TITLE

**"A SYSTEM OF UNDERWATER POWER GENERATION"**

FIELD OF THE INVENTION

The invention relates to a system of underwater power generation. In particular, although not exclusively, the invention relates to a system of converting the kinetic energy of moving water to electrical energy.

BACKGROUND TO THE INVENTION

Clean power generation has become a major concern due to the effects of global warming. Renewable clean power generation has been developed using solar cells, wind turbines and wave turbines. However, an effective renewable power generation system has yet to be developed using ocean currents.

US Patent No. 4,383,182 discloses an apparatus for generating power from ocean currents. The apparatus is winged and is anchored to the ocean floor. A number of propellers are attached to the wing and are rotated by the ocean current. The rotation of the propellers causes rotation of a generator to generate electricity. The problem with this apparatus is that the apparatus is not easily moved to cater for changes in the direction of ocean currents. Further, the generation of energy is dependant upon the size and number of propellers to catch a specific area of current flow.

US Patent No. 4,163,904 discloses an underwater turbine plant for generating electrical power using ocean currents. The turbine is driven by the flow of the water current across the blades of the turbine. Again, the level of electricity generated is proportional to the area of water that the turbine plant is able to capture.

US Patent No. 4,335,319 discloses a hydroelectric power apparatus that includes a powerhouse containing a power generator above the powerhouse located above the surface of the water. A hydraulic turbine is lowered from the powerhouse when the ocean currents are sufficient to drive the turbine. The disadvantage with this apparatus is that power is required to extend and retract the turbine. Further, the ocean current area that is utilised is equivalent to the inlet area of the turbine.

US Patent No. 5,440,176 discloses a hydroelectric power plant similar to that of US Patent No. 4,335,319 in that a series of turbines are extended and retracted dependant upon the velocity of the ocean currents. Similar disadvantages exist with the power plant disclosed in US Patent No. 5,440,176 as with the apparatus disclosed in US Patent No. 4,335,319.

US Patent No. 6,109,863 discloses a fully submersible apparatus for generating electricity. The apparatus includes a buoyant structure having a motor mounted thereto. A series of vanes are connected to the motor. The vanes are rotated by the ocean current to cause electricity to be generated. A disadvantage with this apparatus is that the generation of electricity is dependant upon the area of current that the vanes are able to capture.

US Patent No. 4,313,059 discloses a system for generating electricity from ocean currents. The system uses two drags that are connected to opposite ends of a cable. The middle of the cable is wrapped around a generator. The drags are lowered into the ocean and moved from a drag position to a non-drag position to reciprocate movement of the cable. The disadvantage with this system is that the generator must be able to generate energy when rotated in both directions. Further, the energy supply is not constant as the generator is constantly changing directions.

GB Patent Application 2,214,239A discloses an apparatus for harnessing power from natural fluid flows. The apparatus includes a continuous belt having a number of vanes. The continuous belt encircles a pair of cylinders that are operatively connected to drive a generator. The continuous belt is orientated so that water flow across the vanes to drive the belt and hence rotate the cylinders. The problem with this apparatus is that water flows through a front set of vanes and then through a rear set of vanes on the continuous belt. This creates water turbulence in water that passes through the rear set of vanes and hence efficiency of the apparatus is reduced.

## OBJECT OF THE INVENTION

It is an object of the invention to overcome or alleviate at least one or more of the above disadvantages or provide the consumer with a useful or commercial choice.

## DISCLOSURE OF THE INVENTION

In one form, although it need not be the only or indeed the broadest form, the invention resides in an underwater power generation system comprising:

at least one continuous track lying substantially in a plane;

a plurality of carriages that are movable around the track;

a plurality of foils mounted on the carriages, the foils adapted to drive the carriages around the track in response to water current flowing in a direction that is substantially perpendicular to the plane;

at least one line member comprising a continuous belt connected to the carriages;

at least one power take-off including two pulleys, the belt extending around the two pulleys and operatively connecting the power take-off to the carriages;

wherein movement of the carriages around the track drives the power take-off.

The power take-off may be operatively connected to a pump or generator or the like device.

