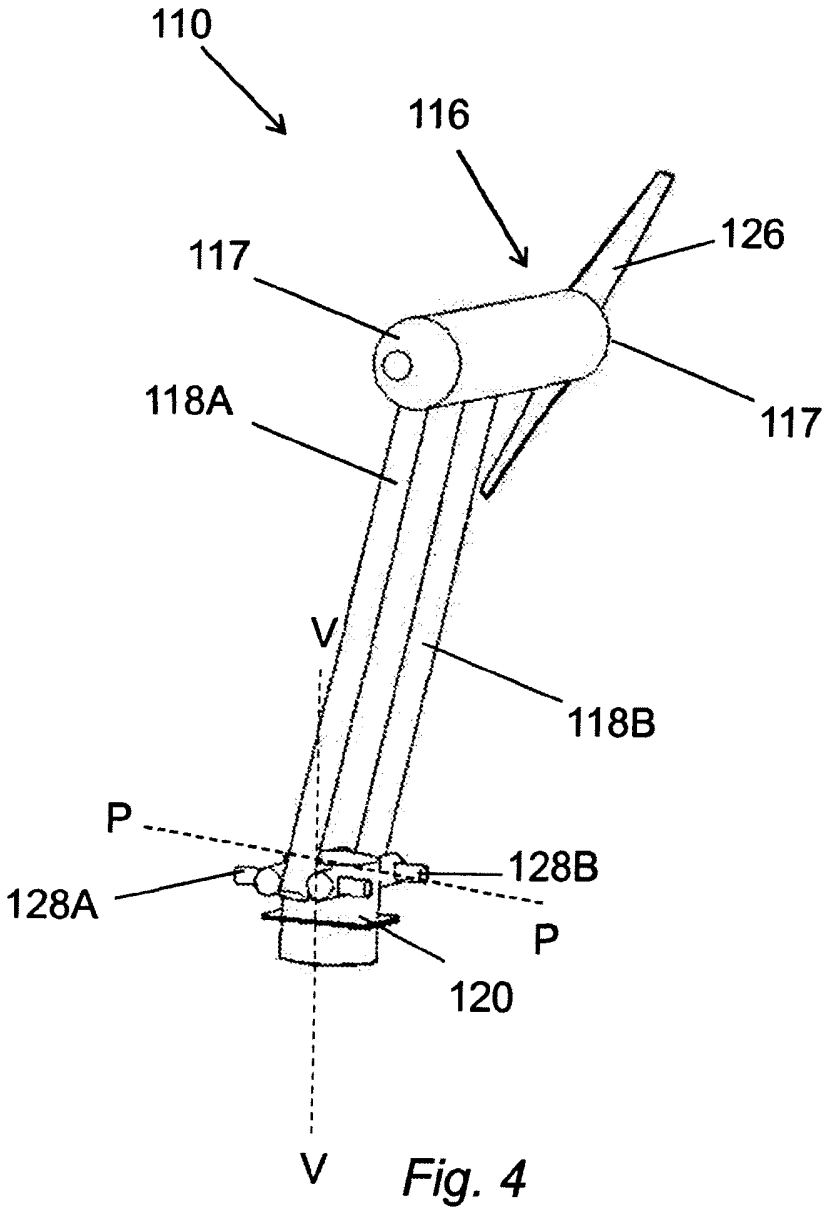

Fig. 4

Water Turbine Assembly

The present invention relates to a water turbine assembly, particularly, but not exclusively, a water turbine assembly for converting kinetic energy in water currents, such as those found in tidal streams, into electricity or other useful energy.

In recent years, political and environmental pressures have created a significant demand for the generation of electricity from so called "renewable sources". One such source of renewable energy can be harnessed by extracting kinetic energy from currents of water produced by the Earth's tidal cycle and converting that kinetic energy into electricity (or other useful forms of energy; e.g. hydraulic pressure etc.) which can then be fed into an energy distribution network such as the national electricity distribution network.

In order to generate optimum power, such tidal turbines must be designed to align themselves with the prevailing direction of water flow and are therefore typically mounted on slip-ring connections which allow the assembly to rotate up to, and through, 360 degrees in response to lateral changes in the direction of water flow, whilst maintaining an electrical connection with the underwater grid supplied by the turbine. However, to ensure optimum efficiency it is also desirable to ensure that the turbine is aligned vertically with the prevailing flow of water at any given depth.

