



PATENT SPECIFICATION

(11) S86343

(21) Application No. S2011/0397

(22) Date of Filing of Application: 07/09/2011

(45) Specification Published: 29 January 2014

(51) Int. Cl. (2011)
F03B 13/00
E02B 9/00

(54) Title: A turbine, and a method for operating a turbine

(72) Inventor: DAVID EDMUND BAIRD

(73) Patent Granted to: TIDAL ENERGY LIMITED, An Irish company, 8 Quay street Westport Co Mayo, Ireland

"A turbine, and a method for operating a turbine"

The present invention relates to a turbine, and to a method for operating a turbine.

5 According to the invention there is provided a turbine comprising a rotor defining a main rotational axis about which the rotor is rotatable, a plurality of blades spaced equidistantly apart circumferentially around the main rotational axis, the rotor being adapted for locating in a stream of flowing water so that each blade passes twice
10 during each revolution of the rotor, and each blade is longitudinally inclined relative to the surface plane of the stream of flowing water at an angle greater than zero and less than 90° when the blade is in water substantially midway in its travel between the two passes through the air/water interface.

15 In one embodiment of the invention the rotor is adapted for locating in a stream of flowing water with each blade longitudinally inclined in a generally upward direction and in the direction of the stream of flowing water when the blade is in water substantially midway in its travel between the two passes through the air/water interface.

20

In another embodiment of the invention the rotor is adapted for locating in the stream of flowing water with a vertical plane containing the main rotational axis extending relative to the general direction of flow of the stream of flowing water at a yaw angle in the range of 0° to $\pm 45^\circ$.

25

In another embodiment of the invention the angle of longitudinal inclination of each blade relative to the surface plane of the stream of flowing water when the blade is in water substantially midway in its travel between the two passes through the air/water interface lies in the range of 10° to 80° , and preferably, lies in the range of 30° to
30 60° , and ideally, the angle of longitudinal inclination of each blade relative to the surface plane of the stream of flowing water when the blade is in water substantially midway in its travel between the two passes through the air/water interface is

approximately 45°.

In another embodiment of the invention each blade comprises an elongated blade, and preferably, each blade comprises a straight elongated blade. Advantageously,
5 each blade is spaced apart radially from the main rotational axis of the rotor, and preferably, the blades are equi-spaced apart circumferentially around the main rotational axis.

Preferably, each blade extends generally longitudinally relative to the main rotational
10 axis, and advantageously, each blade extends substantially parallel to the main rotational axis.

In one embodiment of the invention the blades are carried on respective carrier arms, which preferably extend radially from a main shaft which defines the main
15 rotational axis of the rotor.

In one embodiment of the invention the blades are mounted on the respective carrier shafts at a negative pitch angle. Preferably, the negative pitch angle is in the range of 1° to 15°, and advantageously, the negative pitch angle is in the range of 1° to 8°,
20 and ideally, the negative pitch angle is approximately 4°.

In another embodiment of the invention each blade is of hydrodynamic-lift generating cross-section.

25 In another embodiment of the invention a support means is provided for supporting the rotor with the rotor located in the stream of flowing water, and preferably, the support means comprises a floatable structure, which advantageously, comprises a pontoon.

30 In another embodiment of the invention, a housing is mounted on the support means, the housing defining a hollow interior region, and a means for pressurising the hollow interior region thereof with a gas is provided. The support means and the housing being adapted to be immersed in the stream of flowing water so that a

gas/water interface is defined in the hollow interior region through which each blade passes twice during each revolution of the rotor.

5 In another embodiment of the invention the turbine is adapted to power an electrical generator.

The invention also provides a turbine comprising a support means, a rotor defining a main rotational axis about which the rotor is rotatable, a plurality of blades spaced apart circumferentially around the main rotational axis, the rotor being rotatably
10 mounted in the support means about the main rotational axis and being adapted for locating in a stream of flowing water so that each blade passes twice through an air/water interface adjacent the surface of the stream of flowing water during each revolution of the rotor, and each blade is longitudinally inclined relative to the surface plane of the stream of flowing water at an angle greater than zero and less than 90°
15 when the blade is in water substantially midway in its travel between the two passes through the air/water interface.

Further, the invention comprises a rotor for the turbine according to the invention.

