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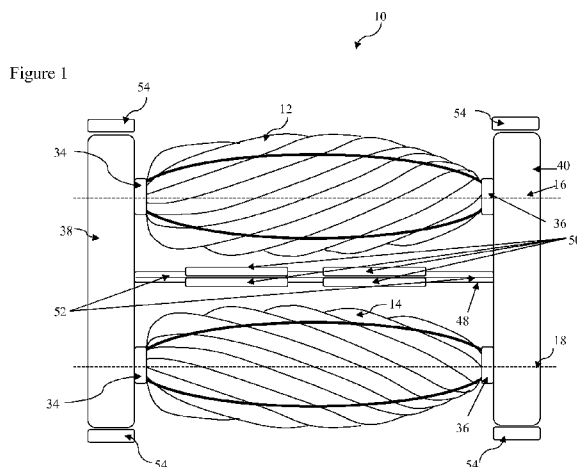
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(54) Title: HORIZONTAL AXIS TURBINE ASSEMBLY AND HYDRO-POWER GENERATION APPARATUS



(57) Abstract: A hydro power generation apparatus (10) for placement in a flow of water comprises first and second counter-rotating horizontal axis turbine assemblies (12,14). The assemblies include an inner housing (20, Fig 2), and a generator (22, Fig 2) and two gearboxes (24,26, Fig 2) mounted within the inner housing (20). A plurality of substantially helical blades (25) are mounted on a rotary casing (32) which extend around and rotate about the inner housing (20) for driving the gearboxes (24,26) and generator (22). Power is transmitted away from the apparatus (10) by a mooring cable (56, Fig 4) and the apparatus controls its own buoyancy to place it at optimum depth in a tidal flow for power generation.



TITLE: HORIZONTAL AXIS TURBINE ASSEMBLY AND HYDRO-POWER GENERATION APPARATUS

5 The present invention relates to a horizontal axis turbine assembly and a hydro-power generation apparatus for use in a flowing body of water.

BACKGROUND OF THE INVENTION

10 In a UK tidal stream energy resource assessment commissioned by the Carbon Trust (RTM), it has been found that many of the potential sites for placement of hydro-electric power generation equipment are small with low water flow rate velocities. Furthermore, a number of larger sites have been identified, but which also have low flow rate velocities. There are only several areas identified around the UK's shores, in which the flow rate velocities exceed 2.5m/s and the depth of water is within 30 to 15 40m, allowing seabed standing devices to be erected. Approximately 50% of the UK resource is within deep sites, with depths of over 40m, which require more sophisticated and expensive equipment to harness the power in the water movement.

20 It is generally recognised that the number of economically viable sites would be greatly increased, both in the UK and in other countries, if a power generation device could be practically and economically installed in depths equal to or greater than 40m. Furthermore, it would also be advantageous to be able to optionally position the device within any available higher velocity currents, generally found closer to the surface.

25 Some devices currently under development are sea or riverbed mounted. A problem of riverbed mounting is that it can reduce the free flow velocity of a body of water and can make access for deployment and maintenance more complex. Even if the mooring costs are kept to a minimum, these issues can reduce the economic viability of a sea or riverbed mounted device. Pile mounted designs, for example, require suitable 30 geological conditions, can present a hazard to surface marine traffic and can have negative environmental and aesthetic impact. Floor mounted devices may require foundations to be laid and may also suffer from significantly reduced flow rates found closer to the seabed or river bed.

Surface mounted devices, which can take advantage of increased velocities present towards the surface of a moving body of water are easily accessible, but are susceptible to weather conditions and also present a hazard to surface marine traffic
5 and can have negative environmental and aesthetic impact.

It is an object of the invention to provide a horizontal axis turbine assembly and hydro-power generation apparatus which reduces or substantially obviates the above mentioned problems.

10

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a horizontal axis turbine assembly for placement in a flow of water comprising
15 an inner housing,
a generator, a first gearbox and a second gearbox mounted axially in-line within the inner housing,
the gearboxes being disposed at opposite ends of the generator,
and a plurality of substantially helical blades extending around and adapted to rotate
20 about the inner housing for driving the gearbox and generator.

The horizontal axis turbine assembly is advantageous because the surface area of the helical blades available for energy transfer is much greater than in known apparatus, enabling the gearboxes to substantially gear up the rotational velocity to the generator
25 for efficient electricity generation at relatively low water flow rates.

The substantially helical blades may be mounted on a rotary casing, which may be adapted to rotate with the helical blades about the inner housing.

30 Each substantially helical blade may be made from a single continuous member. Alternatively, each substantially helical blade may be made from at least two blade members, which may be sealed together to act as a single continuous surface. In a further alternative arrangement, each blade may be made from at least two spaced blade members.

Each substantially helical blade may include a substantially smooth continuous surface.

- 5 Each substantially helical blade may gently curve in a first arc to a tip extending along the outer edge of the blade, the tip curving sharply in a second arc away from the first arc.

- 10 The sharp curving of the blade tip away from the majority of the lightly curved body of the blade has the effect of reducing cavitation, by streamlining the flow of water from the high pressure surfaces to the low pressure surfaces.

- 15 Each blade may be mounted to the rotary casing in a plurality of fixing positions extending along the length of the blade. The blade may advantageously be made from a flexible composite material.