Further features of the present invention will become apparent from the following detailed description.

## BRIEF DESCRIPTION OF THE DRAWINGS

To assist in understanding the invention and to enable a person skilled in the art to put the invention into practical, an embodiment of the invention will be described by way of example only with reference to the accompanying drawings, wherein:

FIG. 1 shows a top view of an underwater power generation system according to a first embodiment of the present invention;

FIG. 2 shows front view of the underwater power generation system of FIG. 1;

FIG. 3 shows a side sectional view of the underwater power generation system of FIG. 1;

FIG. 4 shows a side sectional view of the underwater power generation system of FIG. 1;

FIG. 5 shows a top view of a track shown in FIG. 1;

FIG. 6 shows a cross-sectional view of the track along the line A-A;

FIG. 7 shows a cross-sectional view of the track along the line B-B;

FIG. 8 shows a top view of a wing reinforcement plate and a connection arm;

FIG. 9 shows a front view of the wing reinforcement plate and a connection arm shown in FIG. 8;

FIG. 10 shows a side view of the connection arm of FIG. 8;

FIG. 11 shows a front view of a foil carriage assembly;

FIG. 12 shows a top view of the foil carriage assembly of FIG. 11;

FIG. 13 shows a side view of the foil carriage assembly of FIG. 11;

FIG. 14 shows a bottom view of the foil carriage assembly of FIG. 11;

FIG. 15 shows a front detailed view of the power take-off of the underwater power generation system;

FIG. 16 shows a detailed sectional view of the power take-off of the underwater power generation system;

FIG. 17 shows a detailed side section view of the underwater power generation system;

FIG. 18 shows a top view of an underwater power generation system according to a second embodiment of the present invention;

FIG. 19 shows front view of two drive units forming part of the underwater power generation system of FIG. 18;

FIG. 20 shows a side view of the underwater power generation system of FIG. 18;

FIG. 21 shows a top sectional view of the underwater power generation;

FIG. 22 shows a side sectional view of the underwater power generation system of FIG. 18;

FIG. 23 is a perspective view of a foil carriage assembly with foil mounted to a track;

FIG. 24 is a further perspective view of a foil carriage assembly with foil mounted to a track;

FIG. 25 a front view of a foil carriage assembly with foil mounted to a track;

FIG. 26 a rear view of a foil carriage assembly with foil mounted to a track;

FIG. 27 is a top sectional view of a foil carriage assembly mounted to a track according to FIG. 25;

FIG. 28 is a side sectional view of a foil carriage assembly mounted to a track according to FIG. 25;

FIG. 29 is a top view of an anchored power generation system of FIG. 18;

FIG. 30 is a side view of the anchored power generation system of FIG. 18;

FIG. 31 is a sectional side view of a cable;

FIG. 32 is a top view of an anchored power generation system with funnel;

FIG. 33 is a side view of the anchored power generation system with funnel; and

FIG. 34 is a front view of an anchored power generation system with funnel.

## DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 to 4 show an underwater power generation system 10 that uses water currents to produce electricity. The underwater power generation system 10 includes a frame 20, a track 30, a plurality of foils 40 and a power take-off 50.

The frame 20 is formed from a main cylindrical body 21 with two arcuate attachment arms 22. Main cylindrical body 21 is hollow and has a centre fin 23 that extends rearwardly from the main cylindrical body 21. Side fins 24 are located at the sides of the main cylindrical body 21.

The arcuate arms 22 are used to hold the underwater power generation system 10. Cables (not shown) are attached to ends of each of the arcuate arms 22 and are anchored to an ocean or river floor to hold the underwater power generation system in position. Alternatively, the cables are mounted to a bridge, boat, or the like structure.

Track support members 25 are attached and extend outwardly from the main cylindrical body 21. The track support members 25 are used to mount the track 30. Each track support member 25 is formed from a track arm 26 and a track cradle 27, details of which are shown in FIG. 17. Two bolt holes 28 are located through the cradle to attach the track to the cradle 27.