20 The invention also provides a method for operating a turbine comprising a rotor defining a main rotational axis about which the rotor is rotatable, and a plurality of blades spaced apart circumferentially around the main rotational axis, the method comprising locating the rotor in a stream of flowing water so that each blade passes twice through an air/water interface adjacent the surface of the stream of flowing
25 water during each revolution of the rotor, and so that each blade is longitudinally inclined relative to the surface plane of the stream of flowing water at an angle greater than zero and less than 90° when the blade is in water substantially midway in its travel between the two passes through the air/water interface.

30 The invention will be more clearly understood from the following description of some embodiments thereof, which are given by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a side elevational view of a portion of a turbine according to the invention,

Fig. 2 is an end view of the portion of the turbine of Fig. 1,

Fig. 3 is an axial end view of a detail of the turbine of Fig. 1,

Fig. 4 is a side elevational view of a turbine according to another embodiment of the invention, and

Fig. 5 is an end view of the turbine of Fig. 4.

Referring to the drawings, and initially to Figs. 1 to 3 thereof, there is illustrated a turbine according to the invention, indicated generally by the reference numeral 1, which is suitable for converting kinetic energy in a stream of flowing water 2 to rotational energy for driving, for example, an electrical generator (not shown). The stream of flowing water 2 may be any stream of flowing water, for example, a tidal flow in an ocean, a flow of water in a river, stream or the like, or any other stream of flowing water. The turbine 1 comprises a rotor 4 rigidly mounted on a main shaft 5 which is rotatably mounted in a tubular housing 7. The tubular housing 7 is carried on a floatable support means, which in this embodiment of the invention is a pontoon (not shown) which floats on the surface 9 of the stream of flowing water 2. The stream of flowing water 2 flows in the direction of the arrows A. The main shaft 5 and the rotor 4 define a main rotational axis 10 about which the main shaft 5 and the rotor 4 are rotatable. Bearings 12 in respective opposite ends of the tubular housing 7 rotatably carry the main shaft 5 in the tubular housing 7 about the main rotational axis 10.

The rotor 4 comprises a plurality, in this embodiment of the invention six, high aspect ratio blades 15 which are carried on corresponding carrier arms 17 which extend radially from the main shaft 5. The blades 15 are elongated straight blades which extend parallel to the main rotational axis 10, and are equi-spaced apart circumferentially around the main rotational axis 10. In this embodiment of the

invention the blades 15 are of aerofoil cross-section, and are configured at a negative pitch angle otherwise known as the angle of attack of approximately 4° relative to the corresponding carrier arms 17.

5 The tubular housing 7 is mounted on the pontoon (not shown) so that the main rotational axis 10 extends at an angle α of approximately 45° to the surface plane 9 of the stream of flowing water 2 and with a vertical plane containing the main rotational axis 10 extending substantially parallel with the general direction of flow of the stream of flowing water 2.

10

The pontoon (not shown) also mounts the tubular housing 7 so that each blade 15 passes through the air/water interface adjacent the surface plane 9 twice on each revolution of the rotor 4. In other words, each blade 15 during each revolution of the rotor 4 passes from the stream of flowing water 2 through the surface plane 9 of the stream of flowing water 2 into air above the stream of flowing water 2, and then returns through the surface plane 9 of the stream of flowing water 2 into the stream of flowing water 2.

Each blade 15, since it extends parallel to the main rotational axis 10, is longitudinally inclined at the angle θ of approximately 45° to the surface plane 9 of the stream of flowing water 2, which is similar to the angle α , when the blade 15 is in the stream of flowing water 2 with the blade 15 substantially midway between the two passes through the air/water interface during each revolution. In other words, the blade 15a of Figs. 1, 2 and 3 which is in the stream of flowing water is the blade which is midway between its two passes through the air/water interface, and it is this blade 15a which makes the angle θ with the surface plane 9 of the stream of flowing water 2. Additionally, in this embodiment of the invention the tubular housing 7 extends from the pontoon (not shown) in a direction downwardly and towards the direction from which the stream of flowing water 2 flows, so that the blade in the stream of flowing water 2, which is midway in its travel between the two passes through the air/water interface, namely, the blade 15a in Figs. 1 to 3, inclines generally upwardly and in the general direction of the stream of flowing water 2 at the angle θ of approximately 45° .