- 20 The rotary casing may be substantially ovoid in shape and may be substantially symmetrical about a plane extending perpendicularly through the central longitudinal axis at its mid-point. This symmetrical shape facilitates the manufacture of the casing in two similar parts.

Bearings may be mounted at either end of the inner housing, about which the helical blades rotate. The bearings may be sealed bearings.

- 25 First and second circumferential drive gears may be mounted internally of the rotary casing and may engage respective drive gears mounted in driving communication with the first and second gearboxes, the first and second circumferential drive gears being driven by rotation of the turbine blades.

- 30 The first and second circumferential drive gears may engage first and second sets of planetary gears, which may be in driving communication with the first and second gearboxes.

A first clutch may be provided between the first gearbox and the generator and a second clutch may be provided between the second gearbox and the generator. A brake may be provided in one or each gearbox assembly.

- 5 The clutches enable the engagement of one or both of the gearboxes, thereby providing redundancy in the drive train. For example, if one gearbox requires repair, it can be taken off line using the clutch, but the device can still generate power through the other gearbox. If both gearboxes are online, then the loadings through the gearboxes are significantly reduced, and the chance of overload failures is reduced. If
10 loads are low, then one gearbox can be taken offline to reduce frictional losses.

A respective buoyancy structure may be disposed at each end of the horizontal axis turbine assembly.

- 15 According to a second aspect of the present invention there is provided hydro-power generation apparatus for placement in a flow of water comprising first and second horizontal axis turbine assemblies in accordance with the first aspect of the invention, in which the rotational axes of the first and second horizontal axis turbine assemblies are parallel with one-another and the substantially helical blades of each assembly are
20 adapted to rotate in a different direction, when both are disposed in a water flow.

By virtue of the turbine blades of the respective assemblies helically twisting in opposite directions, the apparatus is substantially stable in use in a water flow.

- 25 The first and second horizontal axis turbine assemblies may be mounted in a supporting structure including a first buoyancy tank and a second buoyancy tank.

- The first buoyancy tank may be connected to and may extend between the front ends of the first and second horizontal axis turbine assemblies and the second buoyancy
30 tank may be connected to and may extend between the rear ends of the first and second horizontal axis turbine assemblies.

Powered control surfaces may be disposed on the buoyancy tanks for controlling the position of the apparatus in a water flow.

A supporting strut may extend between the first and second buoyancy tanks. The strut may be disposed between the first and second horizontal axis turbine assemblies.

- 5 At least one fin may be mounted on the supporting strut for stabilising the apparatus in a water flow. A fin may be mounted to both the upper and lower sides of the supporting strut. The fins stabilise the apparatus in the horizontal plane. Compressed air tanks may also be disposed on the supporting strut.
- 10 A programmable controller, battery, pressure sensor and flow meter may be mounted to the apparatus for controlling the depth of the apparatus in use, in a body of water.

The controller is adapted to maintain the position of the apparatus at a depth where the water flow rate relative to a substantially fixed lateral position of the apparatus is a
15 maximum.

The controller may control the buoyancy of the apparatus by flooding the buoyancy tanks with water or by expelling water from the tanks with air from the compressed air tanks. The controller may maintain the apparatus with neutral buoyancy in order
20 position the apparatus at a substantially fixed depth in a water flow.

The apparatus may be moored by a mooring line, which may be held by a weight deployed on the riverbed or seabed. The weight may be of natural stone, such as granite, or may be made from concrete. Advantageously the apparatus can be moored
25 in any depth of water, for example, in excess of 40m, and additionally be easily positioned within the vertical column for optimal flow conditions at any given time in the tidal/river cycle. The apparatus can generate power in both slow moving water flows, eg less than 2.5m/s and fast moving water flows of around 4.5m/s.

30 BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 shows a schematic plan view from above of a hydro-power generation apparatus;

- 5 Figure 2 shows a schematic side view, partly in cut-away, of a horizontal axis turbine assembly of the hydro-power generation apparatus of Figure 1;

Figure 3A shows a schematic side view of a horizontal axis turbine assembly of the hydro-power generation apparatus of Figure 1, with fluid flow lines shown passing
10 over the turbine blades;

Figure 3B shows a schematic side view of a continuous unitary turbine blade;

Figure 3C shows a schematic end view of the continuous turbine blade of Figure 3B;
15

Figure 4 shows a schematic cross-sectional view through a mooring cable for use with the hydro-power generation apparatus of Figure 1;

Figure 5 shows a schematic side view of the hydro-power generation apparatus of
20 Figure 1, in use, in a body of flowing water;

Figure 6 shows a schematic cross-sectional view through a second embodiment of horizontal axis turbine assembly; and

25 Figure 7 shows a schematic plan view of a hydro-power generation apparatus incorporating a pair of horizontal axis turbine assemblies, as shown in Figure 6.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

30 Referring firstly to Figure 1, a first embodiment of hydro-power generation apparatus is indicated generally at 10. The hydro-power generation apparatus 10 includes first and second counter-rotating horizontal axis turbine assemblies 12,14 mounted side by side with parallel axes 16,18 of rotation. Referring also to Figure 2, each assembly 12,14 includes an inner housing 20 containing a generator 22 and first and second

gearboxes 24,26. The gearboxes 24 and 26 are mounted in-line with the generator 22 and their output shafts drive the generator from either end. Drive gears 28,30 are mounted to the input shafts of the gearboxes 24,26 and are also mounted in-line. Rotation of the drive gears 28,30 causes rotation of the gearbox input shafts and geared drive at increased rotational velocity of the generator 22. Clutches are provided for each of the gearboxes 24,26 enabling selective drive through the gearboxes to the generator 22 by engaging or disengaging one or both gearboxes.

