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(19)日本国特許庁（ＪＰ）　　(12) 公開特許公報（A）　　(11)特許出願公開番号

特開平11－37033

(43)公開日　平成11年(1999) 2月9日

(51)Int.Cl.[6]　　識別記号　　ＦＩ
Ｆ０３Ｂ　13/26　　Ｆ０３Ｂ　13/26
17/06　　17/06

審査請求　未請求　請求項の数１　書面　（全 3 頁）

(21)出願番号　特願平9－231651

(22)出願日　平成９年(1997) ７月24日

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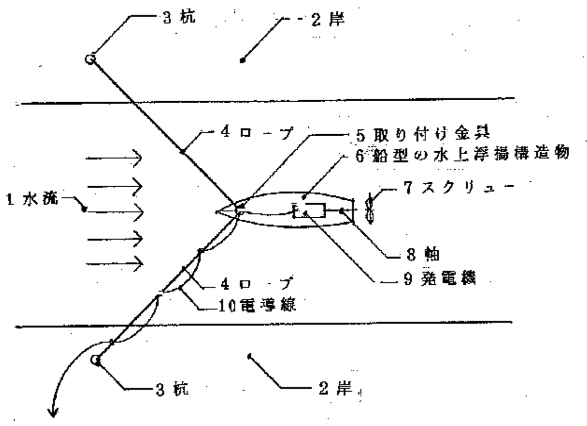
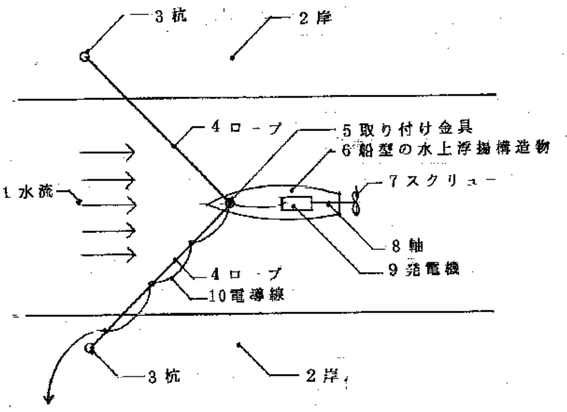
(54)【発明の名称】　船型の水力発電装置

(57)【要約】
【目的】発電時に公害が無く、簡易で安価な発電装置を提供する。
【構成】水流１の岸２に、杭３とロープ４で船型の水上浮揚構造物６を繋留し、スクリュー７によって、発電機９を作動させることを特徴とする。



【特許請求の範囲】
【請求項１】（イ）水流１の岸２に杭３を設置し、ロープ４を固定する。
（ロ）ロープ４で船型の水上浮揚構造物６を繋留する。
（ハ）船型の水上浮揚構造物６の船尾に付けたスクリュー７で回転力を得て発電機９で発電する。
以上のごとく構成された発電装置。
【発明の詳細な説明】
【０００１】
【産業上の利用分野】この発明は、船型の水上浮揚構造物を使用する水力発電装置である。
【０００２】
【従来の技術】従来、発電は水力、火力、原子力による方法や、太陽光、風力、潮力、地熱などのエネルギーによってきた。
【０００３】
【発明が解決しようとする課題】これらには次のような欠点があった。
（イ）従来の水力発電は、水中や護岸の構造が大規模でなければならなかった。また、大規模の発電には大河、高い落差が必要であり、発電所に適する河川は開発され尽くして新たな開発は困難であった。また洪水時の放流や土砂の堆積も困難な事であった。
（ハ）火力、原子力発電には公害が多く発生した。
（ニ）太陽光、風力発電では、装置の投資額に比して発電量が少なかった。
本発明は、これらの欠点を除くためになされたものである。
【０００４】
【課題を解決するための手段】いまこれを、図面について説明すれば、
（イ）水流１に船型の水上浮揚構造物６を繋留する。
（ハ）船型の水上浮揚構造物６の船尾に、スクリュー７を取りつけ、軸８を介し発電機９へ水流の動力を伝達して発電を行う。
【０００５】
【作用】この構造によって、船型の水上浮揚構造物６は水上に向かって安定した姿勢を保つので、船尾に水車又はスクリューを取りつければ、水流によって安定した運動エネルギーを得られるので、簡易な発電装置となる。
日
【０００６】
【実施例】以下、本発明の実施例について説明する。
（イ）水流１の岸２に杭３を設置し、ロープ４を固定する。
（ロ）ロープ４と金具５をつないで、船型の水上浮揚構造物６を繋留する。
（ハ）橋などの構造物から繋留することもできる。
（ニ）船型の水上浮揚高造物６の船尾にスクリュー７を取り付け、水流によって回転力を得、軸８を経て発電機９を作動させて発電する。
（ホ）発電された電力は導線１０を経て必要な電気設備へ供給する。
【０００７】
【発明の効果】水中や護岸に大規模な構造物を必要とせず、簡易な発電装置となるので、小規模な発電が容易である。また、数多く並べることも出来るので、安価であるから数を増やすことによって大規模発電所に匹敵する電力を発電することも出来る。多数の装置を並列縦列に並べる事も容易である。水上に浮揚しているので、水面の上下や水量の増減等の変化に対し、自在に対応する事が出来る。他の自然エネルギー利用の発電装置である風力発電や、太陽光発電に比較すれば、非常に安価に十分な電力が得られる。従来の大規模火力発電や原子力発電のような大規模公害が発生しない。日本の本のような大規模な水力発電が可能な河川はほぼ開発されてしまった国では、小さな流れもエネルギーとして利用できることは、非常に重要であるし、火力や原子力のように大規模な公害が発生しない事は、地球環境に対しても貢献するものである。また小規模河川が多い国には特に適しており、用水路のような狭い水路では多数の装置を並列、直列にした複数の発電はさらに適している。
【図面の簡単な説明】
【図１】本発明の平面図である。
【符号の説明】
１水流
２岸
３杭
４ロープ
５取り付け金具
６船型の水上浮揚構造物
７スクリュー
８軸
９発電機
１０電導線

【図１】



【手続補正書】

【提出日】平成９年１０月２８日

【手続補正１】

【補正対象書類名】明細書

【補正対象項目名】発明の名称

【補正方法】変更

【補正内容】

【発明の名称】　船型の水力発電装置

PATENT SPECIFICATION

Inventors: GEOFFREY WILLIAM HARGREAVES and GORDON HACKWORTH STUART

807,281

Date of filing Complete Specification: Aug. 2, 1957.

Application Date: May 4, 1956. *No. 13952/56.*

Complete Specification Published: Jan. 14, 1959.

Index at acceptance:—Class 69(1), M.

International Classification:—F03c.

COMPLETE SPECIFICATION

Apparatus for Deriving Power from the Up and Down Motion of a Boat or other Floating Object

I, MINISTER OF SUPPLY, London, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for deriving power from the up and down motion of a boat or other floating object due to the waves or swell.

According to the invention a device for suspension in the water below a boat or other supporting float for use in deriving power from the up and down motion of the latter, comprises at least two vanes and a mounting to which they are attached pivotally so that when the device is suspended vertically beneath the float the vanes are able to swing upwardly about their pivots through less than ninety degrees from "open" positions in which they are substantially horizontal, to "closed" positions in which the vanes are inclined each at a small angle to the vertical, and *vice versa*, so that the vanes tend to close as the float moves downwardly and to open and so bring about a pull on the float as the latter moves upwardly.

Preferably, the mounting comprises a stem which is more or less upright when the device is in use and has the vanes attached pivotally thereto at its lower part.

Preferably, also this stem has slidable therealong a collar from which pivotted links extend to the vanes at points remote from their pivots, and there is also threaded over the stem a coiled compression spring which tends to urge the collar upwardly and so close the vanes. Such spring may be fully closed up when the vanes are fully open and so act as a step limiting their movement in the opening direction.

A device in accordance with one form of the invention is illustrated by the accompanying diagrammatic drawings which are not to scale and of which:—

Figure 1 shows the device in elevation with the vanes open in full lines and closed in broken lines; and

Figure 2 is a corresponding plan view.

In this example, a mounting is constituted by a rod-like stem 11 with a rectangular head 12 at its lower end and an eye 13 (not shown in Figure 2) at its upper end for attachment to a suspension cable indicated at 14 in Figure 1. The head 12 has two pairs of lugs 15, 15 and 16, 16 through which and the curled over inner ends of two vanes 17, 18 extend two hinge pins 19, 20. These vanes are formed with bent-up flanges 21, 21 and 22, 22.

Threaded over the stem 11 is first a lower fixed collar 23, then a coiled compression spring 24, then a sliding sleeve 25, and lastly an upper fixed collar 26. The sleeve 25 has apertured radial lugs 27, 28 at its upper end through which extend the bights of two "U"- or "V" shaped links 29, 30, whose free ends are bent outwardly and extend through apertures formed to receive them in the upturned flanges 21, 21 and 22, 22 of the vanes 17 and 18, respectively.

Normally, or when no external forces, or only upward forces act on the vanes 17 and 18 they assume under the influence of the coiled compression spring 24 the closed positions indicated in broken lines in Figure 1. They occupy this position in use when the boat or other supporting float from which the device is suspended is moving downwardly.

When, however, a downward force acts on the vanes as when the boat or other float is moving upwardly on a wave the vanes move against the influence of the spring 24 to the open position (full lines Figure 1 and Figure 2) substantially increasing the drag or resistance of the device to movement through the water, and a substantial tension is applied to the cable 14. The spring 24 tends always to close the vanes as the boat or float reaches the top of each upward motion and in use ensures that they shall be closed as soon as possible after, or even just before, the commencement of each downward motion of the boat or float. In general the weight of the device will be such that it tends to sink more rapidly than the boat or float is ever likely to move downwardly, with a view to avoiding undue slackening and subsequent snatching of the cable 14.

The vanes employed may be of different shape from that shown—for example elongated or semi-circular vanes may be hinged each along a longer side or the diametral edge to the mounting. Also more than two vanes may be employed.

It will be apparent that the repeated tensioning of the cable or rod by which the device is suspended may be utilized in various ways, e.g., to operate a ratchet mechanism. In one application, successive pulls would be used repeatedly to deflect against spring-influence the flexible diaphragm of a diaphragm pump in a life boat or other survival craft for operating a sun still to obtain drinking water from the sea.

WHAT I CLAIM IS:—

1. A device for suspension in the water below a boat or other supporting float for use in deriving power from the up and down motion of the latter, comprising at least two vanes and a mounting to which they are attached pivotally so that when the device is suspended vertically beneath the float the vanes are able to swing upwardly about their pivots through less than ninety degrees from "open" positions in which they are substantially horizontal, to "closed" positions in which the vanes are inclined each at a small angle to the vertical, and *vice versa*, so that the vanes tend to close as the float moves downwardly and to open and so bring about a pull on the float as the latter moves upwardly.

2. A device as claimed in claim 1, wherein the mounting comprises a stem which is more or less upright when the device is in use, and has the vanes attached pivotally thereto at its lower part, and wherein this stem has slidable therealong a collar from which pivotted links extend to the vanes at points remote from their pivots, and there is also threaded over the stem a coiled compression spring which tends to urge the collar upwardly and so close the vanes.

3. A device as claimed in claim 2, wherein the spring is fully closed up when the vanes are fully open and so acts as a stop limiting their opening movement.

4. A device for suspension in the water below a boat or other supporting float for use in deriving power from the up and down motion of the latter due to waves or swell substantially as hereinbefore described with reference to the accompanying diagrammatic drawings.

A. L. BING,
Chartered Patent Agent,
Agent for the Applicant.

PROVISIONAL SPECIFICATION

Power Drogue or Wave Reaction Motor

I, MINISTER OF SUPPLY, London, do hereby declare this invention to be described in the following statement:—

A mechanical device enabling lift-energy derived from wave-motion at sea to be made available for useful work on a floating platform by creation of rhythmic surges of tension in the cable or rod attaching the device to the floating element, the energy available being related to the frequency, velocity, height and profile of the wave-pattern obtaining at any given time.

A. L. BING,
Chartered Patent Agent,
Agent for Applicant.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1959.
Published by The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

807281 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

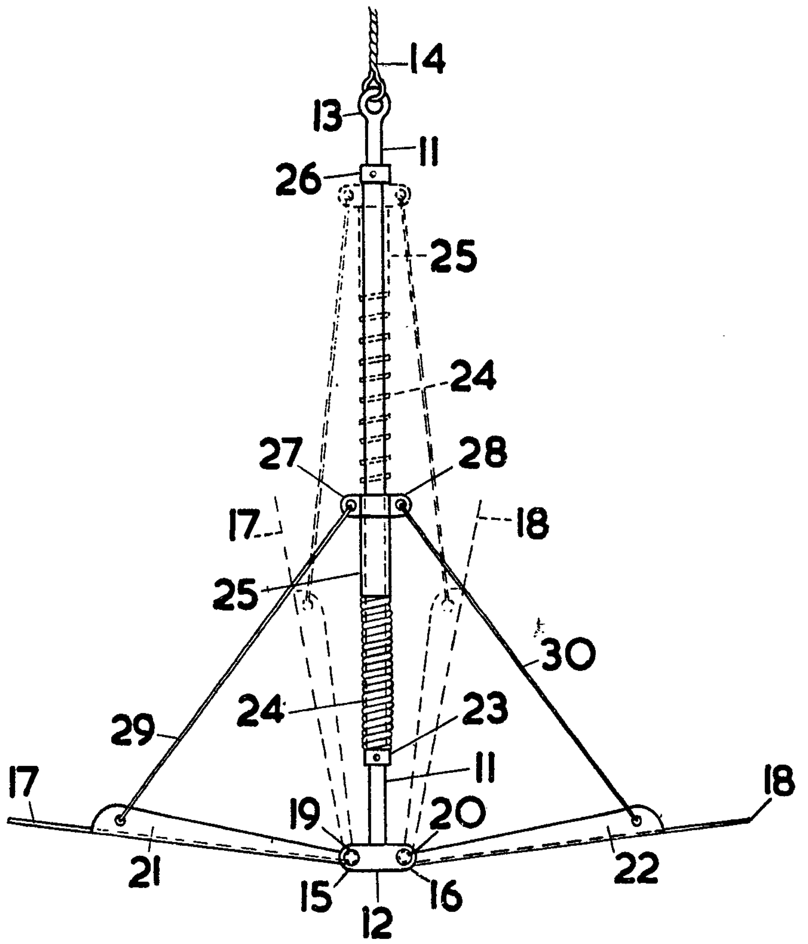


FIG. 1.

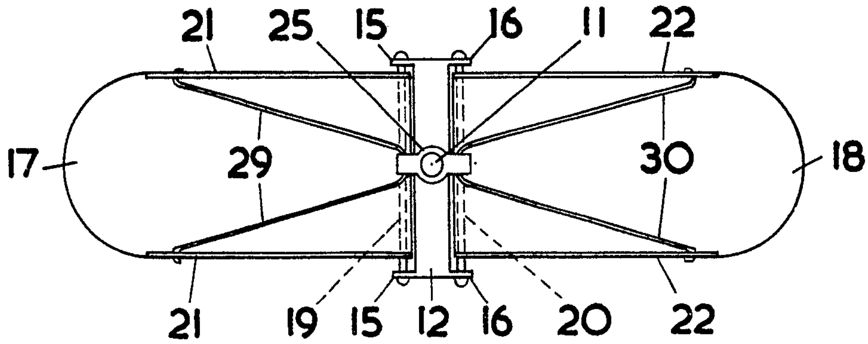


FIG. 2.

United States Patent [19]
Jones

[11] **4,313,716**
[45] **Feb. 2, 1982**

[54] **ARTICULATED, ENERGY CONVERTING STRUCTURE**

[75] Inventor: **Asberry B. Jones,** Slidell, La.

[73] Assignee: **Texaco Inc.,** White Plains, N.Y.

[21] Appl. No.: **37,619**

[22] Filed: **May 10, 1979**

[51] **Int. Cl.**³ **F04B 17/00;** E02B 9/08

[52] **U.S. Cl.** **417/331;** 417/526; 417/527; 417/469; 60/500; 60/505; 60/506

[58] **Field of Search** 417/53, 331, 332, 330, 417/333, 469, 526, 527; 60/497, 505, 506, 500, 501; 290/42, 53

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1542251	3/1979	United Kingdom	60/506

Primary Examiner—Richard E. Gluck
Attorney, Agent, or Firm—Carl G. Ries; Robert A. Kulason; Robert A. Burns

[57] **ABSTRACT**

An articulated marine structure for an offshore body of water which is subject to wave movement. The structure includes at least two floating elements which are pivotally joined along a common edge to permit relative movement between the respective elements in response to wave action. An energy accumulator is operably connected to the respective floats, and is actuated by movement of either float whereby to initiate conversion of wave energy into an alternate, usable energy form.

2 Claims, 5 Drawing Figures

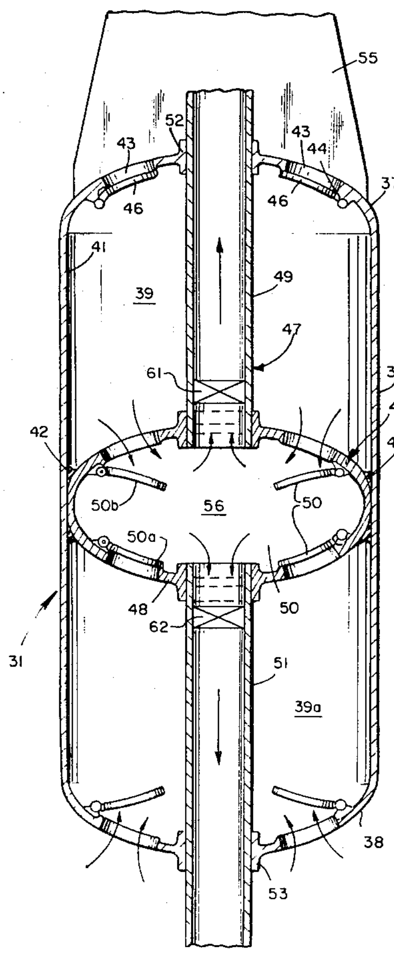

FIG. 1

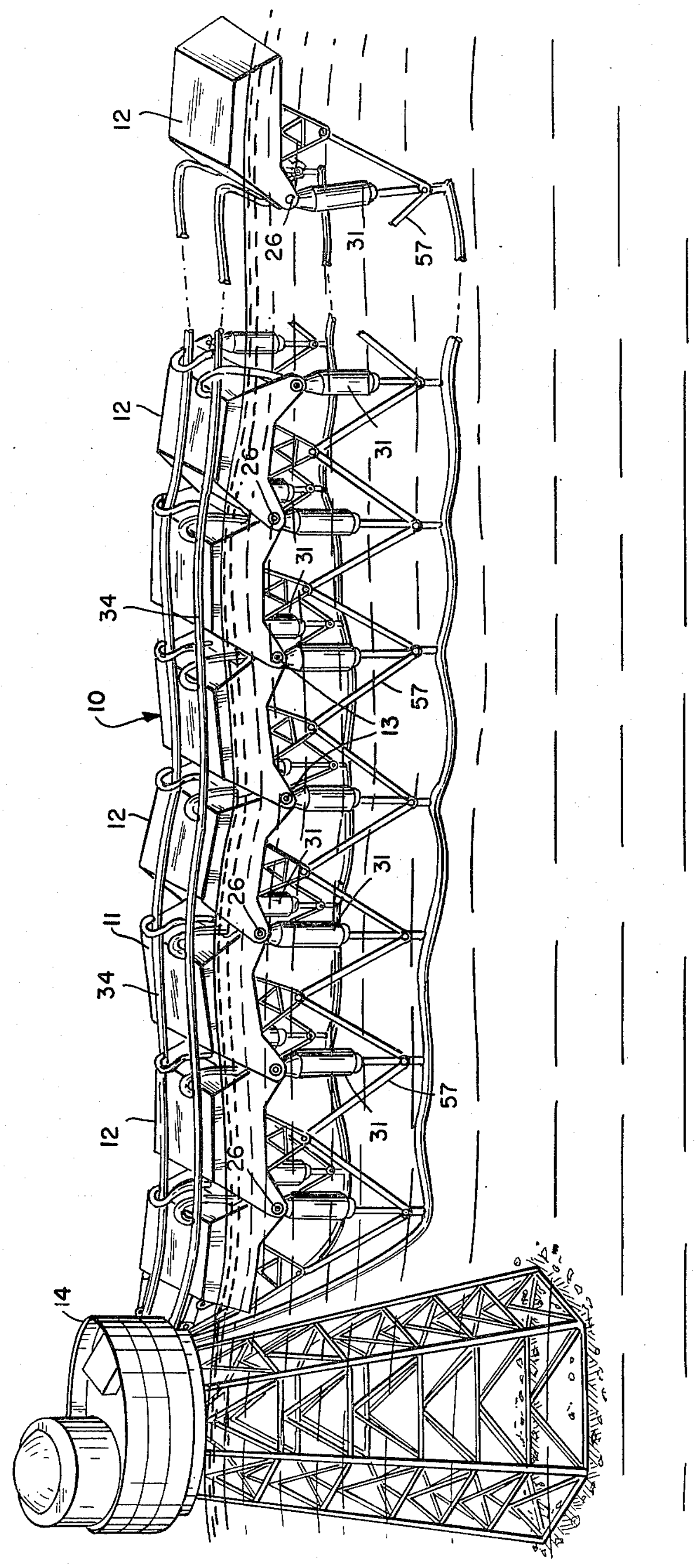

FIG. 2

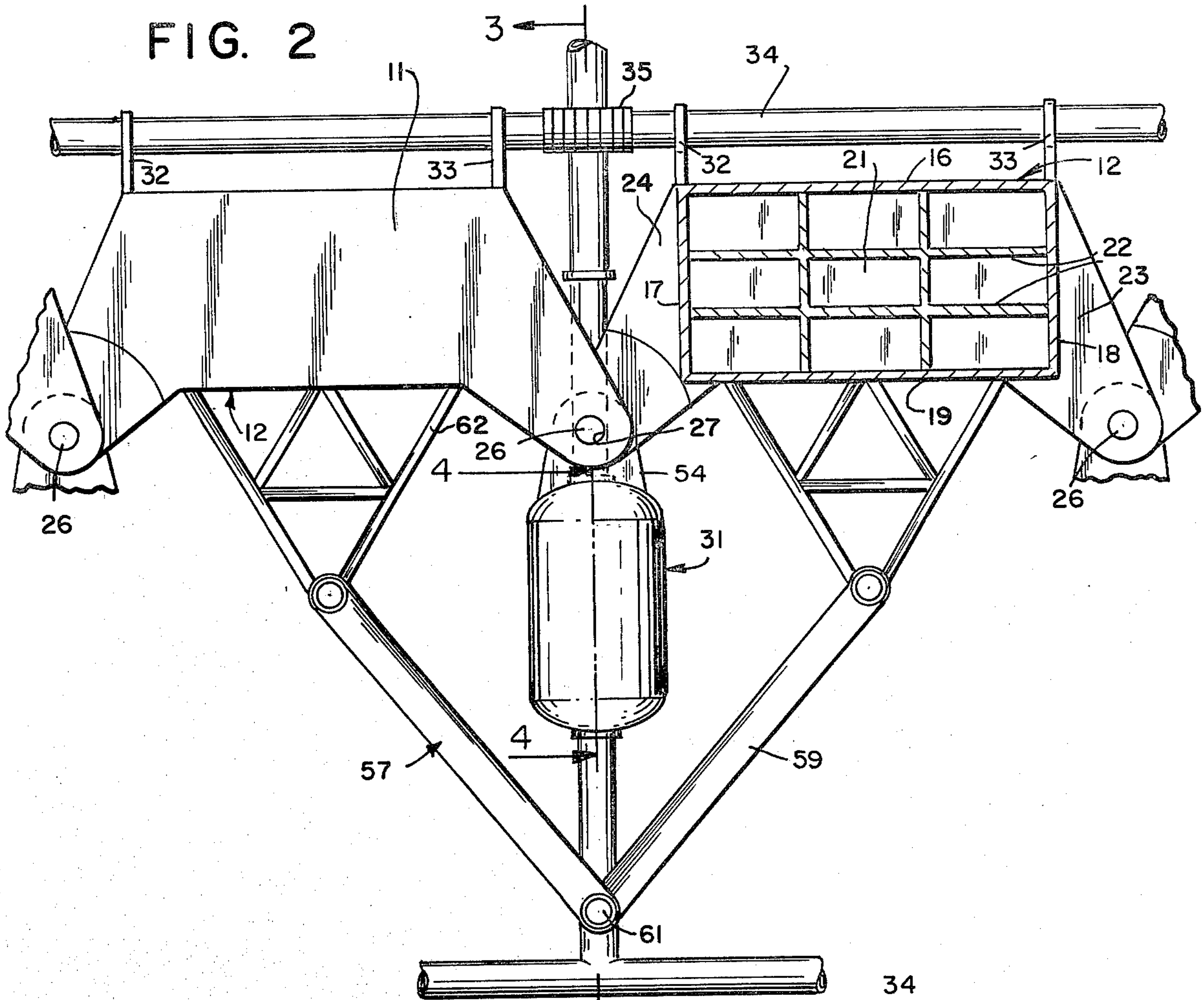
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FIG. 2A

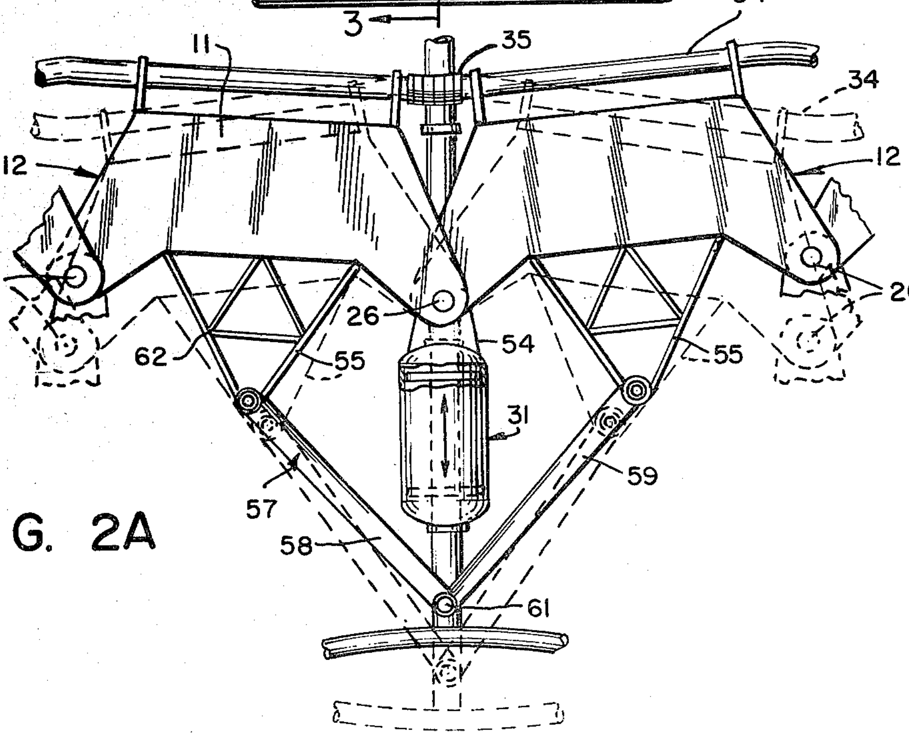
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FIG. 3

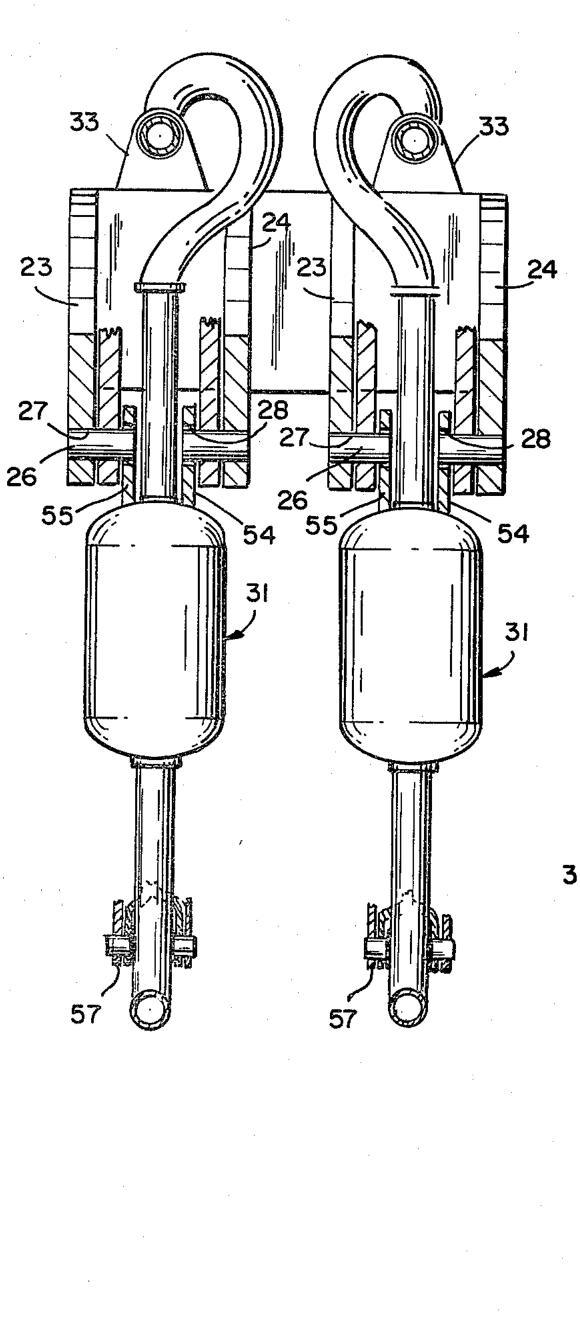
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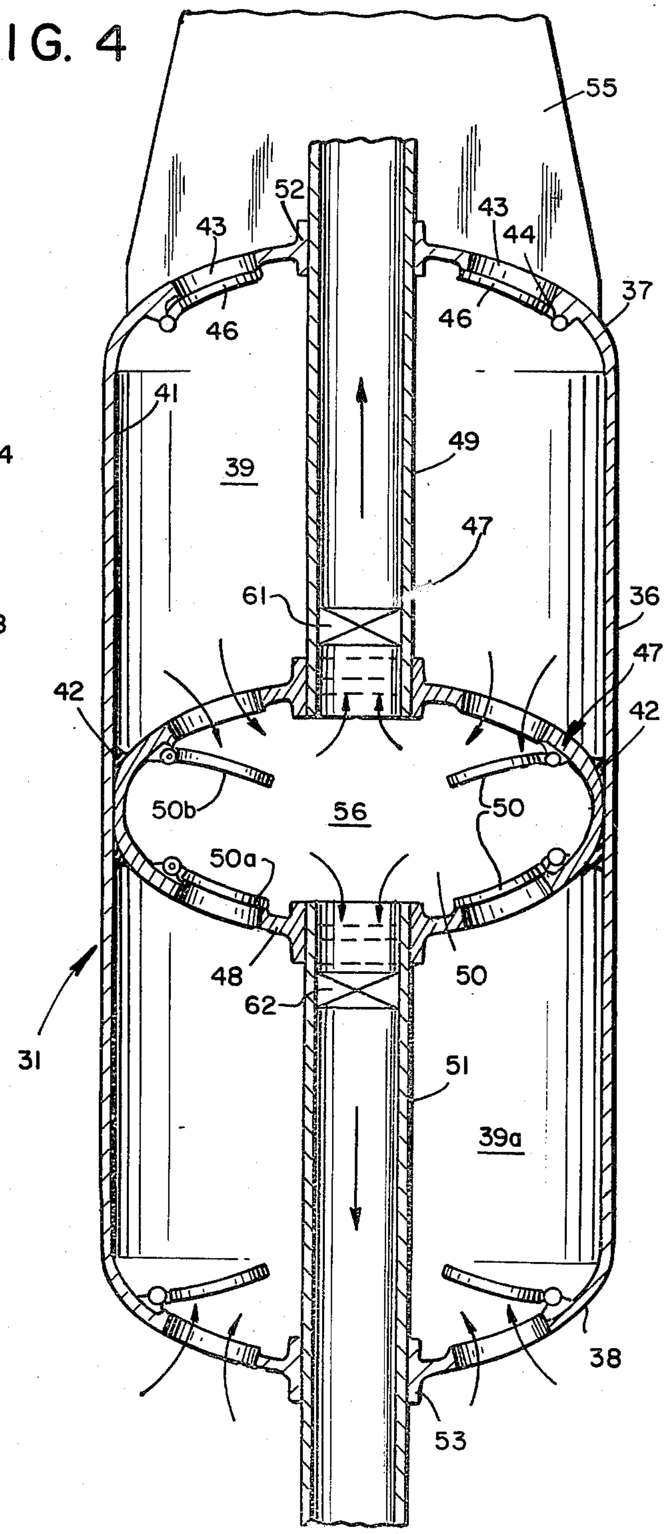
FIG. 4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ARTICULATED, ENERGY CONVERTING STRUCTURE

BACKGROUND OF THE INVENTION

The perpetually moving seas constitute an unlimited source of potentially usable energy. Such a source is conceivably available for use without fear of depletion. Further, the endless motion and the moving waters, particularly those adjacent to a shore, represent vast amounts of potential power if it can be harnessed and controlled.

While this readily available energy is presently extracted and utilized to a minor extent, the major portion remains unharnessed. Once a wave washes onto a shore, its potential energy is, for all practical purposes, dissipated.

Toward capturing at least some of this otherwise lost energy represented by an ocean's wave motion, the present system is provided. The instant system thus comprises a safe and relatively desirable means for constantly monitoring and extracting at least a portion of the ocean's wave power. Without such extraction, the power would be completely dissipated by waves breaking on the shore, and lost.

The wave conversion system herein described functions basically in a floating attitude at the water's surface. Operably, it comprises at least two, and preferably a series of floats, adjacent of which are pivotally connected along a common edge.

Relative pivotal movement between said adjacently hinged units in response to a wave passing thereunder is translated into physical movement. The latter in turn actuates a motion accumulator. Thereafter, said accumulations can be immediately converted into a usable energy form, or transmitted to a central accumulator for conversion to an alternate energy form.

It is therefore an object of the invention to provide means for harnessing potential power represented by wave movement at an ocean's surface. A further object is to provide means for continuously monitoring and extracting potential power as the wave moves toward a shore. A still further object is to provide a floatable, articulated marine structure which is capable of responding to movement of an offshore body of water and converting such movement into a usable energy form.

DESCRIPTION OF THE DRAWINGS

In the drawings

FIG. 1 represents an environmental sketch of the present system anchored at an offshore body of water.

FIGS. 2 and 2A are enlarged sectional views of a portion of FIG. 1.

FIG. 3 a segmentary view in partial cross section showing a portion of FIG. 2.

FIG. 4 is an enlarged segmentary view in cross section taken along line 4—4 in FIG. 2.

The basic objectives of the invention are achieved by providing an articulated marine, raft-like structure which is capable of floatably supporting itself in an offshore body of water. The structure includes a plurality of members such as discrete rafts which are positioned in such manner as to limit displacement thereof in the water. Said members, however, are mutually connected one to the other, in a way that permits limited pivotal movement between adjacent units.

Energy conversion or accumulator means carried on the floating structure are actuated in response to relative pivotal movement by adjacent floating members. Thus, as a wave passes beneath the respective floating members, the latter will each be sequentially displaced in response to the wave's buoyant force. The resulting movement is converted to an alternate form of energy such as hydraulic, electrical, or otherwise.

In one embodiment of the present system, an example of the floating raft presently contemplated, is shown in FIG. 1. The elongated, articulated, marine structure **10** is positioned in a tethered, floating attitude. The structure comprises in essence a series of individual floats or floating members **11** and **12**, each of which is operably engaged with the next adjacent float. The engagement is preferably achieved by way of a suitable means such as a hinge assembly **13**, disposed along a common edge. The latter permits independent, though limited movement of the raft.

Illustrative of the present tethered concept, one end of structure **10** is anchored to a fixed unit such as a piled-in structure or tower **14**. Thus, the individual floating members or rafts **11** and **12**, are free to swing as a unit about the fixed structure **14** in response to a variation in the direction of wave travel.

In an alternate embodiment, the power generating equipment can be disposed within the confines of the respective floats **11** and **12**. Such an arrangement suggests certain conversions which would eliminate or reduce long connecting lines.

It is appreciated that changing of the direction of water flow caused by tide reversal or other natural phenomena, will contribute to the positioning of the floating raft assembly **10**. However, the primary factor which normally regulates water movement is the wind direction at the water's surface.

Normally a floating raft **10** of the type contemplated would be anchored with its fixed end offshore and the raft streaming in a direction toward the shore, or in the direction of prevailing winds. Thus, as each progressive wave approaches the shore it passes beneath each float to sequentially elevate and lower the units **11** and **12**.

The respective float members or elements **11** and **12** are relatively simple in construction. In one embodiment they comprise a metallic rectangular configuration adapted to float at the water's surface. Referring to FIG. 2, each of said floats, **12** for example, comprises an upper deck **16** which is supported by sides **17** and **18**. A lower floor **19** is connected to the respective sides to define an inner buoyancy compartment **21**. The respective members of the float are sealably joined to maintain the water tight integrity of compartment **21**. The latter can be provided with internal support braces **22** which are suitably disposed to reinforce the unit.

Each adjacent side of the respective floats is provided with downward extending hinge projections such as **23** and **24**. The latter are adapted to accommodate one or more hinge elements such as a pin or shaft **26**. Thus, each projection **23** and **24** is further provided with a suitable journal or hinge pin opening **27**. The hinge assembly **13** comprises a plurality of short pin-like members. Alternately it can comprise a unitary elongated shaft-like member which extends across the entire float.

In conjunction with accumulator **31**, float **12** upper deck is provided with a plurality of spaced apart conduit supports **32** and **33**. Said supports function to maintain a fluid carrying line or conduit **34** in place, even during the most violent or erratic motion of the float members.

Since the float members will be in a virtually constant state of movement, line **34** can be provided with a degree of flexibility. However, said line **34** can also be provided with a rigid construction having a series of flexible segments **35** which are capable of twisting and turning as the float movement dictates. These segments would serve to communicate the respective fixed, rigid portions of line **34**.

The number of said feed conduits **34** which are carried along deck **16** is determined primarily by the number of energy converter units **31** employed. In any event, said feed conduits **34** extend for the length of the upper surface of the structure **10** and terminate at the anchored platform **14**.

When a conduit **34** terminates at an accumulator or similar converter on the platform **14**, the conduit usually functions to conduct a pressurized stream of water to the latter. Said stream of water usually is under a sufficient head of pressure to permit the accumulation to be fed to a turbine or similar apparatus for generating electrical energy or the like.

Each pair of adjacent floats **11** and **12** is provided with a single, or preferably with a plurality of transversely arranged accumulator units **31**. Further, the number of accumulators **31** which can be utilized between each pair of floats **11** and **12** will vary depending on the actuating capability of the floats, as well as on the space available.

In one embodiment of an accumulator **31** usable in the instant device, and as illustrated in FIG. **4**, the fluid moving unit comprises a pump having a fixedly positioned first element, which operably receives a second, or movable element. As shown in FIG. **1**, pump **31** is adapted to function in a submerged position beneath hinged rafts **11** and **12**. The pump **31** is thus formed of a suitable metallic material or a fiberglass reinforced resin, which will resist deterioration due to the normal problems presented by operating in a salt water environment.

Referring to FIG. **4**, pump **31** includes primarily elongated cylinder or casing **36** having a dished head **37** and **38** fitted to each end. A pump chamber **39** is thereby defined between the respective ends. The chamber **39** inner wall **41** is sufficiently smooth to slidably accommodate the peripheral edge of seal member **42** thereagainst while forming a substantial fluid tight seal therewith.

Each casing end wall, **37**, for example, is further provided with one or more valves **43**. Said flow control members are preferably check valves, and more preferably a plurality of the latter, spaced about the head **37**. These valves are so positioned to permit a unidirectional flow of water into chamber **39**. As shown, each of the valves **43** is defined by a valve port **44** and a valve cover **46** which is hinged adjacent to the port. Thus, cover **46** will be displaced inwardly in response to water pressure on the outer side thereof, as pump piston **47** is moved longitudinally through chamber **39** and away from head **37**.

Elongated pump piston **47** is slidably carried in the pump chamber **39** to be guided along the inner wall **41** thereof. The central plunger **48** is disposed in a manner that axially extending guide rods **49** and **51** are journalled at the respective end walls **37** and **38** in the closed ends of chamber **39**.

In one configuration and as shown, pump piston **47** comprises coaxially arranged cylindrical shafts **49** and **51**. These not only carry a flow of water therethrough, but are slidably registered within bearings **52** and **53** at the head ends. The respective guide rod ends are journalled to permit longitudinal movement of the piston as water is drawn into an end in response to movement of floats **11** and **12**.

Piston plunger **48** comprises opposed dished members which are joined at their edges to define an inner compartment **52**. Each plunger wall is provided with one, and preferably a plurality of check valves **50**, **50*a*** and **50*b***. Said valves are inwardly displaceable to permit liquid flow into compartment **56** from chamber **39**, as the piston is urged toward an end wall.

As noted, the outer peripheral edge of piston **48** is provided with a sliding seal member **42**. Thus, chamber **39** is divided into two distinct variable sized compartments as piston **47** is moved through chambers **39**–**39*a***.

To properly position pump **31**, pump casing **36** includes mounting brackets **54** and **55** which depend from one end thereof. Said brackets are adapted to be fastened to the respective floats **11** and **12**, at a point adjacent to the common hinged edge **13**. Preferably fastening of pump **31** is made at the hinge pin assembly **26**.

As shown, said mounting brackets **54** and **55** are positioned by virtue of ring bearings **56**. The latter are adapted to slidably register on hinge pin **26** thus to permit a degree of movement of pump **31** as floats **11** and **12** adjust their relative positions.

When properly positioned, pump **31** is free to oscillate or adjust about its mounting brackets **54** and **55** in response to movement of either of the floats **11** or **12**. However, because of its relationship to the latter members, casing **36** will remain relatively constant with respect to the hinge point.

Functionally, as accumulator **31** is actuated in response to movement of the adjacent floats **11** and **12**, piston plunger **48** will be urged through pump chamber **39**. To facilitate movement of piston plunger **48**, each float is provided with a linkage structure **57** which extends downwardly from the floor of the float. In one embodiment, each linkage structure comprises equilength arms **58** and **59** which extend from each float to a common juncture point **61** at the piston end.

Linkage **57** is further positioned by a downwardly extending structure **62**. Said structure depends from the lower side of each float a sufficient distance to allow actuation of piston **47** within the limits of chamber **39**.

Functionally, in response to wave movement, adjacently hinged rafts **11** and **12** will pivotally move about hinge assembly **13**. As the piston **47** advances toward end wall **38**, water will be drawn into chamber **39*a*** through valves **43**.

Concurrently, check valves **46** will be forced open, while **53*a*** are forced to closed position. Water will thus be forced from compartment **39*a***, into compartment **56**. Thus influx of water will then be urged from pump **31** by way of the conduit guide rods **49** and **51**. Said conduits can each include a check valve **61** and **62** which are operable to permit unidirectional flow through the respective conduits.

The pressurized streams of water will then be urged into common conduit **34** by way of the flexible conduit section **35**. Thus, for each reciprocatory movement of plunger **47**, water will be forced under pressure into the central accumulator on platform **14**.

It is appreciated that to maintain unidirectional water flow conduit **34** will be provided with the necessary check valves and regulators such that there will be a controlled feed to the platform based central accumulator.

While not presently shown in detail, means is further provided to limit pivotal movement of the respective floats about hinge point **13**. Thus, under storms, or excessively turbulent water conditions, the floats will be protected by suitable shock absorbers or similar members so disposed to minimize severe float movement.

Other modifications and variations of the invention as hereinbefore set forth can be made without departing from the spirit and scope thereof, and therefore, only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. In combination with a wave articulated facility adapted to be floatably positioned in a body of water and having at least two adjacently positioned rafts which are hinged along a common pivot edge to permit independent movement of each raft about said pivot edge in response to wave movement beneath the facility, and flow conduit means carried on the facility to conduct pumped water therethrough,

a double acting pump operably carried on said facility and comprising an elongated casing having opposed end walls, one end thereof being pivotally engaged with the respective adjacently positioned rafts at said pivot edge, and said casing being communicated with said body of water through check valve means formed at opposite ends of said casing to permit entry of water into the casing,

a double ended piston disposed within said elongated casing having a valved plunger in slidable registry with the casing inner wall, which valved plunger includes an inner compartment,

check valves at opposed longitudinal ends of said plunger, being operable to open into said compartment whereby to admit water to said inner compartment when the plunger is reciprocated,

a pair of hollow shafts defining flow passages, and disposed coaxially with said casing and with each other, each being suitably registered at the casing ends to permit reciprocatory movement of the piston through the casing,

said respective hollow shafts having an inner end thereof connected to said valved plunger, and being in communication with the inner compartment thereof,

check valve means in the respective shafts being operable to permit a unidirectional flow of water from said inner compartment into the respective hollow shafts and the latter being communicated with said flow conduit means on said facility to direct flows of water therethrough,

whereby relative movement between adjacently positioned hinged rafts will cause reciprocal movement of said double ended piston through the pump casing and urge a flow of water through the respective flow conduits.

2. In the apparatus as defined in claim **1**, wherein said double acting pump is disposed beneath said adjacently positioned rafts.

* * * * *

US 20130113214A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2013/0113214 A1**

(43) **Pub. Date: May 9, 2013**

McGrath

(54) **FLOATING VESSEL THAT CONVERTS WAVE ENERGY AT SEA INTO ELECTRICAL ENERGY**

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(21) Appl. No.: **13/710,792**

(22) Filed: **Dec. 11, 2012**

Related U.S. Application Data

(63) Continuation of application No. PCT/EP2011/059637, filed on Jun. 9, 2011.

(30) **Foreign Application Priority Data**

Jun. 11, 2010 (IE) S2010/0379

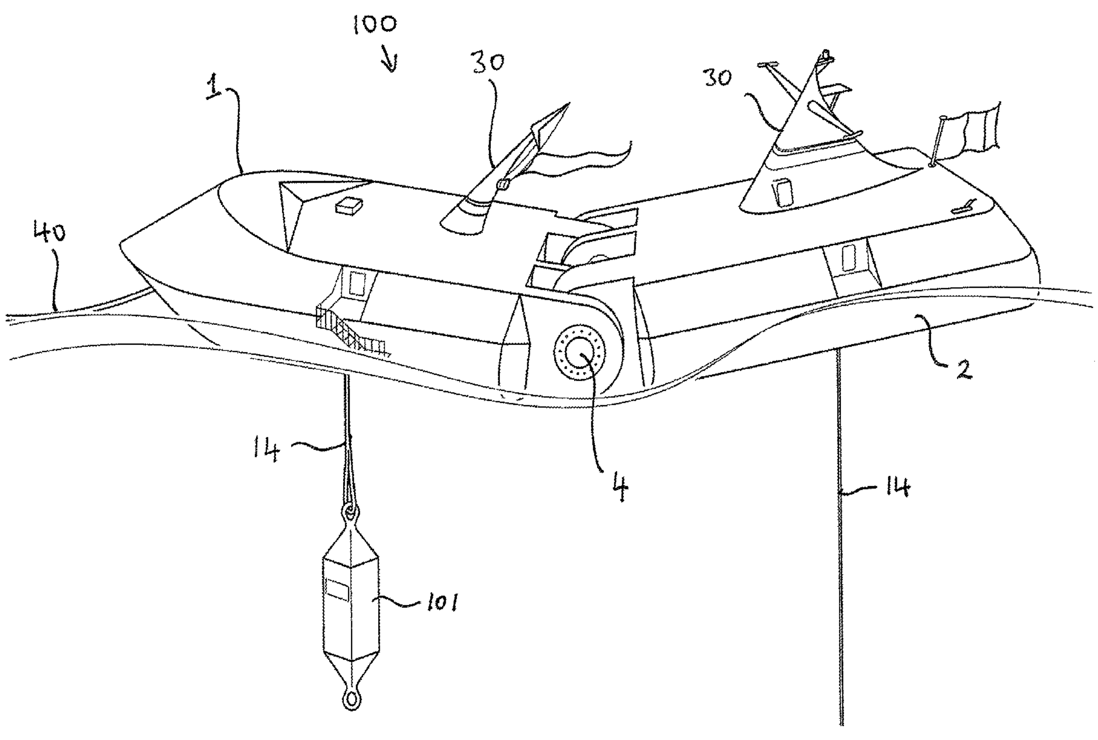
Publication Classification

(51) **Int. Cl.**
F03B 13/20 (2006.01)

(52) **U.S. Cl.**
CPC ***F03B 13/20*** (2013.01)
USPC **290/53**

(57) **ABSTRACT**

An apparatus for converting wave energy into electrical energy comprising a first floating hull (**201**) interconnected to a second floating hull (**202**). A winch mechanism for use in raising a weight suspended on a cable (**14**). The winch mechanism is operated in response to movement of the first hull (**201**) relative to the second hull (**202**), and a generator driven by the downward movement of the weight. Moreover, a method for converting wave energy into electrical energy.



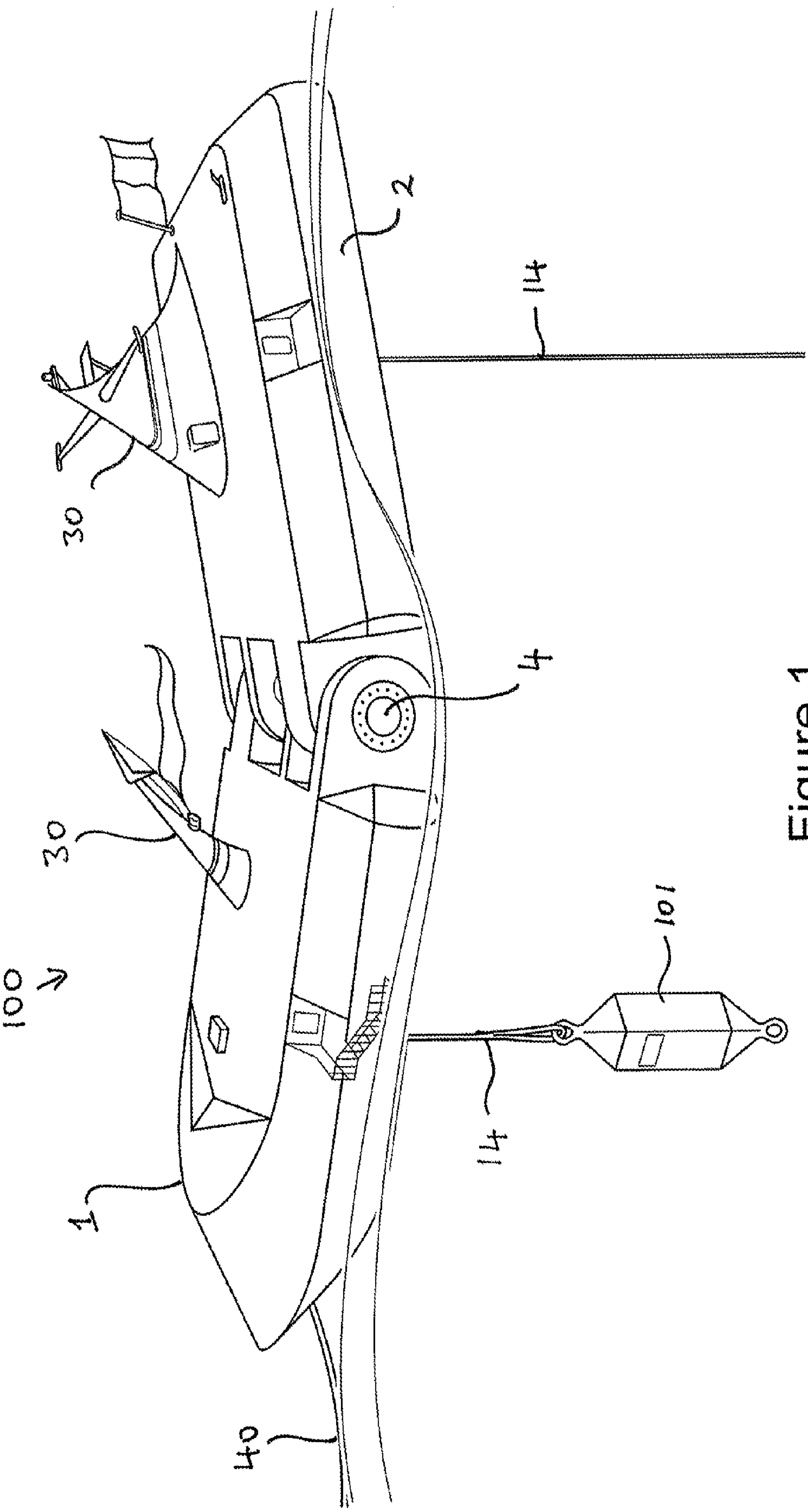
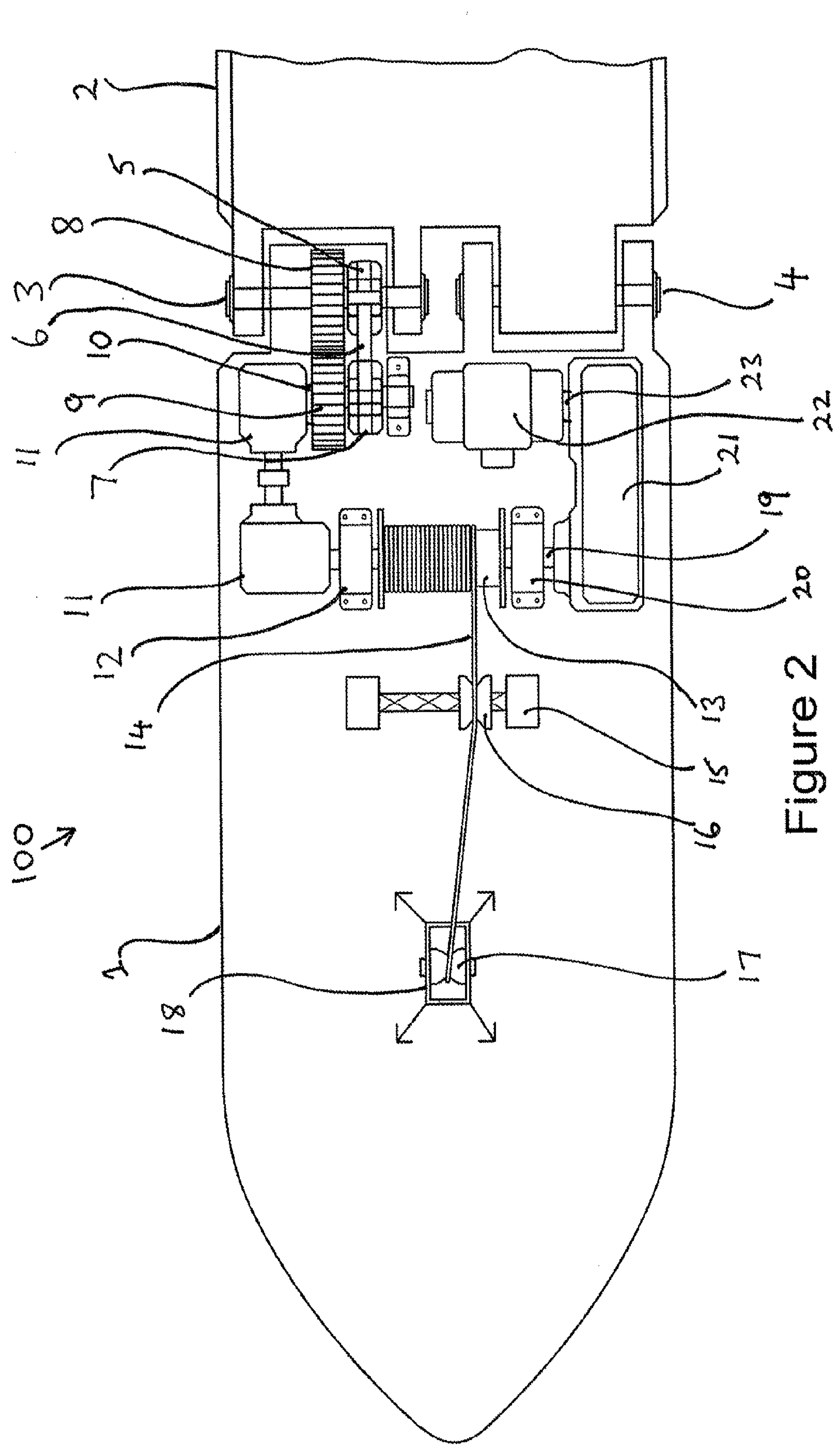


Figure 1



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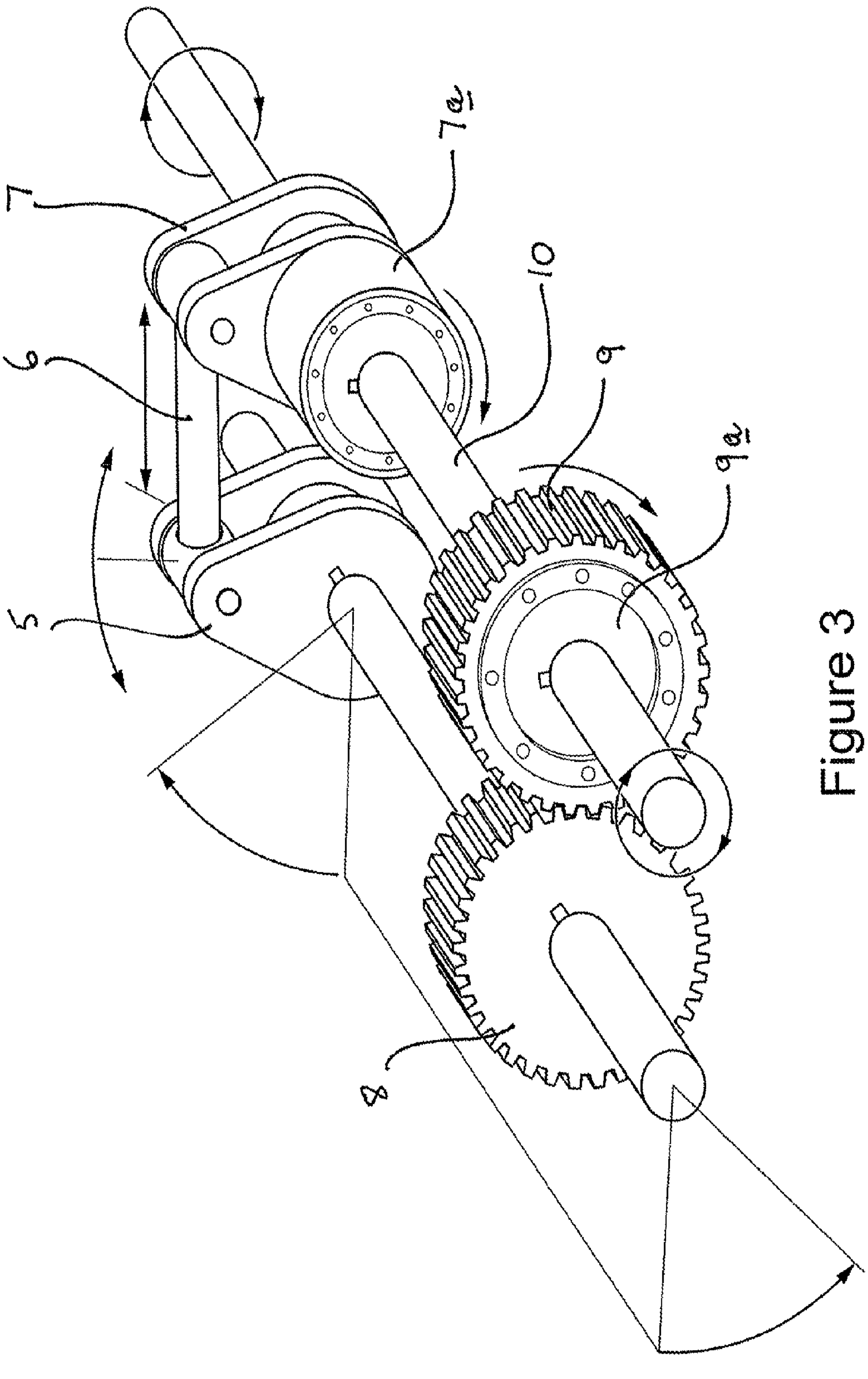

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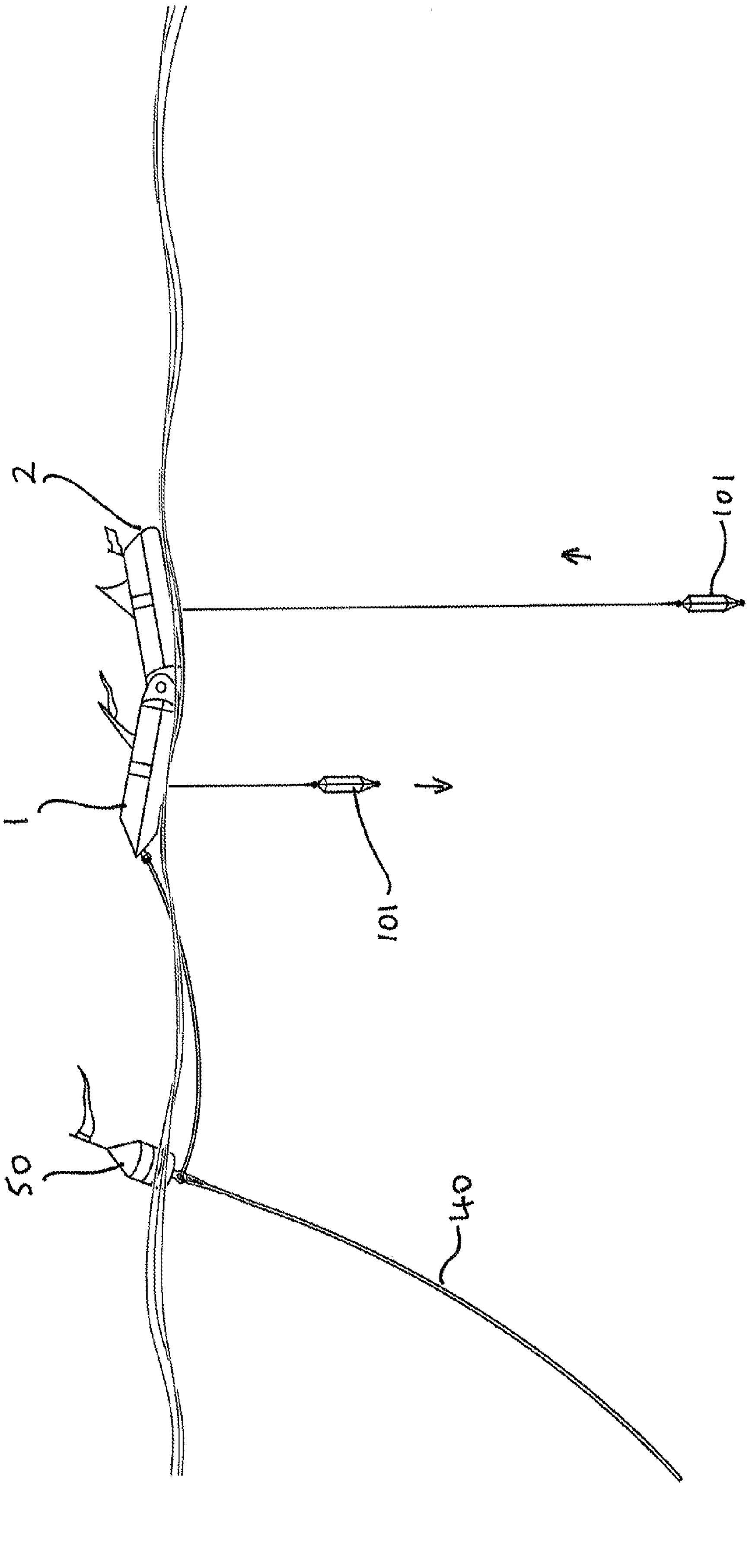
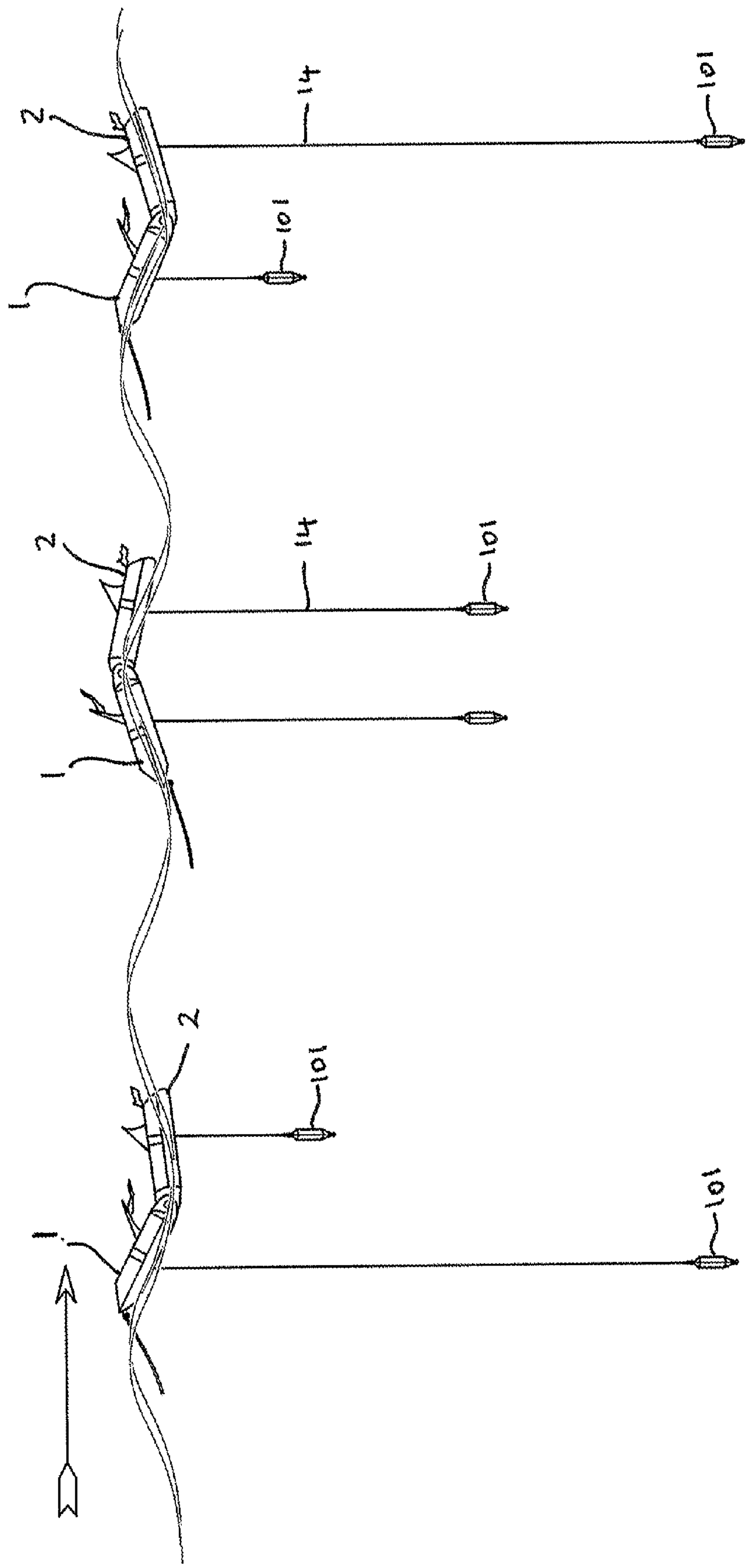


Figure 4



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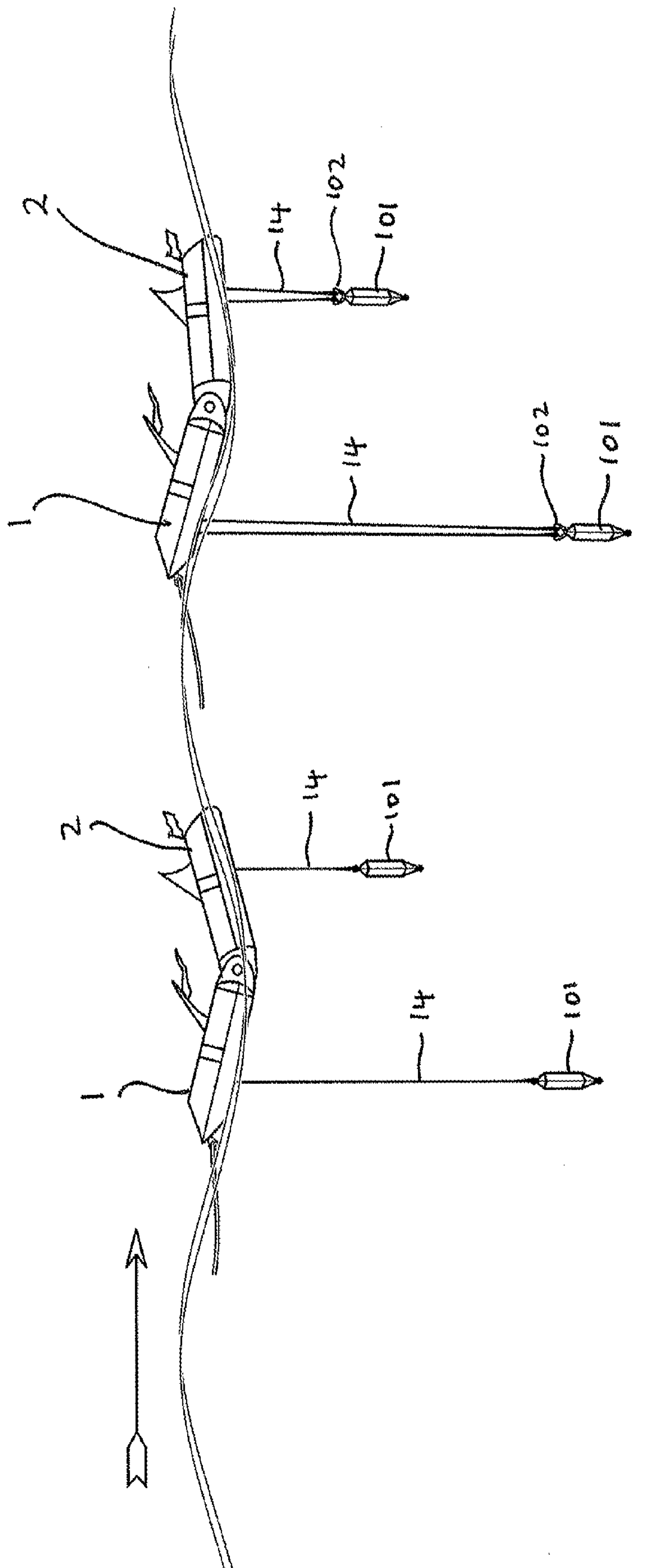

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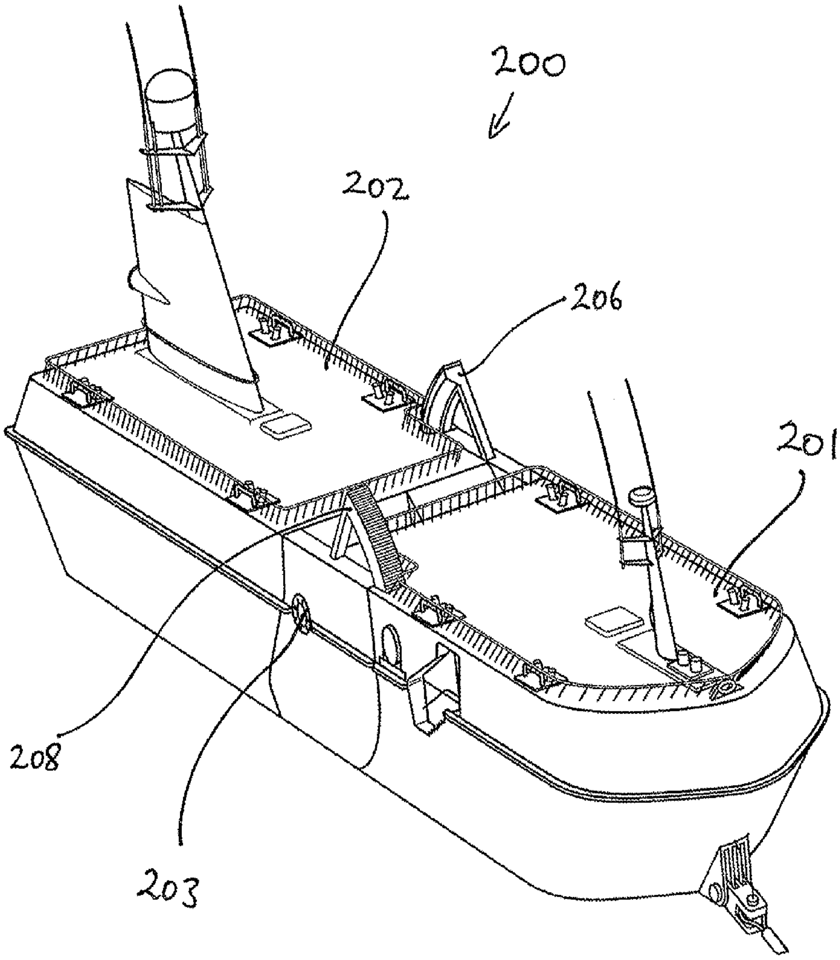

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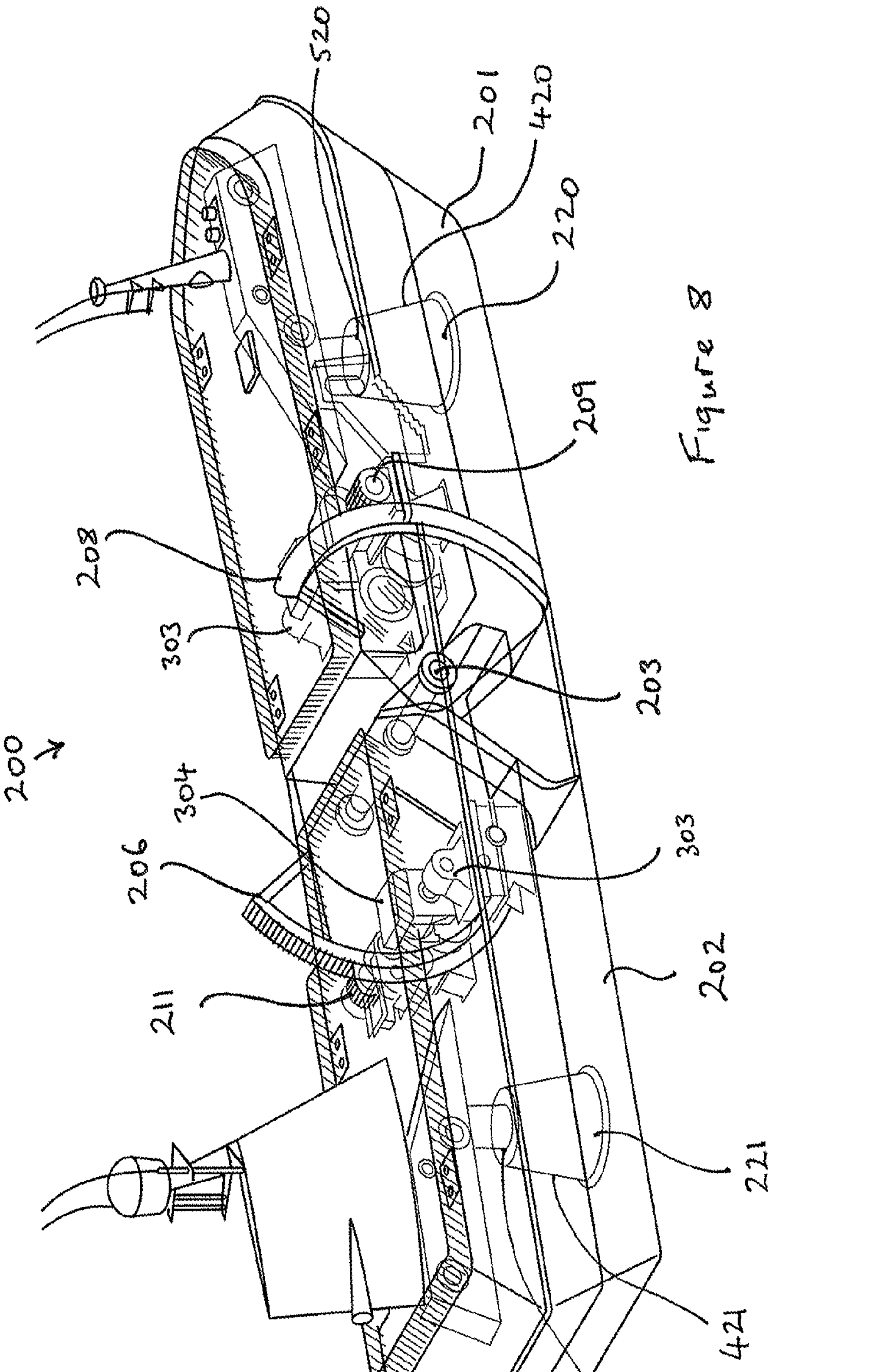
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Figure 8

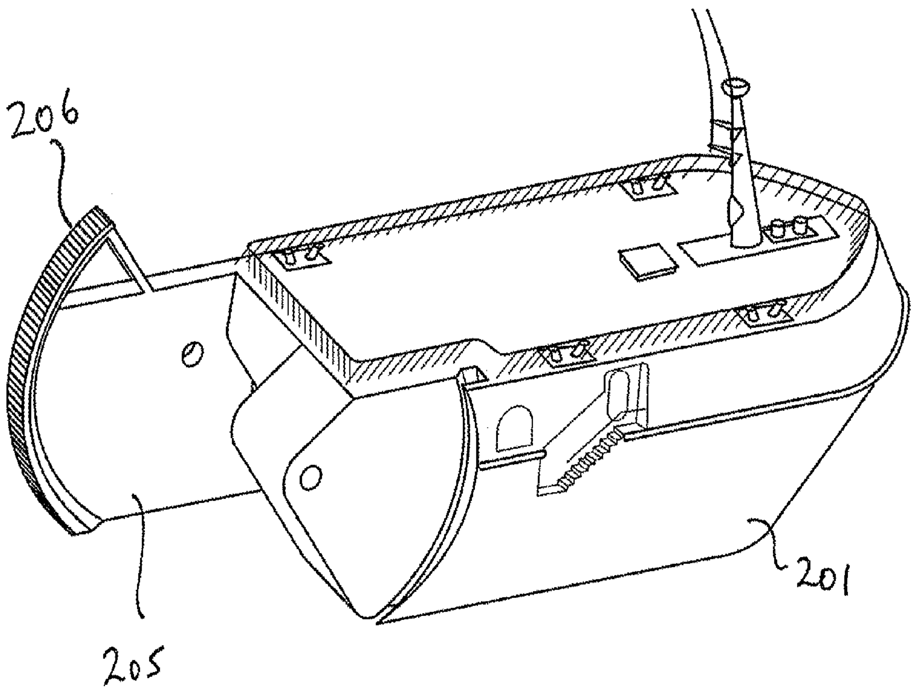
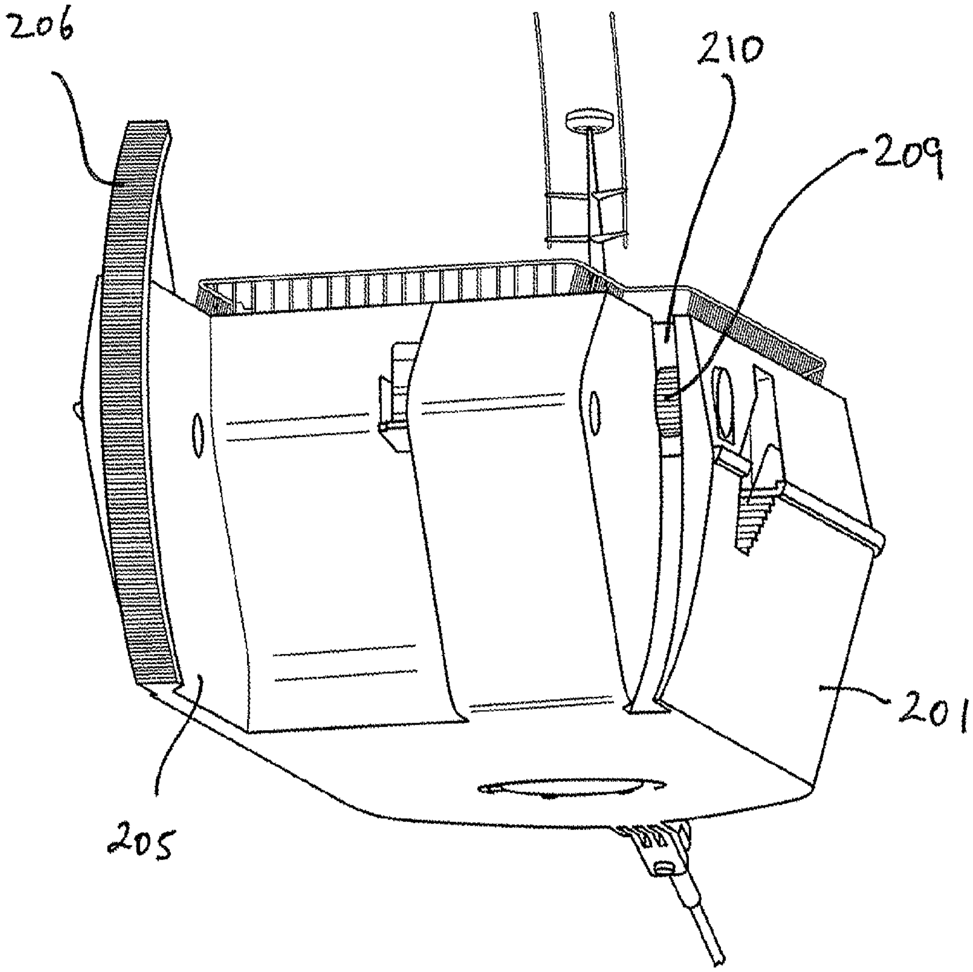


Figure 9



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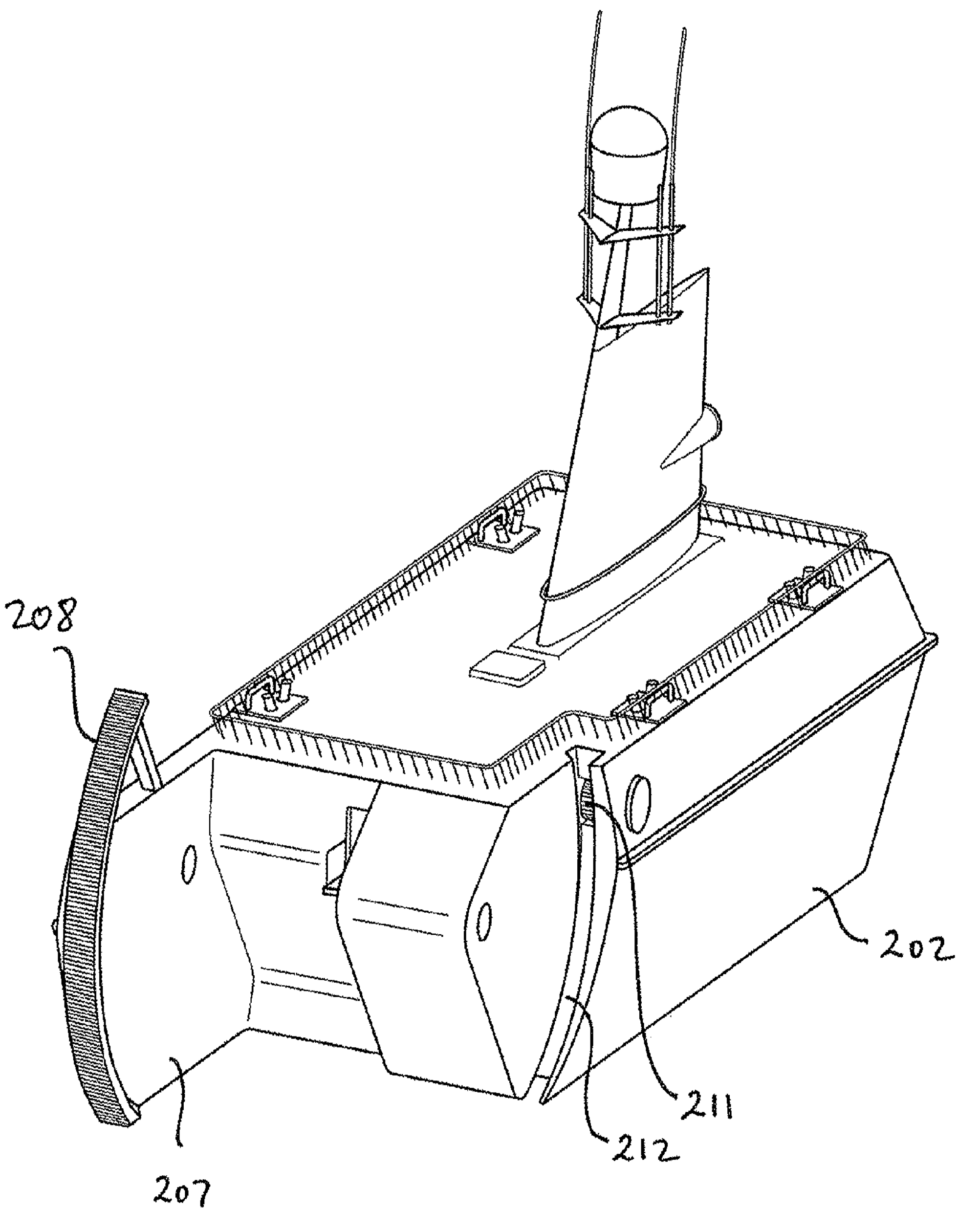

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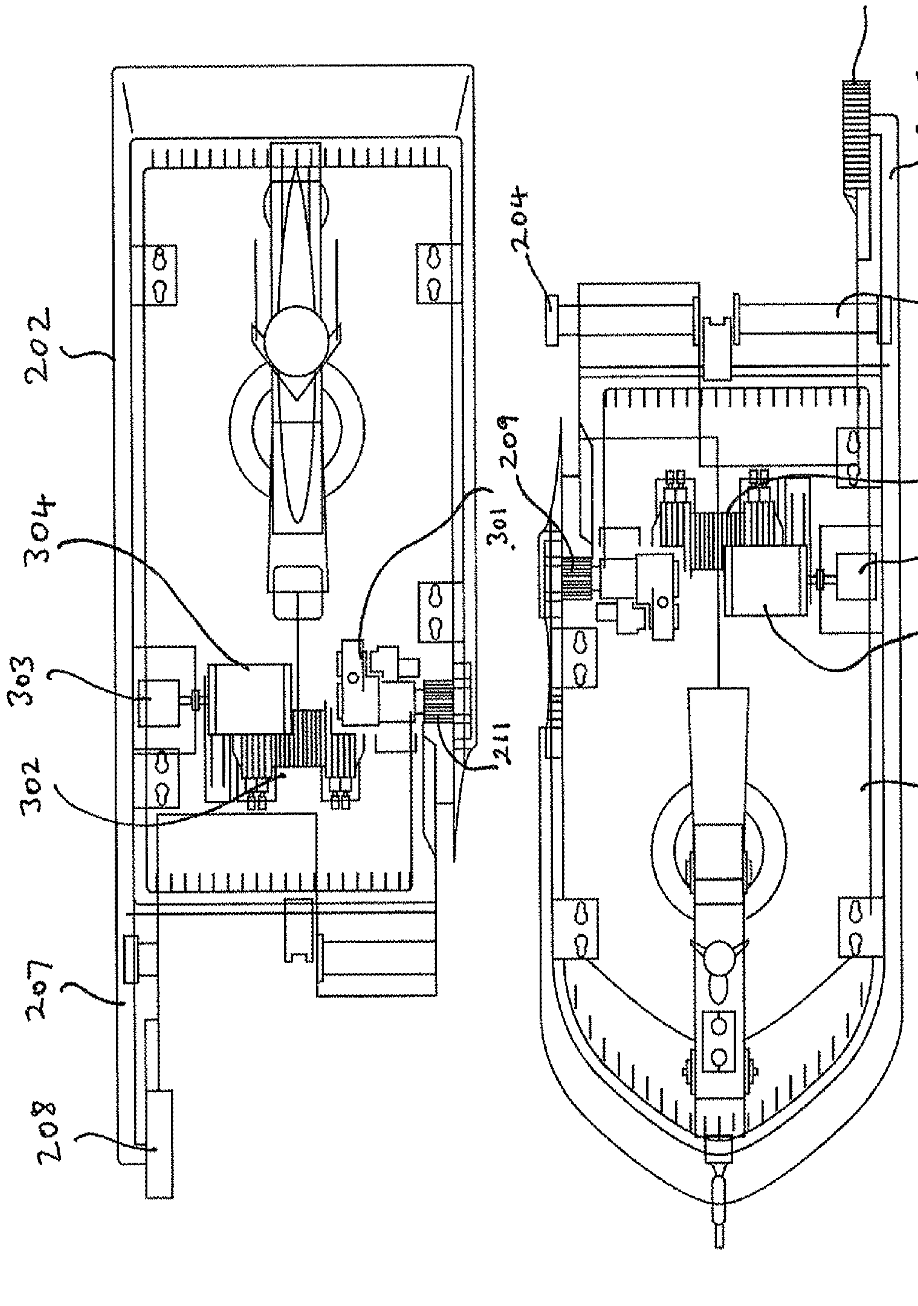
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Figure 12

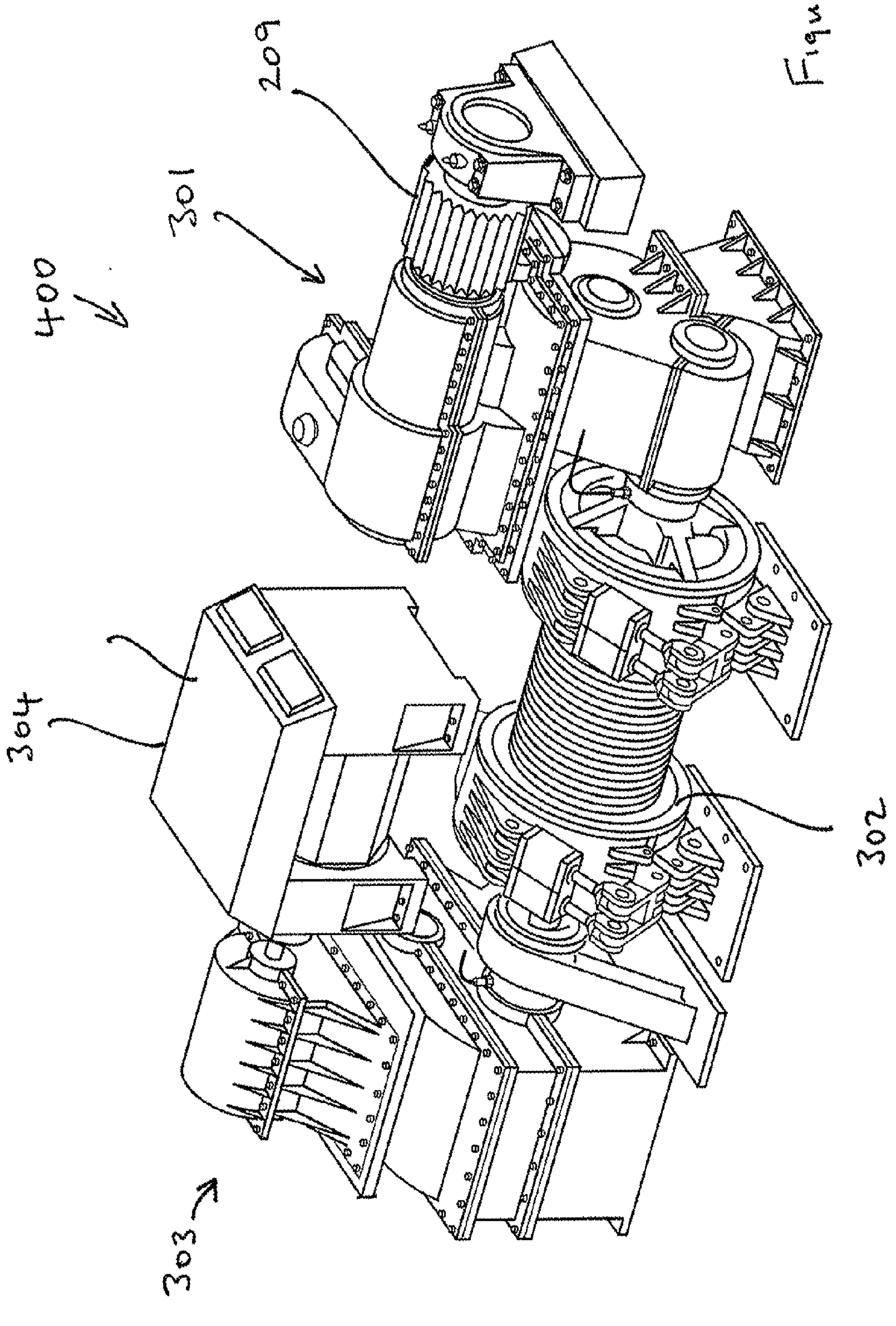


Figure 13

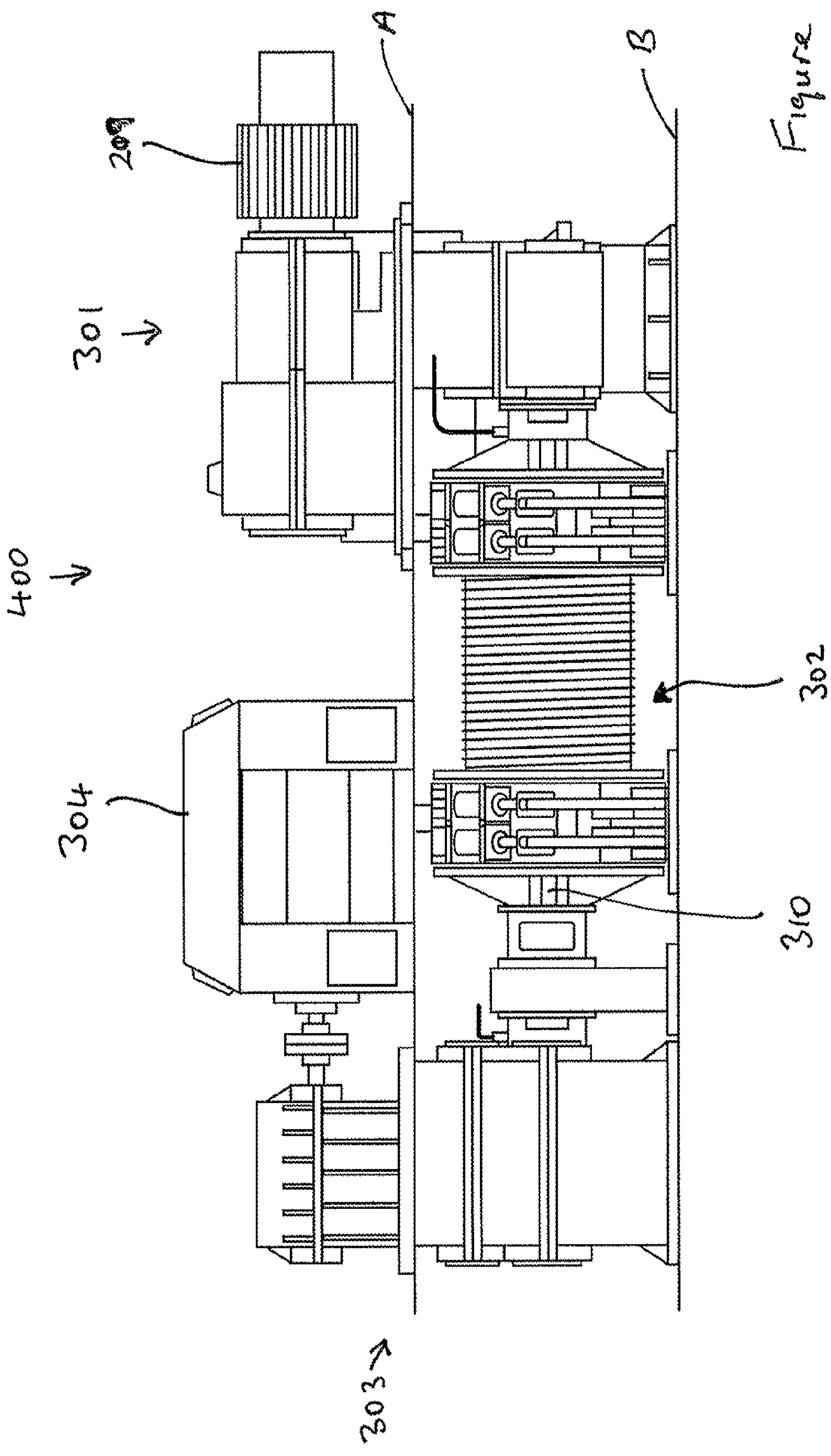


Figure 14

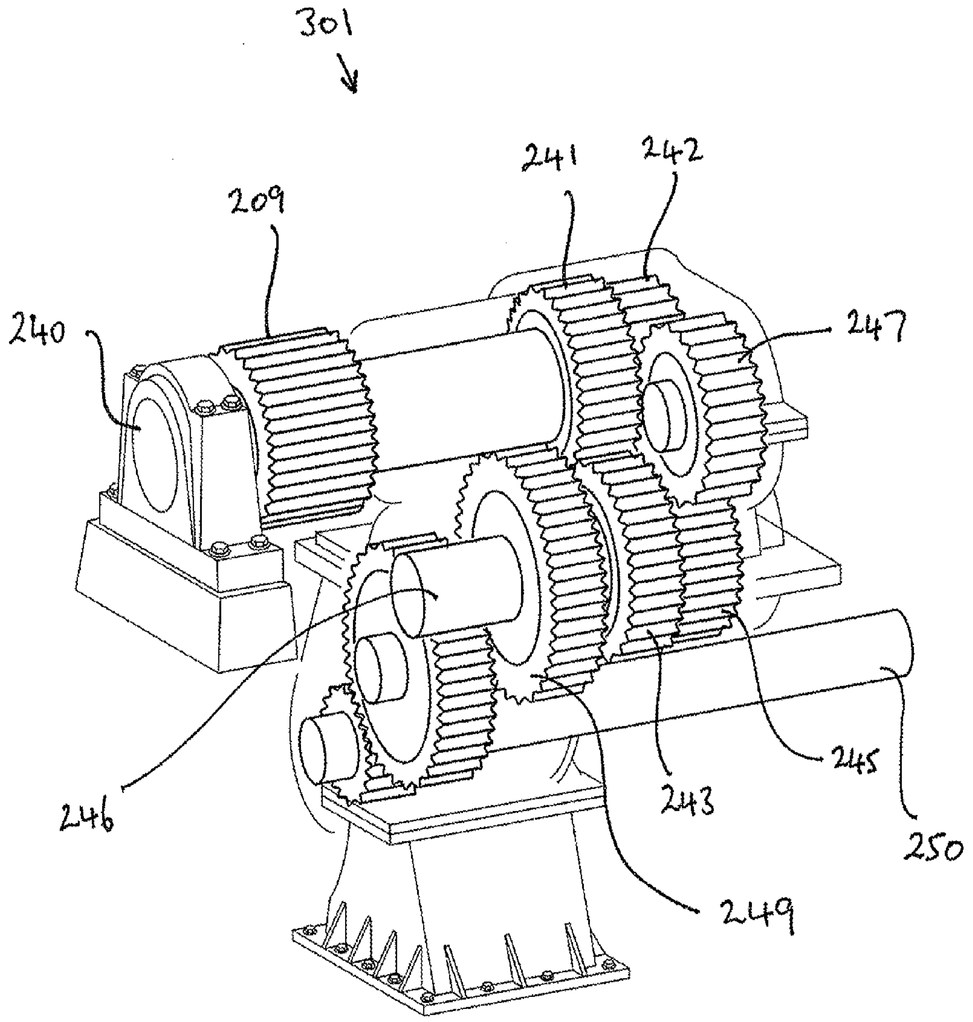
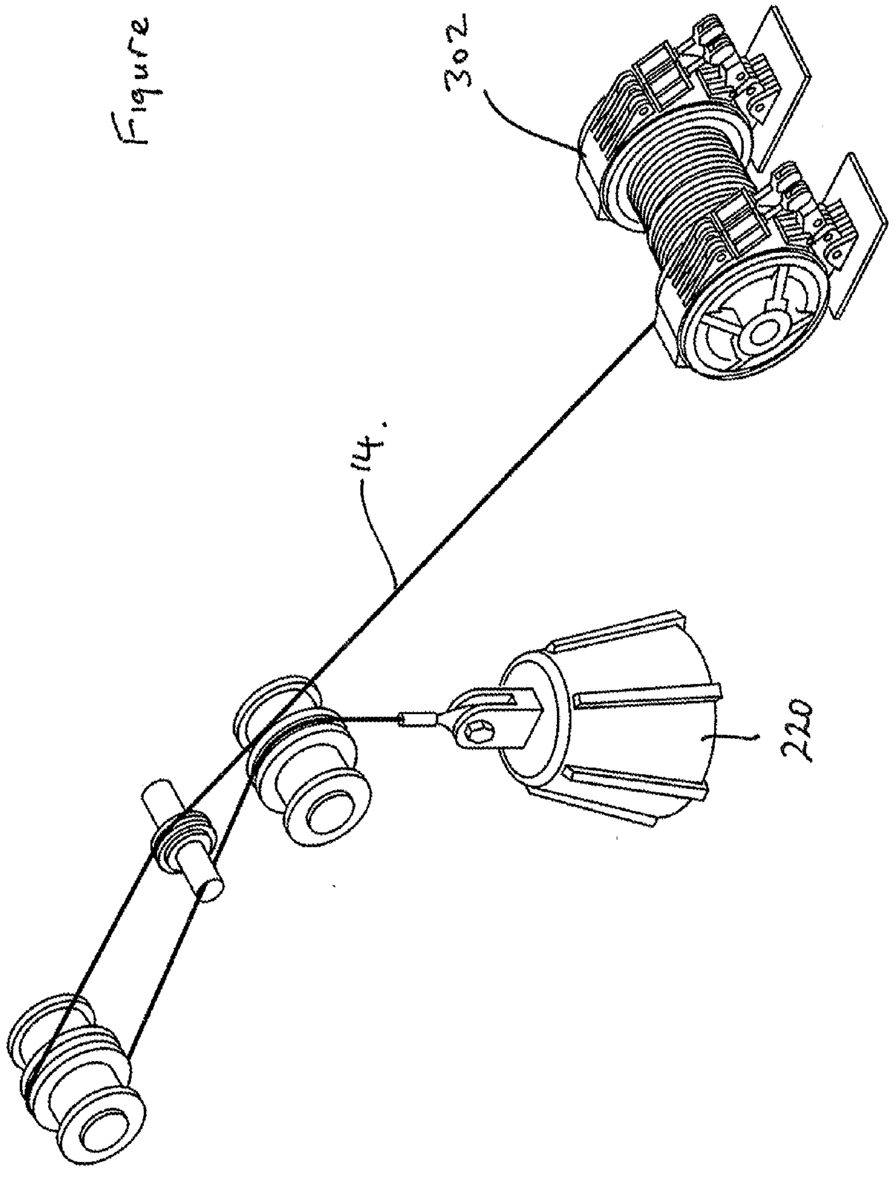


Figure 15

Figure 16



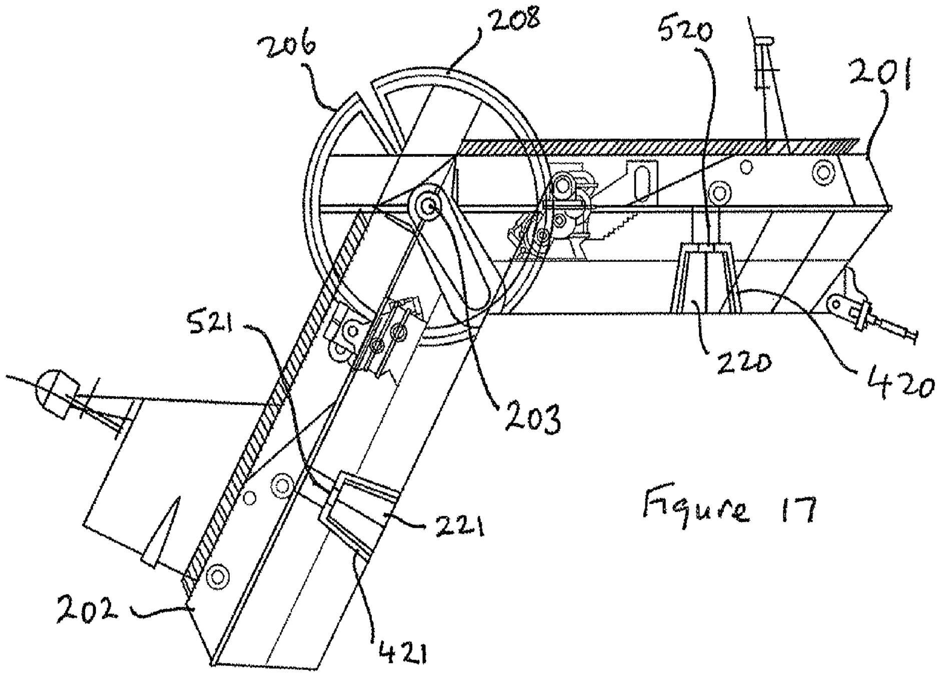


Figure 17

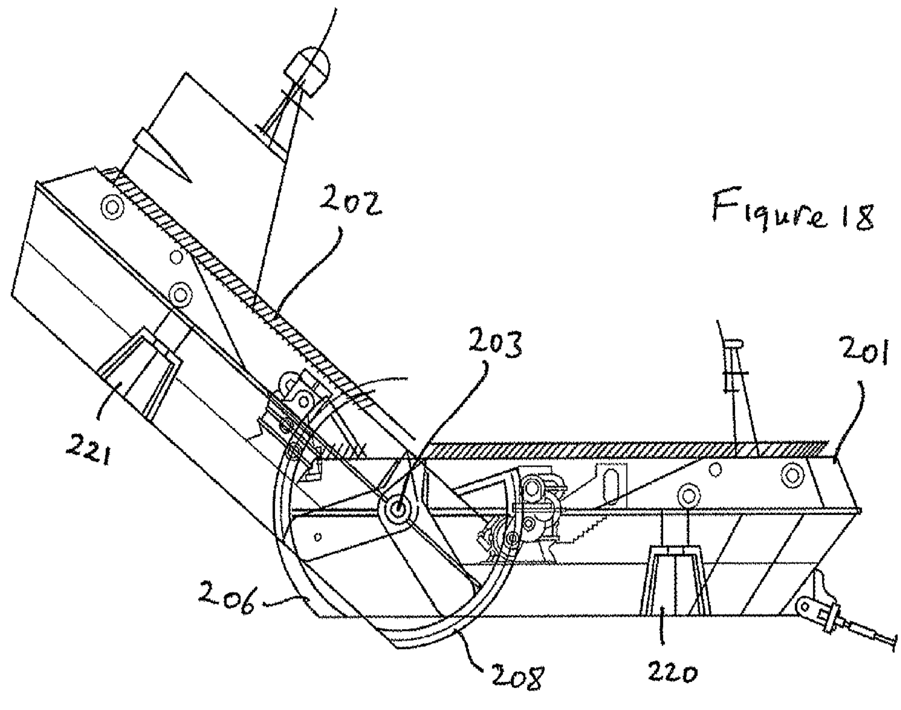


Figure 18

FLOATING VESSEL THAT CONVERTS WAVE ENERGY AT SEA INTO ELECTRICAL ENERGY

CROSS-REFERENCE TO PRIORITY APPLICATION(S)

[0001] This application is a continuation of and claims priority to the commonly assigned International Patent Application No. PCT/EP2011/0059637 (filed Jun. 9, 2011, in the European Patent Office) and the commonly assigned Irish Patent Application Serial No. S2010/0379 (filed Jun. 14, 2006, in the Irish Patent Office), both of which are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to an apparatus that converts wave energy into electrical energy.