It has been found that by mounting the rotor so that each blade passes through the air/water interface of the stream of flowing water 2 adjacent the surface 9 twice during each revolution of the rotor 4 significantly enhances the efficiency of operation of the turbine. It is believed that by passing each blade 15 through air during each revolution, the blade ventilates and thus on passing through the air/water interface into the stream of flowing water 2 brings with it air which when combined with the action of the stream of flowing water 2 on the blade 15, significantly increases the forces acting on the blade and thereby increases the efficiency of operation of the turbine. It is also believed that the ventilation of the blades aid in a reduction of cavitation, which is known to adversely affect power efficiency, and thereby by reducing cavitation, the efficiency of operation of the turbine is enhanced. Additionally, it is believed that the rotor geometry and axis orientation also results in the blades being out of the water medium, which is approximately eight hundred times denser than air, during most of the drag phase, which thus reduces the drag, and in turn improves the efficiency of the turbine. Further experimentation is required before a full explanation can be given as to why ventilating the blades 15 during rotation of the rotor 4 enhances the efficiency of operation of the turbine, and also why the orientation of the blades enhances the efficiency of operation of the turbine.

By inclining the main rotational axis 10 of the rotor 4 at the angle α of approximately 45° to the surface plane 9 of the stream of flowing water 2, it has been found that the turbine is self-starting. A full explanation as to why this should be requires further experimentation. It has also been found that by configuring the rotor 4 in the stream of flowing water with each blade when it is in the stream of flowing water midway in its travel between its two passes through the air/water interface adjacent the surface plane 9 of the stream of flowing water 2 also significantly enhances the efficiency of operation of the turbine. Why this is so has not been fully evaluated, and requires further experimentation.

In use, with the pontoon moored in the stream of flowing water, and with the main drive shaft 5 extending from the pontoon (not shown) as already described, and with

the rotor 4 located in the stream of flowing water 2 as already described, the turbine 1 is ready for use. Immediately on the rotor 4 being lowered into the stream of flowing water 2 with the blades 15 located as already described, the rotor 4 immediately commences to rotate, in one embodiment in a clockwise direction, as
5 illustrated by the arrow 16, and rapidly runs up to its normal operating speed, and thereby converts the kinetic energy in the stream of flowing water 2 to rotational energy of the main drive shaft 5. The main drive shaft 5 can be coupled mechanically to an electrical generator for generating electricity, or to any other suitable converting apparatus for converting rotational energy of the main drive shaft
10 5 to usable energy.

Referring now to Figs. 4 and 5, there is illustrated a turbine according to another embodiment of the invention, indicated generally by the reference numeral 20. The turbine 20 is substantially similar to the turbine 1, and similar components are
15 identified by the same reference numerals. The main difference between the turbine 20 and the turbine 1 is that the turbine is mounted in a dive bell type housing 23 which is carried on a support means, which in this embodiment of the invention comprises a submersible structure (not shown). The housing 23 is carried on the submersible structure (not shown) and defines a hollow interior region 24 which
20 extends over the turbine 20. The housing 23 defines a downwardly facing open mouth 26 to accommodate water from the stream of flowing water 2 into the hollow interior region 24. A means for pressurising the hollow interior region 24, in this embodiment of the invention comprises a compressor (not shown) for delivering compressed air into the hollow interior region 24 through a pipeline 25 for
25 pressurising the hollow interior 24, to in turn define the air/water interface adjacent the surface 9 of the stream of flowing water 2 within the hollow interior region 24. Otherwise, the turbine 20 and its use is similar to that already described with reference to the turbine 1. The hollow interior region 24 is maintained at an appropriate pressure in order to maintain the air/water interface adjacent to surface
30 plane 9 of the stream of flowing water 2 at an appropriate level in the hollow interior region 24 of the housing 23, so that on each revolution of the rotor 4 each blade 15 over its entire length passes twice through the air/water interface adjacent the surface plane 9 defined in the hollow interior region 24.

The turbines 1 and 20 are suitable for operating in any suitable stream of flowing water, for example, in a river, in a tidal flow or any other flow of water. The turbine 20 is particularly suitable for operating in exposed environments, for example, in the ocean, offshore, since the turbine is protected from wind and surface waves.