The track 30, shown in more detail in FIGS. 5 to 7, is oval in shape. The track 30 is formed from two side track plates 31, a bottom track plate 32 and two L-shaped joining plates 33. The track 30, in transverse cross-section, is a rectangular-shaped channel.

Each of the foils 40 is formed from two wings 41, shown in FIG. 17, and a connection arm 42. The two wings 41 are rearwardly splayed with respect to each other and are inclined downwardly with respect to the connection arm 42. The wings 41 are formed from fibre-glass and are of a tear-drop shape when viewed in transverse cross-section.

Each wing has a wing reinforcement plate 43, shown in FIGS. 8 and 9, that extends through the centre of the wing 41. The foil connection arm 42, shown in FIGS. 8, 9 and 10, is formed from a foil connection 44 plate and two inclined connection wing plates 45. The connection wing plates 45 are used to mount respective reinforcement plates 45. Fibreglass is moulded around the reinforcement plates 43, connection wing plates 45 and the top of the foil connection plate 44 to produce the foil and associated wings. A series of holes 46 are located through the foil connection plate 44. The holes 46 are used to mount the foil at a desired angle with respect to foil carriage assembly 60.

The foil carriage assembly 60, shown in detail in FIGS. 11 to 14, is formed from a chain support member 70, two top wheel assemblies 80 and two bottom wheel assemblies 90. The chain support member 70 is formed from a C-shaped channel. A carriage connection plate 71 is attached to and extends upwardly from the chain support member 70.

Each of the top wheel assemblies 80 is formed from a top shaft 81 having two top wheels 82 mounted for rotation adjacent opposite ends of the top shaft 81. Each of the top wheels 82 has a wheel channel 83 located within the top wheel. Washers 84 are located between the top wheels 82 and the top shaft 81. The carriage connection plate 71 is used to mount each top shaft. Each top shaft

is pivotally mounted to the carriage connection plate 71 via an attachment pin 85.

Each of the bottom wheel assemblies 90 are formed from a bottom shaft 91 having a bottom wheel 92 mounted for rotation adjacent the end of the bottom shaft. The bottom wheel 92 is a flat wheel. The chain support member 70 is used to mount the bottom shaft 92. Washers 93 are located between the bottom wheels 92 and the bottom shaft 91, and the bottom shaft 92 and the chain support member 70.

A chain mounting member 73 is connected to the chain support member 70. The chain support member is connected to a drive chain 74. The drive chain 74 extends the periphery of the track 30.

In use, the wheel channels of the top wheels are placed on top of the side track plates 31 to allow the foil carriage assembly 60 to run along the top of the channel 30. The bottom wheels 92 run smoothly along the inside of the channel 30. The bottom wheels 92 are held within the channel by a lubricating strip 75 and prevent the top wheels from becoming derailed from the channel 30. The top shafts 81 pivot as the foil carriage assembly 60 moves around the arcuate section of the track 30. FIG. 18 shows the shafts 81 pivoting as the foil carriage assembly 60 moves around the arcuate sections of the track 30.

The power take-off 50 shown in FIGS. 15 and 16 includes a main gear 51 mounted to a main gear shaft 52. The main gear shaft 52 is mounted via the track 30 and the main cylindrical body 21. The main gear shaft 52 is mounted adjacent the middle of the arcuate section of the track. The main gear 51 engages the drive chain 74 and is driven by the drive chain 74 as the foil carriage assembly 60 moves around the track 30. The power take-off 50 also includes a bottom gear 53 which is attached to the opposite end of the main gear shaft 52 to that of the main gear 81. The bottom gear 53 is located within the centre fin 23.

A speed increase assembly 100 is located adjacent the power take-off. The speed increase assembly 100 includes a speed increase large gear 101 and a speed increase small gear 102, both of which are mounted to a speed increase shaft 103. The speed increase shaft 103 is mounted for rotation

through the main cylindrical body 21. The speed increase gears 101 and 102 are located within the centre fin 23. The speed increase small gear 102 is substantially smaller than the bottom gear 53. The speed increase small gear 102 is connected to the bottom gear via a chain 104. The speed increase large gear 101 is the same size as the bottom gear.

