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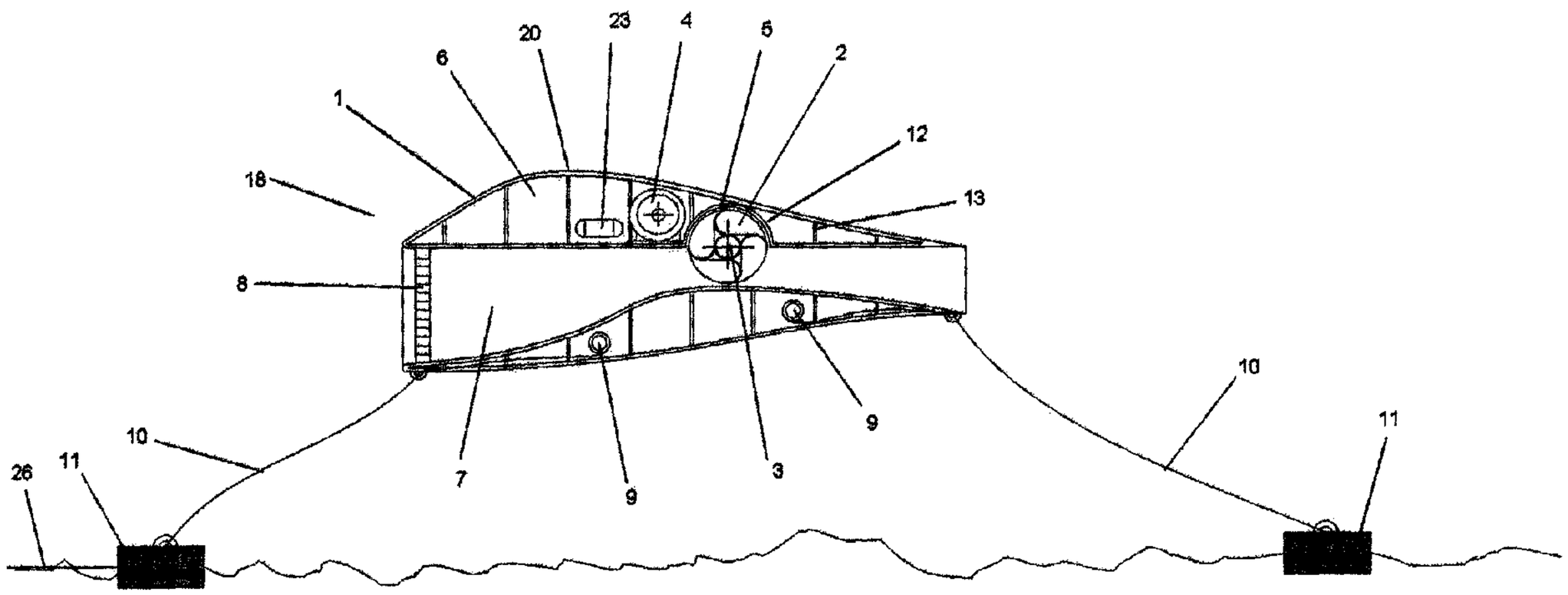
(54) Title: HYDRAULIC TURBINE FOR DEEP OCEAN CONDITIONS



(57) Abrégé/Abstract:
A submersible hydraulic turbine for generating electricity from the marine currents is disclosed. The turbine structure is fully submerged having a horizontal rotor. The rotor shaft is perpendicular to the marine current direction. The rotor is equipped with a number of blades fixed between circular discs and parallel to the turbine shaft. The marine current impinges on the turbine blades rotating the shaft. A gear multiplies the shaft speed and transmits the rotation to an electrical generator. The gear and the generator are located within a sealed casing pressured with air at the same pressure as the surrounding water. On its lower side the casing has a converging duct that increases the current velocity. The upper side of the casing has a prominent bump. The arhimedic force applied on this bump ensures the turbine stability when the generator runs. Four anchor cables secure the turbine structure on the ocean floor.

Hydraulic turbine for deep ocean conditions

Abstract

A submersible hydraulic turbine for generating electricity from the marine currents is disclosed. The turbine structure is fully submerged having a horizontal rotor. The rotor shaft is perpendicular to the marine current direction. The rotor is equipped with a number of blades fixed between circular discs and parallel to the turbine shaft. The marine current impinges on the turbine blades rotating the shaft. A gear multiplies the shaft speed and transmits the rotation to an electrical generator. The gear and the generator are located within a sealed casing pressured with air at the same pressure as the surrounding water. On its lower side the casing has a converging duct that increases the current velocity. The upper side of the casing has a prominent bump. The arhimedic force applied on this bump ensures the turbine stability when the generator runs. Four anchor cables secure the turbine structure on the ocean floor.

Hydraulic turbine for deep ocean conditions

BACKGROUND of INVENTION

1. Field of Invention

This invention relates to a hydraulic turbine for generating electrical power using the mechanical energy of the marine currents.

2. Description of the related art

For the past hundred years a consistent rise in electric energy demand worldwide was noted. The trend is expected to continue even more rapidly for the coming years. The global trends that will affect our future seem to be: the global warming, dwindling supply of oil reserves and the increased opposition to hydroelectric dams. The CO_2 emissions are projected to double during the next three decades unless new policies will be put in place to reduce them. These emissions are responsible for the actual greenhouse effect. Other issue is the oil reserves that are diminishing continuously. The market data suggests that the global oil production could peak during the next decade and then begin a decline throughout the remainder of the 21-century, accompanied by increasingly higher prices. The electricity produced on hydraulic resources (rivers, waves and tides) is well established but the large-scale projects have lost favor due to the very hard environmental impact.

This being the global image, attention is focused on other resources as the wind and marine currents energy able to generate large amounts of electric power without producing polluting emissions and without environmental impact.

The hydraulic turbines driven by the marine currents to generate electricity are well known in the water machines art. Some of the most significant patents of the related art that will be analyzed below are:
U.S. 2,501,696, U.S. 6,109,863, and U.S. 4,335,319.