While the turbines have been described as being mounted on a pontoon or on a submersible structure with its main rotational axis 10 extending relative to the surface plane 9 of the stream of flowing water 2 at an angle α of approximately 45° , it is envisaged that the angle α at which the main rotational axis 10 of the rotor 4 extends relative to the surface plane 9 of the stream of flowing water 2 may be any suitable angle in the range of 10° to 80° and preferably in the range of 30° to 60° . Similarly, it is envisaged that the yaw angle of the vertical plane containing the main rotational axis 10 relative to the direction of the stream of flowing water 2 may be any suitable angle, and typically could be any angle between plus or minus 45° relative to the direction of flow of the stream of flowing water 2. It is also envisaged that the angle θ which each blade makes relative to the surface plane 9 of the stream of flowing water 2 when in the water midway in its travel between the two passes through the air/water interface may be any other suitable angle, and it is believed that the angle θ may range between 10° and 80° , but would preferably range between 30° and 60° . It is also envisaged that the blades while extending in a generally longitudinal direction relative to the main rotational axis 10 may not necessarily extend parallel to the main rotational central axis 10, and it is envisaged in certain cases that the angle θ with which each blade makes with the surface plane 9 of the stream of flowing water 2 when in the stream of flowing water midway in its travel between the two passes through the air/water interface adjacent the surface plane 9 may be achieved by having the blades extending at an angle relative to the main rotational axis 10 of the rotor 4. In which case, it is envisaged that the main rotational axis 10 of the rotor 4 could lie in a plane parallel to the surface 9 of the stream of flowing water, or could in fact lie in the plane of the surface 9 of the stream of flowing water.

Additionally, it is envisaged that while it is desirable that each blade over its entire length should pass twice through the air/water interface adjacent the surface plane 9

of the stream of flowing water 2, in certain cases, it is envisaged that the entire length of the blade need not pass through the air/water interface. In other words, the portion of the blade which does not pass through the air/water interface of the surface 9 of the stream of flowing water 2 would remain continuously immersed in the stream of flowing water.

While the turbine 20 described with reference to Figs. 4 and 5 has been described as operating in a pressurised atmosphere within the hollow interior region of the housing 23, it is envisaged that the pressurised atmosphere may be formed by any gas besides air, and could be formed by a mixture of a gas or gases and air.

The invention is not limited to the embodiments hereinbefore described which may be varied in construction and detail.

15

20

25

30

Claims

1. A turbine to convert the kinetic energy from a stream of flowing water to useful mechanical power comprising a rotor and rotor drive shaft defining a main rotational axis about which the rotor is rotatable, a plurality of hydrodynamic lift-generating blades mounted on their respective carrier shafts at negative pitch angles of approximately 4 degrees, equidistantly spaced apart circumferentially around the main rotational axis, the rotor being adapted for locating in a stream of flowing water, in a "cross-flow" orientation rather than an "axial-flow" orientation, so that each blade passes twice through an air/water interface adjacent the surface of the stream of flowing water during each revolution of the rotor, and each blade is longitudinally inclined relative to the surface plane of the stream of flowing water at an angle greater than zero degrees and less than 90^0 when the blade is in water substantially midway in its travel between the two passes through the air/water interface.
2. A method of converting kinetic energy from a stream of flowing water to useful mechanical power using the apparatus as claimed in Claim 1.
3. A turbine to convert the kinetic energy from a stream of flowing water to useful mechanical power, as claimed in claim 1, further comprising: an electrical generator coupled to the drive shaft.
4. A turbine to convert the kinetic energy from a stream of flowing water to useful mechanical power, as claimed in claim 1, further comprising: the whole turbine assembly mounted inside a submersible dive-bell type structure with an air-compressor and an air-pipeline, suitably controlled, to deliver sufficient compressed air, taken from the ambient atmosphere above the water surface, into the hollow interior region of the submersible dive-bell like structure to maintain a compressed-air to water interface level near the lower edges of the downwardly facing open mouth of the submersible dive-bell type structure, necessary to operate the turbine.