A rotary casing 32, constructed in two sections to aid assembly and maintenance, is disposed around the inner housing 20 and is arranged to rotate about first and second sealed bearings 34,36 mounted at respective ends of the inner housing 20. The rotary casing 32 is substantially ovoid shaped and is symmetrical about three perpendicularly disposed planes, two of which lie on the central axis of the casing. As shown in Figure 2, individual floats or buoyancy tanks 38,40 are mounted at the distal ends of the assembly, and are mounted to the sealed bearings. Helical blades 25 are mounted to the rotary casing 32 and are connected to the casing, for example, with bolts at a plurality of spaced fixing positions. Referring also to Figures 3A to 3C, each helical blade is continuous and has a smooth surface. When mounted to the rotary casing 32, each helical blade 25 includes a major surface region 46 which is slightly curved in a first arc and a tip region 48 extending from the region 46, the tip region being sharply curved in a second arc. The distal end of the tip region 46 lies almost perpendicular to the major surface region 46, and in use, helps to keep turbulence due to cavitation to a minimum.

Referring back to Figure 1, the first buoyancy tank 38 extends across the front of the horizontal axis turbine assemblies 12,14 perpendicular to the axes of rotation 16,18 and the sealed bearings 34 are mounted to the side of the tank 38. Similarly the second buoyancy tank 40 extends across the rear of the horizontal axis turbine assemblies 12,14 perpendicular to the axes of rotation 16,18 and the sealed bearings 36 are mounted to the side of the tank 40.

A structural strut 48 extends between the buoyancy tanks 38,40 and is positioned parallel and mid-way between the horizontal axis turbine assemblies 12,14. A plurality of compressed air tanks 50 are mounted on the strut 48 together with upper

and lower stabilising fins 52. These fins 52 stabilise the assembly in the horizontal plane. Control surfaces 54, powered by servos, are mounted to the ends of the buoyancy tanks 38,40.

- 5 Also mounted to the hydro-power generation apparatus 10 are an Industrial Programmable Logic Controller (PLC), an operating battery, and a plurality of sensors for sensing external pressure readings forward and aft, water flow-rate, water temperature, water salinity, power output, statuses of the gearbox & generator, compressed air levels & orientation (not shown). The PLC can also control automatic
10 lubrication of the generator 22 and gearboxes 24,26 through the clutches.

Referring to Figure 4, a mooring cable for use with the assembly 10 is indicated generally at 56. The mooring cable has two load bearing cores 58 made, for example, from steel, buoyancy fibres 60 running on either side of the load bearing cores 58, at
15 least one ruggedized optic fibre 62 for relaying control information to and from the assembly 10 (two are shown) and two armoured electrical power cables 64 for transmitting the generated electrical power. The inner cables are all retained in a reinforced outer sheath 66. The mooring cable 56 is attached to a weight, for example, of granite or concrete, which can be placed in a desired position on the river
20 bed or seabed in a water flow. A fixed mooring is not required.

In use, as shown in Figure 3A, the horizontal axis turbine assemblies 12,14 of the assembly 10 provide blades 25 with a much larger surface area than in known hydro-power generation devices, which more effectively utilise increases in flow rate as
25 water passes over the surface of the housing, in order to maximise the pressure exerted on the blades. The blades 25 and overall design are such that cavitation of the water flow is reduced to a minimum.

Another advantage over existing designs is that due to the increased surface area of
30 the blades, the required flowrate for operation can be much lower. Additionally, the blades can be customised to suit the environmental conditions expected at a specific installation. With a low external rotational velocity the adverse effects on marine animals is reduced to a minimum.

Under normal operating conditions the assembly 10 is automatically locally controlled by the PLC. The mooring method can be adapted to suit the sea or river bed conditions and the flowrate of the water. If installed in a tidal stream, the generation unit will maintain the same depth but slowly change direction in relation to the mooring during a tide change. The mooring cable 56 requires only enough buoyancy in order that a majority of its own weight is self-supported.

Referring to Figure 5, the assembly 10 is shown at different depths in a water flow, indicated at 68. The sea floor is shown at 70 and the surface of the water is indicated at 72. The assembly 10 can easily be located within a band of water flowing at optimum flow rate, as shown for example, between the dotted lines 74,76. Once neutral buoyancy has been achieved, i.e. no depth change with the control surfaces at zero degrees pitch, depth can be regulated by the control surfaces. This control will only be active if the flowrate is above a pre-determined flowrate. The control surfaces are independently controlled, allowing control over both orientation and depth of the apparatus. Controlling depth with the control surfaces during nominal flow conditions greatly reduces the amount of compressed air being consumed.

The design has the additional advantage of being able to utilise short durational peaks in flow velocity; because any sudden increases in velocity will temporarily force the assembly 10 slightly closer to the sea/river bed.

If maintenance is required, the PLC controls air pressurisation of the buoyancy tanks 38,40 causing the apparatus 10 to return to the surface. Compressed air is stored locally on the assembly, however if multiple units are installed as part of a “farm”, compressed air can be stored centrally. The energy contained within a body of flowing water has a cubic relationship with flow velocity, therefore even a small increase in flow rate equates to a significant increase in energy production. Positioning any device consistently within the higher flow rates, within any body of moving water, has a significant positive impact on commercial viability.