BACKGROUND

[0003] The sustainable production of clean energy has been the subject of intense worldwide discussion for some time now, and it is clear that a great demand exists for this type of energy. The invention is designed to be a source of renewable, non polluting energy, and has the potential to commercially supply some of this demand. The invention described here will convert the available energy of wave action at sea into electrical energy.

SUMMARY OF THE INVENTION

[0004] According to the invention there is provided an apparatus for converting wave energy into electrical energy comprising a first floating hull interconnected to a second floating hull, a winch mechanism on at least one hull for in use raising a weight suspended on a cable, said winch mechanism being operated in response to movement of said first hull relative to said second hull, and an electrical generator driven by the downward movement of the weight.

[0005] Preferably the first hull and second hull are pivotally interconnected.

[0006] The winch mechanism is preferably operable to raise the weight, when the hulls pivot relative to each other, in both upward and downward directions.

[0007] Preferably a drive mechanism is provided to operate a drive shaft in one direction to raise the weight in response to relative movement of the first and second hulls.

[0008] One hull preferably has a gear segment which engages with a gear pinion on the other hull, said gear pinion engaged with said gear mechanism.

[0009] Preferably each hull has a gear segment and a gear pinion for engaging with a corresponding gear pinion and gear segment on the other hull.

[0010] The gear segments preferably have an arc of approximately 110°.

[0011] The first and second hulls are preferably pivotally connected by a link shaft.

[0012] Preferably the weight on one hull is raised, as the weight on the other hull is lowered to operate the generator.

[0013] The gear segment is preferably mounted on a flange which projects from the hull.

[0014] The pinion on each hull is preferably disposed on a front face of the hull.

[0015] Preferably each hull has a recess for accommodating the weight.

[0016] Each hull preferably comprises an upper deck (A) and a lower deck (B).

[0017] Preferably, at least the generator is disposed on the upper deck (A).

[0018] The invention further provides a method for converting wave energy into electrical energy comprising providing a first floating hull interconnected to a second floating hull, and a winch mechanism for in use raising a weight suspended on a cable, said winch mechanism being operated in response to movement of said first hull relative to said second hull, and a generator driven by the downward movement of the weight.

[0019] The basis for the invention is to produce a consistent energy output when exposed to wave action particularly at sea. As it will be necessary for this apparatus to endure for long periods of time and perform effectively in a harsh marine environment, the floating hull upon which this system operates is designed in the manner of a ship's hull. This design can therefore be readily scaled up to the size of a very large vessel, depending upon the application required, ensuring that an exceptionally high level of seaworthiness and endurance is achieved. There are significant advantages to be gained in the building and design of this invention by drawing on the resources of proven ship design technology such as can be integrated into this design.

[0020] One notable feature of this invention is that it does not use a hydraulic system to perform its main function, and therefore presents a much reduced risk of pollution damage to the environment.

[0021] In unmanned machines where large volumes of hydraulic fluids are central to their operation, a constant threat of pollution would exist where the failure of a high pressure pipe or seal, or indeed a total loss of the machine at sea, could result in the spillage of large quantities of hydraulic fluid. This design will need only small quantities of well contained lubricants and these can be specialized to reduce the risk of contamination.

[0022] Environmental impact is further reduced due to the absence of any submerged machinery that is rotating or exposed and hazardous to marine life.

[0023] Preferably, there is provided a drive mechanism which is operated by the relative pivotal movement of the first and second hulls. The drive mechanism is connected to and operates the winch mechanism to raise the weight suspended on the cable.

[0024] The first and second hulls are preferably pivotally connected by a link shaft. Preferably, there is provided a starboard link shaft which is fixed to the first hull and a port link shaft fixed to the second hull.

[0025] In one embodiment each link shaft has preferably mounted thereon a gearwheel engaged with another gearwheel on a primary drive shaft.

[0026] Further the link shaft has mounted thereon a further drive member connected by a rod to a sprag clutch operated drive gear on the main drive shaft.

[0027] The gearwheel and drive members connecting the link shaft to the main drive shaft operate in such a way as to rotate the primary drive in a chosen direction.

[0028] It will be noted that the pivotal movement of say the second or aft hull in both the upward and downward direction as it is crossed by a wave, results in rotation of the primary drive shaft in the same direction.

[0029] The primary drive shaft is therefore rotated in response to relative pivotal movement of the first (forward) and second (aft) hulls, caused by wave action, and rotation of the primary drive shaft enables rotation of the winch mechanism to raise a cable and weight.

[0030] The raising of the weight is therefore the conversion of kinetic energy of the waves to potential energy (or gravitational energy) as the weight is raised to a position on the underside of the hull.

[0031] The mechanism on both the fore and aft hulls is identical, and it may be arranged that while one hull is raising the weight to its uppermost position, the weight on the other hull may be released to generate power through the generator.

[0032] The stored potential energy of the raised weight is therefore converted to electrical energy by the release of the winch mechanism to enable the weight to fall downwardly and the electrical generator is operated.

[0033] The apparatus of the invention will be operated in a suitable depth of water perhaps of the order of 60 meters.

[0034] It is possible that a plurality of similar hulls according to the invention may be connected together.

[0035] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] 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:

[0037] FIG. **1** is a perspective view of an apparatus for converting wave energy into electrical energy according to the invention;

[0038] FIG. **2** is partial schematic top plan view of the apparatus of FIG. **1**;

[0039] FIG. **3** is a schematic view of part of the drive mechanism of FIG. **1**;

[0040] FIG. **4** is a schematic view of the apparatus of FIG. **1** in use;

[0041] FIG. **5** is a further schematic view of the apparatus in use;

[0042] FIG. **6** is a further schematic view of the apparatus in use;

[0043] FIG. **7** is a perspective view of another embodiment of apparatus for converting wave energy into electrical energy according to the invention;

[0044] FIG. **8** is a partial transparent view of the apparatus of FIG. **7**;

[0045] FIG. **9** is a perspective view of the front hull of the apparatus of FIG. **7**;

[0046] FIG. **10** is a further perspective view of the front hull of FIG. **7**;

[0047] FIG. **11** is a perspective view of the rear hull section of FIG. **7**;

[0048] FIG. **12** is a schematic top plan view of the front and rear hull sections of the apparatus;

[0049] FIG. **13** is a schematic perspective view of the operating components of the apparatus of FIG. **7**;

[0050] FIG. **14** is a schematic sectional view of the operating components of FIG. **13** located on the front hull of the apparatus of FIG. **7**;

[0051] FIG. **15** is a perspective view of the power take off system of the apparatus;

[0052] FIG. **16** is a perspective view of the winch mechanism of the apparatus; and

[0053] FIGS. **17** and **18** are schematic views of the apparatus of the Fig. in use.

DETAILED DESCRIPTION

[0054] Referring now to the drawings and referring in particular to FIGS. **1-3** there is shown therein an apparatus for converting wave energy into electrical energy generally indicated at **100**. The apparatus **100** comprises a first or forward hull section **1** and a rear or aft hull section **2**. The hull sections **1** and **2** are pivotally connected together by link shafts **3**, **4**. The link shaft **3** is the starboard link shaft and is fixed to the aft hull section **2**. The link shaft **4** is the port link shaft and is fixed to the forward hull section **1**. Thus, the aft hull section **2** can rotate or pivot about the link shaft **4** whereas the forward hull section **1** can rotate or pivot about the link shaft **3**.

[0055] The link shaft **3** has mounted thereon a gearwheel **8** connected to a gearwheel **9** mounted on a primary drive shaft **10**. Further, the link shaft **8** has fixed thereon a lever member **5** and the primary drive shaft **10** has fixed thereon a lever member **7**. A connecting rod **6** is connected to lever members **5** and **7**.

[0056] The gearwheel **9** has a sprag clutch mechanism **9**a (FIG. **3**) which permits rotation of the gear wheel **9** (and thus the primary drive shaft **10**) in one direction and the lever member **7** has a sprag clutch mechanism **7*a*** which also permits rotation of the primary drive shaft **10** in the same direction. Therefore, as the aft hull section **2** pivots upwardly relative to the forward hull section **1**, the gear wheel **9** and primary drive shaft **10** is rotated in one direction and as the aft hull section **2** pivots downwardly relative to the forward hull section **1**, the cam member **7** rotates the primary shaft **10** in the same direction. The sprag clutch mechanisms on gear wheel **9** and lever member **7** enable the rotation of primary drive shaft **10** in the same direction, as the aft hull section **2** moves upwardly and downwardly relative to the forward hull section **1**. Therefore, continuous rotation of the primary drive shaft **10** is achieved as the hull sections are raised and lowered as a wave passes under the hull sections.

[0057] The primary drive shaft **10** is connected to a drive system comprising a pair of gearing mechanisms **11** which in turn are connected through a drive clutch and brake **12** to a winch spool **13**. The winch spool **13** has wound thereon a warp or cable **14** which is fed over a spooling roller **16** mounted on a spooling mechanism **15**. The cable **14** extends over a final roller **17** mounted in an enclosed section **18** having an aperture (not shown) through which the cable **14** extends downwardly below the hull section **1**. A suitable weight **101** is attached to the free end of the cable **14**. It will be appreciated that the enclosed section **18** is designed to enable the cable **14** to exit the hull **1** through an opening but not compromise the hull **1** in relation to its sea worthiness, to ensure the hull will not flood with water.

[0058] A secondary drive shaft **19** is attached to the winch spool **13** and is mounted on a secondary drive clutch and brake **20**. The secondary drive shaft **19** is connected to a secondary step up gearing mechanism **21** which in turn has an output shaft **23** connected to an AC generator **22**.

[0059] It will be appreciated that the aft hull **2** will have a similar arrangement of gearwheels, link shafts, winch spool and winch cable **14** and weight **101** as the forward hull **1**, so that the forward and aft hulls operate on a weight **101** in a similar manner.

[0060] This system makes full use of the depth of water in which it operates, the distance between the vessel and the seabed is fully utilized as part of the central function of this design.

[0061] This system converts wave energy into an accumulated gravitational force which is then controlled and deployed smoothly to power an AC generator.

[0062] The buoyancy of the hull sections and how they react to wave motion, will determine the force that they can bring to bear on the mechanical components involved in the production of this power, and therefore the efficiency of their power production.

[0063] The size and stability of the hulls **1**, **2** will enable certain fundamental types of repairs to be carried out at sea whilst on station, reducing downtime and the cost of essential maintenance.

[0064] All of the components parts of this design, and in particular those which will enable it to endure at sea and produce electrical energy, are extremely reliable and capable of enduring the harshest conditions at sea.

[0065] This device, once deployed will produce power smoothly because the generators **22** will be driven at a constant speed. This will be an advantage over many designs such as air driven turbines and other machines which tend to produce power in surges making grid connection more complex and expensive.

[0066] This invention is designed in the manner of a vessel or ship floating on station and anchored on the open sea, in such a way as to allow available wave energy to be converted, by means of incorporated machinery, into electrical energy. The resultant electricity will then be fed into the national grid by cable and conventional systems.

[0067] This invention may be comprised of more than two hull sections, and all of these sections will be designed and constructed using the most up to date shipbuilding techniques of ocean going steel hulled ships. All hull sections will be joined or connected together by means of horizontally aligned hinge systems these will be very robust and highly engineered to allow the hull sections to partially rotate in the vertical plane relative to each other.

[0068] While a number of hull sections may be used in any one application, a minimum of two sections will be necessary. For the purposes of this description we will refer to an apparatus that operates using the minimum requirement of two hull sections. The apparatus described here can be said to be "in two half's" and hinged or joined roughly around the middle of its length. A propulsion system for the apparatus may or may not be used and would in any event be superfluous to its main function of wave energy conversion which it will perform while stationary.

[0069] During its period of operation the apparatus will be anchored from a single point to geographically fix its position and also in such a way as to enable it to naturally establish an alignment which will result in the waves moving towards and along the hull sections at right angles to them, as would be normal with an anchoring arrangement of this type.

[0070] The forward section **1** of the vessel, which would constitute the bow section, will be at all times standing into the waves and fastened directly to an anchor/mooring system **40**, **50**, (fixed to the seabed) this forward section **1** will be designed and built having a suitable streamlined bow shape.

[0071] Once positioned and exposed like this to wave action on the open sea, the hulls of the apparatus will respond to this wave action by producing an alternating, semi rotational movement in the vertical plane, with the connecting hinge axis (**4**, **3**) forming the centre of this movement.

[0072] The following stage is the process whereby the vessels alternating movement, as described above, is converted into useable energy via the installation on each hull of the arrangement of shafts, sprag clutches, connections and gearing, (described above) that are powered by the interacting motion of the hull sections through the hinge axis shaft. This enables the partial rotation of the hull movement to be mechanically developed into a fully rotational movement. This installation will be double acting and will have a shaft on each hull which can fully rotate in one direction only.

[0073] Each hull section will have one fully rotating shaft **10**, which are the primary drive shafts. The rpm of each primary shaft **10** will be low and somewhat inconsistent depending on the frequency and amplitude of the waves, however each shaft will be capable of substantial power output due to the leverage the hull sections can bring to bear on the hinge centre shafting **3**, **4** as the vessel reacts to the wave action.

[0074] Each of these primary drive shafts **10** will be coupled to identical winch installations that have been located in alignment together on the deck of each hull section, as described above.

[0075] The winches **13** have a single spool with dimensions appropriate to the application, fitted with heavy duty air/electric clutch and braking systems **12**, **20** and capable of being controlled and operated electronically. The winch is fitted with a sufficient quantity of high specification cable/warp **14** on the spool to take into consideration the depth of water in its proposed working location at sea.

[0076] The requirement being that each warp **14** is of sufficient length to reach to just above the sea bed from the surface in that location. In one embodiment the design may require that a depth of at least sixty metres is available, this minimum depth may to facilitate the operational sequence, and also wave action at this depth is ideally suited. Depths of less than sixty metres may need to be facilitated by the inclusion of a double purchase arrangement which would increase the length of warp and require the weight to be increased by double the amount also. Depths of much more than sixty metres would also be suitable with the anchoring system requirements being scaled up to take into consideration the increase in water depth.

[0077] Further to the winch installations, in both cases the warps **14** will lead out from each winch spool to which they are attached, via a system of blocks and rollers, to positions that have been calculated to optimise the stability and buoyancy of each hull. From these positions the warps will lead vertically down through each hull section, via watertight enclosures which will not compromise each hulls sea-keeping capability, and thereby into the sea where underneath the floating hull the weight **101** is attached to each warp end.

[0078] The layout and arrangement of the mechanical systems as described above will convert the wave energy that the vessel is exposed to into a system that will supply power to the winches; thereby enabling each winch to raise the weight attached to them from the lowest point of the sequence, just above the sea bed and clear of it, to the uppermost point of the sequence, a point just below the underside of each hull. In this manner the apparatus will operate with at least one winch on each hull section, and at least one weight per winch. The weights will preferably be of equal mass and be determined in each case by the particular application and scale of the machine to be operated.

[0079] In addition each winch spool is fitted with two clutches, one on either side of the spool as follows; a primary clutch **12** which will allow each spool **13** to be either disengaged from or engaged with its drive or input shaft from the gearing mechanism **11**, and a secondary clutch which will allow each spool to be disengaged from or engaged with its output shaft.

[0080] The clutches will operate in an alternating sequence; when a winch spool is being driven by its primary input shaft with the primary clutch **12** engaged and in the progress of lifting its attached weight, the output clutch, or secondary clutch **20**, will remain disengaged. When the spool **13** has finished lifting the attached weight the primary clutch **12** will disengage the spool **13** from the primary drive shaft and the secondary clutch **20** will take over to engage the spool with the secondary or output shaft **19**.

[0081] Each winch system therefore will be designed and built to perform two separate functions with one function being operated at a time in a specific sequence. The first sequence, which is the stage which accumulates the energy drawn directly from the wave action, will begin when the winch spool **13** with its braking system released and primary clutch **12** engaged and powered by its respective primary input shaft, will begin to raise its attached weight from where it will be suspended, i.e. just above and clear of the seabed which is the lowest point of the sequence, to a point just below the floating hull which is the uppermost. During this procedure as the weight is being raised by its spool from this lower position the attached cable **14** is taken in tight coils and being wound on to the winch spool **13** until the weight has reached the uppermost predetermined position just below and clear of the hull **1**.

[0082] A winch spool **13** with its weight suspended from it, in this uppermost position has accumulated energy in the windings of the warp as it was coiled around the spool, and is "loaded" with a source of gravitational power or potential energy which it has acquired during the course of its vertical travel to this uppermost point and this energy is now available to be worked in a controlled manner.

[0083] The second sequence is where this accumulated potential energy is deployed in a controlled manner in order to generate electrical power, and this sequence will be activated immediately after the weight has been raised to this uppermost position. The activation of this sequence is initiated by the operation of both the primary **12** and secondary **20** clutches in conjunction with the braking system in the following manner. The brake will be applied to momentarily secure the spool **13** and not allow it to rotate, simultaneously in a coordinated action the primary clutch **12** will be disengaged from the primary drive shaft and the secondary clutch **20** operated to engage the "loaded" spool to its secondary or output shaft **19**. Release of the brake will now "clear" the spool allowing the weight to begin its descent with the spool **13** now coupled to the secondary or output shaft **19** via the secondary clutch **20**, enabling the spool to rotate the secondary shaft. The secondary shaft will transmit this power from the spool through a step-up gearbox **21** adding shaft speed sufficient to run the AC generator **22**. As gravity takes the weight on this descent to its lower position as previously outlined; the action of this descent will cause the spool to rotate as the gravitational force of the descending weight unwinds the cable from around the spool. This descent will be actively controlled by means of an energy producing braking system, or an electronic governing system which can momentarily increase the electrical load on the generator so that a constant rpm may be achieved without wasting power.

[0084] As previously mentioned this description relates to a version of this design that will operate using two joined hull sections, each section having its own shafting, winch, weight, step-up gearing and AC generator installations. During its operation and in order to achieve a continuous output of electrical energy from the vessel as a whole, each hull section will be continuously coordinated with its neighbour in an alternating sequence of power production. That is to say that while one hull section is in its sequence of raising its weight and therefore not producing electrical power its adjoining hull section will be in a sequence of generating power with its weight descending. This alternating sequence would be repeated pro rata for versions of this design that are operated using more than two joined hull sections.

[0085] In FIGS. **4** and **5** there is shown various stages of operation of the system, illustrating how the forward and aft hull sections **1**, **2** pivot upwardly and downwardly relative to each other as waves pass underneath them. As one weight **101** reaches the uppermost position the other weight **101** is in the lowermost position.

[0086] It will be understood that the aft hull section **2** will have the same equipment as forward hull section **1** and will operate in the same way. As shown in FIG. **1** each hull section **1**, **2** may have a fin **30** to increase stability and maintain the hulls **1**, **2** pointing into wind. The hull **1** will be provided with an anchor line **40** which may be attached to a marker buoy **50** and the anchor line secured to the seabed.

[0087] The apparatus may be fitted with a double purchase system (FIG. **6**) having a pulley block **102** after the main warp **14** has led out of the hull which would allow for an increased length of warp to be used in a lesser depth of water. This would of course mean that the weights **101** would need to be increased to twice that of a single purchase installation, in short it is an option for depths of less than sixty metres.

[0088] Referring now to FIGS. **7** to **18**, there is shown therein another embodiment of apparatus for converting wave energy into electrical energy, generally indicated at **200**. The construction and operation of this second embodiment of the invention is many ways similar to that of the first embodiment however, the important technical differences will be discussed below.

[0089] The apparatus **200** comprises a first or forward hull section **201** and a rear or aft hull section **202**. The hull sections **201** and **202** are pivotally connected together by link shafts **203** and **204** so that the forward and rear hull sections **201** and **202** can pivot relative to each other.

[0090] The forward hull section **201** has a flange **205** which carries a geared segment **206** and the rear hull section **202** has a flange **207** which carries gear segment **208**. Further, the forward hull section **201** has a pinion gear wheel **209** exposed in its face **210**, this gear pinion **209** engaging with gear segment **208** on the rear hull **202**. Similarly the rear hull section **202** has a pinion gear **211** on its face **212**, this gear pinion **211** engaging with gear segment **206** on the front hull **201**.

[0091] As the hulls **201**, **202** pivot relative to each other, as a wave passes under the apparatus, the gear segment **208** causes rotation of the pinion **209** and the gear segment **206** causes rotation of the pinion **211**.

[0092] The pinions, **209** and **211** are each, connected to a respective drive and power take off system for raising and lowering a weight **220** and **221** respectively on each hull **201**, **202**.

[0093] The drive and power take off and power transfer system **301**, one per hull section will now be described.

[0094] First, it is to be noted that each hull section **201**, **202** will have an upper deck (A) and a lower deck (B). Referring to FIGS. **13-16**, the overall drive system **400** comprises a power take off/ primary transfer system **301**, a winch spool **302**, and a gear drive system **303** for an electrical generator **304**. The power transfer system **301**, provides rotational power to a drive shaft **250** for the winch spool **302** and rotation of the drive shaft winds in a warp/cable **14** to raise a weight **220** which is suspended beneath the hull section **201**. When the weight **220** has been fully raised, it can be lowered again under gravity by releasing a brake on the spool **302** which in turn rotates an output shaft **310** to drive the electrical generator **304** via the step up gear drive system **303**. The weights **220**, **221** have a corresponding recess **420** and **421** on the underside of each hull and each recess **420**, **421** has a corresponding sealed aperture **520**, **521** for outlet of the cable/ warp **14**.

[0095] As shown, the power transfer, storage and electrical generator are arranged so that the complete apparatus is spread over the two internal decks (A) and (B). As shown in FIG. **14**, part of the power take off system **301**, and part of the gear drive system **303** for the generator **304** are located on the upper deck (A). A very small quantity of water may be carried on board with the cable **14**, each time a weight is raised so the spool **302** is placed below the generator deck (A), and sealed off from the main electrical equipment. Any water ingress due to the cable will be minimised by the way the cable is righted on board, collected in a bilge and periodically discharged overboard via low voltage automatic pumps.

[0096] The power take off **301** has a top section mounted on the upper deck (A) this being the PTO primary and secondary shafting. The primary shaft (FIG. **15**) **240** has mounted thereon the pinion **209** and has two further gears **241** and **242** which drive pinions **243**, **245** on secondary shaft **246**. The secondary shaft pinions **243** and **245** are fitted with sprag clutches which transfer torque in one direction only, one pinion **243** being driven directly by the primary shaft gear **241** while the other pinion **245** is driven indirectly by the primary shaft gear **242** through the idler gear **247**, this arrangement being used to rectify the direction of rotation of the secondary shaft. Since the pinion **209** is rotated in response to pivotal movement between the two hulls **201**, **202**, the reacting hulls effectively transfer oscillatory motion of the primary shaft **240** into a one directional rotation in the secondary shaft **246**. The one directional torque of the secondary shaft **246** is then transferred further by the fixed gear wheel **249** through further step up gearing which is combined within the PTO casing and below the upper deck level. The additional step up gearing drives the spool input shaft **250**.

[0097] In one example, the PTO velocity, gearing and dimensions are:

[0098] Gear Segment **206**, **208** pitch circle diameter=16.250 metres

[0099] PTO input shaft pinion **209** pitch circle diameter=1,300 mm

[0100] PTO input shaft diameter **204** for 1 MW 2 rpm=850 mm

[0101] With a wave height and period of 2 metres and 8 seconds respectively the velocity of the hulls at their circumference will equal 0.5 metres/sec, this equates to 0.16 rpm.

[0102] The gear segments **206**, **208** are rotating at 0.16 rpm, the gear up ratio to the PTO input pinion=1:12.5.

[0103] The PTO pinion **209** and input shaft **240** will rotate at 2 rpm in each direction during pitch and heave.

[0104] It is envisioned that in one embodiment, the gearing produces a step up ratio of 1:5 between the PTO primary shaft **240** and the spool input shaft **250**.

[0105] In the scenario where the device is reacting to wave activity as previously mentioned of 2 metres 8 seconds the winch spool input shaft will be rotating at an average speed of 10 rpm. The winch spool core circumference will measure 6 metres and when rotating at 10 rpm it will wind the cable at a linear rate of 1 metre/second.

[0106] In a scenario where the device is reacting to wave activity of certain preconditions, of approximately 2 metres and 8 seconds, the spool input shaft will be rotating at an average speed of 10 rpm and the spool core circumference will measure 6 metres and when rotating at 10 rpm will wind the cable **14** at a linear rate of 1 metre per second. FIG. **16** shows the spool **302** with the cable **14** and weight **220** attached in a format in which it may be connected on each hull.

[0107] It is envisaged that certain limits (FIGS. **17**, **18**) may be placed on the angular pivotal movement of the forward hull section vis-à-vis the rear hull section **202** and such limits may be dependent on the arc of the gear segments **206**, **208** which may be designed depending on the size of waves encountered in a particular location.

[0108] It is also envisaged that as energy is being stored by the raising of one of the weights **220**, **221**, the other of the weights will be lowered to generate electricity via the generator **304** which will be connected to the grid in a suitable manner.

[0109] A regenerative system to moderate the descent of the weight, during energy release may be provided and suitable electronic management may be provided to control the power output and to facilitate a change over system to bring the generator on each hull **201**, **202** online and in phase during the operational sequence. A supply of compressed air will be required to control the cycle of clutch and the brake systems. Suitable compressors will therefore be provided on board to provide the necessary compressed air supply as desired.

1. An apparatus for converting wave energy into electrical energy comprising:
- a first floating hull (**201**) interconnected to a second floating hull (**202**),
- a winch mechanism (**302**) on at least one hull for in use raising a weight (**220**) suspended on a cable (**14**), said winch mechanism being operated in response to movement of said first hull relative to said second hull, and
- a generator (**304**) driven by the downward movement of the weight.

2. An apparatus as claimed in claim **1** wherein the first hull (**201**) and second hull (**202**) are pivotally interconnected.

3. An apparatus as claimed in claim **2** wherein the winch mechanism (**302**) is operable to raise the weight, when the hulls pivot relative to each other, in both upward and downward directions.

4. An apparatus as claimed in claim **3** wherein a drive mechanism (**301**) is provided to operate a drive shaft (**250**) in one direction to raise the weight (**220**) in response to relative movement of the first and second hulls.

5. An apparatus as claimed in claim **1** wherein one hull (**201**) has a gear segment (**208**) which engages with a gear pinion (**209**) on the other hull, said gear pinion (**209**) engaged with said gear mechanism (**301**).

6. An apparatus as claimed in claim **5** wherein each hull has a gear segment (**206**) and a gear pinion (**209**) for engaging with a corresponding gear pinion (**211**) and gear segment (**208**) on the other hull.

7. An apparatus as claimed in claim **5** wherein the gear segment has an arc of approximately **110**° .

8. An apparatus as claimed in claim **6** wherein the gear segment has an arc of approximately **110**° .

9. An apparatus as claimed in any one of claim **2** wherein the first and second hulls are pivotally connected by a link shaft (**203**).

10. An apparatus as claimed in claim **1** wherein the weight (**220**) on one hull is raised, as the weight (**221**) on the other hull is lowered to operate the generator (**304**).

11. An apparatus as claimed in claim **5** wherein the gear segment (**206**) is mounted on a flange (**205**) which projects from the hull.

12. An apparatus as claimed in claim **6** wherein, the pinion (**209**, **211**) on each hull is disposed on a front face (**212**) of the hull.

13. An apparatus as claimed in claim **1** wherein each hull has a recess for accommodating the weight (**220**, **221**).

14. An apparatus as claimed in claim **1** wherein each hull comprises an upper deck (A) and a lower deck (B).

15. An apparatus as claimed in claim **14** wherein at least the generator (**304**) is disposed on the upper deck (A).

16. A method for converting wave energy into electrical energy comprising providing a first floating hull interconnected to a second floating hull, and a winch mechanism for in use raising a weight suspended on a cable, said winch mechanism being operated in response to movement of said first hull relative to said second hull, and a generator driven by the downward movement of the weight.

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(19) INTELLECTUAL PROPERTY OFFICE
NEW ZEALAND

(11) Publication number: **NZ 580276 A**
(41) Publication date: **27.07.2012**
(51) Int. Cl: *F03B 13/26 A I; E02B 17/02 A I; E02D 27/42 A I; E02D 27/52 A I; F03B 17/06 A I;*

(12) Patent Application

(21) Application number: **NZ20080580276**
(22) Date of filing: **11.04.2008**
(30) Priority: **20070007402 US 11.04.2007**
2008EP02869 WO 11.04.2008

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(54) **Title:**
A method of deploying a hydroelectric tidal turbine through the base of a vessel

(57) **Abstract:**
Disclosed is a method of deploying a hydroelectric turbine. The method includes the steps of: securing a base for the turbine beneath a vessel
securing the turbine to a support of the base which projects upwardly through the vessel
transporting the vessel to a deployment site
and releasing the base from beneath the vessel. The step of releasing the base from beneath the vessel, allows the turbine to pass through the vessel.

Disclosed is a method of deploying a hydroelectric turbine. The method includes the steps of: securing a base for the turbine beneath a vessel; securing the turbine to a support of the base which projects upwardly through the vessel; transporting the vessel to a deployment site; and releasing the base from beneath the vessel. The step of releasing the base from beneath the vessel, allows the turbine to pass through the vessel.

Received at IPONZ on 20 June 2012

A system and method for the deployment of a hydroelectric turbine

Field of the Invention

The present invention is concerned with a system and method for the deployment of a hydroelectric turbine, and in particular a system and method which significantly simplifies the transportation of a hydroelectric turbine and associated base to a deployment site, in addition to simplifying the subsequent deployment of the turbine and base to the seabed.

Background of the Invention

Due to the environmental damage which has been inflicted on the planet as a result of the burning of fossil fuels, renewable energy has finally begun to be given significant attention, with many projects being developed around solar energy, wind energy, and tidal power. Of these alternative forms of energy, tidal power is arguably the most attractive, given that tidal flows are entirely predictable and constant, unlike wind or solar energy which are relatively intermittent and therefore less dependable.

However, harnessing tidal energy does provide its own challenges, in particular with respect to the installation and maintenance of tidal power generators, for example hydro-electric turbines, which by the very nature of the operation of same must be located in relatively fast flowing tidal currents, and more than likely located on the seabed. In addition, in order to be economically viable these turbines must be built on a large scale. As a result the turbines and associated bases/supports are large and cumbersome components, and require significant heavy lifting and transport equipment in order to achieve deployment. The use of such heavy lifting equipment is normally a hazardous undertaking, and is rendered even more dangerous when this equipment is operated at sea under difficult and unsteady conditions.

Received at IPONZ on 20 June 2012

The installation process is further complicated by an increasing shortage in the market of suitable vessels and equipment to perform such drilling work and the extreme danger of engaging divers in high tidal flow sites.

The present invention has therefore been developed with a view to simplifying the deployment of hydroelectric turbines, and which system and method allow the deployment of a hydroelectric turbine which has been pre-installed on a base.

Summary of the Invention

According to a first aspect of the present invention, there is provided a hydroelectric turbine deployment system comprising a base and a hydroelectric turbine supportable on the base; a marine vessel adapted to releasably retain, when afloat, the base therebeneath; wherein the vessel is adapted to allow the base to be released and lowered away from, and/or raised under and connected to, the vessel; and in which the base comprises a support which projects, when the base is connected beneath the vessel , upwardly through the vessel; characterised in that the vessel comprises a portal through which the support projects when the base is mounted beneath the vessel and through which the support mounted turbine can pass.

Preferably, the vessel comprises load bearing means adapted to raise and/or lower the base relative to the vessel.

Preferably, the load bearing means comprises one or more winches.

Preferably, the vessel comprises at least a pair of hulls connected together.

Preferably, the system is adapted to enable ballast to be secured to the base when the base is secured beneath the vessel.

Preferably, the vessel is modular.

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According to a second aspect of the present invention there is provided a method of deploying a hydroelectric turbine comprising the steps of;
securing a base for the turbine beneath a vessel;
securing the turbine to a support of the base which projects upwardly through the vessel;
transporting the vessel to a deployment site;
releasing the base from beneath the vessel;
characterised in that in the step of releasing the base from beneath the vessel, allowing the turbine to pass through the vessel.

Preferably, the method comprises, in the step of securing the base, locating the base on the bottom of a body of water;
positioning the vessel above the base;
and raising the base into position beneath the vessel.

Preferably, the method comprises the step of securing one or more lifting lines to the base prior to locating the base on the bottom of the body of water.

Preferably, the method comprises, in the step of raising the base into position beneath the vessel, utilizing load bearing means on the vessel.

Preferably, the method comprises the further step of adding ballast to the base subsequent to securing the base beneath the vessel.

Preferably, the method comprises securing the support to the base subsequent to securing the base beneath the vessel.

Preferably, the method comprises the further step of testing various operating parameters of the base and/or turbine at a test location prior to deploying the base at the deployment site.

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Brief Description of the Drawings

Figure 1 illustrates a base for a turbine standing on a quay;

Figure 2 illustrates the base of figure 1 having being lowered to the seabed adjacent the quay;

Figure 3 illustrates a deployment vessel floating above the base and adjacent the quay;

Figure 4 illustrates the vessel of figure 3, following the raising of the base into position directly beneath the vessel;

Figure 5 illustrates the vessel and base of figure 4, in which a pair of supports have been secured through the vessel to the base;

Figure 6 illustrates the vessel and the base of figure 5, following the connection of a hydroelectric turbine to the supports; and

Figure 7 illustrates the vessel positioned at a deployment site, lowering the base and turbine towards the seabed.

Detailed description of the drawings

Referring now to the accompanying drawings, there is described and shown a system and method for the deployment of a hydroelectric turbine 10 (only shown in figures 6 and 7), which system comprises the use of a base 12 for the turbine 10, and a vessel 14 to which the base 12 may be coupled, as will be described hereinafter in detail. The system and method of the invention, as will become apparent, substantially avoids the requirement for the use of heavy lifting equipment in the deployment of the hydroelectric turbine 10, and thus significantly simplifies the deployment process.

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In the embodiment illustrated the base 12 comprises a triangular frame 16 having three legs 18, although it will be understood from the following description of the system and method of the invention that the base 12 is an exemplary embodiment and could be of any other shape and/or configuration. In order to begin deployment, the base 12 is positioned on a quay Q beside a body of water W, for example the sea. The base 12 may be transported to the quay Q fully assembled, or more preferably may be assembled on the quay Q from the component parts thereof.

Referring then to figure 2, the base 12 is raised off the quay Q and lowered onto the seabed B adjacent to the quay Q. At this point the frame 12 is relatively lightweight and can be manoeuvred off the quay Q using a relatively small crane (not shown) or the like. A lifting line 20 and associated buoy 22 is connected to each corner of the base 12, preferably prior to lowering of the base 12 onto the seabed B. The number of lifting lines 20 may be varied depending on the size and shape of the base 12, or to meet any other operational requirements.

Referring now to figure 3, the vessel 14 is manoeuvred into position directly above the base 12, beside the quay Q. The vessel 14 is provided with load bearing means in the form of three winches 24, to each of which winches 24 one of the lifting lines 20 can be secured. The winches 24 can thus be used to raise the base 12 into a position beneath the vessel 14, as illustrated in figure 4. It will of course be appreciated that any other functional equivalent to the winches 24 could be employed, and indeed the number of winches 24 and the positions thereof may be varied as required. The vessel 14 and/or base 12 may be provided with locking means (not shown) adapted to secure the base 12 to the underside of the vessel 14 once winched into position. The load will therefore be removed from the winches 24 once the base 12 is locked in position. The winches 24 may however serve as this locking means.

It can be seen that the vessel 14, in the embodiment illustrated, is comprised of a pair of hulls in the form of pontoons 26, which are connected to one another by a pair of cross members 28. The space between the cross members 28 is left empty such as to define a portal 30 in the vessel 14. The base 12 can therefore be accessed through the portal 30

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from above the vessel 14. Thus referring to figure 5 a pair of supports 32 are now connected to the base 12, which work can be undertaken from onboard the vessel 14. As used herein, the term "support" is intended to mean any system or mechanism which enables the turbine 10 to be connected to the base 12 in a suitable fashion, and may not necessarily be of the upright nature depicted by the pair of supports 32 illustrated.

As the base 12 is now safely secured beneath the vessel 14, if required ballast can be added to the base 12 in order to bring the weight of the base 12 to a level which will allow the base 12 and turbine 10 to sit securely on the seabed under their own weight. As this ballast is only added at this stage, the winches 24 do not need to bear this extra load when raising the base 12 into position beneath the vessel 14. The adding of ballast at this stage also ensures that when the base 12 is first lifted off the quay Q and lowered to the seabed B, the crane undertaking the lift does not have to bear the weight of the ballast, and so a relatively small crane can be employed.

Turning then to figure 6, the turbine 10 is now lifted onto the base 12, and in particular the supports 32, again using a relatively small crane positioned on the quay Q. The turbine 10 is then secured to the supports 32 and is then ready to be transported to a deployment site out at sea.

It is envisaged that as this turbine based technology matures, the turbines will grow in size, and so therefore will the distance between the hulls or pontoons 26. However, the winch 24 which is located on the middle of the front cross member 28 will be carrying a significant load, and is not supported. It is thus envisaged that the design of the vessel 14 for larger turbines (or indeed if two or more turbines 10 are to be mounted side by side on a single base 12) will take some form other than a catamaran design, for example a tri-maran. The modular nature of the vessel 14 would make such a modification possible and readily achievable.

In addition, the modular nature of the vessel 14 enables the vessel 14 to be easily dismantled and shipped around the world to the next installation site in the hull of a large cargo ship. This approach may save time as the larger cargo ships are able to travel in far

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worse conditions than the vessel 14. The modular approach also means that the vessel 14 could be reconfigured in the future for different shaped bases 12, i.e. when deploying a larger turbine it may be desirable to widen the distance between the hulls 26, which could be easily done by lengthening the cross members 28. This has obvious cost savings as it is not necessary to build a completely new vessel.

Another advantage embodied by the shape of the vessel 14 is that it is easy to tow as there is very little resistance, as the cross members 28 are positioned to be out of the water and so only the pontoons 26 are sitting in the water. This design will align itself with the tidal flow compared with an alternate design having the cross members submerged. The latter design will be less streamlined and less likely to be in line with the flow. This is an important feature when deploying the turbine 10 when there is some tide running as when the turbine 10 is lowered, the vessel 14 will be orientated correctly to the tide and so the turbine 10 will be automatically deployed in the correct orientation.

The modular approach to the design of the vessel 14 also allows additional equipment to be quickly and easily mounted to the vessel 14 for use during the installation process. Platforms (not shown) supporting such equipment can be easily connected to the vessel 14 using conventional modular connectors (not shown).

Referring to figure 7, once the vessel 14, base 12 and turbine 10 have been positioned above the deployment site the base 12 and turbine 10 can be lowered into position. This is a simple process of unwinding the winches 24 which will allow the base 12 to fall away from beneath the vessel 14. If any locking means (not shown) are provided on the base 12 and/or vessel 14 they will need to be released before unwinding the winches 24. The portal 30 in the vessel 14 is shaped and dimensioned to enable the turbine 10 to pass downwardly through the portal 30, and thus the combined turbine 10 and base 12 can be lowered together from the vessel 14. No further work must then be done in securing the two together when the base 12 has been positioned on the seabed B, thereby greatly simplifying the deployment process. In addition, no lifting equipment such as cranes or the like are required to be operated from onboard the vessel 14.

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The connectivity between the base 12 and vessel 14 also allows the above process to be carried out in reverse, in order to allow the base 12 and turbine 10 to be retrieved from the seabed B. The vessel 14 is positioned over and connected to the base 12, which can then be winched into position beneath the vessel 12, and securely connected therebeneath for transport back to shore or any other desired location.

It is preferable, prior to transporting the turbine 10 to the deployment site, that various tests are undertaken on the turbine 10 and the base 12 while positioned adjacent to the quay Q. Thus referring to figure 6, once the turbine 10 has been secured to the base 12, the base 12 and turbine 10 are lowered to the seabed B, while the vessel 14 remains adjacent the quay Q. The lifting lines 20 are left secured between the base 12 and vessel 14 while the base 12 is positioned on the seabed B, in order to allow the base 12 and turbine 10 to be quickly and easily retracted into position beneath the vessel 14 for transport to the deployment site illustrated in figure 7. When the base 12 is positioned on the seabed B, various tests can be carried out, for example testing/calibration of telemetry sensors (not shown) or the like positioned on the base 12 and/or turbine 10. Once said testing has been completed, the base 12 is winched back into position beneath the vessel 14, and the turbine 10 is then again positioned above deck of the vessel 14. The vessel 14 can then be transported to the deployment site as described herein before with reference to figure 7. If this testing reveals any problems with any aspect of the turbine 10 or base 12, both can quickly be removed from the water W due to being still positioned adjacent the quay Q. Indeed if there is only a problem with some aspect of the turbine 10, then the turbine 10 could be released from the base 12 and taken onto the quay for further testing and/or repair. The base 12 could then be left secured beneath the vessel 14 to await the return of the repaired turbine 10.

It is envisaged that the system of the invention may be used to deploy the base 12 onto the seabed B without the turbine 10 mounted thereto, which would then be subsequently connected to the base 12 by suitable means.

It will therefore be appreciated that the system and method of the present invention provide a simplified yet highly efficient means of deploying a hydroelectric turbine 10, and

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minimises the requirement for heavy lifting equipment, eliminating the need for the use of such equipment on board the vessel 14, in particular at the deployment site.

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Claims

1. A method of deploying a hydroelectric turbine including the steps of;
securing a base for the turbine beneath a vessel;
securing the turbine to a support of the base which projects upwardly through the vessel;
transporting the vessel to a deployment site;
releasing the base from beneath the vessel;
characterised in that in the step of releasing the base from beneath the vessel, allowing the turbine to pass through the vessel.

2. A method according to claim 1 including, in the step of securing the base, locating the base on the bottom of a body of water;
positioning the vessel above the base;
and raising the base into position beneath the vessel.

3. A method according to claim 2 including the step of securing one or more lifting lines to the base prior to locating the base on the bottom of the body of water.

4. A method according to claim 2 or 3 including, in the step of raising the base into position beneath the vessel, utilizing load bearing means on the vessel.

5. A method according to any of claims 1 to 4 including the further step of adding ballast to the base subsequent to securing the base beneath the vessel.

6. A method according to any of claims 1 to 5 including securing the support to the base subsequent to securing the base beneath the vessel.

7. A method according to any of claims 1 to 6 including the further step of testing various operating parameters of the base and/or turbine at a test location prior to deploying the base at the deployment site.

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8. A method of deploying a hydroelectric turbine substantially as herein described in the detailed description of the drawings section of the specification and the accompanying figures.

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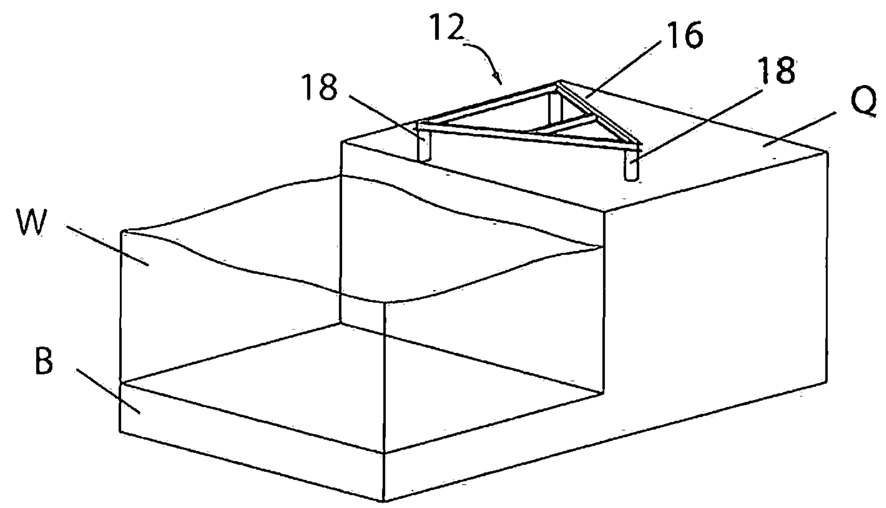

Fig. 1

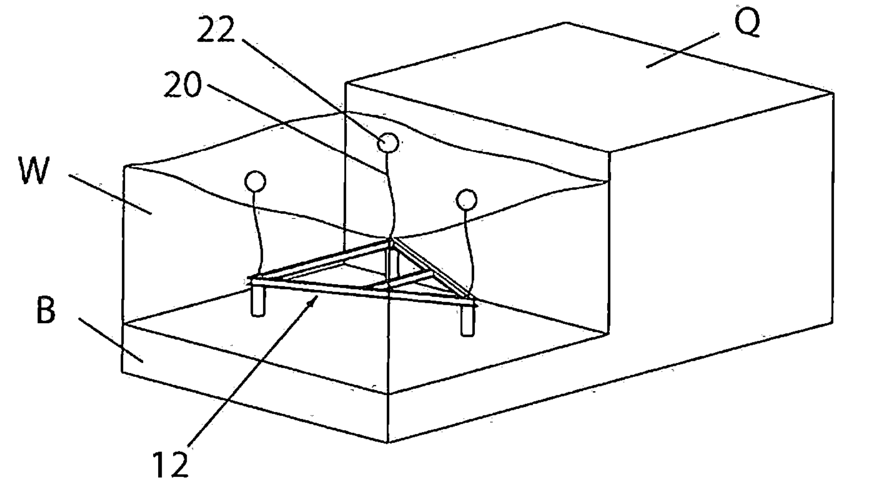

Fig. 2

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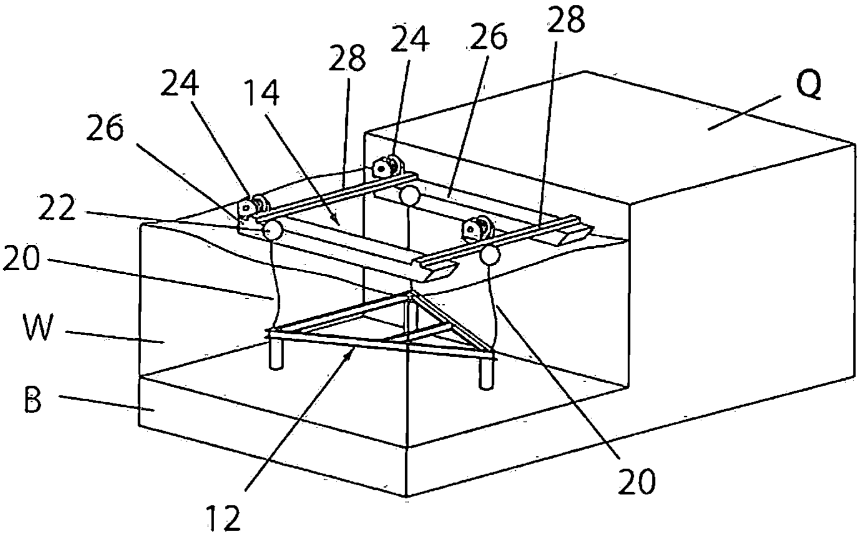

Fig. 3

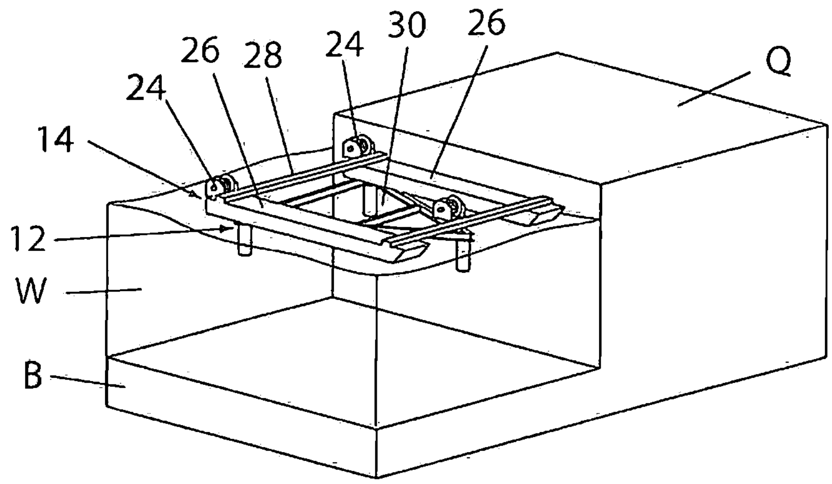

Fig. 4

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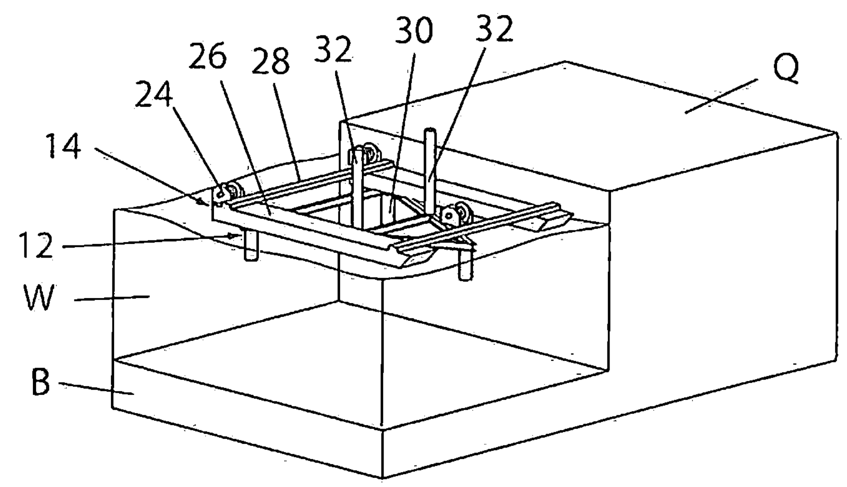

Fig. 5

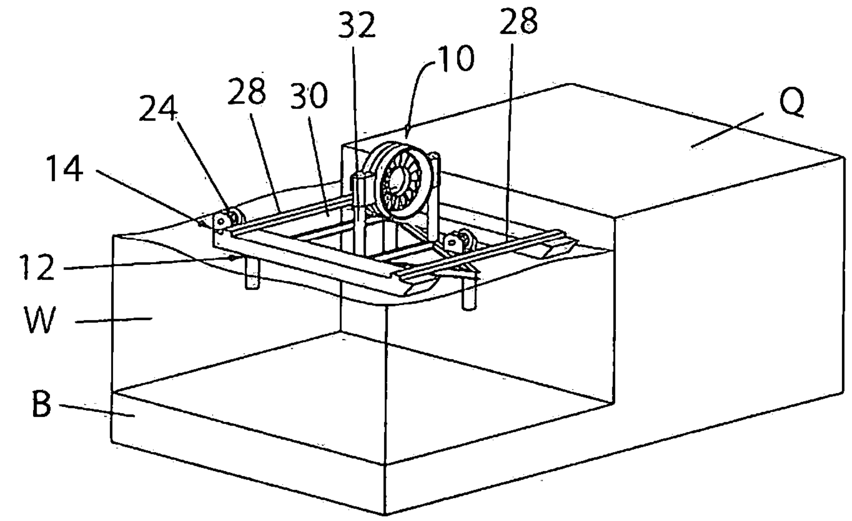

Fig. 6

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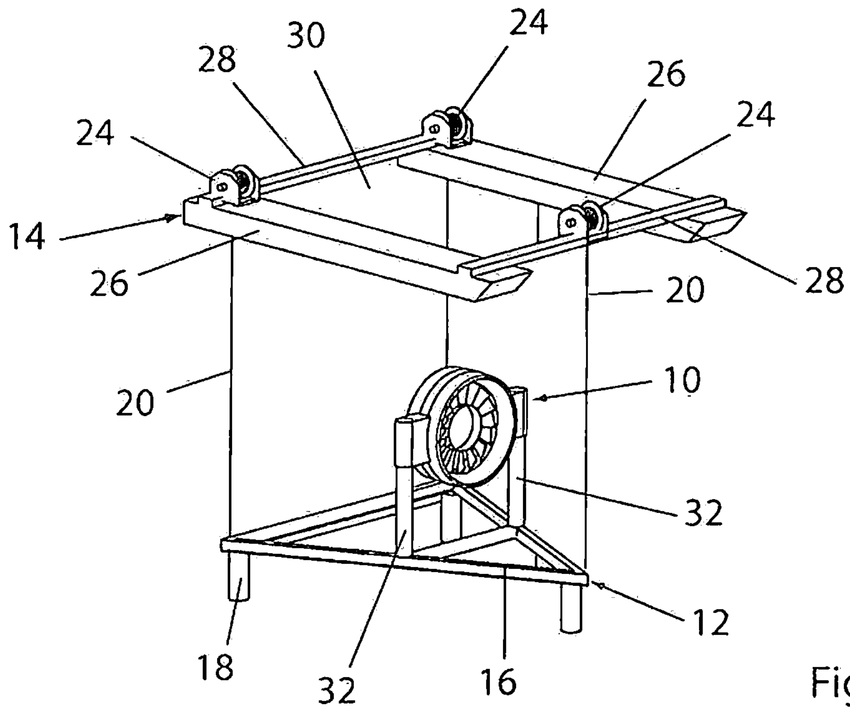

Fig. 7

END

US 20080018114A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2008/0018114 A1**

Weldon

(43) **Pub. Date: Jan. 24, 2008**

(54) **HARVESTING AND TRANSPORTING ENERGY FROM WATER WAVE ACTION TO PRODUCE ELECTRICITY HYDRAULICALLY WITHIN A FLOATING SHIP OR VESSEL**

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(21) Appl. No.: **11/818,939**

(22) Filed: **Jun. 18, 2007**

Related U.S. Application Data

(60) Provisional application No. 60/832,550, filed on Jul. 24, 2006.

Publication Classification

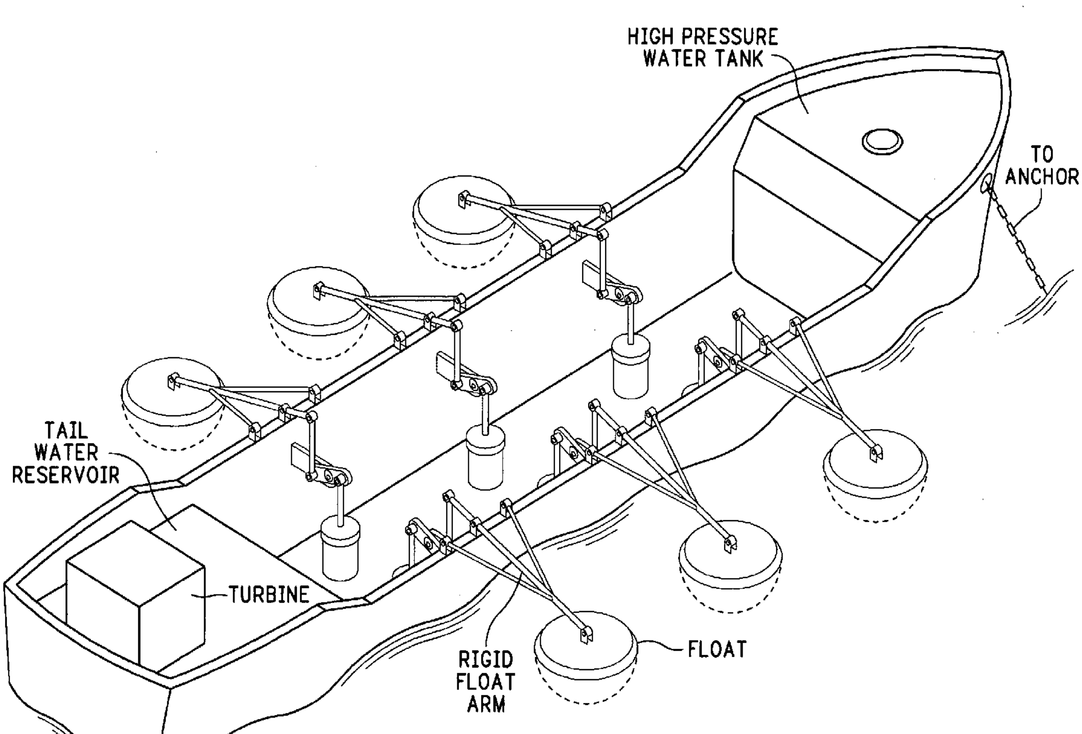
(51) **Int. Cl.**
F03B 13/10 (2006.01)

(52) **U.S. Cl.** **290/53**

(57) **ABSTRACT**

This is a unique way for an anchored vessel at sea near an isolated island or outpost to be able to generate electricity and transfer it from within its hull for use onshore with an electrical underwater cable for that community.

The floating vessel, or electrical station, is unique because it is anchored in water wave action and has a total of (six) side floats, moving up and down from water waves and these floats and float arms are used as simple lever machines rotating on the ship's bow to transfer this energy to fresh and recycled water inside the vessel by means of a water piston and water pipes into a pressurized water tank for turning a water turbine there, then recycling or pumping this water again, and again for generating electricity within the body of this floating vessel.



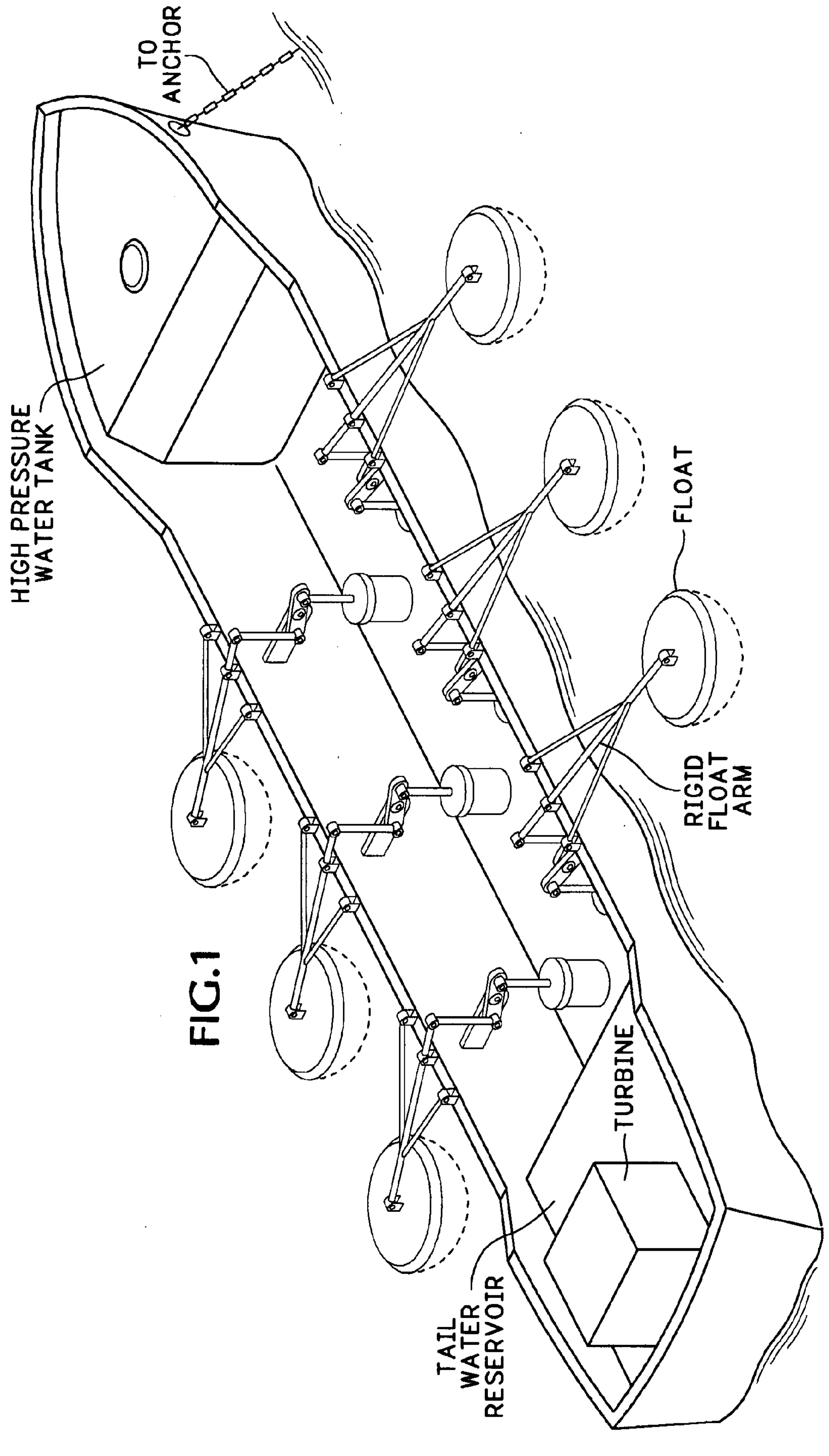

TO ANCHOR
HIGH PRESSURE WATER TANK
FLOAT
RIGID FLOAT ARM
TURBINE
TAIL WATER RESERVOIR

FIG.1

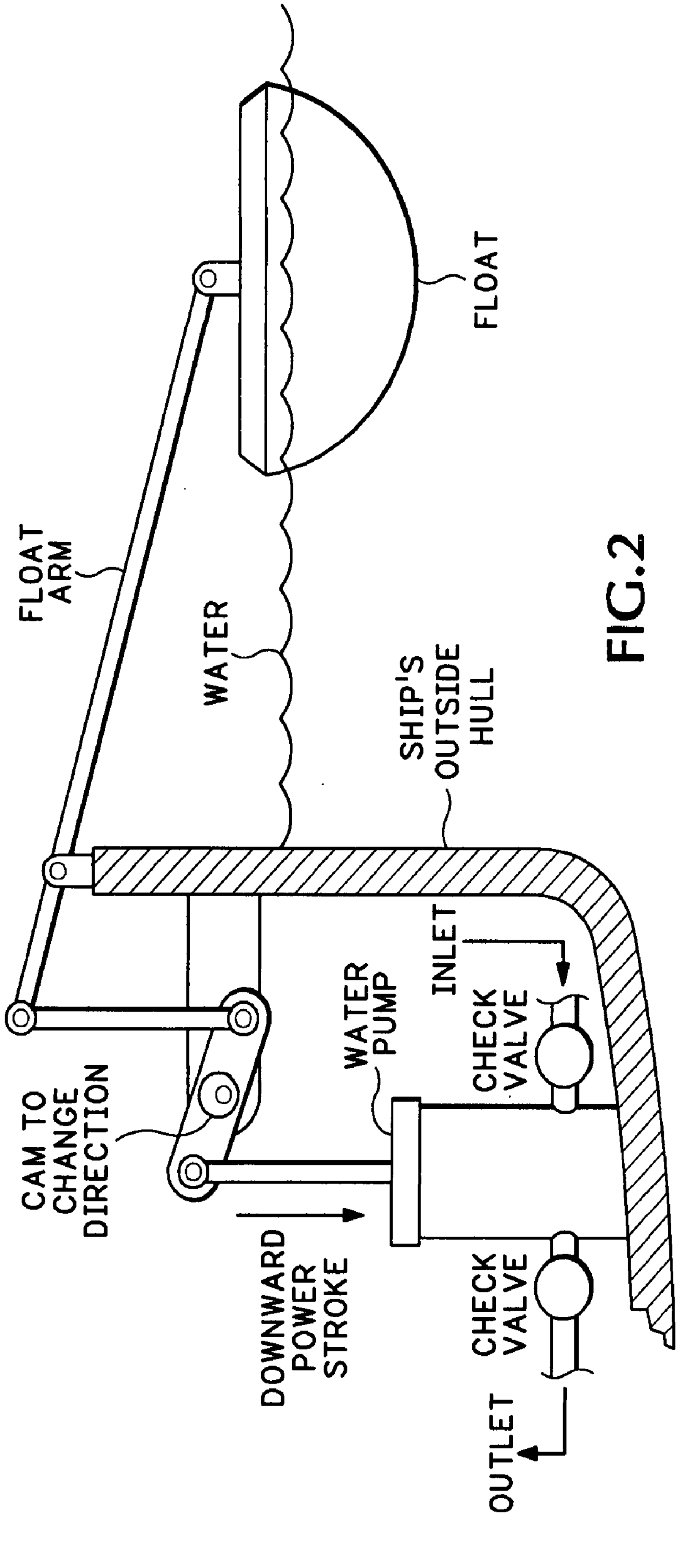

FLOAT
FLOAT ARM
WATER
SHIP'S OUTSIDE HULL
INLET
CHECK VALVE
WATER PUMP
CAM TO CHANGE DIRECTION
DOWNWARD POWER STROKE
CHECK VALVE
OUTLET

FIG.2

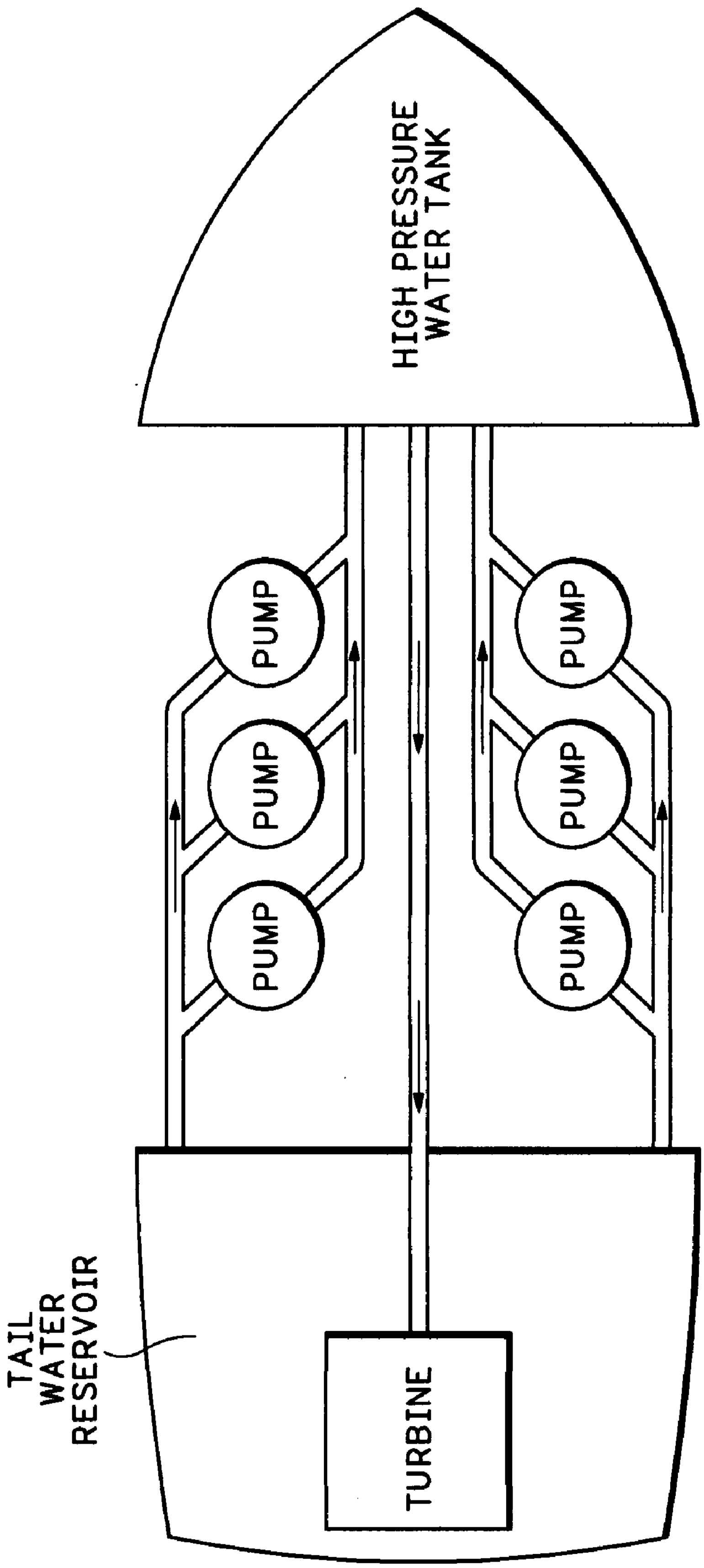

HIGH PRESSURE
WATER TANK
PUMP
PUMP
PUMP
PUMP
PUMP
PUMP
TAIL
WATER
RESERVOIR
TURBINE

FIG.3

HARVESTING AND TRANSPORTING ENERGY FROM WATER WAVE ACTION TO PRODUCE ELECTRICITY HYDRAULICALLY WITHIN A FLOATING SHIP OR VESSEL

(REFER TO PREVIOUS PROVISIONAL) U.S. 60/832550

[0001] This is a utility patent application

CROSS REFERENCE TO SOME RELATED PATENT APPLICATIONS ARE

[0002] U.S. patent numbers:

[0003] U.S. Pat. No. 4,319,454—Mar. 16, 1982 (Perhaps the nearest likeness)

[0004] U.S. Pat. No. 228,860—Oct. 14, 1980 & Jun. 8, 1979

[0005] U.S. Pat. No. 5,027,000—Sep. 7, 1989

[0006] U.S. Pat. No. 4,185,947—Dec. 28, 1977

[0007] U.S. Pat. No. 3,664,125—Mar. 30, 1970

[0008] U.S. Pat. No. 3,746,875—Aug. 4, 1972

[0009] U.S. Pat. No. 4,851,704—Oct. 17, 1988

[0010] U.S. Pat. No. 4,023,041—Mar. 1, 1976

[0011] U.S. Pat. No. 3,012,938—Jan. 25, 1974

[0012] U.S. Pat. No. 4,091,618—Jan. 14, 1976

[0013] U.S. Pat. No. 4,627,240—Feb. 27, 1981

[0014] U.S. Pat. No. 4,719,158—Mar. 27, 1987

[0015] U.S. Pat. No. 3,959,663—Oct. 19, 1974

[0016] U.S. Pat. No. 4,563,591—Jan. 7, 1986

[0017] U.S. Pat. No. 4,389,843—Jun. 28, 1983

BACKGROUND OF INVENTION

[0018] This final invention has come from ideas I originally conceived in the 1960's while boating in the Pacific Ocean off the coast of the states of Oregon and Washington, U.S.A. I then started to develop a way to capture some of the energy of water wave action to produce electricity. To show an earlier time of conception before today's date, I started certified mailings to myself beginning Feb. 19, 1999 that verifies work progress in the years of 1995 and 1996. I have several certified mailings to myself since to show my progress on this invention.

[0019] In earlier conceptions of this invention I was trying to carry this electric generating station only on a fixed support from the floor of the ocean or body of water, as well as trying to harvest tide and current action at the same time.

[0020] In 2002, I was using mechanical means with wire cables and rotating cylinder to transfer the energy to the generator, but now have the new idea of using only hydraulic energy to turn the generator within the body of a vessel.

[0021] My latest conception includes the new way to harvest water wave energy by using a specially constructed float, plus the use of a water reservoir and water pump within the vessel's hull to receive and transport energy to the generator located also in the hull for production of electricity. My invention submitted herewith requires a floating vessel to carry the electrical generating station.

BRIEF SUMMARY OF THE INVENTION

[0022] The object of this invention is to produce electricity from the ocean water or large body of water by harvesting some of the uplifting power or action of a water wave or swell. The actual weight of a float being pulled down by gravity on the wave will transfer its weight as the energy to the turbine to produce electricity. The float and float arm on the vessel will be using the simple lever system as a mechanical means to transfer this energy to the water pump. One end of the lever system extending inside the hull of the ship will pump and force fresh and recycled water into a large water reservoir under pressure for use by an electrical turbine on board the vessel . . . . This vessel will carry the total and complete electrical generating station. Severe storms or water action will not affect the delivery of uniform energy towards the generator. Each float is delivering secondary or indirect energy from the waves, not the direct force of a wave, because the float's actual weight from gravity will be the uniform energy necessary to pass on to the electrical station, but not the direct energy from a rising wave.

[0023] In actual use: The rising and falling floats located at one end of the lever with their fulcrums attached to the vessel's bow, will move up against gravity on the water wave to capture and store energy. The float's weight, on the down stroke, and sometimes out of and above the receding wave, will transfer this energy at the opposite end of the lever. This lever has an attached connecting rod extending down into the vessel that can either pull the attached piston directly up in a vertical direction to do work or change the stroke of the water piston to a "pushing action" of the water piston by employing a "cam and camshaft" between the water piston and the end of the float's arm. I will use the camshaft method in this invention. This change of direction will cause the water pump piston to be pushed down in the hull instead of being pulled up directly by the connecting rod. One side of the cam will be connected to a float arm with a metal rod. The other end of the cam will be connected to the water piston's shaft, which will then move in the opposite direction as it rotates on the camshaft itself. This camshaft will change the pulling direction to a pushing motion from the force of the connecting rod adhered to the float arm. This pushing action now will transfer the energy from the piston in the water pump to water that will go into a large pressurized holding tank. This water tank now under extreme pressure, will allow water to be forced into the water turbine to generate electricity. This electrical energy will carried to shore with a "submarine" or underwater cable.

[0024] Some unique features have been added since the original conception of this invention that I put on paper Apr. 1, 2002, plus simplification for efficient operation and less maintenance for lasting operation of this floating electrical station.

BRIEF DESCRIPTION OF THE VIEWS OF THE DRAWINGS

[0025] Drawing #**1**

[0026] General view of the entire floating electrical station with (6) floats

[0027] Drawing #**2**

[0028] General view of a float arm using the vessel's side as a fulcrum with a float at one end and a cam rod connected to the opposite end and within the vessel's hull, to operate a water pump.

[0029] Drawing #3

[0030] General view and location of two water pumps, water holding tank, turbine, and water lines within the vessel's hull.

DETAILED DESCRIPTION OF THE INVENTION

There will be (3) major parts for the invention

[0031] #1—Floating ship, hull, or vessel showing side floats

[0032] #2—Floats and its hardware

[0033] #3—Water piston area and water flow plan

[0034] #4—Generator or hydro turbine

[0035] A floating (ship or) vessel can be used to produce electricity anywhere in the world where there is some water wave action. The use would be of particular importance for isolated islands needing electricity, or communities on land near the ocean without adequate electricity. The best location for use should be where constant wave or swell action for long periods of time exists.

[0036] A variety of cargo vessels with different lengths, widths, and freeboard with open hulls can be used. A cargo ship approx. 300 feet long would be best to carry this electrical station. The open-type vessel with less than 40 feet freeboard is suggested. There is a surplus of vessels worldwide that could be adapted for this use.

[0037] The construction would allow for low maintenance, easily floated to a new location, and built of materials to withstand salt water and severe weather conditions. A small fossil fueled motor would perform necessary functions on board, such as raising anchors, maintaining drift, pumping water, emergency electricity, air pressure for raising the floats and maintaining an air supply in the pressurized water tank, etc. Some of the electricity generated by ocean waves might also be used for these tasks also. The floating vessel will be equipped with (6) floats, three on each side, that are moving up vertically from water or wave action. When gravity pulls these floats down, the opposite end of the float will rise up and do work within the vessel. The fulcrum of this lever action is secured on the vessels side, between both ends of the floats arms. A metal rod will tie the upper end of the float's arm to the cam below to change direction from a pulling action to a pushing downward direction. The pushing up action of the water piston will force water into a large pressure tank. The pulling motion of the water piston will pull water back into its chamber to be pushed out again. Water will then be forced by this piston into the large and pressurized water tank as energy. This water tank will force water through a turbine nearby to generate electricity. The electricity generated will then be transferred to shore. An underwater or "submarine" cable would be used, available worldwide.

[0038] The vessel should be moved in water by utilizing either towing or pushing boats, consequently the motors, fuel, and original hardware to operate or navigate the vessel could be removed. A vessel with a "no motor" feature, and "gutted out" can be purchased for less money, and would have more room for the new use as an electrical station.

[0039] Anchoring the vessel from the bow to the seafloor or lake bottom will help insure the hull of the vessel will "trail" back from the wave action direction to produce the best action for the floats. Extra anchors on this vessel should be required. The hull can also be anchored or fixed stationary to a coastal or lake outcropping, cliff, or other solid anchor point(s) on the shore, or, rising from the ocean or lake bottom. This vessel will be purchased, built, or remodeled to be very stable in the worst of weather, water or extreme storm actions. The ship's "Roll" and pitch action may help the float action. Stabilizing plates for the vessel located in the water could be used perhaps to get more float action from consistent swells or waves, if the vessel is rising excessively with the water waves. The float system will operate however with any wave action. The floats, their support arms, or beams, should be the only parts of this station exposed to the weather. All other mechanical hardware will be below the "deck" area or covered for protection from salt water or weather.

[0040] The floats can have a plurality of shapes and sizes, from long and cylindrical, round or rectangular, depending upon water or wave action. Cylindrical floats may be best for carrying a large amount of weight when the wave action is coming from one direction. The shape of the floats will be designed to insure the most lift from a swell or wave, also built to resist high winds or storms. Each float with its attached hardware (including the float arms extending within the vessel) will weigh many tons. An electrical or mechanical engineer, after knowledge of water waves in the area, may choose the floats size and weight to determine the maximum electrical output. The floats will be filled with water, but the water reservoir within the float will hold air to keep them floating, but just above its desire to sink below the surface, and mostly "buried" within the water wave. The water level within the float could be adjusted with a fixed air pipe or hose along the floats arm, so the vessel's auxiliary motor could change its weight for best working weight, or storms, travel, repair, out of service, etc. The floats can be raised mechanically to an "out of service" position anytime. The floats themselves could be made of tough plastic or metal and strapped or adhered securely, or made part of the float arm. Metal could add rigidity and weight. The float arm itself will be of metal, reinforced with cable for strength. The length of the float arm is about 80 feet, adjustable at the extreme, upper end, extendable to about 20 feet more than normal use within the confines of the vessel. In other words the float arm head can be adjusted at any length from 0 to 20 feet longer than its shortest length. This upper end of the float's arm will carry the fixed hardware to push and pull the water piston. The adjustable float arm's head and cable assembly will accomplish two things: #1, It will change the energy the water piston receives from the float's arm, depending upon its length or distance from its fulcrum or axle it pivots upon. It is ideal to have all float arm extensions to be located from the fulcrum evenly on all float arms to help receive and deliver the same energy. #2, the arms can be extended or adjusted to reach or better fit the different widths of different vessels as well as the ship's curved bow, where the float is pivoting and anchored at different locations. Any extra weight added to this upper end of the float arm should be added to the lower end of the float arm, or the float, to help enhance the weight of this lower arm so maximum energy can be passed to the primary cylinder.

[0041] The float's arm should be approx. 80 feet long, with its fulcrum or pivoting axle, approx. 53.3 feet from the extreme lower end of the float in the water to the side or bow of the ship. The final 26.7 feet will be extended inside the vessel from this pivot point, but note it has another approx. 20 feet, if needed, with its extension head. The float should have three support arms. The main and centrally located float arm will begin on the top and center of the float in the water, or at its farthest point from the vessel. The two separate supporting side arms for this float will also start (or end) on this topside of the float. From here, the side support arms will widen to a maximum width of approx. 40 feet away from where the center support arm is positioned on the ship's bow. This 80 foot float support with its three arms will all share the same fulcrum or axle that is mounted upon the vessel's bow. The 40 feet of width allows the three arms of the float to be anchored at three places on one main axle. The center arm will be the strongest, as it must carry the major weight of the float plus the arm's weight extending beyond the fulcrum to the center of the vessel. This center arm carries the heavy hardware to do the work. This float arm will support those two separate "side" arms of the float that will help prevent twisting, or other damage due to the violent wave action and will be secured or fixed or become permanently attached to each other as one unit, and will be adhered permanently to the fulcrum's axle. The cylindrical axle thus attached and holding up all three attached float arms, but at separate locations, will be the fulcrum for the float as it moves up and down. The fulcrum or axle holding the heavy float arms will be attached very strongly to the vessel to prevent damage in the extreme low and high positions as well as the vessels pitch and roll actions. Again, the two side arms of the float should be securely held to the main center arm of the float to help withstand the twisting or damaging effect of the water, weather, etc.

[0042] When the floats are in the lower than normal position, they may stop upon hitting the side of the hull on a large vessel. An additional padding material of softer very resilient material could be permanently placed on the float's underside making contact to the hull, or the out of service cable to raise the floats could be used as the stopping point if needed occasionally. On a small vessel, a cushion could be placed under the float arm to contact the hull of the vessel, if ever necessary, in a gentle manner. These cushions should have special shock absorbing qualities. The hull may have to be reinforced where it may contact the hull at this lowest float position if necessary.

[0043] Each float on the vessel should maintain the same weight for producing the same energy or power. When mounting the working floats from the bow to the stem of a vessel, different distances from the bow to the centerline of the vessel will occur. The floats fulcrum or pivoting axles may be moved to conform to the rounding hull, or have the extendable heads used which would change the distance to the center of the vessel, but, again, would not matter. It is necessary to have these axles holding the floats be parallel to each other, or on the same horizontal plane.

[0044] The following paragraphs describe the fulcrum or pivoting axle for the floats on a 300 foot or longer vessel.

[0045] The total length of the axles that are inside and not the "end" axles holding the floats in place should be 45 feet. The "end" axles can be 50 feet, but a minimum of 47.5 feet. There will be room for (3) floats on each side, rotating on an axle or fulcrum totaling 240 feet (each side), or 80 feet for each float. The diameter of the axle or fulcrum should hold the floats weight and hold the pitch and roll stress during extreme weather. There will be two bearings and bearing caps on the axle between the two outside arms of the float. Between each float's outside arm there will be another bearing and cap separating these two arms. The axles will be split here for separate rotation for each float assembly containing the three float arms of each float. The bearing and cap should have a stop groove so each axle won't move horizontally. All bearings should be alike, except the two end bearings, which will not have a split axle in them. The axle will be rigidly supported from the bottom and sides of the vessel to hold the extreme weight of the floats, the float's support arms, and hardware. There will be a framework of steel perhaps coming from the floor of the vessel, as the base, to hold the float arms and the rotating axles. These axles must be high enough for the float arms to clear the top of the hull when moving up and down. The framework to block up the float's arm on the bow can be of different height or thickness, but mounted primarily to support the float arms and secondly to clear the top of ship's hull when the floats are at their lowest and highest positions.

In the Vessel's Hull:

[0046] The connecting rod at the end of the float arm that is extended downward within the vessel's hull is working within a steel pipe or cylinder in the vertical up and down direction and its distance of travel is dictated by the height of the wave at the other end of this float arm. This action will pump water under pressure to a main line on this side of the vessel that all three float areas and water pumps are using together. This water line will go to the large, high pressure tank that will then keep supplying the turbine with high pressured water at an even rate. After the water has passed through the turbine, it will pool up in a small reservoir, then flow by gravity in one pipe that is shared by each side of three working water pump stations. This will help disallow air to entrain itself into the water. The pressurized water tank can be placed at any elevation that is close to the turbine, but the turbine must be placed above the recycled water supply and return water pipe to the water pumps for gravity to flow the water back to the water pumps. There can be several methods used to supply the water from the piston to the water tank receiving the water pressure. This invention will use the following water pipe and valve plan:

[0047] There will be only one collector pipe on each side of the vessel that will transfer the high pressure water from all three water pumps on their respective side to the water holding tank. This one pipe will collect all water pumped from one side of the vessel from the three water pumps and deliver it into the holding tank. There will be "check valves" installed close to the water pump and for extra safety, close to the holding tank also, so water pressure is not lost. Water used by turbine will be recycled and collected in a small lagoon, or open tank type structure. There will be only one recycled water pipe from the base of this water reservoir to supply all three water pistons on their respective sides. This water will be fed to the pumps from the force of gravity. There is the possibility that for reasons of placement, or location of the turbine, a closed pipe system using some of the water pressure from the water tank could be used to force the water to the pumps for its re-use.

Water Pumps:

[0048] There are pluralities of water pumps that can be used, however, I will use the following one in this invention. The water pump will consist of a water piston, a connecting rod from it to the camshaft's cam, and the pipe or metal cylinder it is fitted into. The water piston's cylinder is secured to the bottom of the vessel at the correct elevation for the water piston to operate in at a safe length so that the piston will not touch the chamber's extreme end. This cylinder or water pipe will extend upwards to the cam, but not to touch or contact it when the piston is at its extreme position due to high water wave action. Both the high pressure valves and water return check valves are located below the head of the piston. This will allow the top of the piston's cylinder to be open for the connecting rod from the float's arm to work and not touch the cylinder wall. It will also allow any excessive water forced around the piston rings from pushing water to be expelled for recycling. 12 or more inches of water should be sufficient above, or behind the piston to disallow any air to be sucked along the walls of the piston while it is sucking in water from the front of the head.

The Camshaft:

[0049] (To change direction of the energy from the float arms)

[0050] The camshaft tower should be welded to the bottom hull of the vessel and directly below the end of the upper float arm area. There will be extreme force on the cam-shaft to be lifted upwards due to the heavy weight of the float. The bottom half of the cam and the cam-shaft will be made strong with heavy metal to withstand this force. The top half of the covering on the cam-shaft need only to hold the camshaft together properly.

1. I claim that the use of a cargo vessel or a ship anchored in the ocean carrying side floats and producing electricity with fresh water through a water turbine inside the vessel's hull from the energy of water waves is new.

2. I claim that by using a float and a float's rigid arm in a new way as a simple class #1 simple lever system with the float on the water at one end, and its fulcrum anchored and rotating on the bow of a floating ship or vessel, and the opposite end with a vertical rod extending downward into the ship's hull to operate a water pump that recycles fresh water within this hull is new.

* * * * *

US 20110018275A1

(19) United States

(12) Patent Application Publication

Sidenmark

(10) Pub. No.: US 2011/0018275 A1

(43) Pub. Date: Jan. 27, 2011

(54) WAVE POWER PLANT AND TRANSMISSION

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(21) Appl. No.: 12/867,431

(22) PCT Filed: Feb. 20, 2009

(86) PCT No.: PCT/SE09/00100

§ 371 (c)(1), (2), (4) Date: Oct. 5, 2010

(30) Foreign Application Priority Data

Feb. 20, 2008 (SE) 0800395-6
Oct. 10, 2008 (SE) 0802165-1

Publication Classification

(51) Int. Cl.
F03B 13/18 (2006.01)

(52) U.S. Cl. 290/53

(57) ABSTRACT

A wave energy converter includes a buoy and a transmission unit. In the transmission unit there is a driveshaft, which is driven to rotate either when the buoy rises or sinks, yet always in the same direction. The driveshaft is mechanically coupled to one of the rotating parts of an electric generator and drives this to generate electric current. Further on there is an energy accumulation device, which is also coupled to the driveshaft to accumulate energy when the buoy rises or sinks and the driveshaft rotates and which is then used to drive the generator at the other of the rising and sinking motions. The coupling between the energy accumulation device and the driveshaft can go by the generator's second rotatable part, the air gap between the generator's parts and the generator's first part. The coupling over the air gap gives a torque, which drives the second part to rotate along and which also counteracts the rotation of the driveshaft. The generator's second part is driven by the energy accumulation device to rotate in the other direction, when the torque from the driveshaft does not exceed the counteracting torque.

