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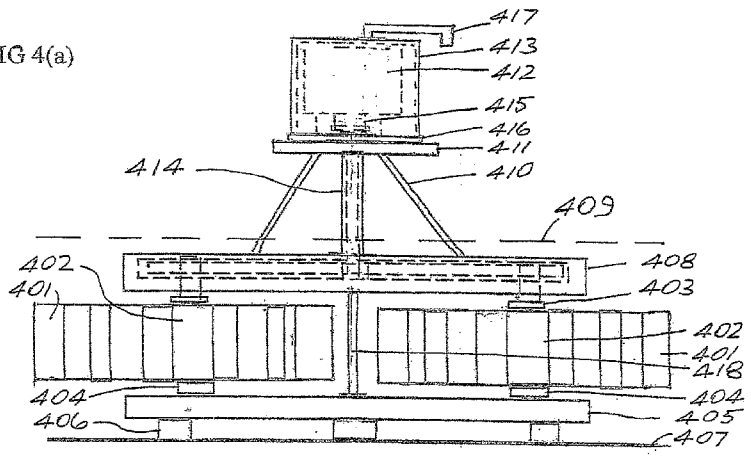
FIG 4(a)



(57) Abstract: An electric power generator has at least one pair of rotors (2, 401) disposed in a common horizontal plane and locatable across a fluid flow stream (421). Each rotor is rotatable about an axis which is orthogonal to a direction of the fluid flow stream and each pair of rotors is arranged to be driven by the fluid flow stream to rotate in contra-directions. Each rotor has an axle (402) rotatable about an axis and a plurality of blades (401) extending substantially radially from the axle. Each rotor of the pair of rotors is connected by a transmission in a housing (408) to drive a common shaft (414) having a longitudinal axis located in the same plane as the axis of each of the rotors. The common shaft is arranged to provide motive force for rotating an electrical generator/alternator (412) which is located about the common shaft axis.

WO 2010/082011 A2

ELECTRIC POWER GENERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electric power generator for the production of electrical energy, in particular, but not exclusively, using tidal or river current motion, although wind energy may, alternatively, be used.

2. Description of the Related Art

An overview of power tidal systems is given in Engineering and Technology, 20th September – 3rd October, 2008, Vol. 3, Issue 16, at pages 46 – 49.

It is known to provide a hydroelectric apparatus located on a sea bed with a turbine mounted beneath a platform such that a rotor is located in a fluid stream and a generator is mounted in a housing on a platform above the water level – see US-A-4335319. The said U.S. patent also has movable fluid directing means which traverses about the rotor to direct fluid according to different requirements upon blades of the rotor.

WO2008/026964A discloses a pair of rotors mounted vertically one above another to drive a common shaft and another pair of horizontally opposed rotors to drive another common shaft. Each common shaft is arranged to drive a separate generator. Such an arrangement is wasteful of fluid energy.

WO2008/002149A discloses a turbine wheel having a plurality of blades in which the blades are generally V-shaped and pivot about the apex of the V-shape, the point of pivot being located on the periphery of a hub. A further flap is arranged to open or close a radially outer arm of the V-shaped blade in dependence upon the position of the blade with regard to fluid flow. Such an arrangement is not believed to be sufficiently robust and is liable to clogging from contaminants within the water stream.

SUMMARY OF THE INVENTION

The present invention seeks to provide a simple low cost electric power generator that may be used in rivers, streams, estuaries, as well as in the sea, but especially in streams having a water depth as low as 0.5 metres.

According to this invention there is provided an electric power generator including at least one pair of rotor means disposed in a common horizontal plane and locatable across a fluid flow stream, each said rotor means being rotatable about an axis thereof which is substantially orthogonal to a direction of the fluid flow stream, each said pair of rotor means being arranged to be driven to rotate in contra-directions by the fluid flow stream, each said rotor means having an axle rotatable about said axis and a plurality of blades extending substantially radially from said axle, and each said rotor means of said pair of rotor means being connected by transmission means to drive a common shaft having a longitudinal axis located in the same plane as the axis of each of said rotor means, said common shaft being arranged to provide motive force for rotating electrical generating means located about said common shaft axis.

Preferably, each said rotor means include a plurality of spacer means radially extending from said axle to a hub, and the plurality of blades extend from said hub.

Advantageously, so as to facilitate the rotor means to rotate in contra-directions, one of the rotor means is connected by intermediate gear means to a first pulley or chain wheel and the other rotor means has a second pulley or chain wheel mounted on the axle thereof.

Conveniently, said common shaft is connected to pulley or chain wheel means and said transmission means includes an endless belt or chain extending about said first pulley or chain wheel and said common shaft pulley or chain wheel means, and a further belt or chain extending about the second pulley or chain wheel and said common shaft pulley or chain wheel means.

Advantageously, said common shaft pulley or chain wheel means is a further pair of pulleys or chain wheels connected about the axis of said common shaft.

Advantageously, deflector means are provided to direct the fluid stream either between adjacent sides of the rotor means to concentrate flow therebetween, and to direct flow away from the blades on an opposite side of the rotor means, or to direct fluid flow to blades on opposing sides of the rotor means, whereby in both

alternatives the blades rotate in opposing directions and the deflected fluid reduces drag on the rotor means.

Preferably, in a bi-directional ebb and flow tidal movement, said deflector means are provided upstream and downstream of said rotor means.

Advantageously, in one embodiment the blades are uni-planar.

In another embodiment, the blades comprise a first planar element secured to the hub and a pivotal second planar element which is tangentially pivotal with respect to the hub to reduce drag.

In such an alternative embodiment a stop is provided for limiting movement of the second planar element when, in extremis, it is in alignment with the first planar element.

Additionally, advantageously, in such an alternative embodiment a weight is provided to assist the second planar element to return into alignment with the first planar element.

Preferably, the rotor means are supported on a base frame which has adjustable feet for contact with a fluid bed.

Preferably, the rotor means are supported between the base frame and an upper frame.

In one embodiment, the transmission means is mounted in a waterproof housing arranged to be located below a water level.

Conveniently, the common shaft is connected to drive the generating means through a gear arrangement.

Preferably, the electrical generator means is releasably secured to the rotor means and transmission means to permit portability and transportation of said electric power generator. It is envisaged such an electric power generator will be transportable on a truck, if not by a human.

In one embodiment, four rotor means are arranged in a quadrilateral formation in a common horizontal plane and connected by transmission means to the common drive shaft arranged to provide motive force to the electrical generator means.

Advantageously, said generator is fitted with at least one buoyancy chamber, said chamber having means arranged to fill the chamber with a gas to float the

generator to a desired location, means for expelling the gas, and means for inserting a mass into the chamber to cause the generator to sink to a river or sea bed.

Preferably, a mesh screen is mounted around the rotor means to prevent marine life over a predetermined size from engaging the rotor means.

This invention causes fluid flow to contra-rotate rotors to increase the generating force available, whereby electric power generation is effected by movements by tide and/or currents in river, streams and estuaries.

The electric power generator of this invention is highly diverse in that the basic design is capable of operating in a wider range of water depths and hitherto, on different types of river bed strata and water flows, using various rotor sizes, reduced resistance using a restrictor or blade changers. Ground works, such as dams and lakes, tunnels, etc., are not a requirement; in situations where the flow is slow, a simple low-cost guide channel restrictor may be installed.

Marine life may be protected by a mesh screen mounted around the movable rotors. Such a screen may allow smaller marine fry to move within the rotors, but by having a suitable size of mesh for the screen, larger marine life, such as trout, salmon, etc., may be inhibited from entry to the rotors.

Anti-rust and anti-fouling treatment of the assemblies plus water flow and rotor movement inhibitors of marine growth may be utilised.

With this invention, installation costs are low and the power transfer cable costs are equivalent to or only slightly higher than that for wind turbines.