Under normal operating conditions the assembly is automatically and locally controlled via the PLC using the readings obtained from the sensors. It will control

orientation and depth positioning. The PLC can be pre-programmed to seek out the highest available flow rate at varying depths within a given operating depth band.

The on-board batteries, which are charged by the generation of power locally, supply the control systems with power. Each system is connected to the PLC and the PLC can be connected to a remote control device, for example, by fibre optics, in the event of malfunction, replacement, or checking. If the PLC detects a malfunction, the apparatus 10 can be programmed to automatically float to the surface or flood the tanks and lay on the sea/river bed.

10

Referring now to Figure 6, a second embodiment of horizontal axis turbine assembly is indicated at 80. Common reference numerals are used to designate parts in common with the first embodiment described. The inner housing 20 is mounted between the buoyancy tanks 38,40 and the substantially ovoid shaped rotary casing 32 is mounted on sealed bearings 34,36 for rotation about the inner housing 20. First and second gearboxes 24,26 are mounted either side of, and drive, the generator 22.

In this embodiment, first and second drive gear rings 82,84 are mounted internally of the rotary casing 32 and engage with corresponding first and second sets of planetary gears 86,88. The planetary gears 86,88 drive the respective gearboxes 24,26 through clutches, which may be disengaged or engaged. The dual planetary gearbox design enables “Duty-Standby” operation, enabling shared loading during peak generation periods & alternate operation at nominal loading. In addition the assembly can still generate power even if one of the gearboxes 24,26 is faulty. This provides built in redundancy and increases the economic viability, in use. A generation device operating with a single gearbox may lose the ability to generate due to a failure during peak flow periods. Within the gearboxes, there are also brake mechanisms for slowing rotation of the blades enabling a “Safe” mode, even under flow conditions.

Blades 90, 92 are mounted to the rotary casing and extend substantially helically along the casing. However, the blades 90,92 only extend about a central region of the rotary casing 32, and extend away from the casing, substantially perpendicular to its central axis, a length substantially equal to the length of the casing. The tips of the blades 90,92 are curved sharply in the same way as the tips of the blades of the first

embodiment, to reduce drag and cavitation. Ideally, in use, the Tip Speed Ratio of the blades is a maximum of 3, that is, reduced from a typical value of between 5 to 7. The blade length may vary from assembly to assembly depending on the intended positioning of the assembly in use. In general, the slower the water flow rate, the
5 larger the possible length of blade for optimum power generation.

A lateral propeller unit 94 is provided at the rear of the buoyancy tank 40, for use in tidal systems. Each propeller unit is capable of bidirectional rotation and is used in manoeuvring, as explained further below.

10

Referring also to Figure 7, a second embodiment of hydro-power generation apparatus is indicated generally at 96. The arrangement is similar to that of the first apparatus 10, shown in Figure 1, and operates in the same way, save that it incorporates a pair of the horizontal axis turbines 80. The apparatus also utilises the lateral propeller units
15 94. The lateral propeller units enable the apparatus to orient itself correctly within a flow. For example, when the assembly is coming out of slack tide, the orientation is controlled in such a way as to remove the risk of twisting of the mooring cable. Typically, when entering a flood tide the assembly would tend, for example, to always rotate clockwise. Similarly, on coming into an Ebb tide the assembly would tend to
20 rotate anticlockwise. These rotations are controlled or prevented by means of the lateral propeller units 94. The lateral propeller units 94 can optionally be incorporated in the first embodiment of generation apparatus 10.

Other advantages of the invention exhibited by one or other or both embodiments
25 include:

- Simplistic Functional Design
- High Energy Conversion ratio due to the increased flow velocity produced across the large surface area of the blades
- 30 • Operation in Low Flow Environments, ie less than 2.5m/s
- Can be Installed and Operated at far greater depths than traditional monopile designs
- Extremely Low Environmental Impact

- Comparatively low Installation & Maintenance Costs
 - Easily Deployed in a Range of Environments
 - Flexible and Scalable
 - Autonomous Control
- 5 • Not Flow Direction Dependant

In use, the substantially ovoid shape of the rotary casing acts as a central duct which focuses flow onto the blades, thus increasing rotational torque generated. The shape of the rotary casing provides a large surface area for mounting the blades, which can
10 take different substantially helical shapes, as illustrated in the drawings. The blades may advantageously be uni-directional, because the device can align with any flow direction.

The apparatus 10 utilises a pair of horizontal axis turbine assemblies 12,14, which are
15 arranged to counter-rotate in order to balance the apparatus in a flow of water. However, where there is a large movement of water and space permits, further pairs of horizontal axis turbine assemblies can be assembled in a single apparatus, as required. For example, it is envisaged that an apparatus (not shown) could include 4,
6, 8 or more horizontal axis turbine assemblies. The pairs of assemblies could be
20 arranged in a line, or arranged in a stack or otherwise arranged to suit a particular flow channel. This is possible, because each assembly can easily be positioned at any depth within a column of water to take advantage of optimum flow rates in the local geological conditions.

25 The apparatus 10 provides an alternative method of electrical energy generation and is suitable for many offshore locations, unsuited to other types of known device. The ability of the apparatus 10 to maintain neutral buoyancy and to locate itself in an optimum flow channel of water ensures that it harnesses the maximum power available in a given flow of water.