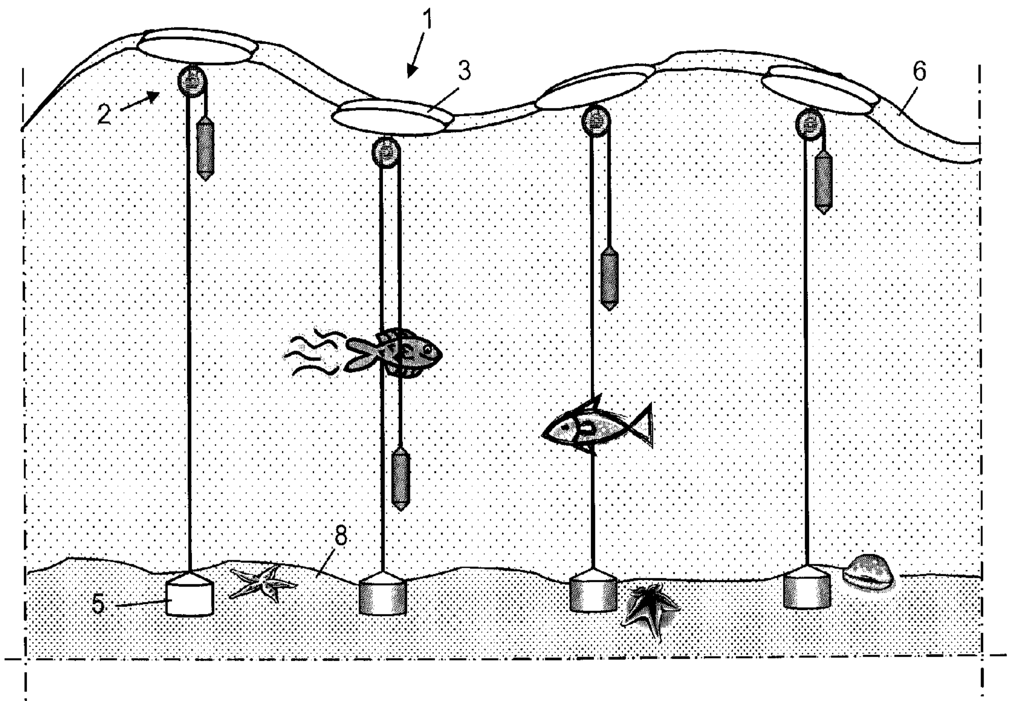


Fig. 1

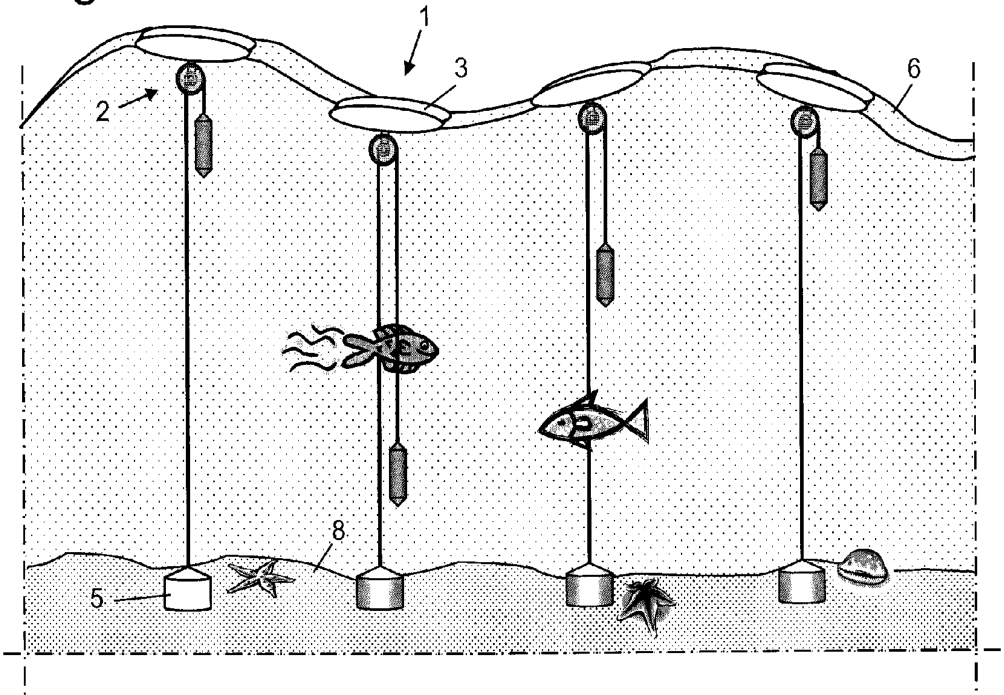


Fig. 2a

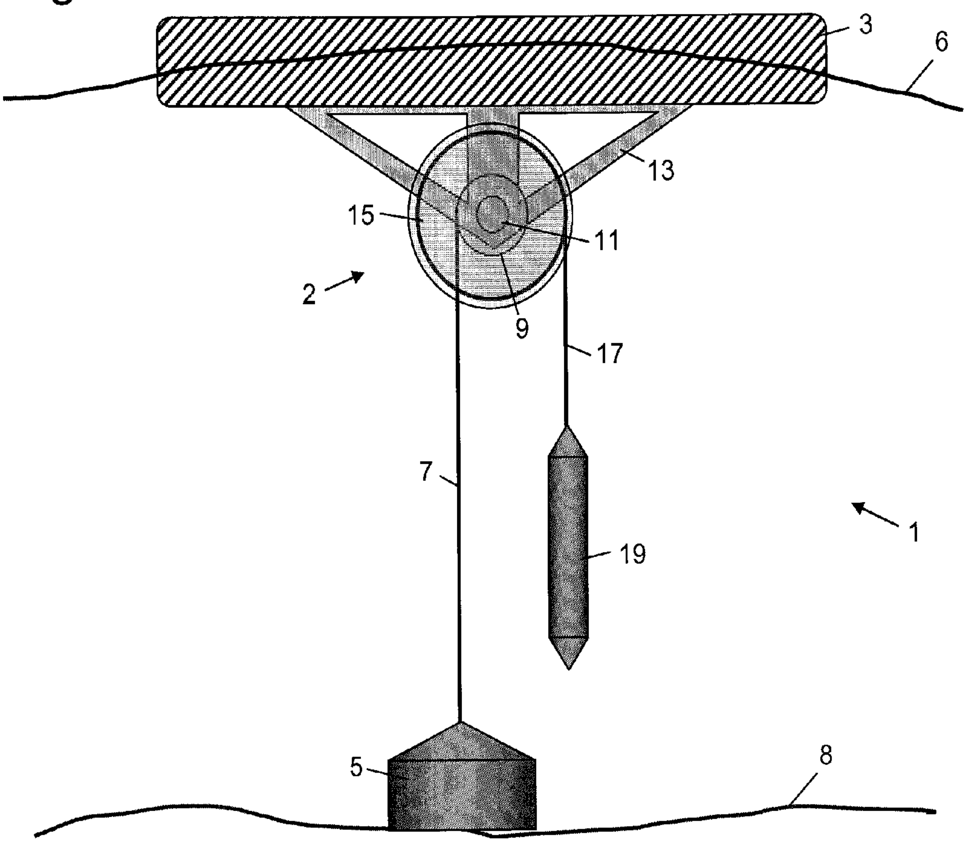


Fig. 2b

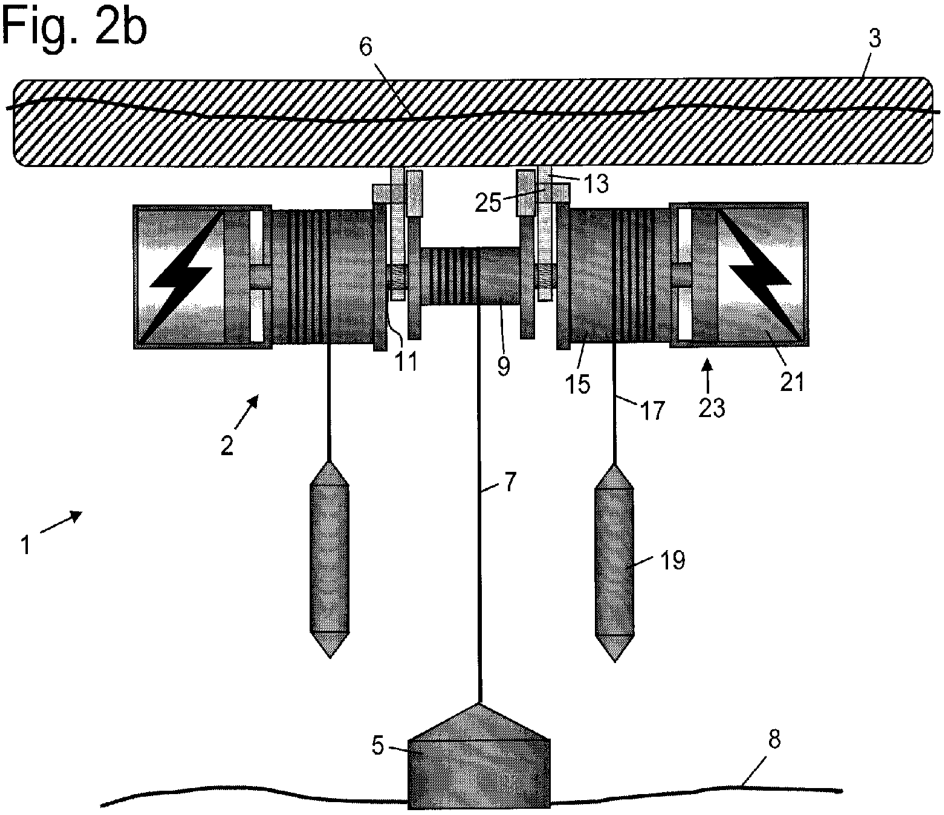


Fig. 2c

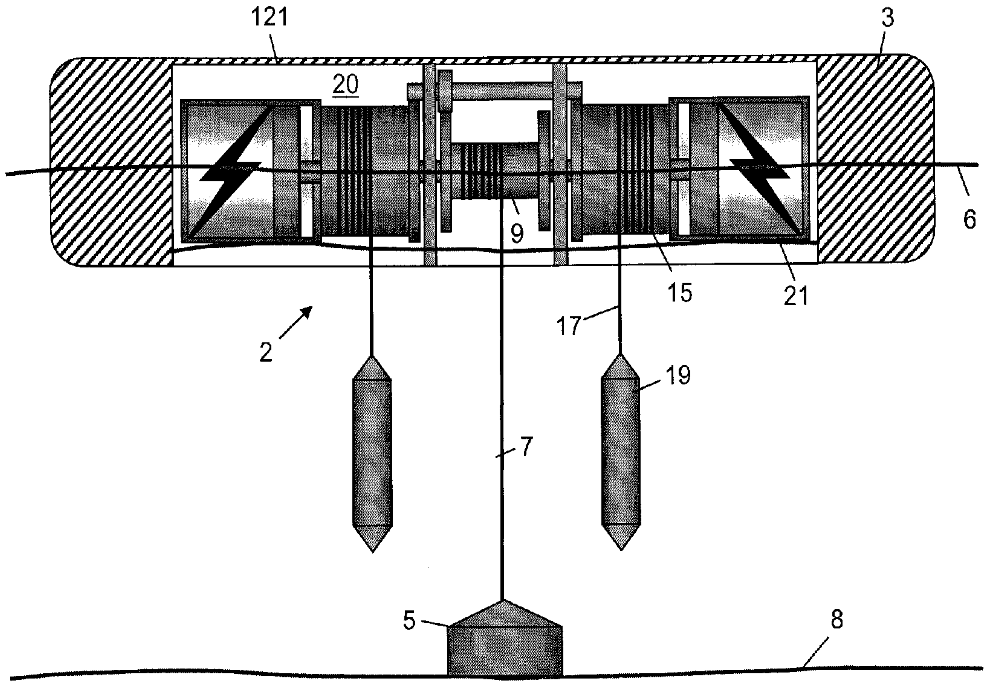


Fig. 2d

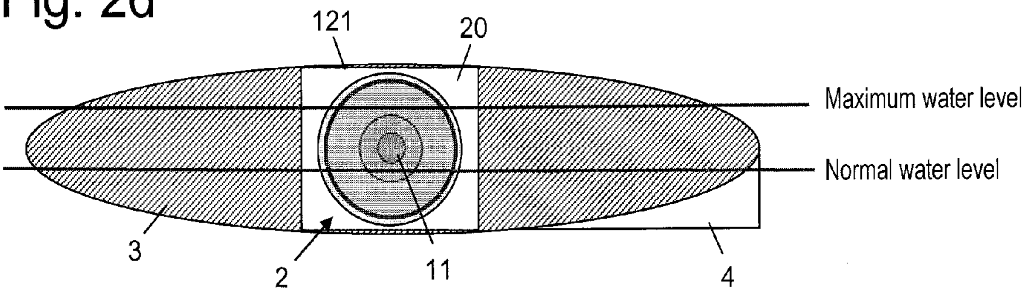

121
20
Maximum water level
Normal water level
3
2
11
4

Fig. 2e

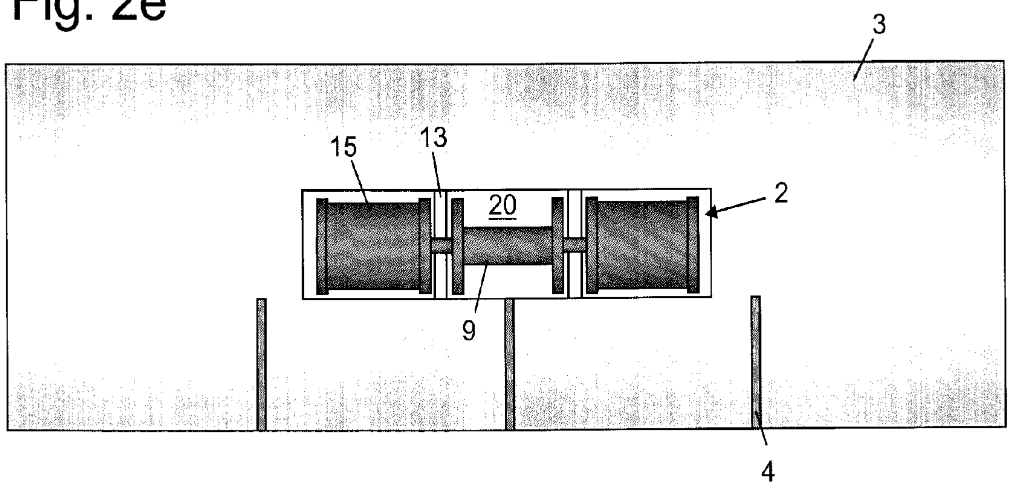
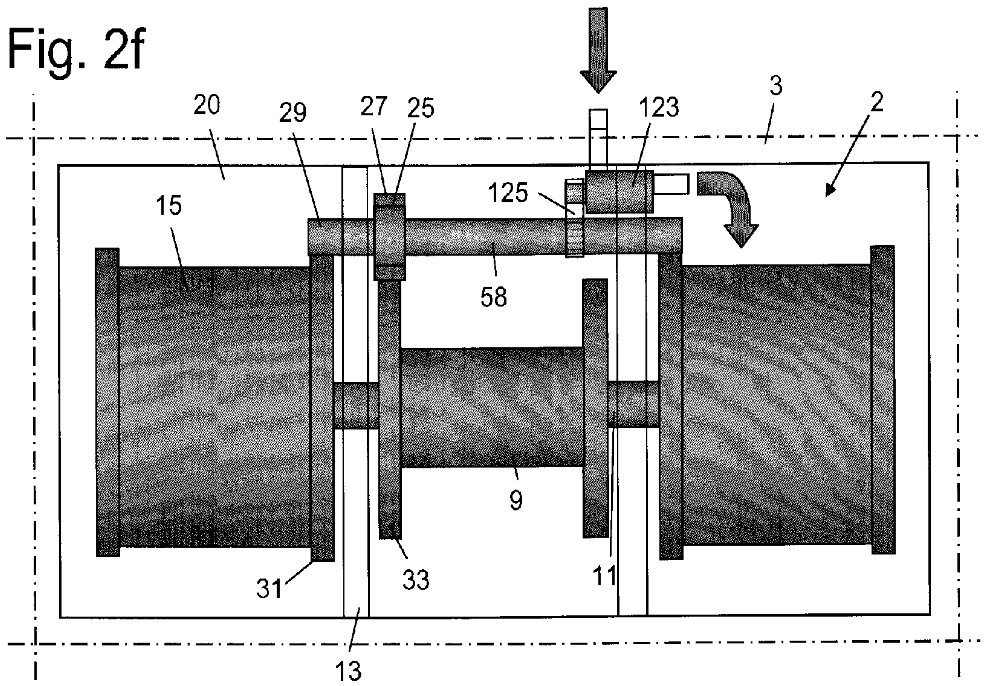

3
15
13
20
2
9
4

Fig. 2f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27
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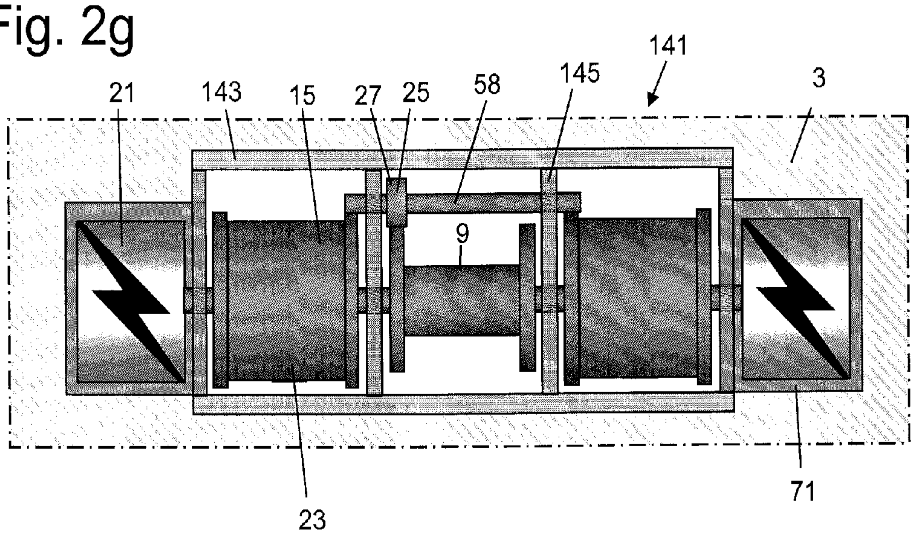
123
3
2
125
15
58
9
31
33
11
13

Fig. 2g


141
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143
15
27
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58
145
3
9
23
71

Fig. 3a

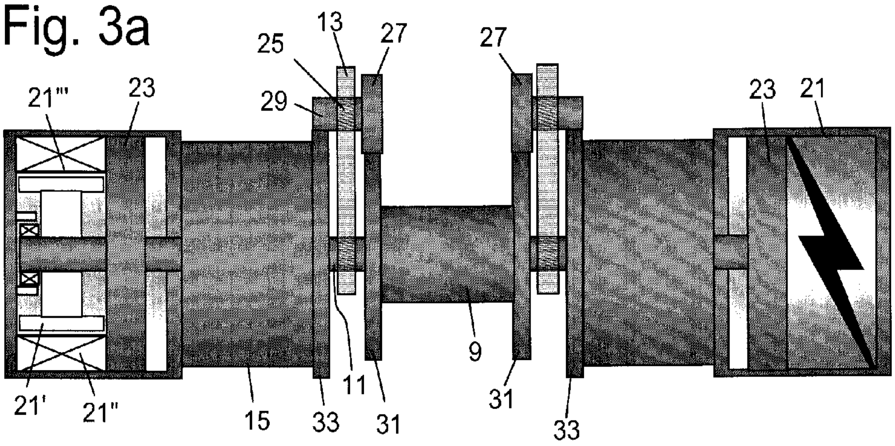


Fig. 3b

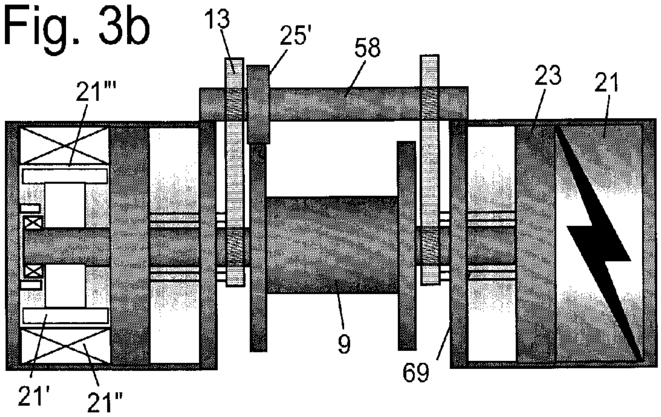


Fig. 3c

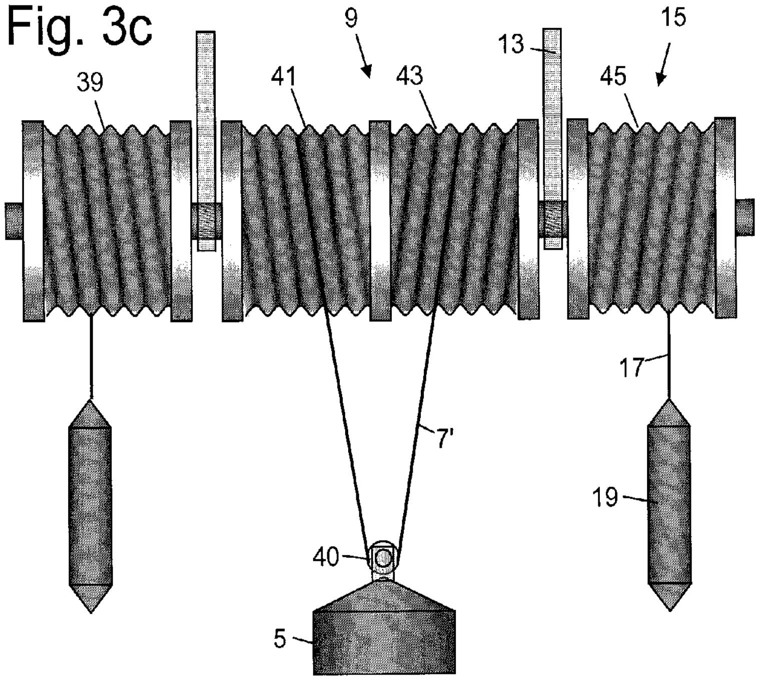


Fig. 3d

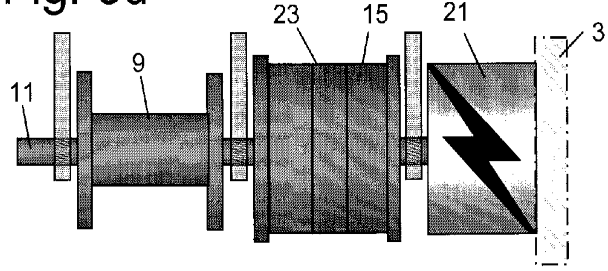


Fig. 3e

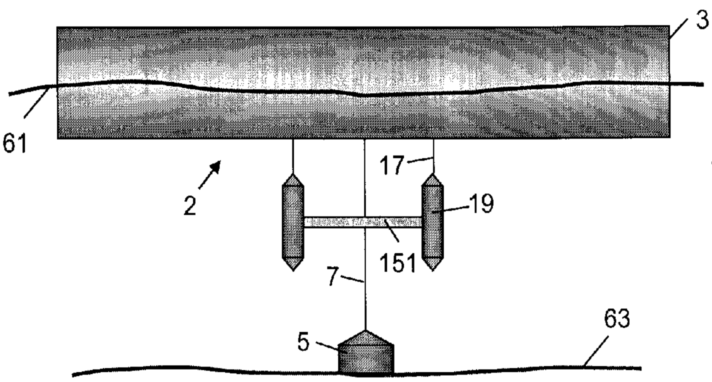


Fig. 3f

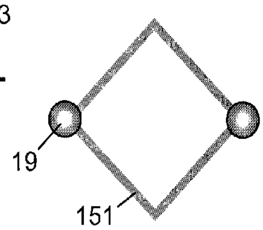


Fig. 4

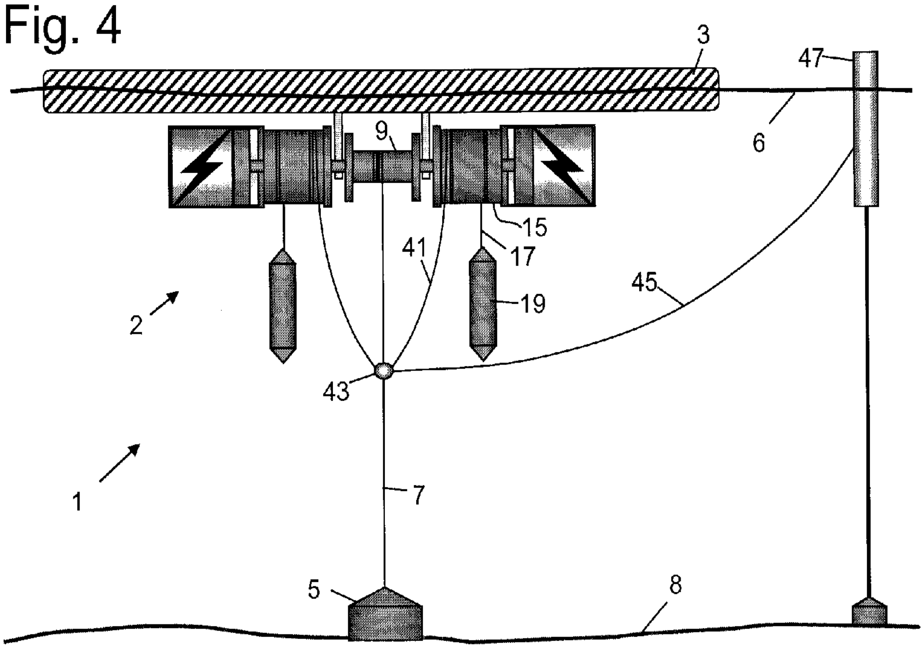


Fig. 5a

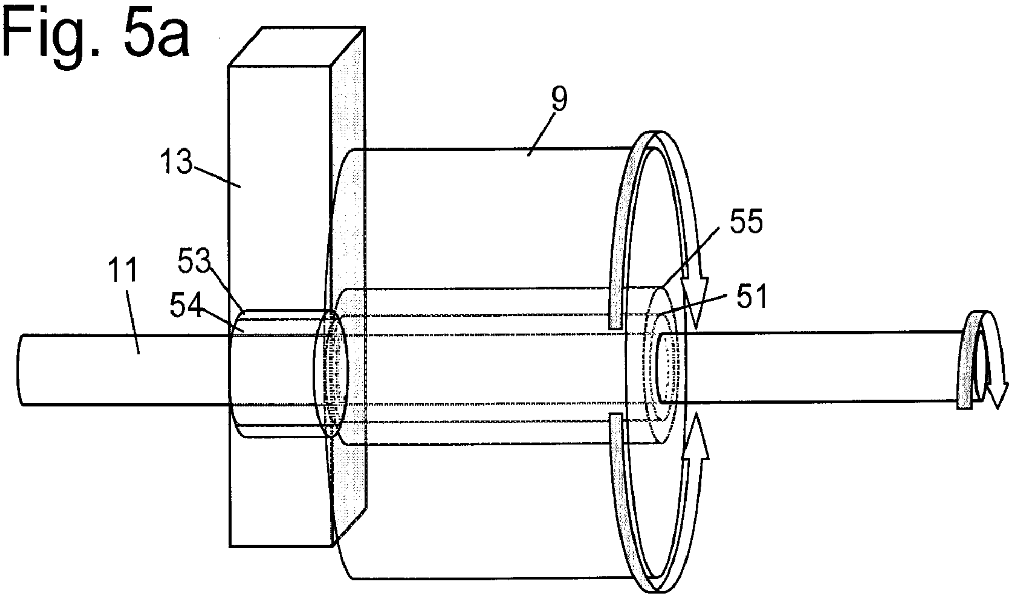


Fig. 5b

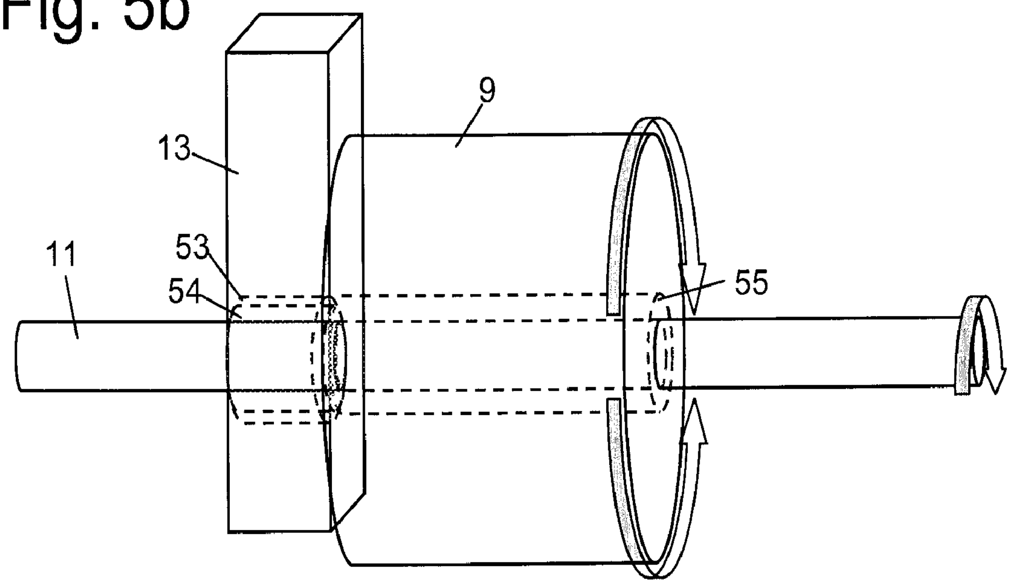


Fig. 5c

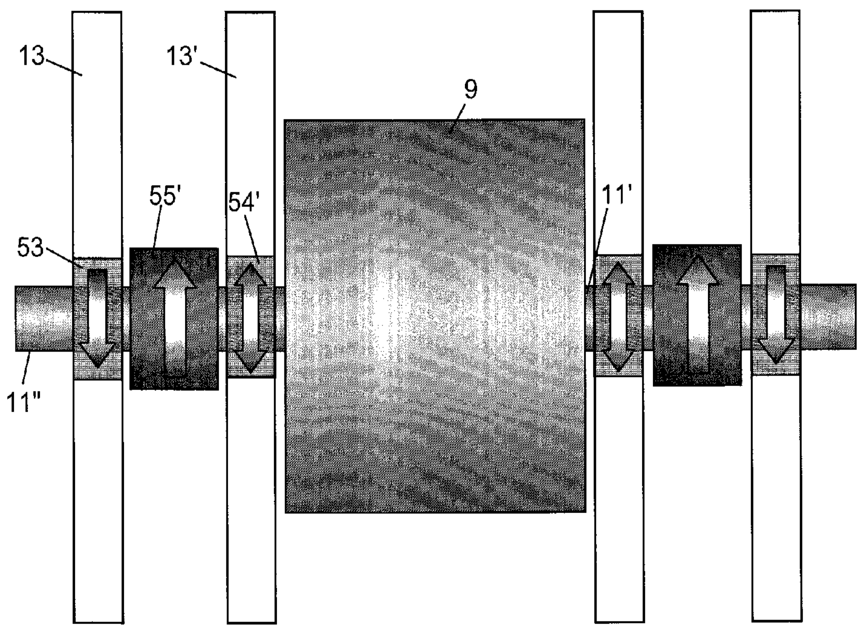

13
13'
9
55'
54'
11'
53
11"

Fig. 5d

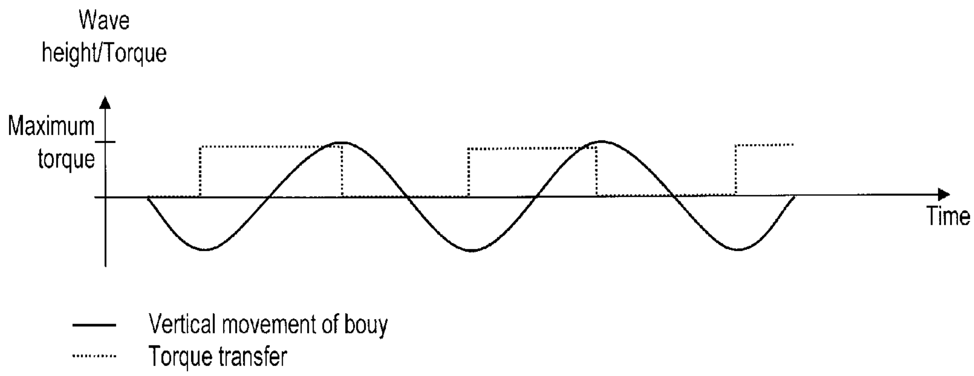

Wave
height/Torque
Maximum
torque
Time
Vertical movement of bouy
Torque transfer

Fig. 5e

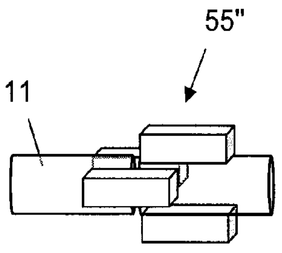


Fig. 5f

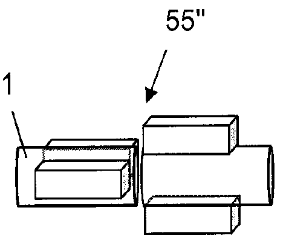


Fig. 6

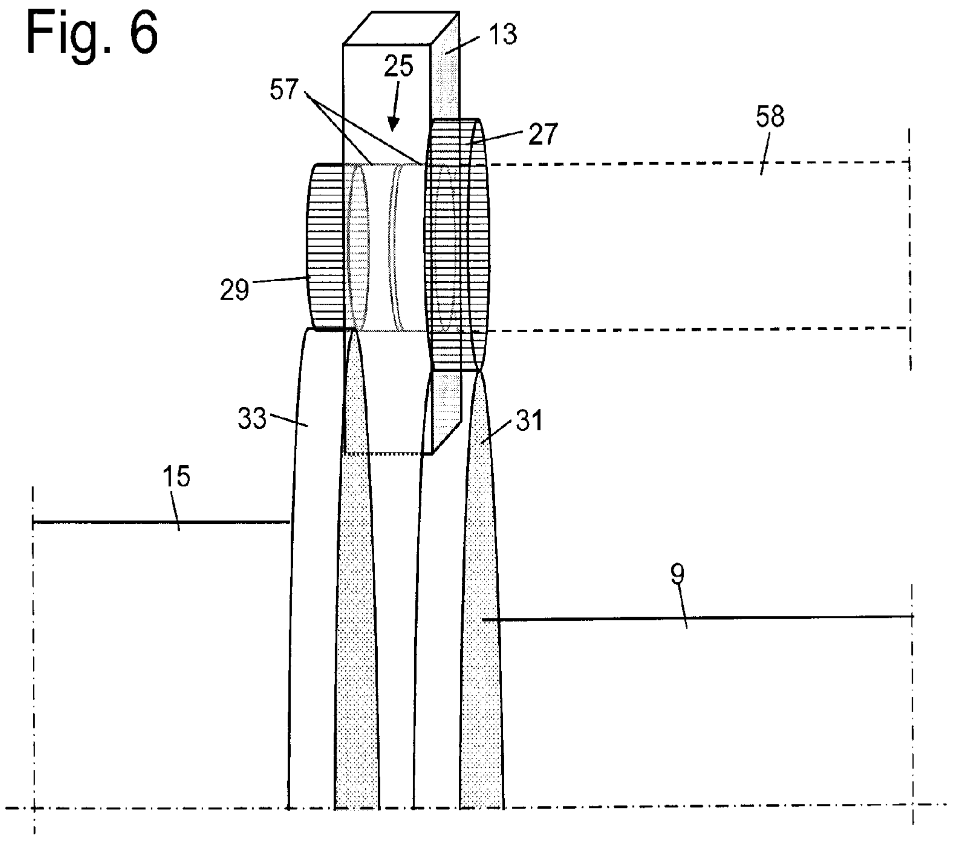


Fig. 7a

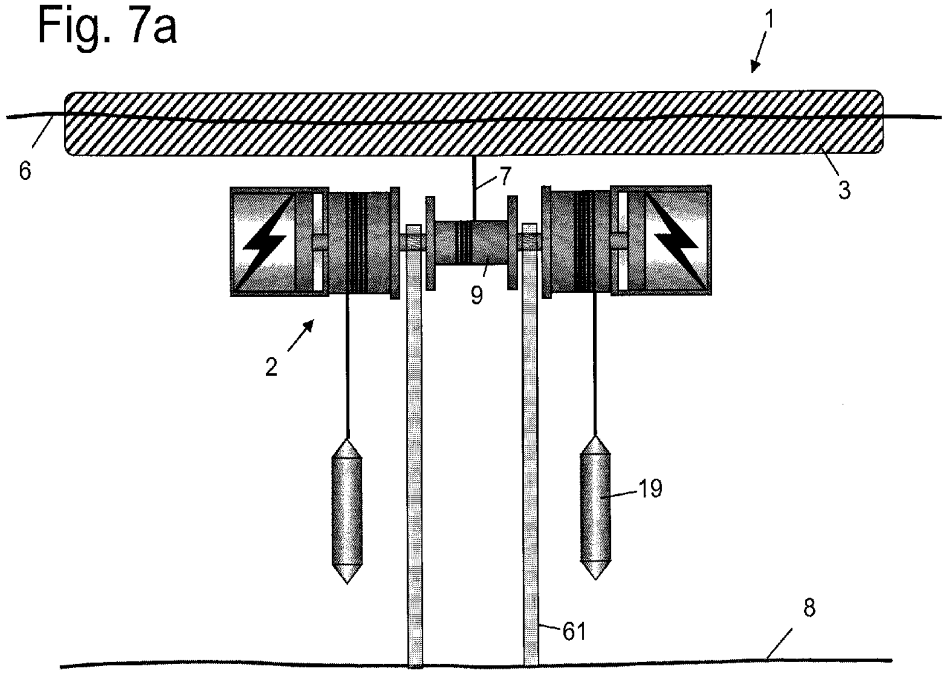


Fig. 7b

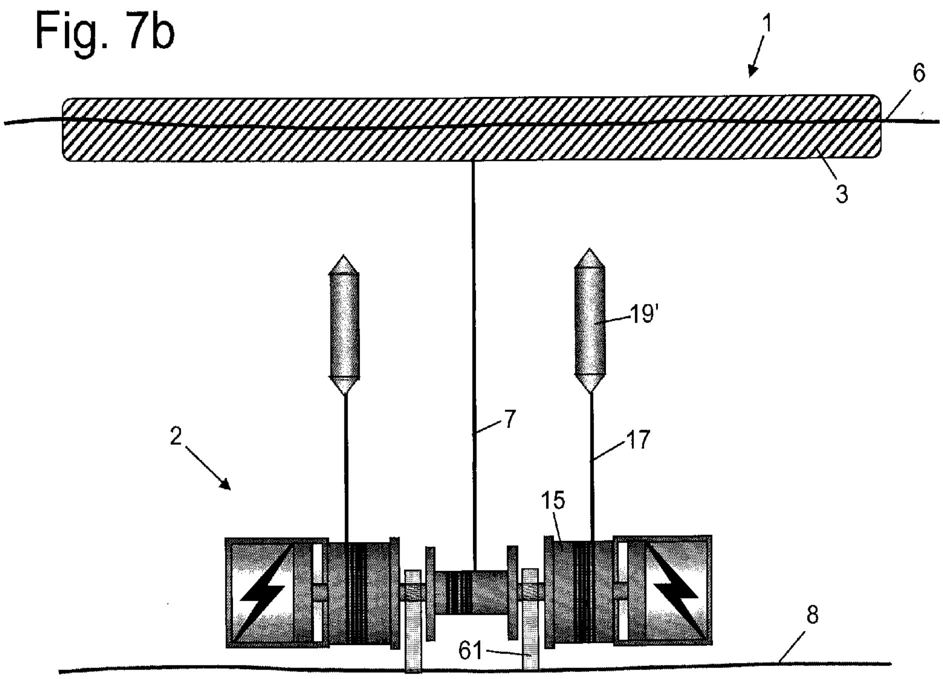


Fig. 7c

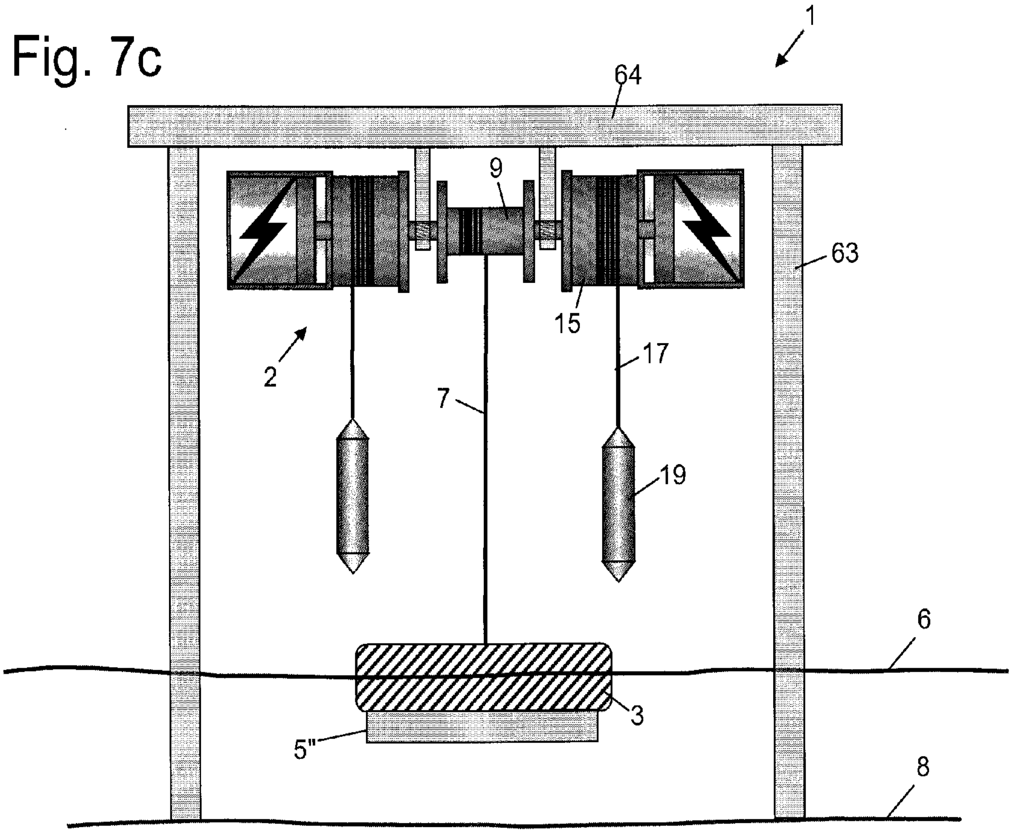


Fig. 7d

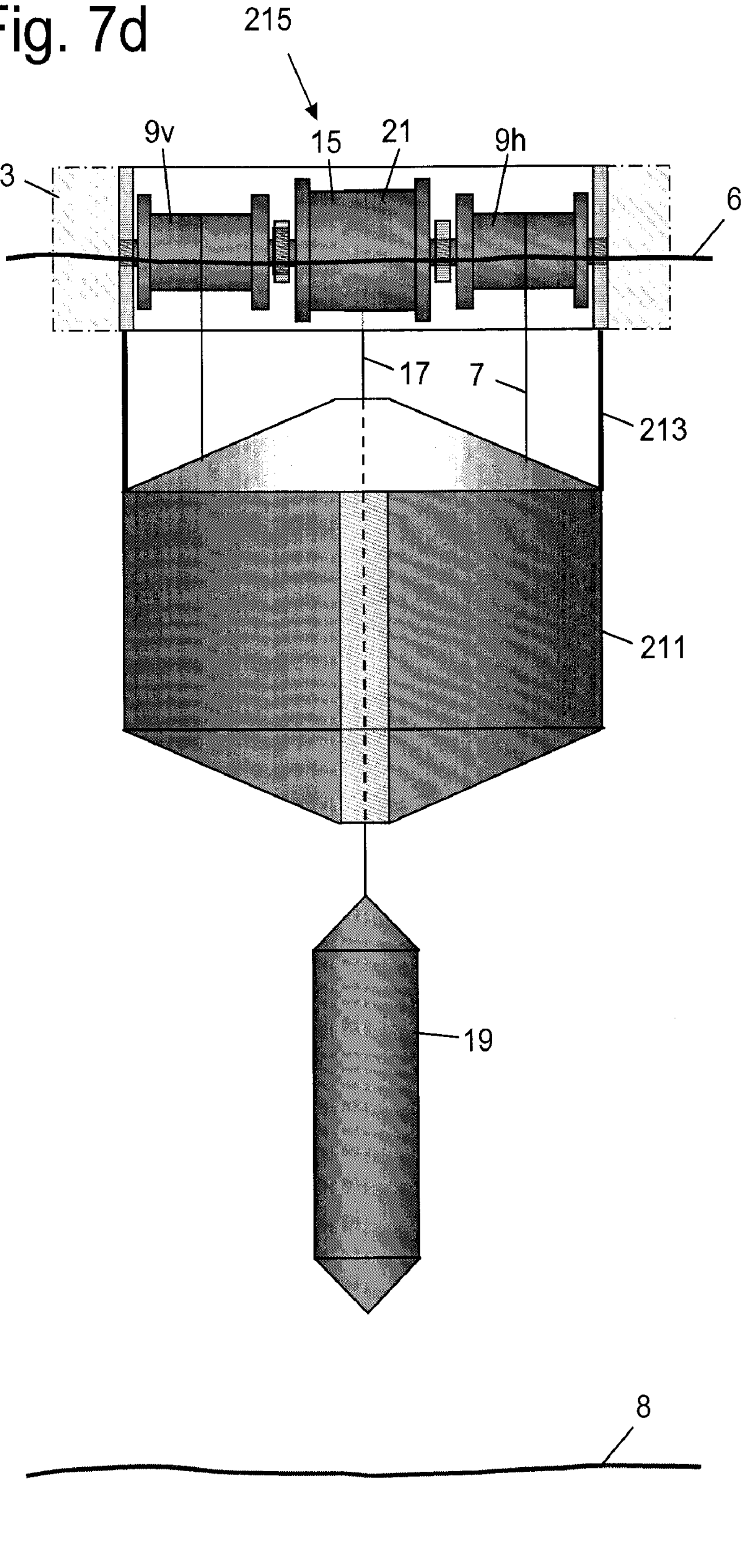


Fig. 8a

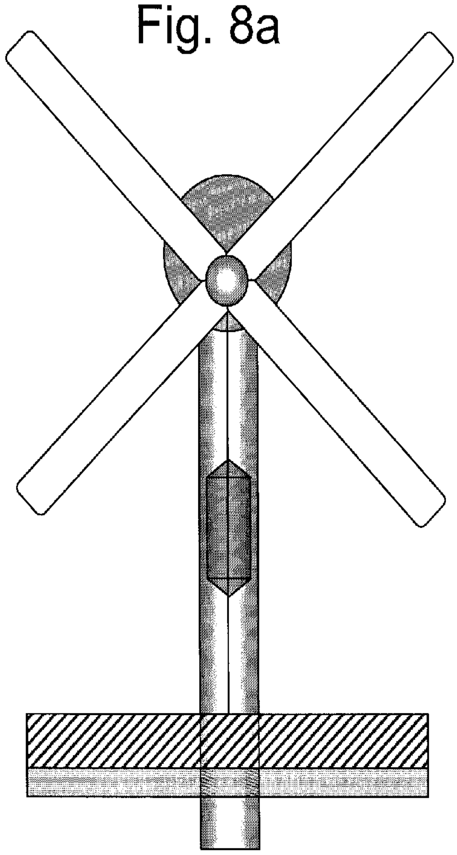


Fig. 8b

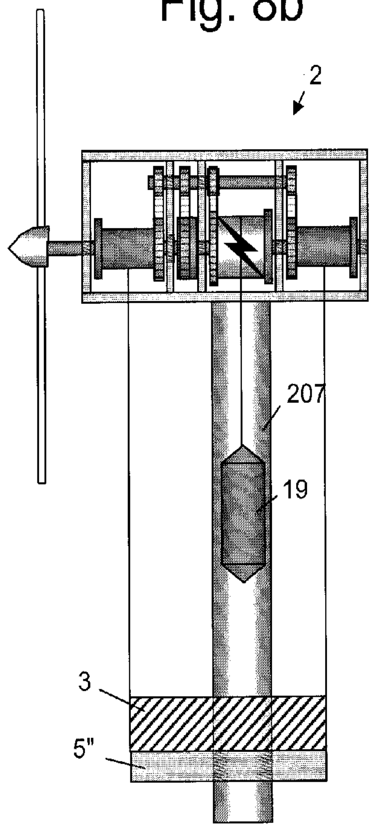
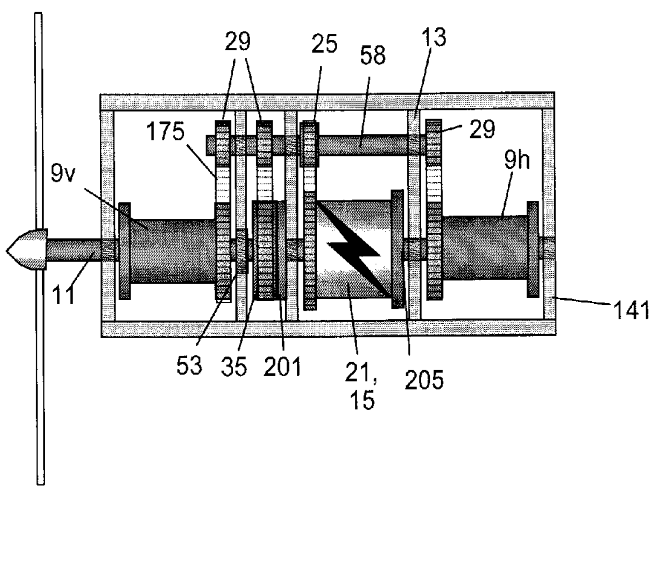


Fig. 8c



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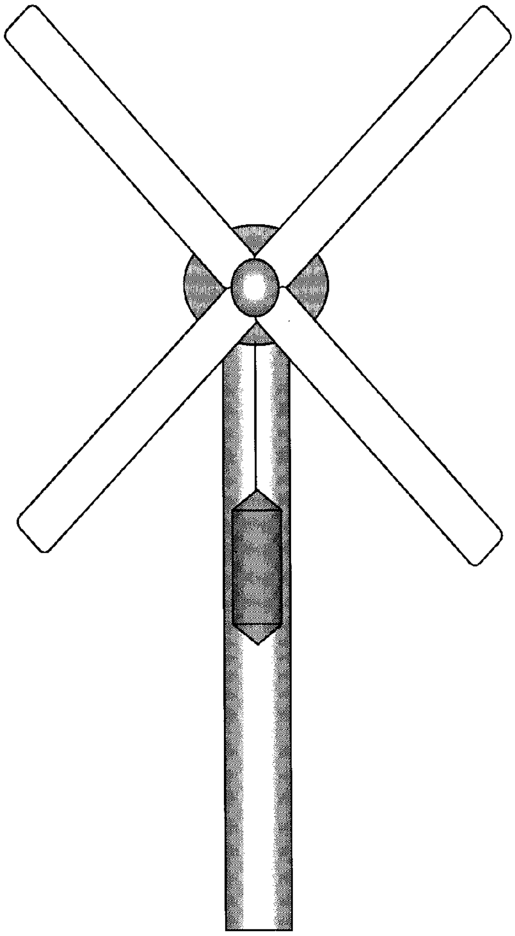

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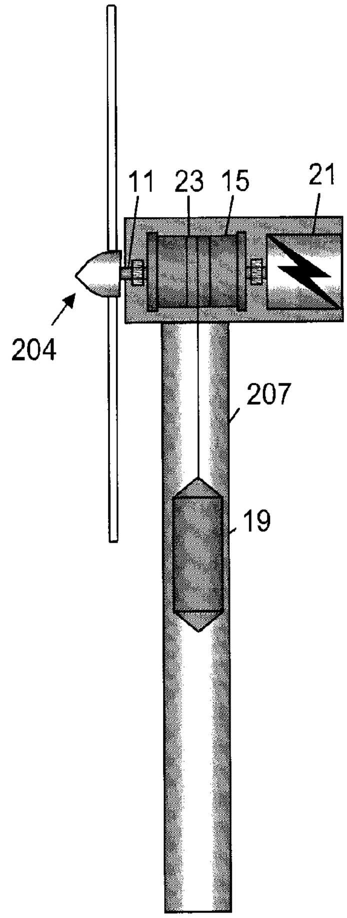


Fig. 8f

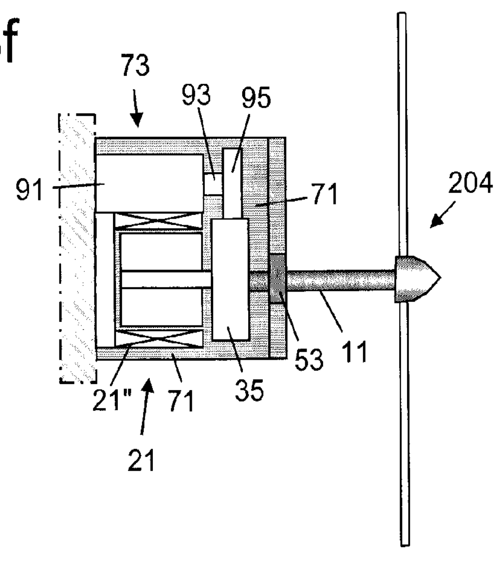
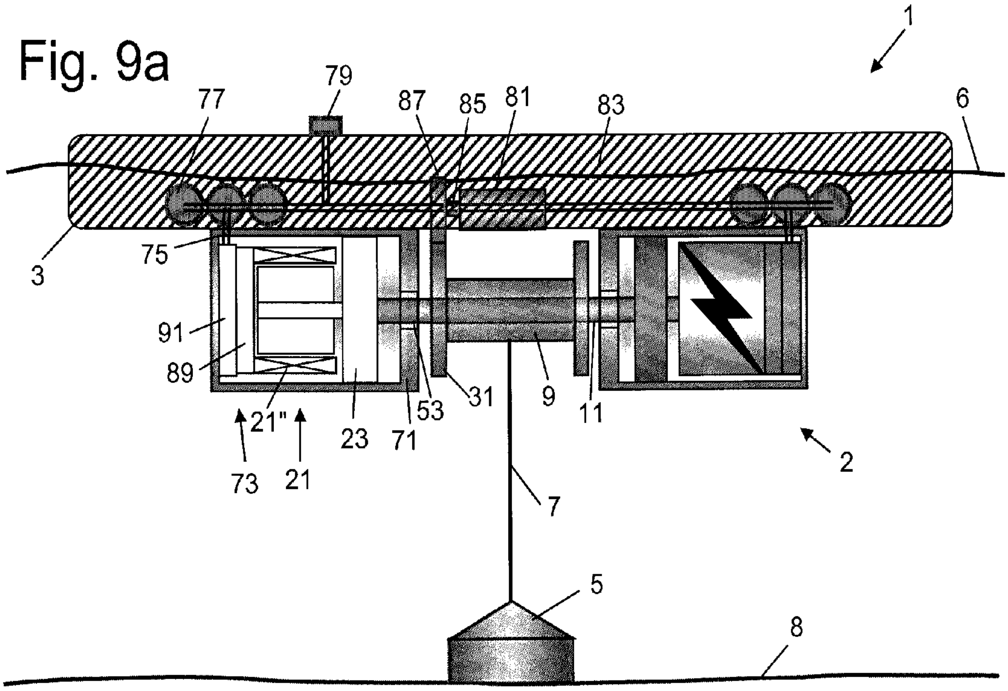
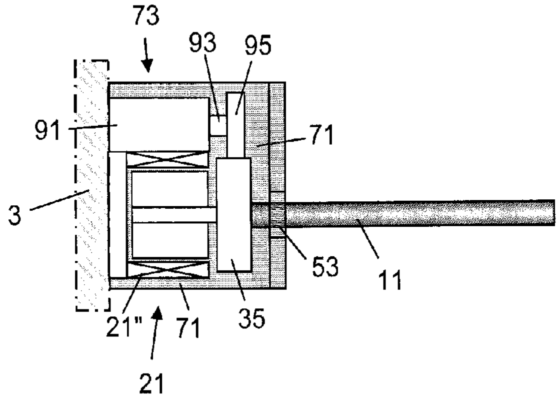


Fig. 9a



1
79
77
87
85
81
83
6
3
75
91
89
21"
23
71
53
31
9
11
2
73
21
7
5
8

Fig. 9b



73
93
95
91
71
3
53
11
21"
71
35
21

Fig. 10a

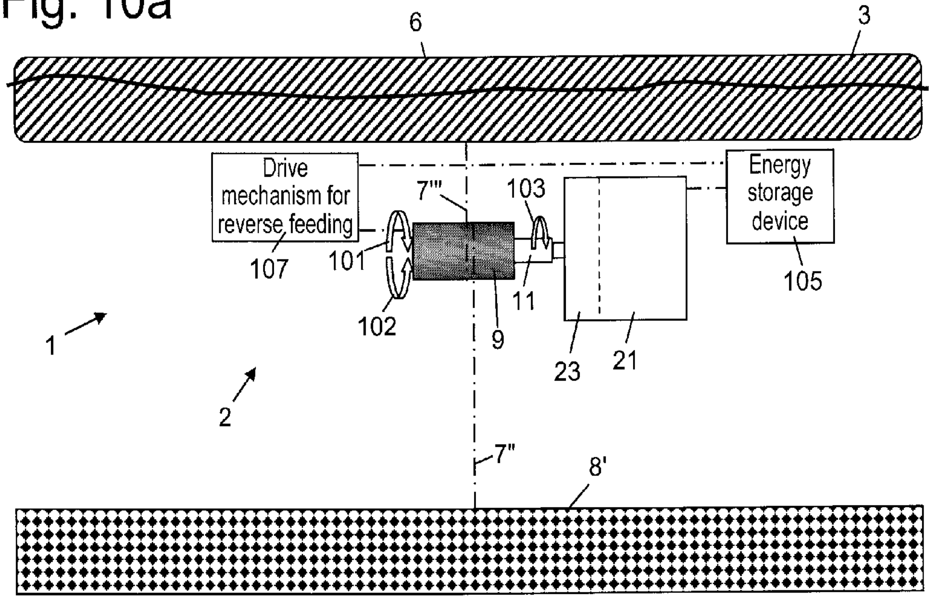


Fig. 10b

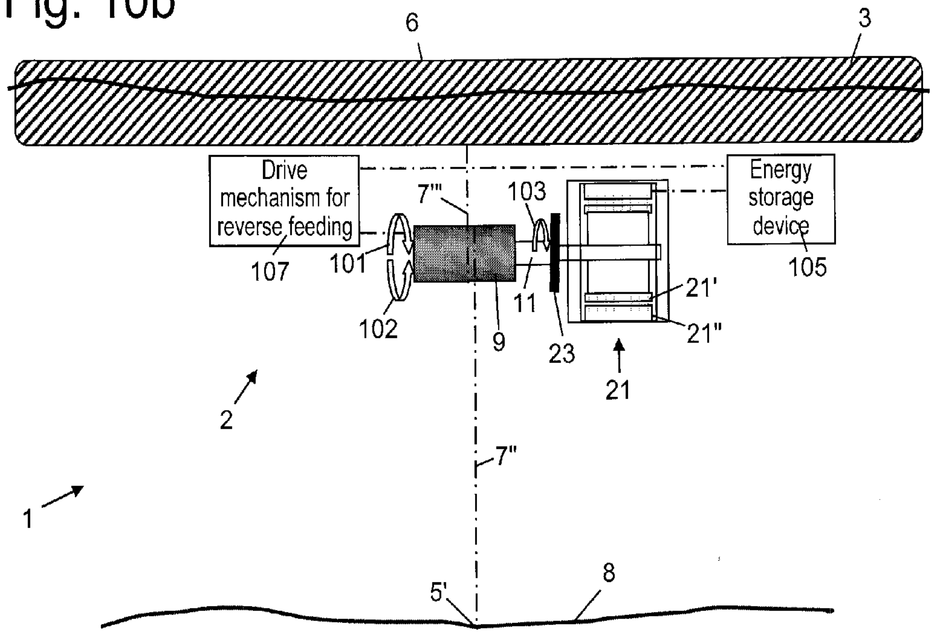
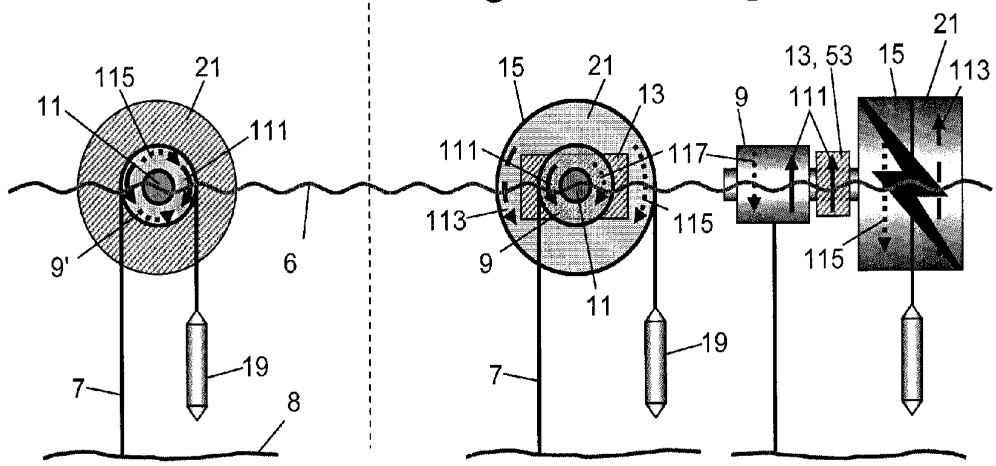


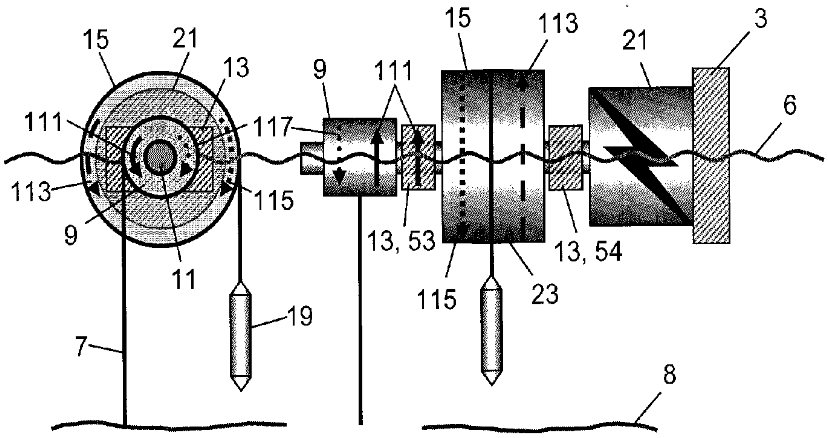
Fig. 11a
Prior art

Fig. 11b Fig. 11c



→ Absorption of wave energy 111
····▸ Reverse feeding 117
····▸ Driving of generator 115
– ✦ Accumulation of wave energy 113

Fig. 11d Fig. 11e



→ Absorption of wave energy 111
····▸ Reverse feeding 117
····▸ Driving of generator 115
– ✦ Accumulation of wave energy 113

Fig. 12a

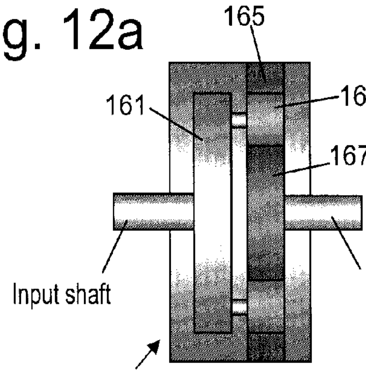


Fig. 12b

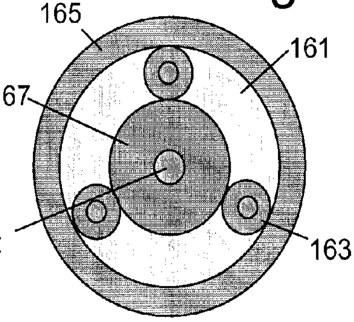


Fig. 12c

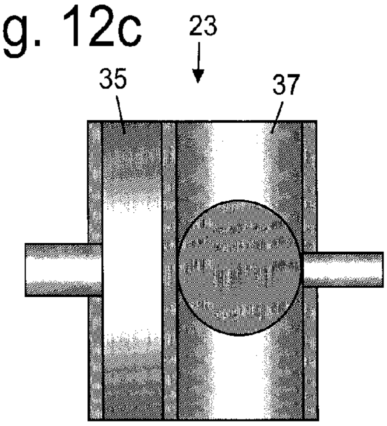


Fig. 12d

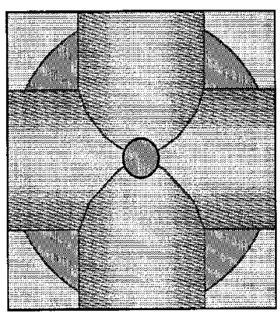


Fig. 12e

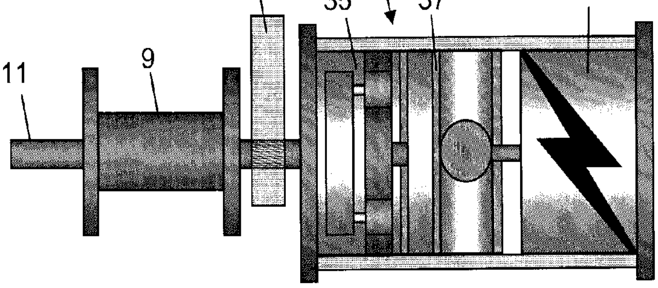


Fig. 13a

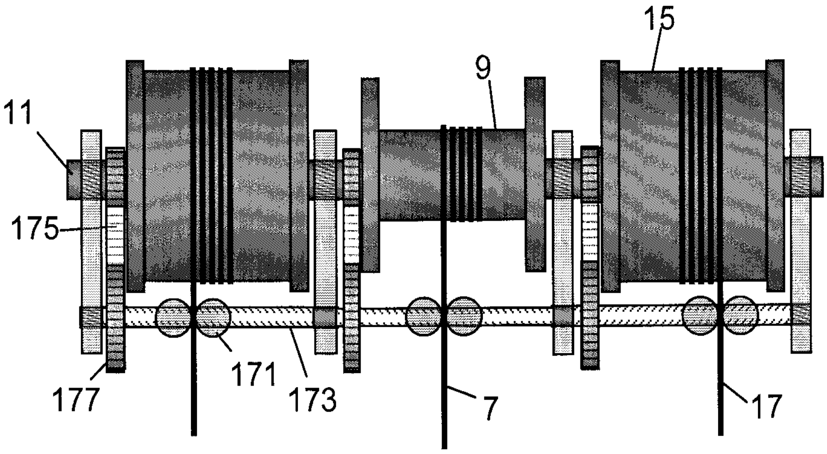


Fig. 13b

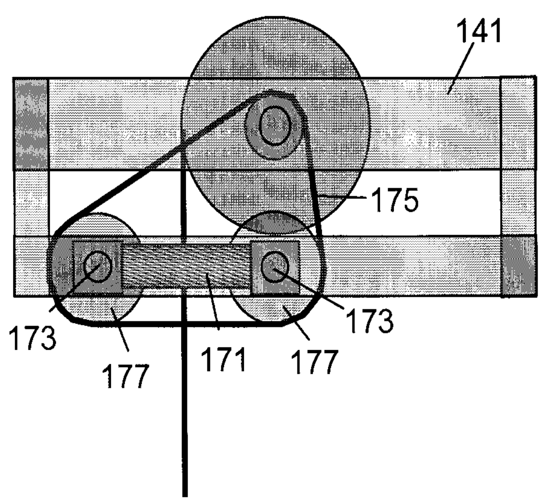


Fig. 13c

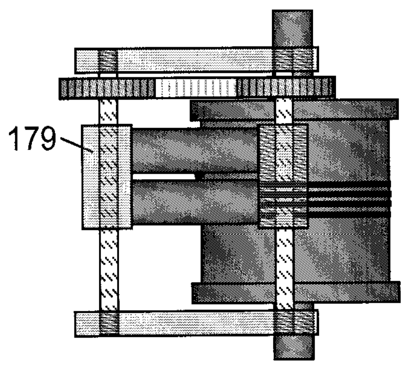


Fig. 14

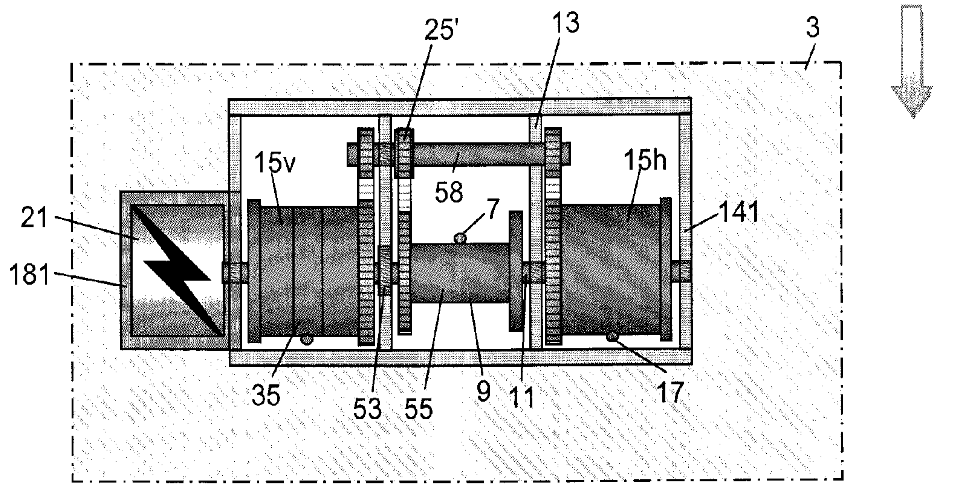


Fig. 15a

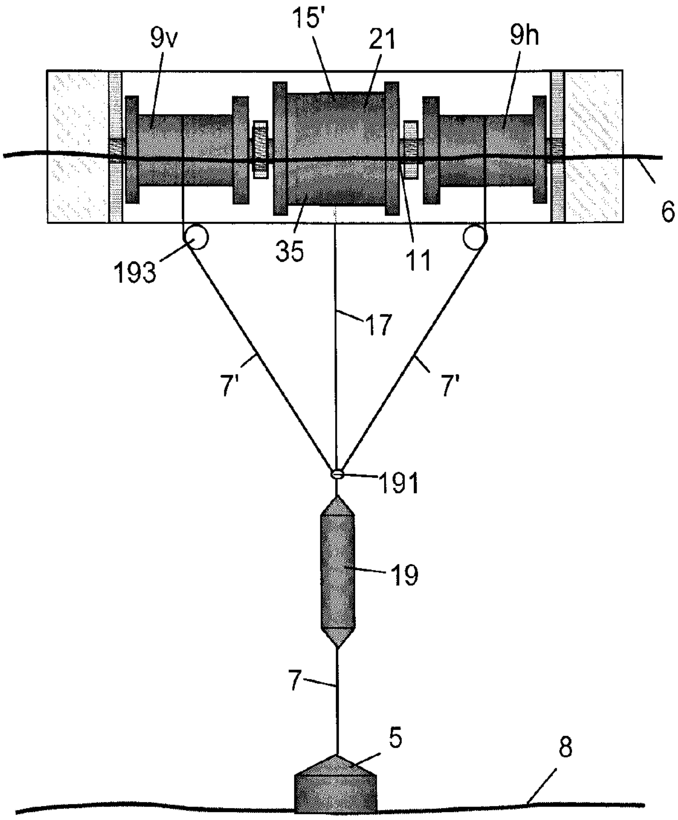


Fig. 15b

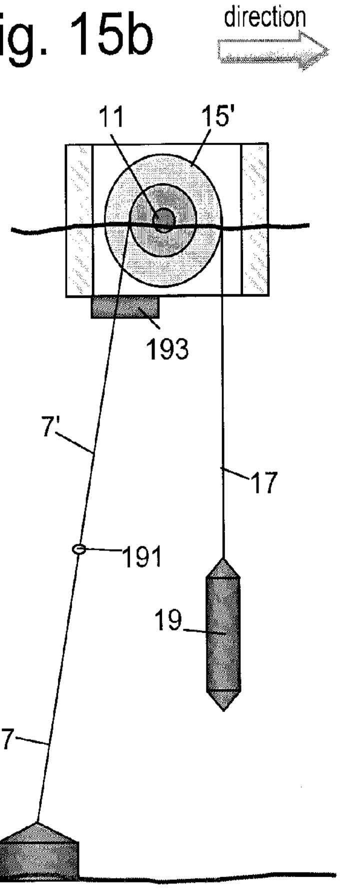


Fig. 15c

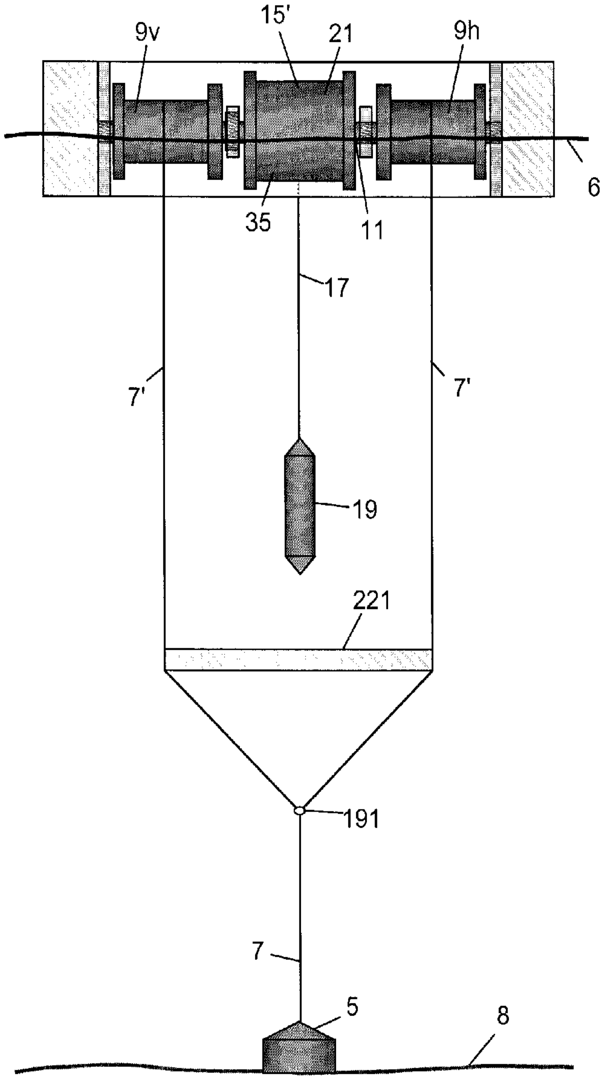


Fig. 15d

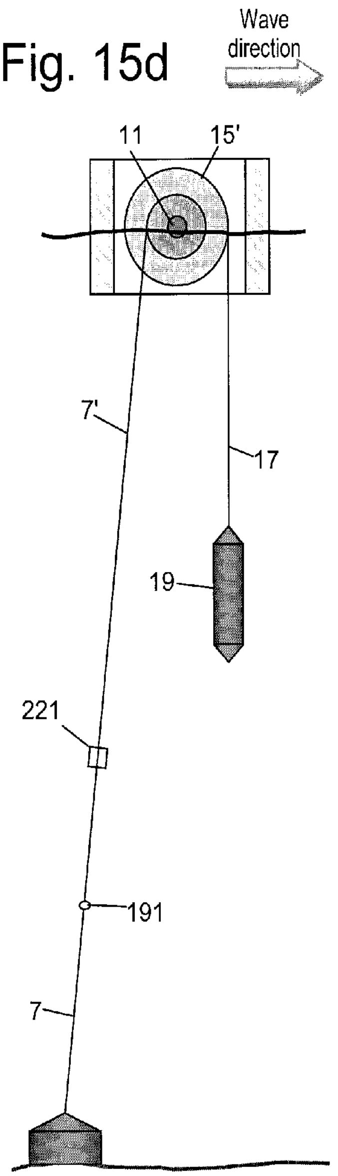


Fig. 15e

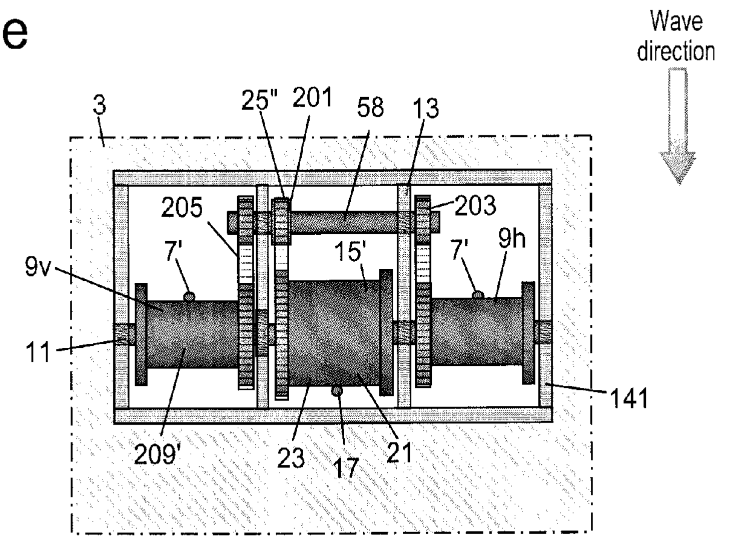


Fig. 15f

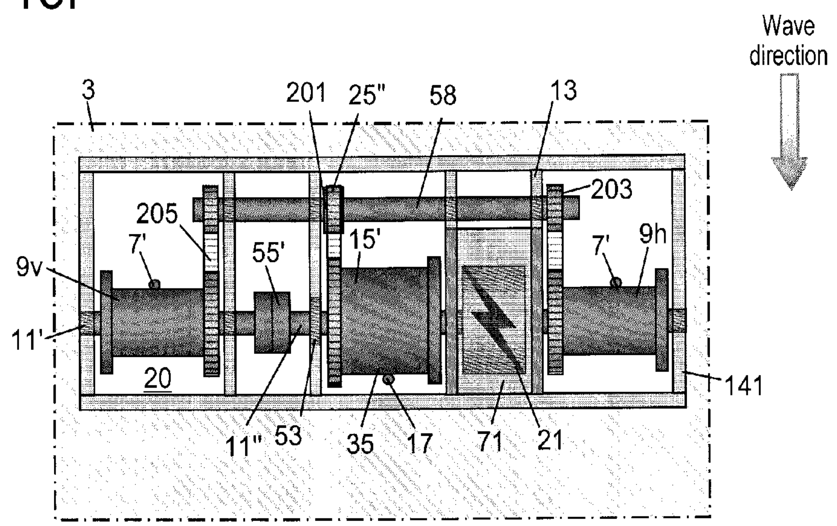


Fig. 15g

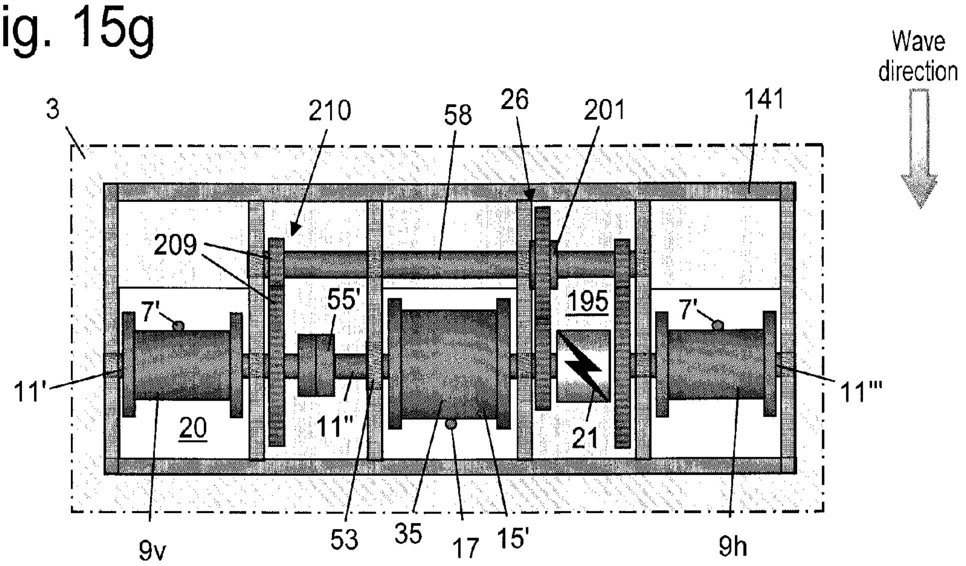


Fig. 15h

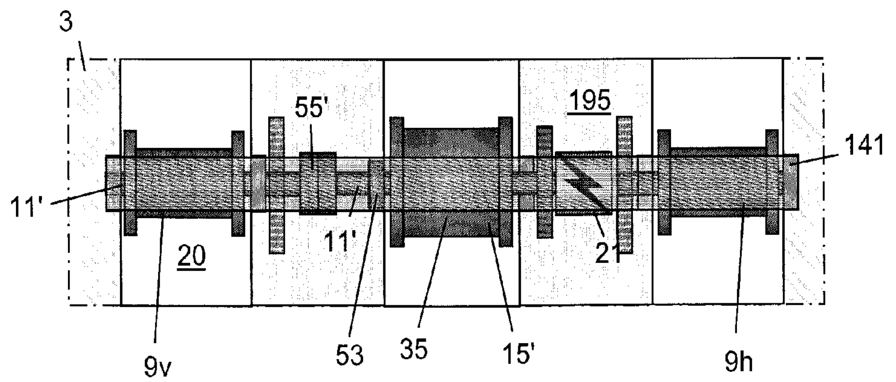


Fig. 15i

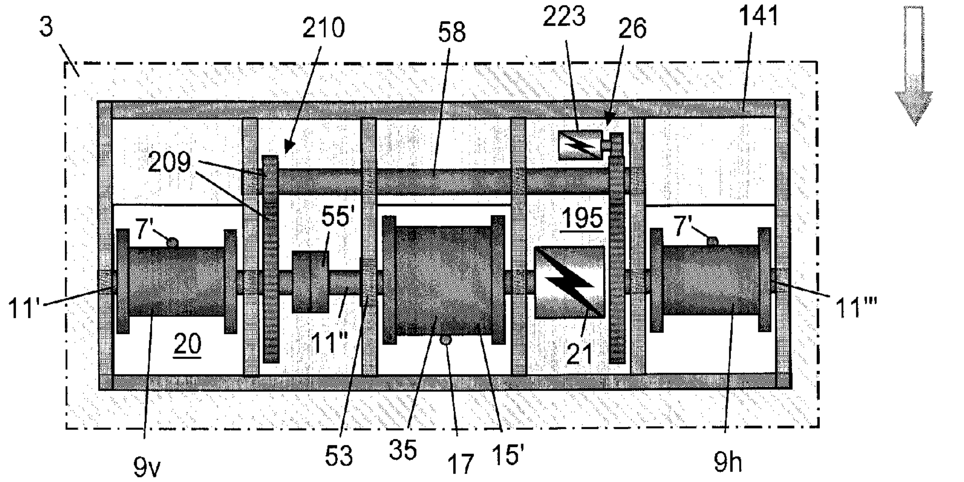


Fig. 16a

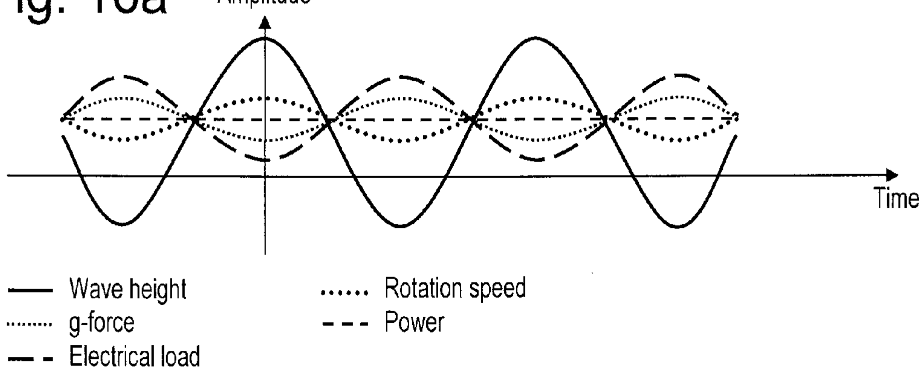


Fig. 16b

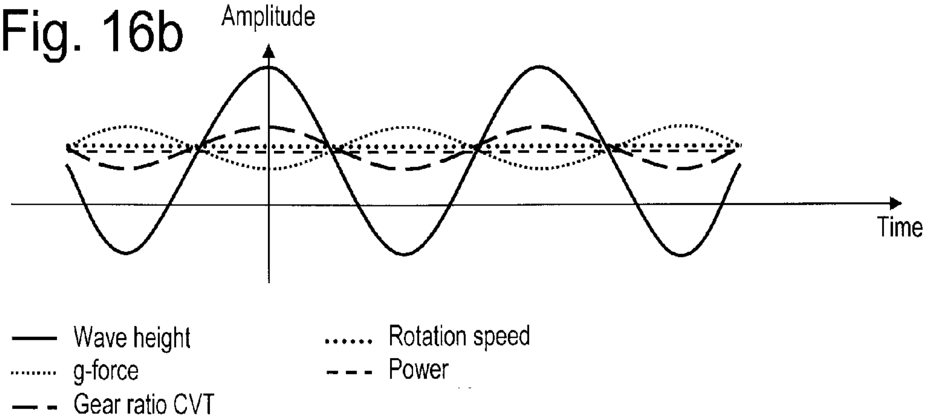
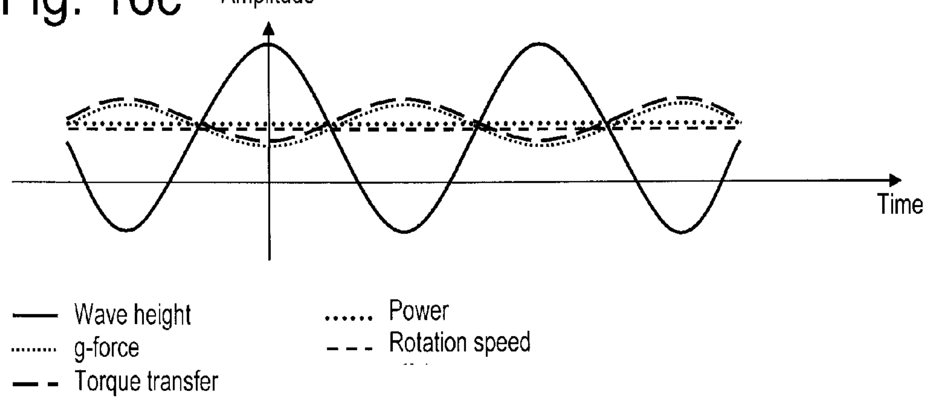


Fig. 16c



WAVE POWER PLANT AND TRANSMISSION

RELATED APPLICATIONS

[0001] This application claims priority and benefit from Swedish patent application No. 0800395-6, filed Feb. 20, 2008, and Swedish patent application No. 0802165-1, filed Oct. 10, 2008, the entire teachings of which are incorporated herein by reference.

TECHNICAL AREA

[0002] The present invention relates to a wave power plant for extraction of electrical energy from motions of water waves, a method of extracting electrical energy from more or less intermittent mechanical energy, such as more or less periodical motions in a body, and a transmission for power plants to be used when such more or less intermittent mechanical energy is available.

BACKGROUND

[0003] Wave power has a large potential of becoming cost efficient since the energy density in ocean waves is very high (approximately 1000 times higher than in the wind), this allowing small wave energy converters in relation to the capacity thereof. Furthermore, wave energy is more predictable than for instance wind power since waves are built by the wind during a long period of time and then continues as swell also after the wind has subsided. This results in slow variations in the average energy content of the waves, which gives system advantages when wave energy converters are connected to the general electric power distribution network.

[0004] A reason why, in spite of this potential, there are so few competitive solutions today is that wave energy is difficult to master. The ocean is a rough environment with high material stress. In stormy weather the energy levels can be a 100 times higher than normal. The wave motion is oscillating and with never ceasing variations in height, length and time period (velocity) from wave to wave, this giving large variations in the energy absorbed by a wave power plant. For direct driven operation, i.e. when the generator in the wave power plant is driven according to the momentary motion of the wave, this results in a low utilization of the power plant, i.e. the so called capacity factor takes a low value. The power of the generator shifts between zero and a top level twice every wave period. The top level may also change very strongly from wave to wave. The general electric power distribution network requires relatively stable levels, both in delivered power and voltage, this resulting in that the electrical control systems for this kind of wave energy converters must, after the generation, make the levels of these more even. Also, the uneven levels results in a costly over-dimensioning of the total electrical system of a wave power plant in order to obtain a proper handling of the top power levels.

[0005] To make wave power competitive a wave power plant is required that can efficiently absorb the wave energy at the same time as the motive force on the generator is leveled, so that a higher capacity factor is obtained. Also, a low system complexity and an efficient use of components are required. The structure of the wave power plant must also be storm proof and have a long life-cycle, and low operational and maintenance costs that can be achieved by a construction allowing long service intervals and includes wearing parts that can be easily accessed.

[0006] Wave power technology has been developed for a long period of time but so far it has not been possible to arrive at a method or a design of a wave power plant, where it has been possible to combine the necessary properties as described above.

[0007] A frequent method of capturing the energy of water waves is to use the vertical motion of the water. Installations that use such technology are sometimes called "point absorbers". One way of using the vertical motion incorporates a buoy having a bottom foundation and an anchor wheel. The bottom foundation is firmly positioned at the sea-floor and is connected to the buoy which follows the ocean surface, i.e. the wave motions. When the surface rises and thereby lifts the buoy, a motive force is created, which is converted to a rotational motion by a driveshaft connected between the foundation and the buoy or by a wire or chain, which runs over an anchor wheel journalled in bearings at the buoy or in the foundation and which at an opposite end is connected to the foundation or the buoy, respectively. The motive force increases due to the increased motion speed of the waves when the wave height becomes higher. The rotational direction and speed of an anchor wheel, is such a wheel is used, is directly dependent on the vertical direction and motion speed of the waves. However, this is not optimal for coupling a conventional generator to the anchor wheel to produce electric energy.

[0008] In order to make a wave power plant driving a conventional rotating generator efficient, the vertical motion of the waves must be converted into a unidirectional rotational movement, and the rotation speed of an electrical generator connected to the transmission must be stabilized. In a device, as described above, using a driveshaft, wire or chain, which is secured to the sea bottom or in a frame structure and which runs along or over an anchor wheel journalled in a buoy, this problem can be solved in the following way. When the buoy is lifted by a wave, a motive force over the anchor wheel is created. Thereupon, when the wave falls, an anti-reverse mechanism is disengaged and the anchor wheel is returned by a counterweight. Then, the motive driving is only active during the rise of the wave and ceases completely when the wave sinks, which is not satisfactory. Attempts have been made to reverse the rotation direction, so that an electrical generator driven by the anchor wheel is driven by the counterweight in the same direction also when the wave sinks. It has also been attempted to reverse the rotation direction of the generator. However, changing the rotation direction of a mechanical transmission or of the generator twice for every wave period results in heavy mechanical wear. Even though the rotation direction can made unidirectional by the transmission, the rotation speed follows the speed of the vertical motion, this causing that the power output from the generator varies according to the speed of the wave motion. This gives to a low capacity factor and high attenuating effects since the mass of the generator all the time alternatingly be accelerated and decelerated. In order to make the motive force and rotation speed of a generator using a mechanical transmission multiple buoys can cooperate, a phase shift existing between the buoys. However, this only works optimally in the case where the buoys are evenly distributed over a wave period, which very seldom occurs the length and speed of the waves always vary. Also, the transmission system becomes more complex and hence hydraulic mechanisms are frequently used in systems of this type. However, hydraulic devices results in complex systems having large transmission losses. A wave power plant of the type described above is disclosed in the published French patent application 2869368, which comprises a floating platform or buoy. Lines run over pulleys at the buoy, one end of the lines being attached to the bottom and the other end carrying a counterweight. The rotation of the pulleys is transferred to generators. The rotation speed and power output from the generator vary according to the motion of the waves. A similar wave power plant is disclosed in U.S. Pat. No. 4,242,593, which drives a wheel or pulley in the buoy only when it is rising. A gearbox is provided for gearing up the rotation speed of the wheel or pulley in the buoy to make it suitable to be used for driving a generator. In U.S. Pat. No. 5,889,336 and the published Japanese patent application 11-6472 a similar wave energy plant is disclosed including a chain which at one end is attached to a bottom foundation end and at its other end has a counterweight. The chain passes over a chain pulley in a buoy. The chain pulley is connected to a generator through a directly acting transmission, which is arranged so the generator always rotates in the same direction. The rotation speed depends on the speed of the vertical motion of the buoy.

[0009] A wave power installation of a somewhat different type is disclosed in U.S. Pat. No. 4,241,579. A driveshaft is mounted to be elevated and sunk between the water surface and the bottom. A number of buoys are by wires connected to counterweights and the lines pass around the common driveshaft for driving only when the respective buoy. In the published British patent application 2062113 a wave energy converter is disclosed including a plurality of different drive mechanisms, each one of which comprises a buoy and a counterweight/bottom foundation/additional buoy and which act on a common driveshaft through one-way couplings. In the published French patent application 2339071 a buoy is used, which is connected to one end of a chain and by the chain drives a driveshaft placed above the water surface to rotate. The other end of the chain carries a counterweight, which is also placed above the water surface. The connection to the driveshaft is of a unidirectional type and the driveshaft may be driven by several such buoys through chains.

[0010] In the published International patent application WO 2005/054668 a wave energy plant including a buoy which is attached to an end of a line is disclosed. The other end of the line is more or less wound up around a drum placed on the bottom of the sea. The drum is connected to a return spring and a generator and drives the generator in both the rising and sinking motion of the buoy. In the wave energy plant according to the published International patent application WO 03/058054 the buoy acts as an winding drum for a line, the lower end of which is connected to a bottom foundation. A return spring, a gear up mechanism and a generator are located inside the drum. The generator is driven in both the rising and sinking motion of the buoy.

SUMMARY

[0011] It is an object of the invention to provide an efficient wave energy plant.

[0012] In a wave energy plant energy from water waves in a pool of water during parts of the motions of the water waves is absorbed for driving an electrical generator. However, part of the absorbed energy is temporarily accumulated or stored in some suitable mechanical way for driving the electrical generator during other parts of the motions of the water waves. Thereby, an equalization over time of the motive force, which drives the electrical generator, can hereby achieved. For the temporary mechanical accumulation of energy a change of potential energy can be used, such as variations of the potential energy of a suitable body. For example, the change of potential energy can be based on elastic forces or on gravitational forces. In the latter case a floating body can be used, i.e. a body having a density lower than that of water, which is located at a varying distance from the water surface and hereby indirectly uses the gravitational forces. The body used for accumulation of energy can in the same case alternatively be a counterweight, i.e. a body having a density higher than that of water, which uses the gravitational forces in a more direct way. The body may in these cases be connected to some elongated means, such as a line, wire or chain, which in the case where it is flexible can be more or less wound around a counterweight drum. The counterweight drum can be journalled at a buoy or at a stationary rack or frame placed on or attached the bottom of a pool of water. The counterweight drum can in one case be mechanically connected to a rotating part of an electrical generator and the weight or buoyancy of the body is used for continuously driving the counterweight drum to rotate in an opposite relative rotational direction compared to the rotational direction of a driveshaft, which is connected to another elongated means, also here for example a line, wire or chain.

[0013] The driveshaft is mechanically arranged for a unidirectional rotation only, driven for example by the rising or sinking motions of a water surface or more particularly by alternatingly rising and sinking movements and/or alternating tilting, back and forth movements of a buoy, i.e. a body having a density lower than that of water, which is floating at the water surface, or alternatively by some other form of oscillatory movement or combination of oscillatory movements in the waves or in the water. The electrical generator is in the above mentioned cases mechanically connected in a transmission path between the driveshaft and the counterweight drum. The electromagnetic coupling between the parts in the electrical generator over the air gap of the generator gives a limited torque in relation to the rotation speed of the generator, the mechanical torque provided by the counterweight drum and the electrical load of the generator. When the driveshaft is rotating faster than the rotational speed in the generator, the counterweight drum is rotated in a first rotational direction, this causing the counterweight to be hoisted up, thereby accumulating potential energy. When the driveshaft is rotating slower than the rotation speed in the generator or is still-standing still, the counterweight drum rotates in a second rotational direction, this causing the counterweight to be lowered, thereby releasing potential energy.

[0014] As an energy accumulation device, which uses elastic forces, an elastic or resilient mechanism may be used, in which the energy is accumulated as a tension in a spring or generally as elastic energy. Such an elastic device may in a different case comprise a container for accumulation of energy as a gas pressure. The container may then be connected to a combined compressor or gas pump and a pneumatic motor such as a scroll pump. This device may have one moving part directly connected to one of the parts of the generator.

[0015] In such a wave energy plant it is possible achieve, using an energy accumulation device, also called energy storing device, and suitable couplings, an equalization of the kinetic energy of the water waves in an efficient way, so that the generator can be driven to continuously generate electricity at a relatively even level.

[0016] Generally, a wave energy plant or in its most common form a power plant using movements, such as more or less periodic motions, of the water of a pool of water, can comprise:

[0017] A buoy or other device, which is arranged at or in the pool of water to be made, in some way, to move by movements of the water in the pool of water. Then, the buoy or the other device is constructed and placed so that it itself, because of movements in the water, obtains movements, which alternate between a movements in one direction and a movement in another direction that is different from the first direction. The movements in the water can comprise wave movements in the water or at the surface of the water, alternating movements, i.e. alternating back and forth movements in the water or at the surface of the water or generally movements alternating between a movement in one direction and a movement in another direction in the water of the pool of water. In the case of a buoy, floating at the surface of the water in the pool of water, this can mean that the buoy, at the up and down movements of the water surface, alternatingly rises and sinks and/or alternately rocks or tilts back and forth. In general then, the buoy has an average density lower than that of water. The other device arranged at or in the pool of water may for example comprise a body having the same density as or a higher density than that of water, which is designed to follow the movements of the water, or a device that is being alternately compressed and expanded due to pressure differences in the water which occur when water waves pass.

[0018] A driveshaft, which is rotationally journalled at some part of the wave power plant. In different designs, it can be journalled at the buoy or at the other device. Alternatively it can be journalled for rotation at a device that is rigidly attached to the bottom of the pool of water, or generally to some device arranged to counteract the movements of the water in the pool of water, such as a body having a relatively large mass or weight.

[0019] A first elongated means, which both is connected to a device arranged to counteract the movements of the water in the pool of water, for example a fixed point at the bottom of the pool of water or a body having a relatively large mass or weight, or to the buoy, respectively, depending on the place where the driveshaft is mounted, and is connected to the driveshaft. The first elongated means may be a flexible means, such as a line, wire or chain, but it can also be stiff, in that case for example comprising a rack gearing segment.

[0020] An electric generator connected to the driveshaft and comprising two parts that are rotatable in relation to each other, a first part and a second part, often called rotor and stator, respectively. An air gap exists between the two rotatable parts.

[0021] An accumulation device for temporary mechanical storage of energy as described above.

[0022] The buoy or the similar device is arranged and the buoy or the other device, the first elongated means, the device arranged to counteract the wave movements, the driveshaft and the energy accumulation device are connected to each other, so that the connection between the first elongated means and the driveshaft makes the driveshaft rotate, substantially for first movements of the water surface or for first movements of the buoy or the similar device, in only one direction, thereby driving said two part of the electric generator to rotate in relation to each other in a first direction and generate electricity and at the same time also supply energy to the accumulation device. Thus, energy from the rotation of the driveshaft is hereby partly converted to electric energy, which is delivered from the electric generator, partly to energy which is stored in the energy accumulation device. The first movements can for a buoy be the movements into which the buoy is set by either one of the up- or down-going movements of the water surface.

[0023] The energy accumulating device is arranged to drive, for substantially second movements, that are substantially different from the first movements, of the buoy or the similar device, said two parts of the electric generator to rotate in the same first rotation direction in relation to each drives said two parts of the electrical generator to rotate in relation to each other. The second movements can for a buoy be those movements, into which the buoy is set by second of the up and down going movements and thus are substantially different from said either one of the up and down going movements of the water surface.

[0024] The first movements of the buoy or the other body can take place in a direction, which is mainly the opposite the direction, in which the second movements of the buoy or the other device are made. Thus, the first movements can take place in a forward direction whereas the second movements take place in a backward direction, either as a translation movements, for example up or down, or as a rotational motion, i.e. angularly, or as a combined translation and rotational movement.

[0025] The driveshaft may be mechanically connected, for example via a mechanical gear, to the first part of the electric generator. An electromagnetic coupling exists in a conventional way over the air gap between the first and second parts of the electric generator at least when these parts are moving in relation to each other. The energy accumulation device may in one special embodiment be mechanically connected to the second part of the electric generator.

[0026] The connection of the energy accumulation device to the driveshaft via the electromagnetic coupling over the air gap between the first and second parts of the electric generator gives a motive force, which counteracts to the rotation of the driveshaft when the driveshaft is rotating, by the connection between the first elongated means and the driveshaft, and thereby is driving the first part of the electric generator. Then, in the above mentioned special embodiment, the second part of the electric generator can rotate in a first direction due to the coupling to the drive shaft through the electromagnetic coupling over the air gap and the first part of the electric generator, when the motive force which is acting on the driveshaft through the coupling between the first elongated means and the driveshaft exceeds the counteracting motive force, energy being accumulated in the energy accumulation device due the mechanical coupling thereof to the second part of the electric generator. At the same time, the first and second parts of the electric generator are rotating in the same first direction in relation to each other. Furthermore, the second part of the electric generator is driven by the energy accumulation device to rotate in the same first direction substantially when the motive force, which acts on the driveshaft through the coupling between the first elongated means and the driveshaft, does not exceed the counteracting motive force. Hereby, the first and second parts of the electric generator are made to continue to rotate in the same first direction in relation to each other also in this case.

[0027] As has been mentioned above, a mechanical gear may be arranged for coupling the driveshaft to the first part of the electric generator. The driveshaft is then suitably connected to an input side of the mechanical gear and the first part of the electric generator is mechanically connected to a first output side of the mechanical gear. In this case, the second part of the electric generator can be rigidly attached to the buoy, if the energy accumulation device is connected to a second output side that is different from the first output side of the mechanical gear. A mechanical gear can generally be regarded to comprise one input side having an input shaft and two output sides, where one of the output sides comprises an output shaft and another output side comprises a housing or enclosure of the mechanical gear, also see the discussion below of only the transmission included in the wave energy plant. For example a planetary gear, the input side may comprise a shaft connected to the planet gear carrier and the two output sides correspond to shafts connected to the sun gear and ring gear, which may be connected to a second shaft or the housing of the planetary gear.

[0028] In the case including a buoy, the buoy can comprise a space which functions as an air pocket and in which at least the main part of the driveshaft is mounted as well as other rotating parts, such as winding drums, in the case where such are provided and couplings between them. Such an air pocket can be a space filled with air, which at its bottom is delimited by a water surface and the other sides of which are different surfaces of the buoy. Then, the air pocket may be formed by a recess in the bottom surface of the buoy.

[0029] The energy accumulation device can in one embodiment comprise a counterweight, arranged as a lead, to also move upwards for said first movements of the buoy or the other device, thereby increasing its potential energy. The coupling of the buoy or the other device, the first elongated means, the driveshaft and the counterweight to each other is then suitably arranged so that the counterweight moves downwards, for said second one of the movements of the buoy or the other device, thereby driving the parts of the electric generator to rotate in relation to each other in the first rotational direction. In the case of a buoy, this can for example mean that, for the first movements, when the buoy e.g. is moving upwards, the counterweight is also moving upwards a distance, which is greater than the vertical distance in which the buoy then vertically moves.

[0030] The energy accumulation device can in the same embodiments comprise a counterweight drum which is rotationally mounted to the driveshaft and a second elongated means for coupling movements of the counterweight to make the counterweight drum rotate. The second elongated means can be flexible or can be a flexible means such as a line, wire or chain, which at a lower end is attached to the counterweight and at its upper end is more or less wound around the counterweight drum. Furthermore, the driveshaft is connected to drive the first part of the electrical generator to rotate and the counterweight drum can in a first case be coupled to rotate the second part of the electric generator, so that the electric generator generates electric current when its second part is rotated in relation to its first part and at the same time gives a torque counteracting this rotation. Hereby, the first and second parts of the electric generator can be made to always rotate always in the same first direction in relation to each other.

[0031] In a second case a mechanical gear can be connected between the driveshaft and the first part of the electrical generator. In this case the driveshaft is connected to an input side of the mechanical gear, the second part of the electric generator is rigidly attached to the buoy or the other device and the counterweight drum is mechanically coupled to a second output going side different from the first output side of the mechanical gear. The driveshaft can hereby, for said first movements of the buoy or the other device, provide motive forces on both of the output sides of the gear, in order to rotate the first part of the electric generator and to rotate the counterweight drum to elevate the counterweight in relation to the driveshaft. The counterweight drum can, for said second movements of the buoy or the other device, provide a motive force, through its coupling to the second output side of the gearbox, in order to rotate the first part of the electric generator.

[0032] Furthermore, in the case including a counterweight and a counterweight drum, an electric cable for the electric connection of the generator can be provided which extends from the generator to the counterweight drum and is partly wound around it, which therefrom extends to a non floatable part which is slidable along the first elongated means and to which it is rigidly connected, so that the sliding part can be maintained at a constant distance beneath the counterweight, and which electric cable extends from the slidable part up to the water surface to be further connected to an electric load. This may allow the wave energy converter to turn in the horizontal plane, such as when the direction of the water waves changes, without causing the electric cable to be entangled with the first elongated means.

[0033] An anchor drum can be mounted for unidirectional rotation around the driveshaft and further be coupled to the first oblong organ to make the anchor drum rotate for the first ones of the movements of the buoy or the other device, and thereby also making the driveshaft rotate. The first elongated means can be flexible, i.e. be a flexible means such as a line, wire or chain, which at one end is more or less wound around the anchor drum. A mechanism can be provided for rotating, for the second movements of the buoy or the other device, the anchor drum so that the flexible organ is kept in a tensioned state. Hereby, in can also be counteracted that the wave energy plant is moved away along the surface of the water. The mechanism can for example comprise a mechanical coupling between the energy accumulation device and the anchor drum or comprise an electric motor.

[0034] The bearing for the anchor drum, which only allows a unidirectional rotation around the driveshaft, at the same time allows the anchor drum, when rotating in the opposite direction, to drive the driveshaft to rotate in the opposite direction, which is the above said only one direction. This bearing can comprise a coupling for limiting or disengaging the motive force with which the anchor drum then acts on the driveshaft.

[0035] A control system for controlling the electrical load of the electric generator can be provided that is arranged to adapt the rotational speed between the first and the second parts of the electric generator. In the case where the energy accumulation device comprises a counterweight or a floating body, control of the electrical load can also be used for adapt the vertical speed of the counterweight or of the floating body, respectively, whereby it also becomes possible for the counterweight or the floating body, respectively, to only move within an adapted or suitable vertical range. The control system can also be arranged to compensate for variations in the torque, which is caused by the inertia of the mass of the counterweight or the floating body, respectively, by adjustment of the rotation speed between first and the second parts of the electric generator. Hereby it can be achieved that the electric generator is capable of supplying a continuous, even power.

[0036] The wave energy converter may have one or more of the following characteristics and advantages:

[0037] 1. Accumulation of energy according to the description above can be used for equalizing the energy of the water waves and thereby generate electricity at an even level, which gives a high capacity factor of the generator and associated power electronic circuits and connections, and a low complexity of the electric power system.

[0038] 2. Excess energy from large waves can be accumulated and used over time to compensate for shortage in smaller waves, which contributes to the high capacity factor.

[0039] 3. Absorption of energy from the water waves can be limited while full power can be maintained even during very heavy wave conditions. This contributes to the high capacity factor, but it also works as a very simple and efficient storm protection system where the wave energy plant all the time works in harmony with the waves, only absorbing the amount of energy that it has a capacity to convert.

[0040] 4. The power output of the generator can be controlled by the fact that the rotation speed of the generator can be adapted to the average rotation speed of the driveshaft. This brings about that the wave energy plant can deliver an even power level in relation to the current wave climate.

[0041] 5. The wave energy plant is highly scalable and its capacity and pattern producing electric power can be optimized for specific wave climates for the highest cost efficiency.

[0042] 6. The wave energy plant has a completely mechanical transmission having a high efficiency, which in simple way converts the oscillating wave movements into a unidirectional rotation, well adapted to a standard electric generator having a rotating rotor.

[0043] 7. The construction can for example mainly be made from concrete, a cheap material which is well tested for ocean environment.

[0044] 8. An electronically adjustable sliding clutch may be used, which is arranged to influence the winding of a line between a bottom foundation and the buoy and which also makes it possible to adjust the force which is needed to maintain the horizontal position of the wave energy plant. Such a sliding clutch may replace and enhance the function of a counterweight, here called a lead, which is often used in similar constructions.

[0045] 9. An anchor drum, which is mechanically connected to the driveshaft, can be used for more or less winding the second elongated means, according to the wave movements. Several revolutions of the anchor line can be wound around the anchor drum and hence it has no technical limitations for wave heights that the installation can handle. The buoy follows the surface of the water in a harmonic way for all wave sizes without reaching any end position, which contributes to the fact that the wave energy plant can very efficiently absorb wave energy, in spite of varying wave heights and at the same time the strain on the construction during storm conditions is minimized.

[0046] 10. Mechanical couplings may be provided, so that if the electrical generator is supplied with electric energy from an external source and acts as an electrical motor, the anchor drum can be controlled to move to perform a controlled winding of the line. This can confer to the wave energy plant the property that it can be assembled on shore before it is towed to the installation site thereof.

[0047] 11. The installation can be done with a minimum of manual assistance. It is mainly only an electric cable that has to be manually connected, which can be done at the surface of the water from a boat. A bottom foundation, which is connected to the second elongated means, and the counterweight are attached to the buoy during transport to the installation site and then they can be released by control of mechanic couplings/locking devices.

[0048] 12. The wave energy converter can easily be designed to be suitable for different installation depths.

[0049] 13. A gearbox can be used to increase the rotation speed of the electrical generator, this allowing the use of a smaller and more resource efficient high speed generator. Such a gearbox can also make it possible to permanently fix the second part of the electric generator, the stator, to the buoy, by connecting the gearbox to the counterweight drum, which can simplify the electrical connection and encapsulation of the generator and reduce the rotating mass in the construction.

[0050] Generally, as described above, a method of extracting electric energy from more or less periodic movement of a body, such as repeated upward and downward movements and/or tilting movements in two opposite directions can comprise the following steps.

[0051] For first movements of the body, these movements can drive two parts of an electric generator to rotate in relation to each other in a first direction and thereby generate electric current and at the same time provide mechanical energy to an energy accumulation device.

[0052] For second movements of the body, which are substantially different from the first movements, the energy accumulation device can drive the two parts of the electrical generator to rotate in the same first direction in relation to each other and thereby generate electric current having the same polarity as during the first movements of the body.

[0053] The transmission used in the wave energy converter as described above can independently be used in other cases of power generation, where a driveshaft is driven intermittently, with changing directions and/or with varying speeds and/or torques. Generally, the transmission then comprises a driveshaft that is arranged to be driven and that by some suitable device, if required, always can be made to rotate in one rotational direction. Furthermore, an electrical generator coupled to driveshaft is provided, which generator comprises two parts that can rotate in relation to each other, and an energy accumulation device. The driveshaft drives the two parts of the generator to rotate in relation to each other in a first direction and thereby generate electric current. The energy accumulation device is coupled with the driveshaft and the electric generator, so that the driveshaft by its rotation can also supply energy to the energy accumulation device and so that the energy accumulation device can later deliver its stored or accumulated energy to cooperate in driving the parts of the generator to rotate in the same first direction in relation to each other. Thereby, electric current can be generated having the same polarity, when the rotational speed and/or the torque of the driveshaft is/are insufficient to drive the parts of the generator to rotate at a maintained rotational speed.

[0054] In the transmission, the driveshaft can be mechanically connected to the first one of the parts of the electrical generator. In the generator there is, as conventionally, an electromagnetic coupling over an air gap between the first and the second part, at least during their movements in relation to each other, which the coupling gives some torque between the two parts. The energy accumulation device can in a first case be mechanically coupled to the second part included in the electrical generator.

[0055] Furthermore, in the transmission a gearbox, e.g. a planetary gearbox, can as described above be connected between the driveshaft and the generator, so that the driveshaft is mechanically connected to the input side of the gearbox or generally to a first rotational part of the gearbox. An output side of the gearbox or generally a second rotational part of the gearbox is then arranged to be driven from the outside to rotate with a varying rotational speed and/or torque in one rotational direction. One of the two parts of the electrical generator is mechanically coupled to another output side of the gearbox, generally a third rotational part of the gearbox, and the energy accumulation device is mechanically coupled to the second part of the generator. The first and second rotational parts of the gearbox can then cooperate to for example drive the third rotational part of the gearbox to rotate with a rotational speed higher than the rotational speeds that each of the parts by itself can achieve when the other of these parts stands still or is not driven.

[0056] The gearbox should in any case have the following functions:

[0057] When the first rotational part is driven from the outside, the second and the third rotational parts are also made to rotate.

[0058] When the first rotational part is not rotating, the third rotational part can drive the second rotational part to rotate.

[0059] The first, second and third rotational parts can also be arranged to rotate around the same geometric rotational axis, i.e. be coaxially mounted.