According to the present invention, there is provided a water turbine assembly for extracting energy from a flow of water, the water turbine assembly comprising:-
an energy converting turbine;
anchoring means for anchoring the water turbine assembly in the flow of water;
first and second substantially rigid pivotable tether members connecting the energy converting turbine to the anchoring means, the first tether member being provided upstream of the second tether member to form a parallelogram arrangement whereby the tether members are pivotable around a substantially horizontal axis which is substantially perpendicular to the flow of water to allow the energy

converting turbine to move between upper and lower depths depending upon the magnitude of the flow of water, whilst maintaining the energy converting turbine level with respect to the anchoring means.

Further features and advantages of the invention will be apparent from the following description and the attached claims.

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

Fig. 1 is a schematic perspective view of a water turbine assembly viewed from an upstream, left hand, underside position;

Fig. 2 is a further view of the water turbine assembly of Fig. 1, viewed from an upstream, right hand, upper position;

Fig. 3A is schematic side view of the water turbine assembly of Fig. 1 in a relatively weak current, generally designated F, and Fig. 3B is a schematic view of the assembly in a relatively strong current, generally designated F, where the water turbine assembly has pivoted further downstream and nearer the water bed; and

Fig. 4 is a schematic perspective view of a second embodiment of the water turbine assembly according to the present invention.

A water turbine assembly 10 according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 3. The assembly 10 comprises lifting means in the form of a flotation member or unit 12 having at least one pair of horizontal wings or faired struts 14 which extend perpendicularly out from each side wall of the flotation unit 12. An electricity generating turbine 16 is mounted at the end of each horizontal wing 14. The horizontal wings 14 are provided with cut-out sections 24 which allow the blades 26 of the turbines 16 to pass therethrough as they rotate on the turbines 16.

The flotation unit 12 and attached components are tethered by a pair of rigid tethers 18 to a base unit 20 which is fixed to a foundation structure 22 (Figs. 3 and 4) such as a gravity foundation provided at an appropriate anchoring location. The base unit 20 is provided with a yaw pin 32 for connection into an appropriate corresponding socket in a fixed foundation (not shown) in order to provide up to, and through, 360 degrees of yaw capability. The yaw pin 32 and corresponding socket may also be provided with electrical connections.

In the present embodiment, the flotation unit 12 comprises a vessel containing a material which is buoyant in water and which is sized to provide sufficient buoyancy for the horizontal wings 14, turbines 16 and rigid tethers 18. An example of a suitable buoyant material is a micro-balloon material, although many other types of material would be equally suitable. The volume of buoyant material in the unit 12 is manipulated during manufacture to ensure optimum buoyancy is provided in order to help maintain the turbines 16 at an appropriate depth in the water column for a given current with optimal gravity foundation mass or other fixing method holding force. As best illustrated in Fig. 2, the flotation unit 12 is curved at both ends in order to hydro-dynamically minimise any drag created. Furthermore, the optional provision of such hydro-dynamically curved surfaces at both ends of the flotation unit 12 results in a symmetrical flotation unit 12 which minimises drag created regardless of the prevailing direction of the water current. The horizontal wings 12 and turbine cowlings 17 are also hydro-dynamically profiled to reduce drag regardless of the prevailing direction of the water current.

As best illustrated in Figs. 3A and 3B, in the embodiment shown, the turbine blades 26 and horizontal wings 14 are mounted toward the trailing edge of the flotation unit 12. The resultant increase in drag towards the trailing edge (rear) of the flotation unit 12 serves to facilitate the pivoting movement of the assembly deeper into the water as the magnitude of water flow increases (as will be described in more detail subsequently).

The tether to the base unit 20 is provided by a first tether 18A and a second tether 18B. The tethers 18A and 18B are provided one in front of the other (with respect to the prevailing direction of current flow) and are each pivotally connected at their lower ends to the base unit 20 by pivot bars 28A and 28B thereby providing a movable parallelogram arrangement. At their upper ends the tethers 18A and 18B are attached to similar pivot bars 30A and 30B (Figs. 3 and 4) in a recess provided on the underside of the flotation unit 12. This allows the tethers 18A and 18B to pivot around horizontal axis P-P (aligned with the plane of the foundation 22 and perpendicular to the prevailing current) in a pendulum-like motion depending upon the direction of the water flow. The pivoting movement of the assembly 10 is illustrated by the arrow A in Figs. 3A and 3B.

As well as providing the pivoting capability previously described, the base unit 20 also swivels around a vertical axis V-V in order to allow the assembly 10 to weathervane with the angle of the oncoming prevailing current. In this regard, the base unit 20 (and associated electrical connection) are able to swivel through 360 degrees.