30

It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the elements and teachings of the various

illustrative embodiments may be combined in whole or in part in some or all of the illustrative embodiments. In addition, one or more of the elements and teachings of the various illustrative embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the

5 various illustrative embodiments within the scope of the claims.

10

CLAIMS

1. A horizontal axis turbine assembly for placement in a flow of water comprising
5 an inner housing,
a generator, a first gearbox and a second gearbox mounted axially in-line within the inner housing,
the gearboxes being disposed at opposite ends of the generator,
and a plurality of substantially helical blades extending around and adapted to rotate
10 about the inner housing for driving the gearbox and generator.
2. A horizontal axis turbine assembly as claimed in claim 1, in which the substantially helical blades are mounted on a rotary casing, which is adapted to rotate with the substantially helical blades about the inner housing.
15
3. A horizontal axis turbine assembly as claimed in claim 1 or claim 2, in which each substantially helical blade is made from at least two blade members.
4. A horizontal axis turbine assembly as claimed in any preceding claim, in
20 which each substantially helical blade includes a substantially smooth continuous surface.
5. A horizontal axis turbine assembly as claimed in any preceding claim, in which each substantially helical blade gently curves in a first arc to a tip extending
25 along the outer edge of the blade, the tip curving sharply in a second arc away from the first arc.
6. A horizontal axis turbine assembly as claimed in any one of claims 2 to 5, in which the rotary casing is substantially ovoid in shape and is substantially
30 symmetrical about a plane extending perpendicularly through the central longitudinal axis at its mid-point.

7. A horizontal axis turbine assembly as claimed in any preceding claim, in which bearings are mounted at either end of the inner housing, about which the helical blades and rotary casing rotate.

5 8. A horizontal axis turbine assembly as claimed in any preceding claim, in which first and second circumferential drive gears are mounted internally of the rotary casing and engage respective drive gears mounted in driving communication with the first and second gearboxes, the first and second circumferential drive gears being driven by rotation of the turbine blades.

10

9. A horizontal axis turbine assembly as claimed in claim 8, in which the first and second circumferential drive gears engage first and second sets of planetary gears which are in driving communication with the first and second gearboxes.

15 10. A horizontal axis turbine assembly as claimed in any preceding claim, in which a first clutch is provided between the first gearbox and the generator and a second clutch is provided between the second gearbox and the generator.

11. A horizontal axis turbine assembly as claimed in any preceding claim, in
20 which a brake is provided in one or each gearbox assembly.

12. A horizontal axis turbine assembly as claimed in any preceding claim, in which a respective buoyancy structure is disposed at each end of the horizontal axis turbine assembly.

25

13. A hydro-power generation apparatus for placement in a flow of water comprising first and second horizontal axis turbine assemblies as claimed in any preceding claim, in which the rotational axes of the first and second horizontal axis turbine assemblies are parallel with one-another and the substantially helical blades of
30 each assembly are adapted to rotate in a different direction, when both are disposed in a water flow.

14. A hydro-power generation apparatus as claimed in claim 13, in which the first and second horizontal axis turbine assemblies are mounted in a supporting structure including a first buoyancy tank and a second buoyancy tank.

5 15. A hydro-power generation apparatus as claimed in claim 14, in which the first buoyancy tank is connected to and extends between the front ends of the first and second horizontal axis turbine assemblies and the second buoyancy tank is connected to and extends between the rear ends of the first and second horizontal axis turbine assemblies.

10

16. A hydro-power generation apparatus as claimed in any one of claims 14 or 15, in which powered control surfaces are disposed on the buoyancy tanks for controlling the position of the apparatus in a water flow.

15 17. A hydro-power generation apparatus as claimed in any one of claims 14 to 16, in which a supporting strut extends between the first and second buoyancy tanks and also between the first and second horizontal axis turbine assemblies.

18. A hydro-power generation apparatus as claimed in claim 17, in which at least
20 one fin is mounted on the supporting strut for stabilising the apparatus in a water flow.
in which compressed air tanks are disposed on the supporting strut.

19. A hydro-power generation apparatus as claimed in claim 17 or claim 18, in which compressed air tanks are disposed on the supporting strut.

25

20. A hydro-power generation apparatus as claimed in any one of claims 11 to 19, in which a programmable controller, battery, pressure sensor and flow meter is mounted to the apparatus for controlling the depth of the apparatus in use, in a body of water.

30

21. A hydro-power generation apparatus as claimed in claim 20, in which the controller is adapted to maintain the position of the apparatus at a depth where the water flow rate relative to a substantially fixed lateral position of the apparatus is a maximum.

22. A hydro-power generation apparatus as claimed in any one of claims 11 to 21, in which the apparatus is moored by a mooring line.

5 23. A horizontal axis turbine assembly substantially as described herein with reference to and as illustrated in Figures 1 to 7 of the accompanying drawings.

24. A hydro-power generation apparatus substantially as described herein with reference to and as illustrated in Figures 1 to 7 of the accompanying drawings.