Two pump assemblies 110 and 120 are located adjacent the speed increase assembly 100. Each pump assembly includes a respective pump gear 111 and 121 mounted to a respective pump shaft 112 and 122. Each respective pump shaft 112 and 122 is connected to and drives pumps 114 and 124. The first pump assembly 110 also includes a transfer gear 113 that is mounted to the pump shaft 112. The speed increase large gear 101 is connected to the first pump gear 111 via a chain 115. The transfer gear 113 is connected to the second pump gear 121 via a chain 125. Each pump is connected to a turbine (not shown).

The foils 40 are attached to the foil carriage assembly 60 using two foil attachment plates 47. The foils attachment plates 47 are connected to the foil connection plate 44 and the carriage connection plate 71. The angle of the foil 40 is able to be adjusted using the series of holes located in the foil connection plate 44. The angle of the foils is determined by numerous elements such as the velocity of the water and the direction of the water current.

In use, the underwater power generation system 10 is located within a water current so that the track 30 is substantially perpendicular to the water current. The water current acts on the foils 40 and cause the foils to drive the drive chain 74 around the track 30. The drive chain 74 in turn drives the main gear 51, main shaft 52 and bottom gear 53. The bottom gear 53 drives the speed increase large gear 101, speed increase small gear 102 and speed increase shaft 103. The rotational velocity of the speed increase large gear 101, speed increase small gear 102 and speed increase shaft 103 is substantially larger than that of the main gear 51, main shaft 52 and bottom gear 53.

The speed increase large gear 101 drives the first pump gear 111, first pump shaft 112 and transfer gear 113. The rotational velocity of the first pump gear 111, transfer gear 113 and first pump shaft 112 is substantially larger than that of the speed increase large gear 101, speed increase small gear 102

and speed increase shaft 103. The transfer gear drives the second pump gear 121 and second pump shaft 122. The pump shafts 112 and 122 drive their respective pumps 114 and 124 which provided pressurised water to drive a turbine to create electricity.

The side fins 24 can be adjusted so that the rotation of the track 30 by the foils 40 does not cause destabilisation.

FIGS. 18 to 21 show an underwater power generation system 210 that uses water currents to produce electricity and also desalinate water. The underwater power generation system 210 includes a frame 220, a track 230, a plurality of foils 240 and power take-off 250.

The frame 220 is similar to that shown in the previous embodiment and is formed from a main body 221 having two arcuate attachment arms 222. Main body 221 is hollow and is shaped to reduce the drag cause by water flowing past the body. Side fins 224 are located at the sides of the main body 221. Tension cables 228 extend from the arcuate attachment arms 222 to the side fins 224 and the main body 221 to provide additional support. A nose 229 extends outwardly from the main body 221 to direct the water current over the foils 240.

Track support members 225 are attached and extend outwardly from the main body 221. The track support members 225 are used to mount the track 230. Each track support member 225 is formed from a track arm 226 and a track cradle 227 similar to that shown in the previous embodiment. The track 230 again is oval in shape. The track 230 is formed from a single rotated T-shaped metal which is attached to the track cradle 227.

Each of the foils 240 is formed as described in the previous embodiment. Each foil 240 has two wings 241 and a connection arm 242. The connection arm 242 has a foil connection 244 plate.

A foil carriage assembly 260, shown in detail in FIGS. 23 to 27, is formed from a foil carriage housing 270, two top wheel assemblies 280 and two bottom wheel assemblies 290. The foil carriage housing 270 is formed from a C-shaped channel. Foil attachment plates 247 extend upwardly from the foil carriage housing. A drag reducing wing 271 covers a portion of the housing and reduces drag when the carriage passes through the water.

Each of the top wheel assemblies 280 is formed from a top shaft 281, a top wheel 282 and a top wheel pivot arm 283. The top wheel pivot arm 283 is L-shaped and is attached to the foil carriage housing 270 via a top wheel pivot arm pin 284. The top wheel pivot arm pin 284 allows the top wheel pivot arm 283 to pivot with respect to the foil carriage housing 270. The top shaft 282 extends outwardly from the top wheel pivot arm 283 and rotatably mounts the top wheel 282. Each of the top wheels 282 has a wheel channel 285 located within the top wheel 282.