The generator described is capable of portability enabling production of electrical power from almost any running water; this would in many circumstances enable military use with field kitchens and field hospitals and other uses displacing the need for vulnerable extended supply lines required by diesel or petrol engine operated generators.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1(a) shows an end view of an electric power generator in accordance with this invention sitting on a river bed with twin rotors submerged below low water

level and a generator gearbox above high water level, only one of the rotors being shown in the end view,

Figure 1(b) shows a perspective view of a battle plate,

Figures 2(a) and 2(b) show a side view and a top plan view respectively of one configuration of the electric power generator in accordance with this invention where a twin rotor, low depth assembly is required,

Figures 3(a) – 3(d) show alternative arrangements for overcoming back pressure on the rotor blades,

Figures 4(a) and 4(b) respectively show a side view and a top plan view of a twin hydroelectric power generator in accordance with the invention,

Figures 5(a) and 5(b) respectively show a side view and a top plan view of a gear and chain drive from the rotors, and

Figure 6 shows an exploded view of the construction of a rotor.

In the Figures like reference numerals denote like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The electrical power generator shown in Figure 1(a) has a main frame assembly 1 within which is mounted a pair of contra-rotating rotor assemblies 2 connected to drive a common drive shaft 3 for driving a generator 4. The main frame assembly 1 is located below an average water level 5 and the generator is located above the water level 5. The main frame assembly 1 has a base plate 6 for locating on a sea or river bed with adjustable legs 7 located in an intermediate frame 8. The rotor assembly 2 has a plurality of radially extending rotor blades 9 connected by spokes 10, which are, preferably, tubular, to a rotor core assembly 11. The radial innermost end of the spokes 10 are connected to the rotor core assembly 11 which, in turn, is connected to drive the axial common drive shaft 3. The drive shaft 3 at its lowermost end is mounted in thrust and taper bearings 13 which are sealed from the elements. The main frame assembly 1 has a top plate 14 through which the common drive shaft 3 passes and mounted on the top plate is a support base plate 15 which is secured to the top plate by suitable fixings, e.g. nut and bolt. Located in the top plate 14 is an upper sealed rotor bearing 16 for the axial drive shaft 3. Mounted on the support base plate 15 is a top frame support 17 made from, for example, U-shaped cross-

sectionally shaped channels. At an uppermost end of the support channel 17, above the water level 5, is a support plate 18 upon which is mounted via an O-ring seal (not shown) a housing base plate 19 for the generator. The base plate 19 is preferably secured to the support plate 18 by fixings 20.

It is to be understood that Figure 1(a) is an end view of the electrical generator in accordance with this invention showing one rotor assembly which is connected by a drive means, for example a belt or a chain, to rotate the shaft 3, the other rotor assembly being similarly attached by drive means to rotate in a contra-direction and via gears to also drive the shaft 3 in a given direction.

Although a generator is described, it is to be understood that an alternator may, alternatively, be utilised, although, in some circumstances, it is envisaged that both the alternator and generator may be connected to the drive shaft.

The drive shaft 3, above the top plate 14, is sealed within a housing tube and support column 21. Lifting lugs 22 are attached to the top plate 14 so that the main frame may be raised and/or lowered. At its upper end the column 21 and shaft 3 are supported within a sealed bearing 23 and connected to drive a multiply gearbox 24.

The generator 4 has a core shaft 25, stator windings 26 and a generator core 27, the generator being located within a housing 28.

The housing 28 has a breather pipe and ball valve 29 and an outlet cable from the generator is connected via an outlet box 30.

In use, the rotors 2 are arranged to rotate in contra-directions (as will be hereinafter described) so as to rotate the shaft 3 which, in turn, rotates the generator 4 to produce electricity which is extracted by a cable from the connecting box 30.

In tidal situations, a V-shaped baffle plate 31, shown in Figure 1(b), may be secured to the main frame assembly 1 so as to ensure fluid flow is directed appropriately to be rotors.

A twin rotor arrangement is shown in Figures 2(a) and 2(b) which is suitable for use where there is little water depth. In Figures 2(a) and 2(b) rotor assemblies 200 having blades 201 are rotatably mounted on axles 202 to rotate in sealed upper bearings 203 secured in a top frame member 204 and lower bearings 205 mounted in a lower frame member 206, the member 206 being for location on a river bed 207. The rotors 200 are arranged to be driven in contra-directions and drive therefrom is

taken via gears or pulleys 208 by duplex chains or belts 209 mounted within a housing 211 to drive a common generator drive shaft 210. The drive arrangement will be more fully described with reference to Figures 5(a) and 5(b). The generator drive shaft 210 drives a generator 212 through a gearbox 213 and the generator is located within a housing 214 having a breather pipe with a ball valve 215. The rotor assemblies 200 are, preferably, protected by marine life protection guards 216 and guides 217 may be provided for directing fluid flow to the blades.

In operation, like the embodiment shown in Figure 1(a), the rotor assemblies 200 are disposed in a common horizontal plane across a fluid flow stream with each rotor assembly being rotatable about an respective axis which is substantially orthogonal to a direction of the fluid flow stream. Each of the rotor assemblies is arranged to rotate in contra-directions by the fluid flow stream and the blades 201 extend radially from an axle 202 on the axis. Each of the rotor assemblies is connected by drive transmission means 208, 209 to drive the common drive shaft 3 having a longitudinal axis located in the same plane as the axis of the rotor assemblies. The common drive shaft is arranged to provide motive force for the rotor of the generator which is located about the axis of the common drive shaft.

A problem with many horizontally disposed rotor assemblies in hydro-generation systems is of the force of water driving the rotor blades being greatly reduced due to the force exerted on the returning, opposite, rotor blades. This problem is indicated in Figure 3(a) where rotor assembly 301 is subjected to a fluid flow direction indicated by broken arrow headed lines 302. Opposing forces on the rotor blades are negated by a baffle plate 303. Thus, by virtue of the baffle plate, fluid flow indicated by broken arrow headed lines 304 is permitted to turn the rotor assembly counter clockwise and the baffle plate 303 directs fluid flow, shown by arrow headed lines 305, away from the rotor blades, thereby increasing efficiency by reducing back pressure on the rotor assembly.

Figure 3(b) shows V-shaped rotor blades 310, with rotational force being applied by broken arrow headed lines 311 and contra-directional flow forces being indicated by broken arrow headed lines 312. The V-shaped blades provide full driving force by entrapping fluid flow in the direction 311 and diverts fluid flow in the direction of arrow headed lines 312.

Figures 3(c) and 3(d) show a rotor blade having a fixed section 320 which may be welded to a rotor ring (shown in Figure 6) and a movable blade section 321, the sections 320 and 321 being hinged together by hinge 322. The movable blade section 321 is arranged to have its opening limited by a stop pin 323 which, in extremis, may be when the sections 320, 321 are aligned in the same plane. In operation with fluid flow in the direction of arrow headed lines 324, so the sections 320 and 321 are open to increase efficiency by accepting full flow pressure; when rotated to be against the flow direction, as indicated by arrow headed lines 325, so movable blade section 321 pivots away from the stop pin 323 to permit the fluid to flow past the section 321. Optional weights 326 may be provided on the movable blade section 321 to drop the section 321 against the stop pin 323 in the slack water section just prior to where flow pressure acts on the blade.

Preferably, the fixed blade section 320 has a length approximately one third that of the movable blade section 321. Although hinged blade sections are shown, the movable blade sections could be made, for example, from elastomeric or rubber compositions.

A twin hydro-generator is shown in Figures 4(a) and 4(b) where twin rotor assemblies 401, each having an axle 402, are mounted in upper and lower bearings 403, 404, respectively. The lower bearing 404 is located in a main frame base section 405 that has adjustable feet 406 for location on a sea or estuary bed 407. The upper bearings 403 are connected to main drive assembly gears and/or chains in a watertight housing 408, the water level being indicated by broken line 409. Spacing between the main frame base section 405 and the watertight housing 408 is maintained by spacing supports 418.