10

Figure 1

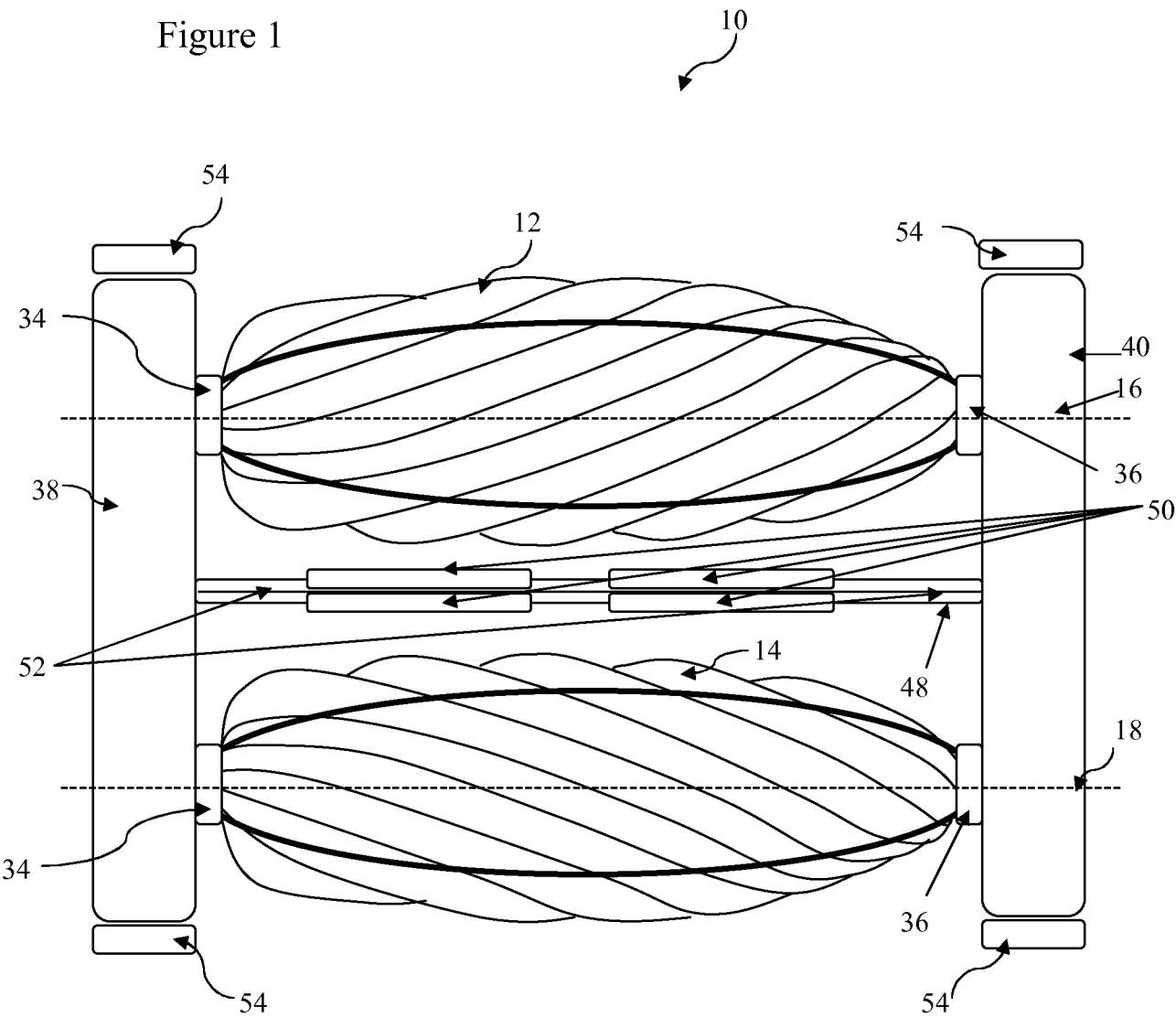
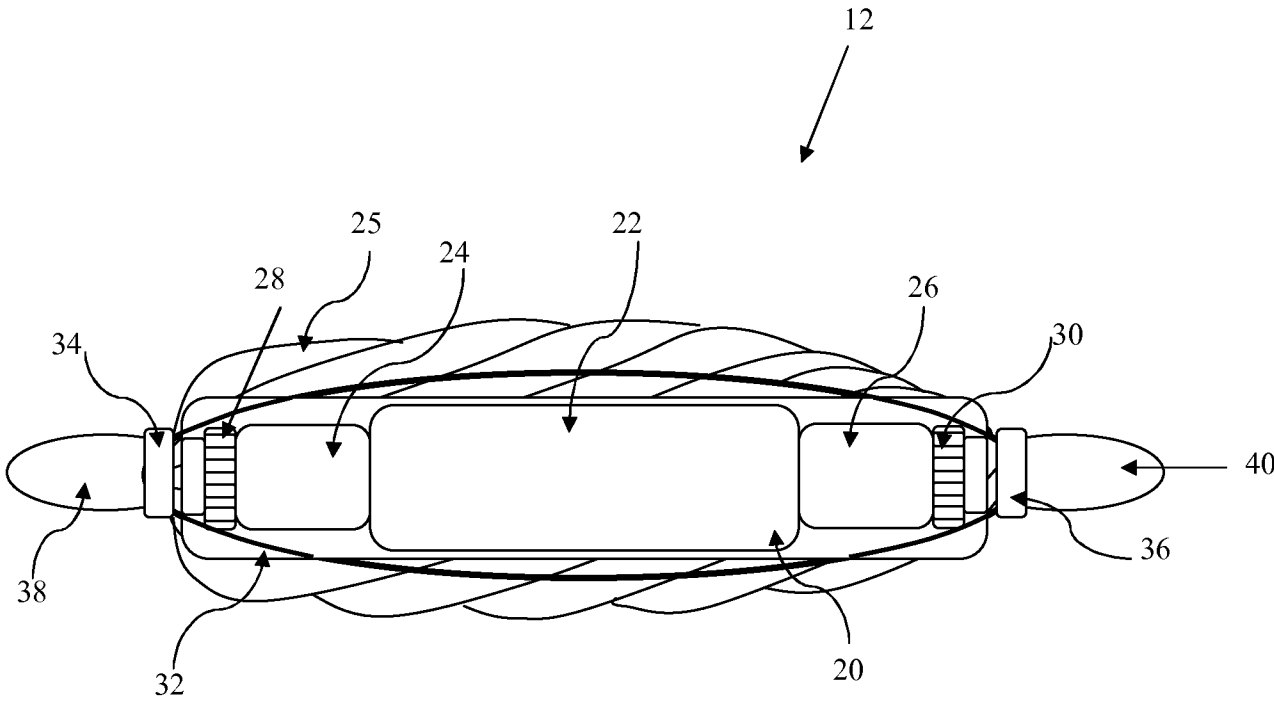