Each of the bottom wheel assemblies 290 is formed from a bottom shaft 291, a bottom wheel 292 and a bottom wheel pivot arm 293. The bottom wheel pivot arm 293 is L-shaped and is attached to the foil carriage housing 270 via a bottom wheel pivot arm pin 294. The bottom wheel pivot arm pin 294 allows the bottom wheel pivot arm 293 to pivot with respect to the foil carriage housing 270. The bottom shaft 292 extends outwardly from the bottom wheel pivot arm 293 and rotatably mounts the bottom wheel 292. Each of the bottom wheels 292 has a wheel channel 295 located within the bottom wheel 292.

In use, the wheel channels 285 of the top wheels 282 are placed on top of the track 230 and the wheel channels 295 of the bottom wheels 292 are placed on the bottom of the track to allow the foil carriage assembly 260 to run along the top of the track 230. The top wheel pivot arm pins 284 and the bottom wheel pivot arm pins 294 pivot as the foil carriage assembly 260 moves around the arcuate section of the track 230. As in the previous embodiment, water acts on the foils 240 to drive the carriages around the track 230.

The power take-off 250 includes two main pulleys 251 which are mounted to respective main pulley shafts 252. A flat tooth belt extends 253 around the two main pulleys 251. The main pulley shafts 252 are mounted via the main body 221. Link arms 254 are attached to the flat tooth belt 253 and to the carriage housing 270. The main pulleys 251 are driven by the flat tooth belt 253 which in turn is driven by the foil carriage assemblies 260 via the link arms 254.

The main pulley shafts 252 are connected to respective secondary drive trains 300. Each secondary drive train drives an alternator shaft 301 that is connected to an alternator 310. A heat exchanger 311 is associated with the

alternator 310 to ensure that overheating does not occur. The alternators 310 are connected to AC to DC inverters 330. The inverters 330 allow power to be transmitted efficiently into, for example, a power grid.

A sea water pump drive 320 is connected to the alternator shaft 302. The sea water pump drive 320 drives a sea water pump shaft that is connected to and drives a sea water pump 321. Salt water is pumped by the sea water pump through a desalinator (not shown) to provide fresh water.

The sea water pump 340 is also connected to a set of accumulators 350 located adjacent the side fins 224. The accumulators are used to pivot the side fins 224 via respective hydraulic ram (not shown). The accumulators 350 enable the side fins 224 to be adjacent without the need to operate the sea water pump 340 for small movements.

An air compressor and electric motor 360 is provided to adjust ballast within the main body 221. Blow valves 361 allow water to flow into and out of the main body 221 by adjusting the amount of air located within the main body 221 via the air compressor. A manifold 362 is used to control the flow of air provided by the air compressor to various sections of the main body 221.

Speed sensors 370 are at various locations on frame 220. The speed sensors 370 provide information on the speed of the water current. A PLC 380 provides a control strategy to control the flow of water into and out of the main body 221. Further, the PLC 380 controls the rotation of the side fins 224 via the accumulators 350.

In order to secure the frame 220 within a water current, cables are attached to ends of each of the arcuate arms 222 via anchor points as shown in FIGS. 29 and 30. The cables 390 are also anchored via an anchor 400 to an ocean or river floor to hold the underwater power generation system 210 in position. There are three types of cables. There is a lead cable 391 that extends from the anchor point, main cables 392 that carry a majority of the load and debris deflector cables 393 that assist in preventing large debris from hitting the foils 240 and damaging the underwater power generation system 210.

FIG. 31 shows a sectional view of the cables 390. Each of the cables 390 includes a core 394 that carries the load and cable foil 395 to reduce water drag. The cable foil 305 is able to rotate with respect to the core 394 so that

the cable foil is able to find a position of least drag with respect to the core 394 in water current.

An adjustment balloon 410 is attached at an end of the lead cable 392. The adjustment balloon 410 is attached to a snorkel 420 to enable air to be released from the balloon 410. Air is pumped into the balloon 410 from the air compressor 360 to inflate the balloon 410. Again, the PLC 380 controller controls the amount of air located within the balloon.