Preferably, four support legs 410 locate a platform 411 for a generator/alternator 412 located in a housing 413. The generator/alternator is driven by a common drive shaft 414 in a tubular housing through a gearbox 415 mounted on a fixing plate 416. The housing 413 has a breather pipe 417 with a float ball similar to that on a diving face mask so that water is prevented is prevented from ingress into the housing.

Deflector plates 420 deflect fluid whether from the ebb direction, shown by arrow headed lines 421, or from the flow direction, indicated by arrow headed lines

422 between the rotors 401 so that they rotate contra-directionally. Deflector plates 425 deflect fluid flow away from the rotors, thereby reducing back pressure and maximising rotational energy. Thus, the deflection plates funnel tidal waters into the rotors and provide deflection to reduce drag on the rotors. Although such an arrangement is preferred, it will be understood that the deflector plates could be arranged to direct fluid to the blades on opposing, outer, sides of the rotors so that the rotors again rotate contra-directionally and whereby drag on the rotors is reduced.

Figures 5(a) and 5(b) show the arrangement of gear and chain drive from the rotors. The axle 402 of one of the rotors (the left hand rotor shown in Figures 5(a) and 5(b)) is connected to drive a gear wheel 501 which meshes with a gear wheel 502 having the same diameter and tooth size. Gear wheel 502 is mounted on a common axle 503 with gear 504.

The axle 402 of the right hand side rotor (as shown in Figures 5(a) and 5(b)) is connected to rotate a gear wheel 505 having the same diameter and tooth size as gearwheel 504. The gear wheel 504 is connected by a chain 506 to drive an upper drive shaft gear 507 and gear wheel 505 is connected by a chain 508 to drive a lower drive shaft gear 509. The gears 507, 509 are secured to the common drive shaft 414. Spring loaded tensioning pulleys/gears 510 may be provided to absorb reverse shock and slack in the chains 506, 508.

In operation, rotation of the rotors in contra-directions will cause, as shown by the arrow headed lines in Figure 5(b), the left hand gear wheel 501 to rotate counter-clockwise which, thus, drives gear wheel 502 clockwise to drive, via chain 506, gear 509 and, hence, shaft 414 clockwise. Rotation of the right hand rotor will cause gear wheel 505 to rotate in a clockwise direction, which via chain 508 will cause gear wheel 507 and, hence, shaft 414 to rotate in a clockwise direction, thereby applying positive single rotation from the contra-rotating rotors.

The construction of a rotor unit is shown in Figure 6. The upper bearing 403 is located via a stub plug and bearing support 602 into an axle core 603 of the rotor, and the core may be, for example, a section of heavy wall API pipe. Four, for example, equi-circumferentially spaced spokes 604 forming carrier spacer assemblies (only three being shown in Figure 6) may be welded to the axle core 603. The spokes

forming carrier spacer assemblies 604 are U-shaped with the outer extremities of the limb of each U-shape being welded to an inner wall of a rotor blade support ring 606.

The lower end of the axle core 603 is connected by a stub plug and bearing support 607 to bearing 404.

Two types of rotor blades are shown in Figure 6, with blade 610 being a fixed type rotor blade generally for use in tidal flow generators connected into U-shaped channels 616 by bolting 617 or welding.

Another type of blade is a hinge type, which was described in Figures 3(c) and 3(d), and these blades may be secured, for example by welding into U-shaped slot 618.

Thus, two types of blade are shown in Figure 6, the fixed blade type for use with deflectors and the hinged blade type generally for use in one wave flow systems, such as rivers, streams, etc., where deflectors may not be used. In practice, the blades will normally be either fixed or pivoted, i.e. hinged.

So as to install the generator of this invention at a desired location in a river or at sea, the generator may be fitted with at least one buoyancy chamber which is, or are, filled with a gas to float the generator to the desired location and, when at the location, the gas is expelled and water or some other mass is inserted into the chambers to sink the generator onto the river or sea bed. By a reverse process, the generator may be raised and floated to a new location, if desired. In a preferred embodiment, a tank may be attached to the frame between the legs 17 and from the tank are provided two pipes to the top of the generator, one small diameter pipe leading to an air operated sea cock and the other leading into the tank. When moving the electrical generator into position, the sea cock is closed so the assembly partially floats and is towed into position, the sea cock is released and water enters the tank allowing the assembly to slowly settle onto the river or estuary bed. Should it be required to lift the electrical generator for any reason, a compressor is used to empty the tank and the sea cock is closed once air bubbles are witnessed, signifying that the tank is empty.

Although in the foregoing embodiments only a pair of rotors have been described, it is envisaged that in another embodiment at least one other pair of rotors may be incorporated either in the direction of fluid flow or transverse to the fluid

flow, with all of the rotors being interconnected by transmission means so that they rotate a common shaft for driving the generator/alternator.

In summary, this invention relates to an apparatus for providing electrical power output from rivers, streams and estuaries. The basic components of the apparatus consist of a submerged main frame, horizontal rotor/s with blades, multiplex chain drive, shaft drive or crown and bevel gear drive to a gearbox and generator assembly in a watertight housing, usually sited above water level.

There are optional guides to direct the stream of water through the rotor/s and blade presentation change capability for certain conditions.

Normally operation is 24/7 where there is a regular one way, uni-directional water flow; a power output cable carries the generated electrical energy to onshore correction and distribution units from which it can be fed to individual or multiple habitations, remote service areas or to the national grid.

An advantage of this apparatus is its adaptability, unlike other, known, generation apparatus which can only operate in deep water, because in this invention the rotor construction and configuration including a common shaft to the electrical generator permits use in shallow or deep water. With this invention, there is minimal ground work requirement, no dams, tunnels, sluices or supporting supply lake is required, thereby reducing visual environment impact; no fuel supply is required, there are no harmful emissions, and the fully portable versions can be used for military use such as remote camps, field hospitals and kitchens.

CLAIMS:

1. An electric power generator including at least one pair of rotor means (2, 401) disposed in a common horizontal plane and locatable across a fluid flow stream (302), each said rotor means (2, 401) being rotatable about an axis thereof which is substantially orthogonal to a direction of the fluid flow stream, each said pair of rotor means (2, 401) being arranged to be driven to rotate in contra-directions by the fluid flow stream, each said rotor means (2, 401) having an axle (402, 603) rotatable about said axis and a plurality of blades (9, 310, 320, 321, 610) extending substantially radially from said axle, and each said rotor means (2, 401) of said pair of rotor means being connected by transmission means (501 – 510) to drive a common shaft (3) having a longitudinal axis located in the same plane as the axis of each of said rotor means, said common shaft being arranged to provide motive force for rotating electrical generating means (4, 412) located about said common shaft axis.

2. An electric power generator as claimed in claim 1, wherein each said rotor means (2, 401) include a plurality of spacer means (10, 604) radially extending from said axle (402, 603) to a hub (606), and the plurality of blades (9, 310, 320, 321, 610) extend from said hub.

3. An electric power generator as claimed in claim 1 or 2, wherein so as to facilitate the rotor means to rotate in contra-directions, one of the rotor means is connected by intermediate gear means (502) to a first pulley or chain wheel (504) and the other rotor means has a second pulley or chain wheel (505) mounted on the axle thereof.

4. An electric power generator as claimed in claim 3, wherein said common shaft (3) is connected to pulley or chain wheel means (507, 509) and said transmission means includes an endless belt or chain (506, 508) extending about said first pulley or chain wheel (504) and said common shaft pulley or chain wheel means (507), and a further belt or chain (508) extending about the second pulley or chain wheel (505) and said common shaft pulley or chain wheel means (509).

5. An electric power generator as claimed in claim 4, wherein said common shaft pulley or chain wheel means is a further pair of pulleys or chain wheels (507, 509) connected about the axis of said common shaft (3).