Figure 2



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Figure 3A

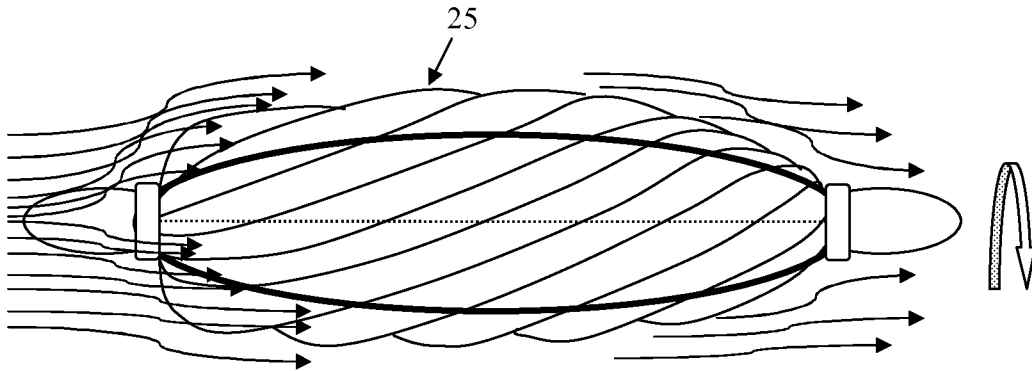
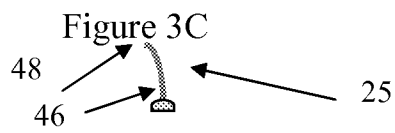