[0060] Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods, processes, instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0061] While the novel features of the invention are set forth with particularly in the appended claims, a complete understanding of the invention, both as to organization and content, and of the above and other features thereof may be gained from and the invention will be better appreciated from a consideration of the following detailed description of non-limiting embodiments presented hereinbelow with reference to the accompanying drawings, in which:

[0062] FIG. **1** is a schematic image of a wave power installation comprising four separate wave energy plants,

[0063] FIG. **2***a* is a side view of a wave energy converter including a counterweight,

[0064] FIG. **2***b* is a front view of the wave energy plant of FIG. **2***a*,

[0065] FIG. **2***c* is a sectional view of a wave energy plant having an alternative suspension of a power train,

[0066] FIG. **2***d* is a different sectional view of the wave energy plant of FIG. **2***c*,

[0067] FIG. **2***e* is a view from underneath only comprising a buoy including steering fins, an anchor drum and a counterweight drum according to FIG. **2***c*,

[0068] FIG. **2***f* is a view from underneath of the wave energy plant of FIG. **2***c* which also shows an air pump,

[0069] FIG. **2***g* is a top view of a power train for a wave energy converter mounted in a frame,

[0070] FIG. **3***a* is a front view of a power train including winding drums, a driveshaft and a generator in the wave energy plant of FIG. **2***a*,

[0071] FIG. **3***b* is a view similar to FIG. **3***a* in which parts of a generator are schematically shown and in which a spiral spring is used as an energy accumulation device,

[0072] FIG. **3***c* is a front view of winding drums having specially designed winding surfaces,

[0073] FIG. **3***d* is a schematic of a power train comprising a generator having a stationary stator,

[0074] FIG. **3***e* is a front view of a wave energy plant including a frame for interconnecting two counterweights,

[0075] FIG. **3***f* is a top view of the frame of FIG. **3***e* for interconnecting two counterweights,

[0076] FIG. **4** is a front view of the wave energy plant of FIG. **2***a* having a specially designed electric cable connection,

[0077] FIG. **5***a* is a detail view of an anchor drum and its couplings located at the shaft,

[0078] FIG. **5***b* is a view similar to FIG. **5***a* for a different design of the couplings,

[0079] FIG. **5***c* is a schematic of an anchor drum having couplings designed in yet another alternative way,

[0080] FIG. **5***d* is a diagram illustrating a control rule for engagement and disengagement of a slipper clutch,

[0081] FIG. **5***e* is a schematic view of a claw clutch in an engaged state,

[0082] FIG. **5***f* is a schematic view of a claw clutch in a disengaged state,

[0083] FIG. **6** is a detail view of a mechanical coupling for return feed between an anchor drum and a counterweight drum,

[0084] FIG. **7***a* is a front view of an alternatively designed wave energy plant including counterweights,

[0085] FIG. **7***b* is a front view of an alternatively designed wave energy converter including buoys instead of counterweights,

[0086] FIG. **7***c* is a front view of yet another alternatively designed wave energy converter including counterweights located above the water surface,

[0087] FIG. **7***d* is a front view of a wave energy plant having an alternative driving operation of the driveshaft by cooperation with a weight suspended in an elastic means,

[0088] FIG. **8***a* is a front view of a combined wind and wave energy plant,

[0089] FIG. **8***b* is a side view of the combined wind and wave energy plant of FIG. **8***a*,

[0090] FIG. **8***c* is a detail view of a power train comprised in the combined wind and wave energy plant of FIG. **8***b*,

[0091] FIG. **8***d* is a front view of a wind power plant, in which a transmission of the same kind is used,

[0092] FIG. **8***e* is a side view of the wind power plant of FIG. **8***d*,

[0093] FIG. **8***f* is a detail view of the wind power plant of FIG. **8***e* having a pneumatic energy accumulation device,

[0094] FIG. **9***a* is a front view of a wave energy plant having an energy accumulation device designed as an elastic means,

[0095] FIG. **9***b* shows an alternative connection of the elastic means of FIG. **9***a,*

[0096] FIG. **10***a* is a schematic front view of a wave energy plant including an energy accumulation device and a return feed mechanism,

[0097] FIG. **10***b* is a view similar to FIG. **10***a* of a wave energy plant converter using the torque which is transferred over the air gap of a generator to obtain energy accumulation,

[0098] FIG. **11***a* is a schematic of a previously known device for driving a generator in a wave energy plant,

[0099] FIG. **11***b* is an schematic similar to FIG. **11***a* but of a differently designed device for driving a generator having a stator that also is rotating,

[0100] FIG. **11***c* is a view from a different side of the device of FIG. **11***b,*

[0101] FIG. **11***d* is a schematic similar to FIG. **11***b* of a device arranged in a different way design for driving a generator having a stationary stator,

[0102] FIG. **11***e* is a view from a different side of the device of FIG. **11***d,*

[0103] FIGS. **12***a* and **12***b* are views from two sides, illustrating the construction and function of a planetary gear,

[0104] FIGS. **12***c* and **12***d* are schematic views, illustrating the construction of a variable mechanical gear (CVT/CVET),

[0105] FIG. **12***e* is a view of a planetary gear and a variable gear which are coupled with a generator in a power train,

[0106] FIG. **13***a* is a front view of a power train having steering rollers for the guidance of lines,

[0107] FIG. **13***b* is a side view of the power train of FIG. **13***a,*

[0108] FIG. **13***c* is a bottom view of the power train of FIG. **13***a,*

[0109] FIG. **14** is a bottom view of a power train including only one generator mounted in a buoy,

[0110] FIG. **15***a* is a front view of a wave energy plant having an alternative design of a power train including only one generator, the stator of which rotates together with the counterweight drum, one counterweight and an alternative guide mechanism for an anchor line,

[0111] FIG. **15***b* is a side view of the wave energy plant of to FIG. **15***a,*

[0112] FIG. **15***c* is a front view of a wave energy plant of FIG. **15***a* having a different type of divided anchor line,

[0113] FIG. **15***d* is a side view of the wave energy plant of FIG. **15***c,*

[0114] FIG. **15***e* is a bottom view of the power train of the wave energy converter of FIG. **15***a,*

[0115] FIG. **15***f* is a bottom view similar to FIG. **15***e* but including a power train in which the stator of the generator is rigidly attached to the buoy,

[0116] FIG. **15***g* is a bottom view of a power train similar to FIG. **15***f,* in which the mechanical components are encapsulated to a larger extent,

[0117] FIG. **15***h* is a front view of the power train of FIG. **15***g,*

[0118] FIG. **15***i* is a view similar to FIG. **15***g*, in which a return feed mechanism in the power train is driven by an electric motor,

[0119] FIG. **16***a* is a diagram illustrating a control rule for compensating for varying accelerations and decelerations of the counterweight using the load of the generator,

[0120] FIG. **16***b* is a diagram illustrating a control rule for compensating for varying accelerations and decelerations of the counterweight using a CVT, and

[0121] FIG. **16***c* is a diagram illustrating a control rule for compensating for varying accelerations and decelerations of the counterweight using the sliding clutch of the return feed mechanism.

DETAILED DESCRIPTION

[0122] In FIG. **1**, a wave power installation is shown for extraction of energy from the movements of waves at a water surface **6** of a pool of water, e.g. movements of water in a ocean. The wave power installation comprises one or more wave energy plants **1**, each including a buoy or a floating body **3**, which is located at the water surface, e.g. floating thereon, and which to a higher or lower degree follows the movements of the waves. In the upwards and downwards movements of the water surface **6** the buoy is made to alternating raise or sink and/or alternating tilt back and forth. Thereby a motive force can be created, in the case shown in relation to the bottom **8** of the water pool, such as a part rigidly attached to the bottom, e.g. a bottom foundation **5**, which can have a mass large enough to keep it steadily on the bottom. If required, the bottom foundation can of course be attached to the bottom in some way and it may then comprise a simple fastening device having a low mass, not shown. As can be better seen in FIGS. **2***a* and **2***b* the buoy **3** and the bottom foundation—alternatively the bottom fastening device—are connected to each other by an anchor line **7**, e.g. a steel wire. The motive force can as an alternative be created in relation to some kind of movable object such as to a weight suspended in the buoy, see FIG. **7***d.*

[0123] In the shown embodiment the anchor line **7** is at one end attached to the foundation **5** and is at its opposite end attached to a power train **2** and more or less wound around a first winding drum, an anchor drum **9**, included in the power train, the winding drum being mounted to rotate about a driveshaft **11**. The driveshaft **11** is in a suitable way journalled at the buoy **3**. As shown in FIGS. **2***a* and **2***b* the buoy can at its bottom side comprise downwards protruding stays **13**, which can be said to constitute a frame and at which the driveshaft **11** is journalled, e.g. at its two ends. On the driveshaft, in the embodiment shown in these figures, there is also a second winding drum, a counterweight drum **15**, on which a line **17** is partly wound at its upper end. The counterweight line **7** carries at its lower end a counterweight **19**. The cylindrical surface of the counterweight drum, on which the line for the counterweight is wound, has in the shown embodiment a diameter that is larger than that of the cylindrical surface of the anchor drum **9**, on which the anchor line **7** from the bottom foundation **5** is wound. The first mentioned diameter can e.g. be considerably larger than the latter one, such as a relation in the magnitude of order of 2:1 to 3:1, but does not have to. The winding drums can also have the same diameter when suitable.

[0124] Instead of having the power train **2** mounted under the buoy **3**, as shown in FIGS. **2***a* and **2***b*, the power train can be mounted in a recess in the buoy, a power train room **20**, as shown in FIGS. **2***c*, **2***d* and **2***e*. Then, the driveshaft **11** can be mounted in a substantially central position in the buoy. The stays **13** can be attached to walls of the power train room **20**.

[0125] Thus, the anchor line **7** and the counterweight **19** are not directly connected to each other as in earlier known constructions. In the earlier known constructions, see the principle picture of FIG. **11***a,* half the motive force of the buoy **3** is accumulated in the rise of the wave by while the anchor line **7** running over the anchor drum **9'**, so that a generator **21** for generating electric current can be driven also when the wave thereafter sinks. In the latter case, the generator is either driven in a reverse direction or the rotation movement is rectified by a mechanical or hydraulic transmission solution, not shown. However, in both cases the generator **21** remains to be direct driven according to the momentary vertical movement of the wave.

[0126] As appears from FIGS. **11***b* and **11***c* the generator can instead be connected to be driven between the counterweight **19** and the anchor drum **9**, so that e.g. a first part of the generator, not shown in these figures, typically corresponding the inner rotating part, the rotor, of a conventionally mounted generator, on one side of the air gap of the generator, not shown, is mechanically connected to the anchor drum and a second part of the generator, not shown in these figures, typically corresponding to the outer stationary part of the generator, the stator, in a conventionally mounted generator, on the other side of the air gap, is mechanically connected to the movements of the counterweight, so that this part can also rotate. Hereby the generator **21** can be driven from two sides with a maintained relative rotational direction between its first part and its second part. When the wave and the buoy **3** raises, the driveshaft **11** is turned forwards by the anchor line **7**, which runs around the driveshaft via the anchor drum **9** and which at its other end is anchored to the bottom **8**, e.g. to a foundation **5**. The counterweight **19** is used to create a resilient resisting force and thereby gives an even torque between the counterweight drum **15** and the driveshaft **11**, which in that way drives the first part and second part of the generator in relation to each other. It is also possible to use other methods to achieve such a driving operation, e.g. gas pressure or a spring for providing a constant force, as will be described below.

[0127] In FIGS. **11***a*, **11***b*, and **11***c* the arrows **111** show absorption of wave energy. The absorption level varies according to the momentary movement and movement direction of the wave. When the driveshaft **11** is turned forwards by the anchor drum **9**, also the generator **21** follows the rotation, so that the counterweight line **17** starts to be wound around the counter weight drum **15**, which can be a part of or be rigidly attached to the second part of the generator, see the arrows **113**, and so that the counterweight is moved upwards. Hereby, potential energy is stored in the counterweight at the same time as a torque appears over the generator (torque=weight of the counterweight*acceleration of gravity (i.e. the gravitational force acting on the counterweight)*radius of the counterweight drum). The torque makes the second part of the generator start rotating in relation to the first part, which is mechanically connected to the driveshaft **11**, so that the counterweight line **17** starts to unwind from the counterweight drum **15**, and hereby potential energy accumulated in the counterweight **19** is converted to electricity, see the arrows **115**. The faster the generator parts rotate in relation to each other, the more electric power is generated, and then also a higher counteracting force is obtained in the generator **21**, i.e. the electromagnetic coupling between the two parts of the generator becomes stronger. When the counterweight **19** reaches a certain velocity, the pulling force from the counterweight becomes equal to the counteracting force in the generator, this resulting in that the rotation speed of the generator and the power output from the generator is stabilized in an equilibrium state.

[0128] This way of connecting and driving the generator **21** can give great advantages, since the generator can be used much more efficiently compared to what have been earlier possible. The same relative rotational direction between the generator parts is maintained all the time and the generated electric power is kept at a substantially even level, which requires a minimum of subsequent electric treatment of the electrical voltage generated by the generator. The arrangement of the generator can also give advantages from a storm safety point of view, since the motive force over the generator and transmission is limited.

[0129] The design of the transmission unit **2** and the function thereof will now be described in more detail with reference in particular to FIGS. **2***a*, **2***b* and **3***a*.

[0130] During the movements of the waves the distance between the buoy **3** and the bottom foundation/bottom fastening device varies. The anchor drum **9** is turned, due to the coupling with the anchor line **7**, in a first direction when the water surface **6** rises, and is then locked to the driveshaft **11**, which thereby is rotated by the anchor drum. When the water surface at the buoy sinks, the driveshaft is locked from rotating backwards in the opposite direction by anti-reverse mechanisms **53** in the shaft stays **13**, see FIGS. **5***a* and **5***b*. To be capable of turning the anchor drum backwards, in a second, opposite direction, and to keep the anchor line in a tensed state when the water level **6** at the buoy **3** sinks, a return feed mechanism of some kind sort is required as will be described below. The driveshaft **11** is in turn connected to the generator **21**. The coupling between the driveshaft and the generator can be fixed or it can as illustrated comprise a mechanical gear **23**, which e.g. has a fixed teeth relation or fixed gear ratio, and which gears up the rotation speed of the generator. Hereby one of the parts of generator that are rotatable in relation to each other, here for the sake of simplicity called rotor and stator, e.g. an inner generator rotor **21'**, compare FIG. **3***a*, to rotate in the first direction. The other rotatable part of the generator, e.g. an outer stator **21"** is rigidly mounted to the counterweight drum **15**. The generator parts are separated by an air gap **21'"**.

[0131] Due to the winding of the counterweight line **17** around the counterweight drum **15** during the forward feeding of the driveshaft **11**, a relatively constant motive force or a relatively constant torque acting on the driveshaft **11** is achieved, which through the connection between the rotor **21'** and the stator **21"** of the generator **21** drives the generator to rotate and generate electric current. When the torque from the anchor drum **9** exceeds the counteracting torque, that is derived from the electromagnetic coupling over the air gap between the rotor and the stator of the generator, when these parts are rotating in relation to each other, more of the counterweight line **17** is wound around the counterweight drum **15** and the excess energy, to which this higher torque corresponds, is accordingly accumulated the hoistening of the counterweight **19**. Thereafter, when the buoy **3** starts to rise with a decreasing speed, to thereupon sink when the water surface **6** sinks, also the rotational speed of the driveshaft **11** and the rotor **21'** in the first rotational direction is also reduced. When the torque from the anchor drum **9** becomes lower than the counteracting torque in the generator **21** according to the discussion above, the counterweight line **17** starts to unwind from the counterweight drum at an increasing speed, until of the driveshaft is blocked from rotating in the reverse direction by an anti-reverse mechanism **53** in the driveshaft stay **13**, see FIGS. **5***a* and **5***b*, and the speed of the backward rotation of the counterweight drum is stabilized by the equilibrium state between the generator and the counterweight **19**. The potential energy accumulated in the counterweight hence continues to drive the generator **21** also in this phase, with a correspondingly even torque as in the previous phase.

[0132] As has been mentioned above, the wave energy is absorbed from the traction force that arises between the buoy **3** and the bottom foundation/bottom fastening device **3** during the rise of the wave. The buoy **3** follows the movements of the wave and thereby moves the driveshaft **11**, on which the anchor drum **9** is mounted, upwards in relation to the bottom foundation. A rotational movement arises which drives the transmission. The vertical movement of the wave is converted into a rotational movement, the speed of which can then be geared up to be suitable for driving the generator **21**. It is the speed of the vertical movement of the wave that determines the amount of energy that can be extracted. The bigger wave, the faster vertical movement and the more energy can be absorbed. Different from the energy in the wave, the vertical speed of the movement does not increase with the square of the wave height, but follows a more linear pattern. But the larger the wave is, the less impact has the attenuating effect of the buoy **3**, this resulting in that the vertical movement and the motive force of the buoy rapidly increase when the wave height increases from a low level to level out towards the linear pattern the higher the wave becomes.

[0133] The anchor drum **9** is in a suitable way mechanically connected to the drive shaft **11**. Such a mechanical coupling can include the following two functions.

[0134] 1. During the rise of the wave the anchor drum **9** shall hook on to the drive shaft **11**, so that the driveshaft is rotated together with the rotational movement of the anchor drum. When the wave sinks, it shall be possible to disengage the anchor drum, so that the anchor drum can be rotated in the reverse direction. Furthermore, the driveshaft **11** shall be blocked from changing its rotational direction when the wave sinks. The drive shaft is in this manner fed forward by the anchor drum in the same rotational direction every time the wave rises and the motive force, and thereby rectifies the motive force absorbed from the wave motions. This makes it possible to drive the generator in a single rotational direction.

[0135] 2. The absorption of wave energy can be limited by the use of a sliding clutch **55**, which consequently can word as an overload protection, see FIGS. **5***a*, **5***b* and **5***c*. Such a sliding clutch also makes it possible to completely disengage the absorption of energy from the movements of the waves, by letting the anchor drum **9** slide against the driveshaft **11** during the rise of the wave, when the accumulation level reaches its upper limit, i.e. when it is not possible to wind more of the counterweight line **17** around the counterweight drum **15** without risking that the counterweight **19** comes to close to and damages the counterweight drum **15** and the buoy **3**. The sliding clutch can also be used to limit the torque to which the transmission is submitted. When the wave sinks, the buoy **3** and the counterweight **19** will be retarded, which gives an increased g-force and hence an increased torque in the transmission. When the wave turns and rises again, the g-force will increase further by the anchor drum **9** starting to be turned forward and lifting the counterweight in relation to the buoy at the same time as the buoy is lifted by the wave. For a too high load the sliding clutch slides and thereby somewhat reduces the acceleration, which in turn also reduces the torque to which the transmission is submitted.

[0136] A mechanical coupling between the anchor drum **9** and the driveshaft **11**, which provides these functions, can be designed in different ways. Such a coupling can comprise one or more anti-reverse mechanisms and a sliding clutch as will be described below.

[0137] Thus a freewheel mechanism or an anti-reverse mechanism **51**, see FIG. **5***a*, for the coupling of the driveshaft **11** to the anchor drum can be provided, which is herein called the anti-reverse mechanism of the anchor drum. In this case, the driveshaft passes through the anchor drum undivided. The anti-reverse mechanism **51** of the anchor drum can be designed like a one way bearing, which is mounted around the driveshaft. When the buoy **3** rises, the anchor drum **9** and the driveshaft **11** is turned, as above, in the first rotational direction, by way of the anchor drum hooking on to the driveshaft with the use of this return blocking mechanism **51**. When the buoy **3** sinks, the return blocking mechanism in the anchor drum **9** is released and the anchor drum **9** can be reversed, rotated in the opposite rotational direction, to wind up the anchor line **7**, such as will be described below, meanwhile the driveshaft **11** is blocked from rotating in the opposite rotational direction by another return blocking mechanism **53**, which is acting between the driveshaft and the stay **13** and which is here called the shaft stay return blocking mechanism **53**. This return blocking mechanism can be arranged at or in the stay bearing **54** for the driveshaft **11**. In this way the driveshaft is always turned in the first rotation direction every time the buoy **3** rises and it can never be turned in the opposite direction.

[0138] If so is required, the transmission unit **2** can be designed, so that motive force, with which the anchor drum **9** acts on the driveshaft **11**, can be disengaged also in the first rotational direction. This can be achieved by a controllable return blocking mechanism **51** of the anchor drum, or preferably with the use of a sliding clutch **55** for the anchor drum, as will be described below. The drive of the driveshaft **11** can then be disengaged, when the accumulation of energy reaches its maximum accumulation level, i.e. when the counterweight **19** cannot be hoisted up any higher without the risk of damaging the anchor drum **15** and/or the buoy **9**. This disengagement of the drive of the driveshaft is then ended, when the buoy **3** starts sinking, so that the anchor drum **9** drives the driveshaft **11** anew when the wave starts rising again. The energy absorption of the wave energy converter is hereby limited and overload of the transmission and the generator **21** can be prevented, when the average wave height exceeds the level, at which the wave energy converter reaches its maximum capacity, i.e. rated power. Even though the energy absorption is hereby temporarily disengaged, the generator can be driven to produce maximum power output, as long as the potential energy stored in the counterweight can be used. The load on the generator **21** and the transmission **23** can hereby be limited at the same time as maximum power output can be maintained, as soon as the average energy level in the waves is high enough.

[0139] An alternative method for disengagement of the driveshaft **11** from the anchor drum **9**, to limit the energy absorption, is that both engagement and disengagement is done when the torque, which is transferred between the anchor drum and the driveshaft, is zero. In this case a claw coupling **55"** can be used instead of a sliding clutch, see FIGS. **5***e* and **5***f*. When the counterweight **19** has exceeded an upper limit, the claw coupling is disengaged as soon as the torque has been reduced to zero, see FIG. **5***f*. The claw coupling is engaged again, see FIG. **5***e*, when the counterweight has reached a certain lower limit, and when the torque is zero again, which may be several wave periods later. The upper limit, as above, must provide enough safety margins so that the counterweight **19** doesn't reach the counterweight drum **15** even if an extreme wave comes. Advantages with this method includes that the disengagement mechanism can manage a higher torque being transferred, low energy consumption only during transition, and minimum of mechanical wear from the disengagement. The disadvantage is that a longer counterweight line **17** is required, which can be limiting in some cases.

[0140] The anchor drum's **9** sliding clutch **55** can be mounted between the anchor drum's return blocking mechanism **51** and the anchor drum, as schematically shown in FIG. **5***a*. The by the sliding clutch transferred torque between the anchor drum and the drive shaft **11** can preferably be controllable in accordance with some suitable electrical signal, by which the maximum energy absorption level in the system can be adjusted.

[0141] In an alternative design the mechanical return blocking mechanism of the anchor drum **51**, does not exist, see FIG. **5***b*. The driveshaft **11** is also in this case passing through the anchor drum **9** undivided. Instead the anchor drum's sliding clutch **55** is used as a return blocking mechanism. The sliding clutch is mounted around the drive shaft **11** with one of its coupling sides and mounted to the anchor drum **9** with its other coupling side. The torque transfer in the sliding clutch **55** is controlled to also give the function of a return blocking mechanism.

[0142] In yet another alternative design there is a detached sliding clutch **55'** without mechanical return blocking mechanism, see FIG. **5***c*. The driveshaft **11** is in this case divided and the anchor drum **9** is firmly attached to the first part of the driveshaft **11'**. There is a sliding clutch **55'** between the first part **11'** and its second part **11"** of the driveshaft, to the side of the anchor drum. The first part of the shaft **11'** is journalled in bearing to an inner stay **13'** between the anchor drum and the sliding clutch at bearing **54'**. The sliding clutch **55'** is, as above, used as a return blocking mechanism and its torque transfer is controlled in the same way as when the sliding clutch is enclosed in the anchor drum **9**.

[0143] When the sliding clutch **55, 55'** is used as a return blocking mechanism, it can be controlled as visualized in FIG. **5***d*. It then alternates between transferring full torque and no torque at all. The anchor drum **9** rotates forward, meanwhile the wave is rising, and is then fed backwards by the below described return feeding mechanism, when the wave is sinking. The alternation in torque transfer hence occurs when the rotational direction of the anchor drum is turned.

[0144] The rotation of the anchor drum **9** and the rotation of the counterweight drum **15** can also be coupled via a mechanical coupling, the above mentioned return feeding mechanism, beside with the help of the electromagnetic coupling through the generator **21**. This can be achieved with help of, among other things, a second sliding clutch **25**, here called the return feeding sliding clutch, see FIG. **6**, which is used for controlling the level of torque, which shall be transferred from the counterweight drum to the anchor drum. The level of this torque can also be adjustable or dirigible. This torque can be used to reverse the anchor drum **9** and by that secure that the anchor line **7** to the bottom foundation **5** is kept in a tensed state, meanwhile the buoy **3** sinks. This torque can also be used for counteracting the driftage of the buoy, away from the sea floor foundation, due to currents and wind at the water surface **6**.

[0145] The return feeding sliding clutch **25** can as shown be mounted in one of the stays **13**, in which the driveshaft **11** is journalled in bearings. Gearwheel **27, 29** runs against the edges **31, 33** on the wind up drums **9** and **15** respectively and these edges can then in the corresponding way be toothed. The gearwheels **27** and **29** is connected to the input- and output-shafts of the sliding clutch **25** and their size in relation to the gearwheels **31, 33** at each wind up drum respectively, is adapted to provide high enough gear ratio for the rotation speed of the anchor drum **9** to be high enough to wind up the anchor line **7** fast enough to keep it tense, when the floating body **3** sinks as fastest. In the shown design the gearwheels **27, 29** is coaxially journalled in bearings and directly connected to the two clutch disks **57** in the return feeding sliding clutch **25**, which are pressed against each other with a controllable force, so that when so is required, a torque of desirable magnitude can be transferred between the counterweight drum **15** and the anchor drum **9**. One alternative return feeding mechanism for the anchor drum is to use an electrical motor in a corresponding way as shown in FIG. **15***i*.

[0146] The gear **23**, that connects the driveshaft **11** to the generator **21**, can give a stepped up rotational speed of the driveshaft so that a higher rotational speed in the generator is obtained, which enables the use of a high speed generator. Since the power output from the generator is proportional to the mass of its rotor **21'** and its stator **21"** and to the rotational speed of the generator, this is of very high importance. Further on, the gear **23** can in general be or comprise a variable gear, where it can comprise e.g. a gear with fixed gear ratio such as a planetary gear **35**, arranged as input stage, see FIG. **12***e*. The outgoing shaft of the planetary gear is then connected to the input shaft of a variable gear **37** (CVT), of which output shaft is connected to the first of the generator's part, like its rotor **21'**. The generator stator **21"**, and the casing of these gears is fixed to each other and the counterweight drum **15** and can rotate freely as one unit around the driveshaft **11**. The gear ratio between the driveshaft **11** and the first part of the generator **21'** is in this case given by the product of the gear ratio of the planetary gear **35** and the gear ratio of the variable gear **37**.

[0147] The maximum rotational speed, that the generator **21** can handle, depends on the choice of generator. A suitable range for the generator's nominal rotational speed is around 1500 to 3000 rpm depending on its maximum capacity, for which the wave energy converter **1** is dimensioned. To gear up the generator to such a rotational speed a gear ratio in the magnitude of 100 to 200 times is required, where the gear ratio also depends on the radius of the anchor drum and the medium motion speed of the buoy where full power shall be reached. When the rotational speed is stepped up, the torque is at the same time stepped down with the same gear ratio, which brings a very high input torques in the gear **23**. A high gear ratio can cause high transmission losses. A planetary gear **35** as above provides a high fixed gear ratio, can manage very high input torques and has a good efficiency. The variable gear stage in the gear **37** can be used to adapt the generator's revolution speed to the actual medium wave height. Such a variable gear can e.g. be a step less variable gearbox or a hydraulic gearbox.

[0148] Alternatively, the transmission unit **2** can be designed with other mechanisms for accumulation of energy from the rise of the water surface **6**, e.g. as elastically stored energy. Any counterweight is then not required, and can instead be replaced by a spring, typically a coil spring **69**, see FIG. **3***b*. The inner end of such a coil spring is then mounted to the stay **13**, while its outer end is mounted to the casing of the gear **23** and is thereby coupled with the generator **21**, to its second part. Energy can also be accumulated as gas pressure which will be described below.

[0149] In the so far described designs, one single anchor drum **9** and two counterweight drums **15** located on either side of the anchor drum can exist, as shown in the corresponding figures. One gear unit **23** and one generator **21** is included in each counterweight drum. One counterweight drum **15** is hence connected to either end of the driveshaft **11**, i.e. the driveshaft is mounted between the two counterweight drums and the driveshaft is journalled in bearings in the stay or the frame **13**.

[0150] The movements of the two counterweight drums **15** can be synchronized with the use of a link shaft **58**, that is journalled in bearings in the stay **13** parts and has gearwheels **29** at both its ends, which concurs with the toothed edges of the counterweight flanges **33**, see FIG. **2***f*. The generator arrangements **21** are freestanding but the counterweight **19** must be kept on the same horizontal level so that the distance between the counterweight and the anchor drum is the same in both arrangements. Otherwise the centre of gravity in the wave energy converter **1** can be displaced, so that the power unit can turn in a faulty manner against the waves, with deteriorated capture ratio between the waves and the buoy **3** as a consequence. The link shaft **58** is in the showed design also used for achieving the return feeding mechanism from the counterweight drums **15** to the anchor drum **9**. For this it also has a gearwheel **27**, which concurs with a ring gear on one of the anchor drums flanges **33** in a similar way as for the return feeding mechanism shown in FIG. **6**.

[0151] The motion of the two counterweight drums **15** can be synchronized thanks to a link shaft **58** which is journalled in bearings in the stay **13** parts and has gearwheels **29** at both ends, which concur with gear rings on the counterweight drums' flanges **33**, see FIG. **2***f*. The generator arrangements **21** are freestanding but the counterweights **19** must be kept on the same horizontal level, so that the distance between the counterweight and anchor drum is the same in both arrangements. In other case the wave energy converter's **1** centre of gravity may be displaced, so that the wave energy converter can turn incorrectly towards the waves with decreased power transfer between the wave and the buoy as a consequence. The link shaft **58** is in the presented design also used for achieving the return feeding from the counterweight drums **15** to the anchor drum **9**. For this purpose it also has a gearwheel **27**, which concur with a gear ring on one of the anchor drum's flanges **33** in a similar way as for the in FIG. **6** presented return feeding mechanism.

[0152] Since the link shaft **58** is made in one piece, to be able to rigidly connect the rotational motion of the counterweight drums **15**, another type of sliding clutch for the return feeding mechanism must be used. The sliding clutch of the return feeding mechanism **25'** is in this case located between the larger gearwheels **27**, which concurs with the flanges **31** of the anchor drums **9**, and the through going link shaft **58**, at which the gearwheels are fixedly mounted. Instead of driving with the help of concurring gearwheels as shown in the figures, a belt-drive or chain-drive can for example be used.

[0153] The stay **13** includes in the designs in accordance with FIGS. **2***a*-**2***b* two from the buoy's **3** underside protruding stay parts, each of which includes a bearing **54** with a return blocking mechanism **53** for the driveshaft **11**, also compare FIGS. **5***a* and **5***b*. Such a design of the transmission unit **2** with an along the driveshaft centralized anchor drum **9** and on both sides of this arranged counterweight drums **15** with belonging gear **23** and generator **21**, gives a symmetrical weight load on the buoy and also a more symmetrical load due to currents in the water compared to the case where only one counterweight drum with belonging generator and counterweight **19** is used, which is connected to one end of the driveshaft **11**.

[0154] The transmission unit **2** with the anchor drum **9**, the driveshaft **11**, the counterweight drums **15**, the gear mechanisms **23** and the generators **21**, can as an alternative be carried in a machine body or in a driveshaft frame **141**, as shown in FIG. **2***g*. The machine body includes a surrounding frame shaped part **143** and a number of shaft stays **145**, which runs between the long, opposite sides of the frame part and which corresponds to the above described stays or stay parts **13**. The shafts of the transmission unit are journalled in bearings in the shaft stays. The number of shaft stays is dependent on different design alternatives. The frame **141** is secured to the buoy.

[0155] In the case where a planetary gear **35** is used, a somewhat different design is possible. A planetary gear is composed by a planet carrier **161**, at which a number of planet gears **163** are journalled in bearings in an orbit on the inside of a ring gear **165** and around a sun gear **167**, at which the planet gears are in gear wheel engagement, see FIG. **12***a*. When the planet carrier rotates and the outer wheel, the ring gear, is fixed, the planet holder drives the inner wheel, the sun gear, to rotate, which steps up the rotation speed? Alternatively the sun gear **167** can be driven by the rotation of the ring gear **165** while the planet holder **161** is held in a fixed position, which also steps up the rotation speed. As above, this can be utilized, so that the planetary gear **35** and the generator **21** e.g. is located inside the counterweight drum **15** and at first hand so that both the planetary gear's ring gear **165** and the generator **21"** are fixed to the counterweight drum, compare e.g. FIG. **2***b*.

[0156] Alternatively only the planetary gear **35** can be located inside the counterweight drum **15** with the ring gear **165** fixed with the counterweight drum. The generator stator **21"** is then instead fixed to the buoy **3** as with the frame **141**, see FIG. **2***g* and also FIG. **3***d*. The drive shaft **11** is journalled in bearings and can rotate freely both at the entrance and exit of the counterweight drum. The shaft load, which is given by the counterweight **19**, is taken up by the driveshaft, which is carried by the shaft stay **145** in the driveshaft frame **141**. The planetary gear **35** thereby gets a low shaft load. The system function remains the same but such a design can simplify the electrical connection and encapsulation of the generator **21** and also simplify the access at service and maintenance. The levy in mass can also be reduced, i.e. the total angular momentum, since the stator **21"** in this case doesn't need to be rotated, which can be of some significance. Also other types of gearboxes can be used in a similar way, at which e.g. the casing or the cover of the gearbox is fixed with the counterweight drum **15**. A planetary gear's ring gear in this case corresponds to the gearbox's house or casing.

[0157] The gear ratio in a planetary gear is given by the difference between the number of teeth on the planet gear and the sun gear. In FIG. **12***a* a planetary gear is shown with one gear steps but it is possible to build in additional gear steps. This can then be according to the principle that two or more planetary gears are coupled with the ring gears fixed to each other. Up to three steps are commonly used which gives relatively low transmission losses. Every step is usually chosen with a gear ratio between 5 and 10, which gives a gear ratio up to 300 with three steps. The higher power the wave energy converter **1** is dimensioned for, the larger diameter the anchor drum **9** needs to have, since the anchor line **7** requires a larger diameter at larger dimensions. An increased diameter of the anchor drum leads to lower rotation speed in relation to the vertical motion of the wave, which leads to that a wave energy converter with larger capacity require a higher gear ratio to achieve the correspondent rotation speed in the generator **21**.

[0158] In FIGS. **11***d* and **11***e* is in the same way as in FIGS. **11***b* and **11***c* schematically presented how the drive of the generator **21** can be achieved for a generator with a with the buoy **3** fixed stator.

[0159] The buoy **3** will at the wave motions apart from moving vertically also always change its angular orientation around a horizontal position, which is taken at a completely calm sea. The driveshaft **11** then rocks sideways all the time, which can get the anchor line **7** and the counterweight line/lines **17** to slide and rub against each other on the anchor drum **9** and the counterweight drum/drums **15**. A track guiding mechanism can then be used, which see to it that resp. lines are winded up in a regularly way. One possibility is to use helicoidal grooves **39**, **41**, **43**, **45** on the drums' **9**, **15** cylindrical winding up surfaces, see FIG. **3***c*. When two counterweight drums are utilized, the direction of their helicoidal grooves can be opposite, i.e. one of the helicoidal grooves **39**, **41** is right handed while the other helicoidal grooves **43**, **45** is left handed, to maintain a symmetrical load on the wave energy converter **1**, due to the motive force relating to the counterweights **19** and the anchor line **7**, to some extent. Helicoidal grooves according to **39**, **41**, **43** and **45** with a shape that follows the profile of the lines can also significantly increase the length of life of the lines since the contact surface between line resp. the wind up drum is increased.

[0160] If only one anchor line **7** is used, the point where this line affects the anchor drum **9** is moved along the axis, when the line is more or less is winded up and unwound. To achieve a more symmetrical load in the case with two counterweight drums **15** the anchor line **7'** can be in a loop, so that it runs from one side of the anchor drum at helicoidal groove **41**, down to the sea-floor foundation **5** and via a pulley **40**, which is journalled in bearing to the sea-floor foundation **5**, and back up again to the other side of the anchor drum via helicoidal groove **43**. The anchor line is then in both its ends more or less winded up on the anchor drum wind up surface in two segments with helicoidal grooves **41** and **43**, which have helicoidal grooves in opposite directions. It is also possible to divide the anchor line by a Y-coupling located a distance under the wave energy converter, see FIG. **15***a* and the description below.

[0161] As will be described below, two anchor drums **9***v*, **9***h* can be placed on either side of a centrally located counterweight drum **15**. Helicoidal grooves for resp. line **7**, **17** can then be arranged in a way corresponding to what is shown in FIG. **3***c*. The counterweight drum can then have two segments with helicoidal grooves with opposite directions, this is not shown.

[0162] As an alternative or a complement to the helicoidal grooves on the winding up drums **9**, **15** guide rollers **171** can be used to guide both counterweight lines **17** and the anchor line **7** around resp. wind up drum, see FIGS. **13***a*, **13***b* and **13***c*. The guide rollers are driven by threaded rods **173**, which are rotated in pace with the drums. The threaded rods for resp. counterweight drum **15** has screw-threads in the opposite direction as seen in FIG. **13***a*, so that the counterweight lines **17** is guided in opposite direction to each other, which is important for the centre of gravity of the wave energy converter to remain centralized.

[0163] Two threaded rods **171** are used for each winding up drum **9**, **15** and these two are rotated by a common teeth belt or chain **175**, which turns belt- or chain-wheels **177**. The guide ends of the guide rollers **171** are connected to end pieces **179**, through which the threaded rods passes and which guides the guide rollers along the threaded rods. The guided rollers are journalled in bearings at the end pieces and can rotate along with resp. line **7**, **17** to minimize friction and wear. The ends of the threaded rods **173** are journalled in bearings at the driveshaft stay **141**.

[0164] Yet another alternative to achieve safe wind up is to use trawl drums, not shown, as is known from the fishing industry.

[0165] To minimize the risk that the counterweights **19**, in the case where two counterweights are used, and their lines **17** tangled with each other the counterweights can be mechanically connected together by a suitable stiff mechanical structure, which holds them physically separated from each other. E.g. a counterweight frame **151** can be used, see FIGS. **3***e* and **3***f*. The counterweight frame can be shaped so that it does not rub against the anchor line **7** and also prevent entanglement with it, e.g. with a rectangular, quadratic or rhombic shape according to FIG. **3***f* or with the shape of a closed curve, such as a round curve, not shown.

[0166] The buoy **3** can generally have the shape of a plate, which can be oblong. Such an oblong plate can then in a convenient way be positioned, so that it mostly has its longer end towards the wave direction. The width of the buoy **3** can be adapted to the average wave length of the waves at the sea surface, so that the buoy has a larger width at larger medium wave length. Different methods can be used to stabilize the buoys' position in relation to the wave direction. The rotating motion of the water particles through the waves in combination with the traction force towards the centre above the foundation **5** can be utilized by introducing fins, see FIGS. **2***d* and **2***e*, on the buoy's **3** underside. Further the buoy's shape can be adapted. The driveshaft **11** can instead of being centralized under the buoy as shown in FIGS. **2***a* and **2***b*, in parallel with the plates length going direction, be a bit displaced in the direction towards the waves.

[0167] For the mounting of the transmission unit **2** inside the buoy **3**, as shown in FIGS. **2***c*, **2***d* and **2***e*, the buoy must have such a size, that it can hold the transmission unit. Seen from the side, in parallel with the driveshaft **11** the buoy can in this case have the shape in the form of an ellipse, i.e. generally an elliptic cylinder. It can have a relatively large section area against the water surface **6** at the same time as it can be pulled against the wave direction with less water resistance compared to a completely rectangular section area.

The buoy **3** can have one or more fins **4** in its back part, seen from the wave direction, which can contribute to steering the buoy straight against the wave direction.

[0168] The transmission unit **2** in this design can be mounted in the transmission unit space **20**, whereby the transmission unit in whole or partly can be made dry and thereby be protected against growth and corrosion and a simpler and cheaper sealing solutions can also be used, see FIGS. **2***c*, **2***d*, **2***e* and **2***f*. When the transmission unit space **20** is made dry, it also contributes with its buoyancy to the buoyancy of the buoy **3**. The transmission unit space can for this purpose at the top be sealed by a cover or a service hatch **121**, so that the transmission unit space constitutes an air pocket. To create and maintain the drainage of the transmission unit space **20** an air pump **123** can be used. The air pump can be driven by the link shaft **58**, e.g. through a belt **125**, and pump air into the transmission unit space which gets the water level to be pushed down, so that the transmission unit **2** is maid dry and the desired air pocket is achieved. The air pump can be mounted at one of the shaft frames **145**, at which the driveshaft **11** is journalled in bearings. The air pump **123** can alternatively be driven by an electrical motor, not shown.

[0169] When the wave energy converter is taken into operation, the service hatch **121** over the transmission unit **2** is closed and the water level in the transmission unit space **20** is pushed down by the air pressure, which the air pump **123** produces. The water level outside varies during the wave period correspondingly to the motive force between the sea floor foundation **5** and the wave and also the mass-moment of inertia in counterweight **19** and buoy **3**. At service first of all the anchor drum **9** is disconnected, then the pressure in the transmission unit space is leveled to the air-pressure outside, so that the water level rises, and thereafter the service hatch **121** can be opened and service be performed. With the right dimensioning and when the motive force from the foundation **5** is disconnected the water level can be leveled just below the driveshaft **11**, so that sealings and air pump **123** never gets under the water surface **6**.

[0170] At major service the complete driveshaft frame **141** with including components as shown in FIGS. **15***g*, **15***h* and **15***i*, can be lifted out and replaced with a replacement unit. The counterweight **19** can be hitched under the buoy **3** meanwhile the exchange is performed. Service of the wave energy converter's transmission, generator and electronics can then be performed ashore.

[0171] In the design with the transmission unit **2** and the driveshaft **11** placed centrally in the buoy **3** the buoy's angular modulation can be used more efficiently. The buoy does follow the water surface, which gives an angular modulation at troughs and wave crests. When the wave rises, the driveshaft **11** rotates and the shaft stays **145** are then disengaged, so that the buoy **3** can rotate backwards with the wave's waterline without affecting the drive. When the waves turns downwards, the driveshaft is locked against the shaft stays, which causes the driveshaft to turn forward in pace with that the buoy following the angular modulation of the wave. This in turn gets the counterweight drum **15** to rotate in forward direction and act to accumulate energy in the counterweight **19** in the same way as during the vertical motion in up going direction. The larger diameter the anchor drum **9** has, the lower input rotation speed the system gets in relation to vertical motion, while rotation speed from the angular modulation is the same irrespective of the anchor drum's diameter. The wave energy converter **1** can in this way be dimensioned with a larger anchor drum **9** to achieve an enhanced effect from the angle modulation in relation to the motive force from the vertical motion but must then also have a large enough width to withstand the in the same pace increased torque, which is transferred to the buoy **3** from the counterweight **19**, when the driveshaft **11** is locked against the shaft stays **145**.

[0172] The function of the wave energy converters **1** is with advantage controlled by a computerized control system, not shown, which especially controls the counterweight span level and compensates for varying accelerations and retardations to achieve as equalized power level as possible in relation to the current wave climate. The control system can also be used for controlling the torque transfer in the anchor drum's sliding clutch **55**, **55'** and the return feeding's sliding clutch **25**, **25'**, control of locking mechanisms, not shown, control hitching of counterweight **19** and sea-floor foundation **5** in the driveshaft frame **141** at transport and service, and also logging of system function and wave data. The control system is supplied with energy from a battery, not shown, which is continuously charged by the generator **21**.

[0173] The control system controls the counterweight span level and monitors the wave energy converters **1** functionality with the help of sensors, not shown, especially for rotation angles/speeds of the rotatable parts, the generator's **21** electrical power output and the buoy's **3** movements.

[0174] The control system can control the counterweight span level by analysing data from a sensor, not shown, that is mounted in the counterweight drum **15** and which continuously tells the system, at which angle it has in relation to the gravitational direction or the shaft stay **13**. The control system can thanks to this track the counterweight **19** position and turning points by calculating the number of revolutions of the counterweight and exactly where it turns. The turning points for each individual wave period are logged. An algorithm calculates if the counterweight span has a tendency to drift upwards or downwards by analysing the turning points during a time period. If the counterweight span is drifting upwards, the counterweight **19** can be lowered in a quicker pace, which leads to that a higher power output is generated from the generator **21** and vice versa. The length on the time period is decided from the accumulation capacity, i.e. the length of the counterweight line **17**. The higher capacity, the longer time period can be used in the calculation, which in turns gives smaller adjustments of the generator's power output.

[0175] Two sensors, not shown, measure the electrical power output and the rotation speed of the generator **21**. These values are recalculated by the control system to show the torque level over the generator. The control system use the torque value to compensate for the counterweight's **19** g-force, which varies due to the mass-moment of inertia and affection by the acceleration force and water resistance, which arises due to the buoy's **3** motions in combination with variations of the driveshaft's **11** rotation speed. At a trough, the counterweight **19** is accelerated in a direction away from the gravitational direction, which gives an increased g-force, and at a crest the counterweight is acceleration a direction back to the gravitational direction, which gives a lower g-force. By regulating the counterweight's velocity of fall in accordance with the varying torque, which loads the generator **21**, the power level can be stabilized.

[0176] As given from the discussion, for the counterweight's **19** turning points not to drift to the end positions of the counterweight, the counterweight's velocity of fall, i.e. the medium rotation speed of the counterweight drum **15**, must be balanced against the driveshaft's **11** rotation speed. When the medium turning point is moved downwards, the counterweight's velocity of fall must be reduced, which leads to a reduced power output from the generator **21** and vice versa. By regulating the counterweight's velocity of fall and thereby the counterweight span level the power output from the generator can be kept as even as possible in relation to mean energy level in the current wave climate.

[0177] Regulation of the counterweight span level can be achieved in different ways. Regulation of the electrical load on the generator is likely the simplest and most cost efficient but there are also other possibilities as described below.

[0178] The mechanical resistance in the generator **21** depends on the electrical load, which is laid over the generator's poles. When the electrical load is increased, the electromagnetic coupling over the air gap **21"** in the generator is increased and thereby the mechanical resistance in the generator, which gets the counterweight **19** to fall slower, since the state of equilibrium between the generator and the counterweight is moved to a lower rotation speed and vice versa, se the regulation rule, which is shown in the diagram in FIG. **16***a*. Since the generator's power is a product of the rotation speed and the torque, the power level becomes even, meanwhile the rotation speed varies in the opposite direction to the g-force and the input torque. This works due to that the top rotation speed in a generator in general is higher than the nominal rotation speed. The generator should manage a top rotation speed that is at least 50% higher than the nominal.

[0179] At a constant electrical load a state of equilibrium becomes present, i.e. the rotation speed of the generator **21** becomes present, which gives an equally high mechanical resistance in the generator as the motive force given by the counterweight **19**, as earlier described. By regulating the generator's ingoing mechanical torque the state of equilibrium is displaced and thereby the rotation speed, at which the state of equilibrium becomes present. The input torque can be adjusted with a gear box with a so called variable gear ratio **37**, CVT ("Continuous Variable Transmission"), which can constitute or be included in the gear **23**. A lower gear ratio gives a higher torque and a lower rotation speed, which in turn balance each other out, but a higher torque also makes the state of equilibrium, between the generator **21** and the counterweight **19**, to take place at a higher rotation speed, which increases the counterweight's velocity of fall, and vice versa, compare with the regulation rule, which is shown in diagram **16***b*. One type of CVT is CVET ("Continuous Variable Electronic Transmission") with input-output shafts aligned, as schematically shown in FIGS. **12***c*, **12***d*. These figures are only symbolic, since the manufacturer does not want to reveal details regarding its mechanical design. Variable transmission gear boxes usually only manage limited torques and a relatively low maximum gear ratio. To minimize the ingoing torque and increase the gear ratio a planetary gear **35** can be coupled in before the variable transmission, as shown in FIG. **12***c*.

[0180] The return feeding's sliding clutch **25**, **25'** between the counterweight drum **15** and the anchor drum **9**, which according to above can be used for keeping the anchor line **7** tensed, can at the same time be used for reducing the torque given by the counterweight **19**, which displaces the generator's **21** and the counterweight's **19** state of equilibrium in the same way as a variable gear does, see the regulation rule shown in diagram in FIG. **16***c* and also compare with the diagram in FIG. **16***b*. Full power of the generator and full speed of the counterweight is reached, when the return feeding mechanism's sliding clutch **25**, **25'** is completely disengaged, so that the full torque from the counterweight loads the generator. When the medium wave height sinks, the torque in the return feeding's sliding clutch increases, which lowers the torque over the generator **21** and hereby the counterweight's velocity of fall is reduced. As sliding clutch e.g. a magnetic particle clutch can be used, which gives low heat losses at low rotation speeds. The torque can be regulated very precisely with the help of the level of a feeding current, so that the higher the current the higher the transferred torque becomes and thereby also the higher break action.

[0181] By using a cone shaped counterweight drum, not shown, the radius for the counterweight line **17** point of contact around the counterweight drum can be increased the higher the counterweight **19** is winded up. The radius and thereby the torque increases the higher the counterweight is hoisted up and thereby makes the generator **21** to rotate faster. In this way, the counterweight's **19** velocity of fall and the generator's power output increases with an increased medium wave height. This principle for regulation of the counterweight's span is self-regulating and hence does not need to be regulated by a control system as the other methods, but lacks the ability to compensate for variations in the counterweight's g-force or the force with which the counterweight affects the drive package, i.e. mainly the motive force in the counterweight line.

[0182] It is possible to design a wave energy converter **1** for automatic installation. The starting position is then, that the sea-floor foundation **5** and the counterweight **19** is hitched at the stay's **13** parts or at the frame **141** with corresponding lines **7**, **17** completely winded up. The wave energy converter is connected to the electrical distribution network and the control system is started. The disengagement mechanism for the return blocking mechanism of the anchor drum is put in locked position according to a control signal from the control system, so that the anchor drum **7**, cannot be disconnected, despite that the counterweight/-s are in their top positions. In the shown designs this means that the sliding clutch **55** mounted around the return blocking mechanism of the anchor drum **51** is put on maximum force- or torque transfer, which is enough to carry the entire weight of the sea-floor foundation. The sliding clutch **25** of the return feeding mechanism can be disengaged.

[0183] Then the control system loosens the hitches, not shown, that holds the counterweight **19** and the sea-floor foundation **5**, whereby the sea-floor foundation starts to fall towards the bottom **8** of the sea-floor. The anchor drum's line **7** is then unwound and the driveshaft **11** starts to rotate and drive the generator/generators **21**. The control system regulates for maximum power and thereby the sea-floor foundation's **5** velocity of fall is slowed down as much as possible, by the electrical power that is produced. Further on the buoy **3** is preferably equipped with an echo-sounder, not shown, that measures the water depth on the site, where the installation takes place. The anchor drum **9** is equipped with the same type of sensor, not shown, as is mounted on the counterweight drum/-drums **15** and the control system can in this way measure how much of the corresponding anchor line **7** that is unwound from the anchor drum. The control system can with help of these values calculate when the sea-floor foundation **5** starts to approach the bottom **8**. To reduce the force of impact the sea-floor foundation's velocity of fall is slowed down by means of the return feeding sliding clutch **25**. When the sea-floor foundation **5** reaches the bottom **8**, the driveshaft **11** stops to rotate and the counterweight/-counterweights **19** instead starts to fall and continues to drive the generator/-generators **21**. The disengagement mechanism for the anchor drum's **9** rotation in relation to the driveshaft is activated, so that the anchor drum can rotate in one direction in relation to the driveshaft. In the shown design this means, that the sliding clutch **55** in the anchor drum is put in normal mode, which means that the by the sliding clutch transferred force is reduced so that the force is not enough to lift the sea-floor foundation **5**. The control system is thereby put into operation mode.

[0184] The outer electrical connection of the generator **21** can be achieved without the use of slip rings, brushes and similar, even when the generator stator" **21** is mounted inside counterweight drum **15**. The generator stator **21"** includes, in a conventional way, electrical windings, in which electrical power is induced at rotation and which are connected to an electrical cable **41**, which is partly winded up on the counterweight drum in parallel with the counterweight line **17**, see FIG. **4**, but closer to the anchor drum **9**. The electrical cable extends from the counterweight drum **15** down to a movable connector **43**, which can move along the anchor line **7**. At the connector the electrical cable **41** is connected to yet another electrical cable **45**, which e.g. extends to a special connector buoy **45**. Hereby the wave energy converter **1** can manage to rotate, when the waves change direction, without lines and cables getting entangled with each other.

[0185] Since the first electrical cable **41** is winded up on the same drum as the counterweight **19**, the connector **43** to will slide along the anchor line **15** with mainly always the same distance below the counterweight. Hereby it can be avoided that the counterweight and the electrical cables **41**, **45** comes to close to each other.

[0186] At an alternative way for energy accumulation the energy can be absorbed as a gas pressure in one or more tanks. Such a wave energy converter **1** is schematically shown in FIG. **9***a*. Here the anchor drum **9** only needs to be connected to the driveshaft **11** via a return blocking mechanism **53**, compare the return blocking mechanism in the shaft stay **13** in FIGS. **5***a* and **5***b*. Any stays are not required, the driveshaft can instead be journalled in bearings directly in the generator housing or the generator casing **71**, which replaces the counterweight drum **15** and which in this case can enclose a fixed gear mechanism such as a planetary gear **35**, generator **21** and a compressor/gas pump **73**. The casing is fixed to the buoy **3**, such as to its underside as shown in the figure or also centralized in the buoy, if a transmission unit space **20** according to above is used for mounting of the transmission unit **2**. From the compressor/gas pump **73** a gas pipe **75** runs to the gas tanks **77**, preferably located at or in the buoy. The gas tanks are also coupled to an over pressure valve **79** and a pneumatic motor **81**. At this motor's outgoing shaft **85**, gearwheel **87** is located, which acts together with teeth on the anchor drum's **9** flange **31**.

[0187] The compressor/gas pump **73** can be a so called scroll pump and it then has a movable part **89**, which is fixedly connected with the generator **21** stator **21"**, and one to the housing **71** fixed part **91**. The driveshaft's return blocking mechanism **53** here acts against the housing.

[0188] When the driveshaft **11** is turned by the rising buoy **3** in this design, a gas pressure is built up, by the scroll pump **73**, in the gas tanks **77**. This gas pressure corresponds to accumulated energy. In pace with the increasing gas pressure, the counteracting force against the driveshaft rotation also increases. Higher waves, that give rise to a quicker medium rotation speed of the driveshaft **11**, thus build up a higher gas pressure and which thereby gives a higher counteracting torque between the generator rotor **21'** and stator". The control system hence does not need to actively control and optimize the operation since the equalization occurs through inertia in the pneumatic pressure. Since the energy accumulation take place by a pneumatic pressure being built up, the overpressure valve **79** can possibly be used instead of the sliding clutch **53** between the anchor drum **9** and the driveshaft **11**. The sliding clutch though has an advantage by that it protects against thrust strains. When the anchor drum **9** does not turn by its coupling to the anchor line **7**, as when the buoy **3** is sinking, it instead turns backwards to stretch the anchor line by that the pneumatic motor **81** rotates and drives the gearwheel **87**, which acts on the flange **31** of the anchor drum.

[0189] Even with the use of gas return pressure it is possible to let the generator stator **21"** be fixed to the buoy **3** and instead connect the compressor **73** to the planetary gears **35** ring gear **165**, see FIG. **9***b*. In this case is the generator's stator is fixed to the generator housing **71**. The generator chassis **91** is also fixed to the generator housing, meanwhile the compressor's **73** gear **95** on its driveshaft **93** is connected to the planetary gear's ring gear, either directly as is shown or via a teeth belt/chain. The ring gear rotates freely around the ingoing driveshaft **11**.

[0190] This design of the transmission unit **2** can have the following advantages:

[0191] No sling clutches are required in the anchor drum **9** or in the return feeding mechanism.

[0192] No counterweights are required and thereby there is no g-force and no counterweight span that must be regulated, since the higher wave, the higher gas pressure and torque over the generator **21**.

[0193] Possible problems with counterweights and lines, outer electrical cables, effect of accelerations, centre of gravity etc. can come down completely or be reduced.

[0194] The case that no counterweight is used gives lower movable weight and thereby the sea-floor foundation **5** can also be made smaller, i.e. with smaller mass. The buoy's **3** lifting force can also be reduced with as much.

[0195] Manage shallower installation depth

[0196] Only the anchor drum needs to be exposed to the ocean water meanwhile other components can be encapsulated.

[0197] The housing for the gear mechanism and the generator can be made with smaller diameter than the one in the earlier described design used counterweight drum.

[0198] The same type of transmission unit **2** as have been described above can be used in other designs of the wave energy converter as becomes evident from FIGS. **7***a*, **7***b* and **7***c*. Instead of the sea-floor foundation there are here sea-floor fastening devices **61**, **63** fastened to the sea-floor. **8**. These sea-floor fastening devices are shaped like frames or pillars, which reach upwards from the sea-floor, and the driveshaft **11** in the transmission unit is journalled in bearings in the frames or at the pillars. In FIGS. **7***a* and **7***b* two vertical pillars are used, which are located completely beneath the water surface **6** and stretches up from the sea-floor, and the driveshaft **11** in the transmission unit is journalled in bearings to these pillars. In the designs according to FIGS. **7***a* and **7***b* the anchor line **7** is fixed to the buoy. In FIG. **7***b* the transmission unit is mounted so close to the bottom of the pool of water that the counterweights are instead shaped like floating bodies **19'**. The frame according to FIG. **7***c* includes two vertical pillars, which reaches upwards from the bottom **8** over the water surface **6** at the side of the buoy **3**. The pillars are at the top connected by a horizontal beam **64**, which is located above the buoy and from which stay parts similar to the stay **13** above protrudes downwards. The driveshaft **11** in the transmission unit is journalled in bearings in these stay parts. It can be especially observed, that at the design according to FIG. **7***c*, energy is absorbed from the waves only when the water surface **6** and the buoy **3** sinks in contrary to the other designs, where energy is only absorbed from the waves, when the water surface and the buoy rises. Hereby the buoy must be given a weight that is greater than the counterweight's **19** and be given enough volume/buoyancy, so that it shall still be able to stay afloat at the water surface **6**. This is shown in FIG. **7***c* by that the buoy **3** is fixed with a ballast **5"**. In this design the counterweight **19** line **17** is winded up around the counterweight drum **15**, when the wave sinks, which significantly reduces the motion span and variation in g-force. With the right dimensioning and with periodical waves the counterweight can in principle be held still. It is also possible to keep the counterweight above the water surface **6**, which gives a higher motive force in relation to the counterweight's mass. This design is especially suited for places, where there are already foundations, e.g. at wind power plants, where the counterweight and its line **17** can run inside the mast, or at oil platforms.

[0199] An alternative design of a wave energy converter **1** with a transmission unit **215** according to FIG. **15***a* with a centrally, between two anchor drums **9***v*, **9***h* located counterweight drum **15** is shown in FIG. **7***d*. In this variant the driveshaft **11** is driven by a weight or load **211**, which hangs beneath the buoy **3** in an elastic organ **213**, which for example can include springs or air springs. At the weight the anchor lines are also fixed. The weight **211** can have a considerable mass compared to the buoy **3** or generally in relation to other parts of the wave energy converter. The forward drive of the driveshaft occurs through joint action between the buoy **3** and the weight **211**. When the buoy after having passed a wave crest sinks, the buoy also moves downwards. Then when the buoy slows down and turn in the next trough, the weight **211** continues due to its inertia to first move downwards, which stretches and prolongs the elastic organ **213** and unwinds the anchor lines **17** so that the anchor drums **9***v* and **9***h* is rotated and in turn drives the driveshaft to rotate. When the elastic organs are prolonged, their traction force on the weight **211** increases, so that its ongoing motion downwards is gradually stopped. Thereafter the force from the elastic organs becomes so great, that the weight will move upwards. This consequently occurs at the buoy's **3** rising movement. When the buoy **3** then slows down again to turn in the next crest, the weight continues to move upwards due to its mass-moment of inertia. The elastic organs **213** are then pulled together and thereby their traction force on the weight **211** is reduces, so that it is no longer balanced by the gravity force, which affects the weight. At the same time the anchor drums **9** can be returned and tense the anchor lines **7** for the next drive of the driveshaft **11**. The weight is then gradually slowed down to a stop and after that again starts to move downwards.

[0200] The counterweight **7** runs through a through going hole in the weight **211** down to the counterweight **19**, which moves with a phase shift to the wave motion, which can reduce its vertical motion and reduce the size of its accelerations and retardations at the wave motion, so that the torque, which loads the generator **21**, becomes a bit more even, which thereby requires less regulation of the rotation speed. Such a design can e.g. be advantageous at large water depths, where it can be difficult to use an anchor line **7** fixed at the bottom **8** for driving of the driveshaft.

[0201] In one design, in which the wave energy converter is mounted in a wind power plant, it is possible to integrate the transmission from the turbine blades with the drive from the waves, so that the same gearbox and generator can be used, see FIGS. **8***a*, **8***b* and **8***c*. The transmission can closest be compared to the one shown in FIGS. **15***a*, **15***b* and **15***e*, which shall be described below. The transmission model with a fixed stator according to FIG. **15***f* can also be used in a similar way but this is not described further here. The main difference is the mounting of the planetary gear **25** in relation to the generator's stator. The function in the planetary gear is in this design to combine the drive from the wind- and wave motions, by letting the wind power plant's rotor rotate the planet gear carrier **161**, while the buoy **3** with ballast **5"** drives the ring gear **165** of the planetary gear, see also FIGS. **12***a* and **12***b*. In this way, the rotation and torque, which are obtained from the wind-resp. wave motions, can be added to each other and together drive the sun gear **167**. Neither planet carrier nor ring gear is allowed to rotate backwards, which for the planet carrier is achieved by the back locking mechanism **53** in the shaft stay **13** and for the ring gear by slipper clutch **201**, which has a function similar to a back locking mechanism. The slipper clutch **201** has the equivalent function as the anchor drum's slipper clutch, see FIG. **5***b* and descriptions thereof, but is in this design located between shaft stay **13** and planetary gear **35**, which makes it possible to limit the torque and energy absorption for both wind- and wave motions with one and the same slipper clutch.

[0202] The generator **21** is mounted alone in the counterweight drum **15** with connected counterweight **19**, which gives the same equalization capabilities as is described for the other designs. The return feeding of the anchor drums is also done in the same way from the counterweight drum **15** via ring gear **29** and tooth band/chain **175** to the link shaft **58**, which in turn is coupled in the corresponding way to the anchor drums **9***v* and **9***h*. The diameter of the anchor drums **9***v* and **9***h* in combination with the buoy **3** and the weight of the ballast **5"**, determines the torque which is put over the ring gear **165** of the planetary gear, and which rotation speed the ring gear gets. These parameters are chosen to match the torque from the wind turbine and the generator's size. As long as the torque, which is obtained from the drive of wind and wave, is higher than the counteracting torque, which is given by the counterweight **19**, energy can be accumulated in the counterweight **19** from both wind- and wave motions. Since the torque from the wind power plant's rotor **204** varies dependently on the wind-force while the torque from the wave drive is constant, it may be necessary to mount a variable transmission gearbox before the planetary gear in the same way as shown in FIG. **12***e*, but the variable transmission gearbox in this design adjusts the torque from the wind drive to the wave drive after the current wind-force. To prevent the tower **207** of the wind power plant to be damaged by the buoy **3**, some kind of sledge mechanism is used, not shown, which guides the buoy along the tower of the wind power plant. Breaking gearboxes is a big problem for today's wind power plants. The transmission of the wave energy converter can also be used in a wind power plant without wave drive to utilize its capabilities to limit the torque and energy absorption. In this case the same type of transmission design as described in FIG. **3***d* can be used but without the anchor drum **9**. The wind power plant's rotor is directly connected to the driveshaft **11**, as shown in FIGS. **8***d* and **8***e*. The counterweight can run inside of the wind power plant's tower **207**. When used in a wind power plant, gas return pressure can also be used instead of a counterweight as shown in FIG. **8***f*. This transmission design is described in more detail in connection to FIG. **9***b*. The counterweight can then be left out and its mass-moment of inertia will then not have any effect, which can be of an advantage.

[0203] In the designs described above, the electromagnetic coupling between the generator's **21** rotor and stator is utilized in most cases, while in other cases an in a special way designed transmission is used for achieving a continuous drive of the generator. Energy accumulation and return feeding can be done in different ways. In general, a wave energy converter **1** can include components as will be seen in FIG. **10***a*. An anchor drum **9** included in a transmission unit **2** is in a suitable way mechanically coupled to both a buoy **3** and to an object **8'**, which can be considered to have a more fixed position than the buoy and which can be constituted by the bottom, e.g. a bottom fastening device **5'**, also see FIG. **10***b*, at which at least one of these two mechanical couplings **7"**, **7'"** includes an oblong organ, such as a flexible organ, typically a line or a wire, but also a stiff shaft can be used in special cases. The anchor drum can be located in a suitable way in relation to the buoy such as under, inside or above. It can rotate in two directions as shown by arrows **101**, **102**. The anchor drum **9** drives a driveshaft **11** at its rotation in one direction, which can then only rotate in one direction, shown by the arrow **103**. The driveshaft is mechanically coupled to the generator **21**, whereby the coupling is symbolically shown at **23'**. The coupling and/or the generator is set up in a way that a part of the rotational energy is accumulated in an energy accumulation device **105** at the rotation of the driveshaft **11**. When the driveshaft is not able to turn the generator, the energy accumulation device drives the generator instead. The energy stored in the energy accumulation device can also be used for returning the anchor drum **9** and for this purpose the energy accumulation device can be coupled to the return feeding mechanism **107**.

[0204] In the case which utilizes the electromagnetic coupling between the generator's **21** two, in relation to each other rotatable parts, the driveshaft **11** is mechanically coupled to the first part **21'** by means of the coupling **23'**, for driving this part to rotate in the direction shown by the arrow **23**, at which the electromagnetic coupling between the generator's parts gives a torque corresponding to the driveshaft's rotation and also gets the other part **21"** to rotate in the same direction, se FIG. **10***b*. The generator's second part **21"** is in some way coupled, so that it at the rotational motion, because of the driveshaft's rotation, accumulates a part of the rotational energy in the energy accumulation device **105**. When the rotation speed of the driveshaft is low, where it no longer is capable of turning the generators second part, the energy accumulation device instead drives the generators second part to rotate in the opposite direction as before.

[0205] In the designs described above, two generators **21** are used. However, since the generator with belonging power electronics and gearbox, if any, is a relatively costly part of the wave energy converter **1**, designs with only one generator can be more cost efficient. Below shall possible designs with only one generator be described.

[0206] In a first design with two counterweights **19** and one to the buoy **3** fixed stator of the generator **21**, see FIG. **14**, there is also, as shown in e.g. FIG. **26**, a return feeding or link shaft **58**. The link shaft couples the movement of the two counterweight drums together, so that the motive force from the right counterweight drum **15***h* is transferred to the left counterweight drum **15***v*. The left counterweight drum includes a planetary gear **35**, which steps up the rotation speed of the generator, and also limits the torque by means of the ring gear's coupling to the left counterweight drum and the counterweight **19**. The location of the wind up drums are moreover the same as in the above described designs and therefore, the buoy **3** in a wave energy converter designed in this way, gets about the same stability or positioning towards the wave as in the design with two generators. The generator **21** can be mounted in a separate generator housing **181** with the generator's stator **21"** fixed to the buoy, as shown in the figure, or alternatively in or at the left counterweight drum **15***v*.

[0207] As shown, the link shaft **58** can be placed in front of the driveshaft **11** seen in the wave direction. This gives a better spacing when drifting away from the sea floor foundation **5**. The drifting brings the anchor lines **7**, which cannot be allowed to come into contact with the driveshaft frame **141**, to stretch out in a direction in relation to the counterweight line in a slanting angle. Alternatively, the link shaft **58** can be placed above the driveshaft **11**, either in a slanting position or straight above.

[0208] Further on it is possible to design the transmission unit **2**, so that only one counterweight **19** is used without the wave energy converter loosing stability or positioning towards the wave direction. Instead such a design can, see FIG. **15***a* for a front view and **15***b* for a side view, enhance the positioning in relation to the wave direction. The anchor line **7** is divided in a Y-coupling **191** into two sub lines and these are led to be winded up around one anchor drum **9***v*, **9***h* each, which are positioned on each side of the single counter weight drum **15'**. Guide rollers **193**, corresponding to the ones described for FIGS. **13***a*, **13***b* and **13***c*, diverts the sub lines, so that they are winded up correctly on the anchor drums. The counterweight **19** runs free despite that the anchor lines joins in a Y-coupling, since the point at the counterweight drum and anchor drum where the resp. line is winded up is on the opposite side of the driveshaft **11**. The driftage from the foundation **5** also gives an angle for the anchor line **7**, **7'**, which gives extra margins. For further safety margins the Y-coupling **191** can be placed below the lowest possible position of the counterweight **19**, not shown.

[0209] In FIGS. **15***c* and **15***d* an alternative of a straight wind up of the divided anchor lines **7'** around the anchor drum **9***v* and **9***h* is shown. A rod **221** holds the lines on a distance from each other and is placed just above the Y-coupling **191**. To decrease the risk of collision between sub anchor lines **7'** and the counterweight **19**, the rod **221** can be placed below the lowest possible position of the counterweight. One advantage with this alternative is that the part of the anchor line **7**, which connects the rod **221** with the sea-floor foundation **5**, can be more or less stiff and e.g. be designed as a ground cable or chain, while the sub anchor lines **7'** can be more flexible for wind up around the anchor drums **9***v* and **9***h*. Further on the rod **221** can be designed to carry the load of itself and the undivided anchor line **7**, which then leads to that a lower force is required for driving the return feeding, not shown in these figures.

[0210] In FIG. **15***e* the transmission unit in a wave energy converter is shown according to FIGS. **15***a* and **15***b* seen from below and with more details. The driveshaft **11** is here fixed only one of the anchor drums, e.g. as shown with the left **15***v*. The left anchor drum **9***v*, the driveshaft and the one and only anchor drum **15'** has the same function and structure as in earlier described designs, in which the generator **21** is build-in to the counterweight drum. The second anchor drum, the right drum **9***h*, is journalled in bearings so that it can rotate freely but its motive force is transferred to the left anchor drum **9***v* by means of a link shaft **58**. The link shaft can be coupled via thereon mounted chain- or gear-wheels **203** to the anchor drums by means of chains or tooth bands **205**, which also runs over the toothed flanges **31**. Alternatively the gear-wheels **203** can be directly connected to the anchor drums' flanges, in the same way as shown in FIG. **2***f*. The return feeding of the anchor drums is done in the corresponding way as earlier but the slipper clutch **25"** is in this case coupled to the counterweight drum **15'**.

[0211] In FIG. **15***f* an alternative to the transmission unit according to FIG. **15***e* is shown. According to FIG. **15***f* the generator's stator **21"** is fixed to the buoy **3** in a corresponding way as shown in FIG. **2***g*. The generator casing **71** is placed on one side of the single, centrally placed counterweight drum **15'**, which results in that the transmission unit **2** must be made wider. The anchor drums **9***v*, **9***h* must be placed with an equal distance from the counterweight drum for the traction force by the counterweight **19** and the foundation **5** via the counterweight lines **7'** shall remain centred in the wave energy converter. This leads to that more stay parts or shaft stays **13**, **145** are required to carry the parts of the transmission units. It is possible to use the same design of the anchor drums as described above for FIG. **15***e*. However, in this case it can be motivated to simplify the left anchor drum **9***v* by using an displaced or free lying slipper clutch **55'** and use the extra space in the transmission casing space **20** for the transmission unit **2**, so that the left anchor drum **9***v* can be fixed to the driveshaft's first part **11'** in the same way as earlier described for FIG. **5***c* while the driveshaft's second part **11"** on the other side of the slipper clutch comprises or is directly connected to the ingoing shaft to the gear **23** and the counterweight **15'** rotates around this second part.

[0212] In FIGS. **15***g* and **15***h* an alternative transmission unit according to FIG. **15***f* is shown, in which the mechanics is to a larger extent encapsulated. The power transmission between driveshaft **11'**, **11"** and the link shaft **58** can in this design preferably be done via gearwheels **209**. A high gear ratio as shown in the figure is used for increasing the rotation speed of the link shaft and decreasing the torque which gives less wear and smaller dimensions of the power transmission. In this design only the drums **9***v*, **9***h*, **15'** are exposed to the sea water in the transmission housing **20**. The generator **21** with all belonging power electronics and the link shaft **58** including the power transmission are encapsulated in a climate controlled environment **195**. The return feeding **26** has in this design been placed on the high speed side of the gear **35**, but could also be placed on the low speed side. One advantage with placing the return feeding **26** on the high speed side is that the space will be used more efficiently since it requires a higher gear ratio in the return feeding compared to the link shafts power transmission **210**. A high speed rotation in the slipper clutch gives higher transmission losses though.

[0213] In FIG. **15***i* an alternative to return feeding, which is described in relation to FIG. **15***g* is shown. Here an electric motor **223** is used instead, which is directly connected to any of the gearwheels **209** on the link shaft **58**. The electric motor gets power from the battery, not shown, which drives the control system and other electronics, not shown. The electric motor is controlled by the control system which in that way can optimize the return feeding. It is also possible to drive the return feeding by means of a spring mechanism, such as e.g. a coiled spring or a constant power spring, not shown.

[0214] A wave energy converter has here been described which can have one or more of the following advantages:

[0215] The counterweight drum/drums limit the maximum resistance in the system and give a sharp limit for the torque acting over the generators.

[0216] The energy accumulation is very simple and efficient and can store energy over long time intervals at the same time as the motive force can be held constant in relation to the average wave height during the time interval.

[0217] The wave energy converter can be dimensioned to utilize the depth on the installation site in an optimal way for the accumulation and for decreasing the weight of the counterweight.

[0218] The storage of energy is stopped automatically when "the accumulator is full" and this can be achieved without the generator losing power.

[0219] The scalability is very good and the wave energy converter can be dimensioned to reach maximum capacity at a selected wave height to get a better utilization factor of the generator.

[0220] It is not necessary to over dimension the whole system to be able to handle absorption of energy at rare occasions when the mean wave height is considerably higher than normal.

[0221] The buoy continuously follows the wave motions independently of how large the waves are. The force limitation in the anchor drum efficiently protects the device from thrusts and overloads.

[0222] The motive force is constant in relation to the gear ratio which enables the use of all types of generators, incl. synchronous AC generators, which are working with constant or variable rotation speed.

[0223] Minimal manual efforts at installation, short course of installation which generators electricity already when the foundation is being lowered down.

[0224] Mainly simple and durable construction.

[0225] Very high utilization factor of the generator and transmission.

[0226] Long service intervals.

[0227] While specific embodiments of the invention have been illustrated and described herein, it is realized that numerous other embodiments may be envisaged and that numerous additional advantages, modifications and changes will readily occur to those skilled in the art without departing from the spirit and scope of the invention. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within a true spirit and scope of the invention. Numerous other embodiments may be envisaged without departing from the spirit and scope of the invention.

1. A wave energy plant comprising:

a buoy or other device arranged at or in a pool of water to be put into motion by motions of the water in the pool of water,

a driveshaft, which is rotatably journalled in bearings to the buoy resp. the other device or to a device arranged to give a counteracting force against the motions of the water in the pool of water,

a first oblong organ, which in one end is coupled to a device arranged to give a counteracting force against the motions of the water in the pool of water resp. to the buoy and in the other end is coupled to the driveshaft,

an electric generator, which is coupled to the driveshaft and includes two in relation to each other rotatable parts, a first part and a second part, and

an energy accumulation device, at which the buoy or the other device is placed and the buoy or the other device, the first oblong organ, the device arranged to give a counterforce against the wave motions, the driveshaft and the energy accumulation device are coupled together, so that the coupling between the first oblong organ and the driveshaft gets the driveshaft to mainly at the first motions in the buoy or the other device, rotate in a unidirectional direction and thereby drive the electric generator's two mentioned parts to rotate in relation to each other in a first rotational direction and generate electric current and thereby also supply the energy accumulation device with energy, characterized in that wherein the energy accumulation device is arranged to mainly at the second motions, which are mainly separated from the first motions, in the buoy or the other device, drive the electric generator's mentioned two parts to rotate in the same first rotational direction in relation to each other and thereby to generate electric current with the same polarity as when the driveshaft drives the electric generator's two mentioned parts to rotate in relation to each other.

2. A wave energy plant according to claim **1**, comprising a buoy, which is arranged to alternately rise and sink and/or to alternately rock back and forth at the up and down motions of the water surface, and the buoy, at which the first motions in the water surface includes either one of the up- and downgoing motions of the water surface.

3. A wave energy plant according to claim **1**, wherein

the driveshaft is mechanically coupled with the generator's first part, at which an electromagnetic coupling exists over an air gap between the electric generator's first and second parts at least during these parts relative movements, and

the energy accumulation device is mechanically coupled to the second part of the electric generator.

4. A wave energy plant according to claim **3**, wherein the coupling of the energy accumulation device to the driveshaft via the electric generator's second part and the electric generator's first part and the air gap between them gives a counteracting motive force, which counteracts the rotation of the driveshaft, when the driveshaft through the coupling between the first oblong organ and the driveshaft rotates and drives the electric generator's first part,

so that the electric generator's second part rotates in a first rotational direction through the coupling to the driveshaft via the electromagnetic coupling over the air gap and the electric generator's first part, when the motive force which acts on the driveshaft through the coupling between the first oblong organ and the driveshaft, exceeds the counteracting motive force at which the energy accumulation device through its mechanical coupling to the electric generator's second part accumulates energy, at which the electric generator's first and second parts at the same time rotates in the same first rotational direction in relation to each other, and

so that the electric generator's second part is driven by the energy accumulation device to rotate mainly in the same first rotational direction, when the motive force, which acts on the driveshaft through the coupling between the first oblong organ and the driveshaft, do not exceed the counteracting motive force, at which the electric generator's first- and second parts is made to continue to rotate in the same first rotational direction in relation to each other.

5. A wave energy plant according to claim **1**, comprising:

a mechanical gear coupled between the driveshaft and the electric generator's first part, at which the driveshaft is coupled to the ingoing side of the mechanical gear and the electric generator's first part is coupled to a first outgoing side of the mechanical gear, at which

an electromagnetic coupling exists over an air gap between the electric generator's first part and second part at least during their relative movements,

the electric generators second part is fixed to the buoy, and

the energy accumulation device is mechanically coupled to a second, from the first separated, outgoing side of the mechanical gear.

6. A wave energy plant according to claim **5**, wherein the mechanical gear's ingoing side includes an ingoing shaft and one outgoing side of the mechanical gear includes an outgoing shaft and one other outgoing side includes a housing or casing for the mechanical gear.

7. A wave energy plant according to claim **1**, comprising an anchor drum, which is journalled in bearings for rotation in a unidirectional rotation around the driveshaft and is coupled to the first oblong organ to bring the anchor drum to rotate with the mentioned first motion of the buoy or the other device and thereby also bring the driveshaft to rotate.

8. A wave energy plant according to claim **7**, wherein the first oblong organ is a flexible organ, a line, wire or chain in particular, which in one end is more or less winded up on an anchor drum, and that a mechanism exists for at the mentioned second of the buoy's or the other device's motions, rotate the anchor drum so that the flexible organ is kept in a stretched state.

9. A wave energy plant according to claim **7**, wherein the bearing for a unidirectional rotation of the anchor drum around the driveshaft, which enables the anchor drum during rotation in the opposite direction to drive the driveshaft to rotate in the opposite direction, includes a coupling for limitation or disengagement of the motive force, with which the anchor drum hereby acts on the driveshaft.

10. A wave energy plant according to claim **1**, wherein the driveshaft is journalled in bearings at a buoy and that the first oblong organ in one end is coupled to a point which counteracts to the buoy's motions, especially to a fixed point like at the bottom of the pool of water or to a fixed of fastened device at the bottom of the pool of water.

11. A wave energy plant according to claim **1**, wherein the driveshaft is rotatably journalled in bearings to one at the pool of water fixed device and that the first oblong organ in one end is coupled to a buoy.

12. A wave energy plant according to claim **11**, wherein the driveshaft is placed below the water surface and that the energy accumulation device includes at least one floating body.

13. A wave energy plant according to claim **1**, wherein the driveshaft is rotatably journalled in bearings to the buoy and that the first oblong organ in one end is coupled with a weight, which is resiliently suspended to the buoy.

14. A wave energy plant according to claim **1**, wherein the buoy includes a space, which functions as an air pocket and in which at least the main part of the driveshaft is located.

15. A wave energy plant according to claim **1**, wherein the energy accumulation device includes a counterweight arranged as a lead which moves upwards at the mentioned first of the buoy's or the other device's motions and at which potential energy is stored, that the coupling between the buoy or the other device, the first oblong organ, the driveshaft and the counterweight is arranged in a way, that the counterweight moves downwards at the mentioned second motion of the buoy or the other device and that the counterweight drives the generator's first and second parts to rotate in relation to each other in the first rotational direction.

16. A wave energy plant according to claim **15**, wherein the energy accumulation device includes a counterweight drum rotatably journalled in bearings to the driveshaft and a second oblong organ for coupling of motions in the counterweight to drive the counterweight drum to rotate, at which the driveshaft is coupled to rotate the electric generator's first part and the counterweight drum is coupled to rotate the electric generator's second part, at which the electric generator generates electric current when its second part rotates in relation to its first part at the same time as it gives a counteracting torque to this rotation, at which the electric generator's first and second parts is brought to rotate in relation to each other, always in the same first rotational direction.

17. A wave energy plant according to claim **15**, wherein the energy accumulation device includes a counterweight drum rotatably journalled in bearings to the driveshaft and a second oblong organ for coupling of motions in the counterweight to drive the counterweight drum to rotate and that a mechanical gear is coupled between the driveshaft and the electric generator's first part, at which the driveshaft is coupled to an ingoing side of the mechanical gear, the electric generators first part is coupled to an first outgoing side of the mechanical gear, the electric generator's second part is fixed to the buoy or the other device and the counterweight drum is mechanically coupled to a second, from the first separated, outgoing side of the mechanical gear, so that the driveshaft at the mentioned first motions in the buoy or the other devices gives motive forces on both outgoing sides of the mechanical gear for rotation of the electric generator's first part and for rotation of the counterweight drum to hoist up the counterweight in relation to the driveshaft and so that the counterweight drum at the mentioned second motions in the buoy or the other device gives a motive force via its coupling to the gear's second outgoing side for rotation of the electric generator's first part.

18. A wave energy plant according to claim **1**, wherein the energy accumulating device includes a counterweight drum and a counterweight and that the second oblong organ is a flexible organ, a line, wire or chain in particular, which in the lower end is fixed to the counterweight and its upper end is more or less winded up on the counterweight drum.

19. A wave energy plant according to claim **1**, comprising a control system for controlling the electric generators electric load or field current for adjusting the rotation speed between the electric generator's first and second parts.

20. A wave energy plant according to claim **19**, wherein the energy accumulation device includes a counterweight or a floating body and that the control of the electric generator's electric load or field current also is used for adjusting the counterweight's resp. floating body's vertical speed, so that the counterweight resp. the floating body moves within an adapted or suitable vertical span at the motions of the buoy or the other device.

21. A wave energy plant according to claim **20**, wherein the control system is arranged to compensate for variations in the torque, which is caused by the levy in mass of the counterweight resp. floating body, by regulation of the rotation speed between the electric generator's first and second parts, which gives a continuous even power output from the electric generator.

22. A wave power plant according to claim **1**, wherein it includes two electric generators and two belonging energy accumulation devices coupled to the driveshaft, at which the first oblong organ is coupled to the driveshaft to a place located between the two pairs of electric generator and belonging energy accumulation device.

23. A wave power plant according to claim **1**, wherein the first oblong organ at least in one end includes two sub organs, at which a first sub organ is coupled to the driveshaft on one side of the electric generator and another sub organ is coupled to the driveshaft on the opposite side of the electric generator.

24. A wave energy plant according to claim **1**, wherein it includes an anchor drum coupled to the first oblong organ and that the first oblong organ includes a flexible organ, a line, wire or chain in particular, which at least in one of its ends is divided into two sub organs, which each one is more or less winded up on the corresponding wind up surfaces of each anchor drum, at which the wind up surfaces have helicoidally running grooves with opposite helicoidal directions.

25. A wave energy plant according to claim **1**, wherein the energy accumulation device includes two counterweight drums journalled in bearings to the driveshaft and a flexible organ, a line, wire or chain in particular, which at least in one of its ends is divided in two flexible sub organs, which each one is more or less winded up around corresponding wind up surfaces on the counterweight drums, at which the wind up surfaces has helicoidally running grooves with opposite helicoidal directions.

26. A method of extracting electrical energy from more or less periodical motions of a body, especially repeated back and forth motions and/or repeated rocking motions in two opposite directions, wherein

that at the first motions of the body let these motions drive two parts of an electric generator to rotate in relation to each other in a first direction and hereby generate electric current and at the same time also supply an energy accumulation device with mechanical energy, and that at the second motions of the body, which mainly is separated from the first motions, let the energy accumulation device drive the electric generators two parts to rotate in the same first direction in relation to each other and thereby generator electric current with the same polarity as at the first motions of the body.

* * * * *

United States Patent [19]

Solell

[11] 4,145,885

[45] Mar. 27, 1979

[54] WAVE MOTOR

[76] Inventor: Yedidia Solell, Rav-Ashi 1, Tel Aviv, Israel

[21] Appl. No.: 854,226

[22] Filed: Nov. 23, 1977

[30] **Foreign Application Priority Data**

Sep. 23, 1977 [IL] Israel 52982
Oct. 21, 1977 [IL] Israel 53179

[51] Int. Cl.² F03B 13/12

[52] U.S. Cl. 60/504; 60/505; 60/507; 60/398; 290/53

[58] Field of Search 60/398, 495, 497, 502, 60/504, 505, 507, 716; 61/20; 185/32, 33; 290/42, 53; 417/100, 330, 331, 337

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Primary Examiner—Edgar W. Geoghegan
Attorney, Agent, or Firm—Benjamin J. Barish

[57] **ABSTRACT**

A wave motor is described comprising a float, a displaceable member coupled to the float so as to be displaced by the ascent and descent of the float, a pair of shafts, and a transmission including a pair of one-way clutches coupling the displaceable member to the shafts to rotate one in one direction during the ascent of the float and to rotate the other in the opposite direction during the descent of the float. In one described embodiment, the displaceable member is a wheel which is partially rotated in opposite directions by the ascent and descent of the float; and in a second described embodiment, the displaceable member is a rack which is moved upwardly by the ascent of the float and downwardly by its descent.

7 Claims, 6 Drawing Figures

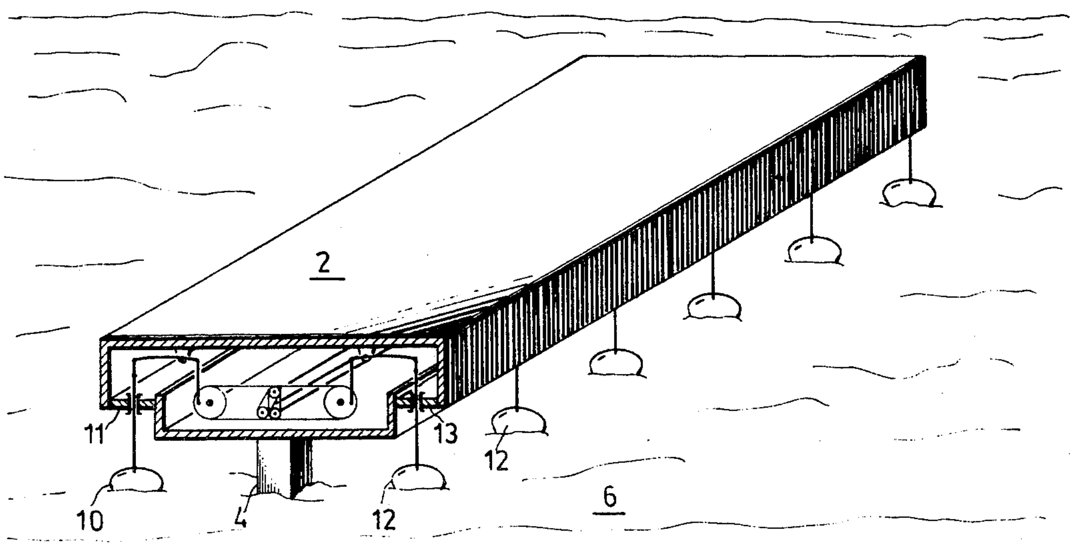
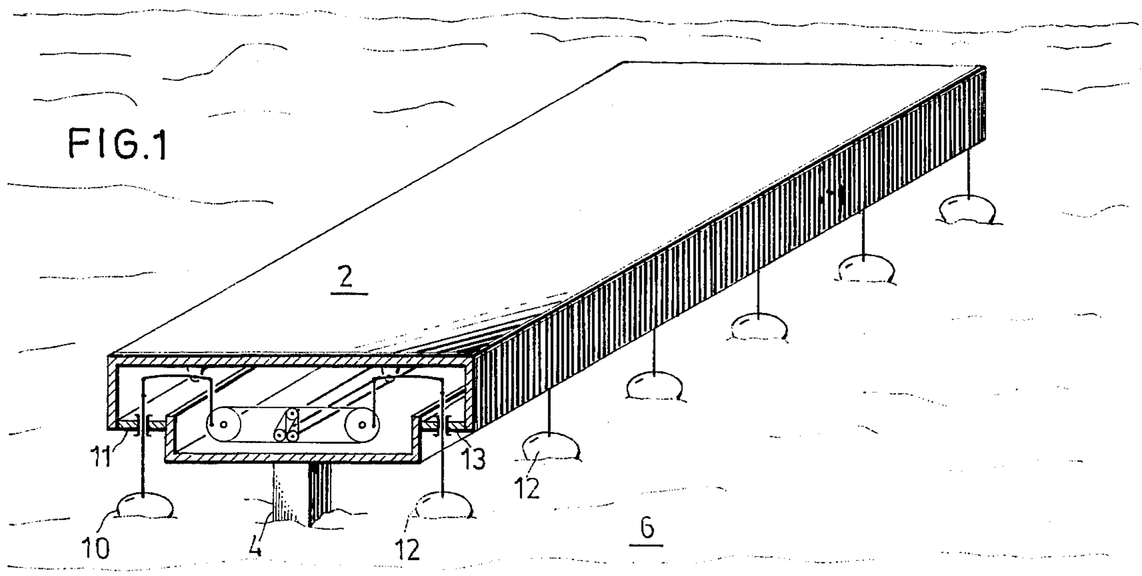


FIG.1



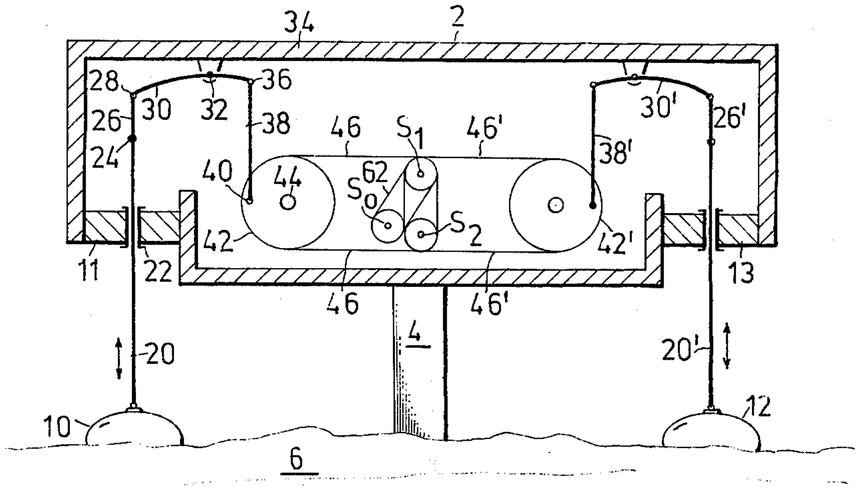
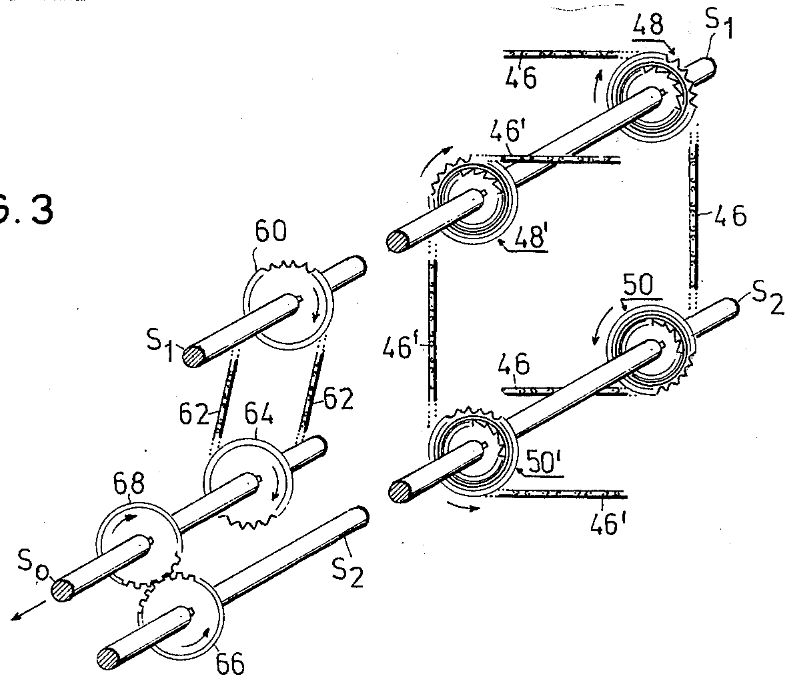


FIG. 2

FIG. 3



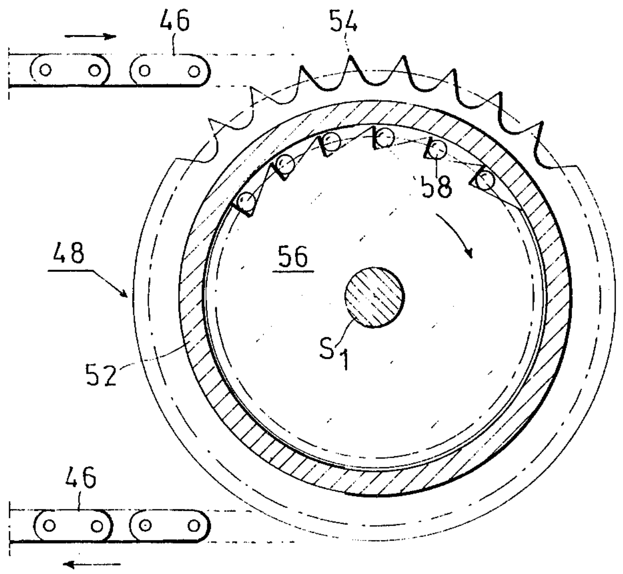


FIG. 4

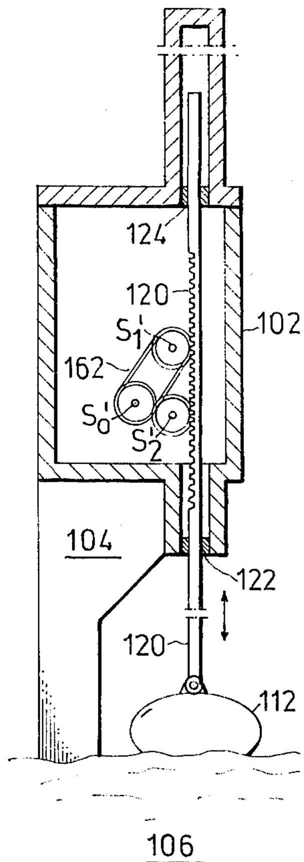


FIG. 5

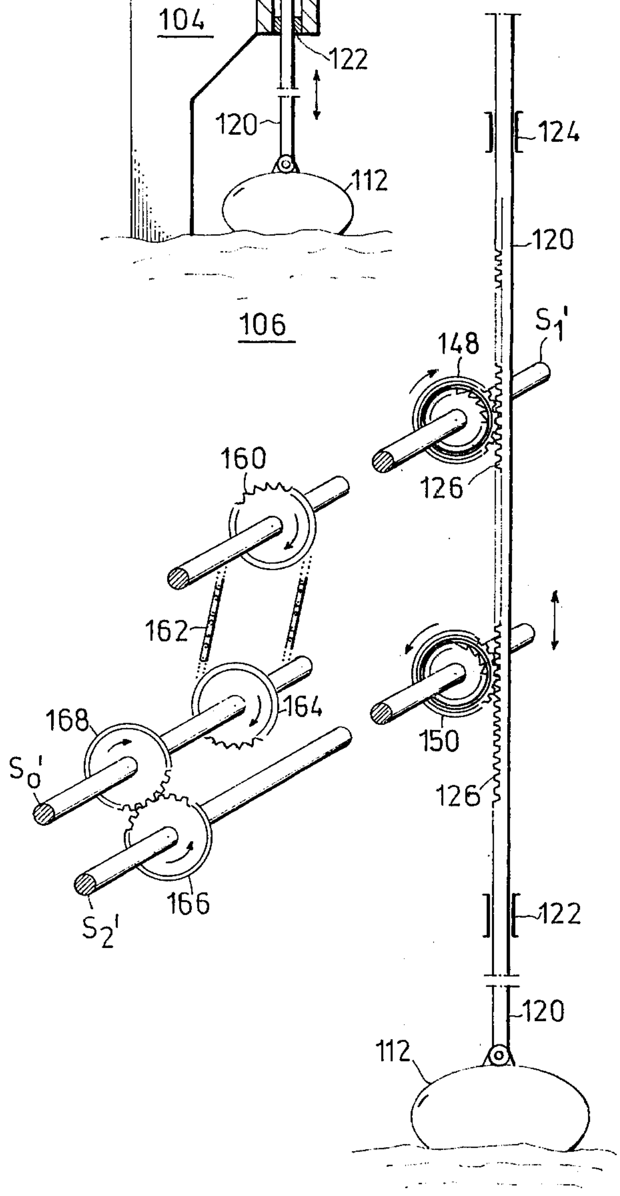


FIG. 6

WAVE MOTOR

BACKGROUND OF THE INVENTION

The present invention relates to wave motors, namely to motors for converting energy from sea waves to mechanical work.

The energy in the sea constitutes a vast reservoir which has remained largely untapped to the present time. Many types of wave motors have been proposed, but as a rule, they have not become economically feasible mainly because of the large initial cost involved in their construction and installation compared to the amount of energy they are capable of extracting from the sea.

An object of the present invention is to provide a wave motor having a relatively simple design and capable of extracting substantial amounts of energy from the sea.

SUMMARY OF THE INVENTION

According to a broad aspect of the invention, there is provided a wave motor comprising: a float; a displaceable member coupled to the float so as to be displaced through a forward stroke by the ascent of the float, and through a return stroke by the descent of the float; a pair of shafts; and a transmission coupling the displaceable member to the pair of shafts; the transmission including a first one-way clutch coupling the displaceable member to one shaft to rotate same in one direction during the displacement of said member through its forward stroke, and a second one-way clutch coupling the displaceable member to the other shaft to rotate same in the opposite direction during the displacement of the member through its return stroke.

In one preferred embodiment of the invention described below, the displaceable member is a wheel coupled to the float by linkage which partially rotates the wheel in one direction during the ascent of the float, and partially rotates the wheel in the opposite direction during the descent of the float. More particularly, in this embodiment, the wheel and the one-way clutches include teeth, the transmission including a closed-loop chain trained around the teeth of the wheel and the one-way clutches.

In a second preferred embodiment described below, the displaceable member comprises a rack coupled to the float so as to be displaced through an upward stroke by the ascent of the float and through a downward stroke by the descent of the float; in addition, the transmission coupling the float to the pair of shafts comprises teeth formed on the rack meshing with gears coupled by the one-way clutches to the pair of shafts to rotate one shaft in one direction during the upward stroke of the rack, and to rotate the other shaft in the opposite direction during the downward stroke of the rack.

In both described embodiments, there are a plurality of drive units each including one of the floats, displaceable members, and transmissions, all coupled to the pair of shafts for driving same in opposite directions.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, somewhat diagramatically and by way of example only, with reference to the accompanying drawings, wherein:

FIG. **1** is a three-dimensional view illustrating one form of wave motor constructed in accordance with the invention;

FIG. **2** is an end view of the wave motor of FIG. **1**;

FIG. **3** is a three-dimensional view illustrating some of the elements in one of the drive units in the wave motor of FIG. **3**;

FIG. **4** illustrates one form of one-way clutch that may be used in the wave motor of FIGS. **1–3**;

FIG. **5** is a vertical sectional view of another wave motor constructed in accordance with the invention; and

FIG. **6** is a three-dimensional view illustrating the main elements in one of the drive units in the wave motor of FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The wave motor illustrated in the drawings comprises an elongated housing, generally designated **2**, mounted by a plurality of columns **4** above a body of water **6** subject to waves. Housing **2** encloses a plurality of drive units each including a float **10** vertically movable with respect to an opening in the housing bottom wall **11** on one side of the mounting columns **4**, and another float **12** vertically movable with respect to an opening in the bottom wall **13** on the other side of the mounting columns. Any desired number of such drive units could be provided lengthwise of housing **2**, each drive unit including a pair of such floats **10, 12**. Housing **2** is mounted over the body of water so as to extend lengthwise substantially perpendicular to the direction of propagation of the waves, whereby a wave will normally intercept one of the floats (e.g. the left float **10**) in each of the drive units, and then will intercept the other float (e.g. the right float **12**) in each drive unit.

As shown particularly in FIGS. **2** and **3**, the wave motor comprises a pair of shafts **S1, S2** extending the complete length of housing **2**. Shaft **S1** is coupled to all the drive units in the manner to be described below so as to be driven thereby in one direction (clockwise as shown in FIG. **3**), whereas shaft **S2** is coupled to all the drive units so as to be driven thereby in the opposite direction (counter-clockwise in FIG. **3**). Both shafts **S1** and **S2** are in turn coupled to an output drive shaft **S0** driven thereby in one direction, in this case in the same direction (clockwise) as shaft **S1**.

Thus, the mechanical power produced by the wave motor illustrated in the drawings is outputted through the output drive shaft **S0**. This shaft may be connected to an electrical generator, a pump, or any other device for utilizing or storing the mechanical energy produced by the wave motor.

The left float **10** of each drive unit is suspended from a rod **20** passing through a guide **22** formed in the lower housing wall **11**. The upper end of rod **20** is hinged at **24** to one end of a short connecting rod **26**, the opposite end of which is hinged at **28** to one end of a lever arm **30** pivotably mounted at **32** to the upper wall **34** of housing **2**. The opposite end of lever arm **30** is hinged at **36** to a connecting rod **38** which in turn is hinged at **40** to an eccentric point on a toothed wheel **42** rotatable about its center axis **44**. Wheel **42** thus serves as an oscillatable member which is coupled to its float **10** so as to be oscillated through a forward stroke (wherein the wheel partially rotates counter-clockwise) by the ascent of the float upon its interception of a wave crest, and through a return stroke (clockwise) by the descent of the float upon its interception of a wave trough.

Toothed wheel **42** is coupled by a transmission to the two shafts S1 and S2 by means of two one-way clutches effective to rotate shaft S1 in one direction (clockwise) during the forward stroke of wheel **42** upon the ascent of float **10**, and to rotate shaft S2 in the opposite direction (counter-clockwise) during the return stroke upon the descent of float **10**.

The foregoing transmission, best seen in FIG. **3**, includes a closed-loop chain **46** trained about the outer teeth on wheel **42**. Chain **46** is also trained about the outer teeth on a first one-way clutch **48** coupled to shaft S1, and on a second one-way clutch **50** coupled to shaft S2.