6. An electric power generator as claimed in any preceding claim, wherein deflector means (31, 303, 420, 425) are provided to direct the fluid stream either between adjacent sides of the rotor means to concentrate flow therebetween, and to direct flow away from the blades on an opposite side of the rotor means, or to direct fluid flow to blades on opposing sides of the rotor means, whereby in both alternatives the blades rotate in opposing directions and the deflected fluid reduces drag on the rotor means..

7. An electric power generator as claimed in claim 6, wherein in a bi-directional ebb and flow tidal movement, said deflector means (420, 425) are provided upstream and downstream of said rotor means.

8. An electric power generator as claimed in any preceding claim, wherein the blades (9, 610) are uni-planar.

9. An electric power generator as claimed in claim 2, wherein the blades (9) comprise a first planar element (320) secured to the hub (606) and a pivotal second planar element which is tangentially pivotal with respect to the hub to reduce drag.

10. An electric power generator as claimed in claim 9, wherein a stop (323) is provided for limiting movement of the second planar element (321) when, in extremis, it is in alignment with the first planar element.

11. An electric power generator as claimed in claim 9 or 10, wherein a weight (326) is provided to assist the second planar element to return into alignment with the first planar element.

12. An electric power generator as claimed in any preceding claim, wherein the rotor means are supported on a base frame (8, 405) which has adjustable feet (7, 406) for contact with a fluid bed (6, 407).

13. An electric power generator as claimed in claim 12, wherein the rotor means are supported between the base frame (8, 405) and an upper frame (14, 408).

14. An electric power generator as claimed in any preceding claim, wherein the transmission means is mounted in a waterproof housing (408) arranged to be located below a water level (409).

15. An electric power generator as claimed in any preceding claim, wherein the common shaft (3) is connected to drive the generating means through a gear arrangement (24).

16. An electric power generator (4, 412) as claimed in any preceding claim, wherein the electrical generator means is releasably secured to the rotor means (2, 401) and transmission means (501, 510) to permit portability and transportation of said electric power generator.

17. An electric power generator as claimed in any preceding claim, wherein four rotor means (2, 401) are arranged in a quadrilateral formation in a common horizontal plane and connected by transmission means to the common drive shaft arranged to provide motive force to the electrical generator means.

18. An electric power generator as claimed in any preceding claim, wherein said generator is fitted with at least one buoyancy chamber, said chamber having means arranged to fill the chamber with a gas to float the generator to a desired location, means for expelling the gas and means for inserting a mass into the chamber to cause the generator to sink to a river or sea bed.

19. An electric generator as claimed in any preceding claim, wherein a mesh screen (216) is mounted around the rotor means to prevent marine life over a predetermined size from engaging the rotor means.

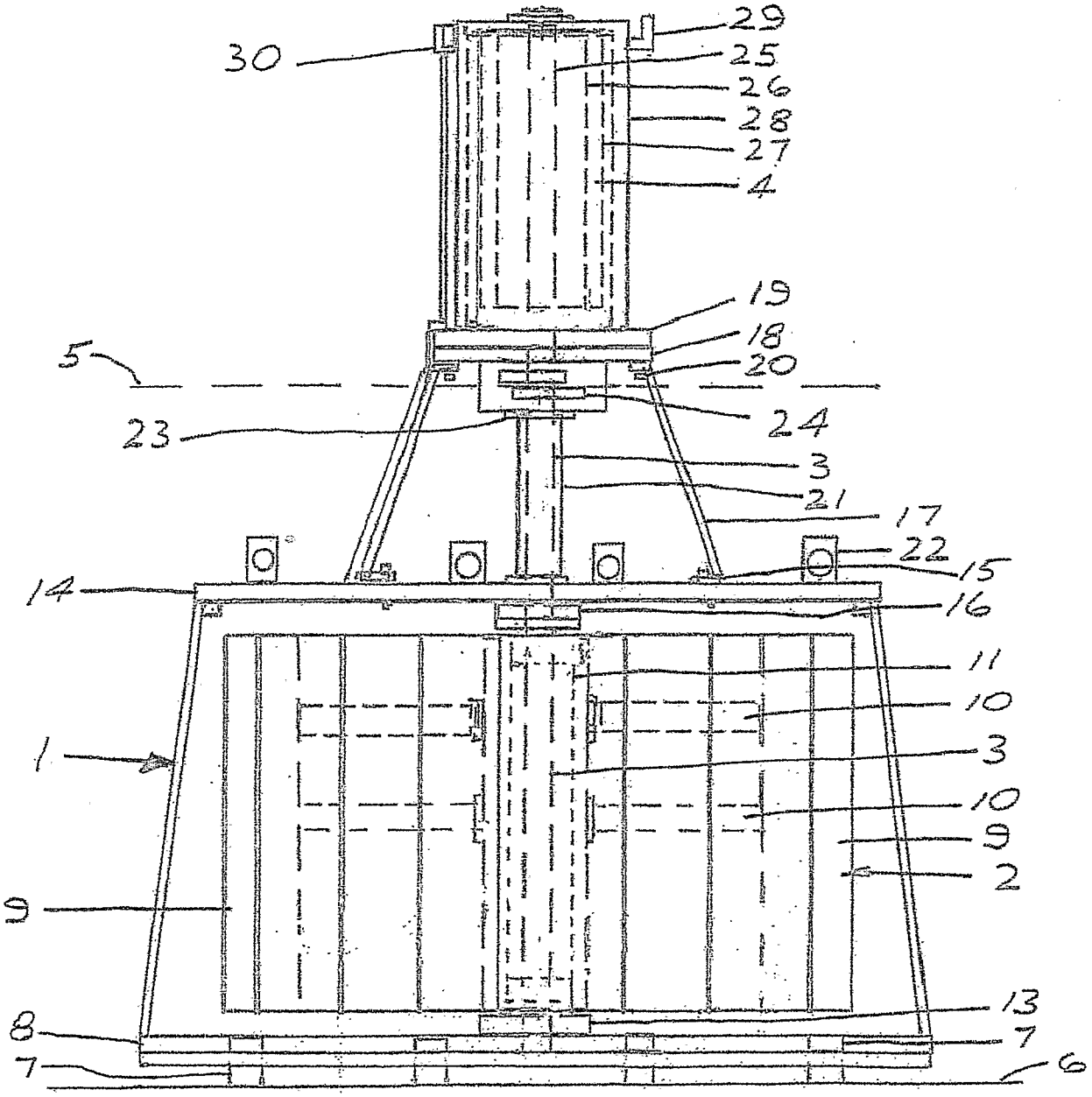

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FIG 1(a)