U.S. Patent 2,501,696 discloses a stream turbine that consists of twin counter rotating propellers, fully submerged. They drive two electric generators installed within a housing. An anchor rope holds the whole structure on the river or ocean bed. The main advantage of this invention is that the turbine doesn't require a solid structure installed on the ocean or rived bed, which allows using the marine currents energy far from the shore. However, the invention has some disadvantages. Having two distinct counter rotating propellers the resulting moment will be not perfectly equal to zero. The difference of these two moments will generate large oscillations that will modify the blades incidence relative to the current direction and, possibly, to touch the ocean bed. A second disadvantage consists of the difficulty to access within the generators housing, especially for the small power generators. Indeed, as a fully submerged machine, an easier or cheaper access should be designed to allow the generator maintenance and overhaul. Other disadvantage is that the turbine doesn't have a specific device for water acceleration upstream the propellers.

U.S. Patent 6,109,863 fixes some of the above disadvantages. It features a fully submerged apparatus with two vertical counter-rotating rotors. They are located within a housing, which has a specific device for water acceleration and flow orientation. The whole structure is hold relative to the river or ocean floor by a number of anchor ropes. Generally, each one of the two rotors will produce two rotating momentums, which are not perfectly equal. Their difference remains unclosed and will generate structural oscillations of the whole structure relative to the equilibrium position. This will modify the rotors incidence angle relative to the current direction. In these conditions the electrical generator will not supply a constant power.

This disadvantage is eliminated when the whole structure is solidly fixed on the ocean floor as is featured in U.S. Patent 4,335,319. This patent discloses a structure half immersed and half over the ocean surface. The immersed part contains the turbine rotor with a vertical shaft acted by the marine currents. An adjustable device increases the water velocity in front of the rotor. The upper part consists of the platform on which is installed the gear and the electrical generator. The platform is solidly installed on four legs on the ocean bed. This invention fixes all the above disadvantages excepting that relative to the small ocean depth restriction. Small depth means low speed marine currents and hence low power.

All the above patents disclose means for generating electrical energy from waves, tides, river or ocean currents and all of them have different disadvantages. Most of these disadvantages were discussed above. There is a mean that eliminates all the above disadvantages keeping all their advantages. This mean will be able to produce large amounts of electrical power using the marine currents energy at a competitive price and without any environmental impact. This mean is described below.

3. Summary of invention

The invention discloses an apparatus and the associated method to produce electrical energy from a marine current by means of a rotor, driven by the water current. The apparatus consists of a fully submerged housing sealed against the surrounding water and a rotor horizontally installed within the said housing. The rotor axis is perpendicular on the marine current direction. The rotor is equipped with a number of semicircular blades fixed between a number of circular discs, concentric to the rotor shaft. Two seals located on the turbine shaft prevent the water to flow within the housing. The rotating movement of the turbine shaft is multiplied through a gear and transmitted to an electrical generator. On the ventral side of the housing a convergent duct accelerates the water flow that drives the lower half of the turbine rotor acting on the turbine blades. The whole housing is anchored to the ocean floor by means of four cables. The structure position is actively controlled by means of four electric motors located within the housing under the accelerating duct. Rolling conveniently the cable length, the whole structure will be maintained in horizontal position. On the upper side, between the turbine rotor and the inlet device, the housing has a boss that creates an archimedic force. When the generator runs this force creates a counter moment relative to the generators moment and maintains the whole structure in stable position. When the generator doesn't run, the tension forces in the cables balance the above archimedic force. The pressure within the housing cavity is maintained as close as possible to the surrounding water by means of a pressure controller. This device is a

pressured reservoir that releases a controlled amount of air to balance the air loss through the housing skin or seals. A submarine cable transports the electrical power from the generator to the shore.

The invention further provides a method and apparatus for an efficiently conversion of the energy of the unidirectional marine currents in electrical power.

It is a further objective of the present invention to avoid the storms, ships and other ocean surface problems by a fully submersible system for electrical power generating from the marine currents energy.

It is a further objective of the present invention to install the electrical generator, the multiplication gear and other devices within a sealed housing.

It is a further objective of the present invention to improve the energy conversion from the marine currents to electric energy by increasing the water velocity in front of the turbine rotor.

It is a further objective of the present invention to minimize the mechanical loads on the said housing by ensuring an air pressure within the housing equal to the pressure of the surrounding water of the housing

It is a further objective of the present invention to balance the electrical generator momentum by the effect of an archimedic force located on the upper side of the housing.

It is a further objective of the present invention to create an optimum velocity profile at the turbine rotor inlet by a suitable shape of the inlet duct, flat at the upper side and curved on the lower side.

It is a further objective of the present invention to anchor the whole system on the deep ocean floor by four cables, two located upstream of the turbine rotor and two located rearward of the turbine rotor.

It is a further objective of the present invention to maintain the horizontal position of the turbine by mean of four electrical motors, each one of them controlling the length of the said cables.

It is a further objective of the present invention to maintain the said pressure within the housing, by means of a pressure controller that releases a small amount of air when necessary to balance the air leakage through the seals and housing skin.

These and other objectives of the invention can be better understood from the following detailed description and reference to the appended illustrations.

4. Brief description of the drawings

Figure 1 is a schematic vertical cross-sectional illustration of the embodiment of the present invention.

Figure 2 is a schematic top-sectional illustration of the embodiment of the present invention.

Figure 3 is a schematic front view illustration of the embodiment of the present invention.

Figure 4 is a schematic vertical cross section through the axis of the turbine rotor.

Figure 5 is schematic vertical cross section perpendicular to the axis of the turbine rotor.

Figure 6 is a schematic view of the electrical motor for position control.

Figure 7 is a schematic view of a package of three hydraulic turbines.