FIG. **4** illustrates, for purposes of example only, one form of one-way clutch which may be used, the construction shown in FIG. **4** being that for clutch **48**. The clutch includes an outer body in the form of a ring **52** having teeth **54** receiving chain **46**, and an inner body in the form of a ratchet **56** fixed to shaft S1 and coupled to the outer ring **52** by means of a plurality of balls **58**. As known in such one-way clutches, the outer surface of the teeth of ratchet **56** is shaped such that when the outer ring **52** rotates in one direction (in this case clockwise), it tends to wedge balls **58** between it and the ratchet, thereby effecting a coupling between the two bodies; whereas when the outer ring rotates in the opposite direction (counter-clockwise), the balls effectively decouple the two bodies so that the outer ring **52** is free-running with respect to the ratchet.

One-way clutch **50** is of the same construction as clutch **48**, except that it effects a coupling between chain **46** and shaft S2 during the opposite direction of movement of the chain (i.e., to rotate shaft S2 in the counter-clockwise direction), and is free-running in the clockwise direction.

It will thus be seen that the ascent of float **10** drives wheel **42** counter-clockwise so as to rotate shaft S2 counter-clockwise via engaged clutch **50**, and the descent of the float drives wheel **42** clockwise so as to rotate shaft S1 clockwise via engaged clutch **48**.

A similar oscillating wheel is provided with respect to the right float **12** to rotate shaft S1 (clockwise) during one stroke of the oscillating member, and to drive shaft S2 (counter-clockwise) during the outer stroke of the member. To facilitate understanding the drive mechanism cooperably with the right float **12**, the same reference numerals have been used but containing a "prime" mark, for the corresponding elements described above with respect to the left float **10**. Thus, the ascent of the right float **12** causes (via the rods **20'**, **26'**, lever **30'**, and connecting rod **38'**) the clockwise rotation of wheel **42'**, which in turn (via its chain **46'**, one-way clutch **48'** coupled to shaft S1, and one-way clutch **50'** coupled to shaft S2) rotates shaft S1 in the same direction (clockwise) as it is driven by the above-described wheel **42** (shaft S2 being decoupled from wheel **42'** by the one-way clutch **50'**); and the descent of the right float **12**, causes the counter-clockwise rotation of wheel **42**, which in turn rotates shaft S2 counter-clockwise (shaft S1 being decoupled by one-way clutch **48'**).

It will be appreciated that each drive unit within housing **2** includes a pair of floats corresponding to the left float **10** and the right float **12**, each pair cooperating with a corresponding mechanism as described above to drive shaft S1 in one direction and shaft S2 in the opposite direction.

As also best seen in FIG. **3**, the two shafts S1 and S2 are both coupled at their left ends to the output drive shaft S0 such as to rotate the latter shaft in one direction, clockwise in this case. For this purpose, the output shaft S0 is coupled to shaft S1 by a direct motion coupling including a gear **60** fixed to the end of shaft S1 and coupled by a chain **62** to another gear **64** fixed to the output shaft S0. Output shaft is coupled to shaft S2 by a motion-reversing coupling including a gear **66** fixed to the end of shaft S2 engaging a gear **68** fixed to the output shaft S0.

The wave motor illustrated in FIGS. **5** and **6** of the drawings comprises a housing, generally designated **102**, which is elongated as in FIGS. **1–4** and is mounted by a plurality of columns **104** above the body of water **106**. Housing **102** encloses a plurality of drive units each including a float **112** vertically movable in the upward direction with a wave crest and in a downward direction with a wave trough. This vertical movement of the float **112** drives a pair of shafts S1', S2' in opposite directions, which shafts in turn drive a single output shaft S0' in one direction, all as described with respect to FIGS. **1–4**, particularly the shafts S1, S2, S0, respectively.

In the embodiment of FIGS. **5** and **6**, however, a simplified arrangement is used for coupling the floats **112** to the two shafts S1', S2'.

Thus, each float **112** is coupled to a displaceable member in the form of a rack **120** such that the rack is displaced through an upward stroke by the ascent of the float and through a downward stroke by its descent. The vertical movement of rack **120** is guided by a pair of bearings **122**, **124** within the housing **102**. Rack **120** is formed with teeth **126** which mesh with the outer teeth of a first one-way clutch **148** and also with the outer teeth of a second one-way clutch **150**.

The one-way clutches **148** and **150** correspond in structure and function to the one-way clutches **48** and **50** in the above-described FIGS. **1–4** and are effective, in the same manner as described there, to rotate shaft S1' in one direction during one stroke of the rack, and the other shaft S2' in the opposite direction during the other stroke of the rack. In the arrangement illustrated particularly in FIG. **6**, it will be seen that the upward stroke of rack **120** will effect the counter-clockwise rotation of shaft S2', and the downstroke of the rack will effect the clockwise rotation of shaft S1'.

As also described above, the two shafts S1' and S2' are both coupled at their left ends to the output drive shaft S0' so as to rotate the latter shaft in one direction, clockwise in this case. This is effected by the provision of gear **160** fixed to the end of shaft S1' and coupled by chain **162** to another gear **164** fixed to the output shaft S0', and by gear **166** fixed to the end of shaft S2' engaging a gear **168** fixed to the output shaft S0', all as described above with respect to FIGS. **1–4** wherein the corresponding elements are numbered **60**, **62**, **64**, **66** and **68**, respectively.

While FIGS. **5** and **6** of the enclosed drawings illustrate only one drive unit driven by one float **112** in a body of water **106**, it will be appreciated that the wave motor would include a plurality of such drive units, namely a plurality of floats arranged longitudinally of the wave motor housing, a plurality of racks each coupled to one of the floats, and a plurality of pairs of one-way clutches each pair coupling one of the racks to the pair of shafts S1', S2', as in the FIGS. **1–4** embodiment.

While the invention has been described with respect to two preferred embodiments for purposes of example, it will be appreciated that many variations can be made. For example, other mechanisms can be used for coupling the two oppositely-rotating shafts **S1**, **S2** to the output drive shaft **S0**, and other one-way clutch mechanisms can be used. Many other variations, modifications and applications of the invention will be apparent.

What is claimed is:

1. A wave motor, comprising: a first float; a first displaceable member coupled to said float so as to be displaced through a forward stroke by the ascent of the float, and through a return stroke by the descent of the float; a pair of shafts; a first transmission coupling said displaceable member to said pair of shafts; said transmission including a first one-way clutch coupling the first displaceable member to one shaft to rotate same in one direction during the displacement of said member through its forward stroke, and a second one-way clutch coupling the first displaceable member to the other shaft to rotate same in the opposite direction during the displacement of the member through its return stroke; a second float; a second displaceable member coupled to said second float so as to be displaced by the ascent and descent thereof; and a second transmission including third and fourth one-way clutches coupling said second displaceable member to said pair of shafts such that the displacement of the second member rotates said one shaft in said one direction and said other shaft in said opposite direction.

2. A wave motor according to claim **1**, wherein each of said displaceable members is a wheel coupled to its respective float so as to be partially rotated in one direction during the ascent of its respective float, and partially rotated in the opposite direction during the descent of its respective float, each of said wheels and one-way clutches including teeth, and each of said transmissions comprising a separate closed-loop chain trained around the teeth of its respective wheel and of its respective two one-way clutches.

3. A wave motor, comprising: a float; a displaceable member coupled to said float so as to be displaced through a forward stroke by the ascent of the float, and through a return stroke by the descent of the float; a pair of shafts; and a transmission coupling said displaceable member to said pair of shafts; said transmission including a first one-way clutch coupling the displaceable member to one shaft to rotate same in one direction during the displacement of said member through its forward stroke, and a second one-way clutch coupling the displaceable member to the other shaft to rotate same in the opposite direction during the displacement of the member through its return stroke; said pair of shafts being coupled to a common output drive shaft, one by a direct-motion coupling, and the other by a motion-reversing coupling, so that said common output drive shaft is driven in the same direction by said pair of oppositely rotating shafts.

4. A wave motor according to claim **3**, wherein there are a plurality of drive units each including at least one of said floats, displaceable members, and transmissions, all coupled to said pair of shafts for driving same in opposite directions.

5. A wave motor, comprising: a float; a displaceable member coupled to said float so as to be displaced through a forward stroke by the ascent of the float, and through a return stroke by the descent of the float; a pair of shafts; and a transmission coupling said displaceable member to said pair of shafts; said transmission including a first one-way clutch coupling the displaceable member to one shaft to rotate same in one direction during the displacement of said member through its forward stroke, and a second one-way clutch coupling the displaceable member to the other shaft to rotate same in the opposite direction during the displacement of the member through its return stroke; said displaceable member comprising a rack coupled to said float so as to be displaced through an upward stroke by the ascent of the float and through a downward stroke by the descent of the float; said transmission coupling said float to said pair of shafts comprising teeth formed on said rack meshing with gears coupled by said one-way clutches to said pair of shafts to rotate one shaft in one direction during the upward stroke of the rack, and to rotate the other shaft in the opposite direction during the downward stroke of the rack.

6. A wave motor according to claim **5**, wherein there are a plurality of drive units, each including a float, a rack, and a pair of one-way clutches, said pair of shafts being driven by all the floats each coupled to one of the racks, each rack being coupled to said pair of shafts via one pair of said one-way clutches.

7. A wave motor according to claim **6**, further including a common housing for said plurality of drive units, the latter extending longitudinally of the housing, and mounting means mounting the housing above a body of water subject to waves with the float of each drive unit depending from opposite sides of the housing so as to be caused to ascend and descend by said waves.

* * * * *

United States Patent [19]
Shim

[11] Patent Number: 5,066,867
[45] Date of Patent: Nov. 19, 1991

[54] METHOD AND DEVICE FOR GENERATING ELECTRIC POWER BY USE OF WAVE FORCE

[76] Inventor: **Hyun J. Shim**, 350-39 Sangdo 3-dong, Dongjak-ku, Seoul, Rep. of Korea

[21] Appl. No.: **70,353**

[22] Filed: **Jul. 6, 1987**

[30] **Foreign Application Priority Data**

Jul. 7, 1986 [KR] Rep. of Korea 5475/1896

[51] **Int. Cl.**[5] **F03B 13/10**; F03B 13/12

[52] **U.S. Cl.** **290/53**; 60/495; 417/330

[58] **Field of Search** 290/53, 42, 54; 417/330, 331-334; 60/495, 507, 504, 398

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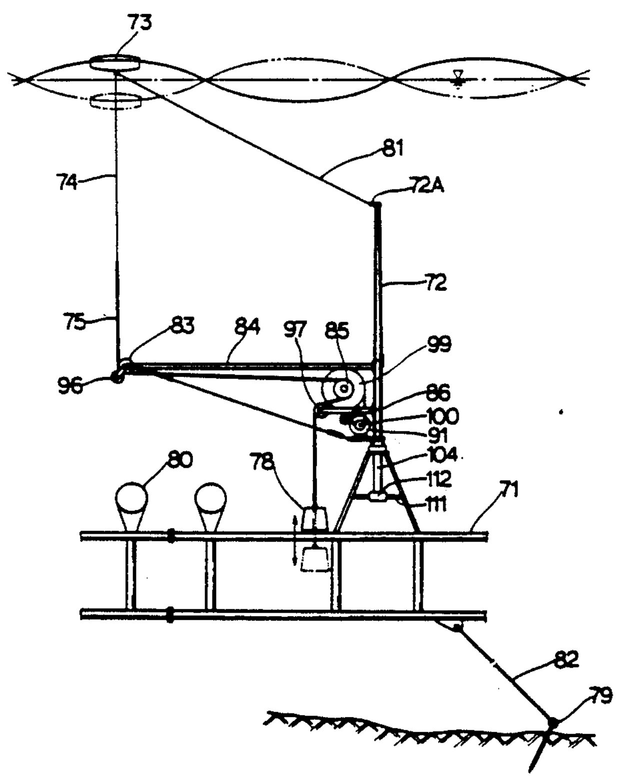
Primary Examiner—A. D. Pellinen
Assistant Examiner—Sharon D. Logan
Attorney, Agent, or Firm—Fliesler, Dubb, Meyer & Lovejoy

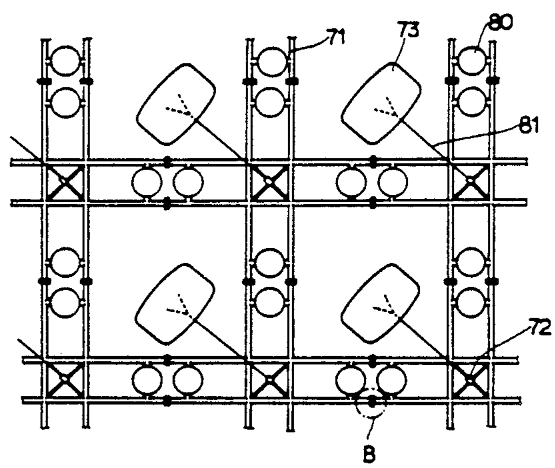
[57] **ABSTRACT**

The invention relates to a method and device for generating electric power by use of wave force.

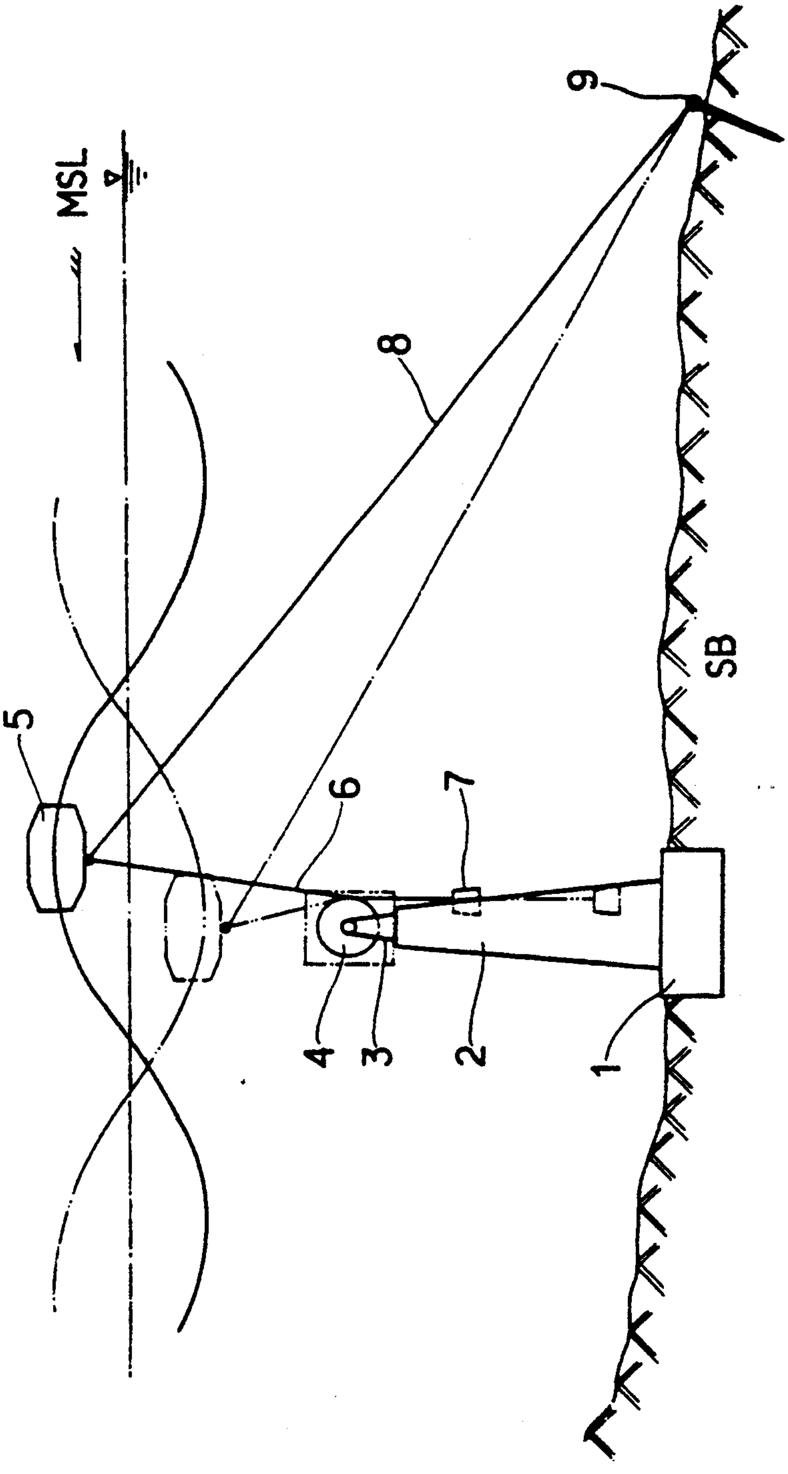
According to the invention, it is possiblke to obtain the required power using the floatation bladders rising and falling repeatedly with waves as a power using the floatation bladders rising and falling repeatedly with waves as a power source and the rotation force of gears connected to the floatation bladders through ropes. The invention has advantages in that the construction of the power generating means and its supporting means are simple, execution of work is easy, a kinetic energy is convertable into an electric energy using the floatation bladders regardless of the magnitude of waves, and even in the deep sea, the base frame is not installed on the sea bed, but in a fixed depth under the mean sea level, and thereby the maintenance and repair of device is carried out without any difficulty.

3 Claims, 10 Drawing Sheets

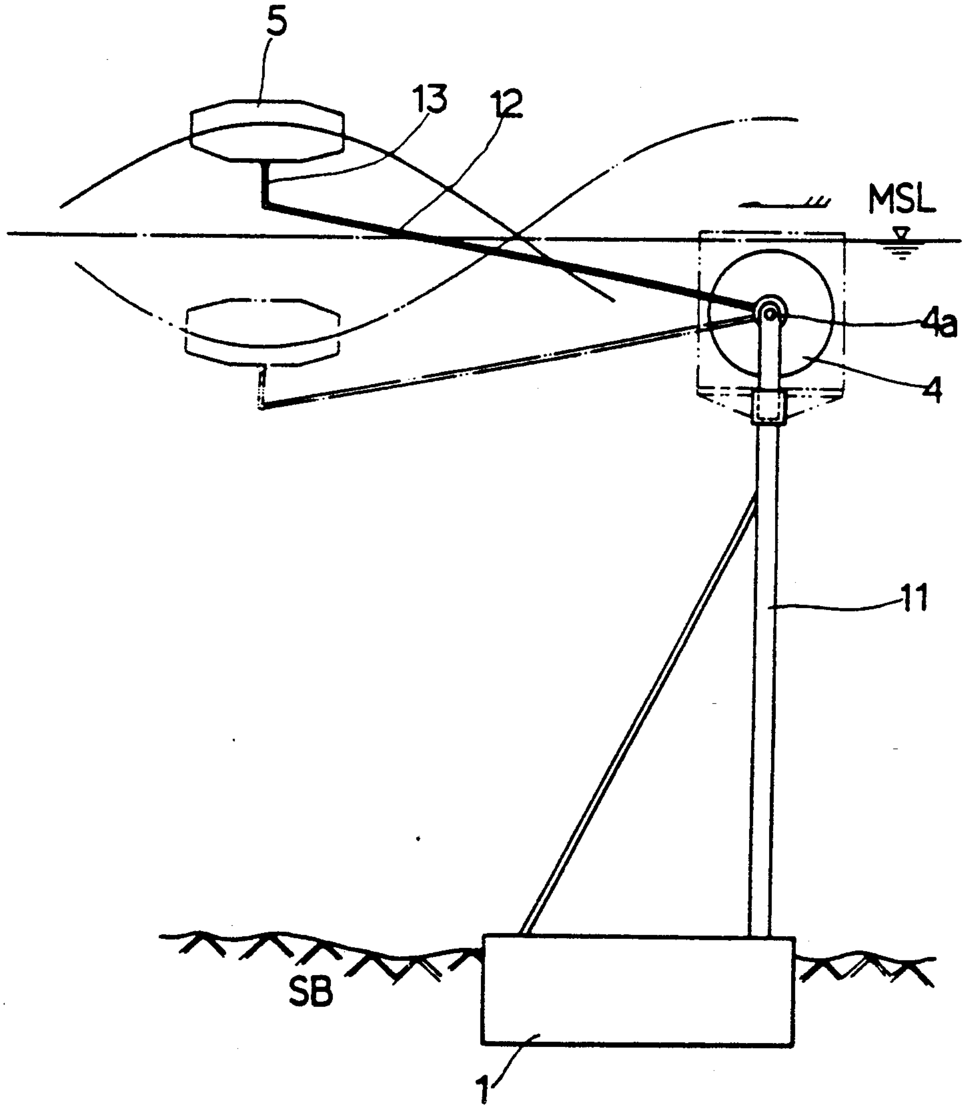




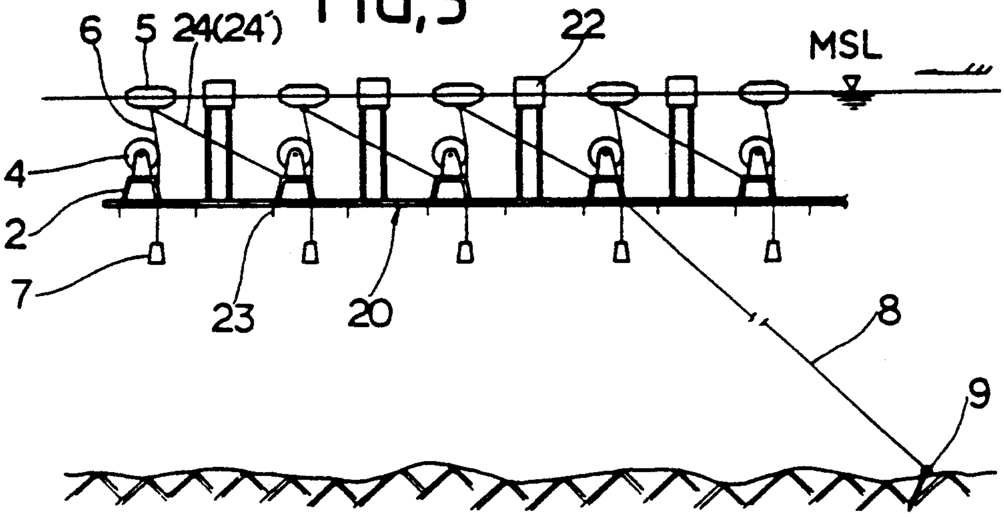
FIG,1



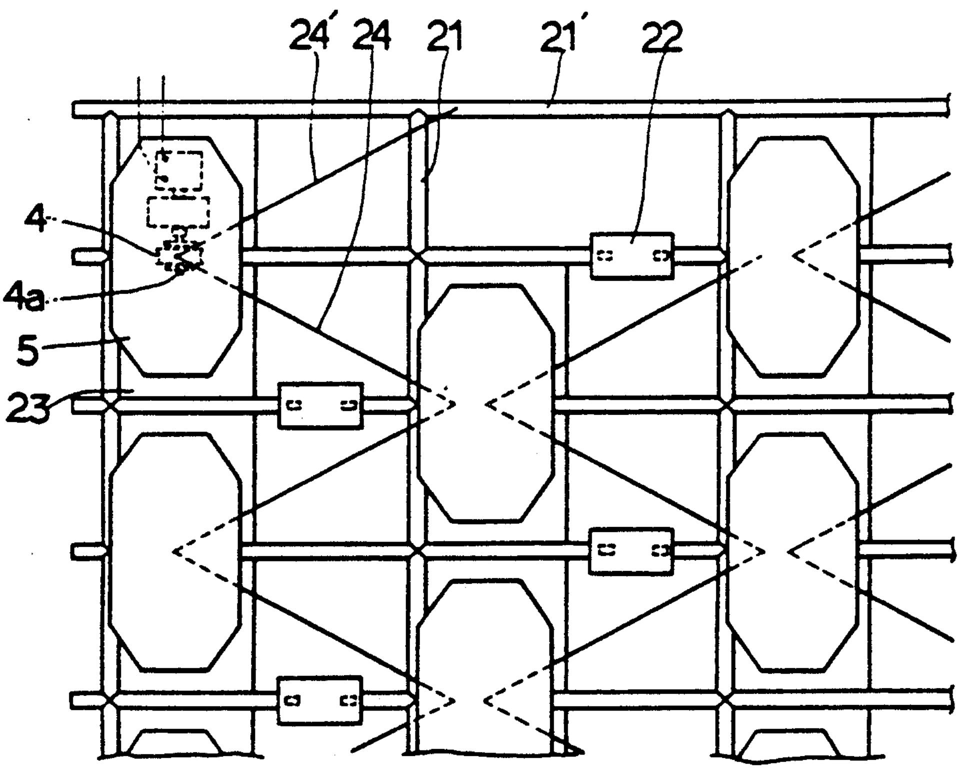
FIG,2



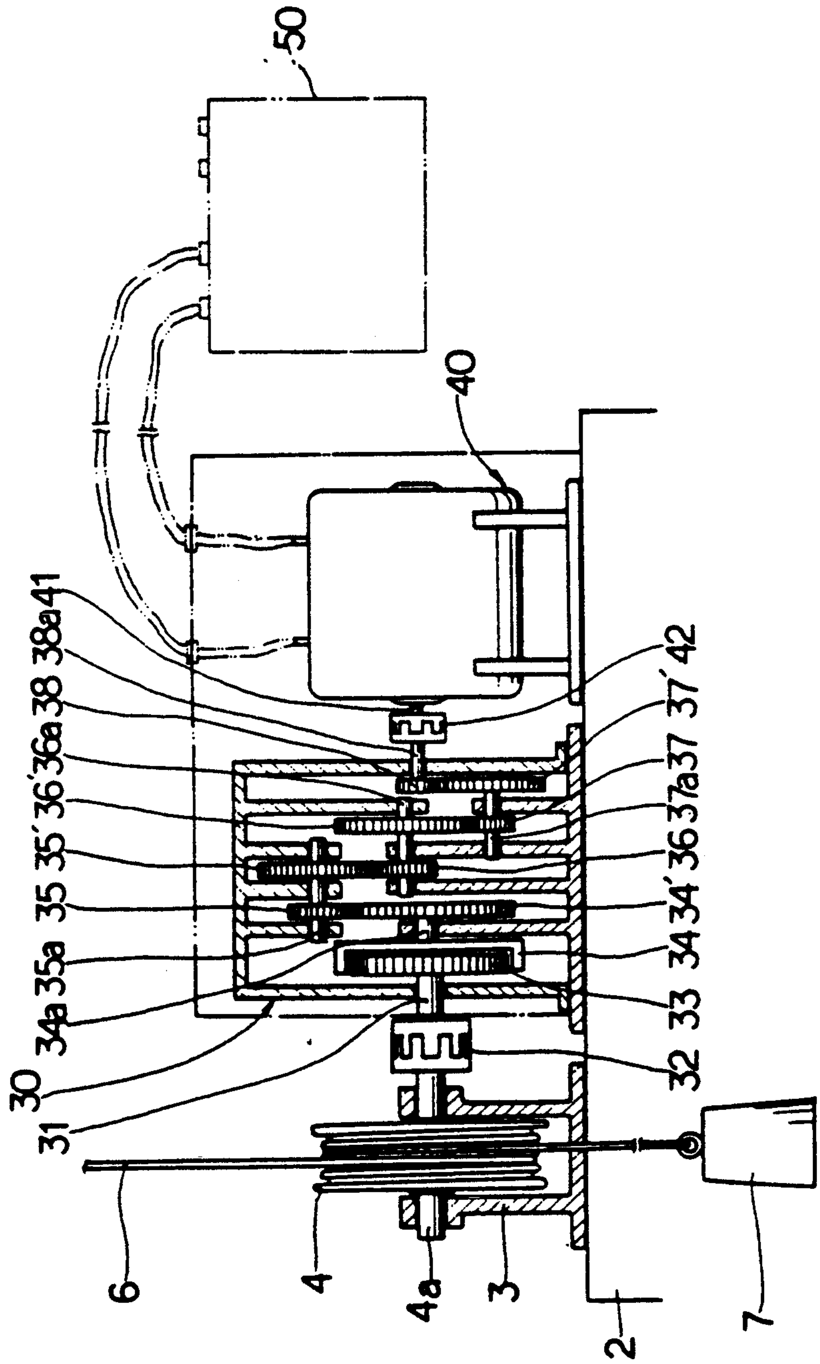
FIG, 3



FIG, 4



FIG,5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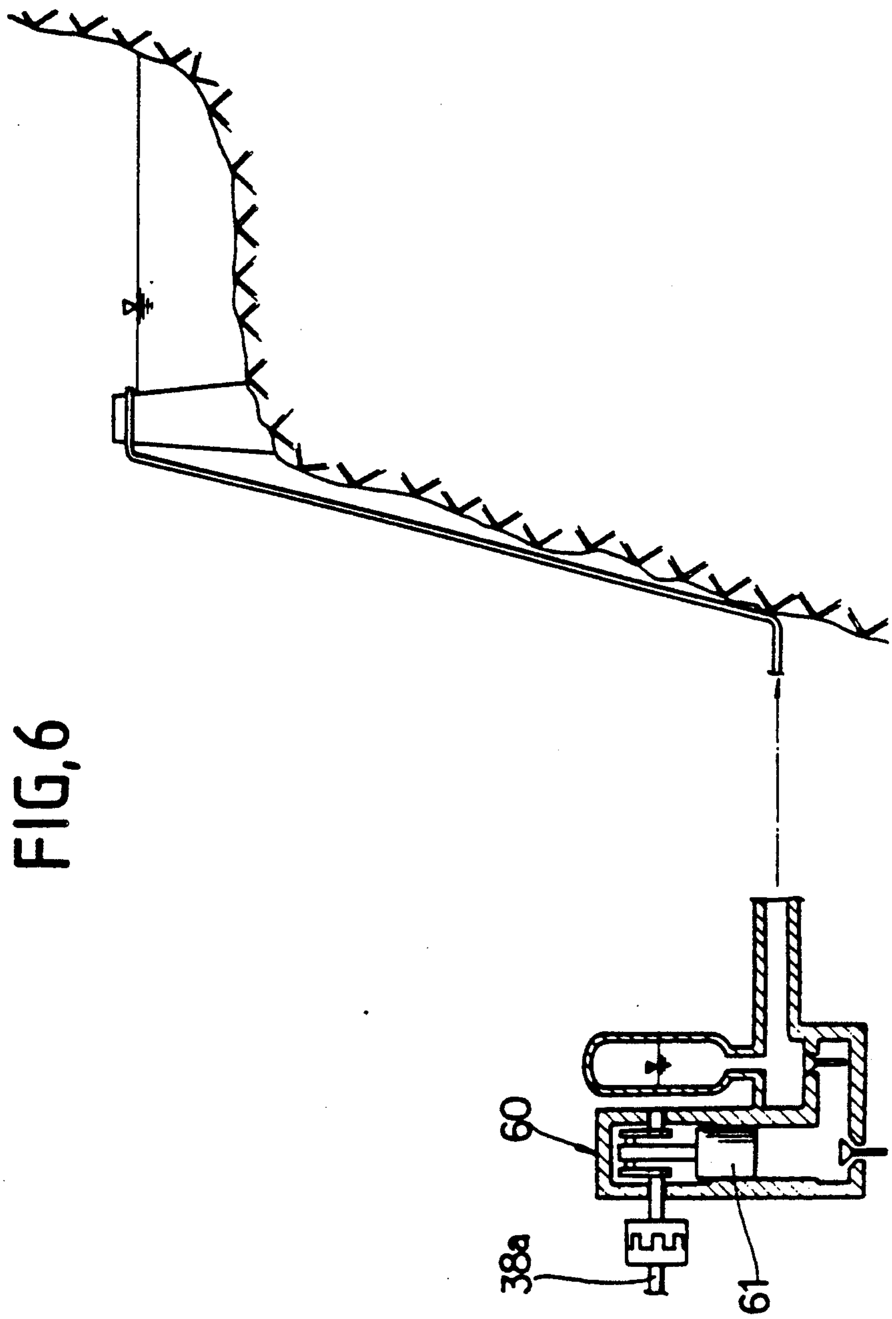

FIG,6

FIG,7

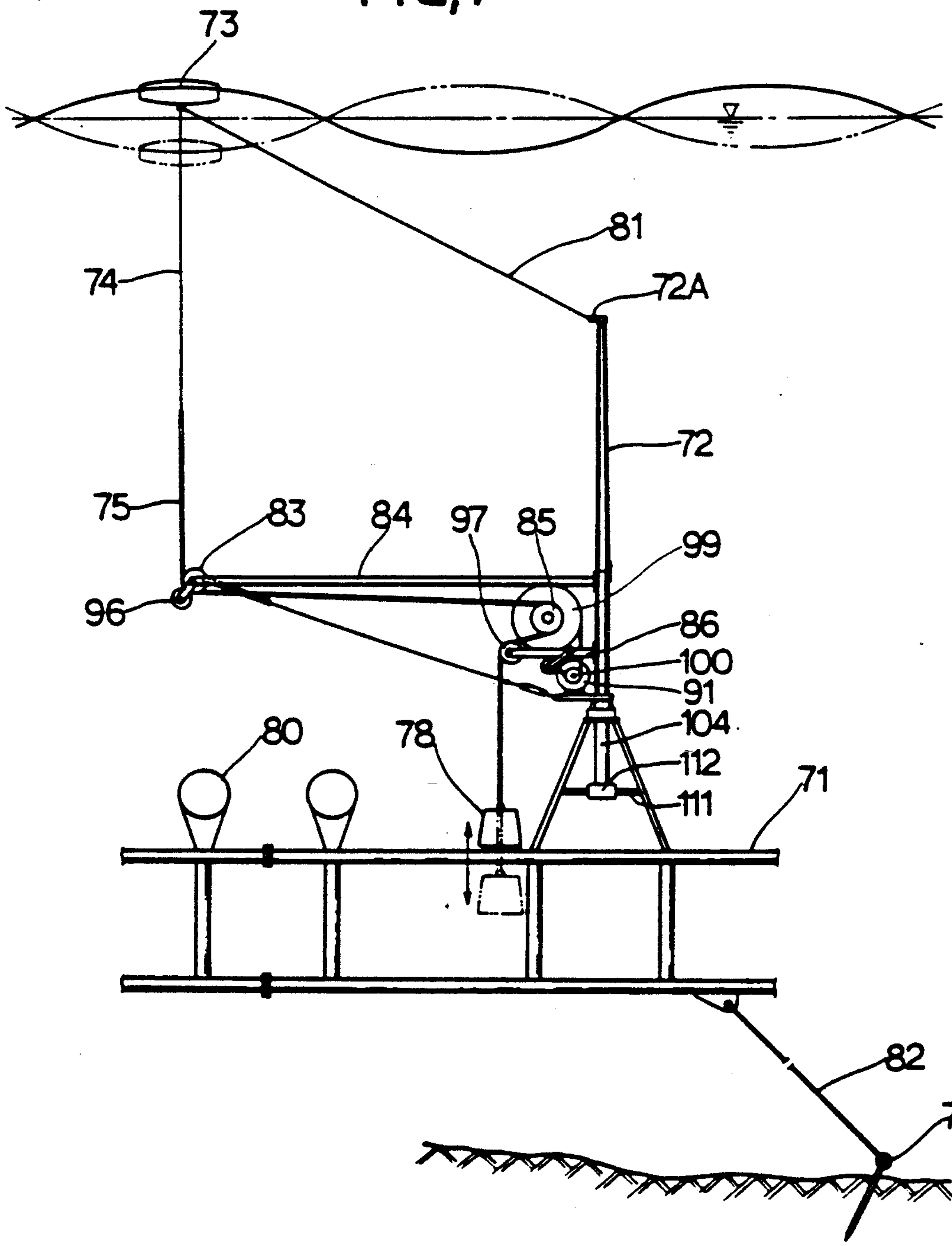
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FIG.8

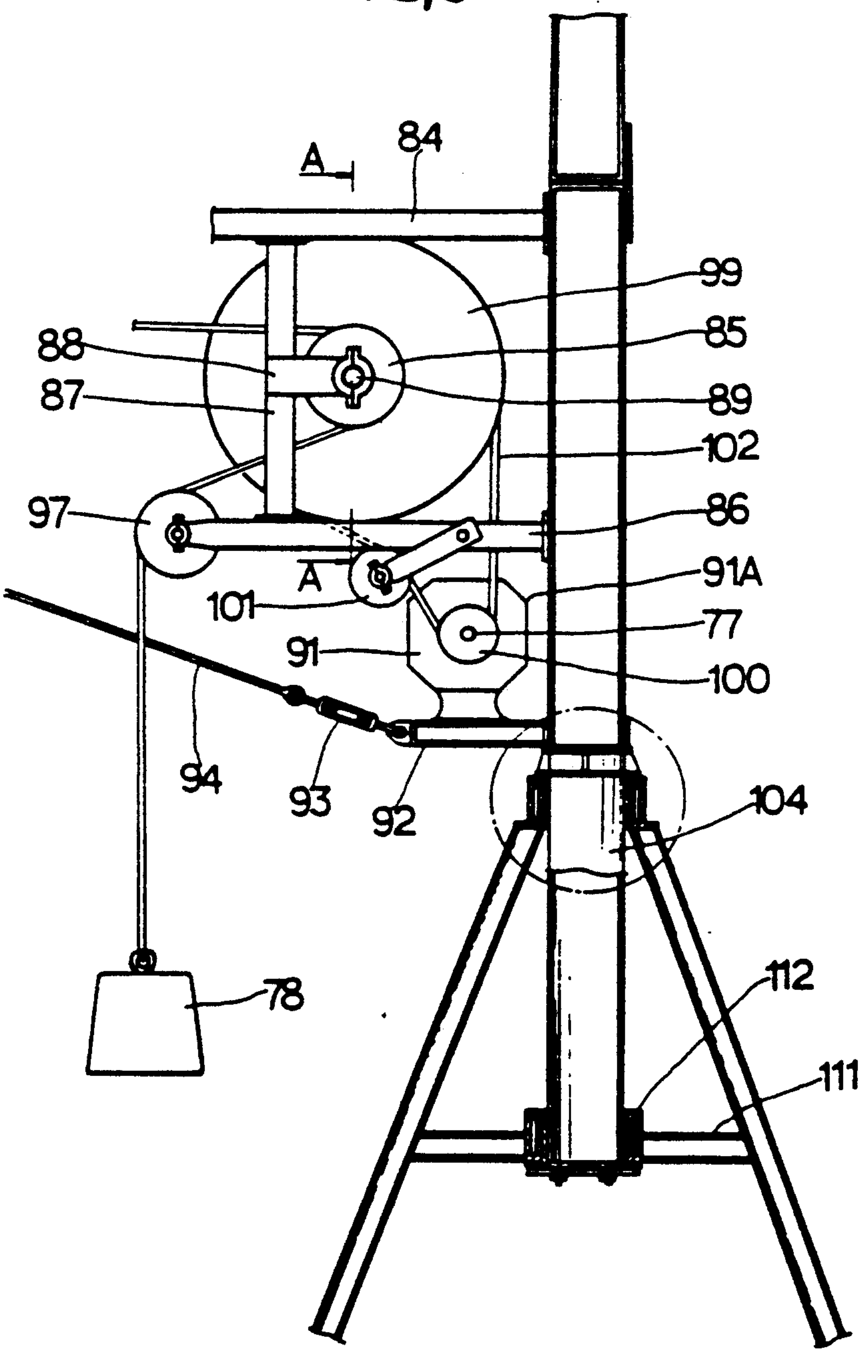

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FIG. 9

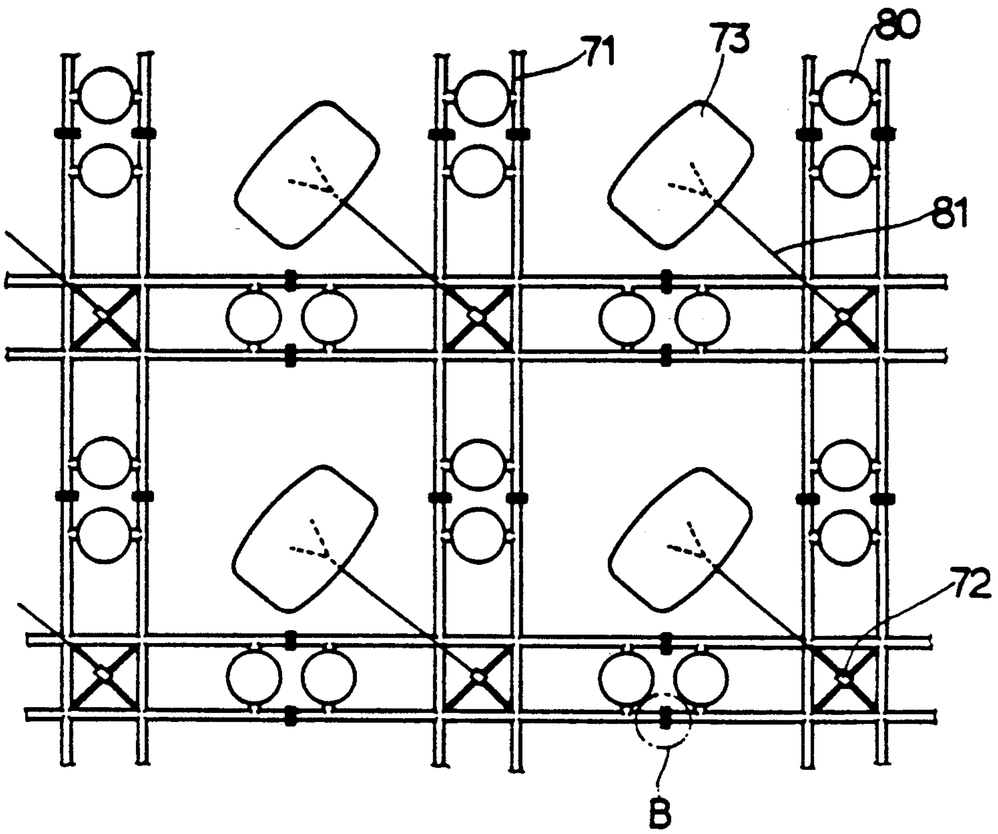


FIG. 10

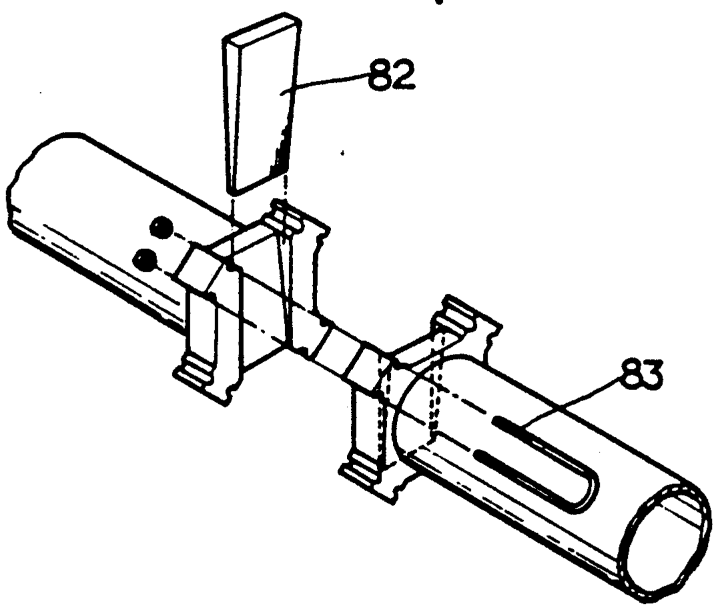


FIG. 11

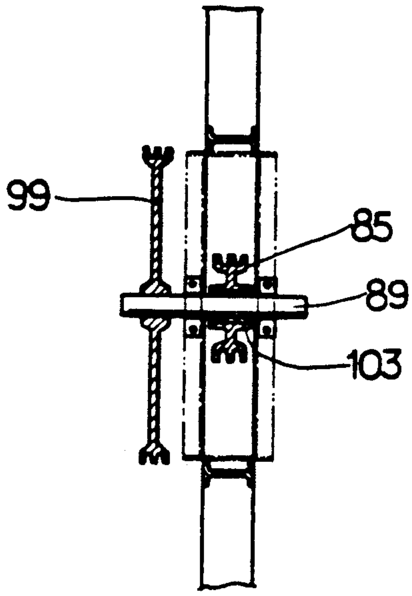


FIG. 12

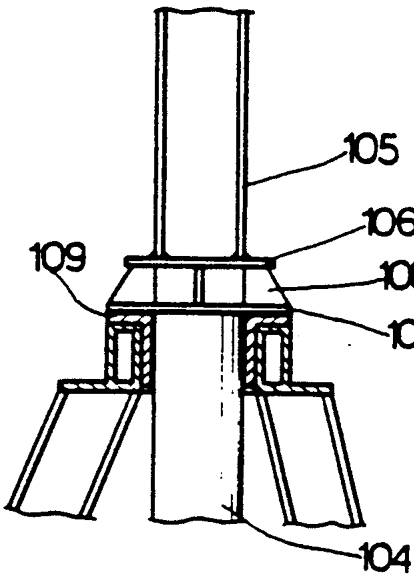


FIG. 13

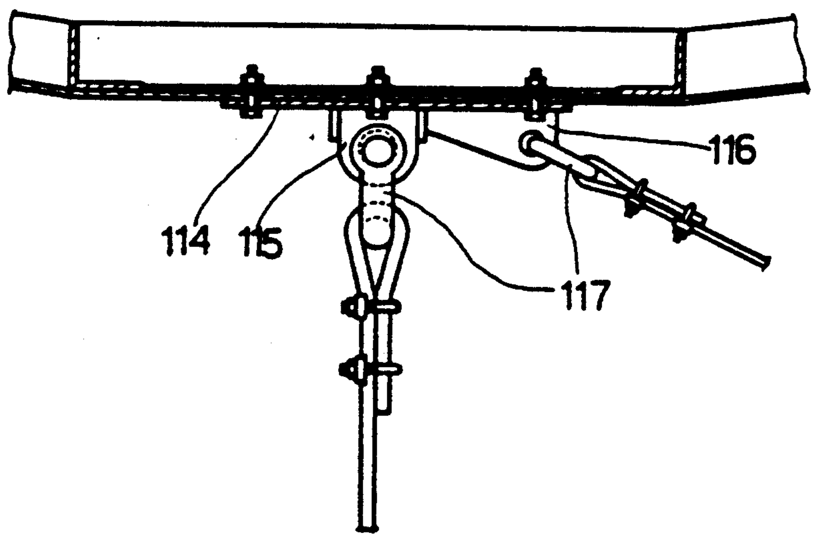


FIG. 14

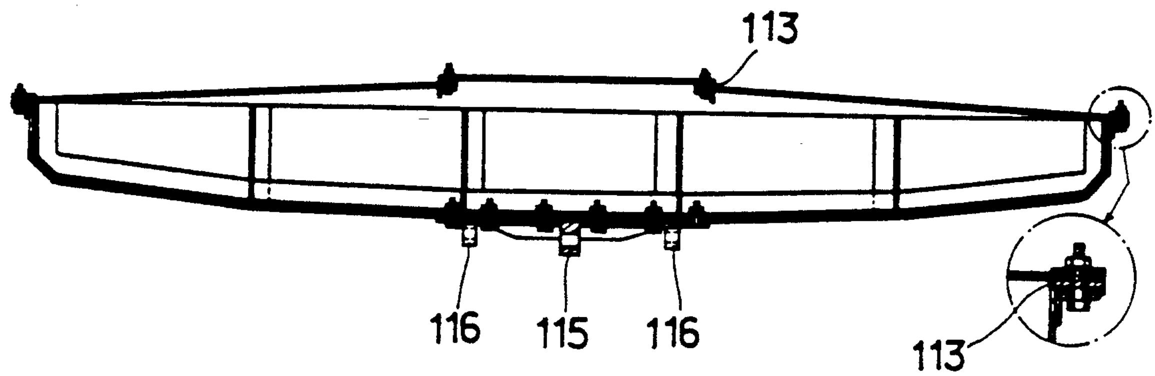
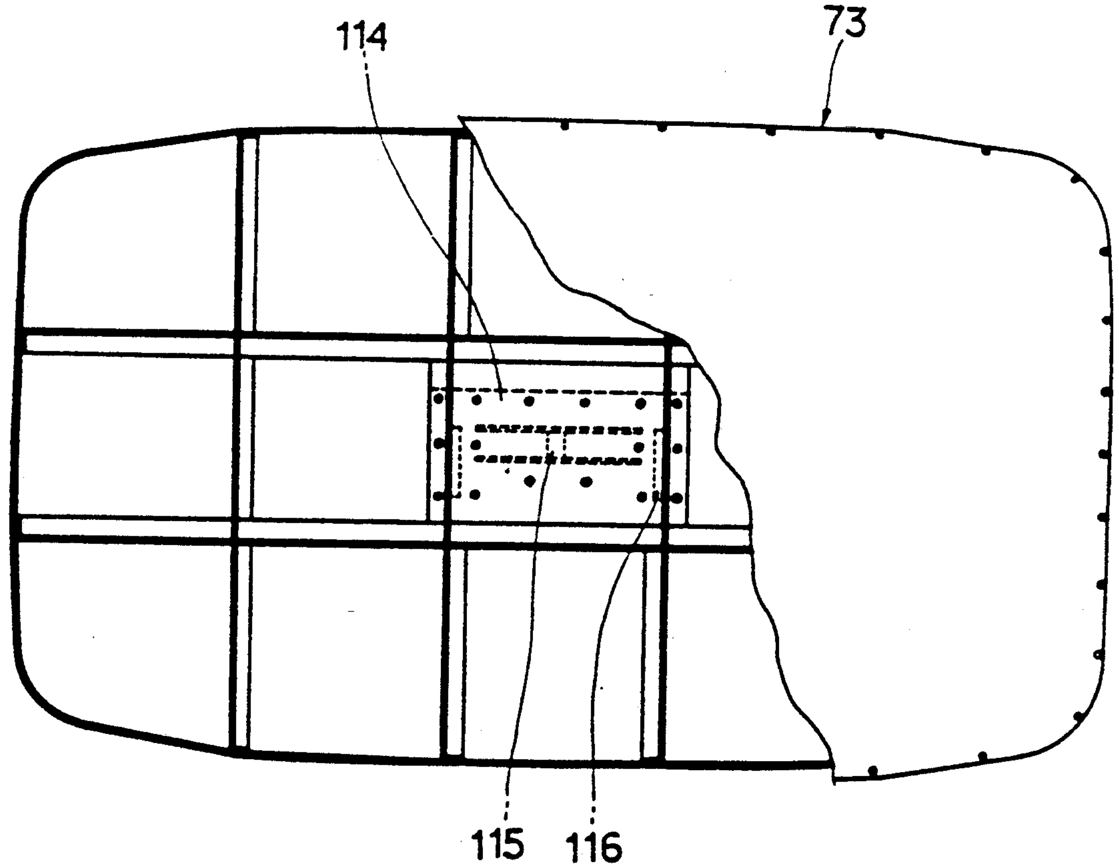


FIG. 15



METHOD AND DEVICE FOR GENERATING ELECTRIC POWER BY USE OF WAVE FORCE

FIELD OF THE INVENTION

The present invention relates to a method and device for generating the electric power using the force of waves produced on the surface of the sea, and particularly to a method and device for generating the electric power by the use of wave force, which is designed to generate the electric energy by making the floatation bladders risen on the surface of the water to rise and fall repeatedly using the difference of heights between the ridges and troughs of waves produced continuously, rotating the pulleys set up in a certain depth under the sea level by means of periodic up and down motion of the floatation bladders, and driving the generators by the power changed in speed through transmission gears.

BACKGROUND OF THE INVENTION

It is well known that the sea has always waves caused by a meteorological action, and such waves vary in size because the height, length, cycle, speed, etc. of waves are changed from time to time, but they have usually a course to advance from the offing toward the seashore.

Accordingly, various proposals and attempts are recently made on a device for generating the electric power by catching and using waves produced repeatedly without interruption with the said wave height, wave length and wave-cycle, and converting them into energy.

There are two kinds of conventional oceanic energy conversion modes: one is designed to make the floatation bladders to rise using the difference between the ebb and flow of the tide, to operate the piston pump, etc. by the rising force to suck the sea water up to a certain height, and then to rotate the turbine for production of electric, power using the head of thus sucked sea water; the other is designed to make the floatation bladders rise by their own rising force at high tide, the sea water to be stored in the floatation bladders at low tide, the floatation bladders to fall under the weight of the sea water, a separate fluid pressure means to be operated, and to obtain the power for generating electricity by a fluid ran out of the fluid pressure means.

However, the above-mentioned conventional device for generating electric power has problems in that it is restricted by the place of installation so that it may be installed only near the inshore contiguous to the sea-shore, and that the overall construction of the device is too complex and incomplete to be put to practical use.

SUMMARY OF THE INVENTION

The principal object of the invention is to provide a method and device for generating electric power by use of wave force, which has not such problems as the conventional method of generating electric power.

It is another object of the invention to provide a method and device for generating electric power, which is designed to apply efficiently not only in the inshore, but also in the deep sea.

It is a further object of the invention to provide a method and device for generating electric power by use of wave force, which is designed to convert efficiently a kinetic energy of waves produced in the inshore and deep sea into an electric energy by means of simple apparatus and easy method of installation.

In one aspect of the invention, the device for generating electric power comprises a supporting means installed in a fixed depth from the sea bottom or mean sea level, a pulley mounted rotatably by the supporting means, a floatation bladder floated on the surface of the sea for rising and falling along the wave-height, a wire rope connected between the floatation bladder and the weight and wound up around the pulley so as to make the pulley rotate according to the up and down movement, and variable transmission gears for converting the rotation force of the said pulley and driving the device for generating electric power or compression pump.

According to the invention composed as described above, it is formed in such structure that the rise and fall of the floatation bladders, which is effected repeatedly along the height of waves produced without cease draws the wire rope and thereby rotates and drives the pulley. Therefore it is possible to simplify the construction of means for generating the power and to make the execution of work simple and easy. Moreover, the rise and fall of the floatation bladders driving the pulley is effected with such short cycle as the moving cycle of waves which are the power sources, the momentum of waves is almost captured for use without failing to catch very small movement of waves, and the pulley is rotated and driven with almost the same magnitude as the momentum of waves. Accordingly it is possible to improve the efficiency of wave utilization.

According to an embodiment of the device for generating electric power by use of wave force, even in a case where many floatation bladders and pulleys are installed in the deep sea, it is of installation structure to be mounted on a frame which is a supporting means rising to a predetermined position under the mean sea level, so that the execution of work is very simple and easy, and it is possible to maintain stably the installing position of the frame at all times independently of the rise and fall of each floatation bladder which is effected continuously.

In another aspect of the invention, the device for generating electric power comprises a rotary column and a generator installed in the fixed depth, from the mean sea level a floatation bladder floated on the surface of the sea for repeating the rise and fall movement, and a chain for transmitting the rise and fall of the floatation bladder to the generator.

According to the invention composed as described above, the floatation bladders rise and fall by waves advancing continuously and repeatedly on the surface of the sea, and the rise and fall movement is transmitted through the rope and chain to a chain pulley connected to the driving shaft gear of transmission and the chain to drive the generator by variable rotation force, so that it is possible not only to reduce the unit cost of electric power by simplifying the construction of power generating means, but also to convert a kinetic energy of waves into an electric energy with the loss of energy minimized by transmitting efficiently the kinetic energy of waves to the generator.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments and operational effects of the invention will now be described in more detail, by way of example, with reference to the accompanying drawings. In the drawings,

FIG. 1 is a side view illustrating an embodiment of the invention,

FIG. 2 is a side view illustrating another embodiment of the invention,

FIG. 3 is a partial side view illustrating further embodiment of the invention,

FIG. 4 is a partial plan view of FIG. 3,

FIG. 5 is a diagram illustrating the construction of the electric motor and the device for generating electric power according to the invention,

FIG. 6 is a diagram illustrating another method of generating electric power according to the invention,

FIG. 7 is a partial elevation view illustrating another embodiment of the invention,

FIG. 8 is a partial enlarged view of FIG. 7,

FIG. 9 is a plan view illustrating a combination of many devices of FIG. 7,

FIG. 10 is a disassembled perspective view showing the part B of FIG. 9,

FIG. 11 is a sectional view taken along the line A—A in FIG. 8,

FIG. 12 is an enlarged view showing the part A of FIG. 8′

FIG. 13 is an elevation view illustrating the connection between the floatation bladder and the rope,

FIG. 14 is a longitudinal sectional view of the floatation bladder,

FIG. 15 is a plan view of partial cut-off floatation bladder.

DETAILED DESCRIPTION OF THE INVENTION

As is shown in FIG. 1 which illustrates an embodiment wherein the device for generating electric power by use of wave force according to the method of the invention is installed in the inshore having a depth of about 9–15 m, a concrete base **1** is laid under the sea bed, a supporting framework **2** having a fixed height is installed on the upper side of the concrete base **1**, and a support member **3** secured to an upper part of the supporting framework **2** is provided with a pulley **4** which is located in a depth of about 3–4 m under the mean sea level.

Subsequently, a floatation bladder **5** having a required buoyant force (approximately 1–3 tons) is floated on the surface of the sea, and the floatation bladder **5** is connected at the middle of its bottom to an end of a wire rope **6** having a fixed length, and after winding one time round the said pulley **4**, the extended end of the wire rope **6** is connected and fixed to a weight **7** (about 200–500 kg).

The bottom of each floatation bladder **5** rising on the surface of the sea is connected to one end of two other anchor ropes **8** (only one is shown in the drawing) and the other end of each anchor rope **8** is connected and fixed to anchors **9** (only one is shown in the drawing) secured in a space to the front side of the supporting framework **2** on which the said pulley **4** is mounted, that is, to both sides of the sea bottom in the main advancing direction of waves as shown by the arrow, so that the floatation bladders **5** rising on the surface of the sea do not move horizontally according to the advancing direction of waves, but operate only in the up and down direction.

When anchors are installed, it is preferable to locate the position of anchors **9** in which each rope **8** is secured, one both sides in a distance equivalent to about 1.2–1.5 times of the depth (9–15 m) from the supporting framework **2** on which the said pulley **4** is mounted, and to maintain the angle between both anchor ropes **8** with the connecting part of floatation bladders **5** as a center in about 30°–40°.

The mounted pulley **4** is designed to rotate counterclockwise and clockwise as the up and down movements of floatation bladders **5** are repeated. According to the invention the power is generated using the rotation force of pulley **4** produced when the floatation bladder **5** obtains an upward bouyant force.

FIG. **5** shows an example of the power transmission process according to the rotation of pulley **4** as described above, in which on the other upper part of the supporting framework **2** on which the said pulley **4** is mounted, are mounted the transmission **30** and the electric generator **40**, respectively, and the edge of input shaft **31** passing outward through one side wall of the transmission **30** and the edge of the rotary shaft **4***a* of pulley **4** are connected by a motor-operated clutch **32**.

At the end of input shaft **31** located in the interior of the transmission **30** is mounted an input gear **33**, which is engaged with a one-way gear **34** designed to rotate only when the said pulley **4** and the input gear **33** rotate by the rising force of the floatation bladder **5**, and at the other end of the shaft **34***a* on which the one-way gear **34** is mounted, the first interlocking gear **34′** is mounted. On the other hand, the other side wall of the transmission **30** is provided with an output shaft **38***a*, and the second, third and fourth interlocking gears **35**, **35′**; **36**, **36′**; **37**, **37′** for changing the rotation force and speed of the said pulley **4** so as to become such one as required for driving of the electric generator **40** are mounted one after another between the output gear **38** secured to the interior end of the output shaft **38***a* and the said first interlocking gear **34′**. Furthermore, the exterior end of the output shaft **38***a* of the said transmission **30** is connected to the end of the driving shaft **41** of the electric generator **40** through the motor-operated clutch **42** so that the electric generator **40** is driven directly by the rotation force increased through the said transmission **30** to generate electric power.

However, according to the said device for generating electric power, or in other words, according to a device generating electric power which is, according to the invention, designed to generate the power using the rotation force of the pulley **4** produced by the upward bouyant force of the floatation bladders **5**, and to be transmitted the power through the one-way gear **34** of the transmission **30**, the driving force necessary for generating the electric power is transmitted not continuously but intermittently, and accordingly the electric power produced by the electric generator **40** is also output intermittently. Therefore, the electric power is first stored in a storage battery **50**, and in a case of need, it is possible to use the electric power charged in the storage battery **50**.

The aforementioned embodiment is to output in increased speed the power generated according to the invention through the output shaft **38***a* of transmission **30**, to drive thereby directly the electric generator **40**, and to generate the electricity. However, the invention may be applied to any ordinary mode for generating electric power in which as illustrated in FIG. **6**, a piston pump **60** is driven by the power transmitted to the output shaft **38***a* of transmission, and the sea water is pressed out to and stored in a dam or reservoir constructed at the seashore by means of the sucking and compressing action of the piston **61** so as to use the head of stored sea water. Moreover, the invention is not limited to the above-described embodiments, but it is possible to adopt other modes of generating electric power as applied according to the principles of the invention.

FIG. 2 shows another embodiment in which the device for generating electric power according to the invention is installed in the vicinity of the inshore as described above. According to the embodiment, a supporting pole **11** is erected vertically on the concrete base **1** laid under the sea bed of the sea bottom, and on the top of the pole **11** is mounted a pulley **4** as described above, and the pulley **4** is located in depth of about 1 m under the mean sea level so as to rotate freely in any direction from the pole **11** as a center.

One end of an operation lever **12** having a fixed length (about 5 m) is secured to the rotary shaft **4a** in which the pulley **4** is fitted as described above, and the other end is connected to the floatation bladder **5** rising on the surface of the sea by a wire rope **13** having short length (about 1 m).

The support of rotary shaft **4a** is rotatably coupled to pole **11**, illustrated in FIG. 2 by inserting the support into the cavity of the pole frame. Accordingly the floatation bladder **5** can rotate round the pole **11** with a fixed radius having the pole **11** as a center in the advancing direction of waves and to be repeated only the rise and fall in the upward and downward direction along the height of waves in a state located in the opposite direction of the advancing side of waves. The operation lever **12** connected to the rotary shaft **4a** of the pulley **4** is travelled upward and downward with the rotary shaft **4a** as a center, and the pulley **4** is also rotated clockwise and counterclockwise, and it is thereby possible to obtain the power to drive the transmission **30** and the electric generator **40** or the piston pump **6**, as described above.

FIG. 3 and FIG. 4 show further embodiments in which the device for generating electric power according to the invention is installed in the deep sea having depth of about 150–120 m.

The reference number **20** in the drawings represents a frame installed in a fixed depth (about 9–10 m) under the mean sea level for mounting the floatation bladder **5** and pulley **4** as described above. The frame **20** comprises a plurality of hollow support pipes **21, 21'** of a predetermined dimension which are arranged in a form of lattice with a certain space on the same plane. On the frame **20** are mounted a plurality of floatation bladders **5** and pulleys **4** having such construction as described in the first embodiment by means of respective supporting framework **2**.

The frame **20** is located always in a proper position under the surface of the sea, in other words, in the depth of about 9–10 m under the mean sea level by the buoyant force of the hollow formed interior of each supporting pipe **21, 21'** connected longitudinally and latitudinally to each other and the air bladder **22** mounted in a fixed position on the supporting pipes **21, 21'** and rising on the surface of the sea.

It is practicable by making the entire load applied to the frame **20** to be equal to the total buoyant force acting by the sum of the self-buoyant force of the hollows of each supporting pipes **21, 21'** and the buoyant force of the air bladders **22**.

In the plane space between supporting pipes **21, 21'** arranged with a certain space as described above, is mounted at one side a rectangular load box **23** of a fixed dimension open to the bottom so that the frame **20** is prevented from floating upward and downward as a whole due to a force acting at the time when each floatation bladder **5** on the top of the wire rope **6** wound around the pulley **4** located in the upper part rises following the waveheight.

On the other hand, a frame **20** is mounted in such way that the frame **20** and the anchor **9** secured to the sea bed of sea bottom are connected each other by an anchor rope **8** or chain so that the frame **20** is prevented from a horizontal travelling beyond a certain distance by the force of waves, and is movable along the advancing direction of waves in the limit of the radius of the anchor rope **8**.

Since each floatation bladder **5** connected to the said pulley **4** via the wire rope **6** is connected by other wire ropes **24, 24'** one end of which is fixed to the supporting framework **2**, a rising and falling movement of the floatation bladder **5** according to the difference of waveheights can be obtained without a horizontal travelling beyond a certain distance in the advancing direction of waves, and on the rotary shaft **4a** of each pulley **4** are mounted the transmission **30** and electric generator **40**, respectively, so as to generate the required electric power.

The device of the invention with such construction as described in the above-mentioned embodiments, must be installed in such way that a plurality of floatation bladders **5**, pulleys **4** and load boxes **23** are mounted on the frame **20**, and the frame **20** is mounted so as to maintain always, a state parallel to the mean sea level in the fixed depth under the mean sea level by means of the selfbuoyant force of each supporting pipes **21, 21'** and air bladder **22**, and thus mounted frame **20** is not allowed to rise together with each floatation bladder **5** when this is rising. To this end, the frame **20** of the device according to the invention is provided with a rectangular load box **23** open to the bottom as described above so as to have a controlling force corresponding to the rising force of each floatation bladder **5**. A detailed example thereof will now be described.

In a case where a frame **20** is made by 32 m$\times$64 m in size and 2048 m^2 (4 m$\times$8 m) in the total surface area, it is possible to install about sixty floatation bladders **5** on a frame **20**.

Considering that the buoyant force B of one floatation bladder **5** is about two tons, and the time in which the rising force acts on each floatation bladder **5** is 3–7 seconds, it is required that the frame **20** is not moved upwards within such time.

Accordingly when the load box **23** installed under the bottom of each floatation bladder **5** is made by 4 m in width, 4 m in length and 1 m in height, and its specific weight is 1 ton, the full load G of the load box **23** amounts to 16 tons ($4\times4\times1\times1$), that is,

$$B{:}2 \text{ tons} > G{:}16 \text{ tons}$$

Wherein the upward buoyant force B acting through each floatation bladder **5** is 2 tons, while the full load of each load box **23** is 16 tons so that the frame **20** is not travelled by the rising action of each floatation bladder **5**, but maintained stably at the horizontal degree in a certain depth under the mean sea level. Moreover, since each floatation bladder **5** is not operated at the same time depending on the difference of deformation cycles of waves, the installing condition of the frame **20** is to be maintained at all times parallel to the mean sea level regardless of the rise and fall of the floatation bladder **5**.

As is shown in FIG. 7, which is a partial elevation view showing a state that a device for generating electric power by use of wave force according to another embodiment of the invention is installed in the sea, and in FIG. 8, which is a partial enlarged-scale view of FIG. 7, the four corners of the lattice-formed frame **71** installed in a fixed depth (about 10 m) in the sea are connected to and supported by the anchor **79** fixed on the sea bed through a rope **82**, and four air pockets **80** per compartment are mounted on the lattice-formed frame **71** of the rotary column **72** in such manner that the buoyant force acting to the air pockets **80** comes to 1.2 times of the total underwater weight represented by a compartment, and the whole device is not swayed or shaken by a little ocean current of the sea bed without appling an excessive force to the rope **82** connected to the said anchor **79**.

The rotary column **72** is supported and fixed rotatably at its lower part by four I-form beams secured to the frame **71**. The upper part of the rotary column **72** is formed of H-form beam, while the lower part is formed of a cylindrical tube. The top 72A of the rotary column **72** is connected to the floatation bladder **73** located on the surface of the sea by the rope **81**, and in the middle of the rotary column **72**, an upper arm **84** provided with the pulley **83** and **96** at the top is mounted perpendicular to the rotary column **72**. Referring to FIG. **8** under the said upper arm **84** a lower arm **86** is mounted perpendicular to the rotary column **72**, and between the upper and lower arms **84**, **86** a reinforcing member **87** is mounted in connection with them, and in the middle of the reinforcing member **87** a supporting member **88** is mounted perpendicular to the reinforcing member **87**.

On the front edge of the supporting member **88** is mounted a rotary shaft **89** of the first sprocket **85** in which the oneway clutch (bearing **103** FIG. **11**) is interposed, and at the extension of the rotary shaft **89** is mounted the second sprocket **99** which is connected to the third sprocket **100** mounted on the input shaft **77** of the transmission through the chain **102**. The chain **102** wound between the second and third sprockets **99**, **100** is constructed in such a way that the tension is regulated by the tension sprocket **101** mounted movably on the lower arm **86**.

The stand **92** of the transmission and the electric generator **91** located under the lower arm **86** and mounted perpendicular to the rotary column **72** is connected at its front edge to one end of the upper arm **84** via the turnbuckle **93** and the tie rod **94**.

Referring back to FIG. 7, the rope **74** connected to the bottom of the floatation bladder **73** located on the surface of the sea and extended in vertical direction is connected to the chain **75** above the pulley **83**, and the chain **75** passes between the pulleys **83**, **96** and winds round the first sprocket **85** and then connected to the plumb 78 having a predetermined weight (about 300 kg) through the pulley **97** mounted at the front edge of the lower arm **86**.

According to such construction, when the floatation bladder **73** is in the rise and fall motion, the rise and fall is transmitted to the first sprocket **85** via the rope **74** and chain **75** and rotates the first sprocket **85** clockwise and counterclockwise, but the second sprocket **99** rotates only when an upward buoyant force acts on the floatation bladder 73, by means of the one-way clutch bearing **103** inserted in the first sprocket **99** In other words, the second sprocket **99** rotates intermittently in one way, and accordingly the third sprocket **100** mounted on the input shaft **77** of the transmission and the electric generator **91** rotate also intermittently to drive the electric generator intermittently.

FIG. **12** is a detailed view illustrating the connecting condition between H-form beam **105** forming the upper part of the rotary column **72** and the lower cylindrical tube **104**, in which the upper flange **106** and lower flange **107** of the top of the cylindrical tube **104** are connected to each other by four ribs **108** formed around the cylindrical tube **104**, and on the surface of the upper flange **106** is welded the lower end of H-form beam **105**. The bottom of the lower flange **107** and the upper part of the cylindrical tube **104** are contacted with and supported by rotatably the upper surface and inner surface of a packing **109** such as teflon, respectively, and at the same time the peripheral surface of such packing **109** is enclosed by a cylindrical hollow steel pipe **110**. The lower end of the rotary column **72** is inserted and secured rotatably in a cylindrical (FIG. **8**) formed on the supporting member **111** (FIG. **8**) welded in the middle of four I-form beams supporting the rotary column **72**. On the periphery of the part in which the cylindrical tube **104** is inserted, in other words, on the inside of the fixture **112** is formed a packing so as to make a smooth rotation of the rotary column **72**.

As is shown in FIG. **11** the second sprocket **99** is mounted on the rotary shaft **89** of the first sprocket **85** in which the one-way clutch bearing **103** is interposed. Consequently, even when the first sprocket **85** rotates clockwise and counterclockwise by the rise and fall of the floatation bladder **73**, only the rotation force produced at the moment the upward buoyant force acts on the floatation bladder **73**, is transmitted to the second sprocket **99**. In other words, when the floatation bladder **73** falls, the first sprocket **85** is out of gear and accordingly the second sprocket **99** is not rotated.

As is shown in FIG. **9**, which is a partial plan view of the device for generating electric power by use of wave force according to the present embodiment, each frame **71** having one floatation bladder **73** forms as a whole a lattice-form arrangement connected to adjacent frames in all directions on the same plane. In other words, in a fixed position on the frame **71** extended in all directions with the rotary column **72** on the frame **71** as a center is mounted an air pocket **80**, so as to provide the frame **71** with the upward buoyant force, and each front edge of the frame **71** is couple with the adjacent frame by a wedge **82** and U-form bolt **83** as shown in FIG. **10**.

As is shown in FIG. **14**, which is a longitudinal sectional view of the floatation bladder **73**, and in FIG. **15**, which is a partially cutout plan view of the floatation bladder **73**, is coupled by bolt with a packing interposed so that the inner part of the floatation bladder is sea-led completely to prevent the sea water from infiltrating into it.

As is shown in FIG. **13** and FIG. **15**, in the middle of the bottom of floatation bladder **73** is attached by bolts a rectangular plate **114** for connecting the ropes, and in the middle of the plate **114** are formed on both sides the first coupling member **115** for coupling with the rope **74** connected to the chain **75** and two second coupling members **116** for coupling with the rope **81** connected to the front edge **72A** of the rotary column **72**. The first coupling member **115** and the second coupling members **116** are connected to ropes **74** and **81** through shackles **117**, and the rope **81** connected to the front edge **72A** of the rotary column **72** is divided into two ropes at the lower part of the floatation bladder **73** and each rope is connected to the second coupling members **116**, respectively. Accordingly, the floatation bladder **73** on the surface of the sea remains at all times in the line of apsides perpendicular to the direction of the wind by means of the rope **74** extended downward vertically from the first coupling member **115** on the bottom and the rope **81** connected to the front edge **72A** of the rotary column **72** from the second coupling member **116**.

In other words, all floatation bladders **73** located on the surface of the sea are arranged in the line of apsides perpendicular to the advancing direction of waves.

As described above, the power is transmitted to the transmission and the electric generator **91** only when the upward buoyant force acts on the floatation bladder **73**, and accordingly the electricity produced out of the electric generator is also output intermittently. Therefore the electricity is stored first in the storage battery and when needed, it is possible to use the electricity charged, in the storage battery. At this moment the casing **91A** in which the transmission and the electric generator **91** are contained, is sealed completely and filled; with the compressed air so as to maintain in the interior of the casing **91A** the pressure equivalent to 1.2 times of the hydraulic pressure applied to the water depth, and the sea water is thereby prevented from infiltrating the casing **91A** of the said transmission and the electric generator **91**.

According to this embodiment, it is designed to output the power produced according to the invention with the speed increased through the transmission, and thereby to drive directly the electric generator to generate the electricity, but in embodying the invention, it is also possible to drive the piston pump or air compressor with the power transmitted to the output side of the transmission and thereby to convert it into a power utilizable actually for the human life.

As described above, this embodiment is designed to obtain the required power using the floatation bladder **73** rising and falling repeatedly without interruption with waves as power source and the rotation force of gears connected to the floatation bladder **73** through the rope **74**. Therefore it is possible to simplify the construction of the means for generating power and the supporting means thereof and to make the execution of work simple and easy. Moreover, since the floatation bladder **73** is almost restrained from moving transversely by two ropes without regard to the magnitude of waves, and the line of apsides of the floatation bladder **73** is always perpendicular to the advancing direction of waves, it is possible to convert efficiently the kinetic energy of waves into an electric energy.

Particularly, even in a case where the device of the above-described embodiment is installed in the deep sea, the base frame supporting it is not installed on the sea bottom, but in a fixed depth under the surface of the sea, and in such a state, it is possible to maintain stably at all times the location of installation and thereby to provide advantages that the maintenance and repair as well as the work of installation are easy.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims in the invention may be practices otherwise than as specifically described.

What is claimed is:

1. A device for generating electric power from waves on a surface of a body of water, comprising:
- a lattice-shaped frame;
- a rotary column mounted on said frame;
- a floatation bladder floating up-and-down on the water surface in response to rise and fall motion of the waves;
- means for transmitting the up-and-down motion of the floatation bladder to a transducer, including a chain coupled to said floatation bladder and a plurality of sprockets being coupled to said rotary column and rotating in gear with the chain; and
- means for maintaining said frame at a predetermined depth under mean water level.

2. A device as in claim **1**, wherein said rotary column is installed rotatably in the advancing direction of the waves, wherein the rotary column and the floatation bladder are connected to each other through a rope so as to maintain the floatation bladder at a distance measured perpendicular to the advancing direction of waves.

3. A device as in claim **1**, wherein said means for maintaining said frame at a predetermined depth comprises a plurality of air pockets for providing a buoyant force of substantially 1.2 times the total underwater weight of said device.

* * * * *

US 20050121915A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0121915 A1**

Leijon et al. (43) **Pub. Date: Jun. 9, 2005**

(54) **WAVE-POWER UNIT AND PLANT FOR THE PRODUCTION OF ELECTRIC POWER AND A METHOD OF GENERATING ELECTRIC POWER**

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(21) Appl. No.: **10/501,068**

(22) PCT Filed: **Dec. 19, 2002**

(86) PCT No.: **PCT/SE02/02404**

(30) **Foreign Application Priority Data**

Jan. 10, 2002 (SE) 0200066-9
Feb. 28, 2002 (SE) 0200613-8

Publication Classification

(51) **Int. Cl.**^{7} **H02P 9/04**; F03B 13/10; F03B 13/12

(52) **U.S. Cl.** **290/42**

(57) **ABSTRACT**

A wave-power unit has a floating body and a rotating electric generator mechanically connected to the floating body. A mechanical movement transmitter is arranged for transmission of vertical movements of the floating body to rotary movements of the generator rotor. A wave-power plant employs a plurality of wave-power units. Use of the wave-power unit and a method of generating electric energy as described.

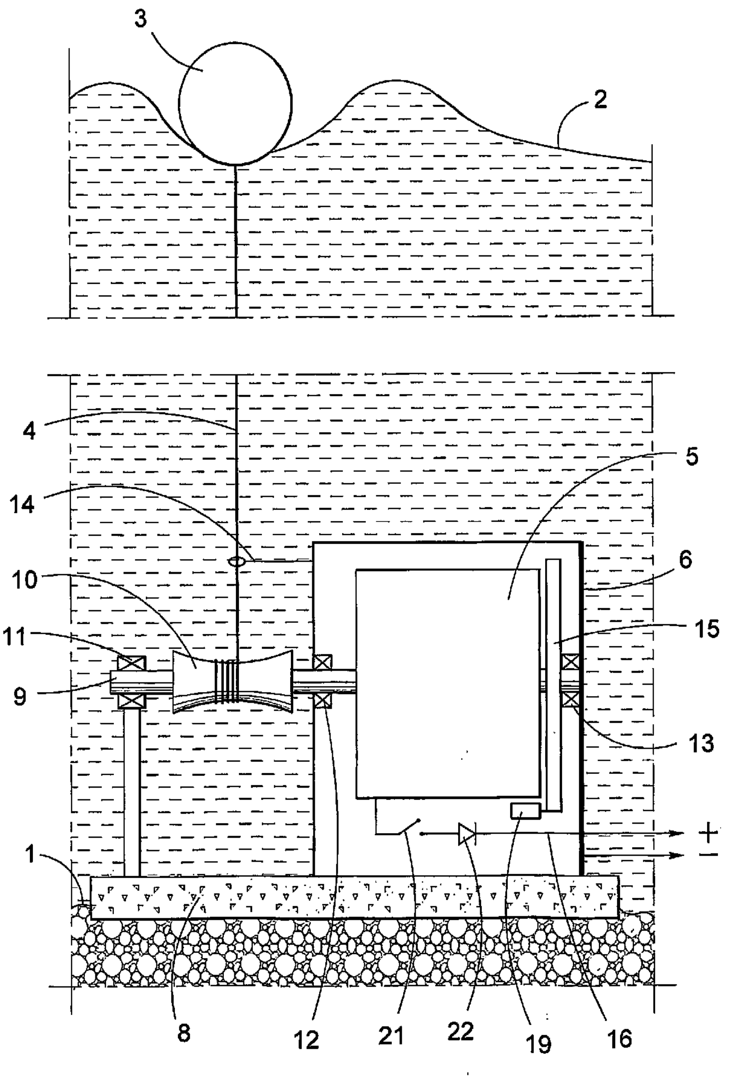


Fig. 1

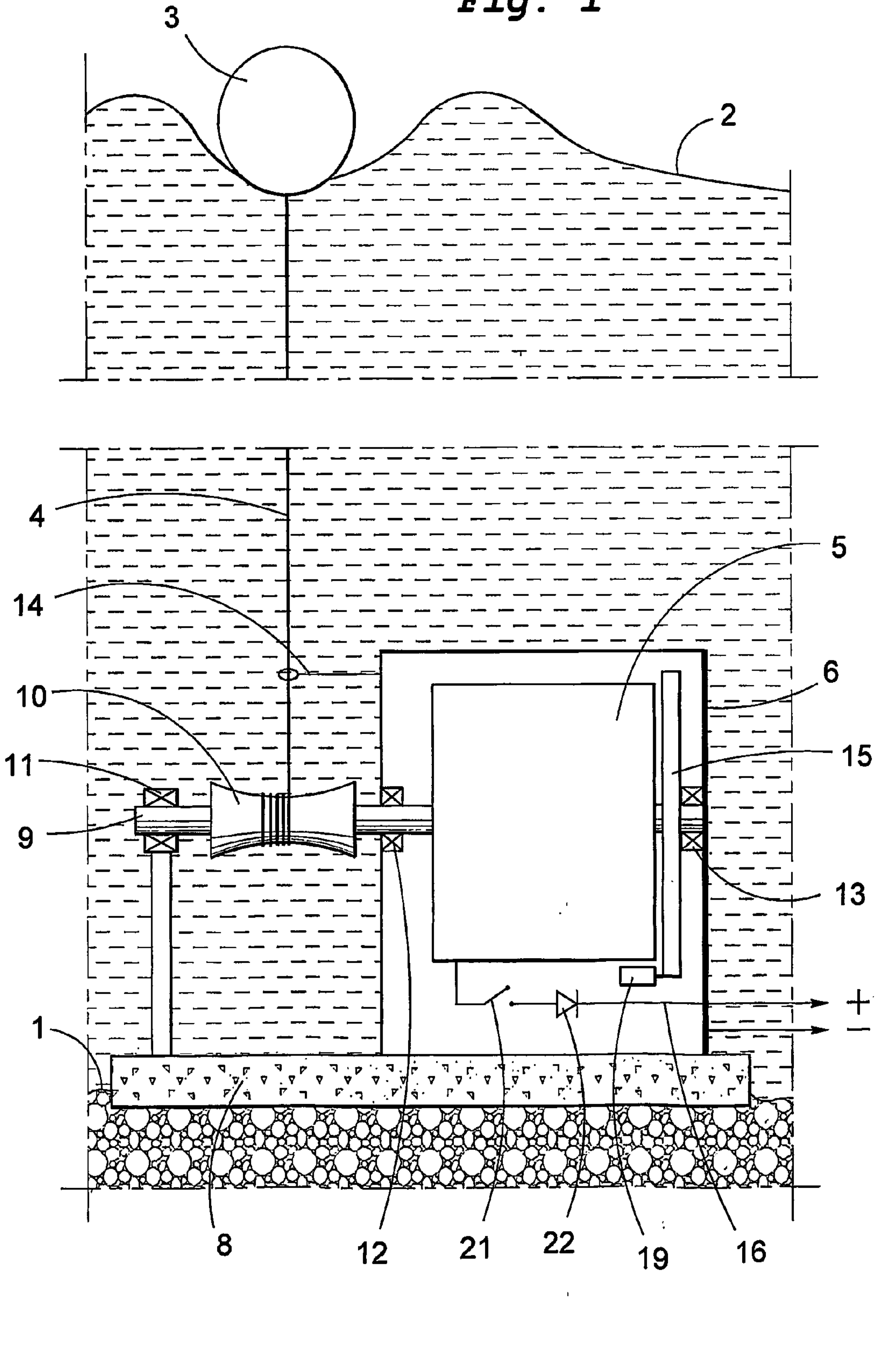


Fig. 2

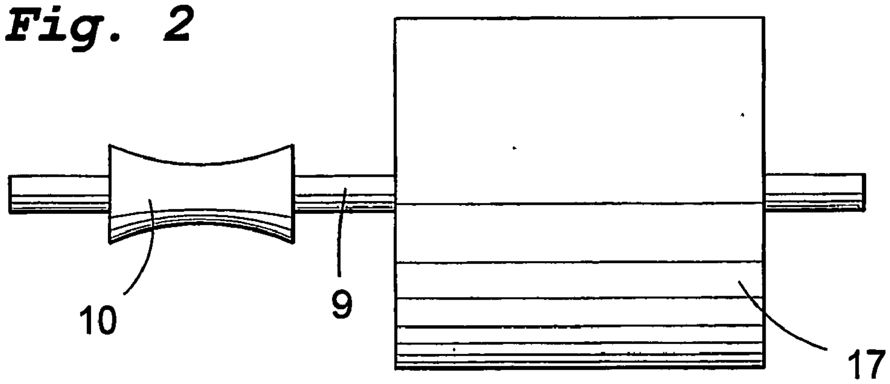


Fig. 3

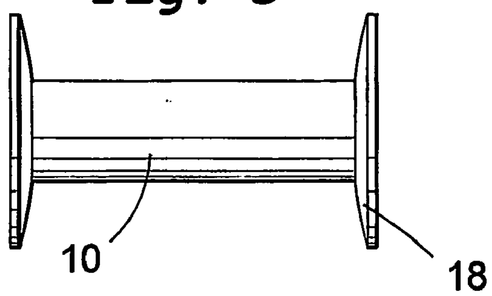


Fig. 4

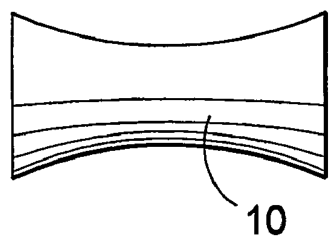


Fig. 5a

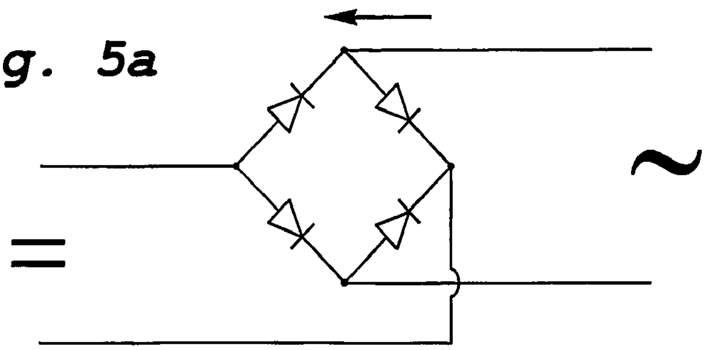
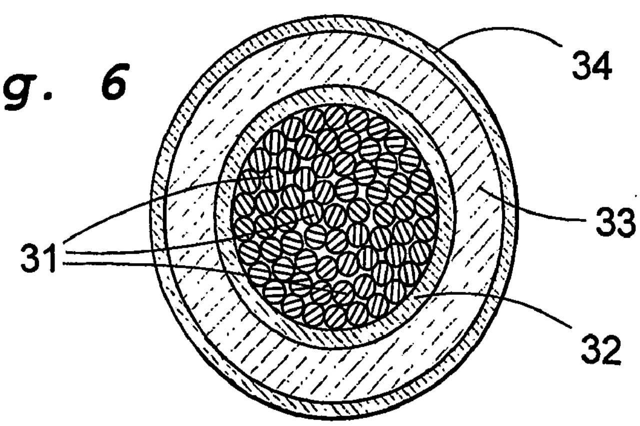


Fig. 6



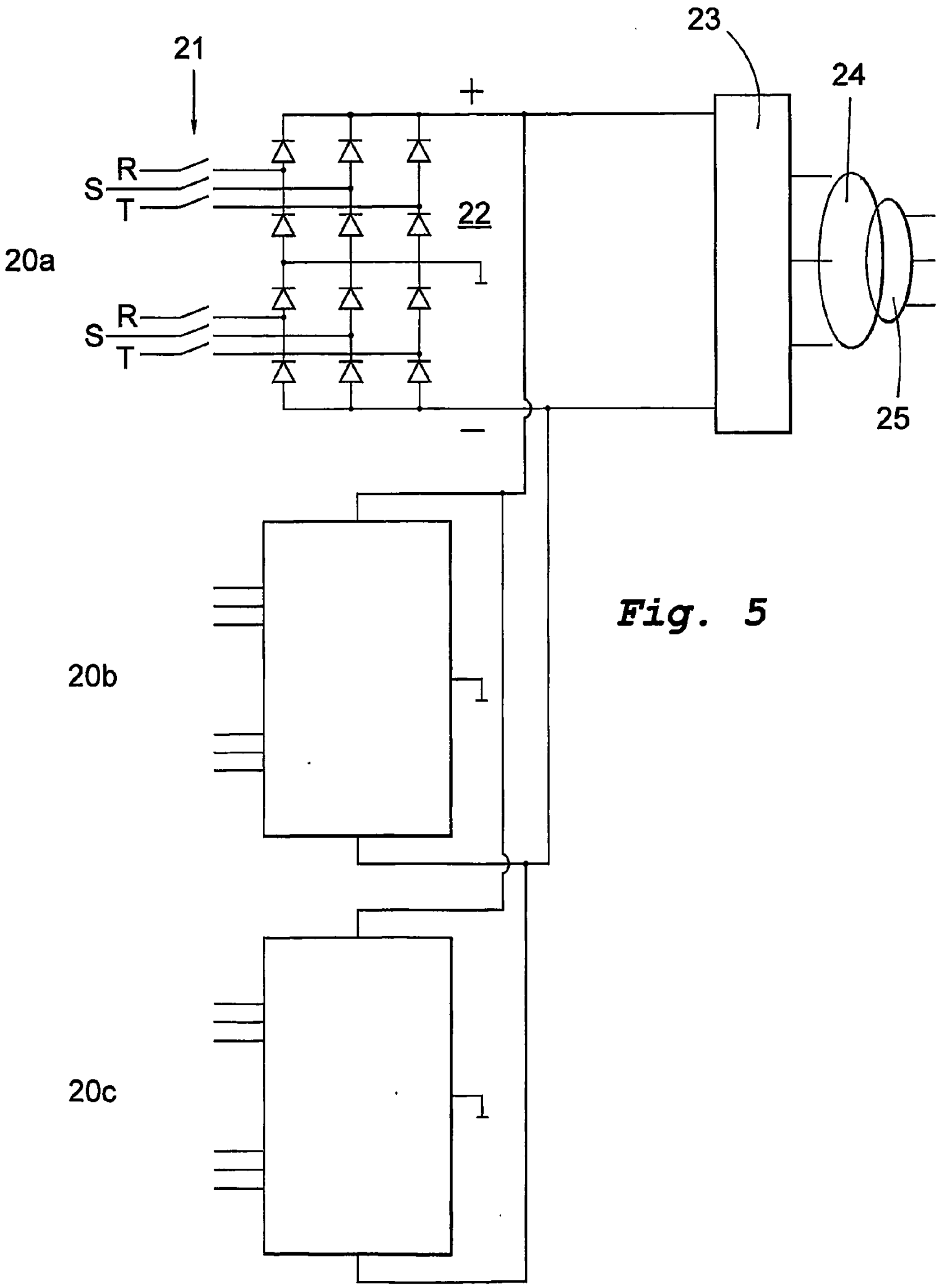


Fig. 5

Fig. 7

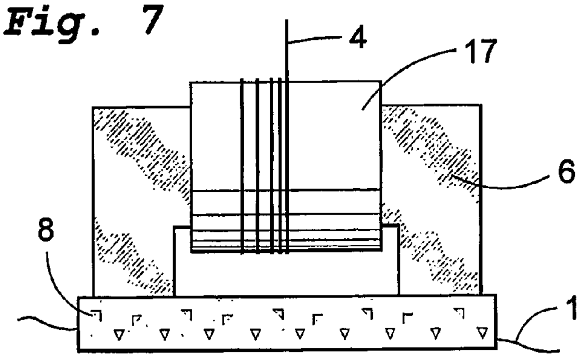


Fig. 8

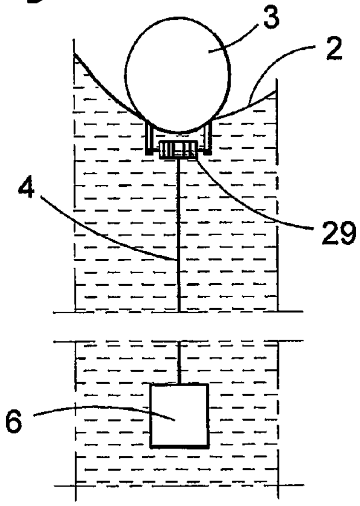


Fig. 9

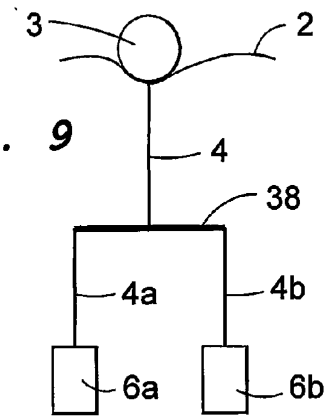


Fig. 10

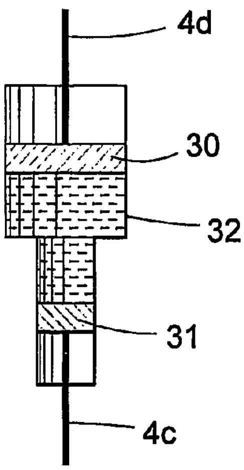


Fig. 11

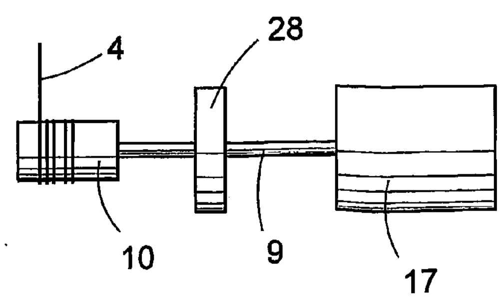


Fig. 12

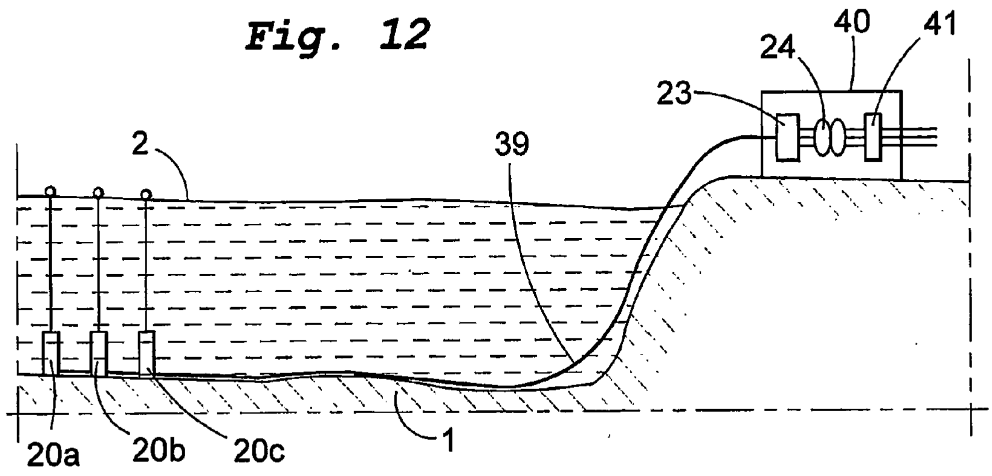

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Fig. 13

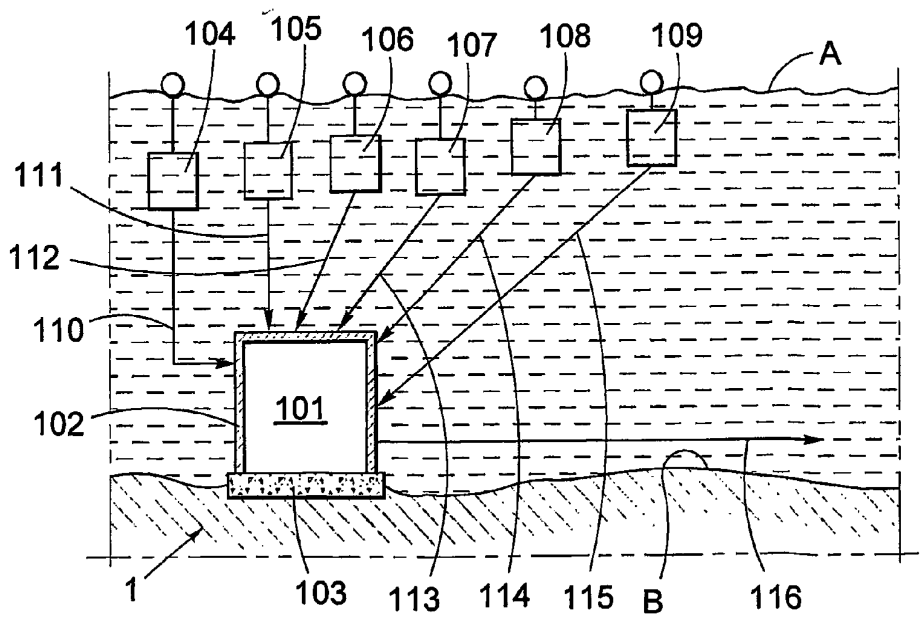
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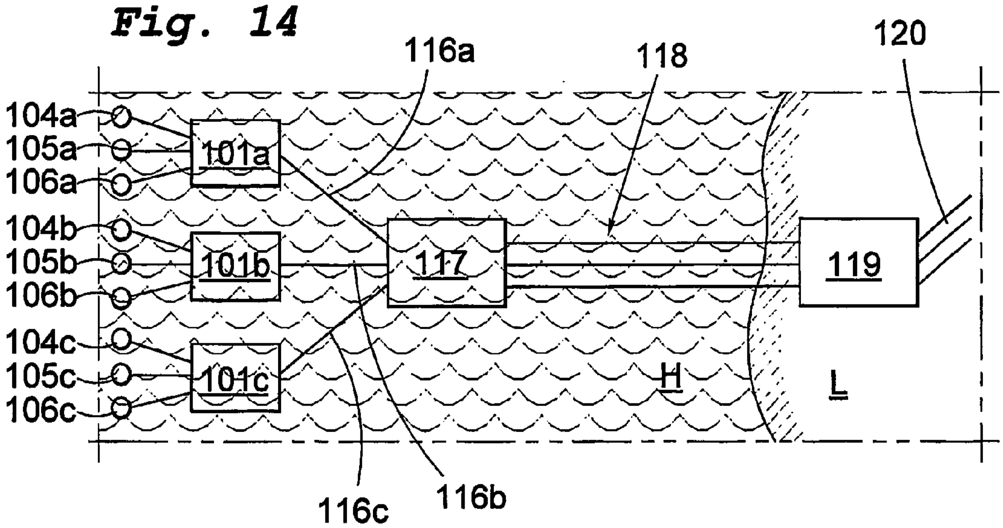
Fig. 14



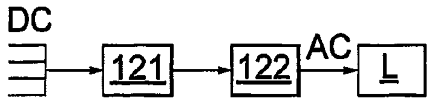


Fig. 15

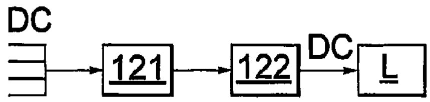


Fig. 16

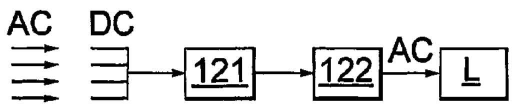


Fig. 17

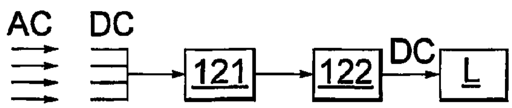
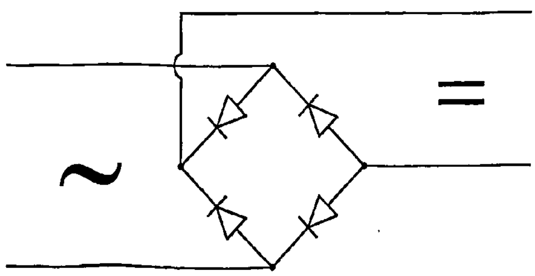


Fig. 18

Fig. 19



WAVE-POWER UNIT AND PLANT FOR THE PRODUCTION OF ELECTRIC POWER AND A METHOD OF GENERATING ELECTRIC POWER

TECHNICAL FIELD

[0001] A first aspect of the present invention relates to a wave-power unit for the production of electric power, comprising a floating body and a rotating electric generator connected to the floating body.

[0002] A second aspect of the invention relates to a wave-power plant comprising a plurality of wave-power units in accordance with the invention.

[0003] A third aspect of the invention relates to the use of the claimed wave-power unit for producing electric current.

[0004] A fourth aspect of the invention, finally relates to a method of generating electric power by mechanically connecting a floating body to an electric generator.

[0005] The wave-power unit in accordance with the invention is primarily intended for, but not limited to, applications up to 500 kW.

BACKGROUND ART

[0006] Wave movement in the sea and in large inland lakes constitutes a potential source of energy that has scarcely been exploited so far. The available wave energy is dependent on the height of the waves, and naturally differs in different locations. The average wave energy during a year is dependent on the various wind conditions, which are greatly influenced by the distance of the location from the nearest coast. Measurements have been carried out in the North Sea, for instance. At one measuring point approximately 100 km west of the coast of Jylland, Denmark, where the depth was about 50 m, wave heights were measured over a long period of time and the available energy was calculated. The following table was obtained:

Height of wave m	Wave period sec.	Output kW/m	Hours/Year
<0.5	—	—	966
1	4	2	4103
2	5	12	1982
3	6	32	944
4	7	66	445
5	8	115	211
>5.5		>145	119

[0007] Thus, during slightly less than half the time the height of the waves is about 1 m, producing an output of 2 kW/m. However, the most energy is available from wave heights in the region of 2-5 meter, taking into consideration that the output increases greatly with increased wave height.

[0008] Various types of wave-power units have been proposed to utilize the energy available from the wave movement in the ocean for generating electric power. However, these have been unsuccessful in competing with conventional production of electric power. Wave-power plants realized so far have been primarily experimental plants or have been used to supply power locally for navigation buoys. If commercial production of electricity is to be possible, thus providing access to the vast reserve of energy in the movement of ocean waves, is it not only necessary to place the units in suitable spots, it is also necessary for the unit to be reliable in operation, highly efficient and low in manufacturing and running costs.

[0009] Many of the known devices for generating electric power from wave energy are based on principles according to which water is pumped or air compressed in order to drive a generator turbine. Several links are thus involved in the energy conversion process, which affects the total efficiency negatively. Such units are also complicated, and thus expensive.

[0010] It is also already known to use an electric linear generator which is directly connected to a floating body. This avoids many of the drawbacks mentioned above.

[0011] From certain aspects, however, a rotating generator offers advantages over a linear generator.

[0012] Besides the above-mentioned types of units with generators driven by turbines it is also already known to directly transmit the wave movements to a rotating electric generator. However, this is only for supplying energy locally and the output is relatively little. Thus, a light buoy is known through U.S. Pat. No. 5,176,552 that is supplied with energy from the movement of the buoy in the waves. A rotating electric generator is thus arranged inside the light buoy. The rotor of the generator is connected by a cable with a substantially stationary plate located deep down in the water. When the buoy is moved up and down by the waves, the cable causes the rotor to rotate. For several reasons this device is not very suitable for producing electric power to supply an electric supply network of a financially interesting size.

[0013] The object of the present invention is, in the light of the above, to produce a wave-power unit of the relevant type which fulfils the demands for high efficiency, reliable operation and cost effectiveness, and enables the generation of electric power for supply to an electric supply network.

DESCRIPTION OF THE INVENTION

[0014] The objective set has been achieved in accordance with the first aspect of the invention in that the wave-power unit described in the preamble to claim **1** comprises the special feature that a mechanical movement transmitting means is arranged to transmit vertical movements of the floating body to rotary movements of the rotor.

[0015] Thanks to the movement transmitting means a rotary movement is obtained which enables the use of a rotating electric generator. The rotary movement is normally oscillating since the linear movement is to and fro.

[0016] The unit in accordance with the invention thus enables the advantages of a rotating electric generator to be exploited without the intermediate energy conversion steps required by known applications, and this in such a manner that generation of electric power on a larger scale is financially practicable.

[0017] In accordance with a preferred embodiment of the claimed wave-power unit at least the stator of the generator is enclosed in a housing anchored in the sea/lake bed.