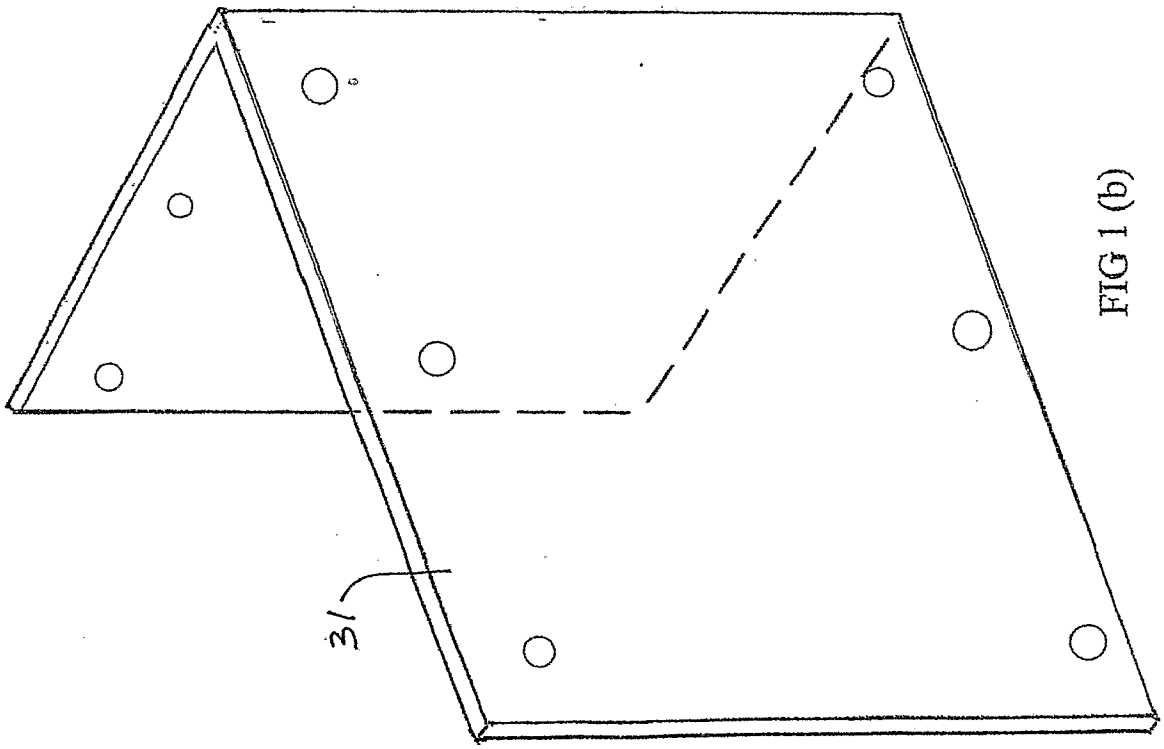

FIG 1 (b)

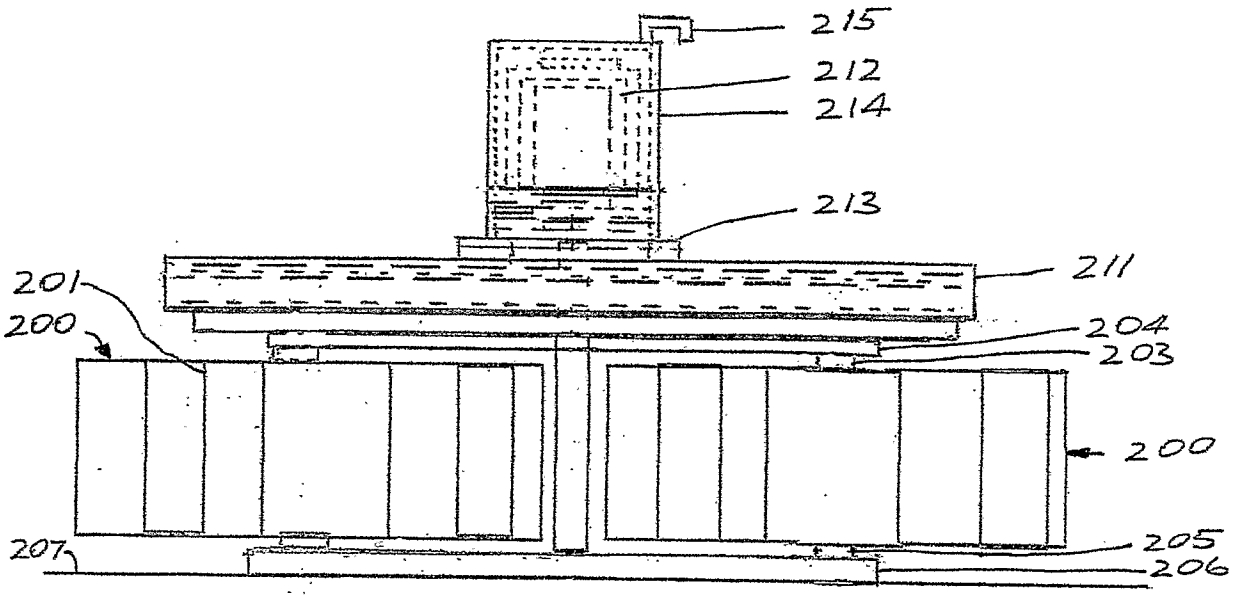
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FIG 2(a)

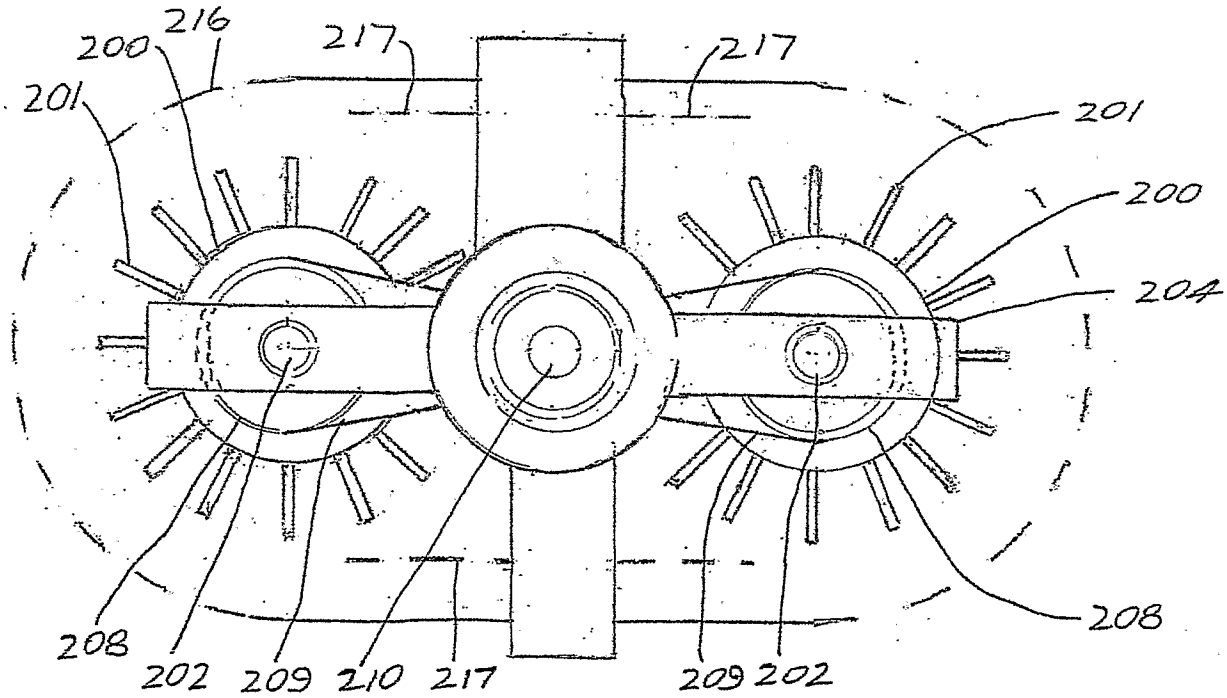
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FIG 2(b)

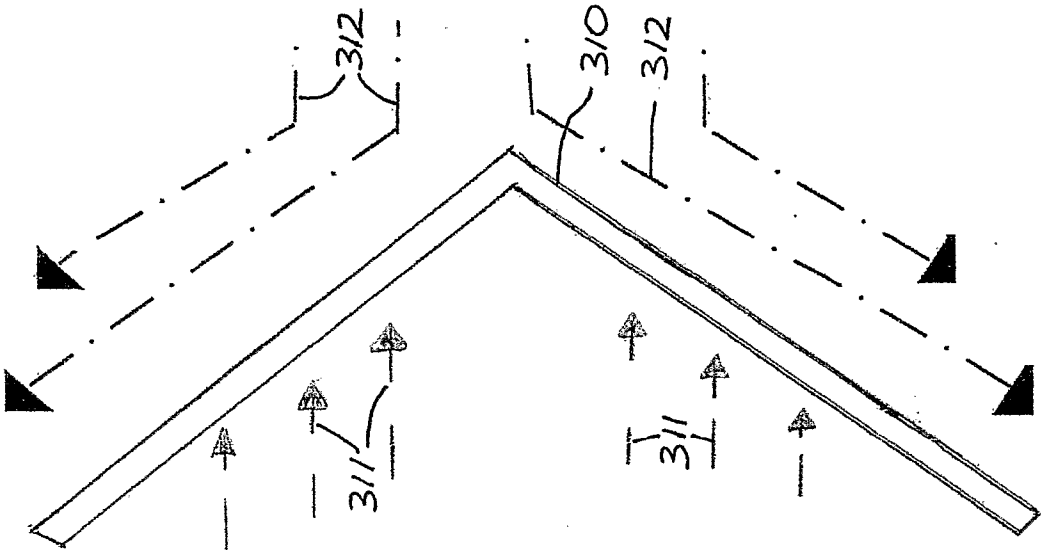

FIG. 3(b)