5. A turbine to convert kinetic energy to mechanical power as described herein with reference to the accompanying drawings

5

10

15

20

25

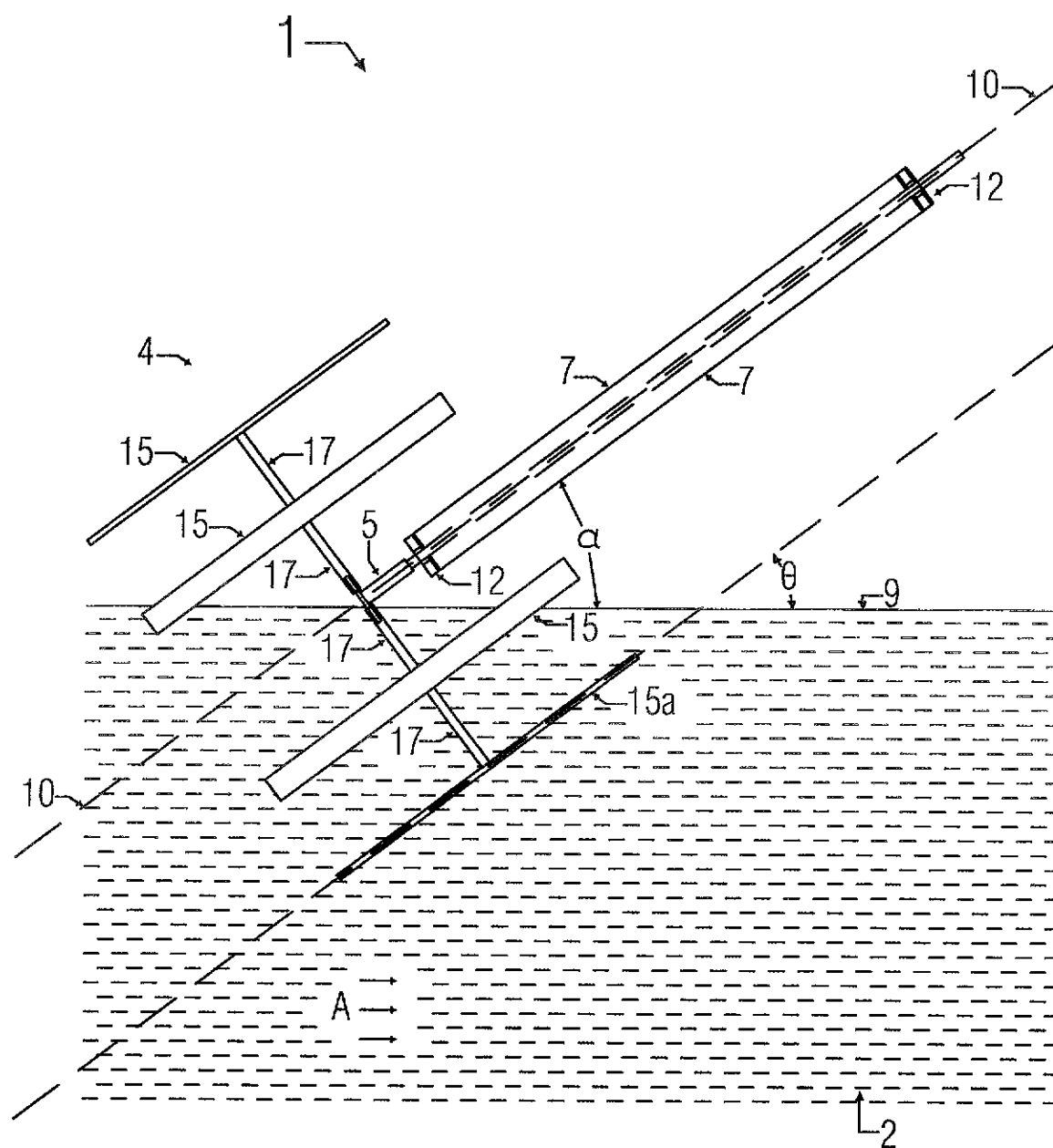


FIG 1

2/5

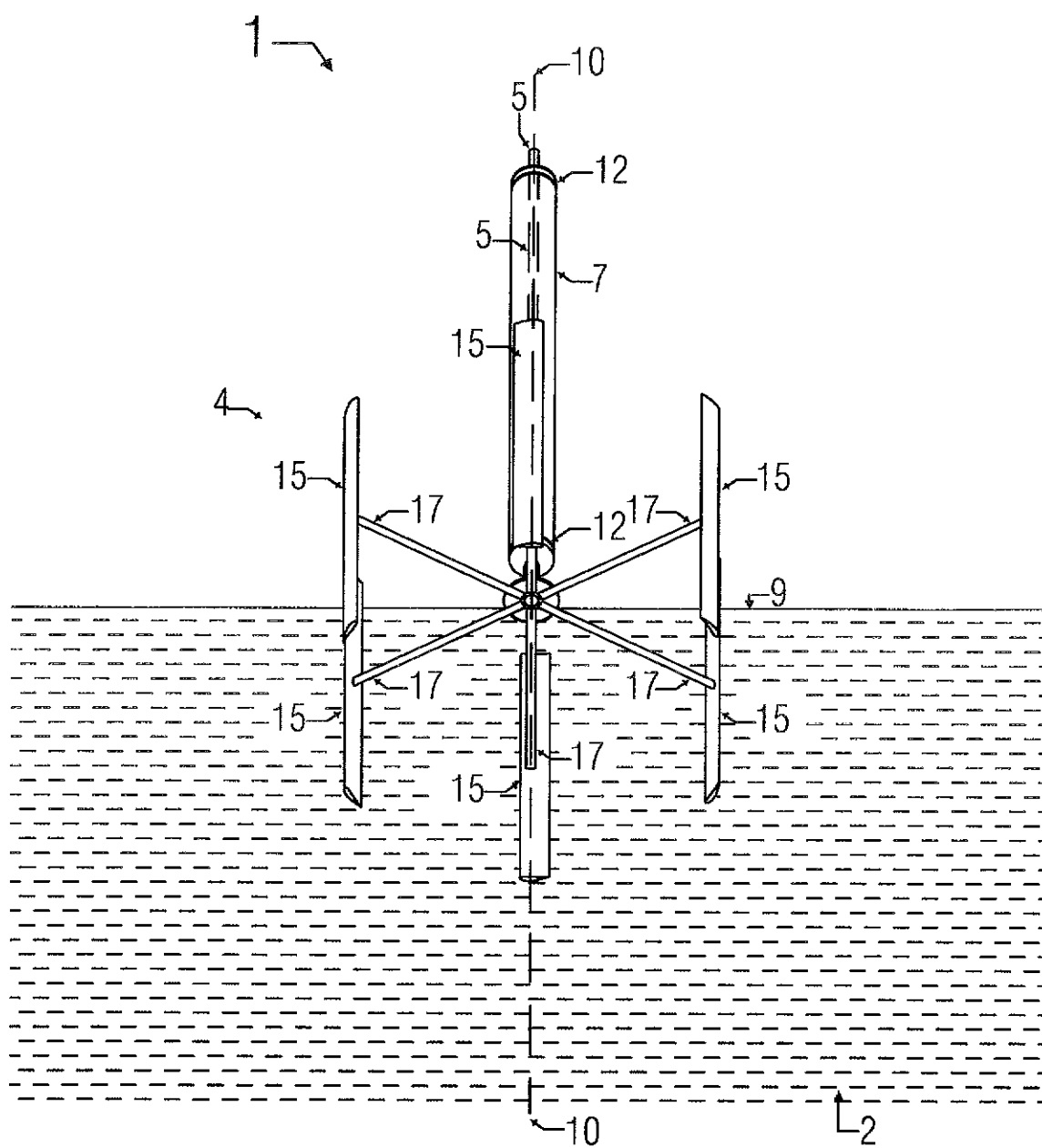