[0018] Enclosing the generator or only its stator in a watertight housing means that it is protected from attack by the surrounding salt water or the influence of living organisms in the water such as acorn barnacles. It also enables the use of a relatively simple generator of standard type. Anchoring the generator in the sea bed via the housing fixes the position of the generator in relation to the floating body and enables optimal utilization of the vertical movements of the floating body.

[0019] In accordance with another preferred embodiment the rotor is also enclosed in the housing.

[0020] The whole generator is thus protected from corrosion and the advantages of the enclosure are thus exploited to a greater extent.

[0021] In accordance with yet another preferred embodiment the rotor is situated on the outside of the stator.

[0022] Although a conventional placing with the rotor inside the stator is in most cases preferable, in certain cases the embodiment with the stator outside enables simpler transmission of the linear movement of the floating body to rotary movement of the rotor.

[0023] In accordance with another preferred embodiment the rotor is connected to a turning body, which turning body is connected to the movement transmitting means.

[0024] The turning body enables efficient conversion of the linear movement to rotary movement to be achieved in a very simple way and allows considerable freedom of design to achieve this. It also creates excellent opportunity for achieving an optimal movement pattern of the rotor.

[0025] In accordance with yet another preferred embodiment the turning body is arranged outside the housing.

[0026] The lead-in through the housing for transmitting the movement will therefore be advantageous from the sealing point of view since in this embodiment it can be designed as a lead-in for a rotating, but otherwise stationary, shaft. This entails least sealing problems.

[0027] In accordance with still another preferred embodiment the unit comprises a first gear mechanism effecting a gear change between the movements of the turning body and the rotor.

[0028] Thanks to the gear mechanism the peripheral speed of the rotor can be increased so that the frequency of the induced voltage is increased. This is advantageous since the speed of the linear movement is relatively slight.

[0029] In accordance with a further embodiment of the claimed wave-power unit the movement transmitting means is secured by its upper end to the floating body and by its lower end to the turning body so that at least the lower part of the movement transmitting means consists of a component that can be rolled up, e.g. a cable.

[0030] In such an embodiment the conversion from linear movement in the floating body to rotary movement in the turning body takes place in a structurally simple manner and with slight losses. At the same time such a design permits the conversion to take place directly in both directions, i.e. up/down-clockwise/counter-clockwise. This is because the cable is wound onto or off the turning body. It will be understood that the windable component may naturally be of some other type such as a wire, chain, tape or the line.

[0031] In accordance with a further embodiment the turning body and the rotor are arranged on a common, substantially horizontal shaft.

[0032] Since these two components are arranged on a common shaft the rotary movement is transmitted substantially without losses and the horizontal orientation of the shaft enables easy conversion of the vertical movement of the floating body to the rotary movement of the turning body.

[0033] In accordance with yet another preferred embodiment the turning body has circular cross section and the diameter of the rotor is larger than that of the turning body. It is particularly advantageous for the diameter of the rotor to be several times greater than that of the turning body.

[0034] Thanks to the rotor having a larger diameter than that of the turning body, the peripheral speed is increased without the need for any special extra gear mechanism since the difference in diameter per se constitutes the gear mechanism. Since the linear movement of the floating body takes place at moderate speed, in the order of 0.5-0.8 m/s, an increase is desirable in order to increase the frequency of the induced voltage.

[0035] In accordance with another preferred embodiment the movement transmitting means is secured by its upper end to the floating body and by its lower end to the rotor, at least the lower part of the movement transmitting means consisting of a component that can be rolled up, such as a cable or the like.

[0036] The movement transmitting means can thus be attached directly to the rotor, which may be a practical solution if the rotor is arranged outside the stator. The construction will thus be very simple and have a minimum number of movable parts.

[0037] In accordance with yet another preferred embodiment spring means is arranged to exert a torsional force on the rotor.

[0038] Applying such a spring means allows the movement transmitting means to be of simple design since it is sufficient for it to be unidirectional and is only active during upward movement of the floating body. During this movement the spring is stretched and its stored energy is used to rotary the rotor during the downward movement of the floating body.

[0039] In accordance with a further preferred embodiment the spring rate of the spring means is adjustable.

[0040] The spring can thus be adjusted to suit the wave conditions as regards wave height and velocity so that resonance is achieved between the movement of the floating body and the spring. This minimizes disturbances in the movement and enables current to be induced in a uniform and harmonious manner.

[0041] In accordance with another preferred embodiment the housing is secured to a base plate arranged to rest on the bed of the sea/lake.

[0042] Since the housing is applied on the sea bed the generator will be stable and substantially unaffected by underwater currents. The base plate may have relatively large mass, which also increases stability.

[0043] In accordance with yet another preferred embodiment the length of the movement transmitting means is adjustable.

[0044] This allows, for instance, for adjustment to different levels of the surface of the sea/lake as in the case of tidal waters.

[0045] In accordance with yet another preferred embodiment the housing is filled with a liquid.

[0046] This embodiment is particularly significant if the generator is placed in relatively deep water since the pressure difference would otherwise make it complicated to efficiently seal the housing. If the housing is filled with a liquid of a type less aggressive than salt water, the risk is substantially eliminated of it later penetrating, even with comparatively simple bushings on the housing. The generator is also cooled by the liquid. The liquid should suitably have the same pressure as the surroundings.

[0047] In accordance with yet another preferred embodiment the housing is primarily made of concrete.

[0048] Concrete is the cheapest possible material that could be used in this context. Furthermore, in many cases it is important for the unit to have a high ballast weight and the material costs are then of considerable significance.

[0049] In accordance with yet another preferred embodiment the floating body is connected via the movement transmitting means to a plurality of generators.

[0050] Such duplication or multiplication on the generator side may in certain cases lead to a totally more economic unit since each generator can be an entirely standard unit and, depending on the locality, a suitable number can be connected to one and the same floating body.

[0051] In accordance with yet another preferred embodiment the stator windings are connected to a rectifier. This rectifier is suitably arranged close to the linear generator below the surface of the water.

[0052] In accordance with yet another preferred embodiment the generator is arranged to produce a voltage of varying frequency. This is because, after being rectified, the output signal is a bipolar DC voltage.

[0053] The generator is thus suited to the movement pattern created in the rotor by the wave movements, the speed varying depending on where in a wave cycle the floating body is and on superimposed variations in the movement of the wave surface.

[0054] In accordance with yet another preferred embodiment the movement transmitting means comprises a second gear mechanism to effect a gear change of the vertical movement of the floating body.

[0055] This offers a supplementary or alternative method of increasing the frequency of the induced voltage.

[0056] In accordance with yet another preferred embodiment the unit comprises a free wheel arranged to convert oscillating rotary movement to unidirectional rotary movement.

[0057] Admittedly this embodiment introduces yet another component in the unit. However, it instead offers the advantage of simpler stator winding design and results in a cleaner profile of the induced voltage.

[0058] In accordance with yet another preferred embodiment the stator winding consists of a cable comprising a current conductor, a first semi-conducting layer surrounding the conductor, an insulating layer of solid insulation surrounding the first semi-conducting layer, and a second semi-conducting layer surrounding the insulating layer.

[0059] A winding of this type can endure current of extremely high voltage being induced. The need of a transformer between the generator and the electric supply network to which the power is being supplied can thus be eliminated. This is particularly important in the environment in which the invention is used.

[0060] The advantageous embodiments of the claimed wave-power unit described above are defined in the claims subordinate to claim **1**.

[0061] The claimed wave-power unit is well suited for combination with several similar units to form a wave-power plant. The second aspect of the invention thus relates to such a power plant wherein the stator winding of each wave-power unit is connected via a rectifier to an inverter which is common to a plurality of wave-power units, which inverter is arranged to supply energy to an electric supply network.

[0062] The claimed wave-power plant provides a practically realizable solution for a system to produce electric current on a larger scale using units of the type claimed, thereby exploiting their advantages, and in which the conversion to DC and then AC creates favourable transmission conditions.

[0063] In accordance with a preferred embodiment of the claimed wave-power plant at least one electric switchgear station is connected to the wave-power unit, which switchgear station comprises a watertight container enclosing switchgear components, which container is anchored in the sea bed.

[0064] In order to obtain economic energy production from generator units at sea that utilize wave movement, it is important to effect technical optimization not only of the generator unit but also of the complete system required to transmit the energy from each energy source to an electric network for transmission and distribution. An important aspect here is that the wave-power plant is located some distance off shore, which distance is sometimes considerable.

[0065] Thanks to its connection to a switchgear station so designed, it can be placed close to the generator unit. This minimizes losses and enables the energy from a plurality of wave-power units to be transferred via a simple common cable connected to the electric supply network on land. This offers a comprehensive solution where both the wave-power unit and the switchgear station can be constructed as standard modules using standard components. Besides being economic in both construction and operation, a power plant in accordance with the invention also offers advantages from the environmental aspect since no switchgear buildings need be built in environmentally sensitive coastal areas.

[0066] In accordance with another preferred embodiment the system comprises a plurality of switchgear stations wherein each is connected to a number of wave-power units. Such an embodiment may sometimes be advantageous if the number of units is large.

[0067] In accordance with yet another preferred embodiment each switchgear station is connected to a receiving station arranged on land.

[0068] In accordance with yet another preferred embodiment at least one of the switchgear stations, normally all of them, comprises a step-up transformer. Alternatively, or as well, a step-up transformer is arranged in the intermediate station. Transmitting the energy at an increased voltage level achieves more favourable transmission both from the technical and the financial aspect.

[0069] In accordance with yet another preferred embodiment the switchgear stations and/or the intermediate station comprise(s) a converter. The voltage can thus be favourably transmitted as AC.

[0070] In accordance with yet another preferred embodiment the switchgear stations and/or the intermediate station comprise(s) means for storing energy. The system can then easily adjust the power supplied depending on fluctuations in available power and power required.

[0071] In accordance with yet another preferred embodiment the switchgear stations and/or the intermediate station comprise(s) filtering means for filtering outgoing and/or incoming current and voltage. The voltage supplied by generator units of the type in question may in many cases be unstable and may vary as to frequency and amplitude, as well as containing heterodyne frequencies. The arrangement of filtering means eliminates these defects or at least reduces them so that a clean voltage, free from disturbance, is transmitted to the network.

[0072] In accordance with yet another preferred embodiment the switchgear stations and/or the intermediate station is/are filled with a non-corrosive, buffered liquid. This prevents aggressive salt water from penetrating, and the components in the switchgear and intermediate stations are protected.

[0073] In accordance with yet another preferred embodiment a filter and/or a transformer is/are arranged after the inverter. This ensures that a clean, ideal voltage can be supplied and that it can be conveyed further to a transmission or distribution network with suitably stepped-up voltage.

[0074] In accordance with yet another preferred embodiment the filter and/or transformer is/are arranged on land.

[0075] This offers a more suitable solution from the plant and operating aspects than if these components were to be situated at sea.

[0076] In accordance with yet another preferred embodiment each wave-power unit is connected to the inverter via a cable arranged on or close to the sea or lake bed.

[0077] Since the cable is arranged close to the sea bed there is less risk than otherwise of it causing any disruption to the surroundings or being tampered with.

[0078] The advantageous embodiments of the claimed wave-power plant described above are defined in the subordinate claims to claim **24**.

[0079] In a third aspect of the invention the objective set is achieved by the use of the claimed wave-power unit or the wave-power plant for generating electric power, thereby gaining advantages of the type indicated above.

[0080] The objective set is achieved in a fourth aspect of the invention in that a method of the kind described in the preamble to claim **37** comprises the special measures of enclosing at least the stator of the generator in a watertight housing, anchoring the housing in the sea/lake bed, and arranging mechanical movement transmitting means to transmit vertical movements of the floating body to rotary movements of the generator rotor.

[0081] In accordance with a preferred embodiment the claimed method is utilized while making use of the wave-power unit and the preferred embodiments thereof.

[0082] Advantages are thus gained equivalent to those described above for the wave-power unit and its preferred embodiments.

[0083] In accordance with another preferred embodiment of the claimed method the spring rate is adjusted so that resonance is obtained with the movement of the floating body that is estimated to occur for most of the time.

[0084] In accordance with yet another preferred embodiment the energy generated is conducted to a switchgear station, the components of which are arranged in a watertight container, which container is anchored in the sea bed.

[0085] The preferred embodiments of the claimed method described above are defined in the subordinate claims to claim **37**.

[0086] The invention is described in more detail in the following detailed description of advantageous examples thereof, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0087] **FIG. 1** is a schematic view from the side of a wave-power unit in accordance with the invention.

[0088] **FIG. 2** illustrates the turning body and rotor of a unit in accordance with the invention.

[0089] **FIGS. 3 and 4** show alternative embodiments of the turning body.

[0090] **FIG. 5** is a circuit diagram illustrating how a plurality of units are combined to form a wave-power plant.

[0091] **FIG. 5***a* shows an alternative rectifying example.

[0092] **FIG. 6** is a cross section through a cable in the stator winding in accordance with one embodiment of the invention.

[0093] **FIG. 7** is a schematic view from the side of a generator in accordance with an alternative embodiment of the invention.

[0094] **FIG. 8** shows a view from the side of a component in a unit in accordance with one embodiment of the invention.

[0095] **FIG. 9** is a side view of another alternative embodiment of the unit in accordance with the invention.

[0096] **FIG. 10** is a diagram illustrating another component of a unit in accordance with an embodiment of the invention.

[0097] **FIG. 11** is a diagram illustrating another component.

[0098] **FIG. 12** illustrates how the wave-power unit forms a wave-power plant and how it is connected to an electric supply network.

[0099] **FIG. 13** illustrates a side view of the wave-power unit connected to a switchgear station.

[0100] **FIG. 14** illustrates an alternative method of connecting the wave-power unit to a supply network.

[0101] **FIGS. 15-18** are charts illustrating various examples of converting the voltage in a power plant in accordance with the invention.

[0102] **FIG. 19** illustrates an alternative rectifying example.

[0103] **FIG. 1** shows a side view of a wave-power unit in accordance with the invention. A floating body **3** is arranged to float on the surface **2** of the ocean. An electric synchronous generator **5** with permanent magnet rotor is anchored via a base plate **8** secured in the sea bed. The generator **5** is arranged in a liquid-tight housing for by the base plate **8** and a cover **6**. The housing is proof against salt water and watertight. It may possibly be filled with a gas or a liquid. The rotor shaft **9** of the generator **5** extends out through a sealed lead-in in one wall of the housing. A turning body **10** is fixed to the protruding part of the rotor shaft **9**. The turning body **10** is in the form of a circular cylinder with concave envelope surface. The shaft is rotatably supported by a first bearing **11** arranged at the side of the turning body **10** facing away from the housing, and a second bearing **12** and third bearing **13** arranged at each side of the housing.

[0104] A cable **4** is secured by one end to the floating body **3** and by its other end to the turning body **10**. The cable **4** is secured to the turning body **10** in such a way that it can be wound onto the body. A cable guide **14** is attached to the housing, through which the cable **4** runs. A spring **15** is arranged to exert a torsional force on the rotor shaft **9** in a first direction of rotation. The spring may be a cylindrical helical spring of the watch spring type. A spring may also be arranged at the other side of the generator. The spring rate can be controlled by a control device **19**. The control device is suitably radio-controlled.

[0105] Wave movements at the surface **2** of the ocean impart a to-and-fro vertical movement to the floating body **3**. When the floating body **3** is in a wave trough, part of the cable will be wound around the turning body **10**. When the floating body is lifted from this position by wave movement the cable runs off the turning body **10** so that this is caused to rotate in a direction opposite to that of the spring **15**, the latter therefore being tightened. This continues until the floating body **3** has reached the crest of a wave. During the following downward movement of the floating body **3** the spring **15** placed under tension by the upward movement will turn the turning body in the opposite direction so that the cable is wound onto the turning body. A resonance working point can be obtained by adjusting the spring. The movements of the floating body **3** are thus converted to an oscillating rotary movement of the turning body **10**, and thus also of the rotor of the generator **5**.

[0106] A cable **16** is connected to the stator winding of the generator and, via a cable lead-in, carries the current outside the housing. Inside the housing the cable is provided with a circuit breaker or contactor **21** and a diode **22** for rectification. The diode may be controlled by a thyristor, IGBT or GTO, for instance, or it may be uncontrolled.

[0107] Components for monitoring and control may also be arranged in the housing.

[0108] As shown in **FIG. 2**, the turning body **10** has a diameter considerably less than that of the rotor **17**. **FIGS. 3 and 4** illustrates a couple of alternative embodiments of the turning body. In **FIG. 3** the turning body **10** is provided with end flanges **18** to ensure that the cable does not slip off. In the example shown in **FIG. 4** this is achieved by the turning body **10** being concave as seen in a longitudinal section.

[0109] A gear exchange is thus obtained that gives the rotor a peripheral speed which is correspondingly greater than the peripheral speed of the turning body. Mechanism for additional step-up may naturally be arranged.

[0110] A wave-power plant in accordance with the invention consists of two or more units of the type described above. **FIG. 5** illustrates how these are connected together to supply energy to an electric supply network. In the example shown the power plant consists of three units, symbolically designated **20***a*-**20***c*. Each unit is connected via a breaker or contactor **21** and a rectifier **22** to an inverter **23** in a bipolar connection according to the figure. The circuit diagram is only drawn in for the unit **20***a*. It will be understood that the other units **20***b*, **20***c* are connected in corresponding manner. The inverter **23** supplies three-phase current to the electric supply network **25**, possibly via a transformer **24** and/or a filter.

[0111] The rectifiers may be diodes, which may be controlled and of type IGBT, GTO or thyristors, comprise controlled bipolar components or they may not be controlled. The voltages on the DC side may be connected in parallel or in series, or a combination of both.

[0112] Alternatively a full-wave rectifier of the type illustrated in **FIG. 5***a* may be used.

[0113] **FIG. 6** shows a cross section through a high-voltage cable that may be advantageous to use for the stator winding in certain applications of the invention. The cable consists of a core with one or more strand parts **31** of copper. The core is surrounded by an inner semiconducting layer **32**. Outside this is a layer of solid insulation **33**, e.g. PEX insulation. Around the insulation is an outer semiconducting layer **34**. Each of the semiconducting layers forms an equipotential surface.

[0114] **FIG. 7** illustrates schematically, seen from the side, an alternative embodiment of the generator in a wave-power unit in accordance with the invention. In this example only the stator is enclosed in the housing **6** which may be of concrete. The rotor **17** is thus not enclosed. It is located outside the stator. Vertical movements of the floating body are here transmitted directly to the rotor **17** since the cable **4** is attached to the outside of the rotor. When the floating body (not shown in this figure) moves up and down, the cable is wound off and on to the rotor **17** so that this performs an oscillating rotary movement. The rotor is journalled directly on the outside of the housing **6**.

[0115] **FIG. 8** illustrates how the cable **4** is provided with a control device controlling its active length, i.e. the distance between the floating body **3** and the generator **6**. In this case the control device consists of a roll **29** secured to the floating body, onto which roll a part of the cable can be wound. The control device may also be designed in some other way or may alternatively be arranged at the connection point of the cable to the rotor, or somewhere else along the cable. The control device allows the length of the cable to be adjusted to varying tidal water conditions. It can also be used to position the floating body immediately below the surface of the water. When the connecting means is of some other type than a cable, wire, chain or jointed rods, a control device suitable for the particular type shall be used.

[0116] **FIG. 9** shows an example in which a floating body **3** is common to two separate generators **6***a*, **6***b*. The cable **4** is connected to a horizontal rod **38** which, via cables **4***a*, **4***b*, is connected to respective generators **4***a*, **4***b*.

[0117] **FIG. 10** illustrates an embodiment in which the cable is provided with a gear mechanism. In the embodiment shown the gear mechanism consists of a piston **30** secured to the upper part **4***d* of the cable and arranged to sealingly move up and down in a container **32** filled with liquid, and of a piston **31** connected to the lower part **4***c* of the cable and similarly arranged to move up and down in the container **32**. The piston **30** connected to the cable **4***d* and the part of the container **32** cooperating therewith have larger diameter than the piston **31** connected to the cable **4***c* and the part of the container **32** cooperating with this piston. The position of the container is suitably fixed. With this arrangement a ratio is obtained between the vertical movement of the upper cable **4***d* and the vertical movement of the lower cable **4***c* that corresponds to the area ratio between the pistons. The gear mechanism may alternatively be designed as a link system, toothed wheel or using screws of different pitch. The gear mechanism may also be designed so that adjustment of the gear ratio is possible.

[0118] **FIG. 11** illustrates how the turning body **10** is connected to the rotor **17** via a free wheel **28**. The free wheel **28** is arranged to convert the oscillating rotary movement of the turning body **10** to unidirectional rotary movement of the rotor **17**.

[0119] **FIG. 12** illustrates a wave-power plant with a plurality of generators **20***a*, **20***b*, **20***c* interconnected. A rectifier is arranged at each generator and, via cables **39** arranged on the sea bed, the DC current is conducted to a station on land with an inverter **23**, a transformer **24** and a filter **41** from whence the electric power is supplied to a distribution or transmission network. The transformer may be omitted if a winding of the type shown in **FIG. 6** is used.

[0120] **FIG. 13** is a basic layout sketch illustrating another advantageous embodiment of the invention. A switchgear station **101** is arranged resting on the sea bed B. The switchgear station **101** consists of a watertight container formed by a housing **102** and a bottom plate **103** which may be of concrete, for instance. The switchgear station **101** is anchored in the sea bed B. The generators **104-109** of a number of wave-power units are connected to the switchgear station.

[0121] Each generator unit **104-109** is electrically connected with the switchgear station **101** by cables **110-115** which, via lead-ins through the housing **102**, are connected to the components inside the switchgear station. The voltage is supplied from each unit as low-voltage direct or alternating voltage.

[0122] The components in the switchgear station **101** are of conventional type and are not shown in the figures. These components may include semiconductors, converters, breakers, measuring devices, relay protection, surge diverters and other over-voltage protection devices, earthing means, load couplers or disconnectors, as well as transformers.

[0123] The switchgear station supplies an outgoing direct or alternating voltage, preferably high voltage, through outgoing cables **116**. The alternating voltage has low frequency and may be three phase or multiphase. Standard frequencies such as 50 or 60 Hz may also be used.

[0124] The incoming low voltage is converted to outgoing high voltage by the transformer in the switchgear station. The converter or inverter in the switchgear station is used when necessary to converter DC-AC or vice versa.

[0125] The voltage is supplied to a receiving station located on land, possibly via an intermediate station, to be fed out on an electric supply network.

[0126] **FIG. 14** illustrates an example of a system in accordance with the invention that may be expedient when a large number of generator units is included in the system. The figure is a symbolic representation of the system seen in bird's eye perspective and shows a sea area H on the left of the figure and a land area L on the right. The components on the left of the figure are located partly under and partly above the surface of the water.

[0127] The system comprises a first group of generator units **104***a*-**106***a*, a second group of generator units **104***b*-**106***b* and a third group of generator units **104***c*-**106***c*. The generator units **104***a*-**106***a* in the first group are connected via under-water cables to a first switchgear station **101***a* located below the surface of the water. Similarly, the two other groups of generators **104***b*-**106***b* and **104***c*-**106***c* are connected to a second switchgear station **101***b* and a third switchgear station **101***c*, respectively. Each of the switchgear stations **101***a*-**101***c* is connected via under-water cables **116***a*-**116***c* to an intermediate station **117**, also located below the surface of the water. The voltage is conducted from the intermediate station **117** as low-frequency three-phase alternating voltage via under-water cables **118** to a receiving station **119** located on land. The voltage is converted in the receiving station to a standard frequency such as 50 or 60 Hz.

[0128] The distance between the generator units and the receiving station may be from a kilometre or so up to many tens of kilometres. When the system is constructed as shown in **FIG. 14** the distance between on the one hand switchgear station and intermediate station and on the other hand intermediate station and receiving station, can be optimized.

[0129] Transmission from the generator units to a receiving station on land may take place in various ways with various voltage conversions. FIGS. **15** to **18** illustrate schematically some examples of this. In each example the generator units are arranged to the left and the receiving station on land L to the right in the figures. **121** denotes a converter/inverter and **122** a step-up transformer. In **FIGS. 15 and 16** the generator units supply direct voltage which in **FIG. 15** is transmitted to land as alternating voltage and in **FIG. 16** as direct voltage.

[**0130**] In **FIGS. 17 and 18** the generator units supply alternating voltage which is converted to direct voltage. In **FIG. 17** this is transmitted to land as alternating voltage and in **FIG. 18** as direct voltage.

[**0131**] Many other alternatives are shown within the scope of the invention, such as a whole-wave rectifier of the type illustrated in **FIG. 19**.

[**0132**] Energy stores and filters may also be housed in each switchgear station **111** and/or in the intermediate station **117**. The energy stores may consist of batteries, capacitors, SMES types, flywheels or combinations thereof, for instance. The filters may comprise active components in similar manner to the converters. Passive LC filters and electromechanical components such as flywheel converters or synchronous condensers are also possible.

1. A wave-power unit for the production of electric power comprising a floating body and rotating electric generator mechanically connected to the floating body, wherein a mechanical movement transmitting means is arranged for transmission of vertical movements of the floating body to rotary movements of the generator rotor, the rotor being connected to a turning body, which turning body is connected to the movement transmitting means, and the movement transmitting means is secured by its upper end to the floating body and by its lower end to the turning body and at least the lower part of the movement transmitting means includes a component that can be rolled up.

2. A wave-power unit as claimed in claim 1 wherein at least the stator of the generator is enclosed in a housing anchored in the sea/lake bed.

3. A wave-power unit as claimed in claim 2, wherein the rotor is also enclosed in the housing.

4. A wave-power unit as claimed in claim 1, wherein the rotor is situated on the outside of the stator.

5. A wave-power unit as claimed in claim 1, wherein the turning body is arranged outside the housing.

6. A wave-power unit as claimed in claim 1, comprising a first gear mechanism effecting a gear change between the movements of the turning body and the rotor.

7. A wave-power unit as claimed in claim 1, wherein the turning body and the rotor are arranged on a common, substantially horizontal shaft.

8. A wave-power unit as claimed in claim 1, wherein the turning body has circular cross section and in that the diameter of the rotor is larger than the turning body.

9. A wave-power unit as claimed in claim 4, wherein the movement transmitting means is secured by its upper end to the floating body and by its lower end to the rotor and in that at least the lower part of the movement transmitting means consists of a component that can be rolled up.

10. A wave-power unit as claimed in claim 1, wherein it is provided with spring means arranged to exert a torsional force on the rotor.

11. A wave-power unit as claimed in claim 10, wherein the spring rate of the spring means is adjustable.

12. A wave-power unit as claimed in claim 1, wherein the housing comprises a base plate, which base plate is arranged to rest on the bed of the sea/lake.

13. A wave-power unit as claimed in claim 1, wherein the length of the movement transmitting means is adjustable.

14. A wave-power unit as claimed in claim 1, wherein the housing is filled with a liquid.

15. A wave-power unit as claimed in claim 1, wherein the housing is primarily made of concrete.

16. A wave-power unit as claimed in claim 1, wherein the floating body is connected to a plurality of generators.

17. A wave-power unit as claimed in claim 1, wherein the stator winding is connected to a rectifier, which rectifier is preferably arranged close to the generator below the surface of the water, preferably inside the housing.

18. A wave-power unit as claimed in claim 1, wherein the generator is arranged to produce a voltage of varying frequency.

19. A wave-power unit as claimed in claim 1, wherein the movement transmitting means comprises a second gear mechanism to effect a gear ratio of the vertical movement of the floating body.

20. A wave-power unit as claimed in claim 1, wherein it comprises a free wheel arranged to convert oscillating rotary movement to unidirectional rotary movement.

21. A wave-power unit as claimed in claim 1, wherein the stator winding consists of a cable comprising a current conductor, a first semi-conducting layer surrounding the conductor, an insulating layer of solid insulation surrounding the first semi-conducting layer, and a second semi-conducting layer surrounding the insulating layer.

22. A wave-power plant comprising a plurality of wave-power units as claimed in claim 1, wherein the stator winding of each wave-power unit is connected via a rectifier to an inverter which is common to a plurality of wave-power units, which inverter is arranged to supply energy to an electric supply network.

23. A wave-power plant as claimed in claim 22, wherein at least one electric switchgear station is connected to the wave-power unit, which switchgear station comprises a watertight container housing switchgear components, which container is anchored in the sea bed.

24. A wave-power plant as claimed in claim 23, wherein a plurality of switchgear stations are connected to the wave-power unit, each switchgear station being connected to a number of wave-power units.

25. A wave-power plant as claimed in claim 23, wherein each switchgear station is connected to a receiving station arranged on land.

26. A wave-power plant as claimed in claim 23, wherein at least one of the switchgear stations comprises a step-up transformer and/or an intermediate station comprising a step-up transformer.

27. A wave-power plant as claimed in claim 23, wherein at least one of the switchgear stations and/or the intermediate station comprises a converter.

28. A wave-power plant as claimed in claim 23, wherein at least one of the switchgear stations and/or the intermediate station comprises means for storing energy.

29. A wave-power plant as claimed in claim 27, wherein at least one of the switchgear stations and/or the intermediate station comprises filtering means for filtering outgoing and/or incoming current and voltage.

30. A wave-power plant as claimed claim 23, wherein at least one of the switchgear stations and/or the intermediate station is filled with non-corrosive, buffered liquid.

31. A wave-power plant as claimed in any one of claims claim 22, wherein a filter and/or a transformer is/are arranged after the inverter.

32. A wave-power plant as claimed in claim 22, wherein the inverter, filter and/or transformer is/are arranged on land.

33. A wave-power plant as claimed in claim 22, wherein each wave-power unit is connected to the inverter via a cable arranged on or close to the sea or lake bed.

34. (canceled)

35. A method of generating electric power by mechanically connecting a floating body to a rotating electric generator, wherein the mechanical movement transmitting means is arranged to transmit vertical movements of the floating body to rotary movements of the generator rotor, the rotor is connected to a turning body, connected to the movement transmitting means, said movement transmitting means being secured by its upper end to the floating body and by its lower end to the turning body, and at least the lower part of the movement transmitting means consist of a component that can be rolled up.

36. A method as claimed in claim 35, wherein the method is utilized while making use of a wave-power unit.

37. A method as claimed in claim 36, wherein the spring means with adjustable spring rate is applied to exert a torsional force on the rotor and in that the spring means is adjusted so that resonance is obtained with the movement of the floating body that is estimated to occur for most of the time.

38. A method as claimed in claim 35, wherein the energy generated is conducted to a switchgear station, the components of which are arranged in a watertight container, which container is anchored in the sea bed.

39. A method as claimed in claim 38, wherein the switchgear station is connected to a receiving station arranged on land.

40. A method as claimed in claim 39, wherein a plurality of switchgear stations are connected to a common intermediate station, which intermediate station is connected to the receiving station.

41. A method as claimed in claim 38, wherein at least one of the switchgear stations and/or the receiving station is/are arranged below the surface of the water, preferably close to the sea bed.

42. A method as claimed in claim 38, wherein voltage generated is step-up transformed in at least one of the switchgear stations and/or the intermediate station.

43. A method as claimed in claim 38, wherein the outgoing voltage from at least one of the switchgear stations and/or from the intermediate station is alternating voltage.

* * * * *

US 20090102200A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2009/0102200 A1**

Greenspan et al. (43) **Pub. Date: Apr. 23, 2009**

(54) **WAVE ENERGY RECOVERY SYSTEM**

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(21) Appl. No.: **12/313,955**

(22) Filed: **Nov. 26, 2008**

Related U.S. Application Data

(63) Continuation of application No. 11/602,145, filed on Nov. 20, 2006, now Pat. No. 7,474,013.

(60) Provisional application No. 60/738,287, filed on Nov. 18, 2005.

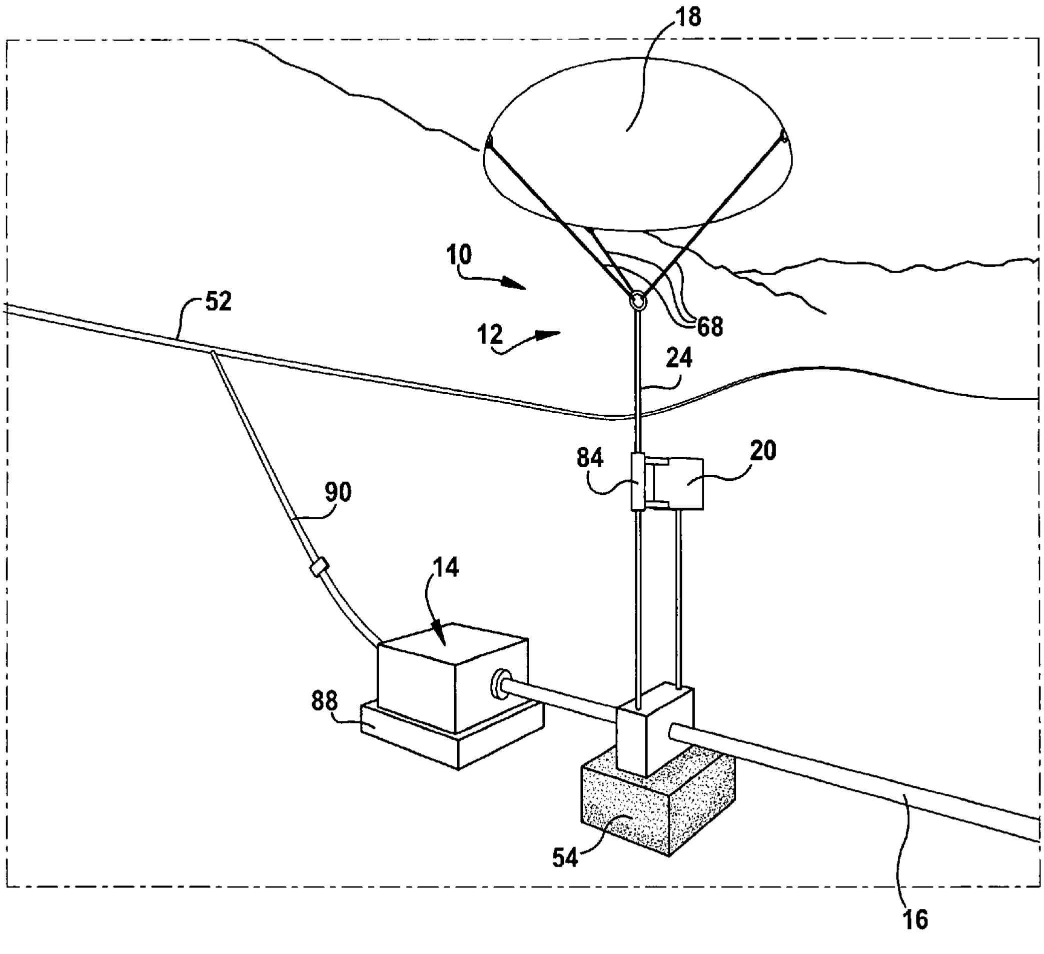
Publication Classification

(51) **Int. Cl.**
F03B 13/18 (2006.01)

(52) **U.S. Cl.** **290/53**

(57) **ABSTRACT**

The present invention includes novel apparatus and methods for recovering energy from water waves. An embodiment of the present invention includes a buoy, a shaft, and an electric power generating device. The shaft is coupled to the buoy such that when the buoy moves vertically in response to a passing wave, the shaft rotates. The shaft is coupled to the electric power generating device such that when the shaft rotates, the generating device produces electric power. Once electric power is generated, it is delivered to shore, where it is stored, used to power a device, or delivered to a power distribution grid.



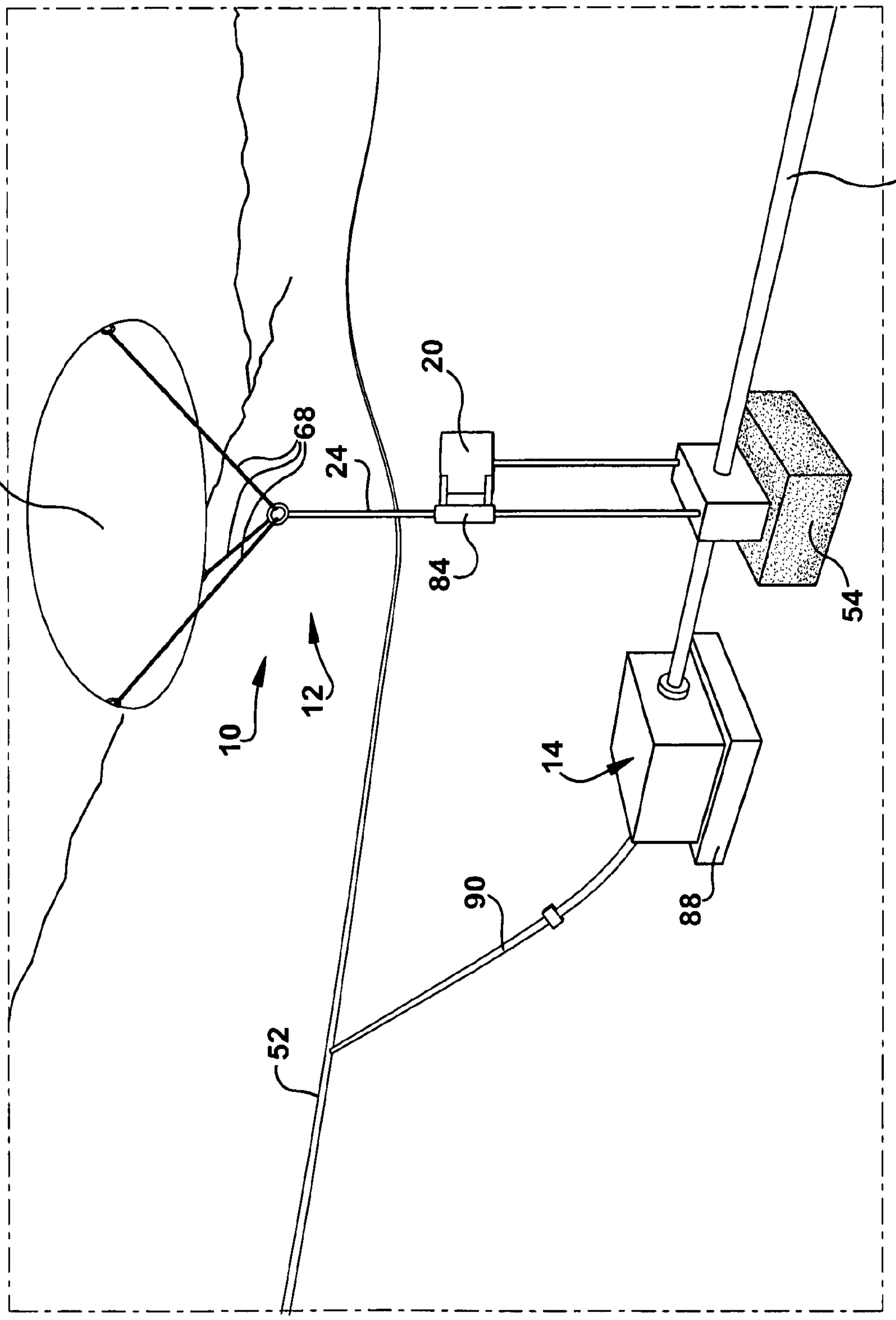


Figure 1

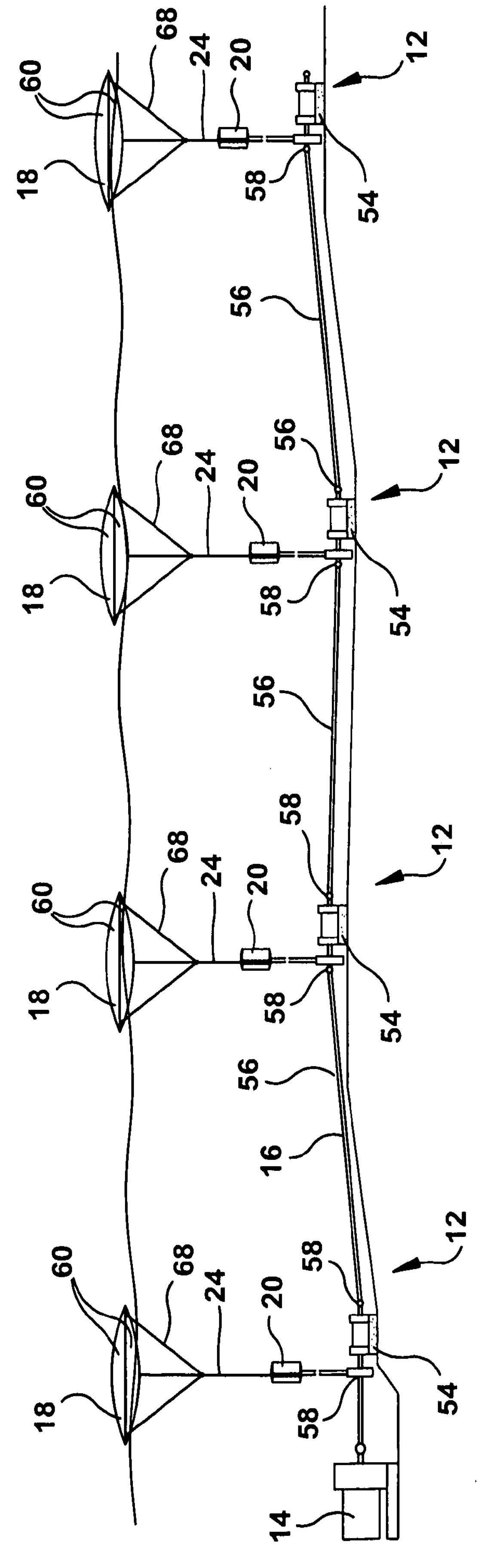


Figure 2

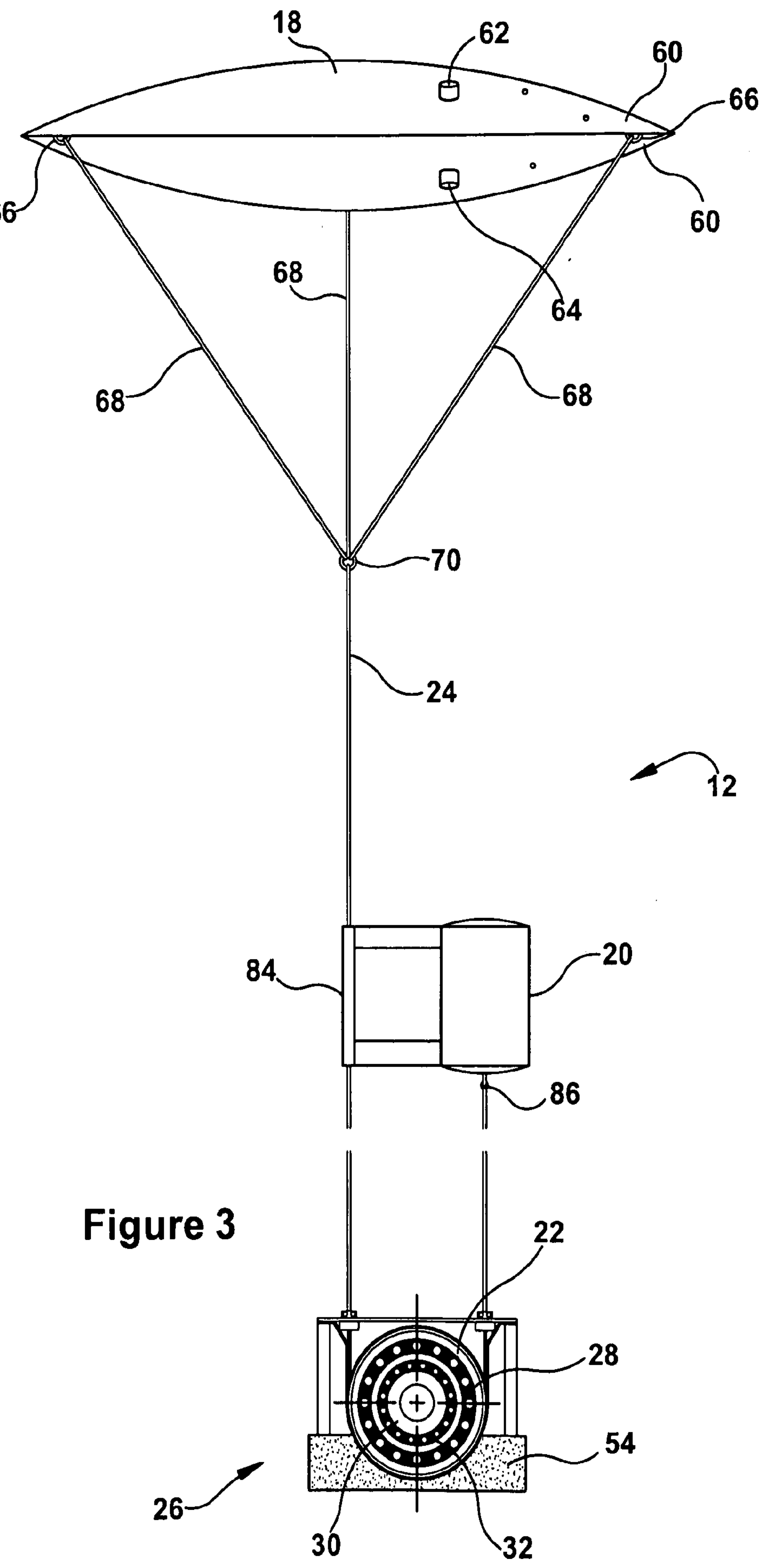


Figure 3

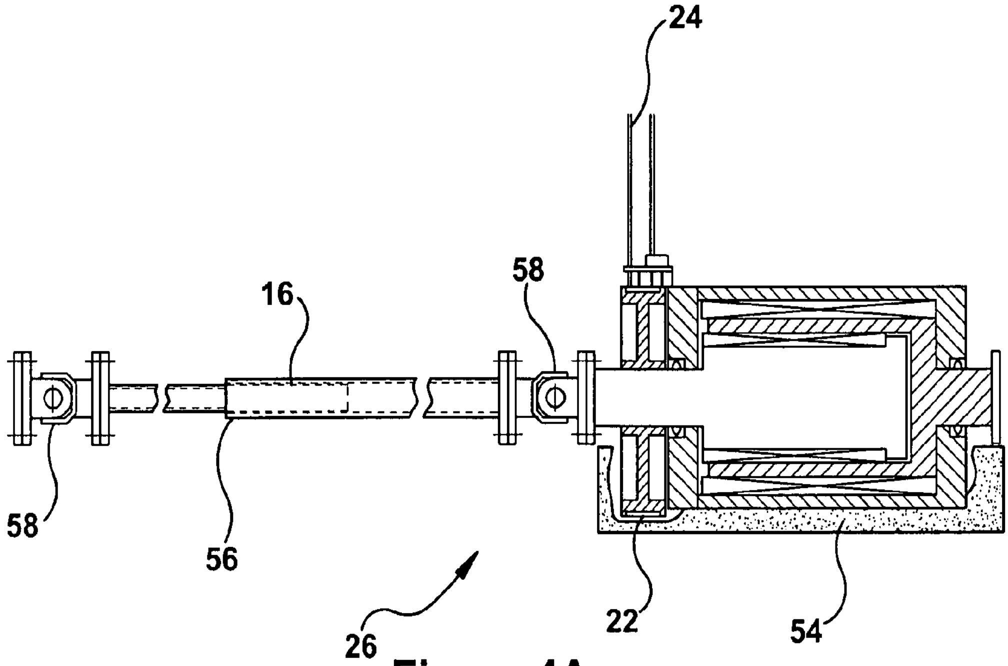


Figure 4A

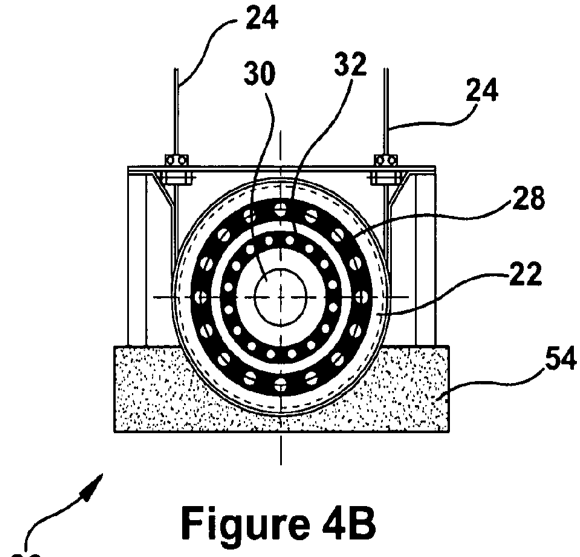


Figure 4B

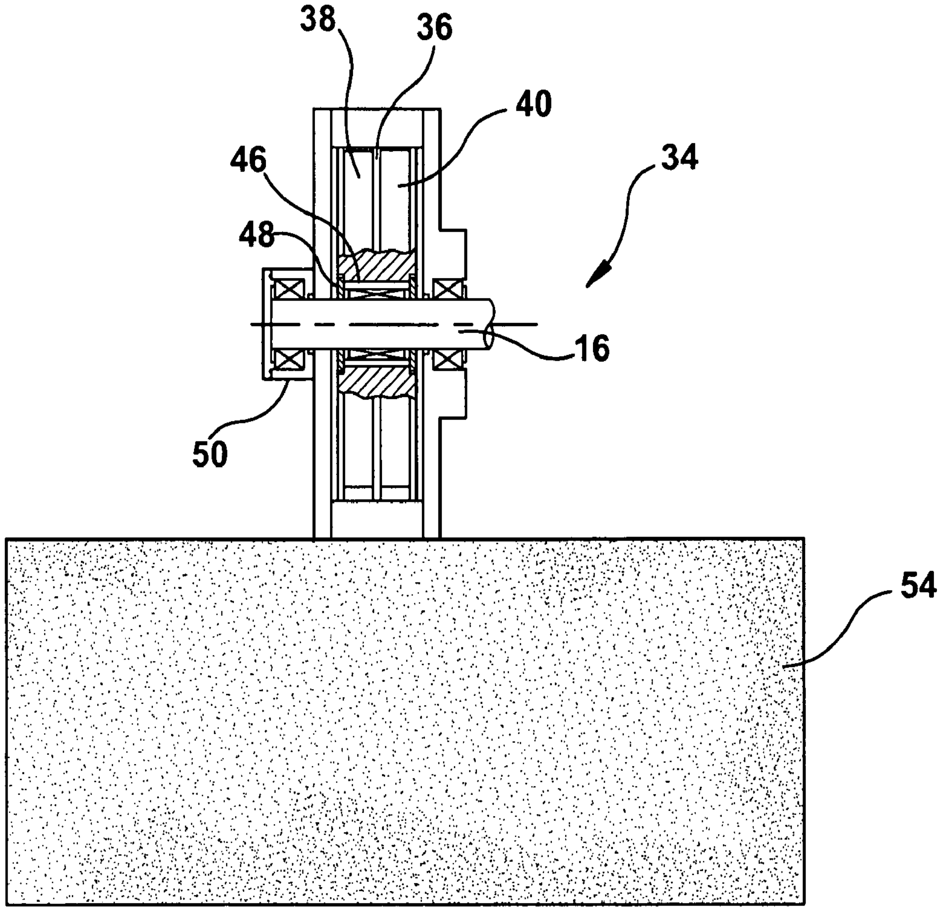


Figure 5A

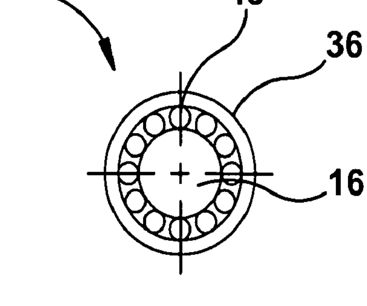


Figure 5B

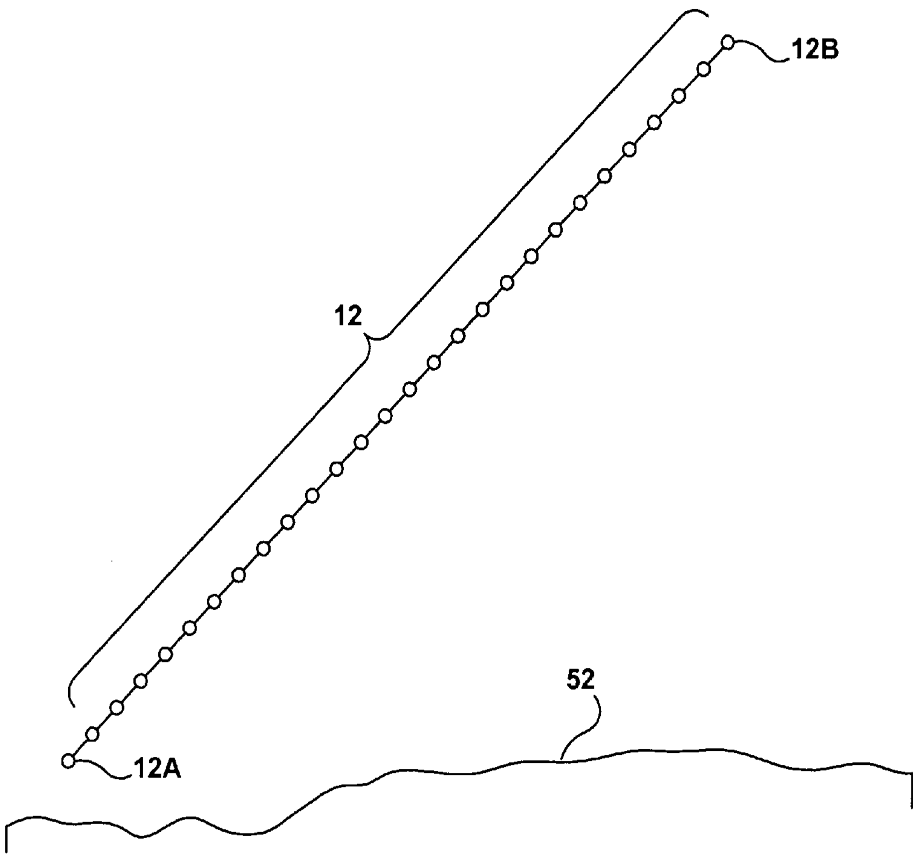


Figure 6

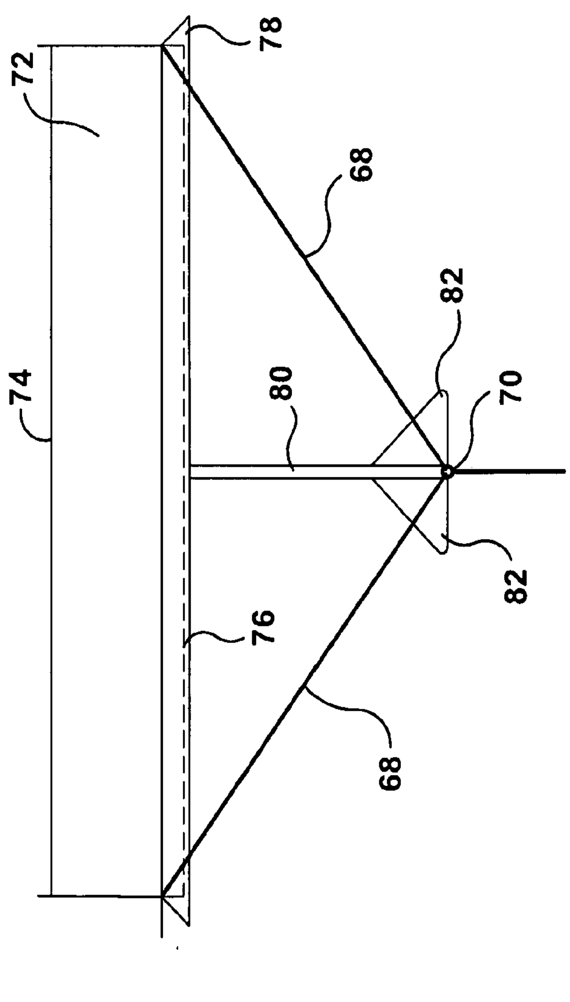


Figure 7A

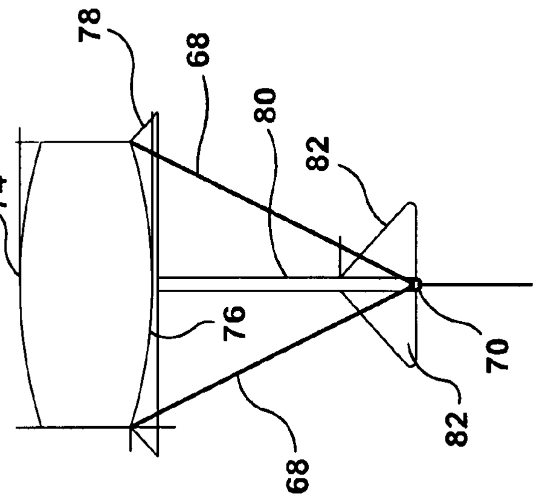


Figure 7B

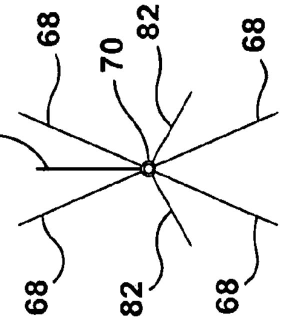


Figure 7C

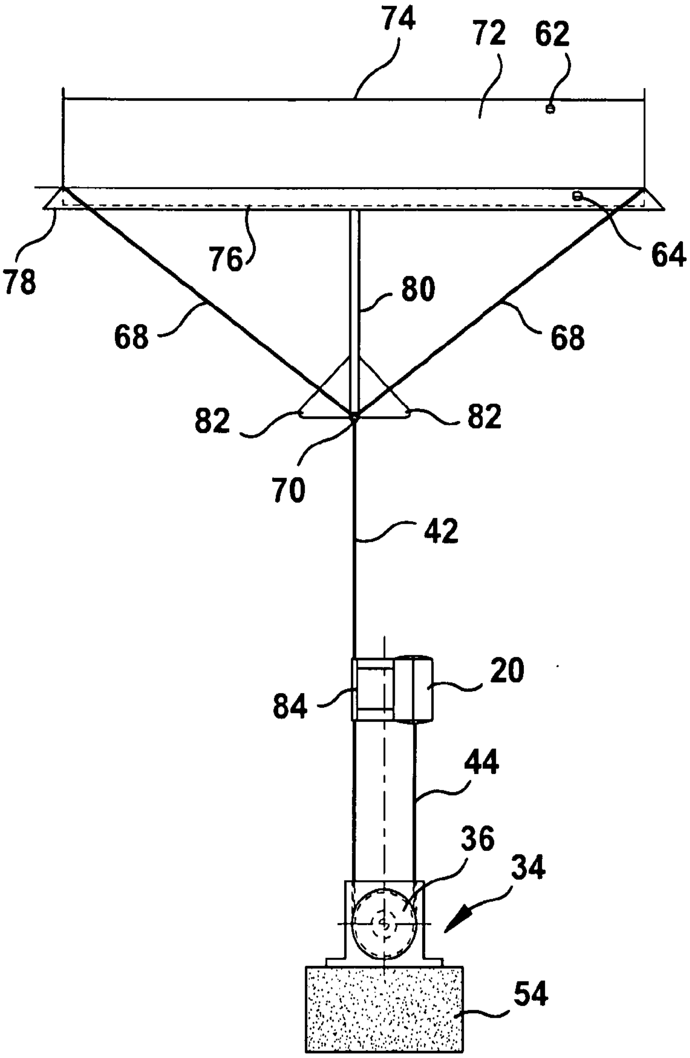


Figure 8A

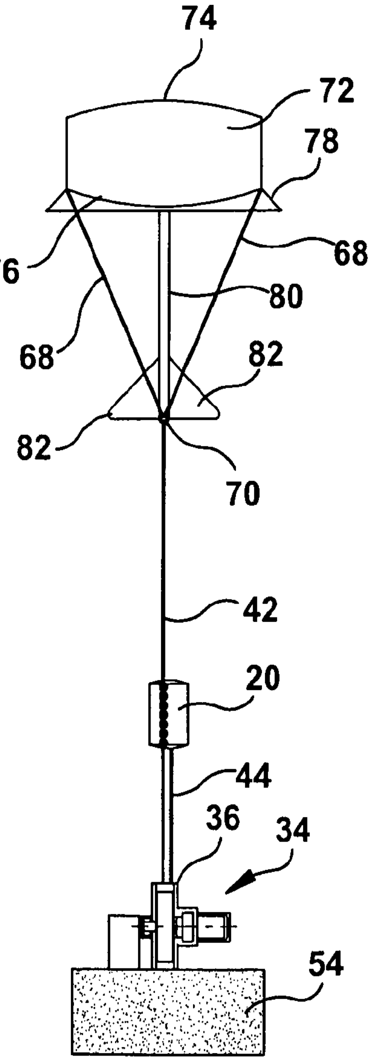


Figure 8B

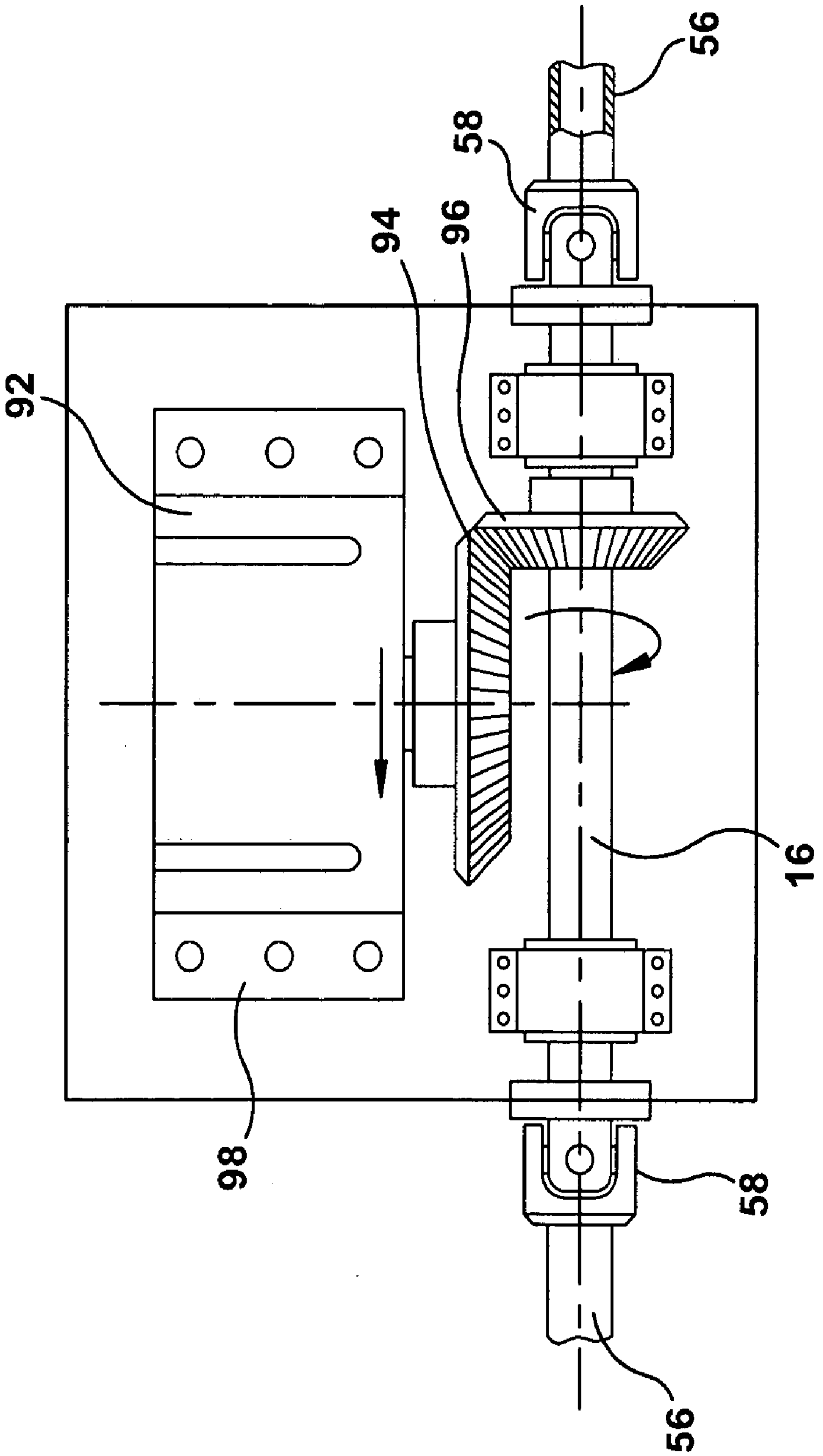


Figure 9

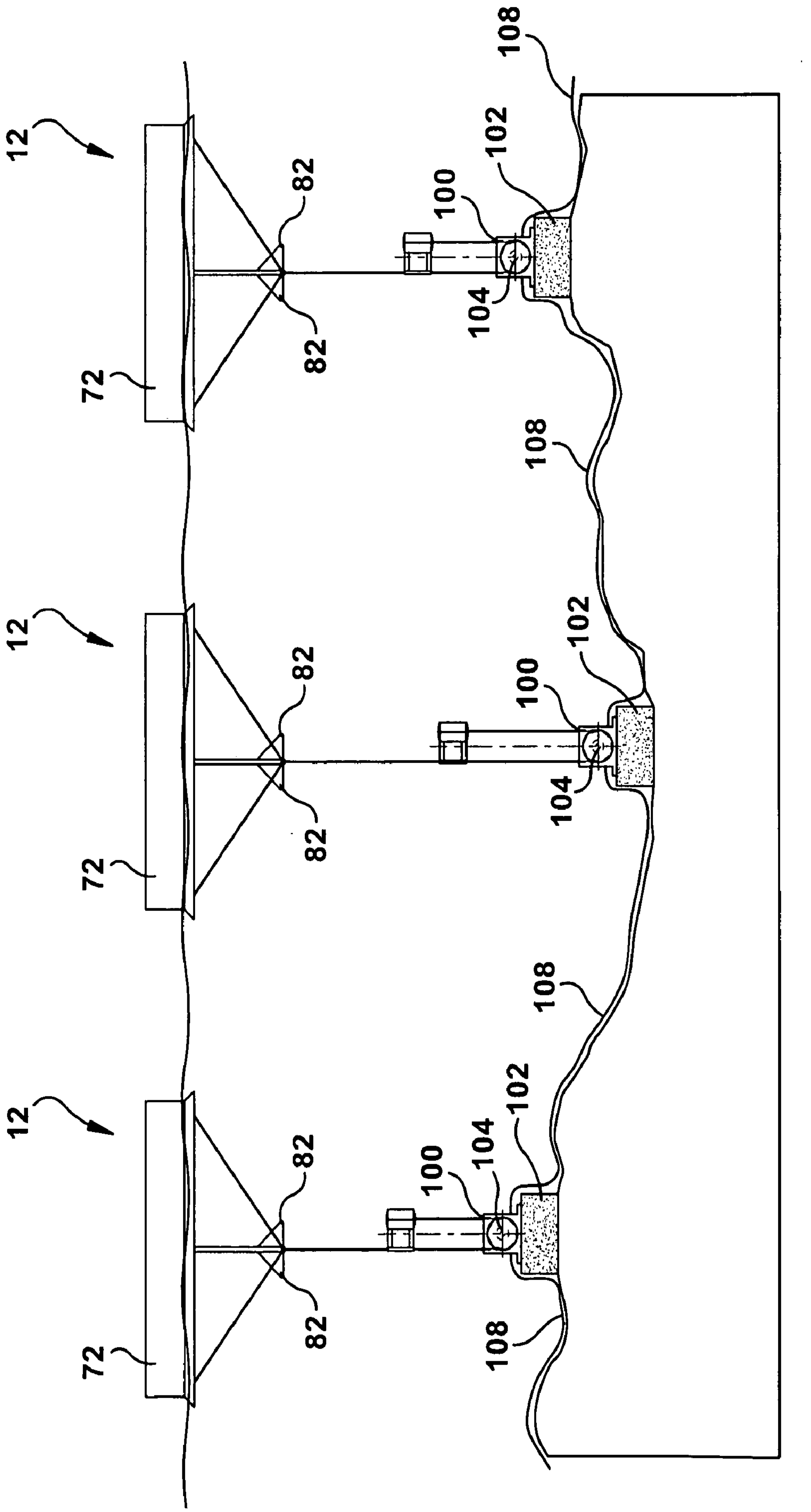


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Figure 10

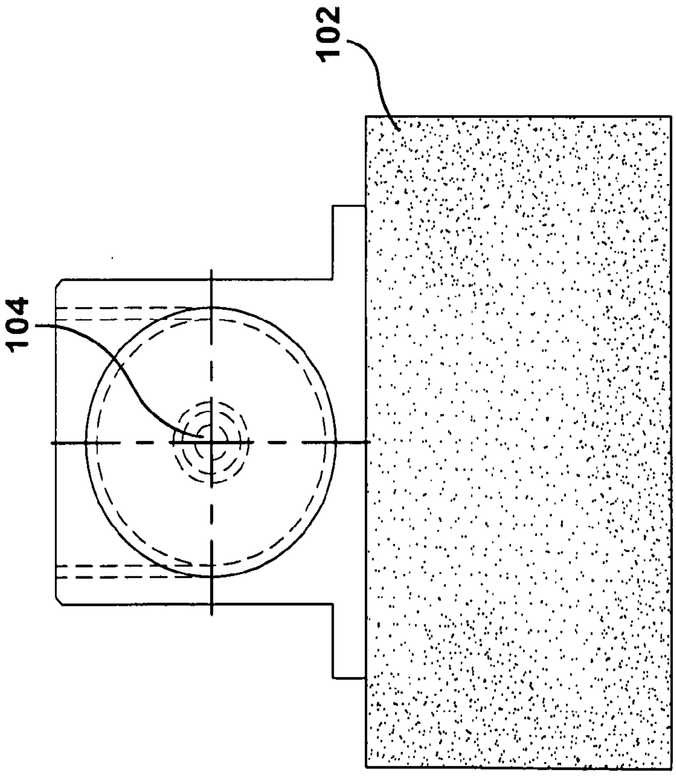

Figure 11A

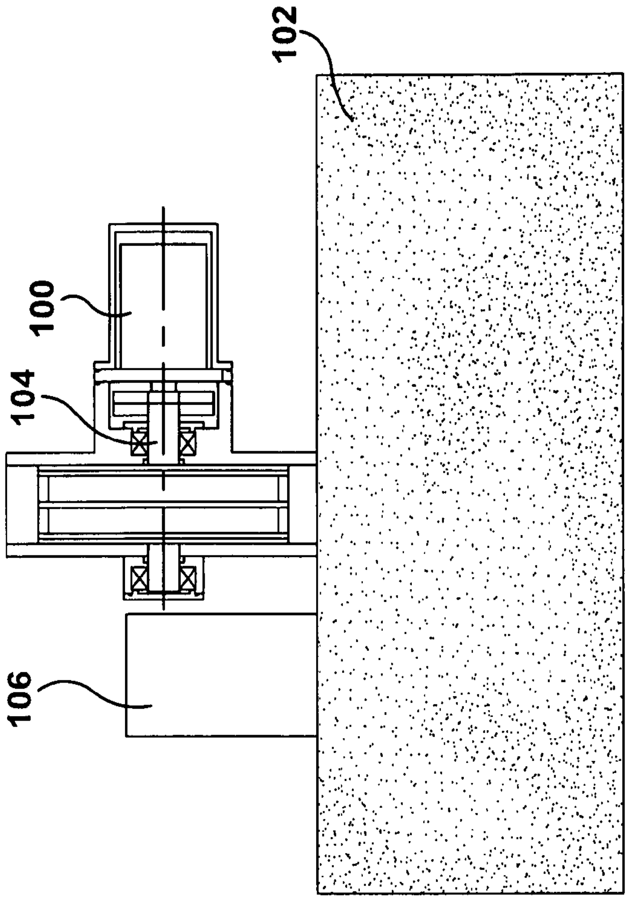

Figure 11B

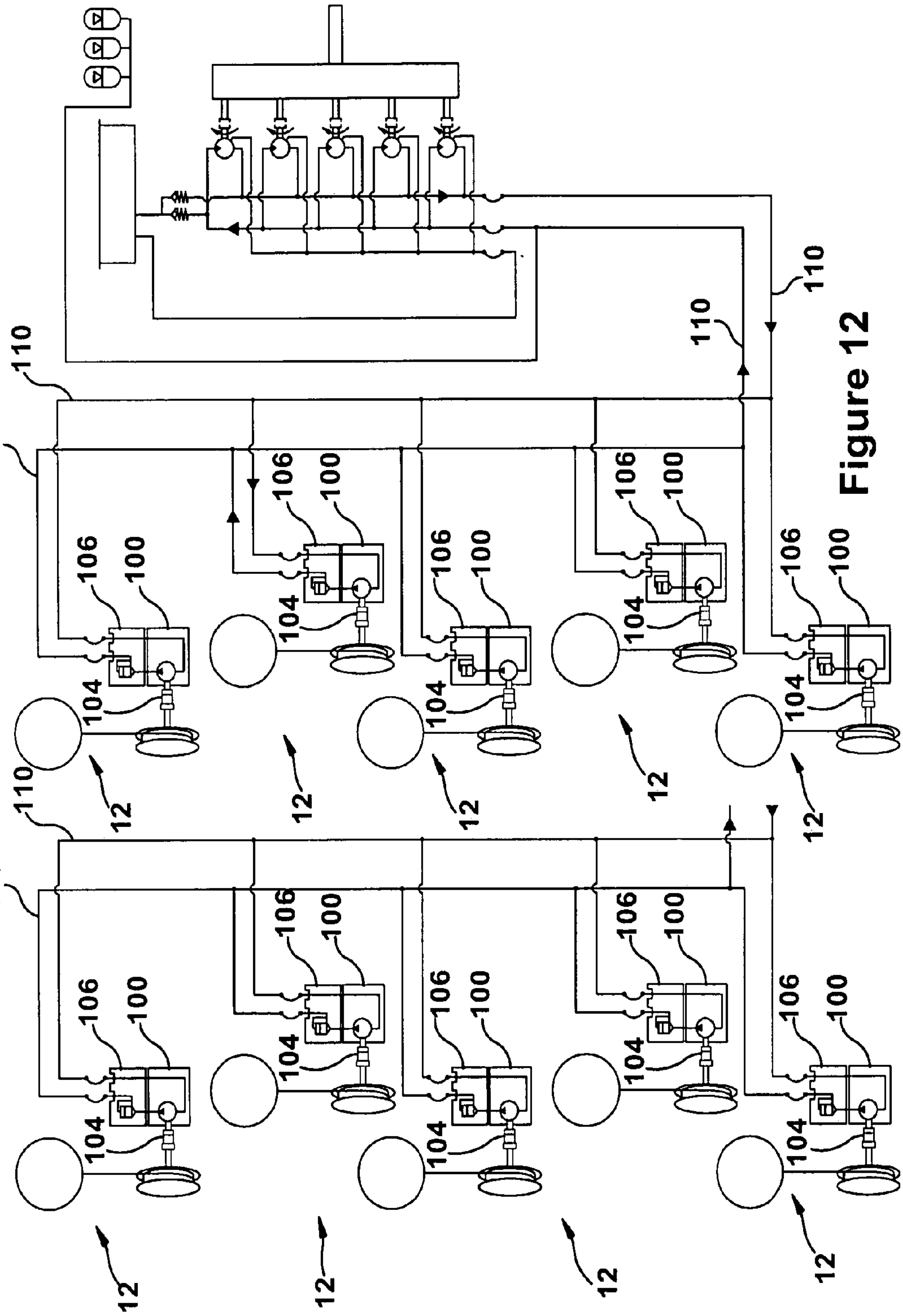

Figure 12

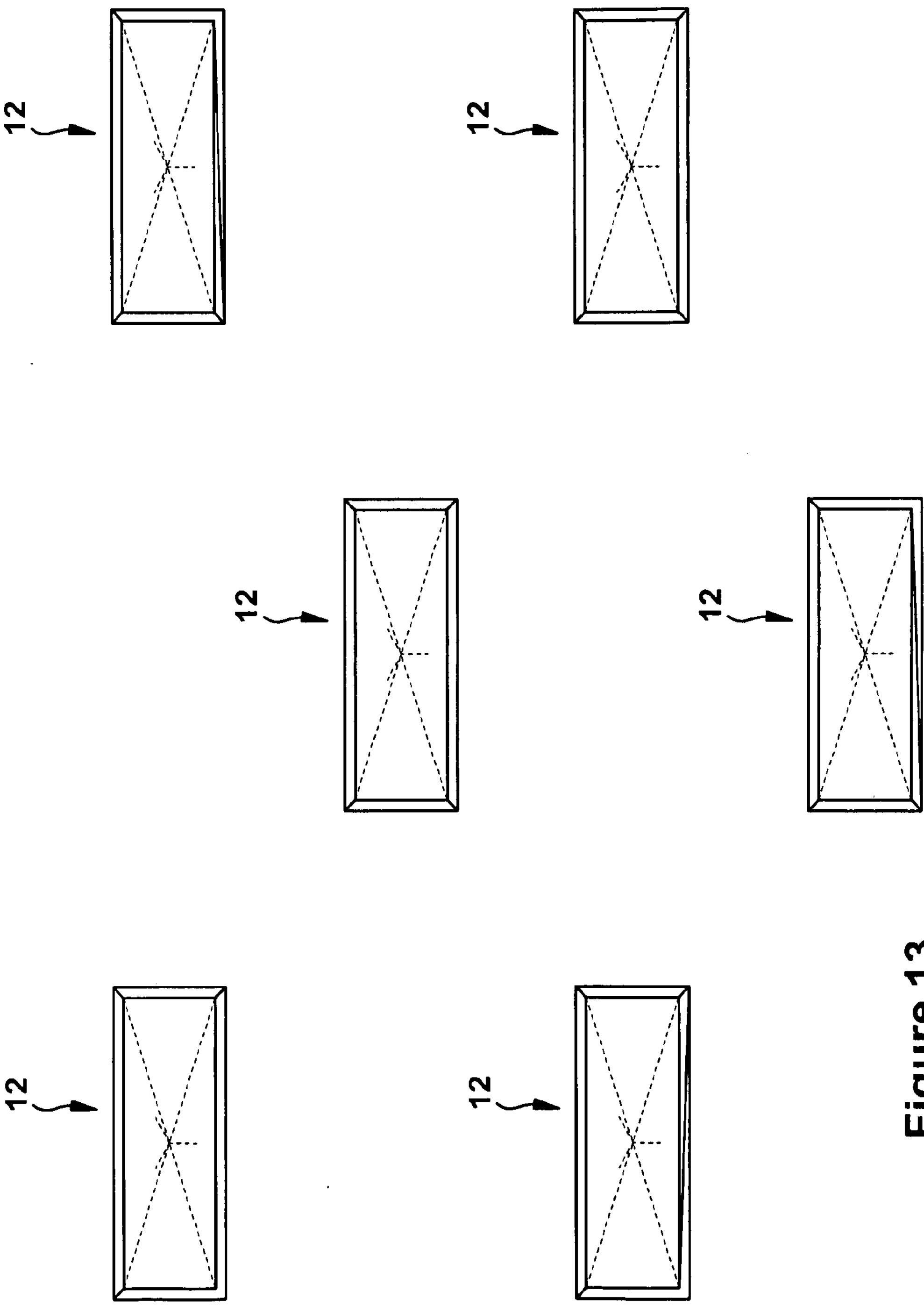

Figure 13

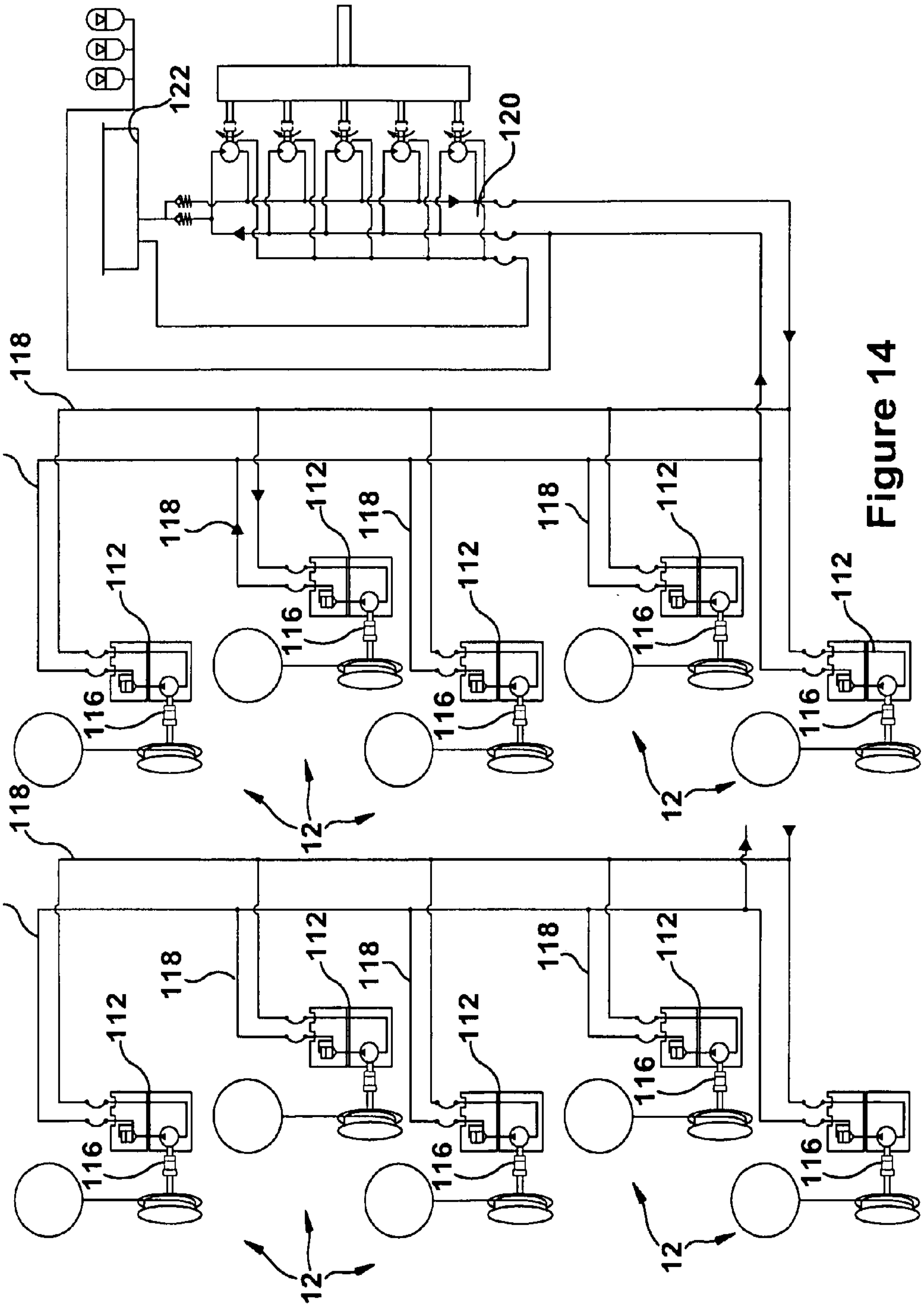

Figure 14

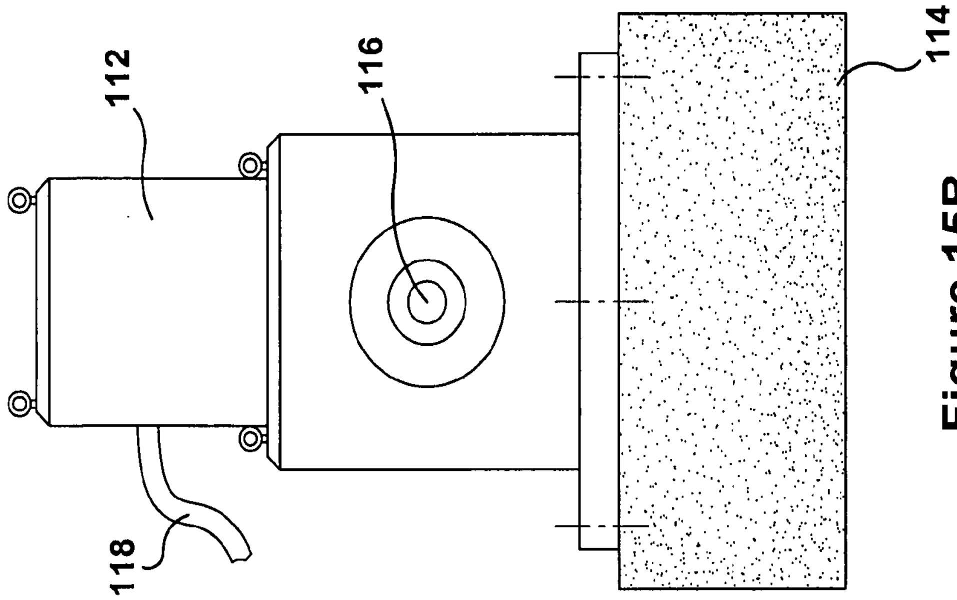

Figure 15B

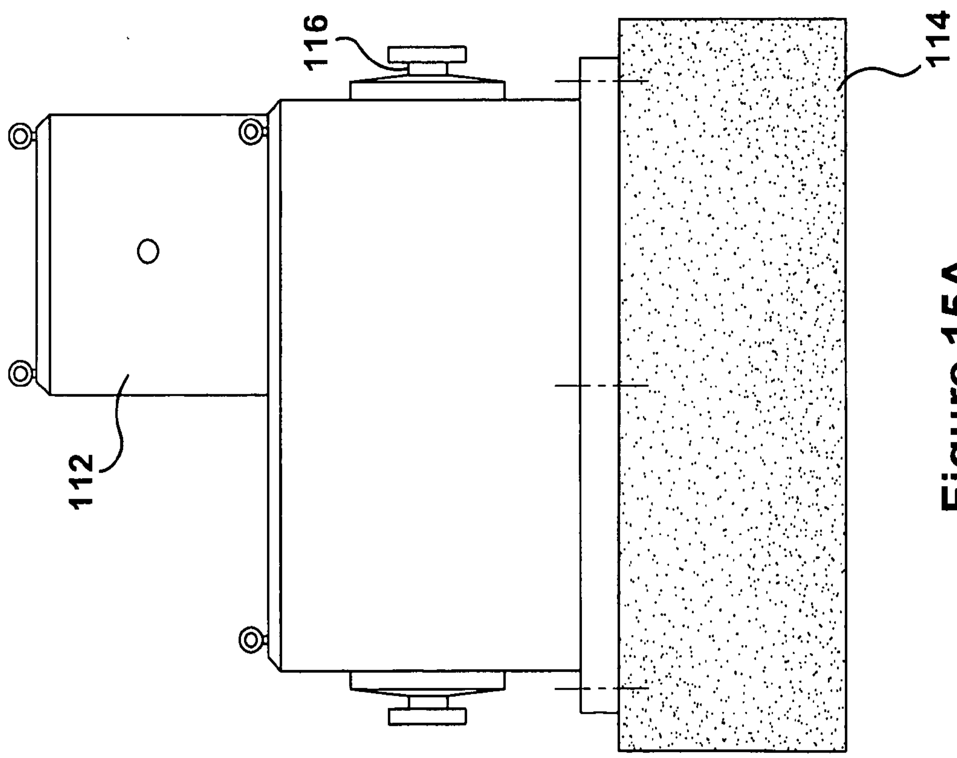

Figure 15A

WAVE ENERGY RECOVERY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Ser. No. 11/602,145 to Greenspan et al. filed on Nov. 20, 2006, and titled WAVE ENERGY RECOVERY SYSTEM, which claims priority from U.S. Provisional Patent Application No. 60/738,287 to Greenspan et al. filed on Nov. 18, 2005, and titled WAVE ENERGY RECOVERY SYSTEM, both of which are hereby incorporated in their entirety by reference.

FIELD OF INVENTION

[0002] The present invention relates generally to systems for recovering energy from waves and, more particularly, the present invention relates to apparatus and methods for transforming vertical displacement of buoys caused by waves into rotational motion to drive the generation of electric power.

BACKGROUND

[0003] Currently, approximately 350 million megawatt-hours of energy are consumed globally each day (which is equivalent to the energy in approximately 205 million barrels of oil). With continued industrial expansion and population growth throughout the developed and developing world, global consumption is expected to increase approximately sixty percent over the next twenty-five years, pushing global energy consumption to over 500 million megawatt-hours per day. Approximately seventy-five percent of energy currently consumed comes from non-renewable sources, such as oil, coal, natural gas, and other such fossil fuels. The current level of fossil fuel usage accounts for the release of approximately six million tons of carbon dioxide into the atmosphere each day. With a finite supply of fossil fuels available and growing concerns over the impact of carbon dioxide, continued reliance on fossil fuels as a primary source of energy is not indefinitely sustainable.

[0004] One approach to sustaining the current global energy consumption rate and accounting for future increases in consumption is to research and develop novel and improved methods for generating energy from renewable sources. Sources of renewable energy include water-powered energy, wind-powered energy, solar energy, and geothermal energy. Of the current practical renewable energy sources, water-powered energy, and specifically wave-powered energy, may hold the most promise for developing a substantial renewable energy source to meet growing global energy needs.

[0005] It has been long understood that ocean waves contain considerable amounts of energy. Given the high level of energy concentration present in waves and the vast areas available for harvesting such energy, wave-powered energy technology represents a significant renewable energy source. Numerous systems have been developed in an attempt to efficiently capture the energy of waves; however, no prior conceived systems or methods have achieved the efficiency or cost-effectiveness required to make wave-powered energy a viable alternative energy source.

[0006] Wave energy recovery systems must successfully operate in very hostile marine or freshwater environments. Such environments are prone to violent storms and the deleterious impact of salt water, plant life, and animal life. Further, due to the offshore location of such systems, a successful system must include an efficient means for delivering the energy output to shore. These and other technical challenges have been addressed and overcome by this invention as herein described.

SUMMARY OF INVENTION

[0007] The present invention includes novel apparatus and methods for recovering energy from water waves. An embodiment of the present invention includes a buoy, a shaft, and an electric power generating device. The shaft is coupled to the buoy such that when the buoy moves vertically in response to a passing wave, the shaft rotates. The shaft is coupled to the electric power generating device such that when the shaft rotates, the electric power generating device produces electric power. Once electric power is generated, it is delivered to shore, where it is stored, used to power a device, or delivered to a power distribution grid.

DESCRIPTION OF DRAWINGS

[0008] Objects and advantages together with the operation of the invention may be better understood by reference to the following detailed description taken in connection with the following illustrations, wherein:

[0009] FIG. **1** is a perspective view of an embodiment of a wave energy recovery system in accordance with the present invention;

[0010] FIG. **2** is a schematic illustration of the wave energy recovery system of Figure I;

[0011] FIG. **3** is a schematic illustration of a motion translating assembly of the wave energy recovery system of FIG. **1**;

[0012] FIGS. **4**A and **4**B are cross-sectional views of a pulley and ratchet mechanism of the wave energy recovery system of FIG. **1**;

[0013] FIGS. **5**A and **5**B are cross-sectional views of another pulley and ratchet mechanism of the wave energy recovery system of FIG. **1**;

[0014] FIG. **6** is a schematic illustration of the wave energy recovery system of FIG. **1**;

[0015] FIGS. **7**A, **7**B, and **7**C are views of an embodiment of a buoy in accordance with the present invention;

[0016] FIGS. **8**A and **8**B are views of a motion translating assembly in accordance with the present invention;

[0017] FIG. **9** is view of a ratchet assembly in accordance with the present invention;

[0018] FIG. **10** is a view of another wave energy recovery system in accordance with the present invention;

[0019] FIGS. **11**A and **11**B are detailed views of the wave energy recovery system of FIG. **10**;

[0020] FIG. **12** is a schematic illustration of another embodiment of a wave energy recovery system in accordance with the present invention;

[0021] FIG. **13** is a schematic view of another wave energy recovery system of the present invention;

[0022] FIG. **14** is a schematic illustration of another embodiment of a wave energy recovery system in accordance with the present invention; and

[0023] FIGS. **15**A and **15**B are detailed views of the wave energy recovery system of FIG. **14**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] While the present invention is disclosed with reference to the embodiments described herein, it should be clear that the present invention should not be limited to such embodiments. Therefore, the description of the embodiments herein is only illustrative of the present invention and should not limit the scope of the invention as claimed.

[0025] A wave energy recovery system, as described herein, converts the energy of sea waves or other such water waves into usable mechanical and electrical energy. Apparatus and methods may be arranged such that the vertical pulse motion of waves of any magnitude and frequency may be converted to other types of motion such as, for example, rotating motion. The mechanical energy of this resulting rotating motion may be arranged to drive gearboxes, motors, pumps, generators, or the like to generate electricity.

[0026] In an embodiment of the present invention, the vertical pulse motion of a wave is translated to a buoy floating at or near the surface of a body of water to vertically displace the buoy. The vertical displacement of the buoy is translated to rotational motion, which is engaged to a pulley and ratchet mechanism to drive an alternating current (AC) permanent magnet generator, resulting in the generation of electric power. A gearbox may be used to convert relatively low revolutions per minute (RPMs) rotating speed into a rotating speed desired to drive the generator. Preferably, a gearbox utilizes a planetary gear set; however, other gear sets could be utilized. The AC permanent magnet generator is coupled to a rectifier to convert the alternating current (AC) produced by the generator to a direct current (DC). The rectifier is coupled to a voltage converter to generate a consistent DC current to be used as a final source of electricity or to be converted back to AC current and delivered to a power generation grid. As used herein, the term “coupled” means directly or indirectly connected in a mechanical, electrical, or other such manner.

[0027] An exemplary embodiment of the present invention is illustrated in FIGS. **1** through **6**. FIG. **1** illustrates a perspective view of a wave energy recovery system **10**. The system **10** comprises a motion translating assembly **12**, a generator **14**, and a shaft **16**. The system **10** is positioned on a seabed relatively close to shore and arranged to generate electric power, delivering that electric power to shore. As will be further described above, the motion translating assembly **12** translates the vertical pulse motion of a wave to rotational motion of the shaft **16**, and such rotational motion of the shaft **16** drives the generator **14**. The generator **14** is preferably an AC permanent magnet generator. As shown in FIG. **2**, a plurality of motion translating assemblies **12** may be arranged in series to assist in rotating the shaft **16** to drive the generator **14**.

[0028] As best seen in FIG. **3**, a motion translating assembly **12** includes a main buoy or float **18**, a retracting buoy or float **20**, an oscillating pulley **22**, a main cable **24**, and a ratchet mechanism **26**. The main cable **24** is coupled on one end to the main buoy **18**, coupled on the other end to the retracting buoy **20**, and wrapped around the pulley **22**. The buoys **18** and **20** are arranged such that, as a wave engages the main buoy **18**, the main buoy **18** is displaced vertically upward (i.e., rises relative to the seabed) and the cable **24** rotates the pulley **22** in a clockwise rotation with respect to FIG. **3**. As the wave passes the main buoy **18**, the main buoy **18** is displaced vertically downward (i.e., falls relative to the seabed), the retracting buoy **24** rises to remove any slack from the cable **24**, and the pulley **22** rotates counterclockwise with respect to FIG. **3**. Thus, as waves pass the main buoy **18**, vertical displacement of the main buoy **18** by a passing wave is transformed into rotational motion of the oscillating pulley **22**. Although the main cable **24** is described as coupled to the main buoy **18** and the retracting buoy **20** and wrapped around the pulley **22**, it will be readily understood by those skilled in the art that any number of arrangements may convert vertical motion of the main buoy **18** to rotational motion. For example, a first cable may be coupled on one end to the main buoy **18** and coupled on the other end to the pulley **22**. A second cable may be coupled to the retracting buoy **20** on a first end and coupled on the other end to the pulley **22**. In such an arrangement, the first and second cables effectively replace one main cable **24** to rotate the oscillating pulley **22** as the main buoy **18** moves vertically.

[0029] As best seen in FIGS. **4**A and **4**B, the oscillating pulley **22** is coupled to the ratchet mechanism **26** such that rotational motion is transferred from the pulley **22** to the ratchet mechanism **26**. Preferably, the pulley **22** and ratchet mechanism **26** are constructed from stainless steel. The internal mechanism of the ratchet mechanism **26** consists of three major components: an outer ring **28**, an inner ring **30**, and roller cams **32**. The outer ring **28** is attached to the pulley **22** such that the outer ring **28** rotates as the pulley **22** rotates. The inner ring **30** is attached to the shaft **16** such that the shaft **16** rotates as the inner ring **30** rotates. The ratchet mechanism **26** functions as a one-way ratchet; therefore, the rotation of the pulley **22** is only translated through the ratchet mechanism **26** to the shaft **16** when the pulley **22** rotates in one direction. For example, with reference to FIG. **3**, the rotation of the pulley **22** is only translated to the shaft **16** when the main buoy **18** is raised by a passing wave and the pulley **22** rotates clockwise. When the wave moves past the main buoy **18** and the buoy **18** falls, the counterclockwise rotation of the pulley **22** is not translated to the shaft **16**. This arrangement insures that the shaft **16** rotates in only one direction as it drives the generator **14**.

[0030] One alternative ratchet mechanisms **34** to the ratchet mechanism **26** described above and illustrated in FIGS. **4**A and **4**B is illustrated in FIGS. **5**A and **5**B. In this alternative embodiment, a pulley **36** includes a first groove **38** and a second groove **40**. A main buoy cable **42** is attached to the pulley **36** on a first end, attached to the main buoy **18** on second end, and wound around the first groove **38** (as seen in FIG. **8**A). A retraction buoy cable **44** is attached to the pulley **36** on a first end, attached to the retraction buoy **20** on second end, and wound around the second groove **40** in a manner opposite of the wind of the main buoy cable **42** (see FIG. **8**A). As will be readily understood by those skilled in the art, in such an arrangement, the pulley **36** rotates in a first direction when the main buoy **18** moves upward and the retraction buoy **20** moves downward, and the pulley **36** rotates in a second and opposite direction when the main buoy **18** moves downward and the retraction buoy **20** moves upward. The shaft **16** passes through an aperture through the center of the pulley **36**, and a plurality of eccentric rollers **46** are positioned between the pulley **36** and the shaft **16**. Similar to the description above, the ratchet mechanism **34** translates rotational motion from the pulley **36** to the shaft **16** when the pulley rotates in the first direction but does not translate rotational motion from the pulley **36** to the shaft **16** when the pulley **36** is rotated in the second direction.

[0031] Whether rotational motion is transferred from the pulley **36** is controlled by the eccentric nature and positioning of the rollers **46**. The rollers **46** are slightly elliptical and positioned such that, when the pulley **36** is rotated in the first direction, the rollers **46** are engaged with both the shaft **16** and the pulley **36**, thus mechanically transferring motion from the pulley **36** to the shaft **16**. When the pulley **36** is rotated in the second direction, the rollers **46** rotate slightly to create a gap between the rollers **46** and the pulley **36**, thus allowing the pulley **36** to slip with respect to the shaft **16**. Seals **48** may be utilized to prevent water from flowing into contact with the rollers **36**, which may optionally be lubricated. In addition, a housing **50** may be utilized to enclose the pulley **38** and ratchet mechanism **34** and to provide bearing surfaces for the shaft **16**.

[0032] As aforementioned and illustrated in FIG. **2**, a plurality of motion translating assemblies **12** are coupled to the shaft **16** to drive the generator **14**, which is located at an end of the system **10** that is closest to shore. In such an arrangement, it is preferable that the shaft **16** only rotates in one direction. As multiple motion translating assemblies **12** assist in rotating the shaft **16**, limiting the shaft **16** to only one direction of rotation allows the assemblies **12** to cooperate in driving the generator **14**.

[0033] In an embodiment of the present invention, as shown schematically in FIG. **6**, a plurality of motion translating assemblies **12** extend diagonally from the shoreline **52** at approximately a 45 degree angle. Preferably, the system **10** includes approximately thirty motion translating assemblies **12**. The assemblies **12** are spaced approximately 30 feet apart, with the assembly **12**A closest to the shoreline **52** approximately 500 feet off shore, and the assembly **12**B farthest way from the shoreline **52** approximately 3000 feet off shore. Such an arrangement generally results in each incoming wave raising and lowering each main buoy **18** at a different point in time. As a wave progresses towards the shoreline **52**, it first encounters the assembly **12**B farthest off shore and raises and then lowers that assembly's **12**B main buoy **18**. Over time, the wave progresses through the plurality of assemblies **12** until it reaches the assembly **12**A closest to the shore. Such an arrangement insures that any single wave will not raise and lower the plurality of main buoys **18** at the same point in time, but will raise the plurality of main buoys **18** over a period of time. The raising of main buoys **18** over time as the wave progresses towards the shoreline **52** causes different motion translating assemblies **12** to rotate the shaft **16** at different times, resulting in constant rotation of the shaft **16** at a generally constant speed. Preferably, the arrangement of assemblies **12** is such that at least five of the approximately thirty assemblies **12** are actively rotating the shaft **16** at any point in time.

[0034] An arrangement that results in a constantly rotating shaft **16**, rotating at a generally constant speed, is a desirable method for driving a generator **14**. A gearbox optionally may be used to couple the shaft **16** to the generator **14**. The gearbox may manipulate the rotation speed of the shaft **16** to convert the rotational input into the generator **14** to an optimal rotation speed for the generator **14**. For example, if the plurality of motion translating assemblies **12** rotates the shaft **16** at a relatively low speed, the gearbox may increase the rotation speed to provide a higher and more efficient rotation speed to the generator **14**.

[0035] The generator **14** has been described and illustrated as located at the end of the system **10** that is closest to the shore. It will be readily understood by those skilled in the art that the generator **14** is not limited to such positioning. For example, the generator **14** may be located at an end of the system **10** farthest away from the shore; two generators **14** may be used, with one generator **14** located at the far end and the other generator **14** located at the near end; or a generator **14** may be located in the middle of the system **10**, between two motion translating assemblies **12**. Positioning the generator **14** on the seabed surrounds the generator with water, which cools the generator **14** as it generates electric power. As generators **14** typically give off heat, providing a readily available method of cooling the generator **14** increases the efficiency of the generator **14**.

[0036] Each motion translating assembly **12** is secured to a support platform **54** to maintain a static position with respect to the seabed. In an exemplary embodiment, the support platform **54** is a concrete slab with vertical pillars. The concrete slab **54** has enough mass to maintain its position on the seabed and resist movement due to tides, thrust from the main buoy **18**, storms, or other inclement weather. The concrete slab **54**, along with the vertical pillars, supports the pulley **22** or **36**, the ratchet mechanism **26** or **34**, and the shaft **16**. Preferably, the support platform **54** is a rectangular slab of concrete measuring ten feet in width, eight feet in depth, and four feet in height. Such a concrete slab weights approximately twenty-five tons and can withstand substantial forces without moving.

[0037] As best seen in FIG. **2**, each motion translating assembly **12** is coupled to an adjoining assembly **12** by the shaft **16**. The shaft **16** is comprised of a plurality of individual shaft segments **56**, which extend from a ratchet mechanism **26** or **34** secured to a support platform **54** to another ratchet mechanism **26** or **34** secured to an adjacent support platform **54**. To reduce or eliminate concerns over the unevenness or irregularity of the seabed and precise placement of individual support platforms **54**, the shaft segments **56** are coupled to the ratchet assemblies **26** or **34** by constant velocity joints **58** (as best seen in FIG. **4**A). The constant velocity joints **58** are preferably constructed from stainless steel and allow orbital deflection through a variety of angles. Such an arrangement allows the plurality of motion translating assemblies **12** to continuously drive the shaft **16** even when unevenness of the seabed causes an assembly **12** to be positioned lower or higher relative to the adjoining assemblies **12**.