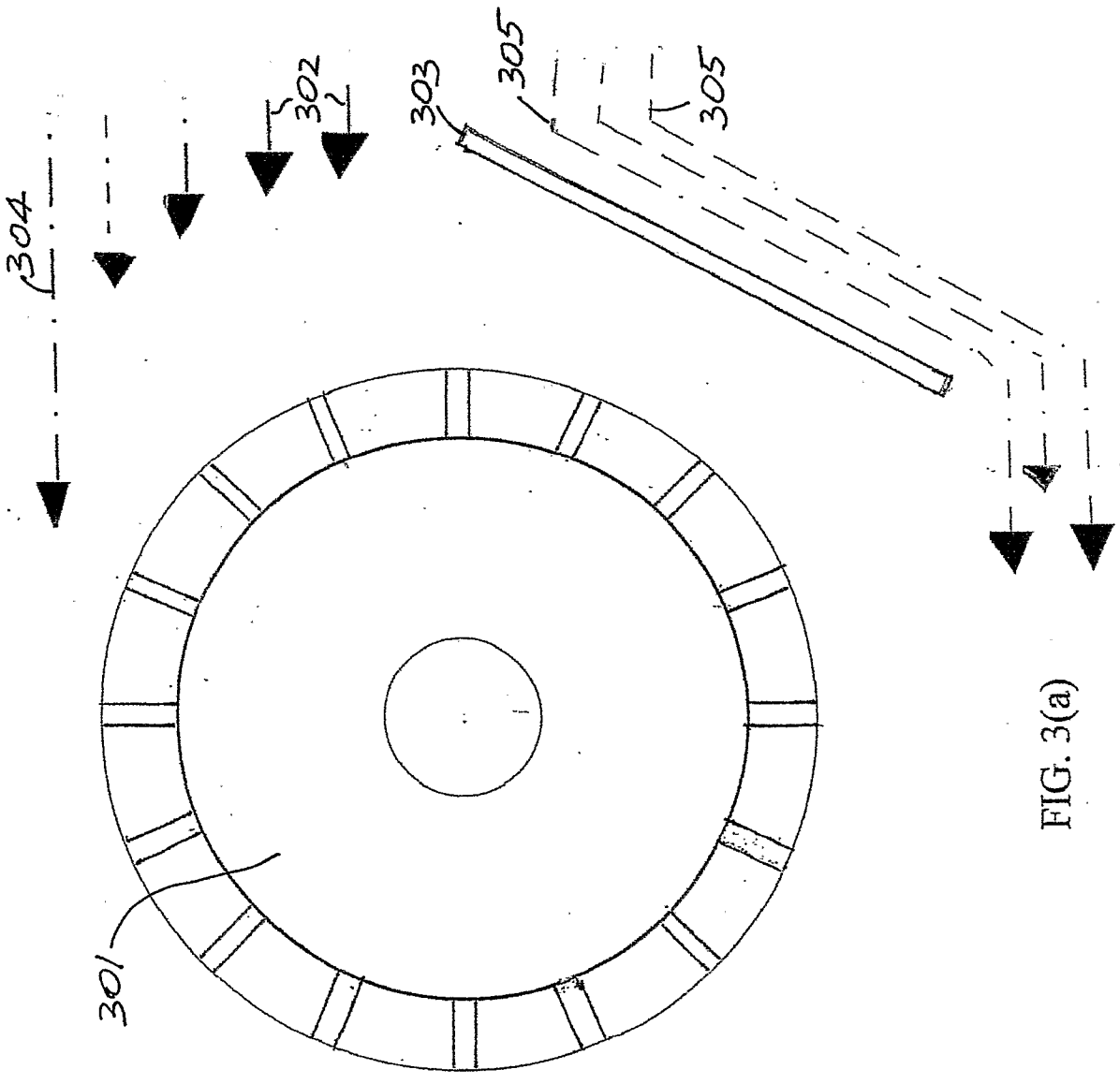

FIG. 3(a)

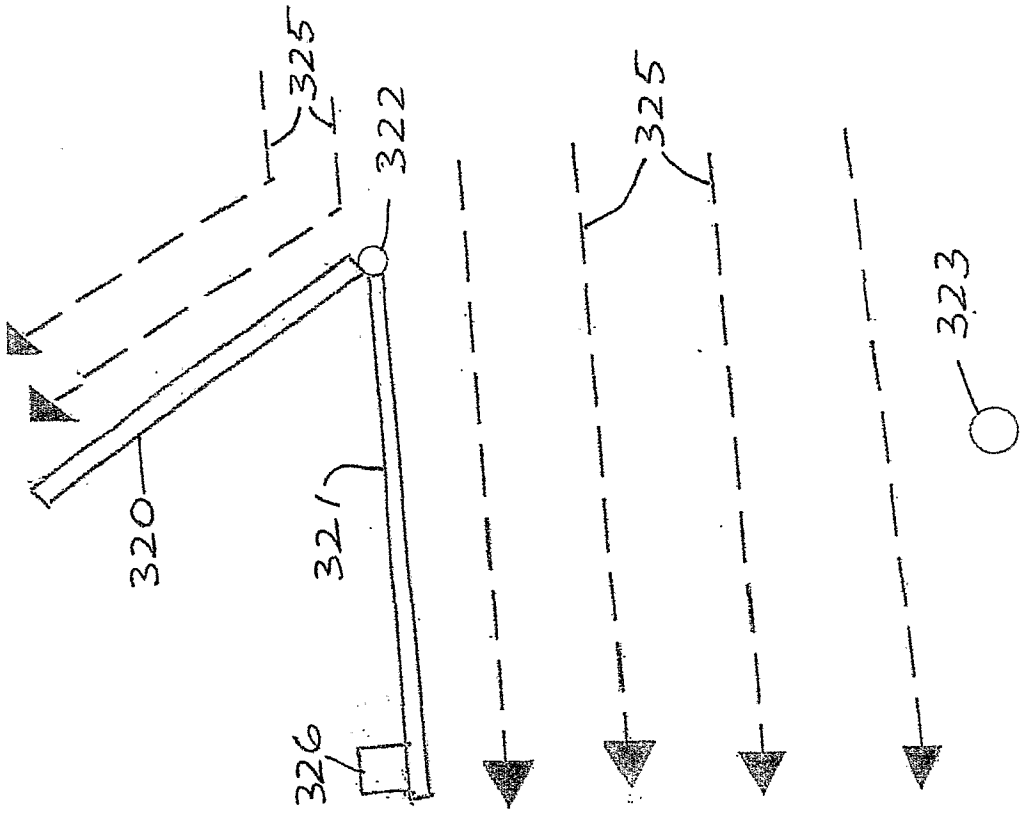

FIG 3 (d)