5. DESCRIPTION OF THE INVENTION

Figure 1 illustrates a fully submersible hydraulic turbine for generating electricity from the marine currents energy. The system as is illustrated in Figure 1 has a fully submerged housing 1, a rotor 2 whose horizontal axis 3 is oriented perpendicular on the flow direction of the marine current and an electrical generator 4. The rotor 2 is equipped with a number of blades 5 fixed parallel with the rotor axis 3. The generator 4 receives the rotation movement from the rotor 2 and transforms it in electrical energy. The generator 4 is located in a sealed cavity 6 within the upper side of the housing 1. At the lower side of the housing 1 there is a convergent duct 7 and an inlet device 8. Under the duct 7 and within the housing 1 there are four electrical motors 9. Four anchor cables 10 tie the housing 1 to four anchors 11 located on the ocean floor. A semicircular diaphragm hides the upper half of the rotor 1 and leaves free the lower half of the rotor, within the convergent duct 7. The upper side of the duct 7 is flat and the lower side is concave/convex as can be seen in Figure 1. The stiffness of the housing 1 and the duct 7 is ensured by means of a number of ribs 13.

Figure 2 illustrates a top view of the housing 1 and its content. The blades 5 are positioned on the rotor 2 by mean of a number of discs 14. The discs are located on a shaft 15 having the same axis 3. Two bearings 16 bear the shaft 15 relative to the housing 1. Two seals 17 located on the shaft 15 prevent the surrounding water 18 to enter the housing 1. A gear 19 transmits the rotation movement of the shaft 15 to the generator 4.

On figures 3 and 1 a bump 20 can be seen on the upper side of the housing 1, between the generator 4 and the inlet device 8.

Figures 4 and 5 illustrates that the blades 5 are positioned on the disc rim 21.

On figure 7 can be seen an artist image about how a package of three turbines are installed and connected to the remote station.

The marine current enters the turbine through the inlet device 8. Flowing through the convergent duct 7 the water will have a higher velocity at the rotor inlet than at the inlet device 8. Due to the concave/convex shape of the lower side of the duct 7, close to the rotor 2, the water velocity will be higher at the duct bottom than at the flat upper side of the duct. That will create a suitable velocity profile at the rotor inlet.

On the arc length AB the water impinges on the turbine blades 5 that rotate the discs 14. The tangential velocity of the rotor on the arc AB is tuned to be half of the maximum water velocity on the same arc. Consequently, the water flows between the blades of the arc AB producing a rotation movement of the discs 14 and reaches the rotor core close to the shaft 15. From here the water flows between the blades on the arc BC producing again a rotational movement of the discs 14. After the water leaves the blades on the arc BC, continues to flow downstream through the divergent part of the duct 7. By mean of the shaft 15 the rotational movement of the discs 14 is transmitted to the gear 19 that multiplies the rotational movement to a speed convenient for the electrical generator 4.

The rotational movement of the rotor 2 requires an equal and counter rotational momentum. In order to maintain the housing 1 in horizontal position this counter momentum must be applied on the housing 1. The archimedical force F applied on the bump 20 creates the required counter momentum. When the generator does not run this force is closed by the tension in anchor cable 10.

The sealed cavity 6 of the housing 1 is filled with air meanwhile the ocean water surrounds the housing. In order to minimize the stress of the ribs 13 the air pressure within the cavity 6 is maintained at a constant level by mean of the pressure regulator 23. This device balances the air loss across the shin of the housing 1 or across the seals 17.

The electrical motors 9 maintain in active mode the horizontal position of the housing 1. Same time the electrical motors 9 are used to rise the housing 1 at the ocean surface for maintenance or to get down in immersion. In this order the shaft 24 of the electrical motor 9 is equipped with a spool 25. On the spool 25 the cable 10 is rolled to get in immersion the housing 1 and de-rolled when the housing 1 has to get the ocean surface.

A power cable 26 transports the electrical energy produced by mean of the generator to the ocean shore. The power cable 26 double the anchor cable 10 from the generator 4 until the ocean floor and after that lies on the ocean bed until the remote station 27 on the ocean shore.

The power cable 26 contains a separate electrical wire for active control of the turbine parameters: speed, power, vibration, bearings temperature, air pressure and temperature within the housing 1, sealing. An operator located on the ocean shore at the remote control station 27 surveys on a permanent basis the above turbine parameters.

Hydraulic turbine for deep ocean conditions

CLAIMS

I claim:

1. A fully immersed apparatus for generating electricity from water currents energy, comprising:

a housing having a inner cavity filled with air and sealed against the surrounding water and a convergent/divergent duct located on the lower side of the housing,

a rotor having a horizontal shaft, perpendicular to the flow direction of the water, borne on two bearings relative to the said housing and having a plurality of blades located on a plurality of circular discs that are concentric to the said rotor,

an electrical generator connected to the said rotor by mean of a multiplication gear, both of them located within the said housing

2. The apparatus of claim 1 including

said rotor having the shaft located on the upper side of the said convergent/divergent duct in such way the upper half of the said rotor is located inside the said housing and the lower half within the said duct

3. The apparatus of claim 1 including

the said blades are located on the rim of the said rotor parallel with it and having a circular arc profile

4. The apparatus of claim 1 including

an air pressure regulator located within the said housing to control and maintain the air pressure within the said housing equal to the pressure of the ocean water surrounding the said housing

5. The apparatus of claim 1 including

four anchor cables for securing the said housing in its position relative to the ocean floor

6. The apparatus of claim 1 including

four electrical motors located within the said housing that control and maintain in horizontal position the said housing

7. The apparatus of claim 1 including

a power cable that transmits the generated electrical energy from the said electrical generator to the ocean shore

8. The apparatus of claim 1 including

a remote control cable that allows the active control of the main operation parameters of the said apparatus.