In use, as the flow of water in a given tidal current passes over the rotor blades 26 they will rotate, thereby generating electricity. As the flow of water passes the assembly, the various components (blades 26, flotation unit 12, horizontal wings 14 etc.) of the assembly 10 will simultaneously produce hydro-dynamic drag. This results in a rearward force on the assembly (in the direction of the flow F) which, due to the tethering effect of the parallelogram arrangement provided by members 18 attached to the base unit 20, causes the flotation unit 12 to pivot around axis P-P. In so doing, the flotation unit 12 and hence the turbines 16 move deeper into the surrounding flow of water. In a weaker current (depicted by single arrow F in Fig. 3A) the assembly will therefore be relatively high in the water and in a stronger current (depicted by triple arrow F in Fig. 3B) the assembly 10 will be relatively low in the water. It can therefore be seen that as the magnitude of the current increases, the flotation unit 12 will move gradually deeper into the water. As it moves down through the water column (pivoting around the base unit 20) the

velocity of the prevailing water current passing over the turbines 16 has a tendency to decrease (since they will now be closer to the boundary layer at the water bed) such that the assembly will automatically reach a new point of equilibrium. This means that the turbines 16 are always maintained at an optimal depth in the water column. Furthermore, the overturning thrust forces on the gravity base, foundation or other fixing means are optimally offset by the buoyancy and therefore the mass of the gravity foundation can be reduced from those required by previous systems.

The fixed lengths of the tethers 18A and 18B ensure that the flotation unit 12 and hence the turbine 16 is maintained level in the water. This is because the tether members 18A and 18B, combined with the fixed pivots 28A, 28B, 30A and 30B, form a movable parallelogram. Therefore, the top side of the parallelogram (the flotation unit 12 and associated components) will always be aligned parallel with the bottom side of the parallelogram (the base unit 20). The stability of the flotation unit 12 in the current of water is also improved by the hydro-dynamic stabilising effect of the horizontal wings 16. This ensures that the planes swept by the blades of the two turbines 16 are always located perpendicular to the flow of water, thereby maximising the efficiency of the assembly 10.

As the tide cycle changes from a rising tide to a falling tide the assembly 10 will automatically reconfigure itself accordingly. For example, if the illustration in Fig. 3A is taken to show a relatively weak rising tide, as high tide is approached, the flotation unit will gradually begin to pivot upwards in the water column until it is more or less located above the base unit 20. As the tide begins to fall the flow of water relative to the assembly 10 will reverse in direction and the flotation unit 12 will gradually rotate around axis V-V and then begin to pivot downwards in the water column around axis P-P. In this regard, the off centred nature of the blades 26 and wings 14 results in a rearward centre of resultant drag which ensures that the apparatus will turn around vertical axis V-V, in response to the reversal of water flow direction, before subsequently pivoting down around horizontal axis P-P.

A water turbine assembly 110 according to a second embodiment of the present invention will now be described with reference to Fig. 4. In order to minimise repetition, similar features of the apparatus described subsequently are numbered with a common two-digit reference numeral and are differentiated by a third digit placed before the two common digits. Such features are structured similarly, operate similarly, and/or have similar functions as previously described unless otherwise indicated.

The water turbine assembly 110 comprises a single electricity generating turbine 116 mounted on a pair of tethers 118A and 118B. In the present embodiment, no flotation means are required on the assembly 110; instead the joints between the tethers 118A, 118B and the turbine 116 and / or the joints provided at pivot bars 128A, 128B are arranged to provide lifting means in the form of the turbine 116 fairing and or the turbine blades 126 which provide a lift component as the water flows there-over. A lower end-stop arrangement may be provided to prevent the assembly 110 pivoting too low in the water column when e.g. there is an insufficient flow of incident water to provide lift.

Although the specific embodiments discussed above are described in the context of a marine tidal turbine, the reader will understand that the assemblies are also suitable for other water environments, such as for example, rivers and estuaries. The term "water bed" therefore includes for example river beds, estuary beds and sea beds.

Modifications and improvements may be made to the forgoing without departing *from the scope of the invention, for example*:-

The length of the tether members 18A and 18B may be pre-adjusted or actively adjusted in order to allow the turbines 16 to be situated at an optimum depth within particular tidal streams.

Although in the first described embodiment, the assembly 10 is shown with one turbine 16 on each side of the flotation unit 12, many turbines could be provided on each side of the flotation unit if desired for a particular application. In a further alternative embodiment, the flotation unit 12 could be provided with a single, centrally located turbine 16.