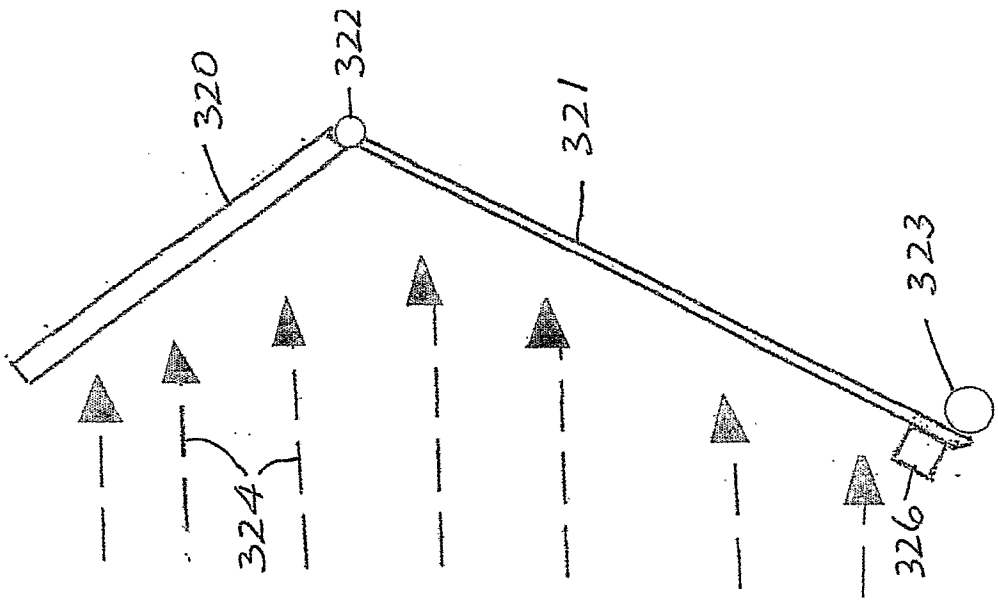

FIG 3(c)

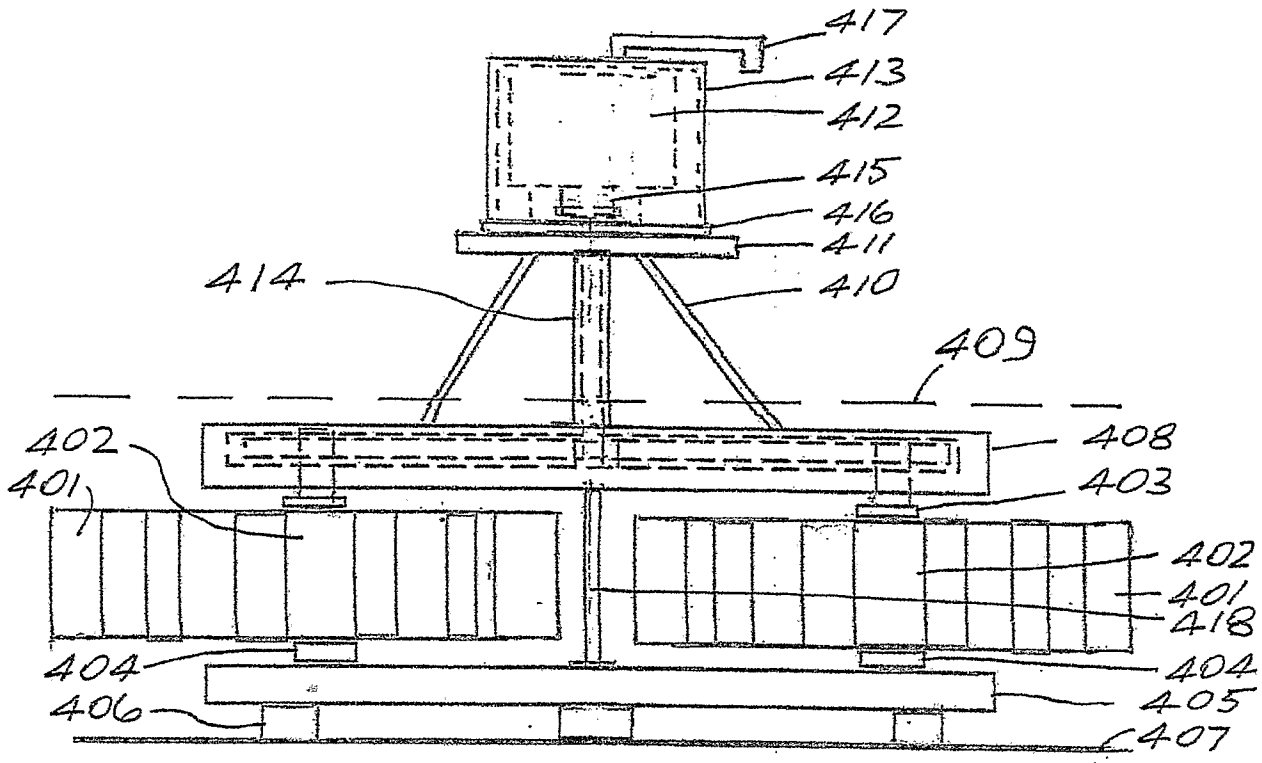
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FIG 4(a)

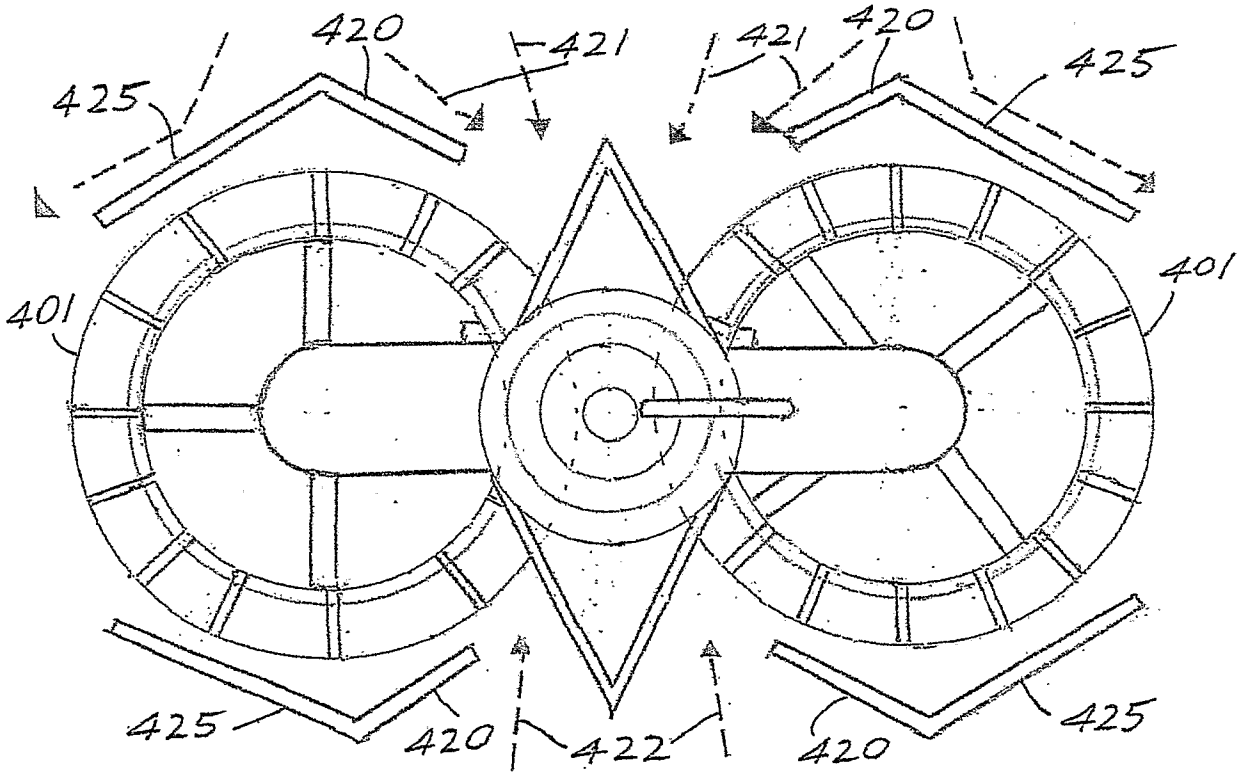
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FIG 4 (b)