9. The apparatus of claim 1 including

the said convergent/divergent duct that has an upper flat side and a lower concave/convex side that allow the water to increase the flow velocity and have the optimal profile before to impinge the rotor blades

10. The apparatus of claim 1 including

the said housing that has a bump on the upper front side, the said bump creating a counter –rotating moment to balance the said generator moment by mean of the archimedic force that occurs on the said bump

11. The apparatus of claim 1 including

a said rotor whose blades have a chord length which is two third relative to the rotor radius

12. The apparatus of claim 1 including

a said convergent/divergent duct whose cross area at the end of the convergent portion is a quarter of the inlet cross area of the said convergent/divergent duct

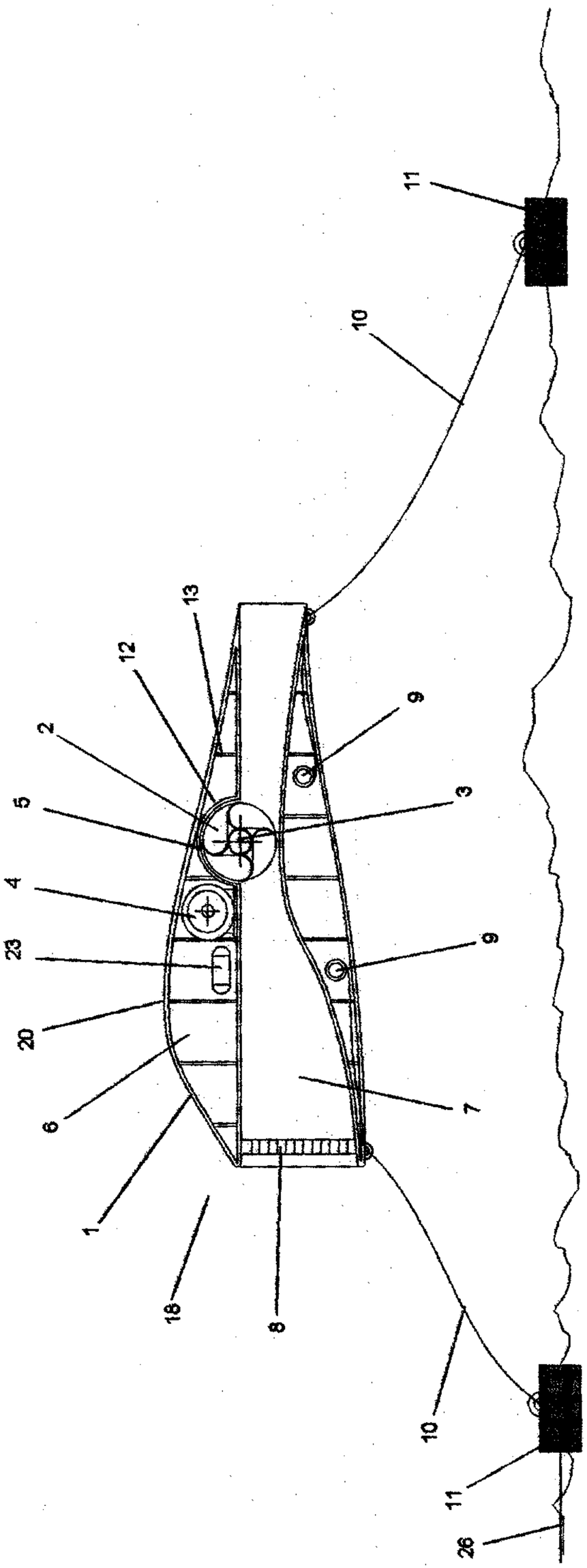


Figure 1

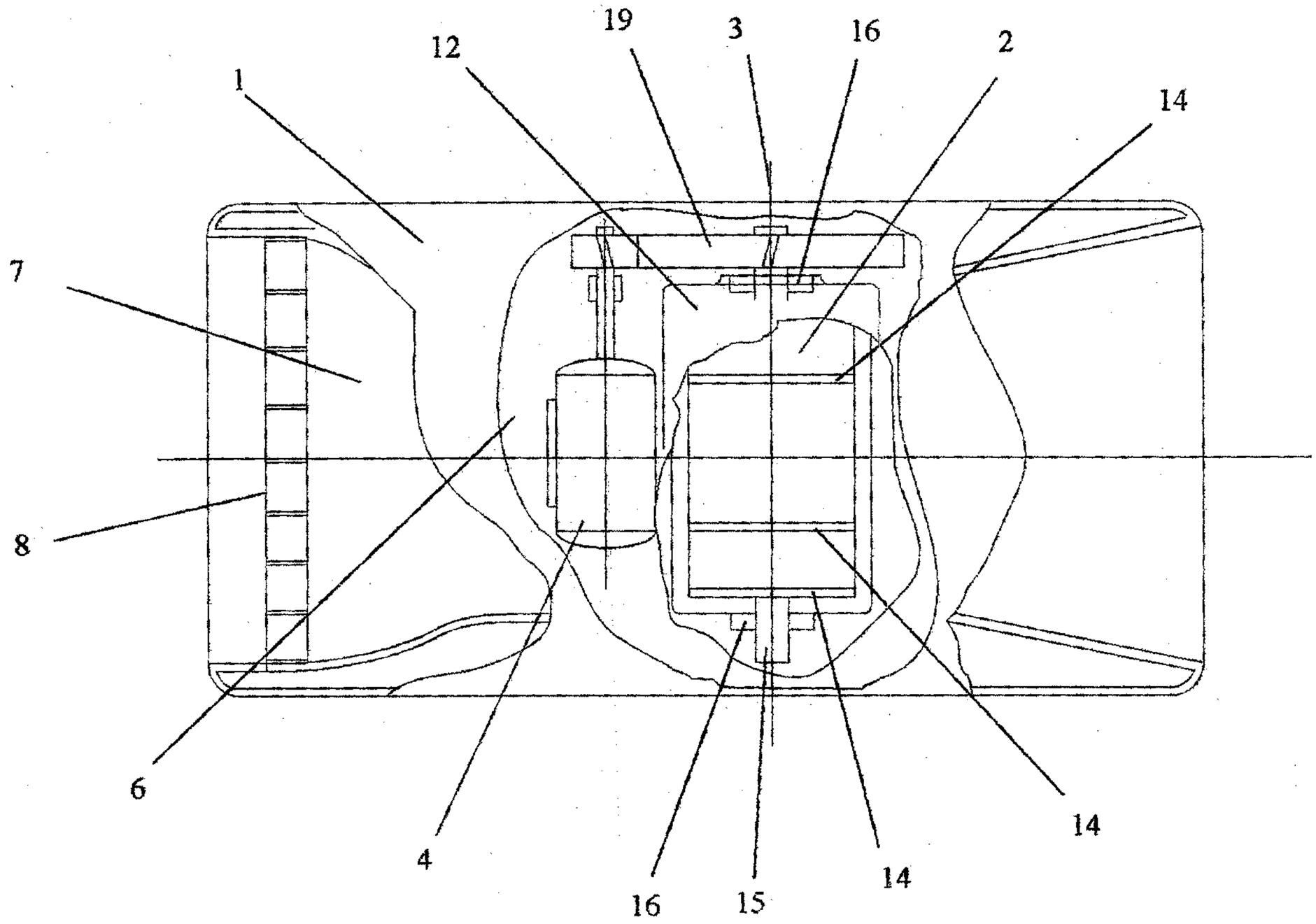


Figure 2

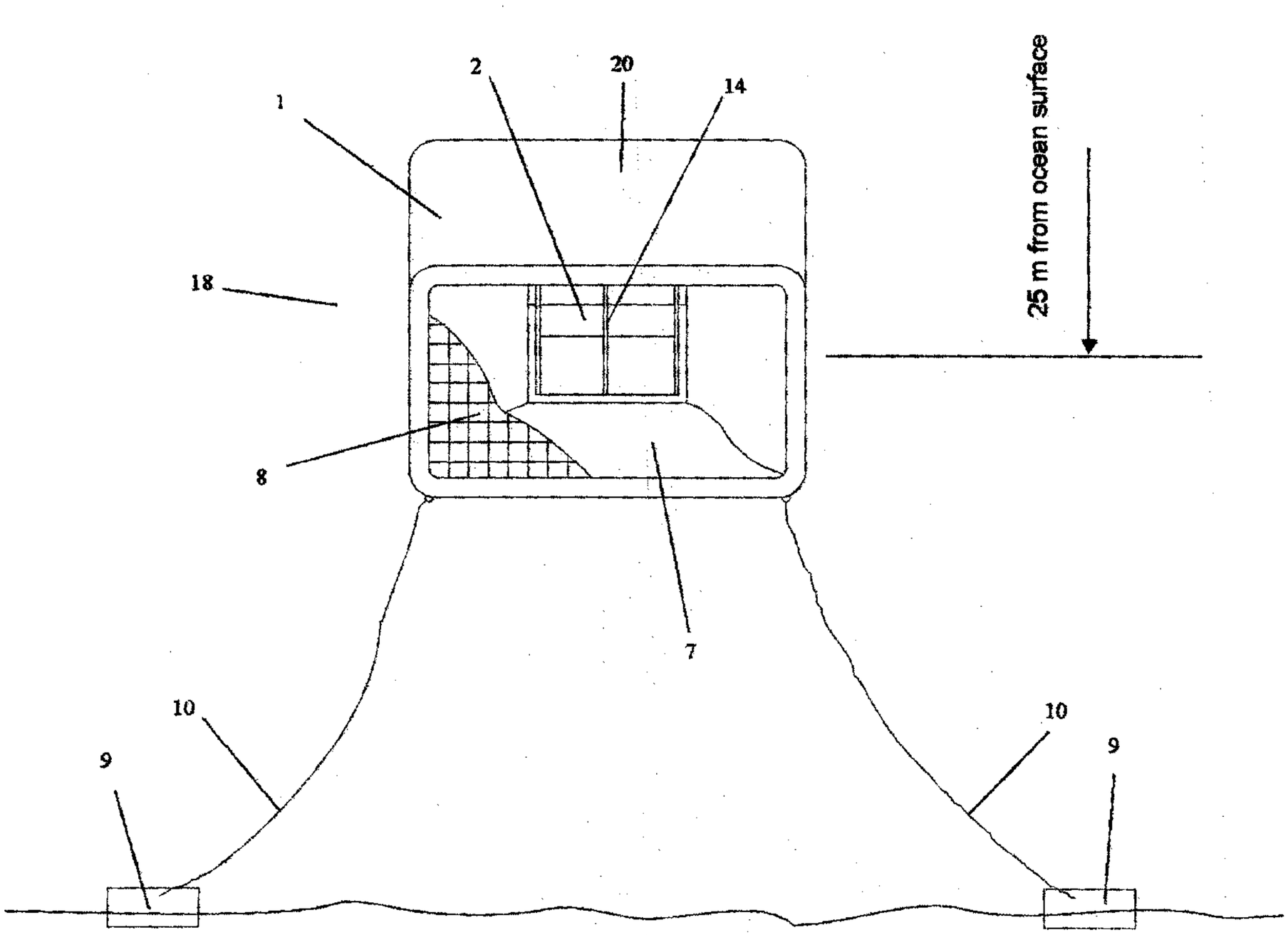


Figure 3

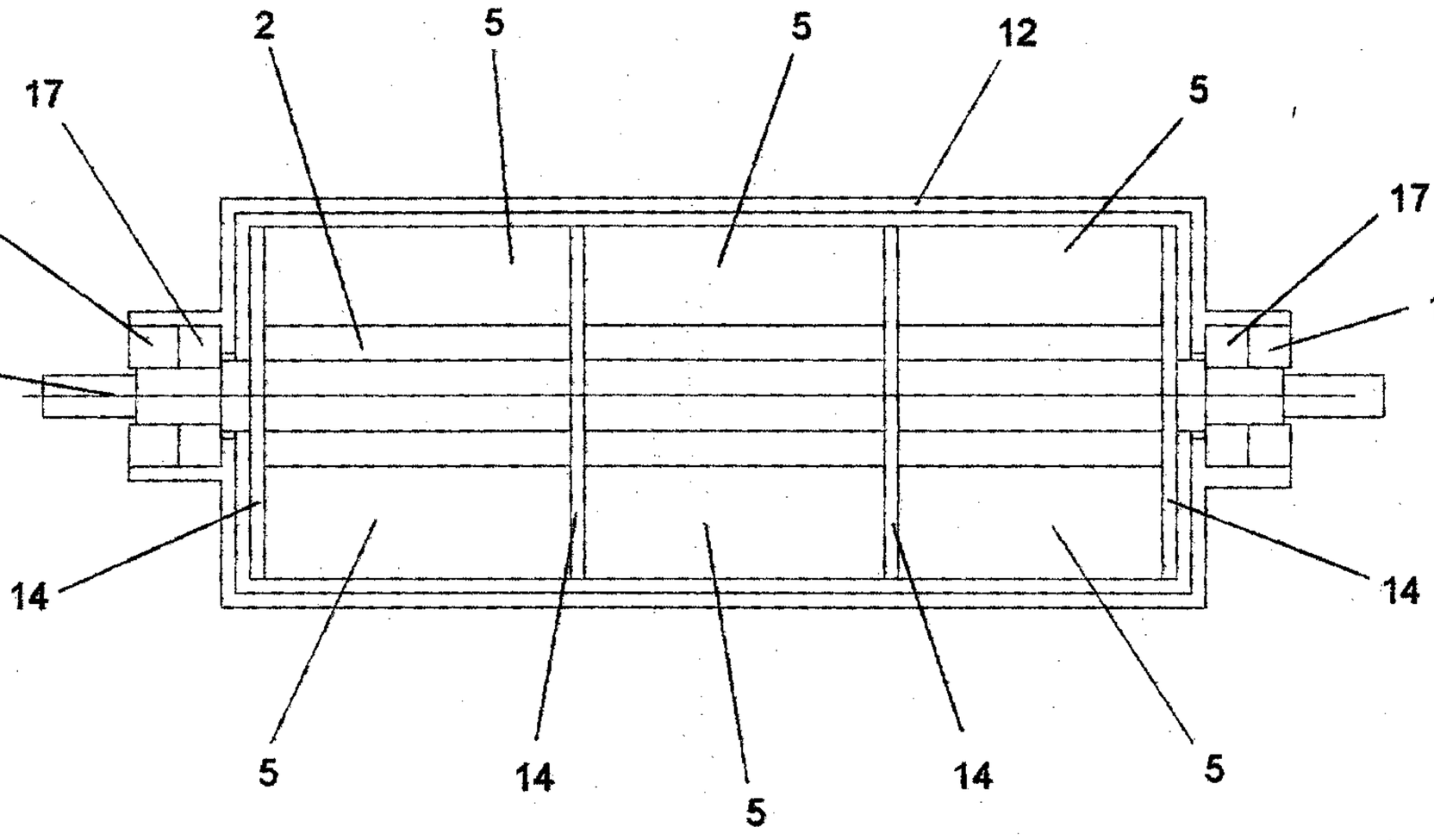
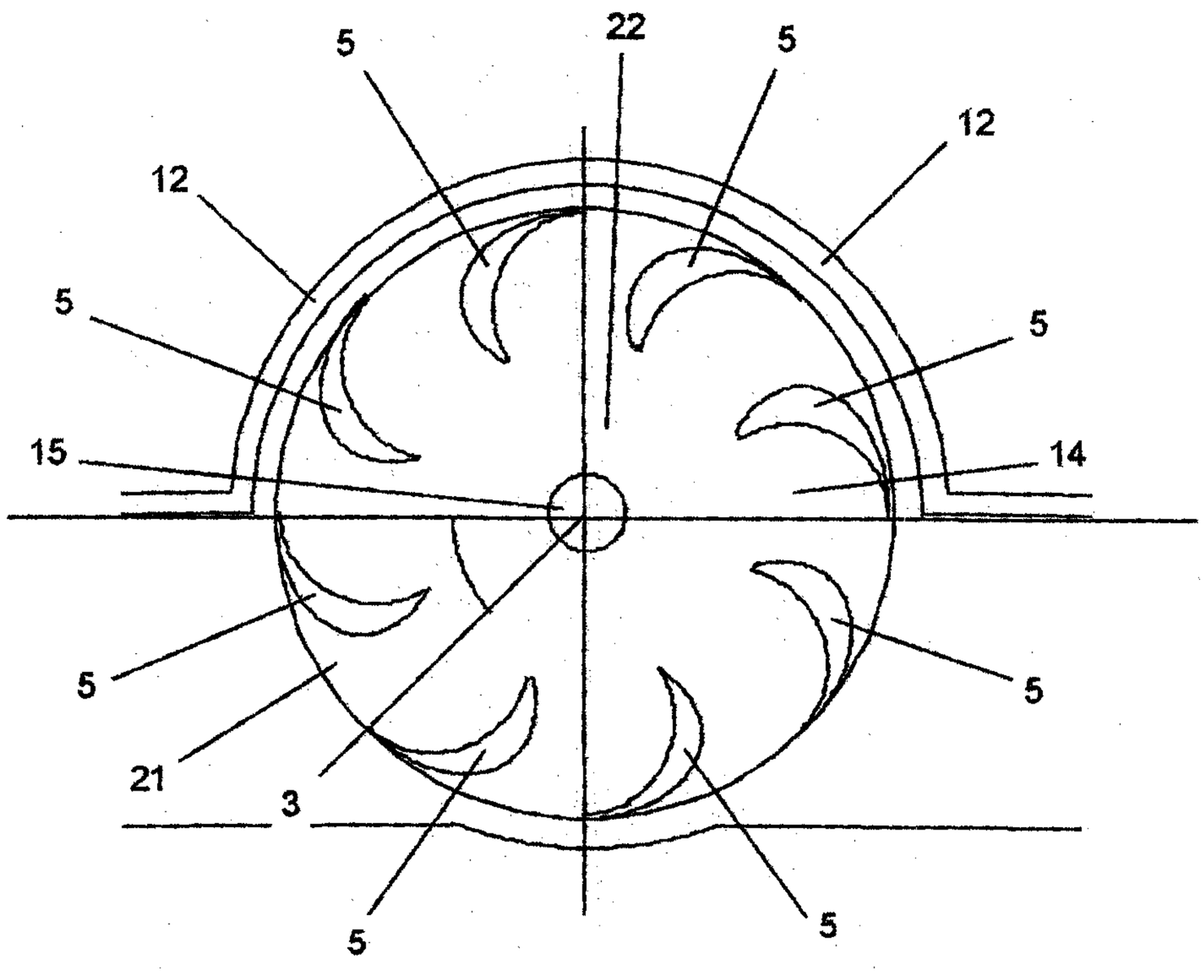