A GPS telemetry system 430, located adjacent the end of the snorkel 420, transmits operational details of the underwater power generation system 210 such as speed of the water current, the position of the frame 220 with respect to the water current and the speed of the foils to a land based operator. Further, the GPS telemetry receives operational instructions such as moving the frame 220 left or right and/or adjusting the height and turning the alternators and/or sea water pump on or off sent by a land based operator.

In use, the underwater power generation system 210 is located within a water current so that the track 230 is substantially perpendicular to the water current. The water current acts on the foils 240 and cause the foils to move around the track 230 and consequently drive the flat tooth belt 253. The flat tooth belt 253 in turn drives the main pulleys 251 and hence the alternators 310 and sea water pump 320.

Once the sea water pump 340 has commenced operation the accumulators 350 are filled to capacity so that the side fins 224 can be moved as desired. The PLC 380 receives feedback from the speed sensors and uses its control strategy to adjust the position of the frame to an optimum position within the water current. The position of the frame is changed by moving the side fins 224, adjusting the amount of water within the main body 221 and adjusting the amount of air within the balloon.

FIGS. 32 to 34 show a funnel 440 attached to an underwater power generation system 210. The funnel 440 is tapered with a larger end of the funnel 440 located furthest away from the frame 220 and a smaller end of the funnel located adjacent the foils 240. Water, as it passes through the funnel, increases in velocity and hence, in turn, the velocities of the foils 240 are also increased. This increases the output of the alternators 330 and the sea water pump 340.

The underwater power generation systems detailed above are environmentally friendly as they use natural water current to create electricity without the creation of any pollution. The electricity produced is a renewal energy source as water currents such as those found in rivers, oceans and created by the tides, occur frequently.

The underwater power generation systems all have foils that rotate in substantially in a single plane. The underwater power generation system is positioned so that the plane that the foils are located is perpendicular to the flow of the water current. Hence, less turbulence is created as the foils are propelled by the water at the same instant resulting in increased efficiency. A further advantage of the pathway being perpendicular to the flow of water current is that the foils always provide a drive to the line member as the pass along the entire pathway.

It should be appreciated that various changes and modification may be made to the embodiment described without departing from the spirit or scope of the invention.

CLAIMS

1. An underwater power generation system comprising:

at least one continuous track lying substantially in a plane;

a plurality of carriages that are movable around the track;

a plurality of foils mounted on the carriages, the foils adapted to drive the carriages around the track in response to water current flowing in a direction that is substantially perpendicular to the plane;

at least one line member comprising a continuous belt connected to the carriages; and

at least one power take-off including two pulleys, the belt extending around the two pulleys and operatively connecting the power take-off to the carriages;

wherein movement of the carriages around the track drives the power take-off.

2. The underwater power generation system of claim 1 wherein the carriages are each connected to the belt via a link arm.

3. The underwater power generation system of any one of the preceding claims wherein the track is T-shaped in transverse cross-section.

4. The underwater power generation system of any one of the preceding claims wherein each carriage includes a drag reducing wing covering a portion of the carriage.

5. The underwater power generation system of any one of the preceding claims wherein the power take-off is operatively connected to a pump or generator.

6. The underwater power generation system of any one of the preceding claims wherein the power take-off is operatively connected to a generator.

7. The underwater power generation system of any one of the preceding claims wherein the track is mounted to a frame.

8. The underwater power generation system of claim 7 wherein the frame includes a main cylindrical body, two arcuate arms and track supports.

9. The underwater power generation system of claim 8 wherein each track support includes a track arm and a track cradle.

10. The underwater power generation system of claim 8 or 9 further including an air compressor and electric motor to adjust ballast within the main body.

11. The underwater power generation system of any one of the preceding claims wherein each foil is formed from two wings and a connection arm.

12. The underwater power generation system of any one of the preceding claims wherein each carriage is formed from a housing, at least one top wheel assembly and at least one bottom wheel assembly.

13. The underwater power generation system of any one of the preceding claims wherein each foil is pivotally mounted to its respective carriage.