[0038] In an embodiment of the present invention, as best shown in FIG. **3**, the main buoy **18** includes two ten-foot diameter opposed spherical dishes **60** fused together at their edges. The dishes **60** are preferably constructed of aluminum. The curved shape of the dishes **60** permits a breaking wave to wash over the top of the buoy **18**, thereby exerting a force on both the front of the buoy **18** and on the rear of the buoy **18** to assist in maintaining the buoy **18** in a substantially stationary position. The main buoy **18** is equipped with two remotely operated valves—an air inlet valve **62** and a water inlet valve **64**. The valves **62** and **64** are remotely controlled to take in water through the water inlet valve **64** for additional ballast to stabilize the floating position of the buoy **18**, or to take in pressurized air through the air inlet valve **62** to expel water and reduce water ballast in the buoy **18**. The valves **62** and **64**

are arranged such that the buoy **18** may take on enough water ballast to completely submerge the buoy **18**. A complete submersion of the buoy **18** may be desirable to reduce or eliminate damage to buoys **18** or other system components when violent storms or other such hazards are present. Once a storm passes, the buoy **18** may take in pressurized air through the air inlet **62** to expel water ballast and return the buoy **18** to its operative position. Furthermore, the main buoy **18** can be adjustably raised or lowered through the intake and expulsion of water ballast to dynamically adjust the buoy **18** position in response to changing wave conditions to maintain optimal operative positioning for the buoy **18**.

[0039] Referring again to FIG. **3**, the buoy **18** may be equipped with three pivoted rings **66** through which the buoy **18** is connected to the main cable **24**. Three connector cables **68** may be attached to the pivoted rings **66** on one end and attached to a common ring **70** on the other end. The main cable **24** may be attached to the common ring **70** on one end and wrapped around the oscillating pulley **22** or **36** as previously described. In a preferred embodiment, the main cable **24** and the connector cables **68** are approximately ⅜ inch in diameter, with the connector cables **68** approximately 10 to 15 feet in length and the main cable **24** approximately 100 to 200 feet in length.

[0040] While the shape of a main buoy may be as illustrated in FIG. **3** or any other configuration capable of floating, a preferred embodiment of the main buoy **72** is illustrated in FIGS. **7**A, **7**B, and **7**B. The main buoy **72** includes a generally rectangular body, with the top **74** and bottom **76** surfaces slightly bowed out. A skirt **78** extends from the bottom **76** of the buoy **72**, and a rigid member **80**, such as a pipe, extends downward from the bottom **76** of the buoy **72**, and at least one keel member **82** is attached to the pipe **60**. Optionally, multiple keel members **82** may be attached to the pipe **80**. Preferably, three keel members **82** are attached to the pipe **80**, each 120 degrees apart. The pipe **80** is preferably ten feet in length, and the keel members **82** are triangular shaped and three feet high and three feet wide. As a wave passes the buoy **72** the turbulence in the water is near the surface. Positioning the keel members **82** ten feet below the surface of the water places avoids the turbulence of the wave. Such an arrangement provides stability to the buoy **72** and eliminates or reduces lateral movement, wobbling or rocking of the buoy **72**. The elimination of such movement increases the vertical displacement of the buoy **72** and allows recovery of an increased percentage of a wave's energy.

[0041] The rectangular shape of the main buoy **72** may produce greater thrust in the motion translating assemblies **12** and produce greater rotational motion of the shaft **16**. A rectangular component placed in rough waters has a tendency to turn such that its longer vertical surface faces the incoming waves. By offering a greater surface area to incoming waves, the rectangular buoy **72** catches more of the wave, thereby providing more thrust to the main cable **24** as the buoy **72** is moved upward by a passing wave. Preferably, the rectangular buoy **72** is thirty feet wide, ten feet deep, and five feet high.

[0042] The positioning and shape of the skirt **78** also tends to eliminate or reduce lateral movement, wobbling, and rocking of the buoy **72**. The shape of the skirt **78**, in cooperation with the downward forces produced by the main cable **24** and connector cables **68**, holds the buoy **72** level on the surface of the water as a wave passes. As the wave displaces the buoy **72** upward, the buoy **72** remains level, thus reducing or eliminating lateral movement, wobbling, and rocking. As described above, maximizing vertical movement also maximizes the energy recovered from a wave.

[0043] Referring again to FIGS. **8**A and **8**B, the buoy **72** is attached to a pulley **36** in a manner similar to that previously described. Three connector cables **68** connect the buoy **72** to a common ring **70**. A main pulley cable **42** connects the common ring **70** to a first groove **38** in the pulley **36**. In addition, as described above, the rectangular buoy **72** includes an air inlet valve **62** and a water inlet valve **64** for the intake and expulsion of water ballast to position the buoy **72** to perform optimally or avoid hazards. Preferably, the main buoy **72** is constructed from aluminum; however, the present invention includes buoys constructed of any material that allows the buoy to float and rise and fall as waves pass.

[0044] The retracting buoy **20**, as best shown in FIGS. **3** and **8**A, is preferably constructed from aluminum, is cylindrically shaped, and includes a guide sleeve **84**. Similar to the main buoys **18** and **72**, the retracting buoy **20** is equipped with a pair of valves—an air inlet valve to intake air and expel water ballast, and a water inlet valve to intake water to increase water ballast. The bottom of the retracting buoy **20** is equipped with a ring **86** that is attached to a main cable **24**, which is then wrapped around an oscillating pulley **22** (as seen in FIG. **3**). Alternatively, the ring **86** may be attached to a retracting pulley cable **44**, which is then attached to an oscillating pulley **36** and wound around a second groove **40** of the pulley **34** (as seen in FIG. **8**A).

[0045] The guide sleeve **84** is attached to the side of the retracting buoy **20**. The guide sleeve **84** is arranged to slide along the cable **24** or **42** to maintain a controlled reciprocating motion that recoils the oscillating pulley **22** or **36** as a wave progresses past the main buoy **18** or **72**. In a preferred embodiment, the retracting buoy **20** is approximately 16 inches in diameter and 24 inches in height.

[0046] With respect to the cost of building traditional power plants, a wave energy recovery system **10** is very inexpensive to build and install. To install a system **10**, components of the system **10** may be loaded onto pontoons or other such floating platforms. The pontoons may be evenly spaced along the surface of the water. The spacing of the pontoons may be approximately equal to the desired operative distance between installed support platforms **54** along the seabed. Pulleys **22** or **36** and ratchet mechanisms **26** or **34** may then be secured to support platforms **54** on the pontoons. These assembled support platforms **54** may be lowered into position on the seabed from the pontoons, using any conventional means, such as chains or cables. The ratcheting mechanisms **26** or **34** may be coupled together by shaft segments **56** and constant velocity joints **58**, as previously described. In one alternative, the ratcheting assemblies **26** or **34** may be coupled together with the shaft segments **56** while the support platforms **54** are on the pontoons, and the plurality of support platforms **54** may be lowered together to the seabed.

[0047] Once the ratchet assemblies **26** or **34** are coupled together, cables **24** or **42** and **44** are wrapped around each pulley **22** or **36**, and a retracting buoy **20** may be attached to one end of the cable and the guide sleeve **64** installed along the cable. The main buoys **18** or **72** may be partially submerged to approximately an operative position by taking in and expelling water ballast using the air and water inlet valves **62** and **64**. The free end of the main cable **24** may be attached to the common ring **70** and the length of the main cable **24** properly adjusted. As shown in FIG. **1**, the generator **14** may be positioned on the seabed and connected directly to one end of the shaft **16**. Such an arrangement translates reciprocating vertical motion from the main buoys **18** or **72** to rotational motion of the shaft **16** coupled to the generator **14**. The generator **14** includes a support platform **88** similar to the support platforms **54** of the motion translating assemblies **12**. The generator support platform **88** is constructed from concrete and is designed to resist movement due to tides, storms, and other such inclement weather. As will be readily appreciated by those skilled in the art, the rotational motion of the shaft **16** is converted to electric power by the generator **14**. A power cord **90** is attached to the generator **14** to deliver the electric power generated to shore. Preferably, the generator **14** is an alternating current (AC) permanent magnet generator. A rectifier is wired to the generator **14** to convert the alternating current to DC current. A voltage converter is coupled to the rectifier to generate a consistent DC current. Such a DC current can be used as a final source of electricity, or the DC current may be converted back to AC current.

[0048] Although the ratcheting mechanism **26** and **34** have been shown as coupled to the shaft **16**, the ratcheting mechanisms may be arranged to engage the shaft **16** through a gear. Referring to FIG. **9**, a ratcheting mechanism **92** is illustrated. The ratcheting mechanism **92** is not directly engaged with the shaft **16**. The mechanism **92** is positioned above the shaft **16** and uses a pair of gears **94** and **96** to engage the shaft **16**. Similarly as previously described, the ratcheting mechanism **92** transfers rotational motion from the pulley (located within the housing **98**) to the shaft **16** when the pulley is rotated in a first direction, and does not transfer motion from the pulley to the shaft **16** when the pulley is rotated in a second direction. The arrangement illustrated in FIG. **9** allows for the removal of a damaged ratchet mechanism **92** and replacement of that mechanism **92** without shutting down the system to stop the rotation of the shaft **16**.

[0049] Although the foregoing embodiments of the present invention have been directed to a plurality of motion translating assemblies **12** arranged to rotate a shaft **16** to drive a single generator **14**, it will be readily understood by those skilled in the art that the present invention as described may be applied to any number of arrangements to transform vertical displacement of a buoy to mechanical or electrical energy. For example, each motion translating assembly **12** may be arranged to drive a shaft attached to a generator dedicated to that assembly **12**. In another example, the energy of a wave may be harnessed to drive a pump to move hydraulic fluid to drive a generator.

[0050] With reference to FIGS. **10**, **11**A, **11**B, and **12**, another embodiment of the present invention is illustrated. The motion translating assemblies **12** are arranged to drive dedicated generators **100** coupled to each support platform **102**. The assemblies **12** are arranged as previously described. However, a permanent magnet generator **100** is attached to each support platform **102**. The vertical motion of the main buoy **18** or **72** is translated to rotational motion to rotate a driveshaft **104**. The driveshaft **104** is coupled to and drives the generator **100**, which produces electric power. The generated electric power can be delivered to shore, either for immediate use or to feed into a power distribution grid. Optionally, the electric power can be stored on the support platform **102** to be subsequently delivered to shore. One method of storing the electric power on the support platform **102** is to couple the generator **100** to a supercapacitor **106**. Supercapacitors offer relatively high cycle lives, having the capacity to cycle millions of times before failing; low impedance; rapid charging; and no lose of capability with overcharging. As illustrated in FIG. **10**, a power cable **108** may be attached in series to each supercapacitor **106** to deliver stored electric power to shore. As a wave passes the motion translating assemblies **12**, some assemblies produce electric power, while others are momentarily idle. Similar to the cooperation of assemblies **12** to rotate the shaft **16** previously described, the plurality of supercapacitors **106** placed in series cooperate to deliver a consistent current of electric power to shore. A programmable logic control device may optionally be incorporated into the system to control the generators **100**, supercapacitors **106**, and other system components to delivery a consistent electrical current to the shore.

[0051] The driveshafts **104** may be arranged to only rotate in one direction as previously described, or may optionally be arranged to rotate in both clockwise and counterclockwise directions. An AC permanent magnet generator may be arranged to generate electric power regardless of the direction the driveshaft **104** rotates. Generators may also be arranged to eliminate any need for a gearbox when generating electric power. With reference to FIG. **12**, a system may be optionally arranged such that each dedicated generator **100** has a dedicated power cable **110** to deliver electric power to shore. The electric power generated by the plurality of generators **100** may be accumulated on shore and delivered to a power distribution grid.

[0052] The use of dedicated generators **100** secured to each support platform **102** allows for easy installation of the wave energy recovery system. As illustrated in FIG. **13**, support platforms **102** may be placed randomly, without concern for the positioning of adjacent platforms **102**. Each motion translating assembly **12** and dedicated generator **100** is self-sufficient and does not rely on adjacent assemblies **12**. Flexible power cables **108** or **110** allow a generator **100** or supercapacitor **106** to deliver electric power to shore from nearly any location on the seabed, either in series or in parallel.

[0053] With reference to FIGS. **14**, **15**A, and **15**B, yet another embodiment of the present invention is illustrated. The motion translating assemblies **12** are arranged such that each assembly **12** drives individual pumps **112** secured to each support platform **114**. The assemblies **12** are arranged to rotate a driveshaft **116** coupled to each pump **112**. Pressure lines **118** couple each pump **112** to a multiple hydraulic pump drive system **120**, typically located on shore. Each pressure line **118** transmits pressure generated by each pump **112** to a central pressure repository or accumulator **122**. This pressure repository **122** releases pressure at a constant rate to drive a flywheel of the multiple hydraulic pump drive system **120** to generate electric power. Such an arrangement results in self-sufficient assemblies **12** and pumps **112**. It will be readily understood how the inclusion of flexible pressure lines **118** allows for easy installation, as described above. Similar to the previous description, the multiple hydraulic pump drive system **120** generates an AC current, which is converted to DC current by a rectifier. A voltage converter generates a consistent DC current to be used as a final source of electricity or to be converted back to AC current.

[0054] The embodiments, as described herein, allow for easy and inexpensive relocation of a wave energy recovery system. As will be readily understood, a system may be relatively easily and quickly disassembled and moved to a more desirable location. In addition, the modular nature of the embodiments allows for rapid expansion of an existing and operative system. In addition, the location of systems on a seabed provides for a self-cooling system, which improves operation and lowers maintenance costs.

[0055] The preferred embodiment of the invention is shown in the accompanying drawings. However, nothing in this disclosure or the drawings should be interpreted to limit the broadest scope of the invention as recited in the appended claims. And while the invention has been described with reference to the preferred embodiment, obviously other embodiments, modifications, and alternations clearly falling within the scope of the invention as claimed would be evident to a reader upon reading and understanding this specification and the accompanying drawings. To the extent covered by the appended claims, all such embodiments, modifications, and alterations are contemplated by the present disclosure.

Having thus described the invention, we claim:

1. A wave energy recovery system comprising:
- a motion translating assembly comprising;
  - a main buoy; and
  - a shaft coupled to said main buoy, wherein vertical motion of said main buoy is translated into rotational motion of said shaft; and
- an electric power generating device coupled to said shaft, wherein rotational motion of said shaft results in said electric power generating device generating electric power.

2. The wave energy recovery system of claim **1**, wherein said motion translating assembly further comprises:
- a retracting buoy;
- a pulley, coupled to said shaft; and
- a cable, coupled on a first end to said main buoy, coupled on a second end to said retracting buoy, and wrapped around said pulley.

3. The wave energy recovery system of claim **2** wherein the coupling of said pulley to said shaft translates rotational motion from said pulley to said shaft when said pulley rotates in a first direction and does not translate motion from said pulley to said shaft when said pulley rotates in a second direction.

4. The wave energy recovery system of claim **3** wherein said motion translating assembly is one of a plurality of motion translating assemblies comprising said wave energy recovery system.

5. The wave energy recovery system of claim **1** wherein said shaft is comprised of a plurality of shaft segments.

6. The wave energy recovery system of claim **5** wherein each of said plurality of motion translating assemblies is coupled to an adjacent motion translating assembly by one of said plurality of shaft segments.

7. The wave energy recovery system of claim **6** wherein each of said plurality of shaft segments is coupled to one of said plurality of pulleys by a constant velocity joint.

8. The wave energy recovery system of claim **1** further comprising a support platform, wherein said shaft is rotatably coupled to said support platform.

9. The wave energy recovery system of claim **8** wherein said buoy is positioned proximate to a surface of a body of water and said support platform is positioned proximate to a bed of said body of water.

10. The wave energy recovery system of claim **1** wherein said electric power generating device is an alternating current permanent magnet generator.

11. The wave energy recovery system of claim **1** further comprising a gearbox, wherein said gearbox is coupled to said shaft and coupled to said electric power generating device.

12. The wave energy recovery system of claim **1** further comprising a capacitor coupled to said electric power generating device.

13. The wave energy recovery system of claim **1** wherein said main buoy comprises:
- a water intake valve; and
- an air intake valve.

14. The wave energy recovery system of claim **1** further comprising a power cable coupled to said electric power generating device.

15. The wave energy recovery system of claim **1** wherein said main buoy comprises:
- a rectangular body; and
- a skirt coupled to said rectangular body.

16. A wave energy recovery system comprising:
- a motion translating assembly comprising;
  - a main buoy; and
  - a shaft coupled to said main buoy, wherein vertical motion of said main buoy is translated into rotational motion of said shaft;
- a pump coupled to said shaft, wherein rotational motion of said shaft results in said pump generating pressure;
- a pressure line coupled to said pump; and
- an electric power generating device coupled to said pressure line.

17. The wave energy recovery system of claim **16**, wherein said electric power generating device is a multiple hydraulic pump drive system.

18. The wave energy recovery system of claim **17** wherein said motion translating assembly is one of a plurality of motion translating assemblies comprising said wave energy recovery system.

19. The wave energy recovery system of claim **18** wherein said pump is one of a plurality of pumps comprising said wave energy recovery system;
- further wherein, pressure from said plurality of pumps is accumulated to drive said hydraulic generator.

20. A method for recovering energy from waves comprising:
- positioning a plurality of buoys in a body of water;
- positioning a shaft in said body of water;
- positioning an electric power generating device in said body of water or proximate to said body of water;
- coupling each of said plurality of buoys to said shaft;
- coupling said shaft to said electric power generating device;
- translating vertical motion of said buoy to rotational motion of said shaft; and
- engaging rotational motion of said shaft to said electric power generating device to generate electric power.

* * * * *

US 20100102562A1

(19) **United States**

(12) **Patent Application Publication**

Greenspan et al.

(10) **Pub. No.: US 2010/0102562 A1**

(43) **Pub. Date: Apr. 29, 2010**

(54) **WAVE ENERGY RECOVERY SYSTEM**

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(21) Appl. No.: **12/466,960**

(22) Filed: **May 15, 2009**

Related U.S. Application Data

(60) Provisional application No. 61/127,699, filed on May 15, 2008.

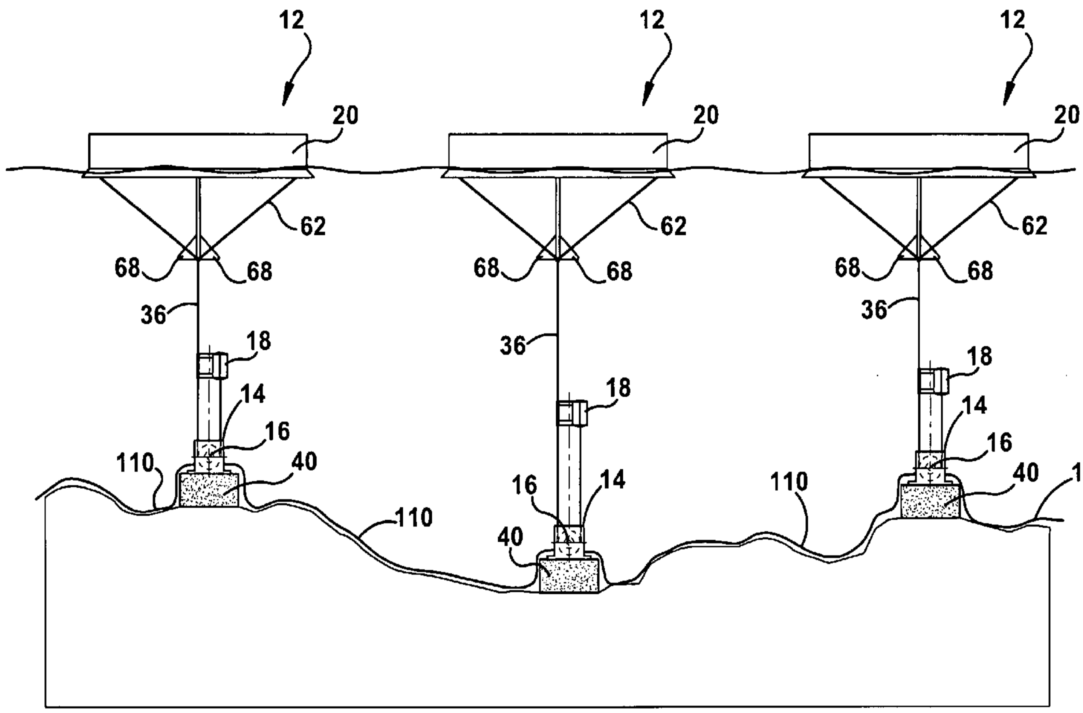
Publication Classification

(51) **Int. Cl.**
F03B 13/16 (2006.01)

(52) **U.S. Cl.** **290/53**

(57) **ABSTRACT**

The present invention includes novel apparatus and methods for recovering energy from water waves. An embodiment of the present invention may include a buoy, a shaft, and an electric power generating device. The shaft may be coupled to the buoy such that when the buoy moves vertically in response to a passing wave, the shaft rotates. The shaft may be coupled to the electric power generating device such that when the shaft rotates, the generating device produces electric power. Once electric power is generated, it may be delivered to shore, where it is stored, used to power a device, or delivered to a power distribution grid.



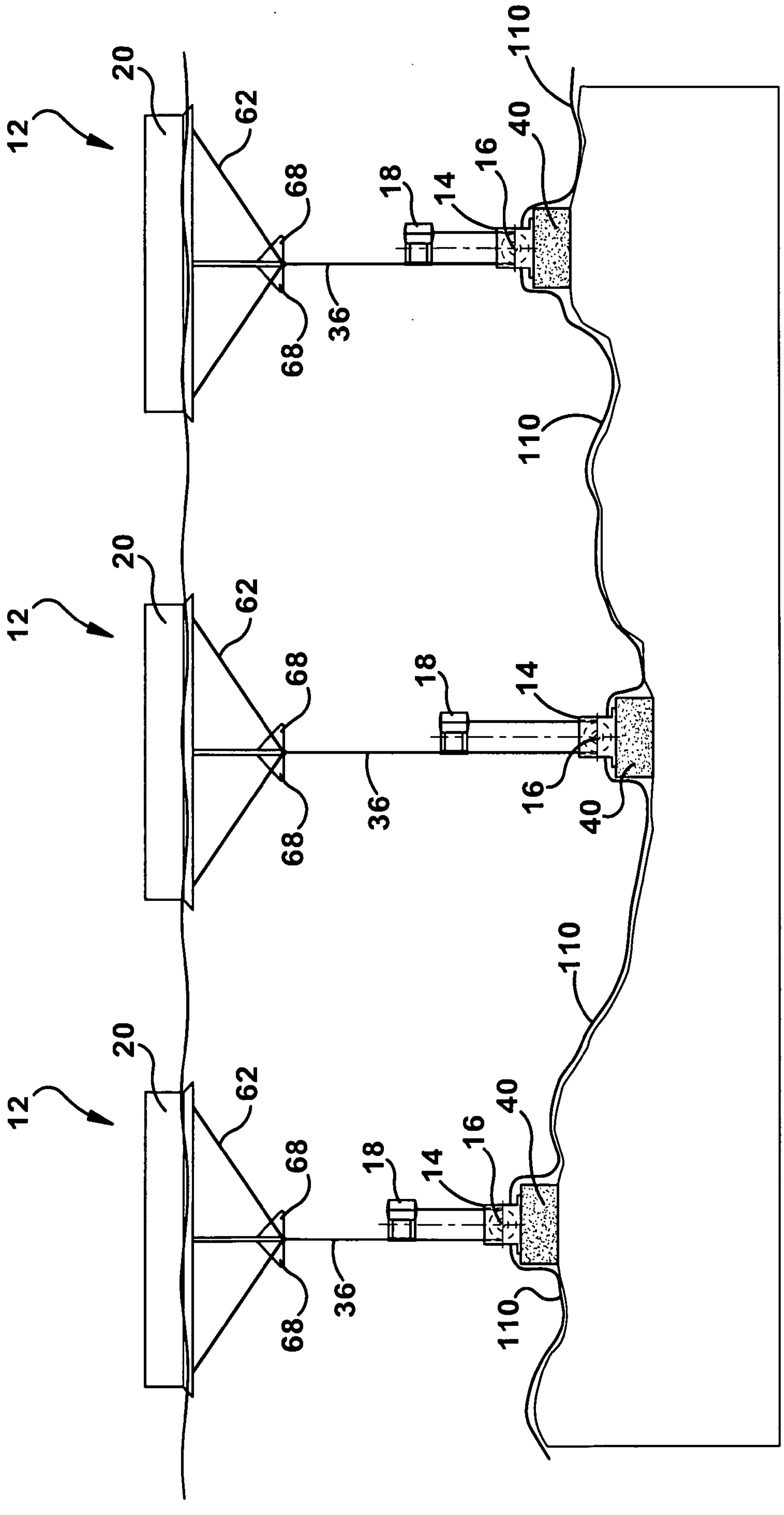

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Fig. 1

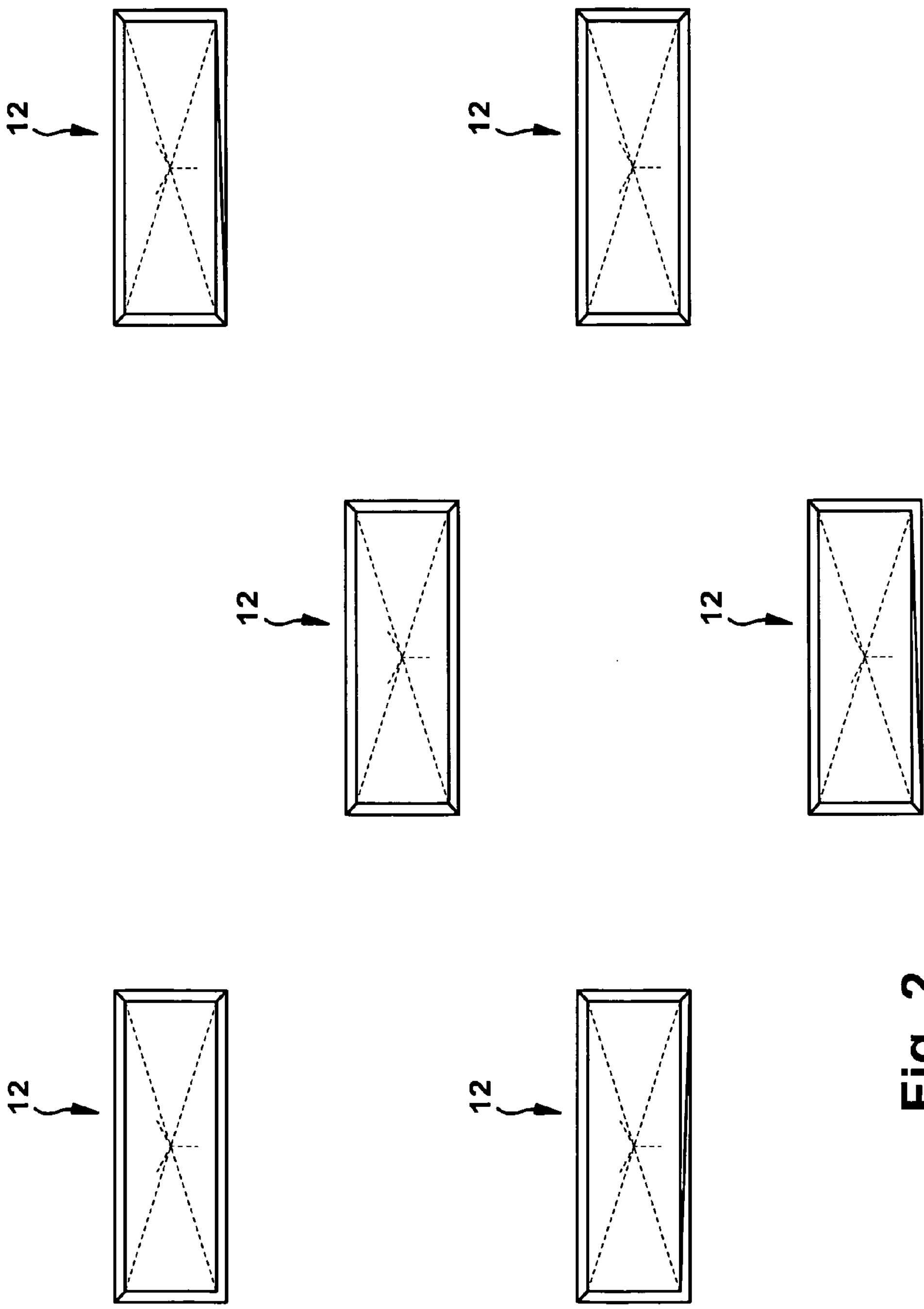
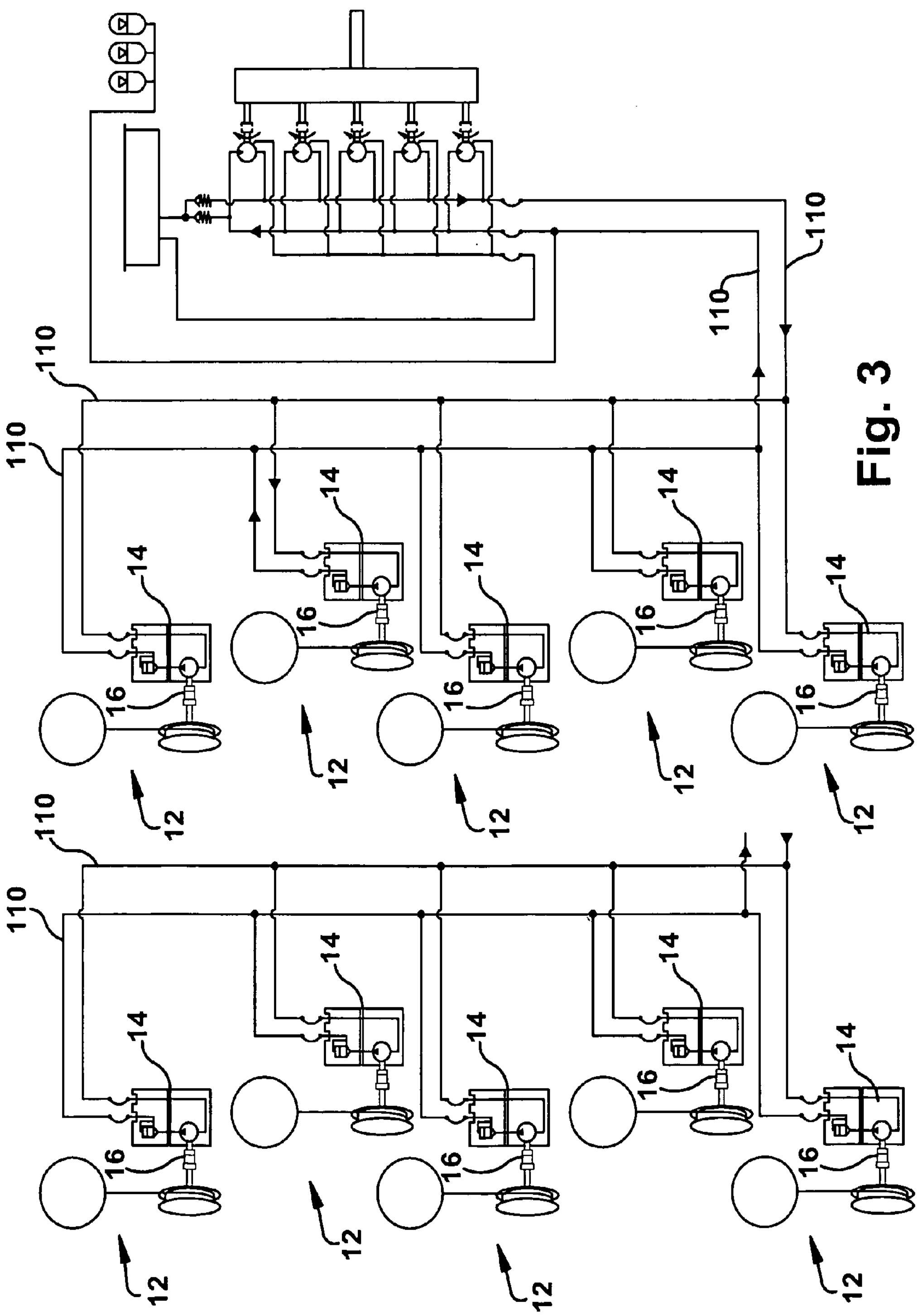


Fig. 2



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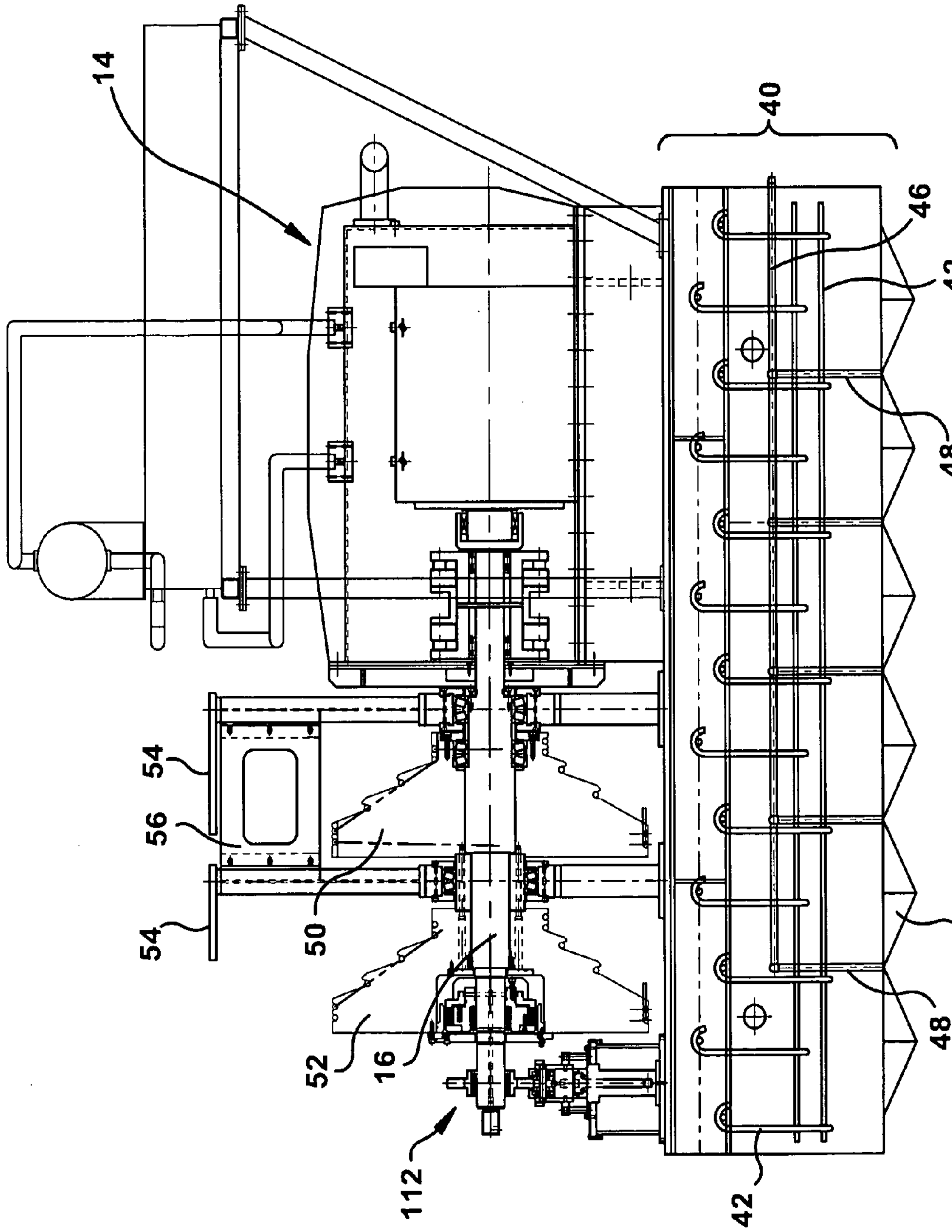


Fig. 4

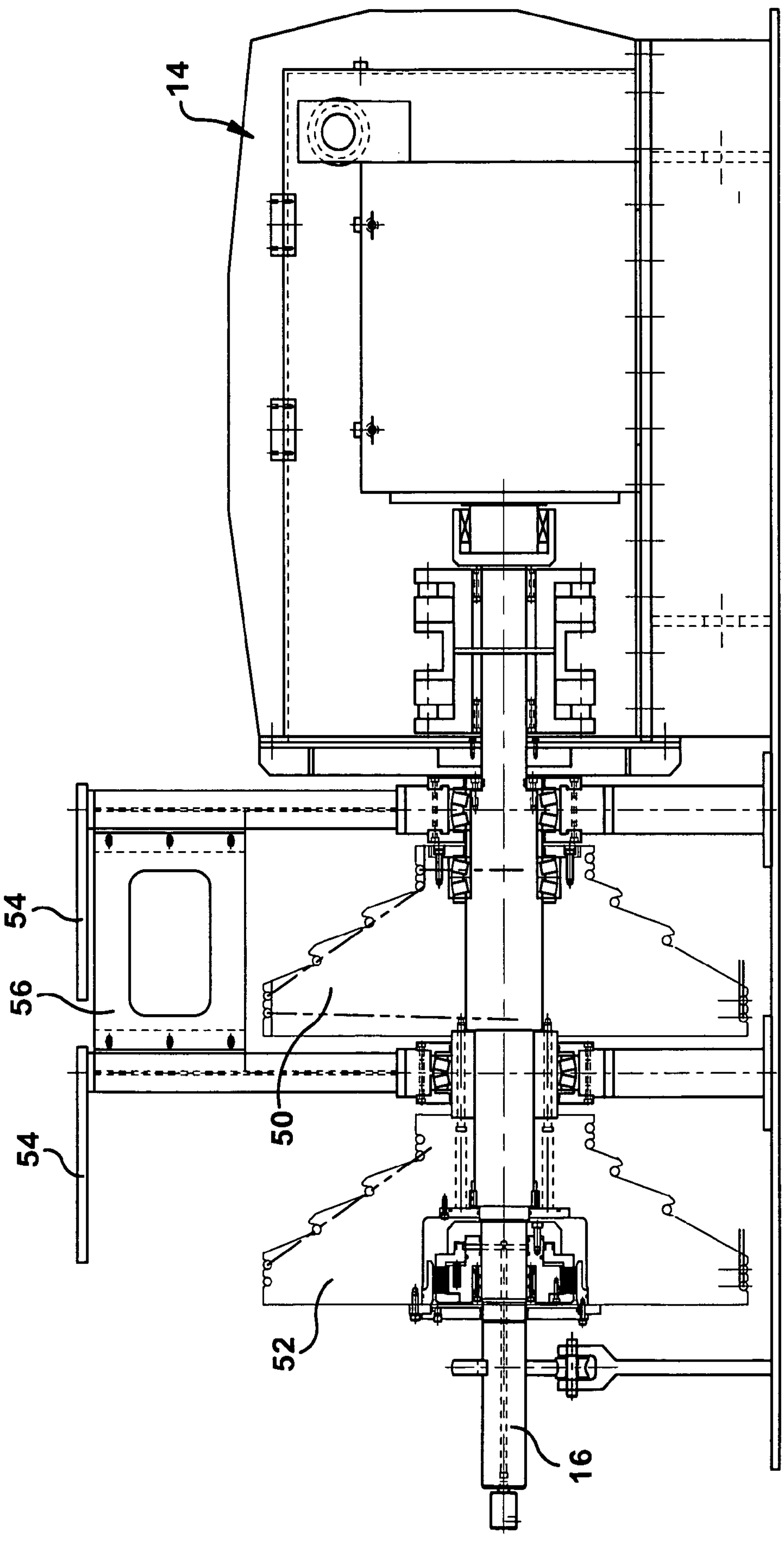
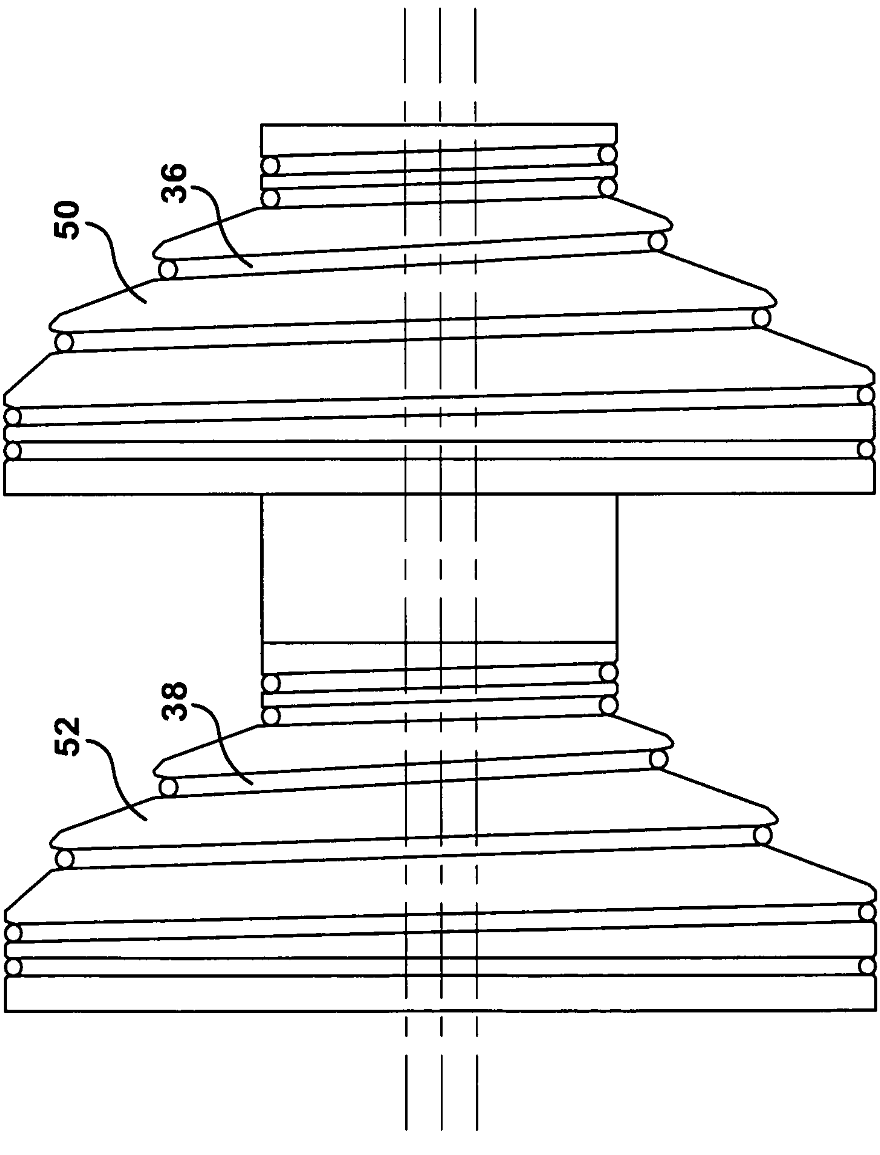


Fig. 5



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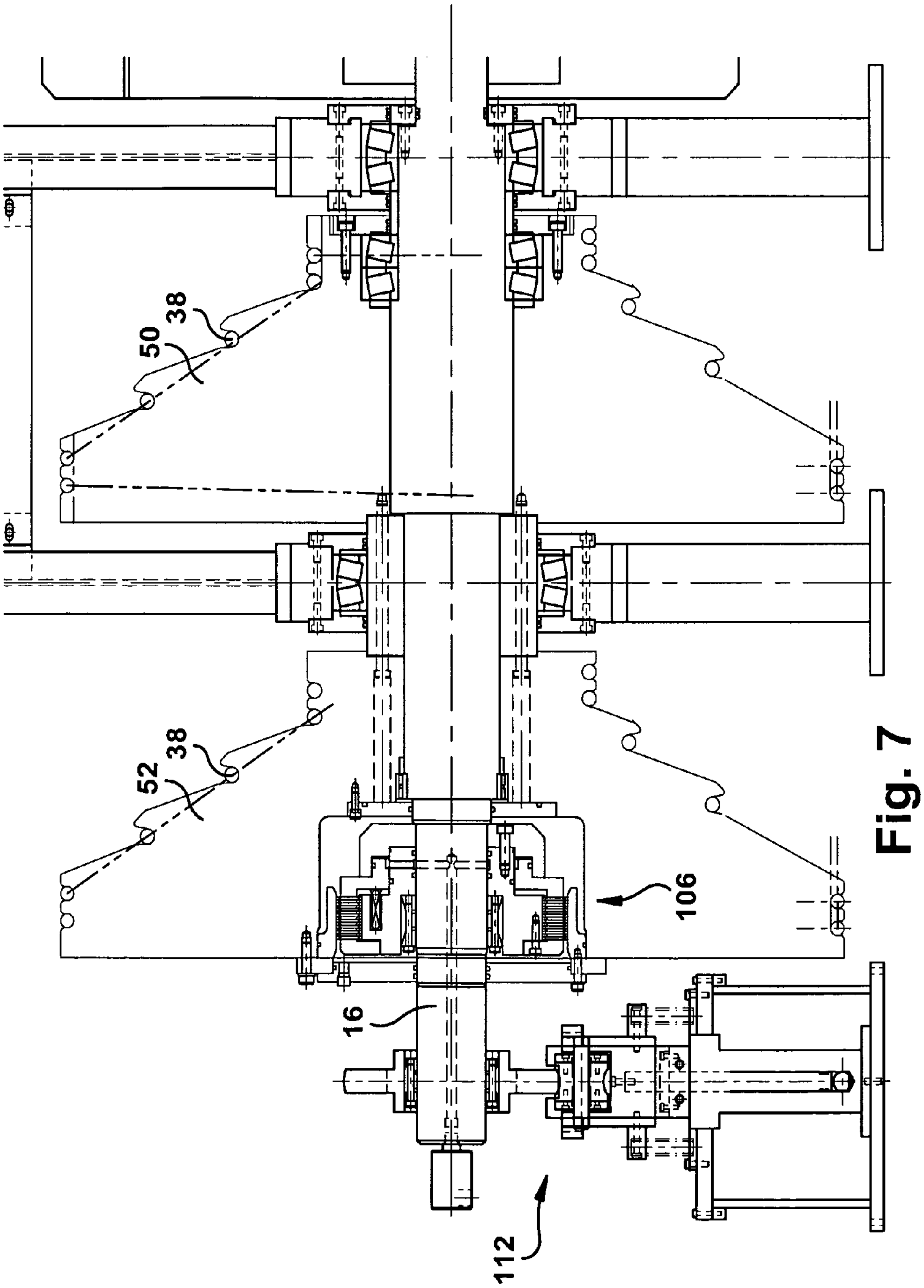

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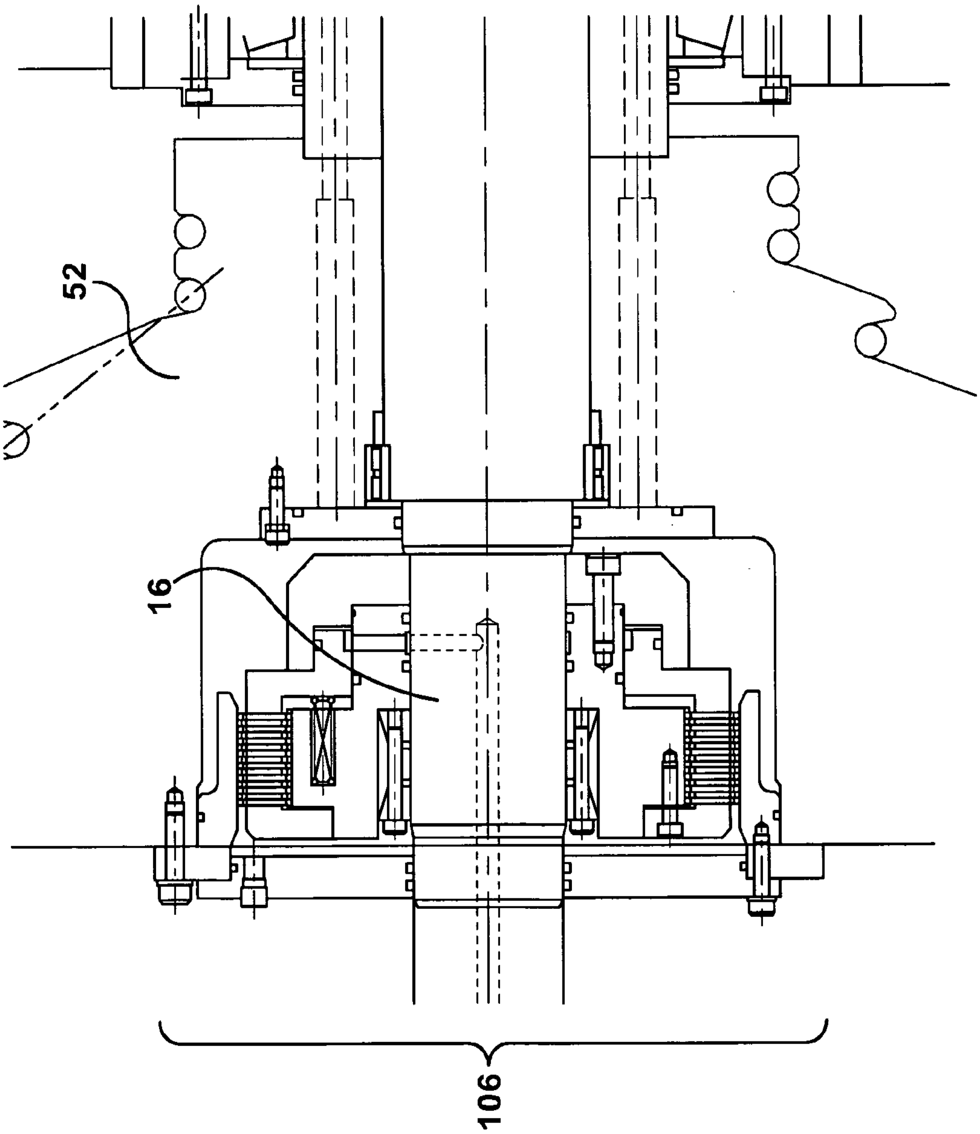
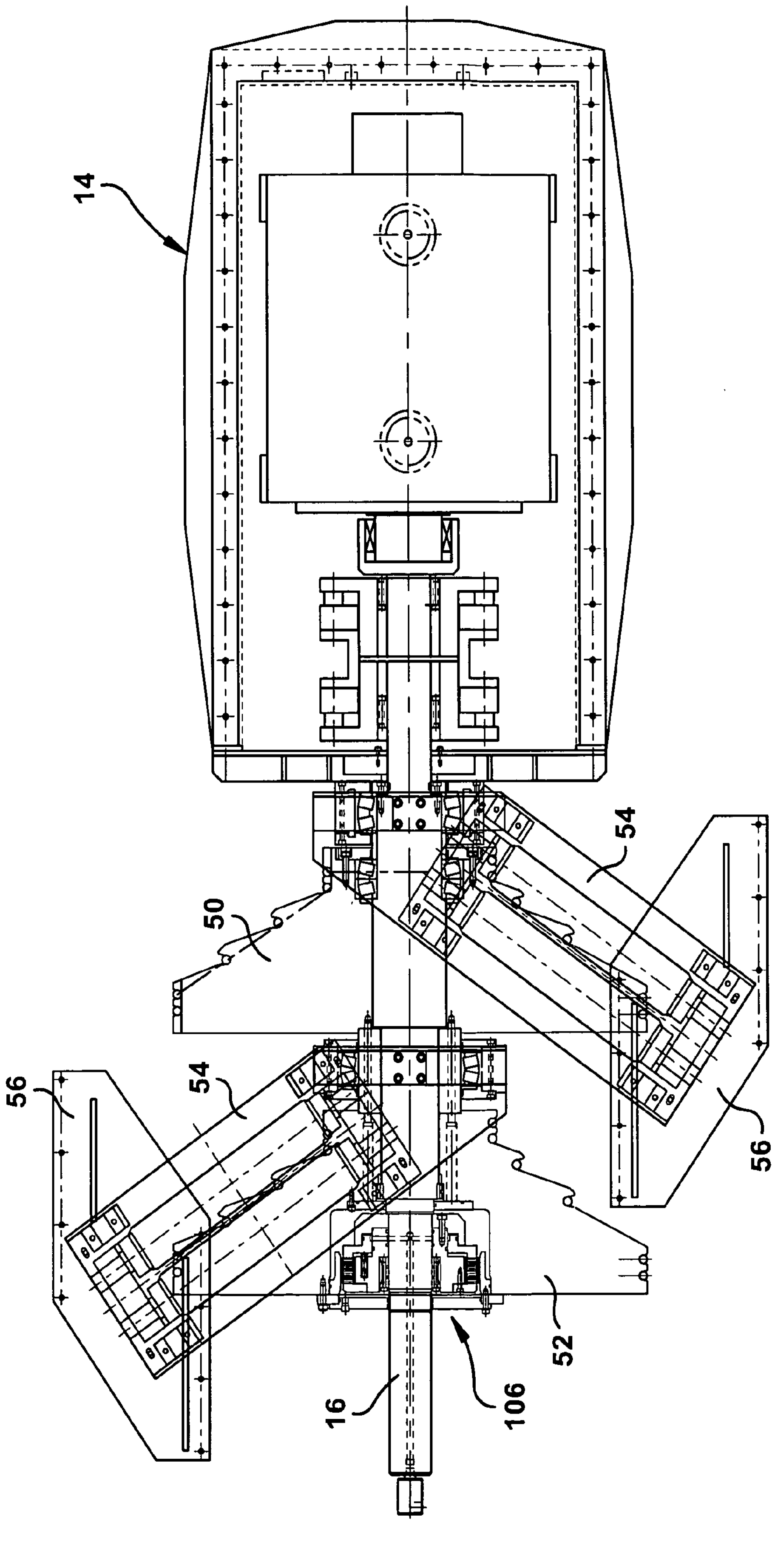


Fig. 8



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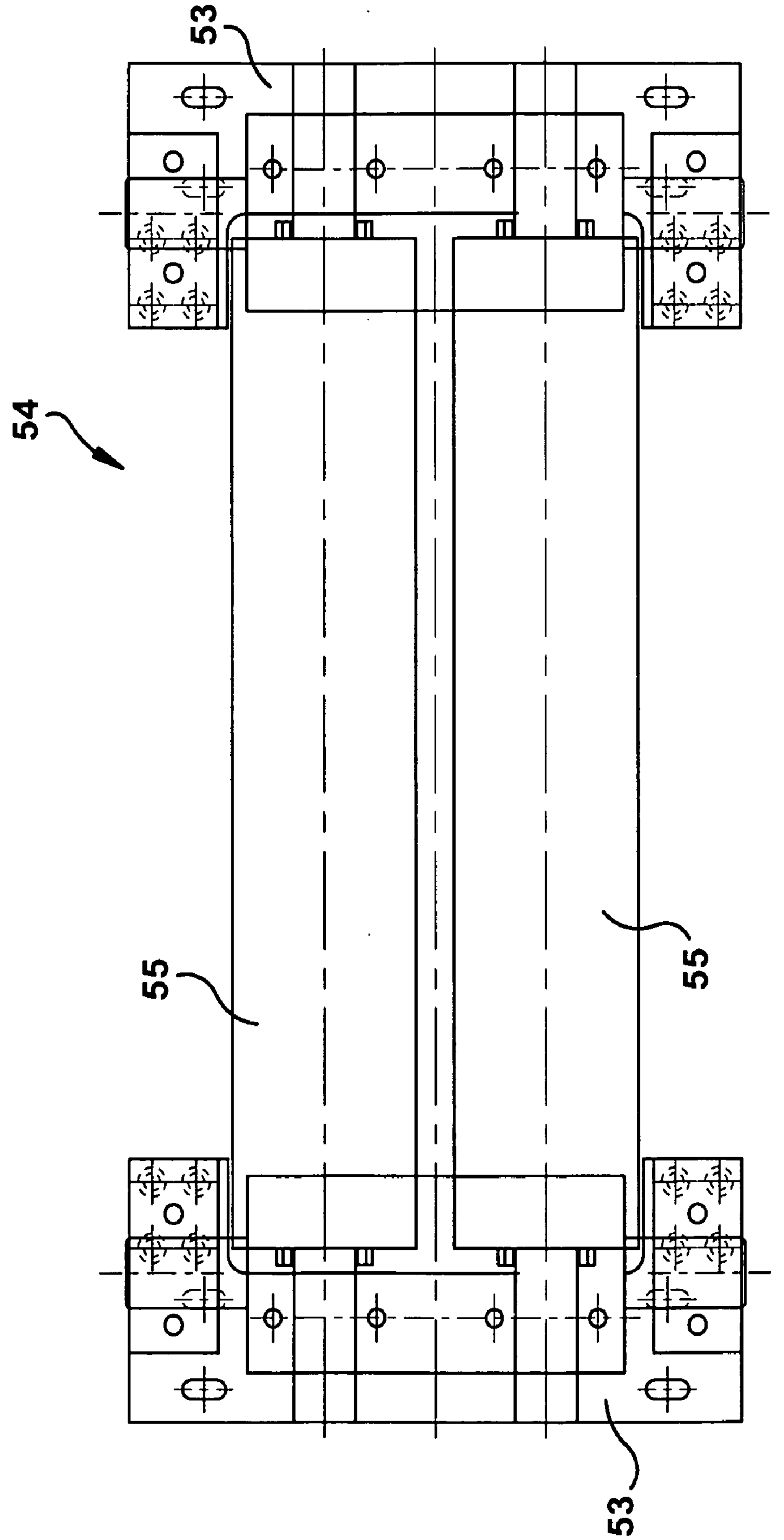

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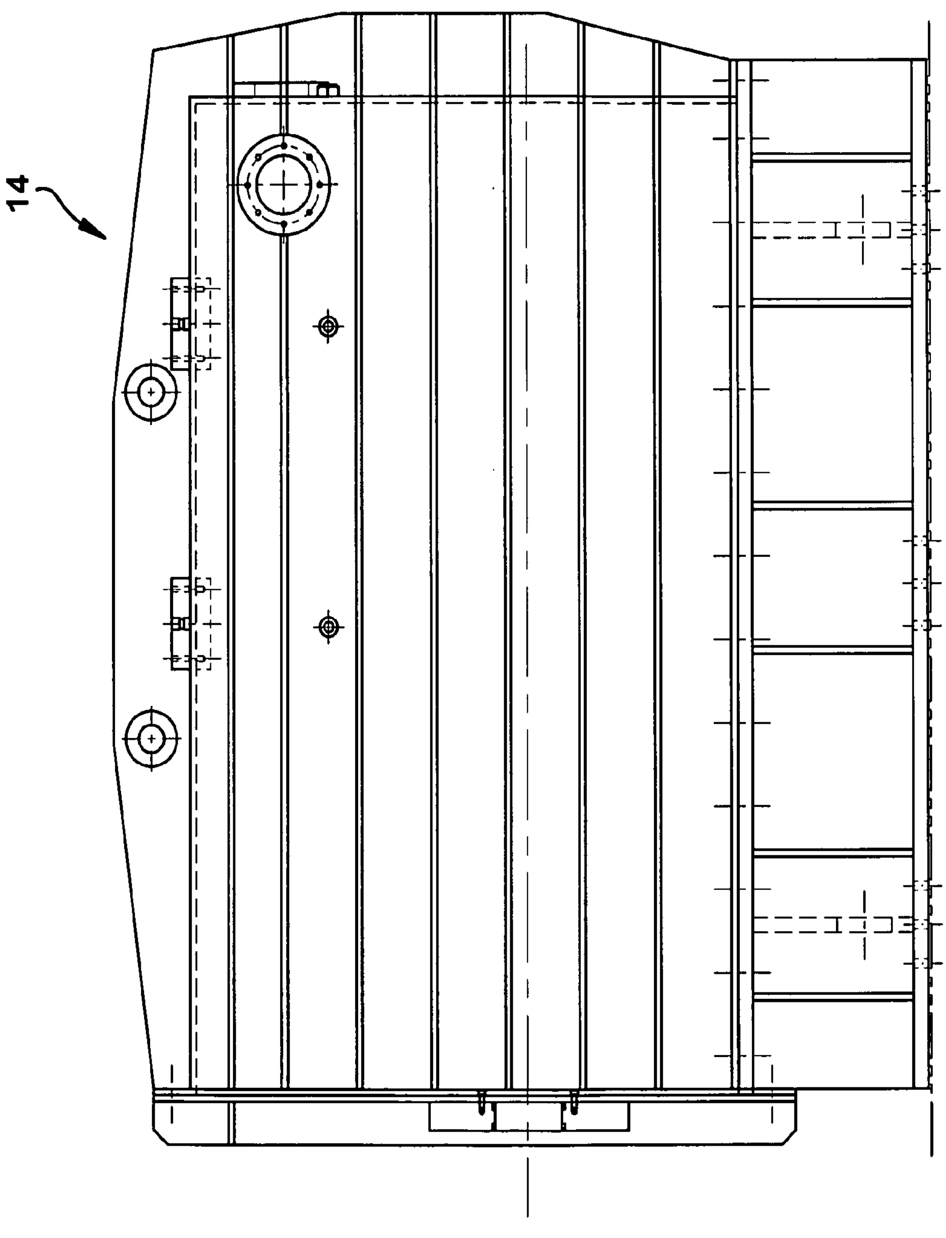

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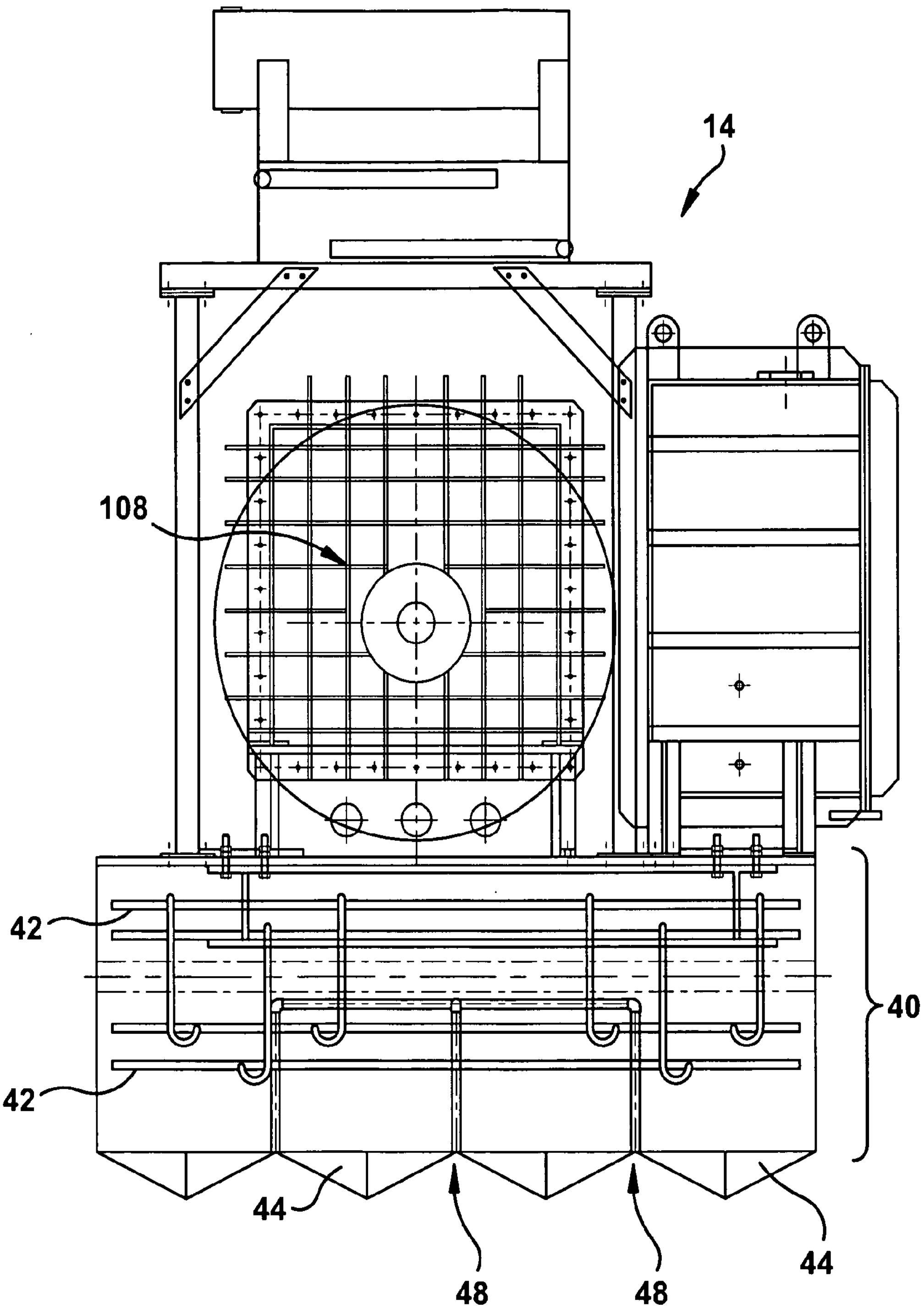


Fig. 12

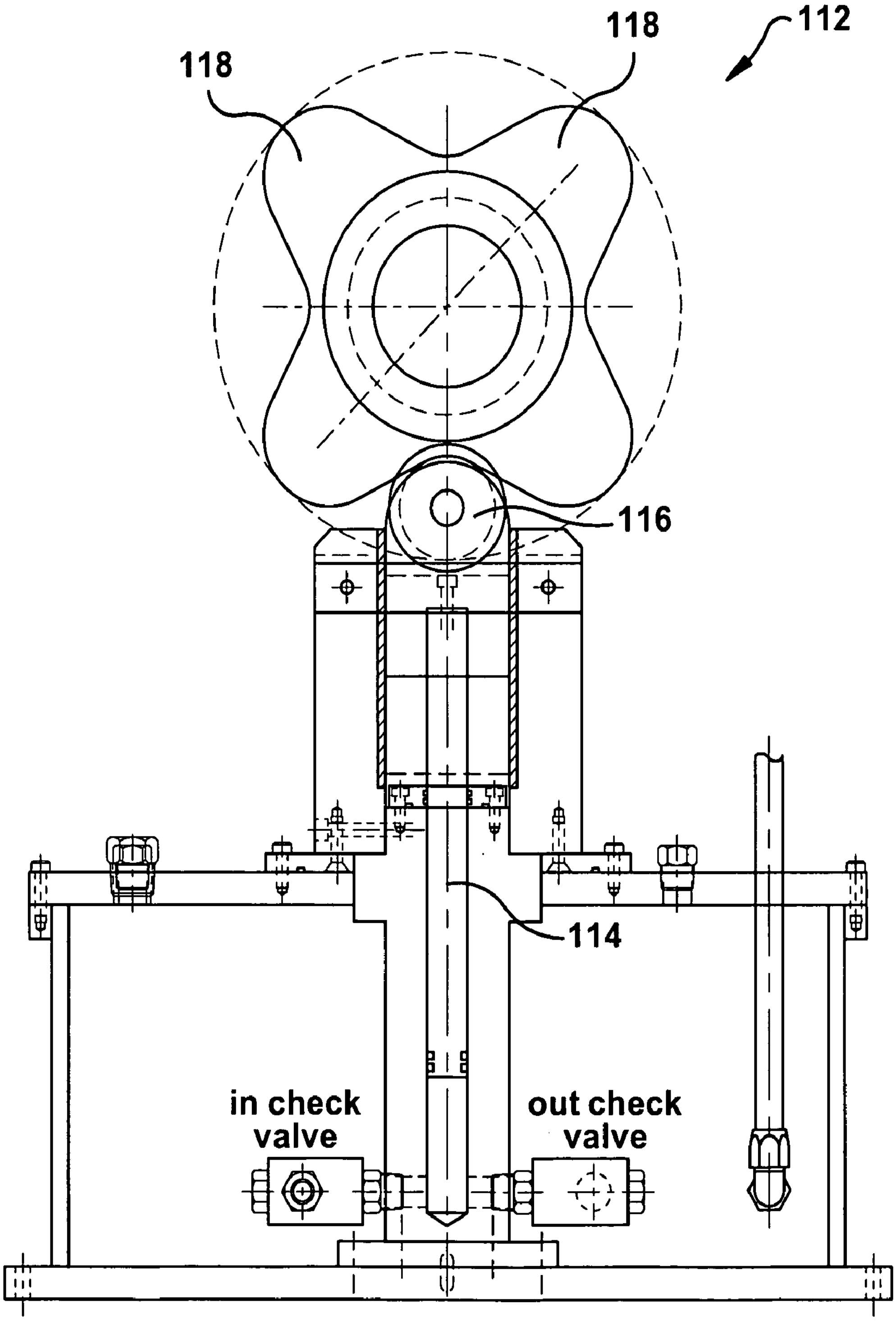


Fig. 13

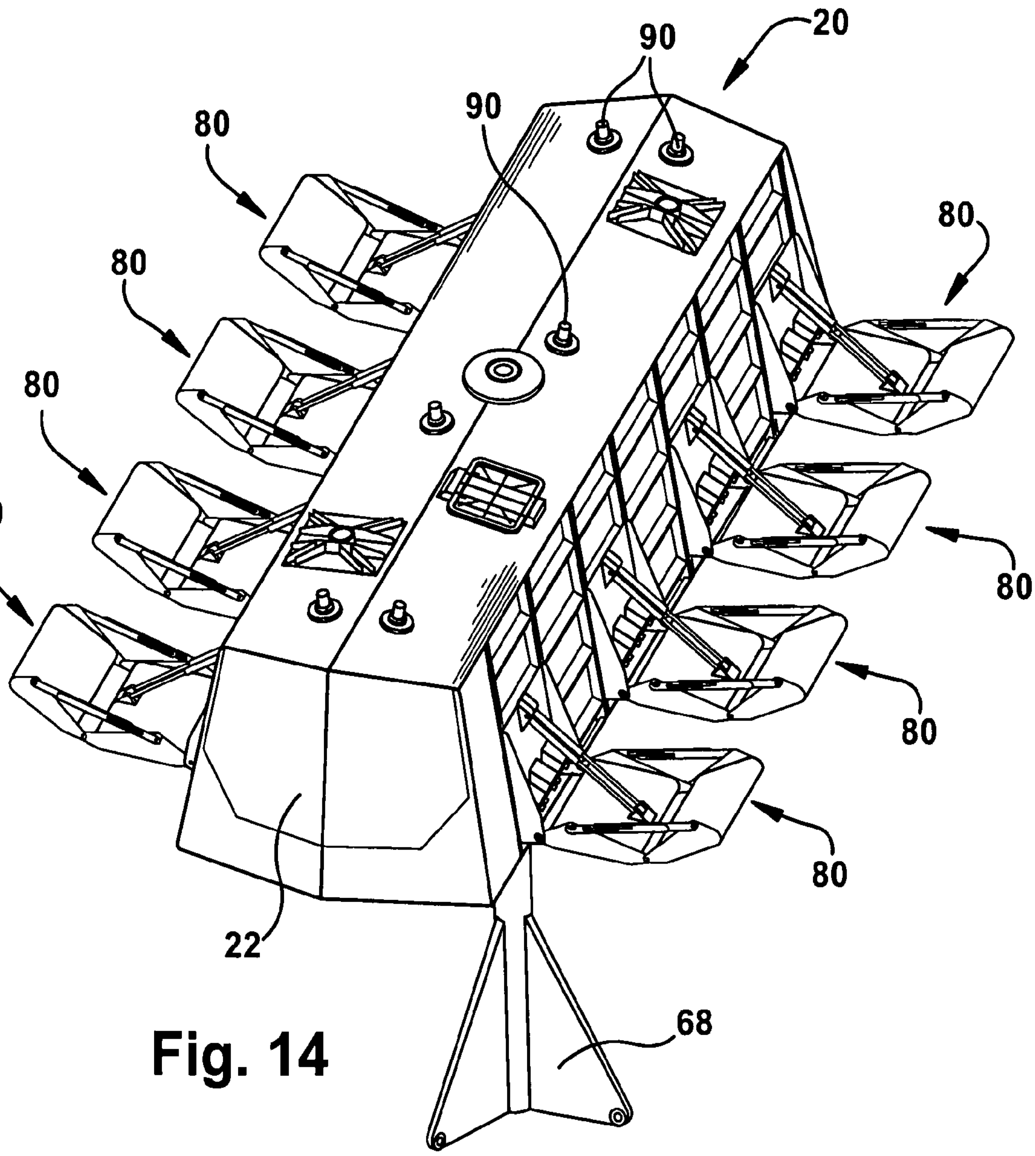
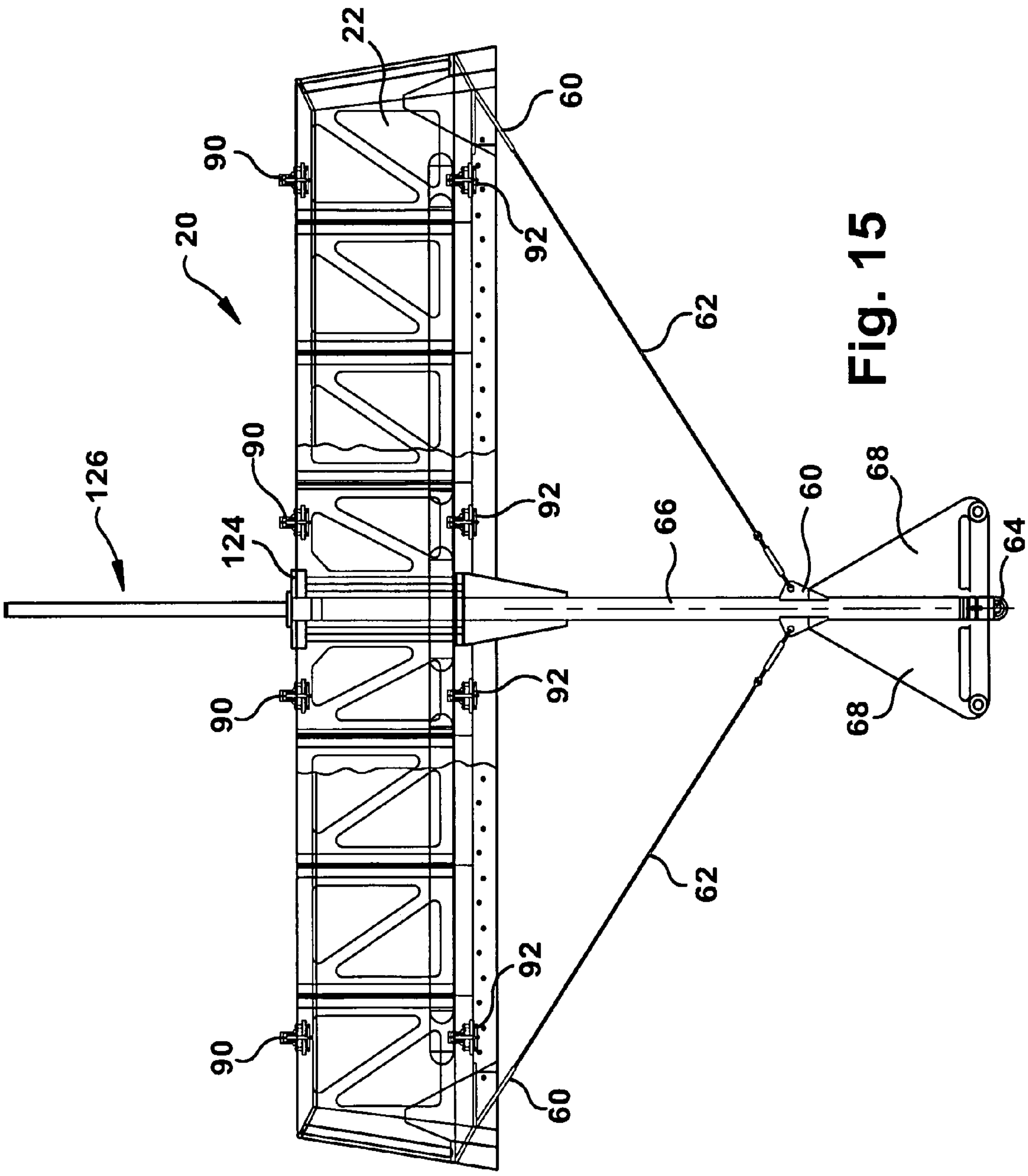


Fig. 14



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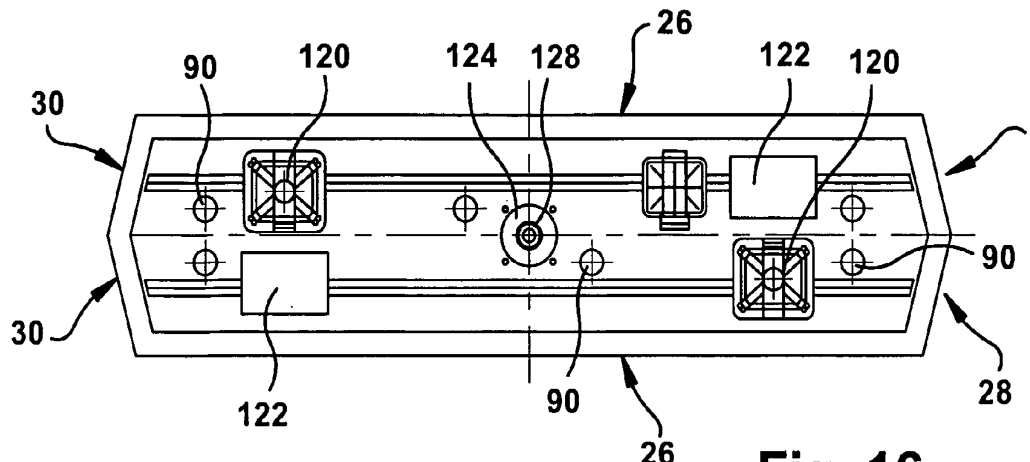
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Fig. 16

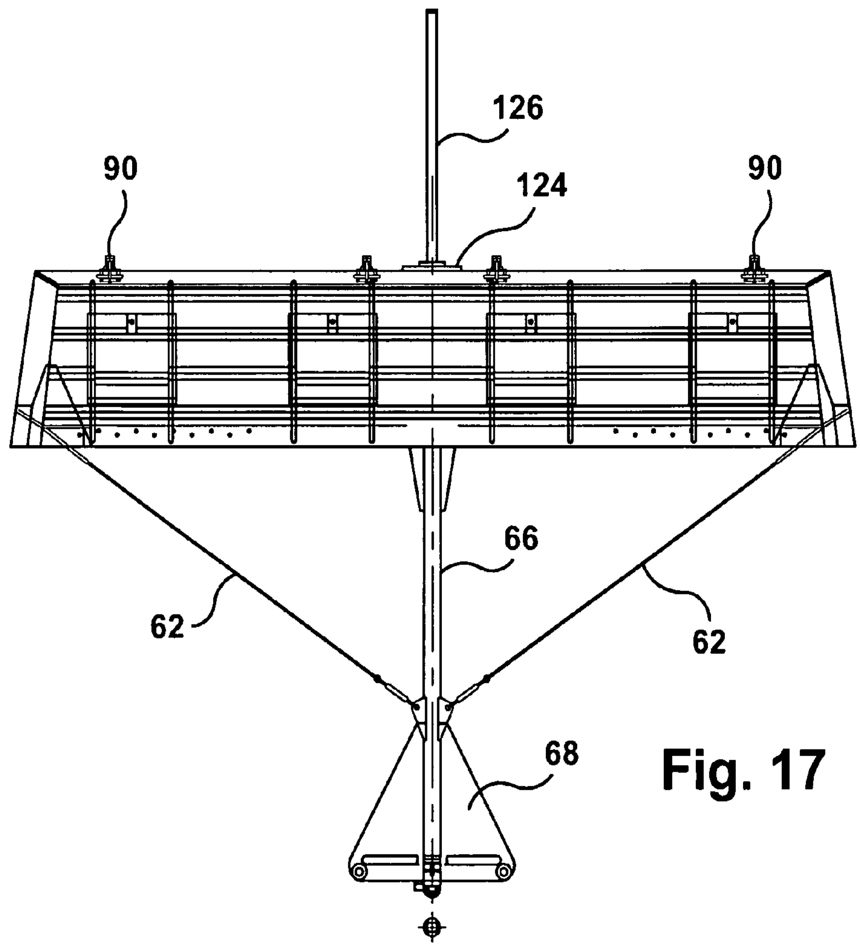
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Fig. 17

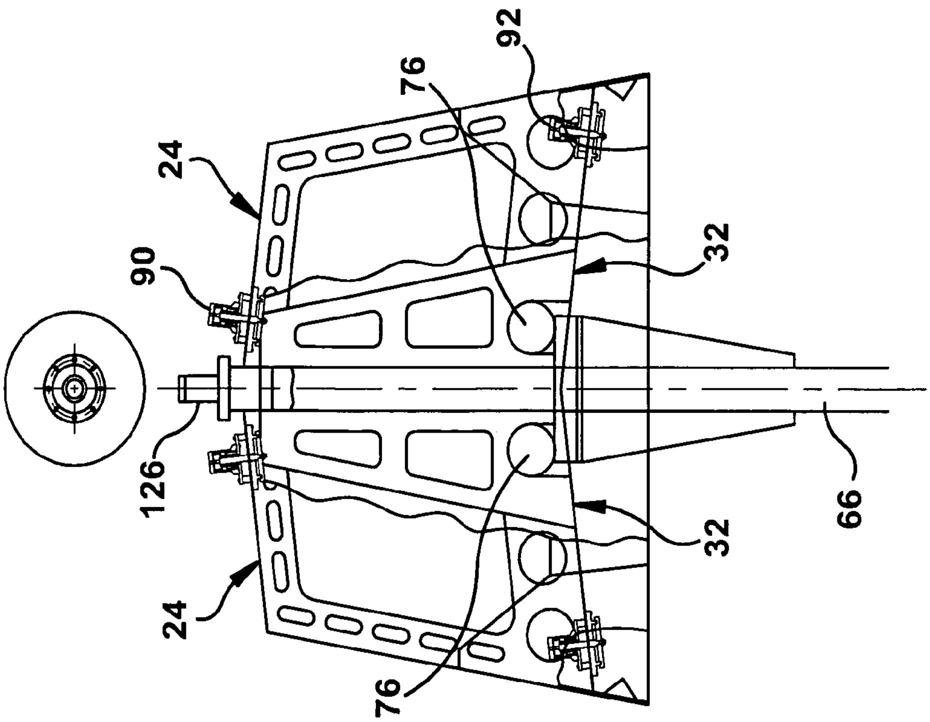
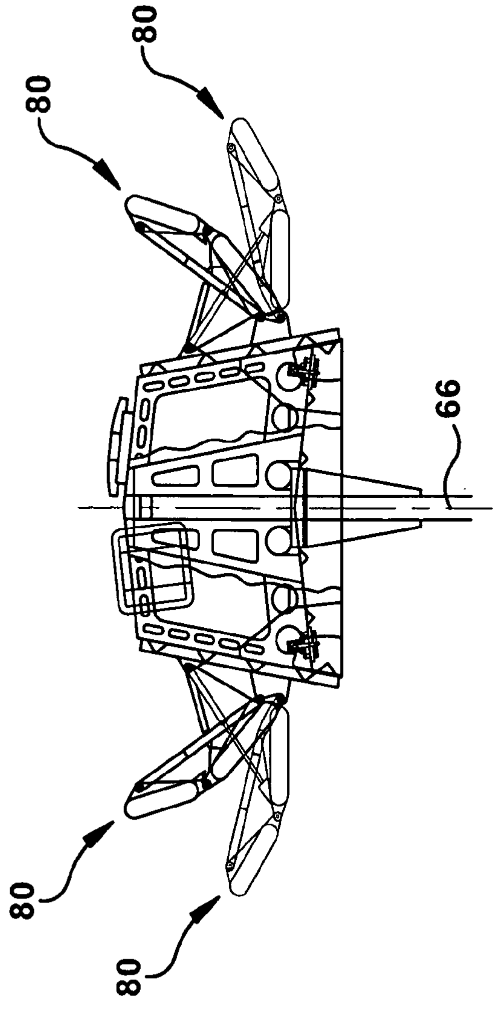


Fig. 19



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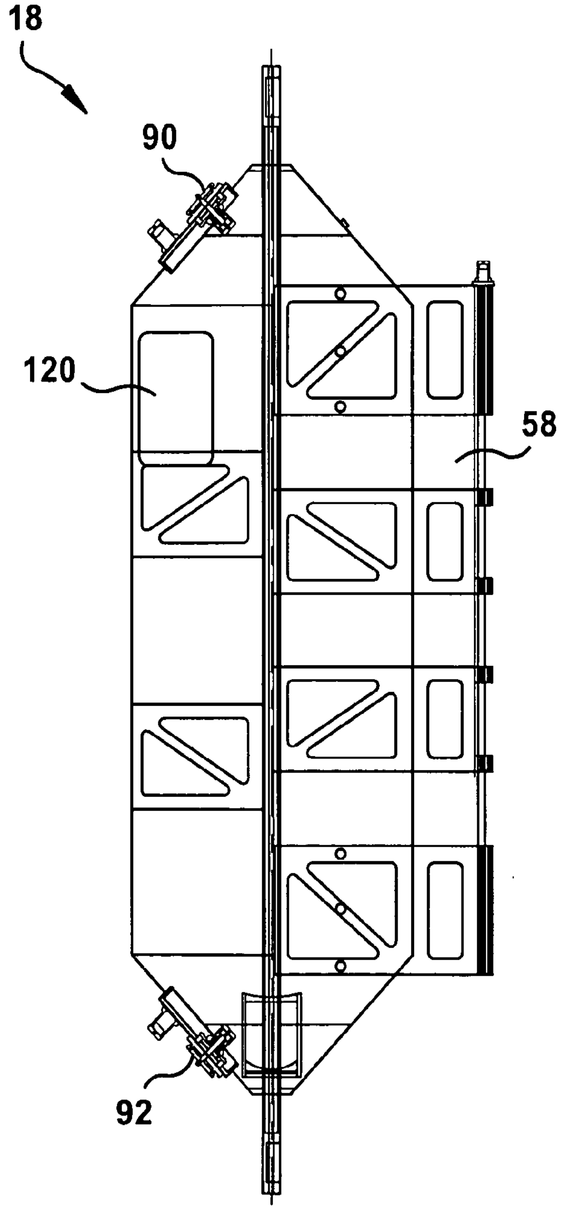


Fig. 20A

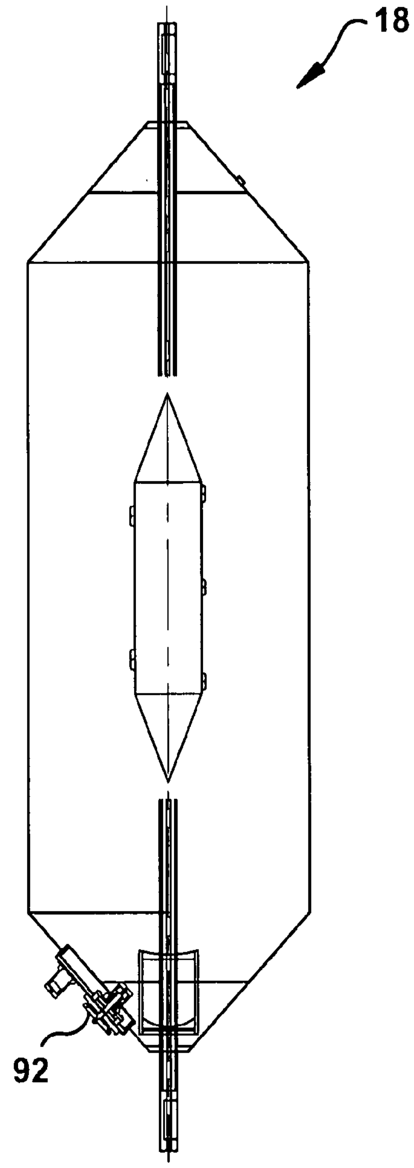


Fig. 20B

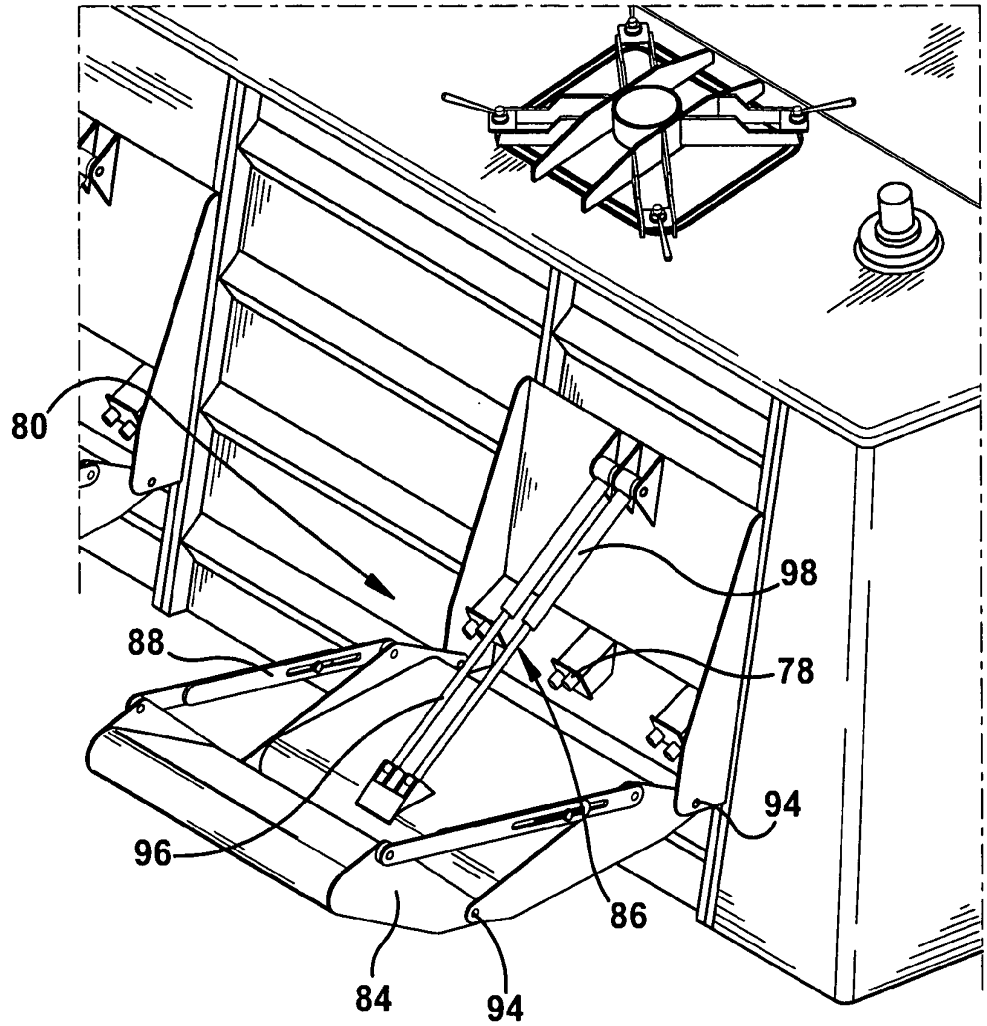


Fig. 21A

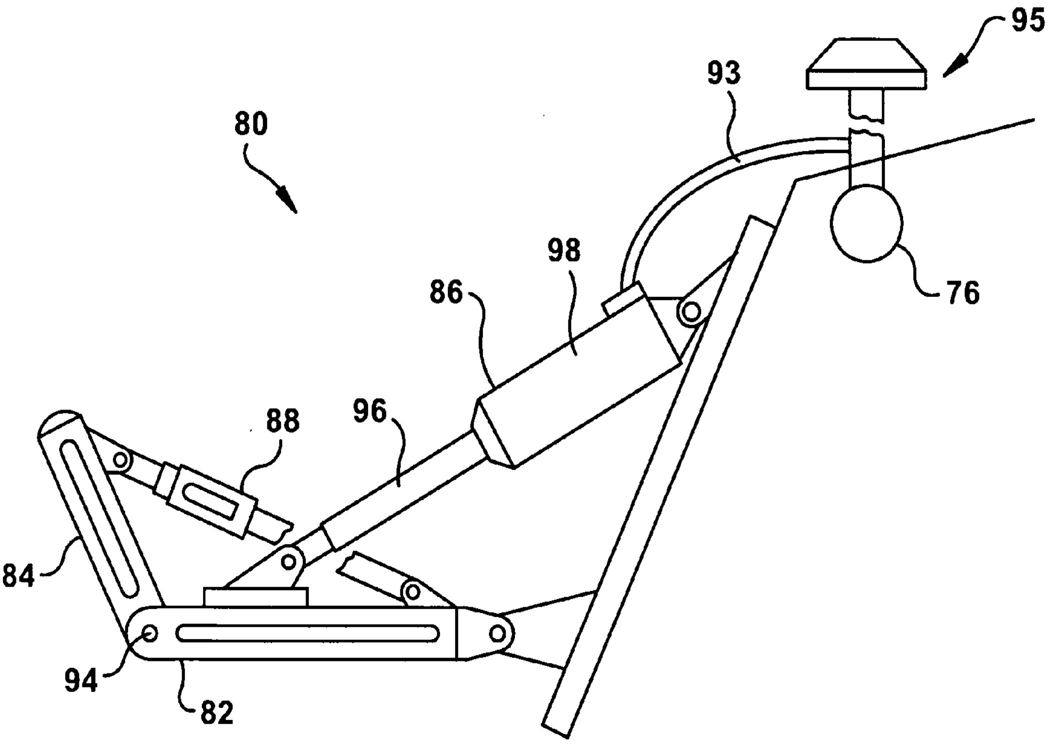
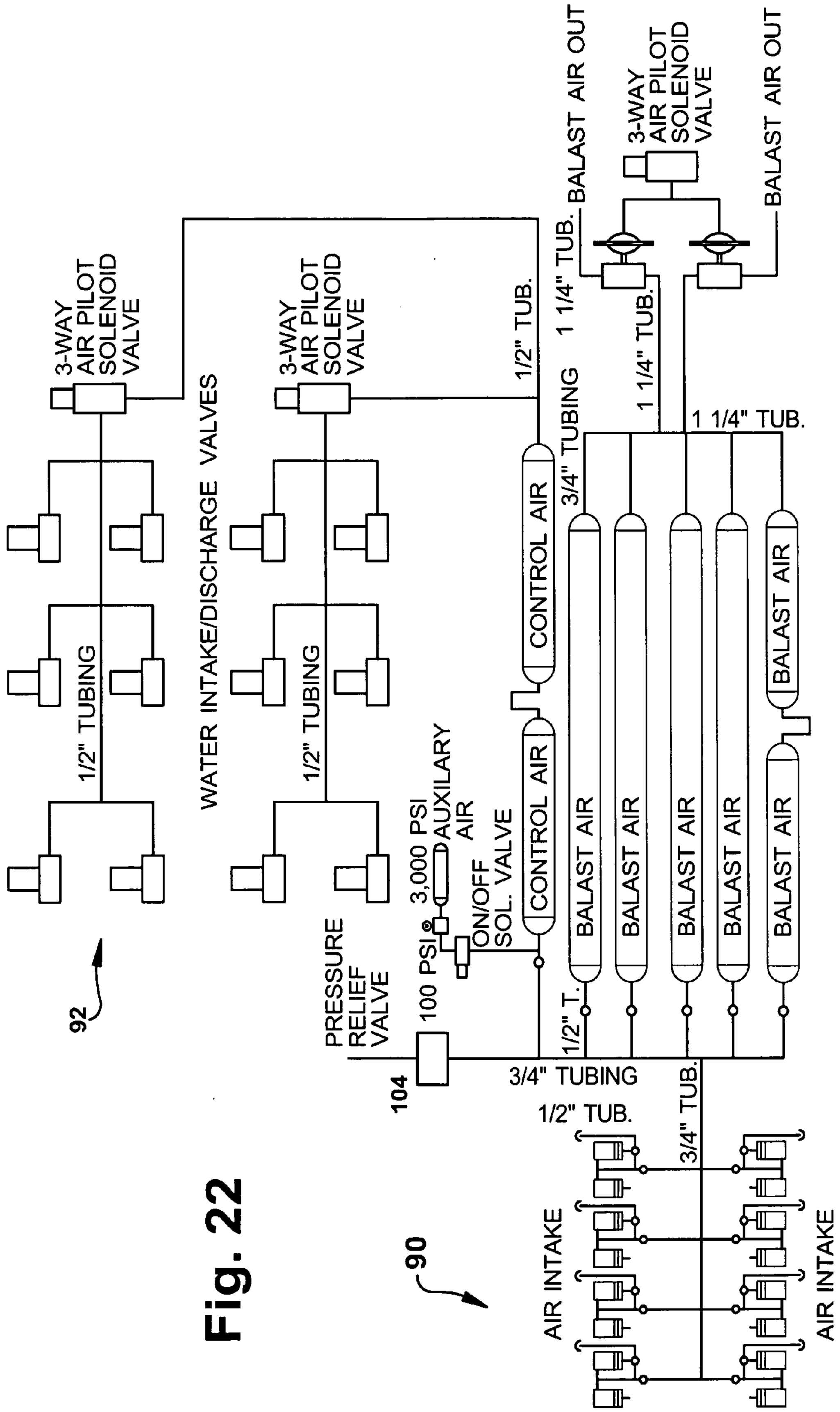


Fig. 21B


3-WAY AIR PILOT SOLENOID VALVE
3-WAY AIR PILOT SOLENOID VALVE
3-WAY AIR PILOT SOLENOID VALVE
1/2" TUBING
1/2" TUBING
WATER INTAKE/DISCHARGE VALVES
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1/2" TUB.
1 1/4" TUB.
1 1/4" TUB.
1 1/4" TUB.
BALAST AIR OUT
BALAST AIR OUT
3/4" TUBING
CONTROL AIR
CONTROL AIR
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BALAST AIR
BALAST AIR
BALAST AIR
BALAST AIR
BALAST AIR
3,000 PSI AUXILARY AIR
ON/OFF SOL. VALVE
100 PSI
PRESSURE RELIEF VALVE
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AIR INTAKE
AIR INTAKE