Although the first described embodiment shown in the diagrams has a pair of wing struts 14 extending from the flotation unit 12, a single or plurality of wing struts 14 could be provided on each side of the flotation unit 12. Furthermore, the wing struts 14 could alternatively be simple struts which attach the turbine(s) 16 to the flotation unit 12. In such an embodiment, the requirement for cut-out sections may be removed.

Rather than providing buoyant material in the flotation unit 12 of the first embodiment, the flotation unit 12 could be filled with air / gas in order to maintain the required degree of buoyancy. This would allow the quantity of air to be either actively adjusted during use of the assembly, or pre-adjusted prior to installation of the assembly, in order to optimise the buoyancy of the flotation unit 12 in the water.

In a further alternative embodiment a plurality of flotation units 12 could be provided.

In the embodiment shown in Figs. 3A and 3B, the turbine blades 26 and horizontal wings 14 are mounted toward the *trailing* edge of the flotation unit 12; however, the turbine blades could alternatively be mounted toward the *leading* edge of the flotation unit 12. In this embodiment, a tail could be provided to facilitate yawing of the apparatus in the flow of water. In this regard, a powered yaw mechanism could additionally be provided if desired in order to assist yawing of the assembly.

CLAIMS

1. A water turbine assembly for extracting energy from a flow of water, the water turbine assembly comprising:-
an energy converting turbine; anchoring means for anchoring the water turbine assembly in the flow of water;
first and second substantially rigid pivotable tether members connecting the energy converting turbine to the anchoring means, the first tether member being provided upstream of the second tether member to form a parallelogram arrangement whereby the tether members are pivotable around a substantially horizontal axis which is substantially perpendicular to the flow of water to allow the energy converting turbine to move between upper and lower depths depending upon the magnitude of the flow of water, whilst maintaining the energy converting turbine level with the anchoring means.

2. A water turbine assembly according to claim 1, further comprising lifting means for controlling the depth of the energy converting turbine for a given magnitude of water flow.

3. A water turbine assembly according to claim 2, wherein the lifting means comprises a flotation unit.

4. A water turbine assembly according to claim 2, wherein the lifting means comprises hydrodynamic surfaces on a portion of the water turbine assembly to produce a lifting or lowering force dependent upon the magnitude of the water flow.

5. A water turbine assembly according to any preceding claim, wherein the substantially rigid tether members are actively adjustable in length to allow the depth of the assembly to be altered depending upon the surrounding flow characteristics.

6. A water turbine assembly according to any preceding claim, wherein at least a turbine is provided on either side of the water turbine assembly.

7. A water turbine assembly according to any preceding claim, wherein blades of the energy converting turbine are mounted toward a trailing edge of the energy converting turbine.

8. A water turbine assembly according to claim 3, wherein the or each turbine is attached to the flotation member by a horizontal wing member.

9. A water turbine assembly according to claim 8, wherein the or each horizontal wing member is provided with a cut out section to allow passage of a turbine blade therethrough as the blades of the or each turbine rotate.

10. A water turbine assembly according to any preceding claim wherein components of the assembly are hydro-dynamically shaped to maintain stability and reduce drag regardless of the direction of the flow of water.

11. A water turbine assembly according to any preceding claim, wherein the anchoring means comprises a base unit adapted to allow rotation of the water turbine assembly around a vertical axis in response to changes in direction of the flow of water.

12. A water turbine assembly according to any preceding claim, wherein the energy converting turbine comprises an electricity generating turbine.

13. A water turbine assembly according to claim 12, wherein the base unit further comprises means for maintaining an electrical connection between the water turbine assembly and an anchoring location while the water turbine assembly rotates in response to the changes in direction of the flow of water.

14. A water turbine assembly according to claim 13, wherein the means for maintaining the electrical connection is adapted to allow rotation up to and through 360 degrees around the vertical axis.

15. A water turbine assembly according to any preceding claim, further comprising a gravity foundation member or other fixing means.

16. A water turbine assembly as hereinbefore described with reference to the attached drawings.

Application No:	GB1106988.7	**Examiner:**	John Twin
Claims searched:	1 to 16	**Date of search:**	8 August 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1,2,10	JP 62267577 A (Sanuki Tekko) - note parallel links 5
X	1	US 2010/0164230 A1 (Belinsky et al.) - see eg para.12; note tethers 25
A	-	GB 2473354 A (Kingston)
A	-	WO 2005/057006 A1 (UWS Ventures) - see figs. 4,5

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

F03B

The following online and other databases have been used in the preparation of this search report

EPODOC, TXTE, WPI

International Classification:

Subclass	Subgroup	Valid From
F03B	0013/26	01/01/2006
F03B	0017/06	01/01/2006