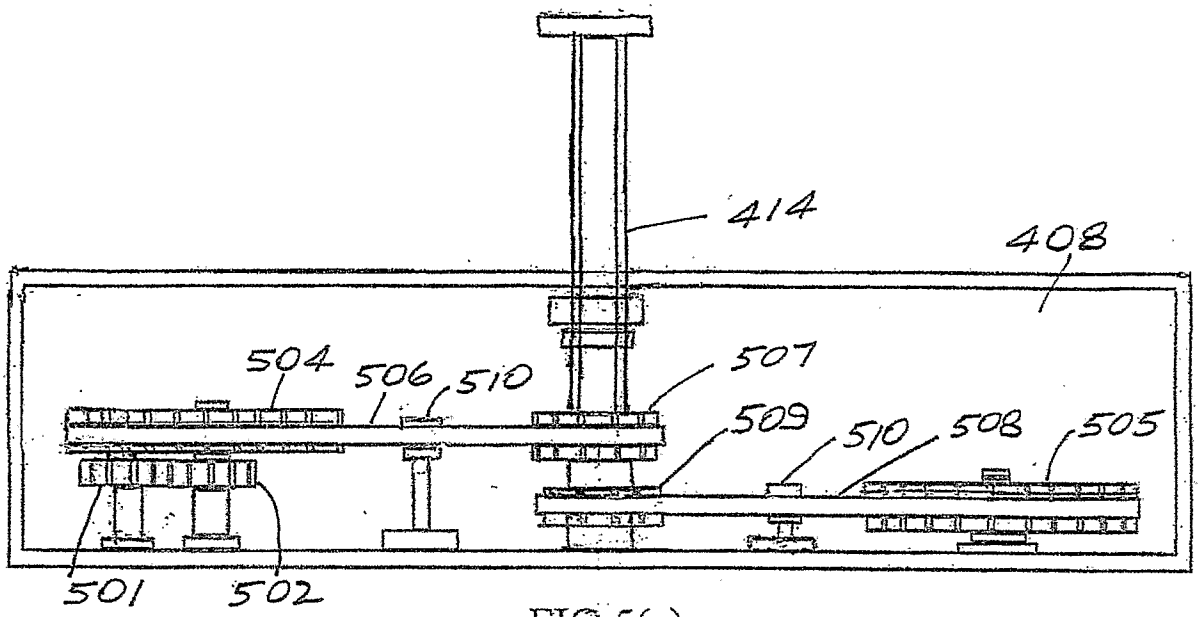
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FIG 5(a)

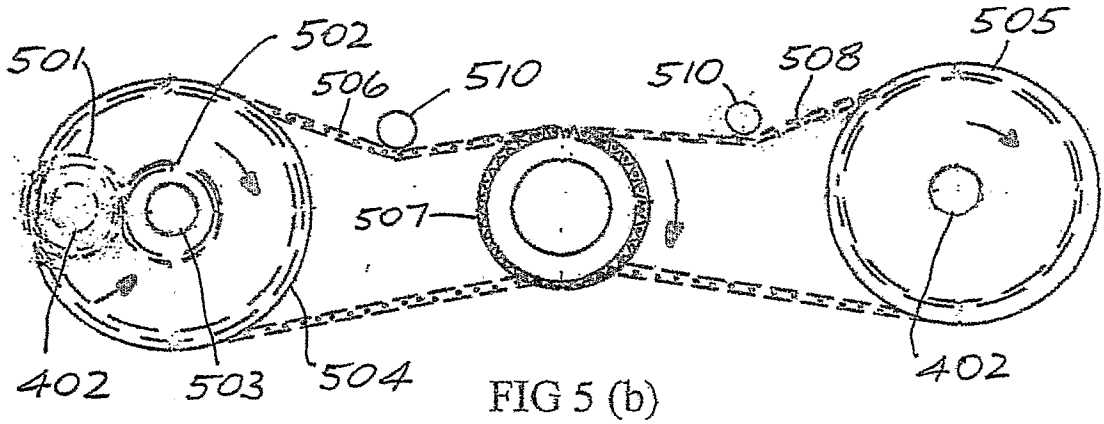
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FIG 5 (b)

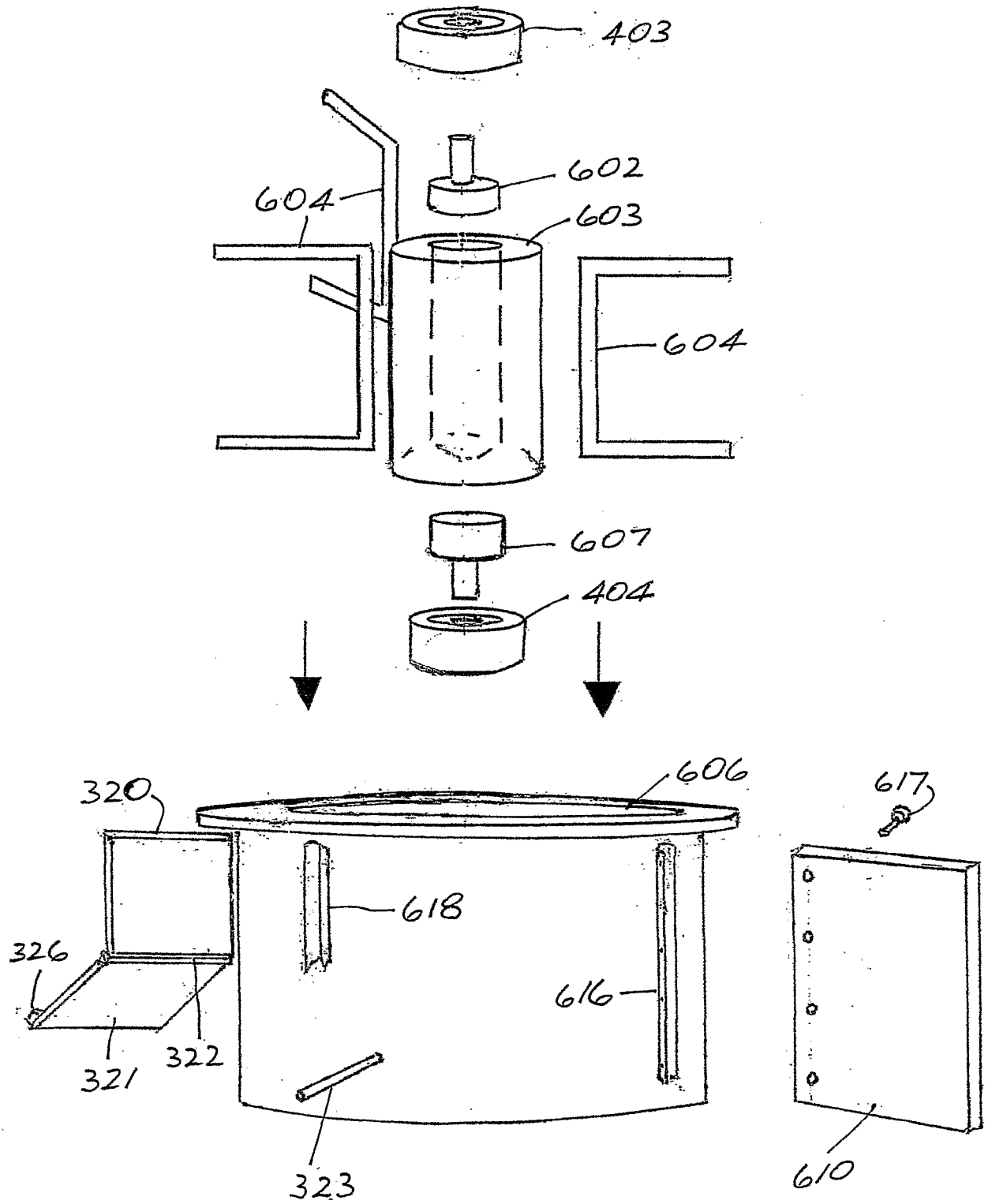
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FIG 6