FIG 2

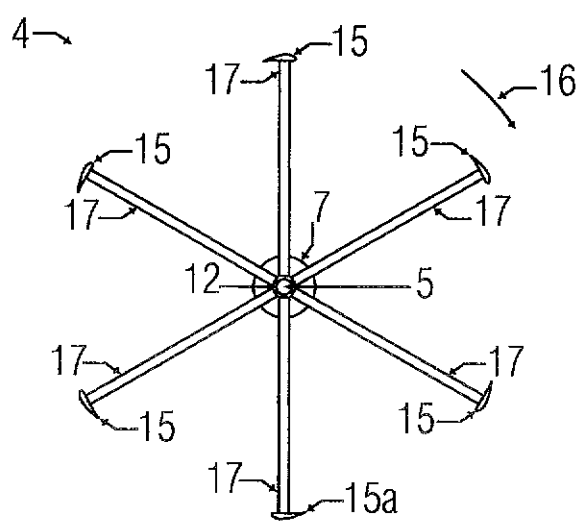


FIG 3

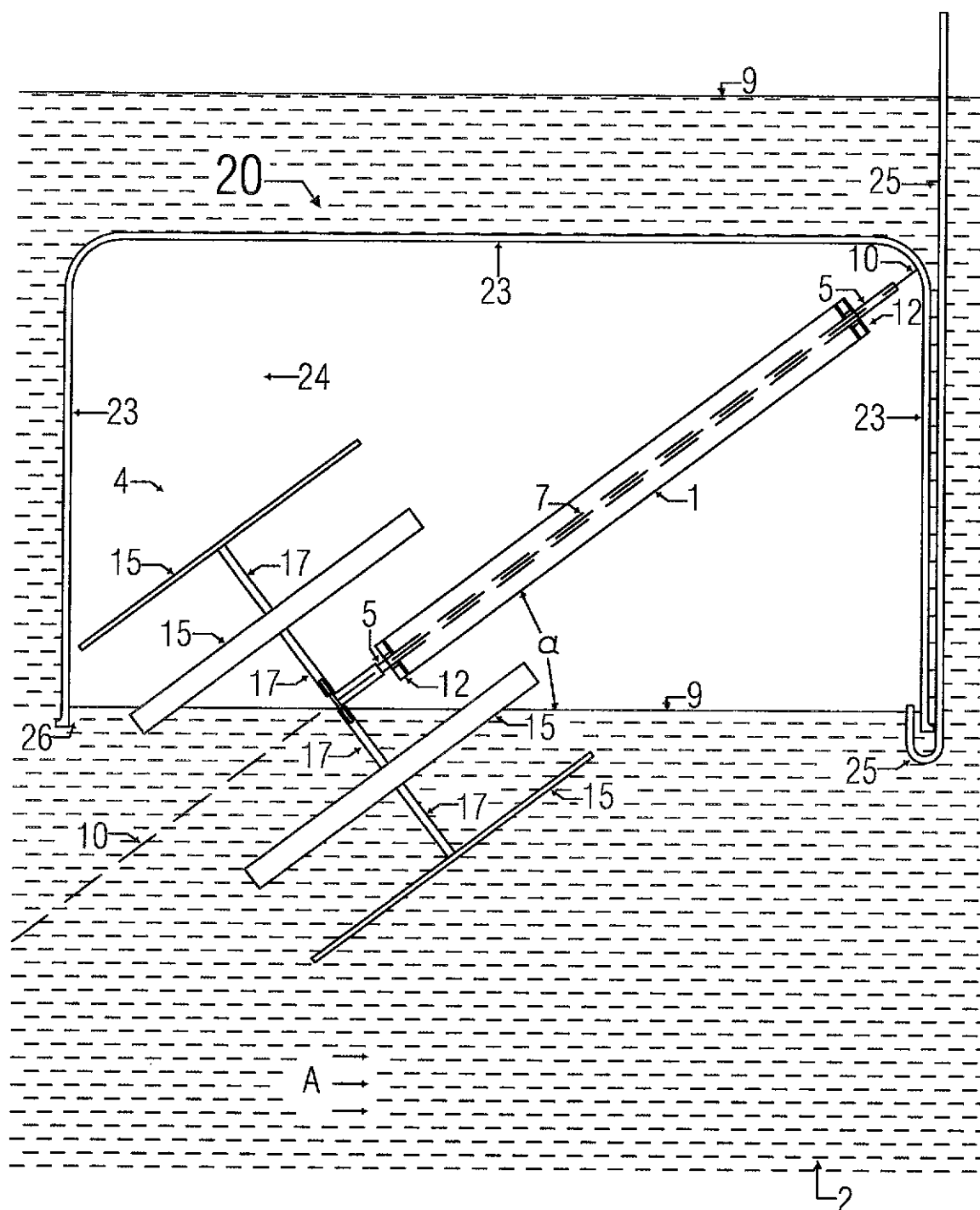


FIG 4



FIG 5