Figure 4



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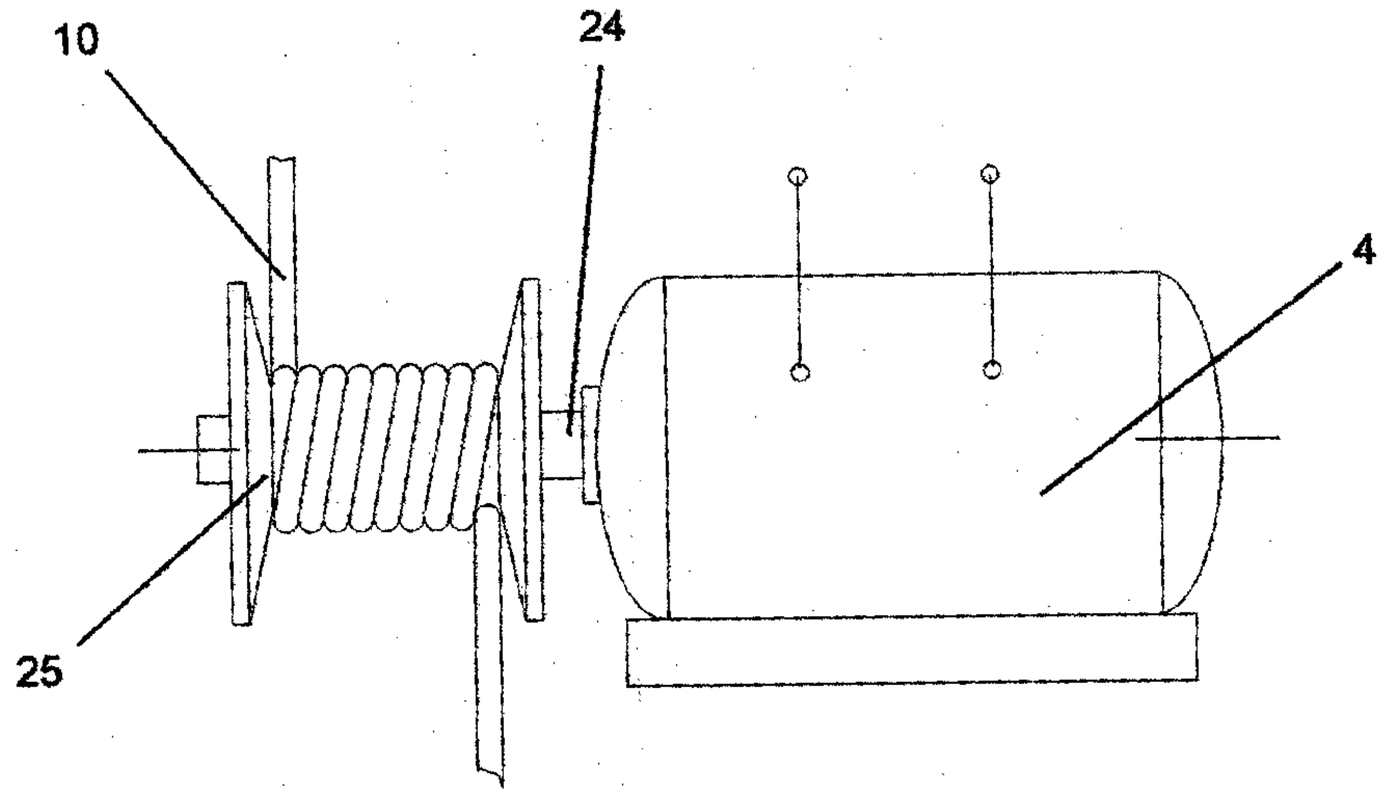