Figure 3B



Figure 3C



25

56

Figure 4

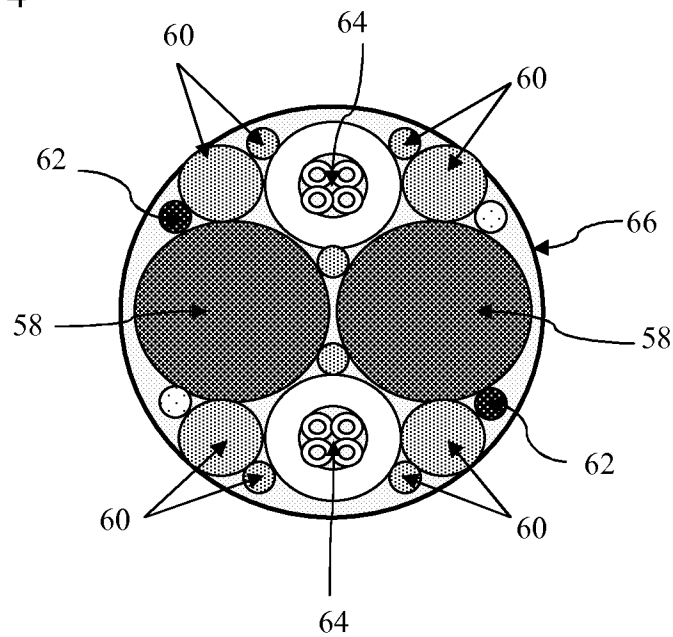


Figure 5

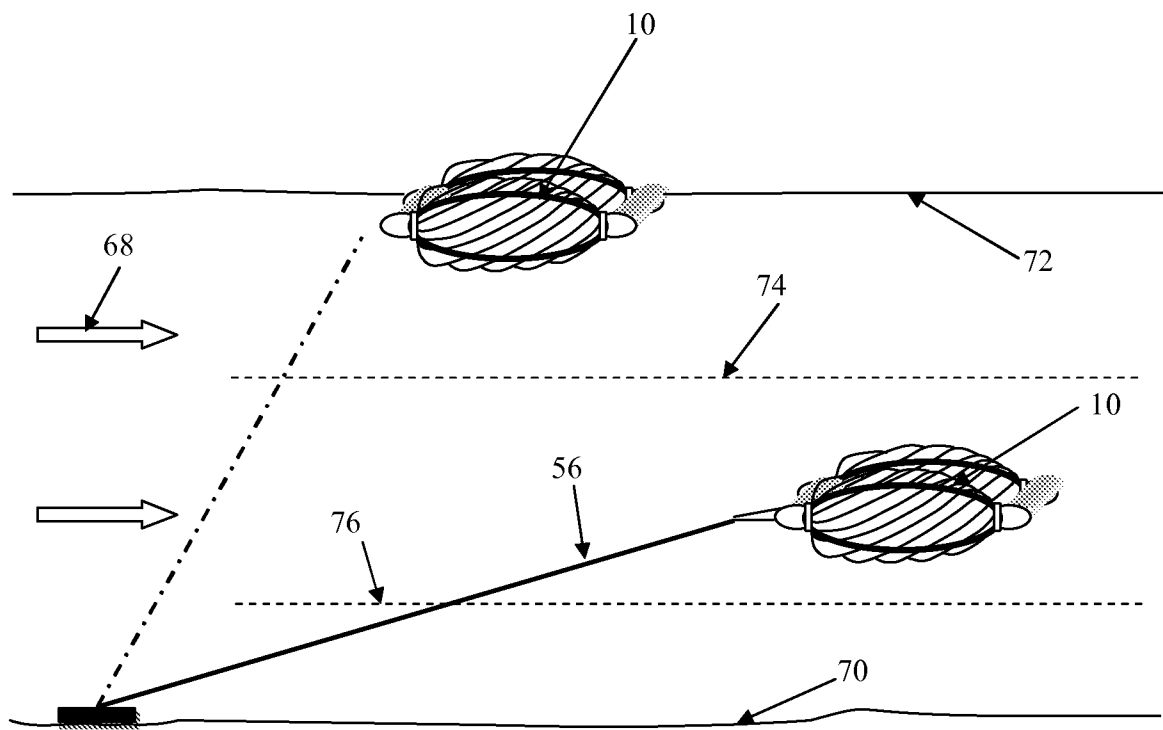


Figure 6

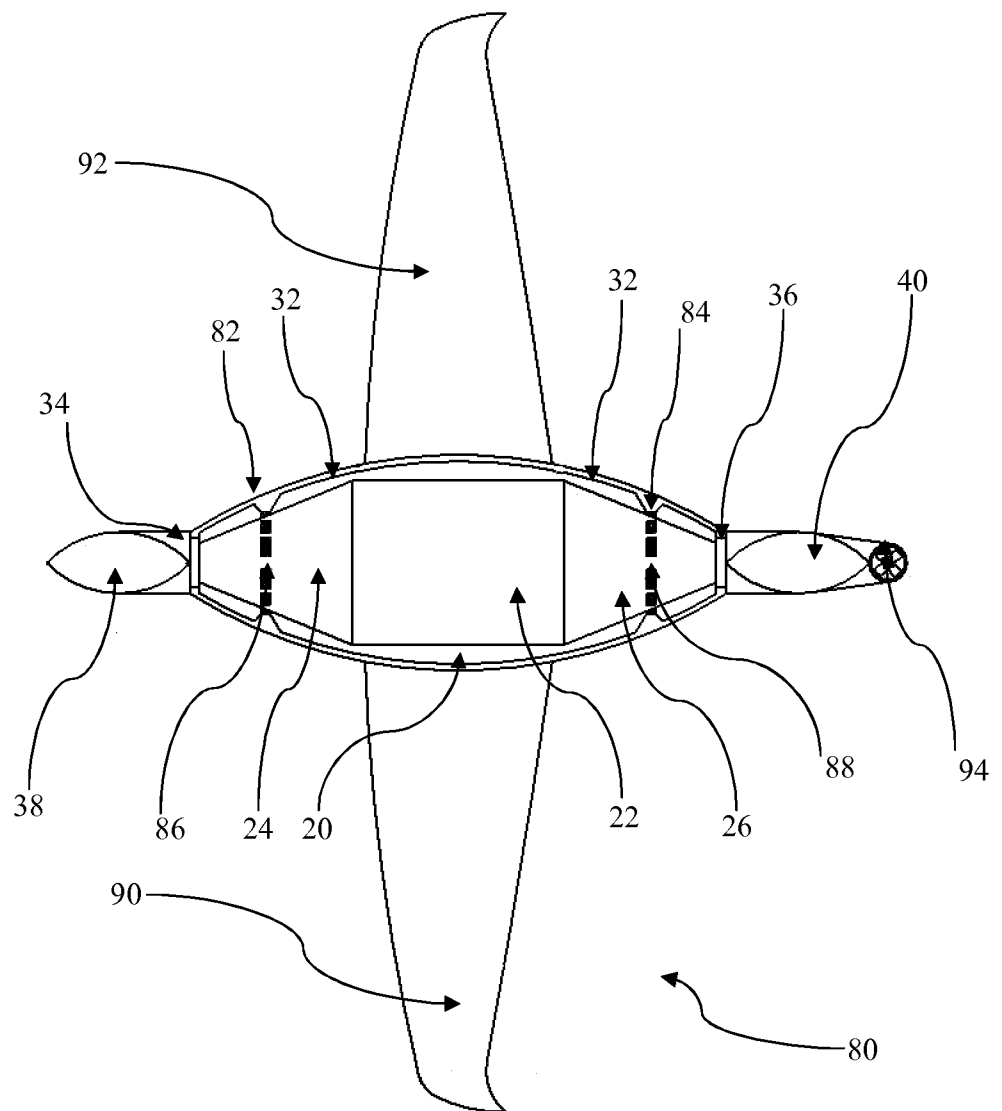


Figure 7