Figure 6

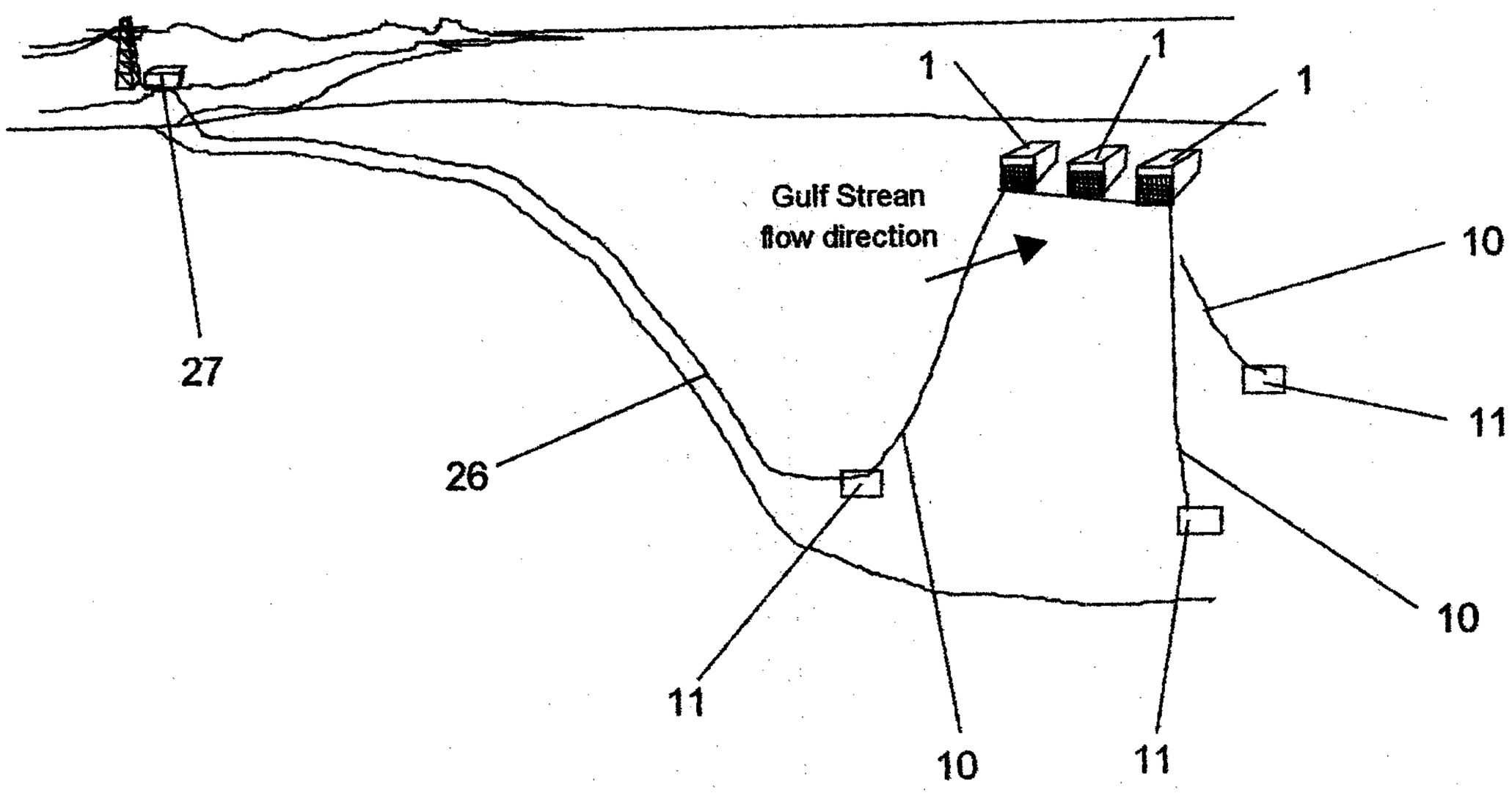
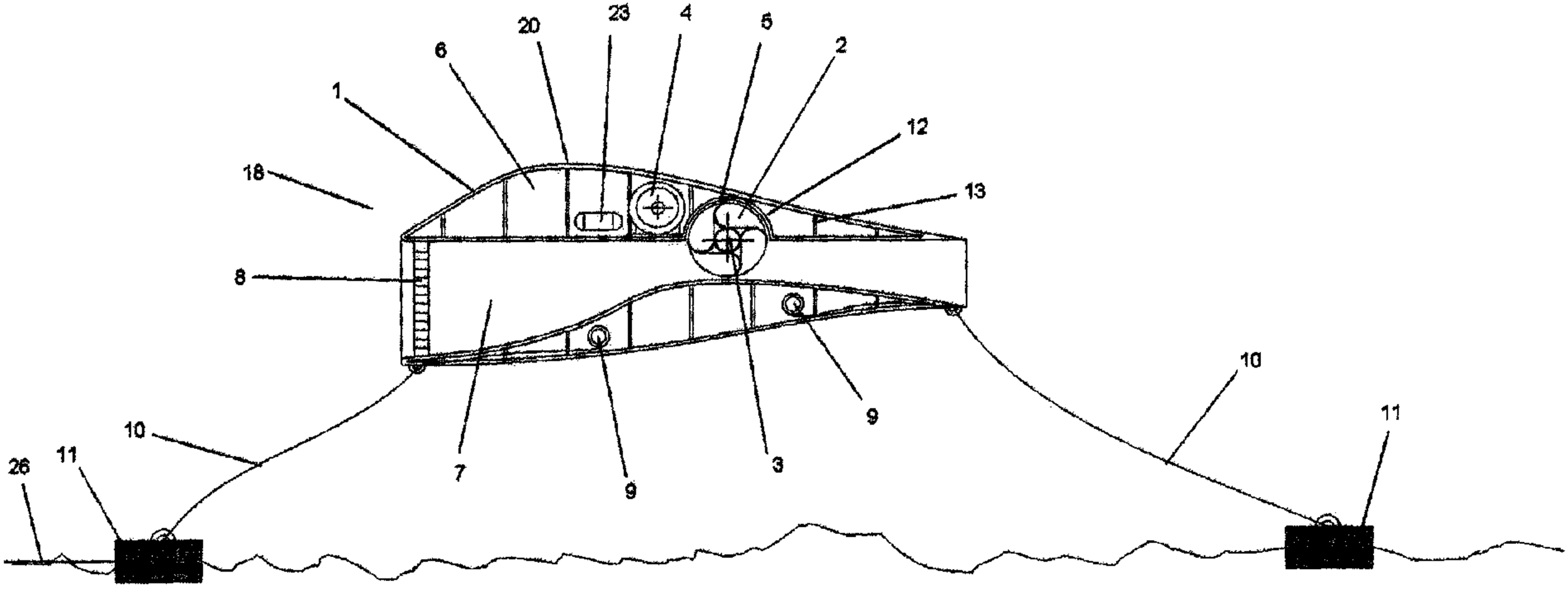


Figure 7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