Fig. 22

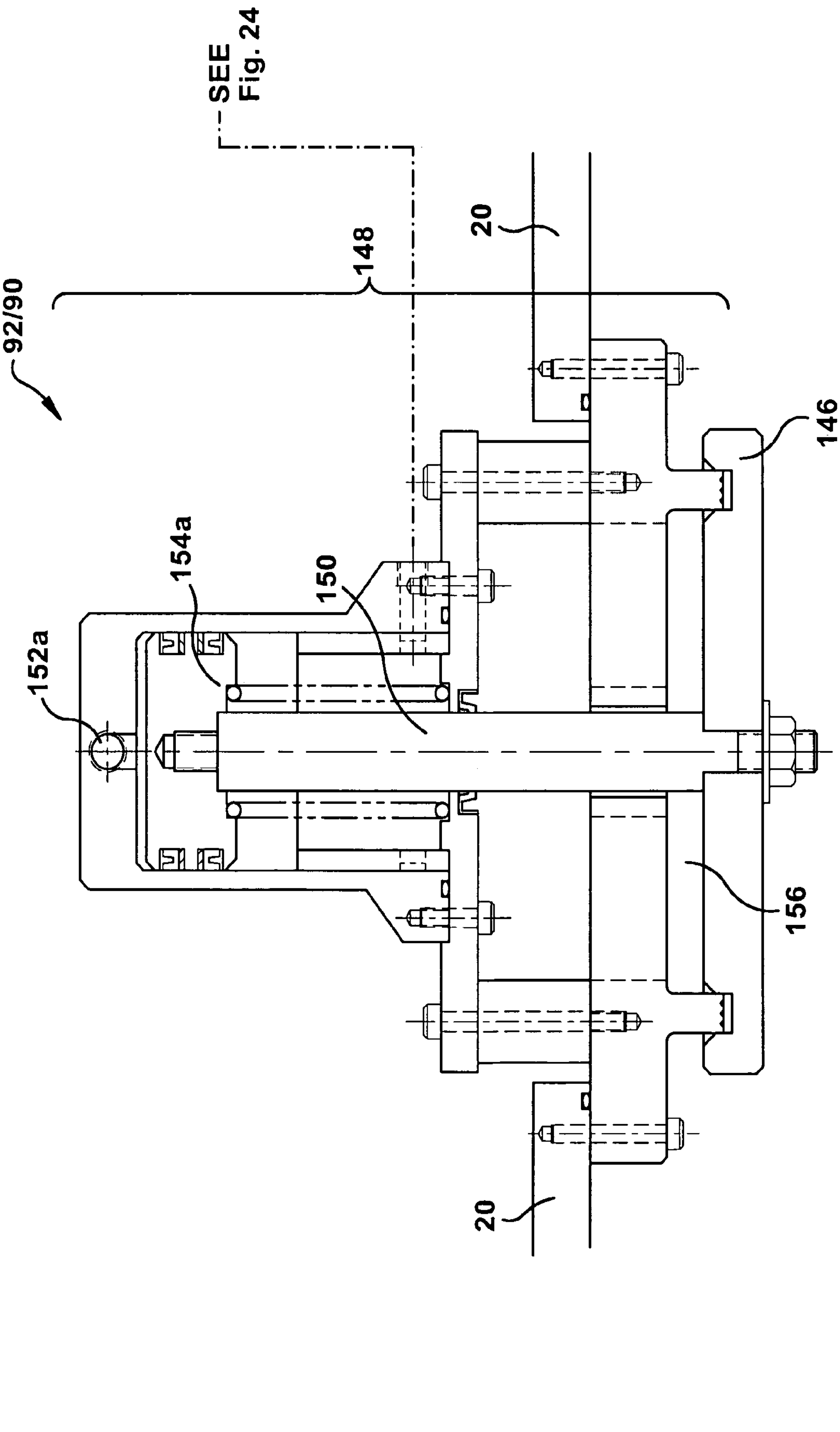


Fig. 23

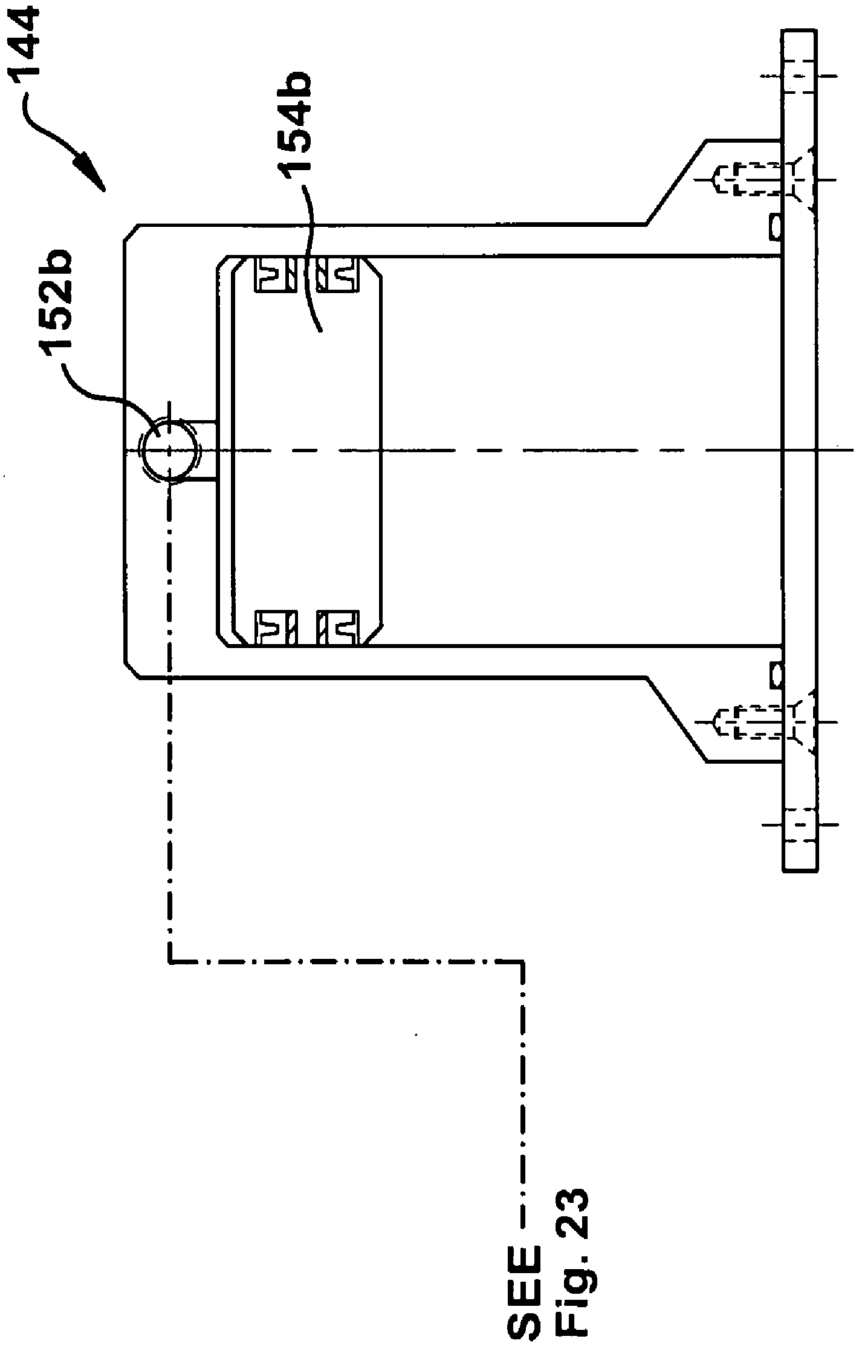


Fig. 24

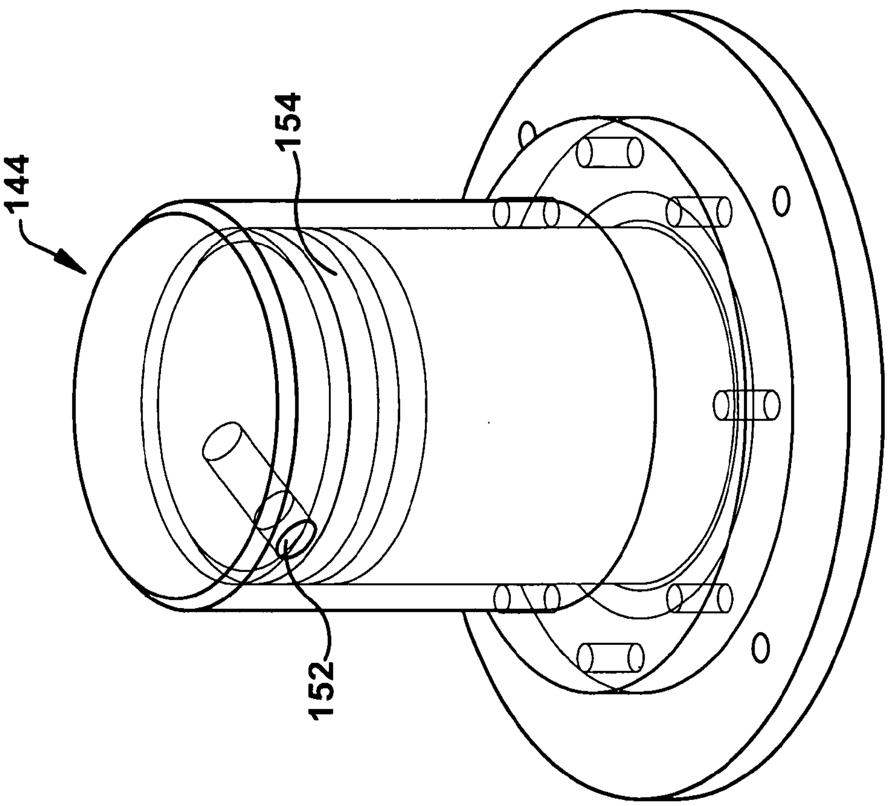


Fig. 26

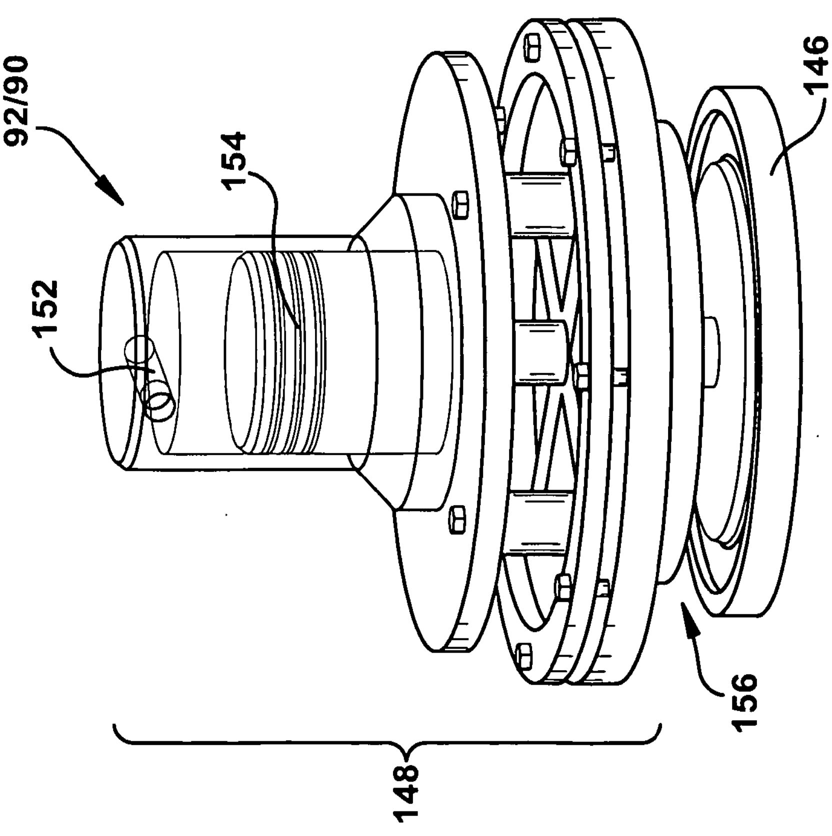
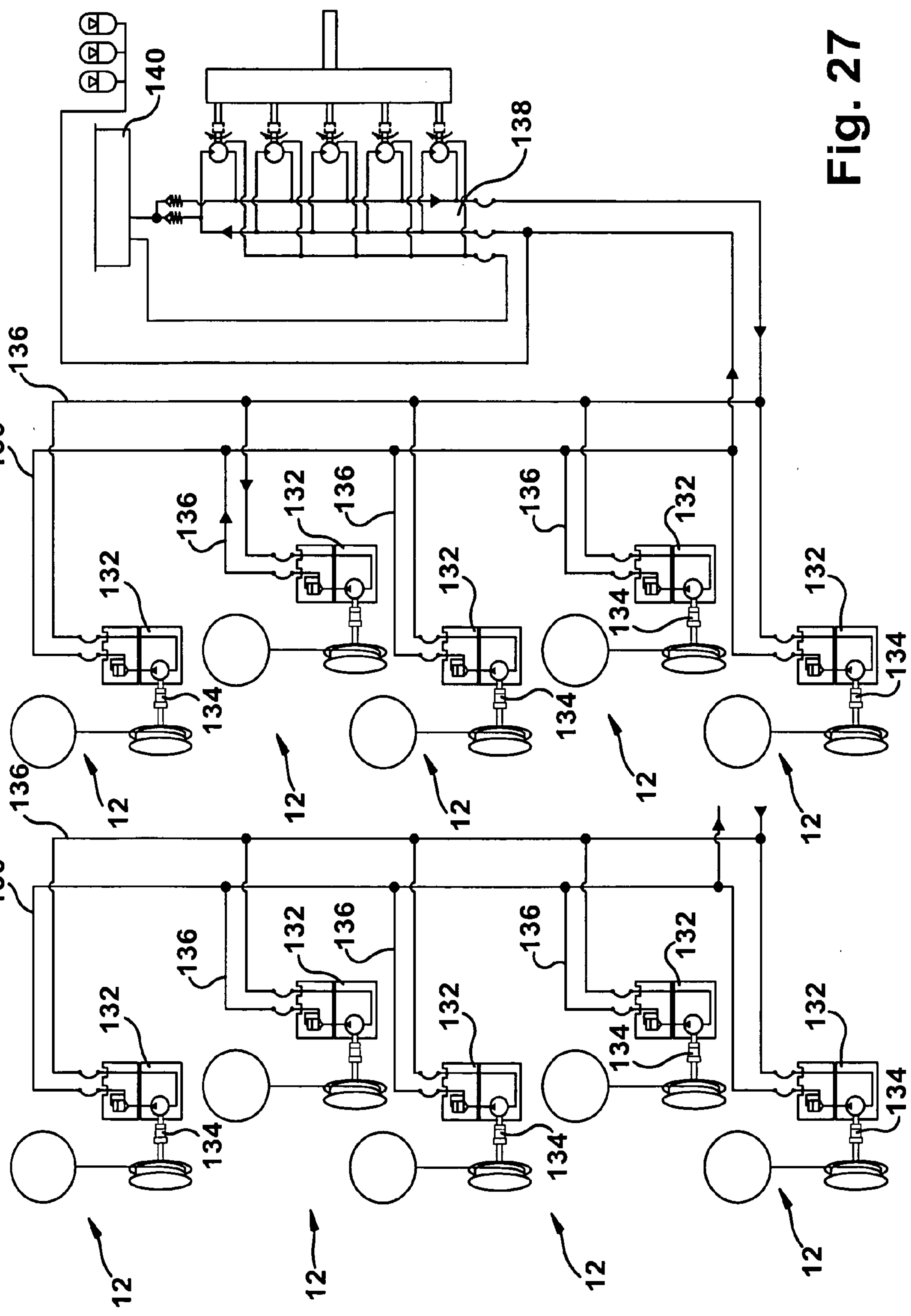


Fig. 25



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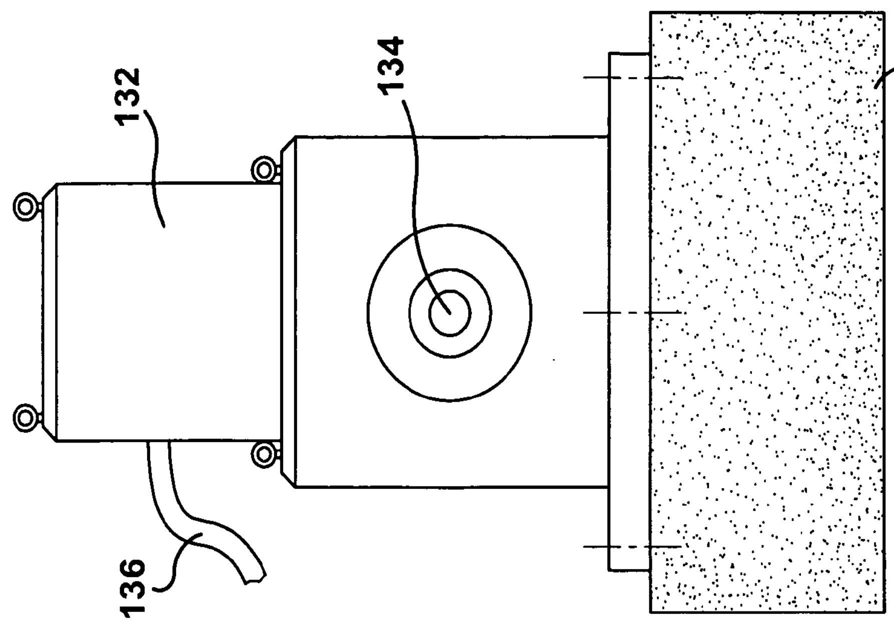

Fig. 29

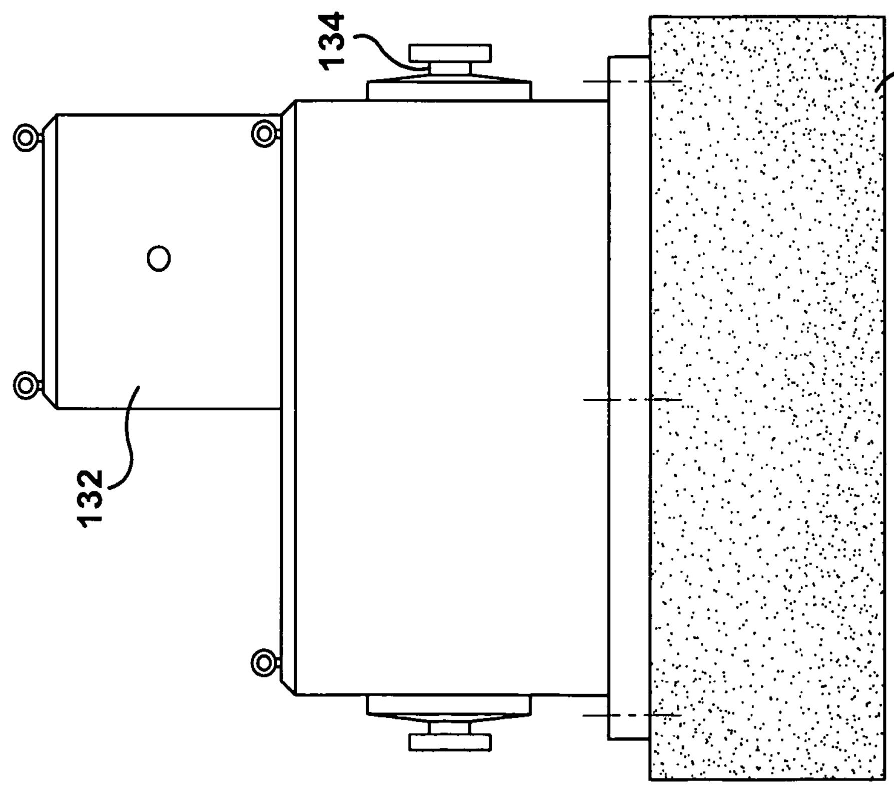

Fig. 28

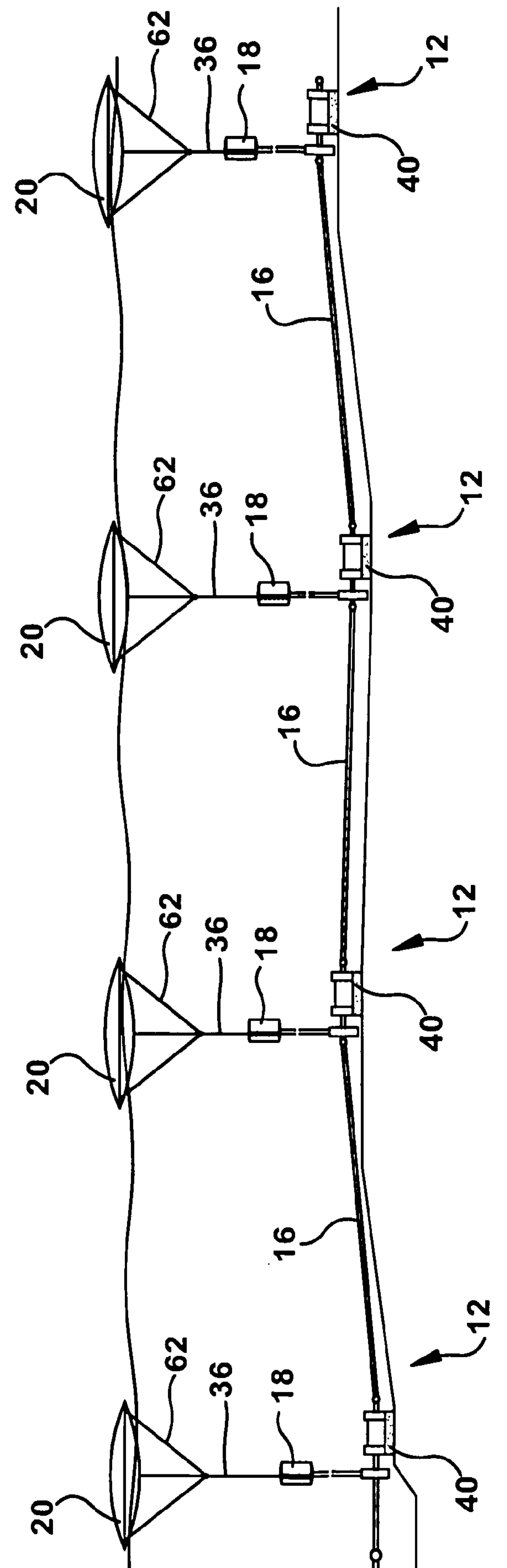

Fig. 30

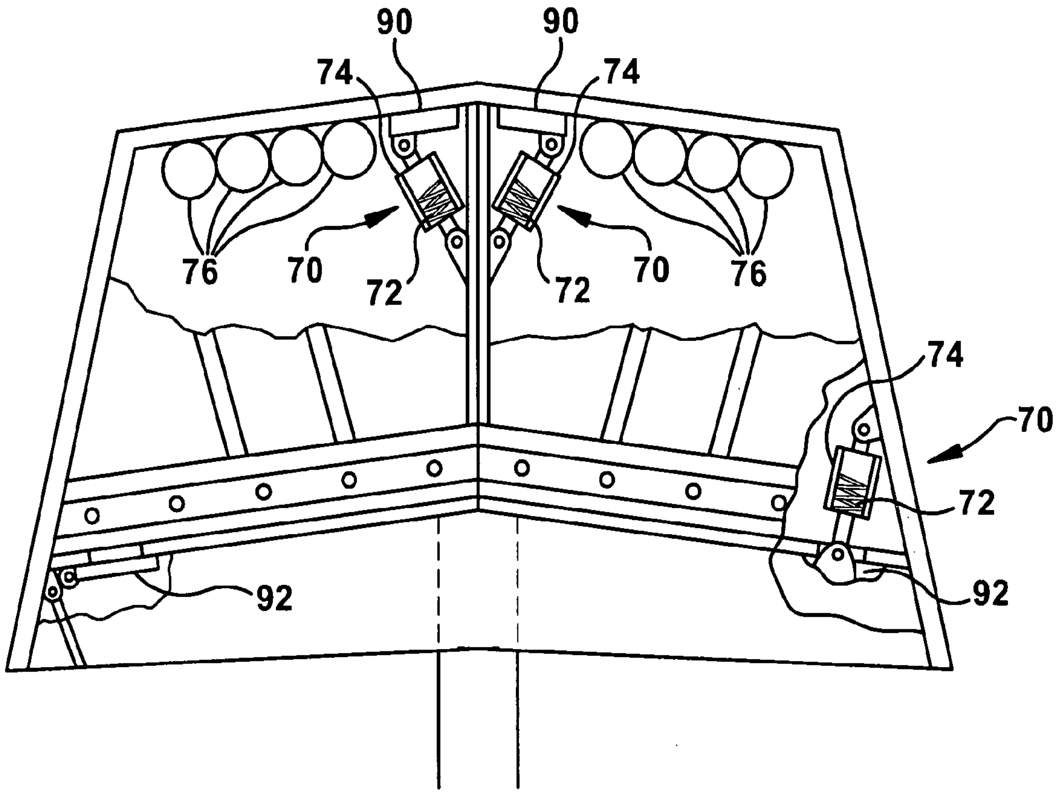

Fig. 33

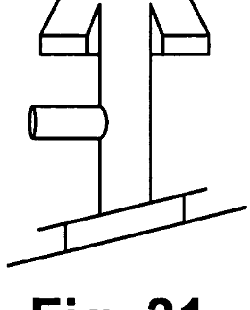

Fig. 31

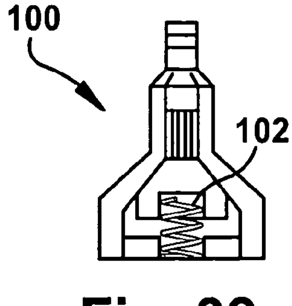

Fig. 32

WAVE ENERGY RECOVERY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims benefit from U.S. Provisional Patent Application No. 61/127,699, entitled "Wave Energy Recovery System," filed on May 15, 2008, which is hereby incorporated in its entirety by reference.

FIELD OF INVENTION

[0002] The present invention relates generally to systems for recovering energy from waves and, more particularly, the present invention relates to an apparatus and methods for transforming vertical displacement of buoys caused by waves into rotational motion that is converted into energy, such as electric power.

BACKGROUND

[0003] Currently, approximately 350 million megawatt-hours of energy are consumed globally each day (which is equivalent to the energy in approximately 205 million barrels of oil). With continued industrial expansion and population growth throughout the developed and developing world, global consumption is expected to increase approximately sixty percent over the next twenty-five years, pushing global energy consumption to over 500 million megawatt-hours per day.

[0004] Approximately seventy-five percent of energy currently consumed comes from non-renewable sources, such as oil, coal, natural gas, and other such fossil fuels. The current level of fossil fuel usage accounts for the release of approximately six million tons of carbon dioxide into the atmosphere each day. With a finite supply of fossil fuels available and growing concerns over the impact of carbon dioxide, continued reliance on fossil fuels as a primary source of energy is not indefinitely sustainable.

[0005] One approach to sustaining the current global energy consumption rate and accounting for future increases in consumption is to research and develop novel and improved methods for generating energy from renewable sources. Sources of renewable energy include water-powered energy, wind-powered energy, solar energy, and geothermal energy. Of the current practical renewable energy sources, water-powered energy, and specifically wave-powered energy, may hold the most promise for developing a substantial renewable energy source to meet growing global energy needs.

[0006] It has been long understood that ocean waves contain considerable amounts of energy. Given the high level of energy concentration present in waves and the vast areas available for harvesting such energy, wave-powered energy technology represents a significant renewable energy source. Numerous systems have been developed in an attempt to efficiently capture the energy of waves; however, no prior conceived systems or methods have achieved the efficiency or cost-effectiveness required to make wave-powered energy a viable alternative energy source.

[0007] Wave energy recovery systems must successfully operate in very hostile marine or freshwater environments. Such environments are prone to violent storms and the

[0008] deleterious impact of salt water, plant life, and animal life. Further, due to the offshore location of such systems, a successful system must include an efficient means for delivering the energy output to shore. These and other technical challenges have been addressed and overcome by this invention as herein described.

SUMMARY OF INVENTION

[0009] The present invention includes novel apparatus and methods for recovering energy from water waves. An embodiment of the present invention includes a buoy, a shaft, and an electric power generating device. The shaft may be coupled to the buoy such that when the buoy moves vertically in response to a passing wave, the shaft rotates. The shaft may be coupled to the electric power generating device such that when the shaft rotates, the electric power generating device produces electric power. Once electric power is generated, it may be delivered to shore, where it is stored, used to power a device, or delivered to a power distribution grid.

DESCRIPTION OF DRAWINGS

[0010] Objects and advantages together with the operation of the invention may be better understood by reference to the following detailed description taken in connection with the following illustrations, wherein:

[0011] FIG. **1** illustrates a view of an embodiment of a wave energy recovery system.

[0012] FIG. **2** is a schematic view of an embodiment of a wave energy recovery system.

[0013] FIG. **3** is a schematic illustration of another embodiment of a wave energy recovery system.

[0014] FIG. **4** is a side cross-sectional view of a platform, generator, and drum mechanism of the wave energy recovery system of FIG. **1**.

[0015] FIG. **5** is a side cross-sectional view of the drum mechanism and generator of FIG. **4**.

[0016] FIG. **6** is a side view of the drum mechanism of the wave energy recovery system of FIG. **1**.

[0017] FIG. **7** is a magnified view of the drum mechanism of FIG. **4**.

[0018] FIG. **8** is a magnified view of a clutch of the drum mechanism of FIG. **7**.

[0019] FIG. **9** is a top view of the drum mechanism and guide plates.

[0020] FIG. **10** is a top view of the guide plates of FIG. **9**.

[0021] FIG. **11** is a side view of the generator.

[0022] FIG. **12** is a rear view of the generator and platform of the wave energy recovery system of FIG. **4**.

[0023] FIG. **13** is a front view of an oil pump of the wave energy recovery system of FIG. **4**.

[0024] FIG. **14** is a perspective view of a buoy.

[0025] FIG. **15** is a side view of a buoy in accordance with the present invention.

[0026] FIG. **16** is a top view of a buoy.

[0027] FIG. **17** is another side view of the buoy of FIG. **16**.

[0028] FIG. **18** is a side view of the buoy of FIG. **14**.

[0029] FIG. **19** is a close up side view of the buoy of FIG. **18** without paddles.

[0030] FIGS. **20**A and **20**B are views of a retracting buoy.

[0031] FIG. **21**A is a close up perspective view of a paddle mechanism of FIG. **14**.

[0032] FIG. **21**B is a close up side view of an alternative paddle mechanism.

[0033] FIG. **22** is a schematic view of a valve and cylinder system.

[0034] FIG. **23** is a side cross sectional view of a valve.

[0035] FIG. **24** is a side cross sectional view of a return tank for the valve of FIG. **23**.

[0036] FIG. **25** is a perspective view of a valve of FIG. **23**.

[0037] FIG. **26** is a perspective view of the return tank of FIG. **24**.

[0038] FIG. **27** illustrates a schematic illustration of an alternative embodiment of a wave energy recovery system.

[0039] FIGS. **28** and **29** illustrate detailed views of the wave energy recovery system of FIG. **27**.

[0040] FIG. **30** illustrates a view of an alternative embodiment of a wave energy recovery system.

[0041] FIG. **31** illustrates a manifold for use with a buoy of the wave energy recovery system.

[0042] FIG. **32** illustrates a check valve of a pedal compression mechanism for use with a buoy of the wave energy recovery system.

[0043] FIG. **33** illustrates a view of an alternative embodiment of a pneumatic system for the wave energy recovery system.

DETAILED DESCRIPTION

[0044] While the present invention is disclosed with reference to the embodiments described herein, it should be clear that the present invention should not be limited to such embodiments. Therefore, the description of the embodiments herein is only illustrative of the present invention and should not limit the scope of the invention as claimed.

[0045] A wave energy recovery system, as described herein and illustrated in FIGS. **1-33**, converts the energy of sea or ocean waves or other such water waves into usable mechanical and electrical energy. Apparatus and methods may be arranged such that the vertical pulse motion of waves of any magnitude and frequency may be converted to other types of motion such as, for example, linear or rotational motion. The mechanical energy of this resulting motion may be arranged to drive gearboxes, motors, pumps, various types of generators, or the like so as to generate energy, such as electrical power.

[0046] In an embodiment, the vertical pulse motion of a wave may be translated to a buoy **20** floating at or near the surface of a body of water to vertically displace the buoy **20**. The vertical displacement of the buoy **20** may be translated to linear motion of a cable that is coupled to the buoy **20**. The cable may be wrapped around a pulley or drum **50**, and the linear motion of the cable may be translated to rotational motion of the pulley or drum **50** to drive a generator **14**, thereby capable of generating electric power. The generator **14** may be of any appropriate type, such as an alternating current (AC) permanent magnet generator. In addition, a plurality of motion translating assemblies **12** may be arranged in series or parallel. The system **10** is capable of operating without a gearbox, as there is no switching of gears, with the drums **50**, **52** and use of a gearbox may decrease the efficiency of the generator **14**.

[0047] The AC permanent magnet generator **14** may be coupled to a rectifier to convert the alternating current (AC) produced by the generator **14** to a direct current (DC). The rectifier may be coupled to a voltage converter to generate a consistent DC current that may be used as a final source of electricity or to be converted back to AC current and delivered to a power generation grid. As used herein, the term “coupled” means directly or indirectly connected in a mechanical, electrical, or other such manner.

[0048] FIG. **1** illustrates a wave energy recovery system **10**. The system **10** may comprise a motion translating assembly **12**, a generator **14**, a shaft **16**, and a platform **40**. The system **10** may be positioned at any appropriate location on the floor of the ocean or other body of water and may be positioned relatively close to shore. The system **10** may be arranged so as to generate electrical power and deliver that electrical power to shore. As will be further described below, the motion translating assembly **12** may translate the vertical pulse motion of a wave to rotational motion of the shaft **16**, and such rotational motion of the shaft **16** may drive the generator **14**.

[0049] In an exemplary embodiment illustrated in FIG. **1**, each motion translating assembly **12** may be arranged to drive a shaft **16** attached to a generator **14** independently connected to and dedicated to that assembly **12**. The vertical motion of the main buoy **20** may be translated to rotational motion to rotate a shaft **16** that is coupled to and drives the generator **14** so as to produce electrical power.

[0050] As an alternative, a plurality of motion translating assemblies **12** may be coupled to a shaft to drive the generator, which may be located adjacent to the motion translating assembly **12** that is closest to the shore, as illustrated in FIG. **30**. In such an arrangement, it would be preferable that the shaft **16** only rotate in one direction. As multiple motion translating assemblies **12** assist in rotating the shaft **16**, limiting the shaft **16** to only one direction of rotation may allow the assembles **12** to cooperate in driving the generator **14**. The coupling of numerous motion translating assemblies **12** to one generator may provide for a continuous rotation of the shaft **16** and an efficient method of driving the generator **14**.

[0051] The generated electrical power may be delivered to shore, either for immediate use or to feed into a power distribution grid. As an alternative, the system **10** may be arranged so as to generate electrical power and to utilize and store that electrical power locally on the system **10** to drive devices on the system **10** or near the system **10**.

[0052] With further reference to FIG. **1**, a motion translating assembly **12** may include a main buoy or float **20**, a retracting buoy or float **18**, and a main cable **36**. The main cable **36** may be coupled on one end to the main buoy **20**, coupled on the other end to the retracting buoy **18**, and wrapped around the drum **52**. As an alternative, each drum **50**, **52** may have its own dedicated cable **36**, **38**. In addition, each dedicated cable **36**, **38** may be coupled to its own dedicated buoy **18**, **20**. For example, the main cable **36** may be coupled to the main buoy **20** and the drum **50**, and the other cable **38** may be coupled to the retracting buoy **18** and drum **52**, so that when one drum **50** turns in a first direction, such as clockwise, for example, the other drum **52** may turn in the same or an opposite direction, such as counterclockwise, for example.

[0053] While the motion translating assembly **12** and the ability to rotate is discussed in terms of utilizing drums **50**, **52**, it is to be understood that any appropriate type of rotating mechanism or apparatus may be utilized, such as pulleys (not shown), for example. If pulleys are utilized, they may be located within a pulley housing (not shown). As an alternative embodiment, the main cable **36** may be coupled on one end to the main buoy **20**, coupled on the other end to the retracting buoy **18**, and wrapped around an oscillating pulley (not shown) that may be located within a pulley housing.

[0054] The buoys **18** and **20** may be arranged such that, as a wave engages the main buoy **20**, the main buoy **20** may be displaced vertically upward (i.e., rises relative to the ocean floor) and the cable **36** rotates the drum **50** in a clockwise rotation. As the wave passes the main buoy **20**, the main buoy **20** may be displaced vertically downward (i.e., falls relative to the ocean floor), the retracting buoy **18** rises to remove any slack from the cable **38**, and the drum **52** rotates counterclockwise. Thus, as waves pass the main buoy **20**, vertical displacement of the main buoy **20** due to passing waves is transformed into linear motion of the main cable **36** and rotational motion of the drums **50**, **52**.

[0055] Although the cables **36**, **38**, buoys **20**, **18** and drums **50**, **52** have been described as being coupled in various ways, it will be readily understood by those skilled in the art that any number of additional arrangements may be utilized to convert vertical motion of the main buoy **20** to rotational motion, and should not be limited to those arrangements described herein.

[0056] The drums **50**, **52** may be coupled to the shaft **16** such that rotational motion of the drums **50**, **52** translates to rotational motion of the shaft **16**. The shaft **16** may be coupled to the generator **14** such that rotational motion of the shaft **16** translates to rotational motion of the generator **14**. The generator **14** may utilize such rotational motion to generate energy, such as electrical power. As the generator **14** generates electrical power, the power may be delivered to the shore through a power cable **110** attached to the generator **14**.

[0057] The drums **50**, **52** may drive the shaft **16** that drives the generator **14** to create electrical power. The inner drum **50** may operate the main buoy **20**. The outer drum **52** may operate the counter buoy **18**. The drums **50**, **52** may be of any appropriate shape or size, such as of a substantially conical shape, cylindrical shape, or the like. If of a conical shape, the drums **50**, **52** may be wrapped with the cable or wire **36**, **38** all the way up and around the incline of the cone shape. The conical shape may allow the drums **50**, **52** to rotate via a linear graduation, thereby providing a linear power graduation. Thus, the drums **50**, **52** may spin at low rpms and, for example, may be prevented from rotating more than sixty (60) turns. Linear graduation may be achieved by providing the same distance between each step or location where the wire **36** or **38** is placed or wrapped on the drum **50** or **52**. However, as an alternative, the system **10** may utilize a non-linear graduation.

[0058] The system **10** also may utilize a standard hydraulic clutch **106**. For example, when the drums **50**, **52** spin at or near 60 RPMs, the clutch **106** may be activated to slow movement of the drums **50**, **52**. As is well known in the art, the clutch **106** may operate due to frictional engagement of a clutch plate and a flywheel. The flywheel may be a large steel or aluminum “disc,” that may be bolted to the driveshaft **16**. The flywheel may act as a balancer for the generator **14**, dampen vibrations, and provide a smooth-machined “friction” surface that the clutch **106** can contact. The main function of the flywheel is to transfer engine torque from the engine to the transmission.

[0059] The clutch disc may be similar to a steel plate and covered with a frictional material that is located between the flywheel and the pressure plate. In the center of the disc is the hub, which is designed to fit over the shaft **16**. When the clutch **106** is engaged, the disc may be “squeezed” between the flywheel and pressure plate, and power from the drum **52** may be transmitted by the disc’s hub to the input shaft of the transmission.

[0060] The pressure plate may be a spring-loaded “clamp,” which may be bolted to the flywheel. It may include a sheet metal cover, release springs, a metal pressure ring that provides a friction surface for the clutch disc, a thrust ring or fingers for the release bearing, and release levers. The release levers lighten the holding force of the springs when the clutch is disengaged. The springs may be of a diaphragm-type, multiple coil type, or other type as will be appreciated by one of ordinary skill in the art. Some high-performance pressure plates are “semi-centrifugal,” meaning they may use small weights on the tips of the diaphragm springs to increase the clamping force as engine revolutions increase.

[0061] The “throw-out bearing” is the heart of clutch operation. When the clutch pedal is depressed, the throw-out bearing moves toward the flywheel, pushing in the pressure plate’s release fingers and moving the pressure plate fingers or levers against pressure plate spring force. This action moves the pressure plate away from the clutch disc, thus interrupting power flow.

[0062] Mounted on an iron casting called a hub, the throw-out bearing slides on a hollow shaft at the front of the transmission housing. The clutch fork and connecting linkage convert the movement of the clutch pedal to the back and forth movement of the clutch throw-out bearing.

[0063] To disengage the clutch **106**, the release bearing is moved toward the flywheel by the clutch fork. As the bearing contacts the pressure plate’s release fingers, it begins to rotate with the pressure plate assembly. The release bearing continues to move forward and pressure on the release levers or fingers causes the force of the pressure plate’s spring to move away from the clutch disc.

[0064] To engage the clutch **106**, the clutch pedal is released and the release bearing moves away from the pressure plate. This action allows the pressure plate’s springs to force against the clutch disc, engaging the clutch to the flywheel. Once the clutch **106** is fully engaged, the release bearing may be stationary and may prevent rotation with respect to the pressure plate.

[0065] A mechanical or hydraulic linkage may operate the clutch **106**. A hydraulic clutch linkage may be similar to a mini hydraulic brake system. With a hydraulic mechanism, the clutch pedal arm operates a piston in the clutch master cylinder. This forces hydraulic fluid through a pipe to the clutch slave cylinder where another piston may operate the clutch disengagement mechanism. A master cylinder may be attached to the clutch pedal by an actuator rod, and the slave cylinder is connected to the master cylinder by high-pressure tubing. The slave cylinder is normally attached to a bracket next to the bell housing, so that it may move the clutch release fork directly.

[0066] Similar to depressing the brake pedal on your car, depressing the clutch pedal may push a plunger into the bore of the master cylinder. A valve at the end of the master cylinder bore closes the port to the fluid reservoir, and the movement of the plunger forces fluid from the master cylinder through the tubing to the slave cylinder. Since the fluid is under pressure, it is capable of causing the piston of the slave cylinder to move its pushrod against the release fork and bearing, thus disengaging the clutch.

[0067] When the clutch pedal is released, the springs of the pressure plate push the slave cylinder’s pushrod back, which forces the hydraulic fluid back into the master cylinder. One of the advantages of a hydraulic linkage is the physics: a small amount of pedal force can be used to manipulate what would normally be a heavy clutch with a shaft and lever linkage.

[0068] As an alternative, instead of utilizing a hydraulic clutch **106**, the system **10** may utilize a sprag clutch (not shown) and flywheel. A sprag clutch is a one-way freewheel metal roller clutch. It resembles a roller bearing with rollers shaped like a figure eight and cocked with a spring. When the unit rotates in one direction, the rollers stand up and bind because of friction, and when the unit is rotated in the opposite direction, the rollers slip or freewheel. The process of changing up gears involves preparing for the change by releasing a clutch that prevents the transmission from turning faster than the gear that it is currently in and engaging the sprag such that it is freewheeling. The gearchange occurs by engaging the higher gear through the sprag to change from freewheeling to driving.

[0069] Once the sprag has engaged drive in the higher gear, a clutch is engaged to place the transmission in that gear without the need for the sprag, which is then disengaged. By engaging and disengaging the various clutch packs within the transmission, one sprag can be used for all gearchanges. Depending on the relative rotating direction between inner and outer ring the clutch either transmits a friction-driven moment or detaches drive end and output end. It is to be understood that all roller bearings may be made out of any appropriate type of material, such as a synthetic composite.

[0070] As shown in FIGS. **4**, **5**, **9** and **10**, the system **10** may also include a guide plate **54**. There may be any appropriate number of guide plates **54**, but preferably there is the number of guide plates **54** as drums. In addition, the guide plates **54** may be of any appropriate shape and size, but are preferably of a rectangular shape and of a size equivalent to that of the angled portion of the conical drums **50**, **52**. As illustrated in FIG. **10**, the guide plates **54** may include an end portion **53** and a guide rail **55**. Preferably, there are two end portions **53** and two guide rails **55**, but it is to be understood that there may be any appropriate number of end portions **53** and guide rails **55**. The end portions **53** may be located at either end of the individual guide rails **55** to maintain the guide rails **55** in the appropriate spaced relation to one another.

[0071] The rectangular guide plates **54** may guide the wires **36**, **38** onto the conical drums **50**, **52**. The guide plates **54** may be bolted to the drum housing **56**, where there may be one guide plate **54** for each drum **50**, **52**. The guide plates **54** guide the wires **36**, **38** onto the appropriate step or location of the respective drum **50**, **52**. The guide plates **54** may be attached to the drum housing **56** at any appropriate location or angle, but are preferably located parallel to the platform **40** and above the drums **50**, **52** near the top of the housing **56**. The guide plates **54** are also preferably located at an angle that is similar to the outer conical shape of the drums **50**, **52**, as shown in FIG. **9**.

[0072] With reference to FIGS. **4**, **7**, and **13**, the wave energy recovery system **10** may also include an oil pump **112**. The oil pump **112** may be operated from and run off of the driveshaft **16**. The oil pump **112** may include a piston **114**, a piston ball **116**, and a plurality of petals **118**, as can be best seen in FIG. **13**. As the shaft **16** spins, the petals **118** spin around, in a manner similar to a fan, for example, and push the piston ball **116** up and down, thereby moving the piston **114** up and down. Thus, the oil may be pressurized and sent through the system **10** due to this action of the piston **114**.

[0073] As shown in FIG. **4**, the generator **14** may be located on top of the platform **40**. Preferably the generator **14** is located towards one end of the platform **40** and the drums **50**, **52** are located toward the other end of the platform **40**. Positioning the generator **14** on the seabed surrounds the generator **14** with water, which cools the generator **14** as it generates electric power. As generators **14** typically give off heat, providing a readily available method of cooling the generator **14** may increase the efficiency of the generator **14**.

[0074] In addition, the wave energy recovery system **10** may also include a radiator or coolant system **108**, as shown in FIGS. **11** and **12**. The radiator **108** may be of any appropriate type. As the drums **50**, **52** spin faster, the oil in the generator **14** can become very hot. As the oil is passed through the generator **14**, the radiator **108** cools the oil, and then the oil may proceed back through the system **10** to the oil pump **16** to start its journey over.

[0075] As discussed above, each motion translating assembly **12** may be secured to a support platform **40** to maintain a static position with respect to the seabed. With reference to FIGS. **4** and **12**, in an exemplary embodiment, the platform or base **40** may be constructed of concrete with a plurality of steel reinforcement bars or rebar **42** located throughout the platform **40** to aid in reinforcing the concrete platform **40**. Preferably, the platforms **40** may be moveable from one location to another when it is desired to move the platform **40**, but stable and stationary enough the remainder of the time so that they do not shift once placed on the ocean or seabed floor.

[0076] Thus, the platform **40** preferably has enough mass to maintain its position on the seabed and resist movement due to tides, thrust from the main buoy **20**, storms, or other inclement weather. The platform may be of any appropriate shape and size, however, the support platform **40** is preferably a rectangular slab of concrete measuring ten feet in width, eight feet in depth, and four feet in height. Such a concrete slab may weigh approximately twenty-five tons and can withstand substantial forces without moving.

[0077] The platform **40** may also include diamond shaped pockets **44** on the underside of the platform **40** as well as airways **46**, **48** throughout the platform **40**. The diamond shaped pockets **44**, which are approximately the shape of pyramids, may also be made out of cement. When the diamonds **44** are in contact with the sand, mud, etc. of the ocean or sea floor, the diamonds **44** may create suction cups that may prevent the base **40** from being able to pull away from the floor. The move the base **40**, there may be vertical airways **48** within the base **40**. When it is desired to move the platform **40**, pressurized air is pushed through the horizontal side airway tube **46**, the air is then pushed through airways **48** and out through the intersection of the diamond edges **44** of the base **40** that breaks the suction via the internal airways **46**, **48**.

[0078] The plurality of motion translating assemblies **12** may be arranged in any appropriate location or manner away from the shoreline, as illustrated in FIGS. **1**-**3**. In an embodiment, the plurality of motion translating assemblies **12** may extend diagonally from the shoreline at any appropriate angle, such as an approximately 45-degree angle. In addition, the system **10** may include any appropriate number of assemblies **12**, such as approximately thirty motion-translating assemblies **12**. The assemblies **12** may be spaced at any appropriate distance from one another, such as being spaced approximately 30 feet apart. Such an arrangement generally results in each incoming wave raising and lowering each main buoy **20** at a different point in time.

[0079] As a wave progresses towards the shoreline, it may first encounter the motion translating assembly **12** located farthest off shore and raises and then lowers the translating assembly's **12** main buoy **20**. Over time, the wave progresses through the plurality of assemblies **12** until it reaches the assembly **12** closest to the shore. Such an arrangement may be beneficial in that any single wave will not raise and lower the plurality of main buoys **20** at the same point in time, but will raise the plurality of main buoys **20** over a period of time. The raising of main buoys **20** over time as the wave progresses towards the shoreline causes different motion translating assemblies **12** to rotate the shaft **16** at different times, resulting in constant rotation of the shaft **16** at a generally constant speed and thus providing a constant supply of energy to the power grid.

[0080] An embodiment of a main buoy **20** for use with a wave energy recovery system **10** is illustrated in FIGS. **14-20**. The buoy **20** may include numerous features and sub-systems that improve the durability or service life of the system **10**. In addition, the buoy **20** may include numerous features and subsystems for enhancing the overall efficiency and functionality of the system **10**.

[0081] For example, the buoy **20** may include numerous features that provide for the dynamic positioning of the buoy **20** relative to the surface of the water. Minor adjustments in the position of the buoy **20** may increase the efficiency of the system **10** as the height and frequency of waves change. When violent storms or other such hazards are present, the buoy **20** may be selectively submerged below the surface of the water so as to reduce or eliminate damage to the buoy **20** or other system components. Once the storm passes or other such hazards subside, the buoy **20** may be returned to an operative position at or near the surface of the water.

[0082] The buoy **20** may be of any appropriate shape and size and may be made out of any appropriate material. The buoy **20** may be constructed from a metal frame and an aluminum skin. however, the buoys **20** may be constructed out of any appropriate material that allows the buoy **20** to float and rise and fall as waves pass. The main buoy **20** may be of any appropriate size, such as the approximate size of an automobile, for example. The buoy **20** may be unable to fall or tip over in the water due to its shape and size. The shape of the main buoy **20** may be of any appropriate shape or configuration capable of floating, such as a generally rectangular body, cylindrical body, or the like. While shown as of generally rectangular shape in the FIGURES, it is to be understood that this is not meant to be limiting in any way, and is for illustrative purposes only.

[0083] As illustrated in FIGS. **1**, **15**, and **17**, the buoy **20** may be equipped with a plurality of connector cables **62** that are coupled at one end to the buoy **20** and are coupled at the other end to the main cable **36**. The connector cables **62** may be coupled to the buoy **20** by any appropriate means. For example, the connector cables **62** may be coupled via connector rings (not shown), pistons (not shown), pivot connection, or the like. If the connector cables **62** are coupled to the buoy **20** by pistons, the pistons may be of any appropriate type, such as pneumatic pistons.

[0084] The pistons may be pressurized or depressurized to better position the buoy **20** with respect to the surface of the water. In one embodiment, a piston may be pressurized so as to affect the angel at which the buoy **20** is positioned with respect to the surface of the water. Placing the buoy **20** at an angle may provide for greater wave impact on the buoy **20** so as to increase the vertical displacement of the buoy **20**, thus increasing the energy recovered by the buoy **20**.

[0085] For example, the connector cables **62** may be coupled to the buoy **20** by a pivot connection **60** through which the buoy **20** is connected to the main cable **36**. Three connector cables **62** may be attached to the pivot connection **60** on one end and attached to a pivot connection **60** on the other end. There may be a common ring **64** located at the bottom of a rigid member **66**. The main cable **36** may be attached to the common ring **64** on one end and wrapped around the drums **50**, **52** as previously described. In a preferred embodiment, the main cable **36** and the connector cables **62** are approximately ⅜ inch in diameter, with the connector cables **62** approximately 10 to 15 feet in length and the main cable **36** approximately 100 to 200 feet in length.

[0086] Referring again to FIGS. **1**, **15**, and **17**, a rigid member **66**, such as a pipe, may extend downward from the bottom **76** of the buoy **20**, and at least one keel member **68** is attached to the pipe **66**. Optionally, multiple keel members **68** may be attached to the pipe **66**, but preferably, there are three keel members **68** attached to the pipe **66**, each **120** degrees apart. The pipe **66** is preferably ten feet in length, and the keel members **68** are triangular shaped and three feet high and three feet wide. As a wave passes the buoy **20** the turbulence in the water is near the surface. The keel members **68** may be located at any appropriate position.

[0087] Positioning the keel members **68** approximately below the surface of the water, such as ten feet below the surface, for example, places avoids the turbulence of the wave. Such an arrangement provides stability to the buoy **20** and eliminates or reduces lateral movement, wobbling or rocking of the buoy **20**. The elimination of such movement increases the vertical displacement of the buoy **20** and allows recovery of an increased percentage of a wave's energy.

[0088] A particular shape of the main buoy **20**, such as a rectangular or cylindrical shape, for example, may produce greater thrust in the motion translating assemblies **12** and produce greater rotational motion of the shaft **16**. A rectangular component placed in rough waters has a tendency to turn such that its longer vertical surface faces the incoming waves. By offering a greater surface area to incoming waves, the buoy **20** may catch more of the wave, thereby providing more thrust to the main cable **36** as the buoy **20** is moved upward by a passing wave. The rectangular buoy **20** may be of any appropriate size, such as thirty feet wide, ten feet deep, and five feet high, for example.

[0089] The retracting buoy **18**, as best shown in FIGS. **1**, **20**A, and **20**B, may be of any appropriate size and shape and may be made out of any appropriate material, such as being constructed from aluminum and being cylindrically shaped. The retracting buoy **18** may also include a guide sleeve **58**. Similar to the main buoy **20**, the retracting buoy **18** may also be equipped with a pair of valves **90**, **92**, such as an air inlet valve to intake air and expel water ballast, and a water inlet valve to intake water to increase water ballast. The retracting buoy **18** may also include a manhole or hatch **120** to give access to the inside of the retracting buoy **18** in case any repairs may need to be made. The bottom of the retracting buoy **18** may be attached to a cable **38** by any appropriate means, such as a ring or fastener.

[0090] The guide sleeve **58** may be attached to the side of the retracting buoy **18**. The guide sleeve **58** may be arranged to slide along the cable **36** to maintain a controlled reciprocating motion as a wave progresses past the main buoy **20**. In an embodiment, the retracting buoy **18** may be approximately **16** inches in diameter and **24** inches in height.

[0091] With respect to the cost of building traditional power plants, a wave energy recovery system **10** is very inexpensive to build and install. To install a system **10**, components of the system **10** may be loaded onto pontoons or other such floating platforms. The pontoons may be evenly spaced along the surface of the water. The spacing of the pontoons may be approximately equal to the desired operative distance between installed support platforms **40** along the seabed. These assembled support platforms **40** may be lowered into position on the seabed from the pontoons, using any conventional means, such as chains or cables.

[0092] Once the drums **50**, **52** are coupled to the shaft **16**, the cables **36** and **38** may be wrapped around each drum **50** and **52** respectively, and a retracting buoy **18** may be attached to one end of the cable and the guide sleeve **58** installed along the cable. The free end of the main cable **36** may be attached to the common ring **64** and the length of the main cable **36** properly adjusted.

[0093] Each motion translating assembly **12** may be arranged to drive a shaft **16** attached to a generator **14** dedicated to that assembly **12**. The motion translating assemblies **12** are arranged to drive dedicated generators **14** coupled to each support platform **40**. However, a permanent magnet generator **14** is attached to each support platform **40**. The vertical motion of the main buoy **20** is translated to rotational motion to rotate a driveshaft **16**. The driveshaft **16** is coupled to and drives the generator **14**, which produces electric power. The generated electric power can be delivered to shore, either for immediate use or to feed into a power distribution grid. Optionally, the electric power can be stored on the support platform **40** to be subsequently delivered to shore.

[0094] In an alternative embodiment, the electric power may be stored on the support platform **40** by coupling the generator **14** to a supercapacitor (not shown). Supercapacitors offer relatively high cycle lives, having the capacity to cycle millions of times before failing; low impedance; rapid charging; and no loss of capability with overcharging. A power cable **110** may be attached to each supercapacitor to deliver stored electric power to shore. As a wave passes the motion translating assemblies **12**, some assemblies produce electric power, while others are momentarily idle. A programmable logic control device may optionally be incorporated into the system to control the generators **14** and other system components to delivery a consistent electrical current to the shore.

[0095] The driveshafts **16** may be arranged to only rotate in one direction or may optionally be arranged to rotate in both clockwise and counterclockwise directions. An AC permanent magnet generator may be arranged to generate electric power regardless of the direction the driveshaft **16** rotates. Generators **14** may also be arranged to eliminate any need for a gearbox when generating electric power. The system **10** may be arranged such that each dedicated generator **14** has a dedicated power cable **110** to deliver electric power to shore. The electric power generated by the plurality of generators **14** may be accumulated on shore and delivered to a power distribution grid.

[0096] The use of dedicated generators **14** secured to each support platform **40** allows for easy installation of the wave energy recovery system. The wave energy recovery system **10** may be secured to the ocean floor by a support platform **40**. As discussed above, the support platform **40** may be a concrete slab with enough mass to maintain its position on the ocean floor and resist movement due to tides, thrust from the main buoy **20**, storms, or other inclement weather.

[0097] As illustrated in FIG. **2**, support platforms **40** may be placed randomly, without concern for the positioning of adjacent platforms **40**. Each motion translating assembly **12** and dedicated generator **14** is self-sufficient and does not rely on adjacent assemblies **12**. Flexible power cables **110** allow a generator **14** or supercapacitor to deliver electric power to shore from nearly any location on the seabed, either in series or in parallel.

[0098] As illustrated in FIGS. **14-20**, the buoy **20** includes a generally hollow hull or body **22**. The body **22** optionally may be internally supported by beams (not shown) or others such structural members. The body **22** may be arranged to include a number of generally flat surfaces such as, for example, a pair of top surfaces **24**, a pair of side surfaces **26**, a pair of front surfaces **28**, a pair of back surfaces **30**, and a pair of bottom surfaces **32**.

[0099] The pair of top surfaces **24** may be arranged at an angle to one another so that a peak is formed between the pair of top surfaces **24**. Such a peak will encourage rain or other such precipitation to run off the top surfaces **24**, thus discouraging the pooling of water on the top surfaces **24**. The side **26**, front **28**, and back **30** surfaces of the buoy **20** each may be arranged at an angle with respect to a vertical plane.

[0100] Such an arrangement may limit lateral movement of the buoy **20** and enhance vertical movement of the buoy **20** as waves impact the front, back, and sides of the buoy **20**. For example, as a wave impacts the front, back, or sides of the buoy **20**, the angled surface of the buoy **20** causes a portion of the energy of the wave to encourage the buoy **20** to be displaced vertically.

[0101] In another example, as a wave washes over the buoy **20**, the portion of the wave washing over the buoy **20** may commonly impact the opposing side of the buoy **20**. When the side is positioned at an angle to a vertical plane, the portion of the wave washing over the buoy **20** may encourage the buoy **20** downward. In addition, the wave washing over the buoy **20** encourages the buoy **20** to move laterally back toward the direction from which the waves originated, thus offsetting the lateral movement of the buoy **20** due to the initial impact of the wave. Upon studying the description and FIGURES provided herein, it will be readily understood by those skilled in the art that arranging the side, front, and back surfaces at an angle relative to a vertical plane may facilitate the vertical movement of the buoy **20** and decreases the lateral movement of the buoy **20**.

[0102] The pair of bottom surfaces **32** may be arranged at an angle to one another so as to form a generally concave bottom. Such an arrangement may promote the stability of the buoy **20** by reducing or eliminating wobbling or other such oscillation of the buoy **20** as waves impact the buoy **20**. The buoy **20** may also include a skirt **34** extending from the bottom surfaces **32** of the buoy **20**. The skirt **34** may be of any appropriate shape, size and material. The positioning and shape of the skirt **34** may further reduce or eliminate any undesired lateral movement, wobbling, and rocking of the buoy **20**. The shape of the skirt **34**, in cooperation with the downward forces produced by the main cable **36**, may hold the buoy **20** level on the surface of the water as a wave passes. As the wave displaces the buoy **20** upward, the buoy **20** remains level, thus reducing or eliminating any undesired lateral movement, wobbling, or rocking Maximizing the vertical movement of the buoy **20** also maximizes the energy recovered from a wave.

[0103] The main buoy **20** may further be equipped with valves, such as an air inlet valve **90** and a water inlet valve **92**. The buoy **20** may also include valves **90**, **92** located in the top and bottom sides **24**, **32** of the buoy **20**. There may be any appropriate number of valves **90**, **92**, but there are preferably six (6) valves **90** located on the top **24** of the buoy **20** and six (6) valves **92** located on the bottom **32** of the buoy **20**. The top valves **90** allow air in to raise the buoy **20** and the bottom valves **92** allow water in to sink the buoy **20**, thereby steadying the buoy **20** with ballast. The buoy **20** is intended to float near the top of the water in order to receive the effect of the waves. The water within the buoy **20** may be kept at any appropriate level, but is preferably maintained at about ⅛" around the bottom of the buoy **20**. The air and water levels from the valves within the buoy **20** may be electronically regulated.

[0104] The valves **90**, **92** may be operated by any appropriate means, but are preferably remotely operated. The valves **90** and **92** may be remotely controlled to take in water through the water inlet valve **92** for additional ballast to stabilize the floating position of the buoy **20**, or to take in pressurized air through the air inlet valve **90** to expel water and reduce water ballast in the buoy **20**. The valves **90**, **92** may be arranged such that the buoy **20** may take on enough water ballast to completely submerge the buoy **20**.

[0105] The buoy **20** may also include a series of valves **90**, **92** provided to allow fluids to enter and exit the hull **22** of the buoy **20**. In one embodiment, six valves **90** are located along the top surfaces **24** of the buoy **20**, and six valves **92** are located along the bottom surfaces **32** of the buoy **20**. Such an arrangement may provide for the intake and expulsion of fluids from the hull **22** of the buoy **20**.

[0106] In one example, the topside valves **90** may be arranged so as to allow atmospheric air into the hull **22** of the buoy **20** and may be arranged so as to allow the expulsion of atmospheric air from the hull **22** of the buoy **20**. In another example, the bottom-side valves **92** may be arranged so as to allow water from the surrounding body of water into the hull **22** of the buoy **20** and may be arranged to allow for the expulsion of water from the hull **22** into the surrounding body of water.

[0107] Through such arrangements, the amount of water in the hull **22** may be controlled and, thus, the amount of ballast in the hull **22** may be controlled. The amount of ballast in the hull **22** may be used to control the location of the buoy **20** with respect to the surface of the water. Controlling the location of the buoy **20** with respect to the surface of the water may allow the buoy **20** to be submerged to protect the buoy **20** from inclement weather. Such control also may allow for precisely locating the buoy **20** with respect to the surface of the water to increase the efficiency of energy recovery from passing waves.

[0108] Valves **90**, **92** such as those described herein may be arranged to open or close through the application of mechanical forces on the valves **90**, **92**. In one example, the valves **90**, **92** may be coupled to a spring **150** or other such biasing member to encourage the valves toward either an open or a closed position. In another example, the valves **90**, **92** may be coupled to a pneumatic member, such as a pneumatic cylinder, to selectively encourage a valve into either an open or closed position. It will be readily understood from this description and accompanying illustrations that a valve may be coupled to both a biasing member and a pneumatic member to selectively open and close valves. In addition, it will be understood that other forces, such as gravity, surrounding environmental pressures, hydraulic pressure, and the like, may be utilized to encourage a valve into a desired position.

[0109] With regard to the surrounding environment being utilized to assist in the opening or closing of the valves **90**, **92**, in one example the buoy **20** may be designed such that fluid pressure from the surrounding body of water may be utilized to encourage a valve into an open or a closed position. Similarly, a buoy **20** may be designed such that pressure from the surrounding atmosphere may be utilized to encourage a valve into an open or a closed position. Such environmental forces may be accounted for in the design of valves, springs, pneumatic members, and the like so as to ensure the formation of effective valves.

[0110] In one embodiment, a pneumatic system **70** may be incorporated into a buoy **20** to selectively open and close the valves **90**, **92**. The valves **90**, **92** may be coupled on the outer edge of the body or hull **22** of the buoy **20**. The pneumatic system may include air inlet and outlet valves **90**, **92**, a plunger valve **148** and a return tank **144**. The plunger valve **148** may include a plunger **146**, a spring **150**, an air hole **152***a*, a piston **154***a*, and an inlet/outlet **156**. The return tank **144** may include an air hole **152***b* and a piston **154***b*. The air hole **152***b* of the return tank **144** may be in communication with the valve **90**, **92**.

[0111] For example, as shown in FIGS. **23** and **24**, as the valve **92** pushes the spring **150** down to open the plunger **146**, air is pushed down and sent to the return tank **144**. The air sent to the return tank **144** pushes down the piston **154***b* thereby creating a pressurization of the tank, which may aid in closing the plunger **146** as the displaced air in the return tank **144** forces the piston **154***b* back to its original position, as shown in FIG. **24**.

[0112] The plunger valve **148** may be coupled to a source of pressurized gas that may selectively pressurize the plunger valve **148**. The selection to pressurize the valves **90**, **92** may be driven by computer logic and controls located in any appropriate place, such as either on the buoy **20**, near the buoy **20**, or remotely from the buoy **20**, for example. The spring **150** may be located within the approximate center of the plunger valve **148**. The spring **150** may be of any appropriate type, but is preferably an approximate seventy-pound (70 lb.) spring. The plunger **146** may face any appropriate direction, but preferably faces an outward direction.

[0113] In one embodiment, the pneumatic system may be arranged such that, when the plunger valve **148** is pressurized, a bottom-side valve **92** is encouraged into the open position, as shown in FIG. **23**. Such an arrangement may facilitate the filling of the hull **22** with water from the surrounding body of water. Once the plunger **146** is in the closed position, water may be prevented from entering the buoy **20**.

[0114] As an alternative, as illustrated in FIG. **33**, pneumatic systems **70** may be incorporated into a buoy **20** to selectively open and close the valves **90**, **92**. A pneumatic system **70** may include a spring **72** and a pneumatic cylinder **74**, wherein each pneumatic cylinder **74** may be coupled on one end to the door of a valve **90**, **92** and may be coupled on the other end to the body or hull **22** of the buoy **20**. The pneumatic cylinder **74** may be coupled to a source of pressurized gas that may selectively pressurize the cylinder **74**. The selection to pressurize the cylinder **74** may be driven by computer logic and controls located either on the buoy **20**, near the buoy **20**, or remotely from the buoy **20**.

[0115] The pneumatic cylinder **74** may be arranged such that, when the cylinder **74** is pressurized, a bottom-side valve **92** is encouraged into the open position. The spring **72** may be arranged such that the spring **72** encourages the bottom-side valve **92** into the closed position to assist in closing the valve **92** when the cylinder is selectively depressurized or in the event that the pneumatic cylinder **74** or the logic driving the cylinder **74** fails. Such an arrangement may facilitate the filling of the hull **22** with water from the surrounding body of water.

[0116] When a system operator or computer logic determines that it is desirable to submerge the buoy **20** due to inclement weather or other such hazard, one method of submerging the buoy **20** is to fill the hull **22** with enough water to overcome the buoyancy of the buoy **20**, thereby submerging the buoy **20**. As the bottom-side valves **92** are commonly in contact with the body of water, the environmental pressures tend to hold the valves **92** in the closed position. Such environmental pressures, along with the arrangement of the spring **72**, serve to seal the bottom-side valves **92** such that the valves **92** normally resist water entering the hull **22**. However, when it is desirable to open the valves **92** and allow water to enter the hull **22**, the pneumatic cylinder **74** is pressurized to overcome the environmental pressures and the spring force to open the valves **92**. When sufficient water has entered the hull **56** to submerge the buoy **20** to its desired depth, the pneumatic cylinders **74** may be depressurized, and the spring **72** may return the valve **92** to its closed position. The buoy **20** may include a depth meter (not shown) to assist in determining when the buoy **20** reaches the desired depth.

[0117] With further reference to FIG. **33**, the pneumatic cylinder **74** may be arranged such that, when the cylinder **74** is pressurized, a topside valve **90** is encouraged into the closed position. The spring **72** may be arranged such that the spring **72** also encourages the topside valve **90** into the closed position so that the valve remains closed when the cylinder **74** is selectively depressurized. Maintaining the valve **90** in the closed position may seal the hull **22** so that rain or other moisture is not permitted to enter the hull **22**.

[0118] The closing of the topside valves **90** by pressurizing the cylinder **74** may assist in facilitating the expulsion of water from the hull **22** through the bottom-side valves **64**. When a system operator or computer logic determines it is desirable to return the buoy **20** from a submerged position to an operative position at the surface of the water, the buoy **20** may be raised by expelling water from the hull **22** back into the surrounding body of water so as to increase the buoyancy of the buoy **20**.

[0119] One method of expelling water from the buoy **20** is to close and seal the topside valves **90**, open the bottom-side valves **92**, and pressurize the hull **22** such that the water in the hull **22** flows out of the bottom-side valves **92** and back into the surrounding body of water. The cylinders **74** may be pressurized so as to apply a substantial force on the doors of the topside valves **90**, thereby sealing the valves **90**, i.e., holding the valves **90** closed against the internal pressure building in the hull **22** that is used to expel the water.

[0120] Once the water is expelled from the hull **22**, the cylinders **74** coupled to the topside valves **90** may be depressurized, and the springs **72** coupled to the topside valves **90** may apply a sufficient force to the door of the topside valve **90** to maintain the valve **90** in a closed position so as to keep unwanted moisture out of the hull **22**. In another embodiment, the springs **72** coupled to the topside valves **90** apply a sufficient force to maintain the valve **90** in a closed position, but also allow the valve **90** to serve as a release valve that vents pressure that may develop in the hull **22** during the operation of the wave energy recovery system **10**.

[0121] A complete submersion of the buoy **20** may be desirable to reduce or eliminate damage to the buoys **20** or other system components when violent storms or other such hazards are present. Once a storm passes, the buoy **20** may take in pressurized air through the air inlet **90** to expel water ballast and return the buoy **20** to its operative position. Furthermore, the main buoy **20** may be adjustably raised or lowered through the intake and expulsion of water ballast to dynamically adjust the buoy **20** position in response to changing wave conditions to maintain optimal operative positioning for the buoy **20**.

[0122] Ballast is used to provide moment to resist the lateral forces on the buoy **20**. If the buoy **20** is insufficiently ballasted it will tend to tip, or heel, excessively in high winds. Heeling may occur when there is too much wind or water pressure to one side, thereby causing the buoy **20** to lean over to one side. In addition, too much heel may result in the buoy **20** flipping over or out of its preferred position in relation to the waves. Adding water ballast below the vertical center of gravity increases stability. When the buoy **20** heels, it must then lift the ballast clear of the water, at which point it is obvious that it does provide righting moment. One advantage of water ballast is that it can be dumped out by having a valve at the bottom of the ballast chamber, reducing the weight of the buoy **20**, and then added back in by opening up the valves and letting the water flow in after the buoy **20** is back in its ideal position.

[0123] When a system operator or computer logic determines that it is desirable to submerge the buoy **20** due to inclement weather or other such hazard, one method of submerging the buoy **20** is to fill the hull **22** with enough water to overcome the buoyancy of the buoy **20**, thereby submerging the buoy **20**. As the bottom-side valves **92** are commonly in contact with the body of water, the environmental pressures may tend to hold the valves **92** in the closed position. Such environmental pressures, along with the arrangement of the spring **150**, serve to seal the bottom-side valves **92** such that the valves **92** normally resist water entering the hull **22**.

[0124] However, when it is desirable to open the valves **92** and allow water to enter the hull **22**, the plunger valve **148** is pressurized to overcome the environmental pressures and the spring force to open the valves **92**. When sufficient water has entered the hull **22** to submerge the buoy **20** to its desired depth, the plunger valves **148** may be depressurized, and the spring **150** may return the valve **92** to its closed position. The buoy **20** may also include a depth meter (not shown) to assist in determining when the buoy **20** reaches the desired depth.

[0125] In one embodiment, a plunger valve **148** is arranged such that, when the plunger valve **148** is pressurized, a topside valve **90** is encouraged into the closed position. The spring **150** may be arranged such that the spring **150** also encourages the topside valve **90** into the closed position so that the valve remains closed when the cylinder **74** is selectively depressurized. Maintaining the valve **90** in the closed position may seal the hull **22** so that rain or other moisture is not permitted to enter the hull **22**.

[0126] The closing of the topside valves **90** by pressurizing the plunger valves **148** may assist in facilitating the expulsion of water from the hull **22** through the bottom-side valves **92**. When a system operator or computer logic determines it is desirable to return the buoy **20** from a submerged position to an operative position at the surface of the water, the buoy **20** may be raised by expelling water from the hull **22** back into the surrounding body of water so as to increase the buoyancy of the buoy **20**.

[0127] One method of expelling water from the buoy **20** is to close and seal the topside valves **90**, open the bottom-side valves **92**, and pressurize the hull **22** such that the water in the hull **22** flows out of the bottom-side valves **92** and back into the surrounding body of water. The plunger valves **148** may be pressurized so as to apply a substantial force on the doors of the topside valves **90**, thereby sealing the valves **90**, i.e., holding the valves **90** closed against the internal pressure building in the hull **22** that is used to expel the water.

[0128] Once the water is expelled from the hull **22**, the plunger valves **148** coupled to the topside valves **90** may be depressurized, and the springs **150** coupled to the topside valves **90** may apply a sufficient force to the door of the topside valve **90** to maintain the valve **90** in a closed position so as to keep unwanted moisture out of the hull **22**. In another embodiment, the springs **150** coupled to the topside valves **90** apply a sufficient force to maintain the valve **90** in a closed position, but also allow the valve **90** to serve as a release valve that vents pressure that may develop in the hull **22** during the operation of the wave energy recovery system **10**.

[0129] The methods of affecting buoyancy through intake and expulsion of water from the hull **22** described above may be used to either submerge or raise a buoy **20** or precisely position a buoy **20** at the surface of the water. Precise positioning of a buoy **20** at the surface of the water may increase the efficiency of the system with regard to recovery of energy, safety, etc. Other methods of precise positioning of the buoy **20** may include the use of pressure chambers **76** located on the buoy **20**. In addition, it is also preferable that the inside of the buoy **20** maintains a certain amount of pressurized air. Any appropriate amount of pressurized air may be used, such as maintaining a pressure of three psi within the buoy **20**. Maintaining the buoy **20** full of pressurized air may aid in maintaining the buoyancy of the buoy **20**.

[0130] The buoy **20** may also include at least one cylinder or tank **76**, but preferably six tanks located at any appropriate location on the buoy **20**, but preferably located along an outer edge of the buoy **20**. Five of the tanks **76** may include ballast air from the paddle mechanism **80**. When the paddles **82**, **84** move to stabilize the buoy **20**, the paddles **82**, **84** may push air into the ballast air tanks **76**. The sixth and last tank **76** may be a control tank that provides air that may be used to open and control valves **90**, **92**.

[0131] As illustrated in FIG. **19**, a plurality of pressure chambers or tanks **76** may be distributed along the bottom side of the buoy **20**. In one example, a pressure chamber **76** may be arranged as an elongated tube positioned in the hull **22** and running along the inner surface of the bottom side of the hull **22**. Although pressure chambers **76** are described and illustrated as running along the bottom side of the hull **22**, it will be readily appreciated by those skilled in the art that pressure chambers may be distributed anywhere throughout the buoy **20**. For example, pressure chambers may be located along the internal surfaces of the topside, as illustrated in FIG. **33**, along internal surfaces of the sides of the hull, or within structural members supporting the hull.

[0132] Pressurizing the pressure chambers **76** to different pressures may control the buoyancy of the buoy **20**. Increasing the buoyancy will generally raise the position of the buoy **20** with respect to the surface of the water. Decreasing the buoyancy will generally lower the position of the buoy **20** with respect to the surface of the water. As will be subsequently discussed herein, mechanical systems attached to the buoy **20** may be utilized to pressurize the pressure chambers **76**. Computer logic or system operators may determine that a change in the buoy's **20** position relative to the surface of the water will increase the efficiency of the system **10**. The computer logic or system operator then may increase the pressure in the chambers **76** or may decrease the pressure in the chambers **76** so as to affect buoyancy and more optimally position the buoy **20**.

[0133] The pressure chambers **76** may be further utilized as a source of pressurized gas to control other systems or functions of the buoy **20**. In one example, the pressure chambers **76** may be used as a source of pressurized gas for pressurizing the pneumatic system **70** so as to move valves **90**, **92** to open and closed positions, as described herein. In another example, pressurized gas in the pressure chambers **76** may be used so as to pressurize the hull **22** such that water is expelled from the hull **22** when it is desirable to return a submerged buoy **20** to the surface of the water.

[0134] The buoy **20** may further include at least one paddle mechanism **80**. The paddle mechanism(s) **80** may be located at any appropriate location on the buoy **20**, but preferably located on its side(s) **26**. The paddle mechanisms **80** may help to stabilize the buoy **20** by keeping the largest face of the buoy **20** on the wave so that the buoy **20** rises and falls horizontally.

[0135] The paddle mechanisms **80** may include an inner paddle **82**, and outer paddle **84**, and a main piston **86**, and an adjustment piston **88**. The pair of paddle members **82**, **84** may be coupled by a hinge pin **94** such that the paddles **82**, **84** may be adjusted to positions at varying angles relative to one another. The paddle mechanisms **80** may also pump air within the buoy **20** so that the buoy is filled with pressurized air to keep the buoy **20** stationary. Preferably, during operation of the system **10** the buoy **20** should not move above eighteen feet due to the waves. The buoy **20** moves approximately three to four feet up and down with the waves all the time.

[0136] The positioning and shape of the paddle mechanisms **80** also tend to eliminate or reduce lateral movement, wobbling, and rocking of the buoy **20**. The shape of the paddles **82**, **84**, in cooperation with the downward forces produced by the main cable **36** and connector cables **62**, holds the buoy **20** level on the surface of the water as a wave passes. As the wave displaces the buoy **20** upward, the buoy **20** remains level, thus reducing or eliminating lateral movement, wobbling, and rocking As described above, maximizing vertical movement also maximizes the energy recovered from a wave.

[0137] Mechanical systems attached to the buoy **20** may be utilized to pressurize the pressure chambers **76**. One exemplary embodiment of such a mechanical system is illustrated in FIG. **21**A. FIG. **21**A illustrates a paddle compression mechanism **80** for pressurizing the pressure chambers **76** of the buoy **20**. Each paddle mechanism **80** may include an inner paddle flap **82** and an outer paddle flap **84**. Each of the paddle flaps or members **82**, **84** may be adjustable in order to achieve the maximum power from each wave. The paddle compression mechanism **80** utilizes mechanical movements caused by the interaction of the paddle mechanism **80** with waves in order to generate pressure and to deliver that pressure to the pressure chambers **76**.

[0138] As discussed above, the inner paddle **82** may be connected to the buoy **20** by a hinge pin **94** so that the inner paddle **82** may be adjusted to positions at varying angles relative to the side **26** of the buoy **20**. The adjustment piston **88** is coupled to both paddles **82**, **84** such that the expansion or contraction of the adjustment piston **88** controls the positioning of the paddle members **82**, **84** relative to each other. The length of the adjustment piston **88** may be rigidly set such that the relative position of the paddles **82**, **84** is rigid or otherwise static.

[0139] In one embodiment, the paddles **82**, **84** may be positioned such that inner paddle **82** is generally positioned at the surface of the water and parallel to the surface of the water. The outer paddle **84** is positioned above the surface of the water and at an acute angle to the surface of the water. Such an arrangement may maximize the impact force of a passing wave on the paddle mechanism **80**.

[0140] The paddle **82** at a location parallel to the surface of the water may be positioned so as to recover the energy of the vertical or upward movement of a passing wave. The paddle **84** located at an acute angle to the surface of the water may be positioned so as to recover the energy of the lateral movement of the passing wave. The paddle mechanism **80** may also include rubber stops **78** to prevent the outer paddle **84** from slamming against the inner paddle **82** in cases of rough water or when the operator desires to fully fold the outer paddle **84** up to the inner paddle **82**, for example.

[0141] The main piston **86** may be coupled on a first end to a paddle member **82** and is coupled on a second end to the body of the buoy **20**. As will be readily appreciated, upward movement of the paddle members **82**, **84** may cause the piston shaft **96** to move and to pressurize the piston cylinder **98**. As an alternative, and as illustrated in FIG. **21**B, a fluid line **93** may be coupled the piston cylinder **98** to an intake manifold **95**, and the intake manifold **95** may be coupled to a pressure chamber **76** that is positioned within the buoy **20**.

[0142] The fluid line **93** may couple the piston cylinder **98** in fluid communication with the pressure chamber **76** such that the pressure generated in the piston cylinder **98** by the movement of the paddles **82**, **84** is relayed or otherwise communicated to the pressure chamber **76**. It will be readily appreciated that, as waves impact the paddles **82**, **84** and repeatedly move the paddles **82**, **84**, the pressure chamber **76** may be continuously pressurized during normal operation of the buoy **20**.

[0143] In an embodiment, the buoy **20** may be arranged so as to have a plurality of paddle compression mechanisms **80**, with each mechanism **80** pressurizing one or more pressure chambers **76** located within the hull **22** of the buoy **20**. In an embodiment, eight paddle compression mechanisms **80** are arranged on the buoy **20**, with one mechanism **80** on each side surface **26** of the buoy **20**. In addition, each mechanism **80** may be arranged such that it may generally slide vertically along the surface of the buoy **20**. Such an arrangement facilitates the desirable positioning of the paddles **82**, **84** relative to the surface of the water.

[0144] As shown in FIG. **31**, the intake manifold **95** may be arranged so as to regulate the pressure in a pressure chamber **76** and to block water from entering the pressure chamber **76**. The manifold **95** may be arranged with a relief valve **104** to release air from the pressure chamber **76** if the pressure in the chamber **76** rises above a predetermined level, as shown in FIG. **22**. For example, it may be determined that the maximum desirable pressure in a pressure chamber **76** is 125 psi. The relief valve **104** may be arranged to release air from the pressure chamber **76** whenever the pressure in the chamber **76** rises above 125 psi.

[0145] The manifold **95** may include an oil pan (not shown) that is filled with oil or another similar liquid substance. The oil and the oil pan may be arranged such that air released from the pressure chamber **76** may pass through the oil in the oil pan and be released to the surrounding environment. The oil and the oil pan may also be arranged to as to block or otherwise prevent water from the surrounding environment from passing through the manifold **95** and into the pressure chamber **76**. The oil used in the oil pan may be a vegetable oil, fish oil, or other appropriate organic substance that would not cause any environmental issues in the event that the oil is spilled into the environment surrounding the buoy **20**.

[0146] As shown in FIG. **32**, the paddle compression mechanism **80** may further include a check valve **100**. The check valve **100** may be located anywhere along the fluid path between the main piston **86** and the pressure chamber **76**. In one embodiment, the check valve **100** may be located at the coupling of the fluid line and the main piston **86**. The check valve **100** may include a spring **102** that biases the valve to close the fluid path between the main piston **86** and fluid line **93**. In addition, the check valve **100** may be arranged such that gravity also assists in closing the fluid path between the main piston **86** and fluid line **93**.

[0147] The check valve **100** may serve as a one-way-flow system. The check valve spring **102** may be arranged so as to open the fluid path between the main piston **86** and fluid line **93** when sufficient pressure builds up in the piston cylinder **98** so that the pressure may be communicated to the pressure chamber **76**. Such an arrangement allows air to flow from the piston cylinder **98** to the fluid line **93** and on to the pressure chamber **76**, without allowing air to flow from the fluid line **93** back into the piston cylinder **98**. As the paddle compression mechanism **80** only pressurizes the piston chamber **98** when a wave impacts the paddles **82**, **84**, it will be readily understood that such a one-way-flow system may facilitate pressurization of the pressure chambers **76** by the paddle compression mechanisms **80**.

[0148] Referring to FIGS. **14**, **16**, and **20**, a number of components or devices may be positioned on the top surfaces **24** of the buoy **20**. For example, a manhole **120** may be located in the top surface **24**, so as to provide access to the hull **22** of the buoy **20**. The manhole **120** may be utilized by workers during the installation of a buoy **20** to prepare the buoy **20** for operation. The manhole **120** may also be utilized by workers for general maintenance, troubleshooting, or repairing of the buoy **20** during operation of the buoy **20**. The manhole **120** may be equipped with a cover (not shown) to prevent water or other substances from unintentionally entering the hull **22** of the buoy **20**. There may be any appropriate number of manholes **120** located in the buoy **20**, but there are preferably two manholes.

[0149] With reference to FIGS. **16** and **20**, solar panels **122** may also be positioned on the top surfaces **24** of the buoy **20**. The solar panels **122** may generate electricity to be either delivered to shore or for use locally on the buoy **20** to power systems on the buoy **20**. Supercapacitors or ultracapacitors (not shown) may also be included for storage of the energy generated by the solar panels **122**.

[0150] The energy generated by the solar panels **122** may be utilized locally to operate systems on the buoy **20**. For example, the energy may be used to operate logic circuits that control the positioning of the buoy **20** and the paddle compression system **80**. The energy also may be used to power solenoid valves used to operate the pneumatic systems previously described. The energy may also be used to run other systems such as, for example, warning lights that alert ships of the buoy's **20** position, antennas that send signals to alert ships of the buoy's **20** position, global positioning equipment, receivers to receive instructions from shore or international alerts, transmitters to send information to shore, and the like. The solar panels **122** may also be charged by a rechargeable battery.

[0151] As an alternative embodiment, a platform **124** may be positioned and secured on the top surfaces **24** of the buoy **20**. The platform **124** may be of any appropriate shape or size and should not be limited to that illustrated in FIGS. **15** and **16**. A number of components, devices, and systems may be mounted onto the platform **124**. Preferably, a tube **126** may be mounted within the platform **124** that may provide a container for housing various items, as shown in FIGS. **15-17**. For example, an antennae array **128**, which may include beacons, lights, communication antennas, cell phone antennas, radio antennas, signal relay antennas, global positioning equipment, and the like may be positioned within the tube **126**.

[0152] Such communication antennas **128** may extend the reach of communication methods hundreds or thousands of miles across the ocean. The tube **126** may be maintained above the water surface so that air may be removed through the tube **126** for use with the buoy **20**. The tube **126** also maintains and keeps the antennae array **128** located above the water surface so that the valves **90**, **92** may be operated remotely via the antennae **128**.

[0153] Other embodiments of wave energy recovery systems **10** are described in U.S. patent application Ser. No. 11/602,145 to Greenspan, et al., filed Nov. 20, 2006, and entitled "Wave Energy Recovery System," which is hereby incorporated in its entirety.

[0154] With reference to FIGS. **27-29**, another embodiment of the present invention is illustrated. As an alterative, the energy of a wave may be harnessed to drive a pump to move hydraulic fluid to drive a generator. The motion translating assemblies **12** may be arranged such that each assembly **12** drives individual pumps **132** secured to each support platform **40**. The assemblies **12** may be arranged to rotate a driveshaft **134** coupled to each pump **132**.

[0155] Pressure lines **136** may couple each pump **132** to a multiple hydraulic pump drive system **138**, for example, which may be located on shore. Each pressure line **136** may transmit pressure generated by each pump **132** to a central pressure repository or accumulator **140**. This pressure repository **140** may release pressure, such as at a constant rate, to drive a flywheel of the multiple hydraulic pump drive system **138** to generate electric power. Such an arrangement may result in self-sufficient assemblies **12** and pumps **132**.

[0156] It will be readily understood how the inclusion of flexible pressure lines **136** may allow for easy installation, as described above. Similar to the previous description, the multiple hydraulic pump drive system **120** may generate an AC current, which is converted to DC current by a rectifier. A voltage converter generates a consistent DC current to be used as a final source of electricity or to be converted back to AC current.

[0157] The embodiments, as described herein, allow for easy and inexpensive relocation of a wave energy recovery system. As will be readily understood, a system may be relatively easily and quickly disassembled and moved to a more desirable location. The modular nature of the embodiments allows for rapid expansion of an existing and operative system. In addition, the location of systems on a seabed provides for a self-cooling system, which improves operation and lowers maintenance costs as well.

[0158] The embodiments of the invention have been described above and, obviously, modifications and alternations will occur to others upon reading and understanding this specification. The claims as follows are intended to include all modifications and alterations insofar as they come within the scope of the claims or the equivalent thereof.

Having thus described the invention, we claim:

1. A wave energy recovery system comprising:
a motion translating assembly comprising:
a main buoy; and
a shaft coupled to said main buoy, wherein vertical motion of said main buoy is translated into rotational motion of said shaft; and
an electric power generating device coupled to said shaft, wherein rotational motion of said shaft results in said electric power generating device generating electric power.

2. A wave energy recovery system comprising:
a motion translating assembly comprising:
a main buoy;
a retracting buoy; and
a main cable coupled on one end to the main buoy and coupled on the other end to the retracting buoy;
a shaft;
a drum coupled to the shaft, wherein the main cable is wrapped around the drum, such that rotation motion of said drum is capable of translating into rotational motion of said shaft; and
a generator could to said shaft such that rotational motion of said shaft is capable of translating into rotational motion of said generator.

3. A method for recovering energy from waves comprising:
positioning a plurality of motion translating assemblies in a body of water;
positioning a shaft in said body of water;
positioning an electric power generating device in said body of water or proximate to said body of water;
coupling each of said plurality of motion translating assemblies to said shaft;
coupling said shaft to said electric power generating device;
translating vertical motion of said motion translating assemblies to rotational motion of said shaft; and
engaging rotational motion of said shaft to said electric power generating device to generate electric power.

* * * * *

US 20110304145A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2011/0304145 A1**

RAISCH (43) **Pub. Date: Dec. 15, 2011**

(54) **METHODS AND DEVICES FOR CONVERTING WAVE ENERGY INTO ROTATIONAL ENERGY**

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(21) Appl. No.: **13/159,419**

(22) Filed: **Jun. 14, 2011**

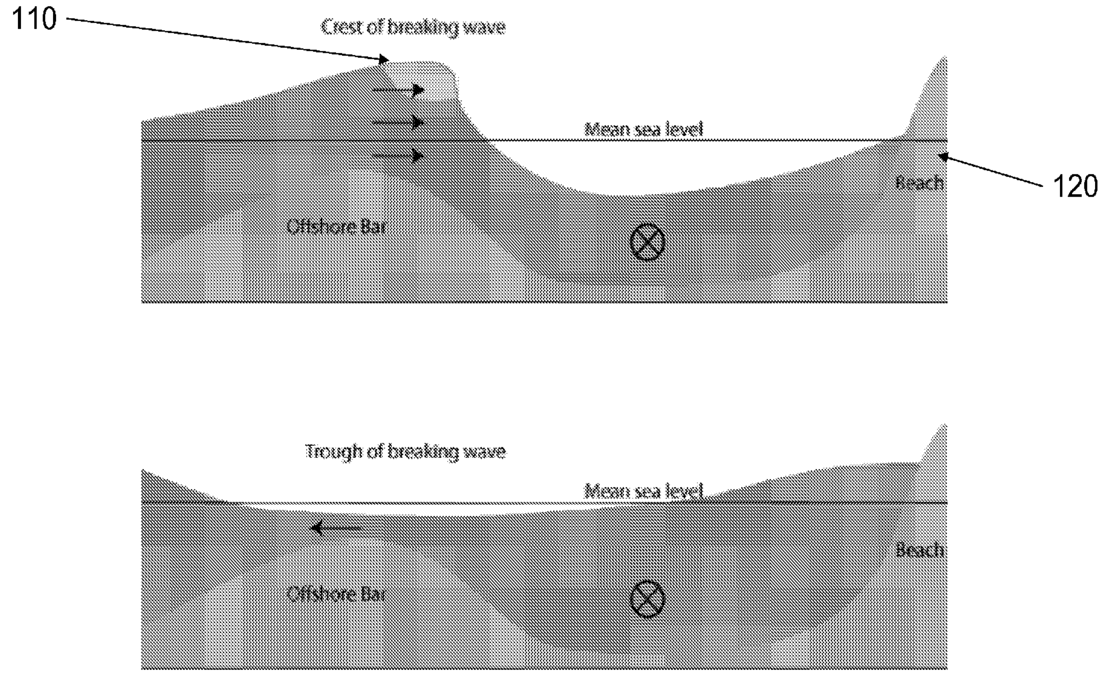
Publication Classification

(51) **Int. Cl.**
F03B 13/18 (2006.01)

(52) **U.S. Cl.** **290/53**; 60/497

(57) **ABSTRACT**

The invention discloses devices and methods for converting wave energy to rotational energy. Specifically, the invention allows for two or more flotation elements to move in opposite directions in response to a wave contacting a wave energy transducer according to embodiments of the present invention. Motion of the flotation elements leads to rotation of associated wheel assemblies, thus allowing for generation of rotational energy and by extension, electricity.



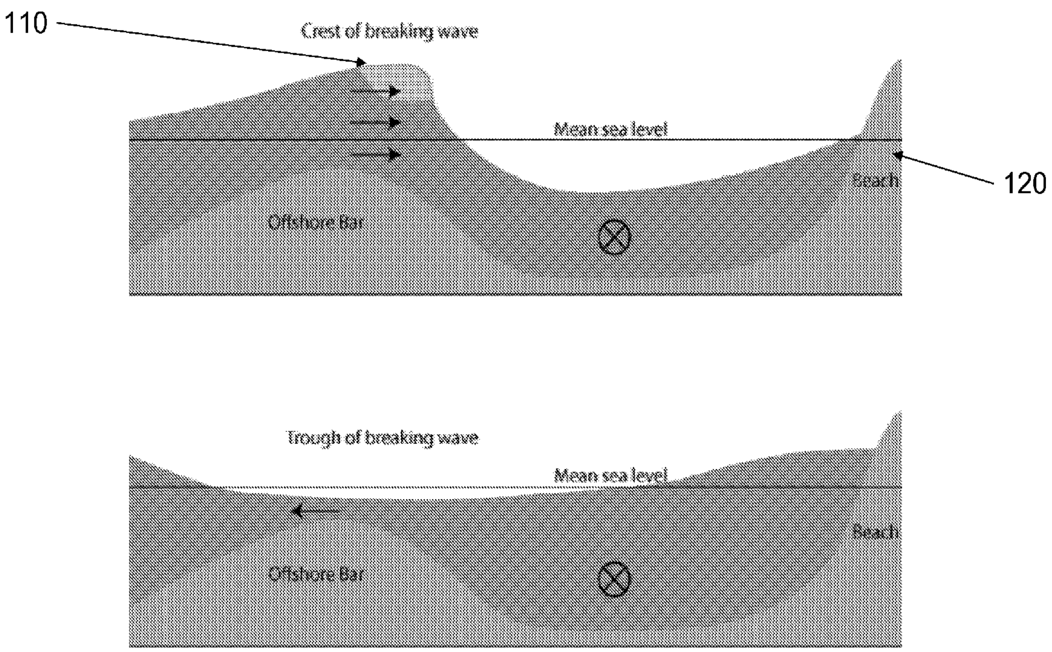

110
Crest of breaking wave
Mean sea level
120
Beach
Offshore Bar
Trough of breaking wave
Mean sea level
Beach
Offshore Bar

FIG. 1

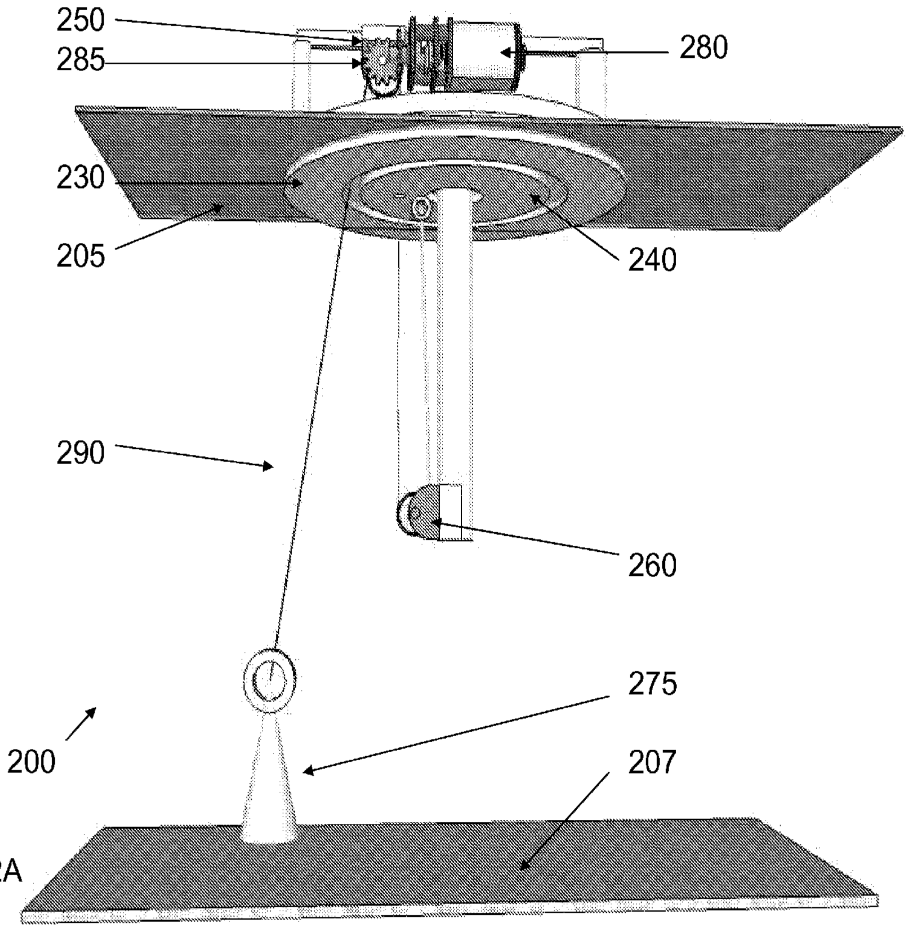


FIG. 2A

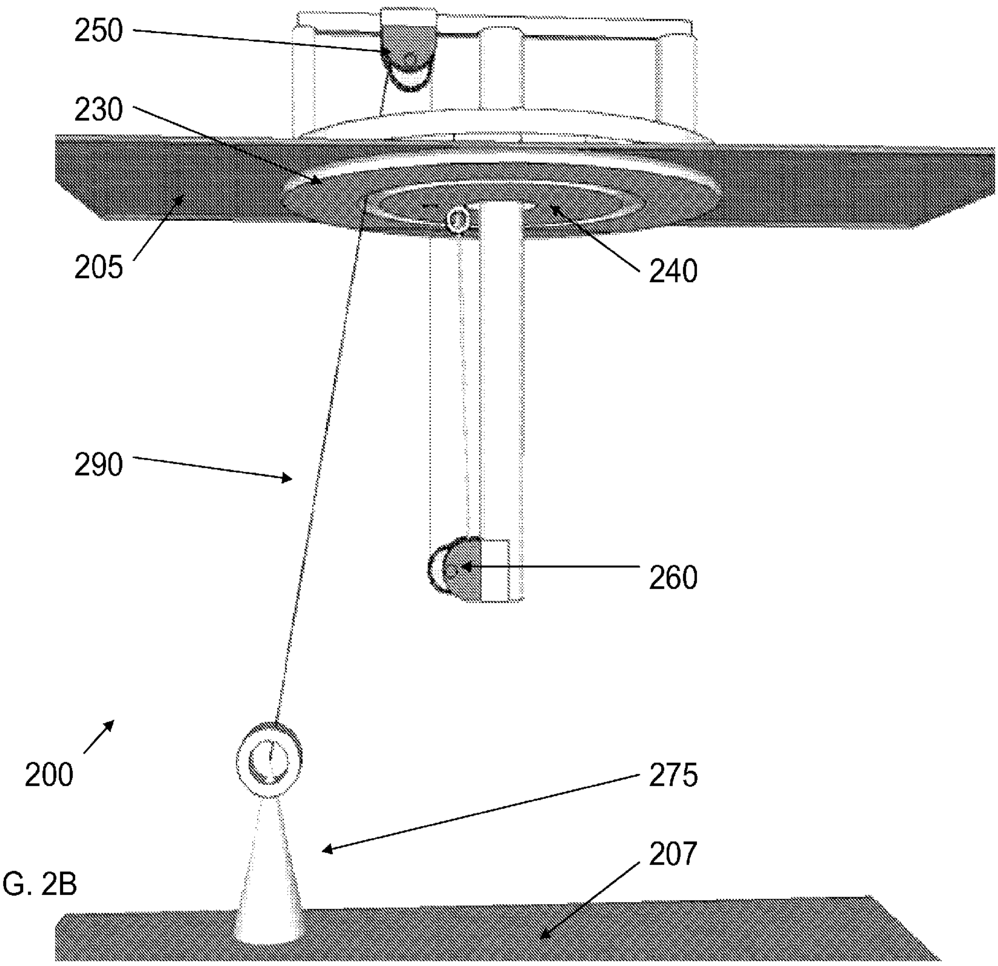


FIG. 2B

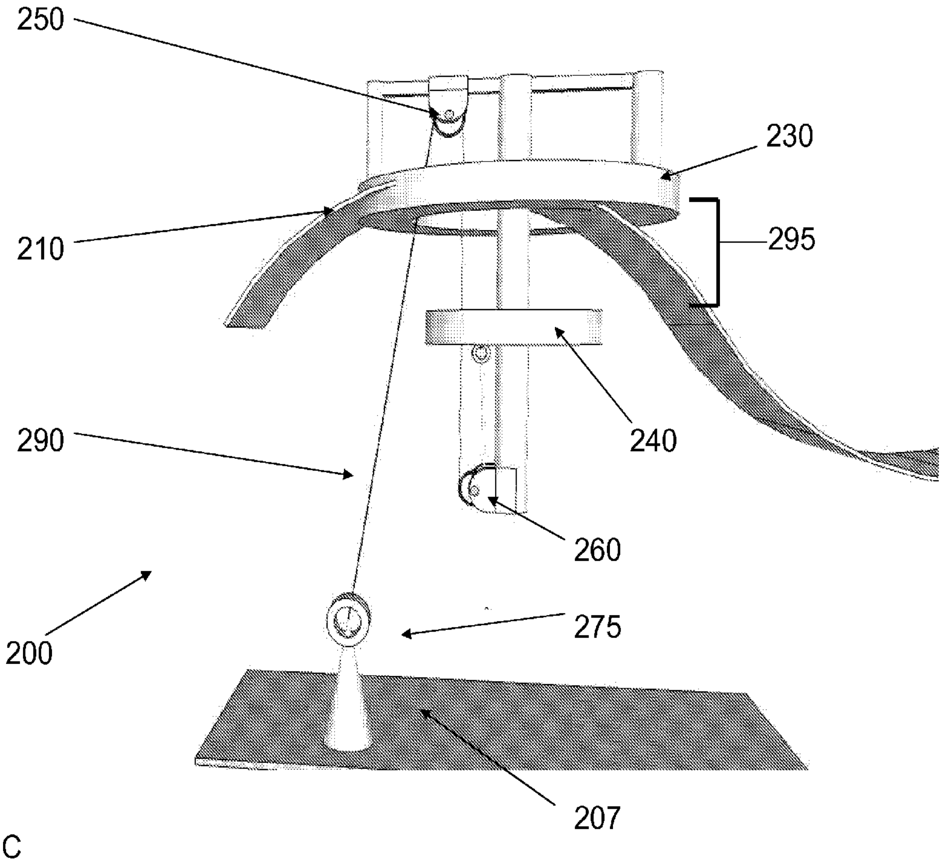


FIG. 2C

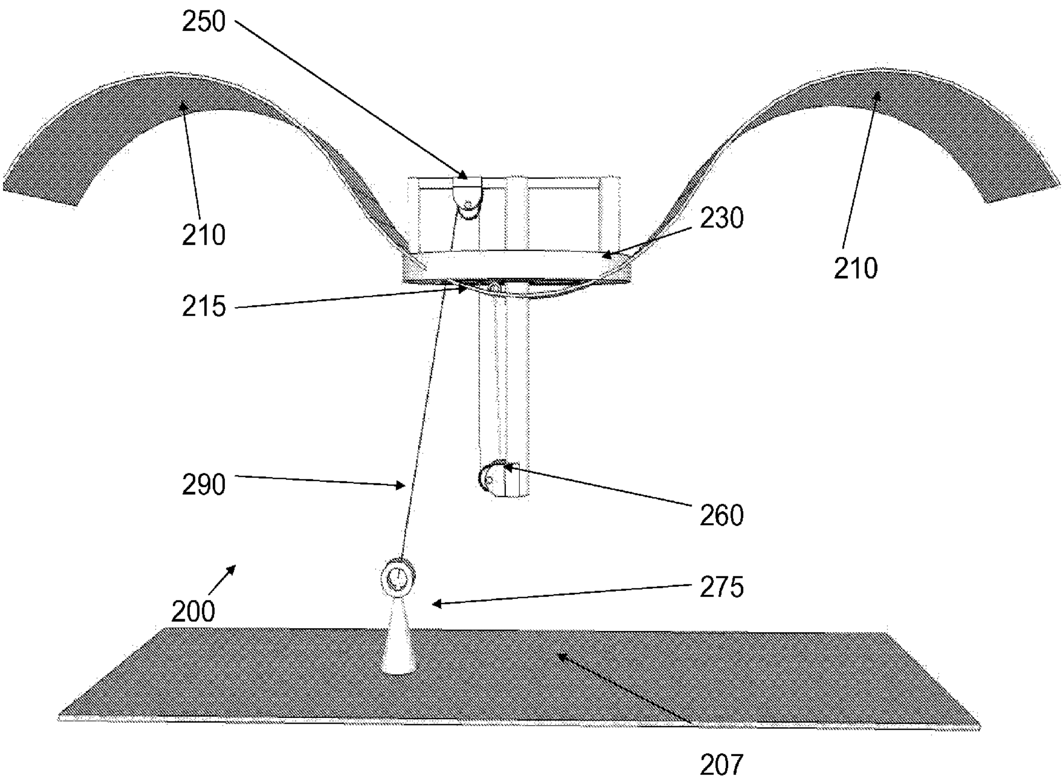


FIG. 2D

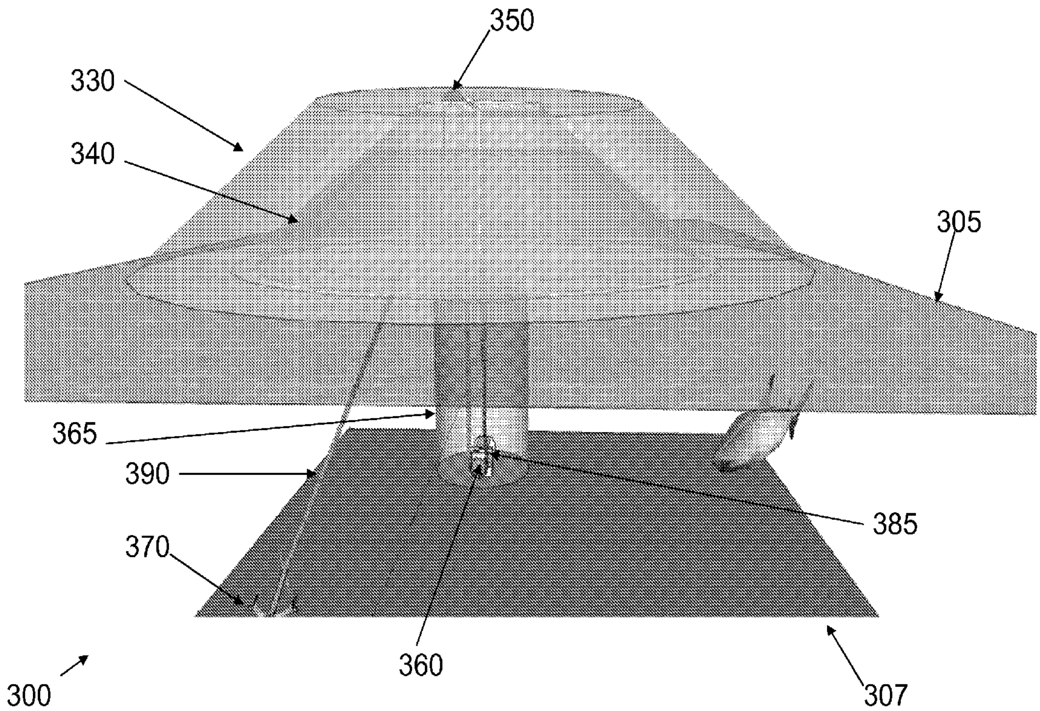


FIG. 3

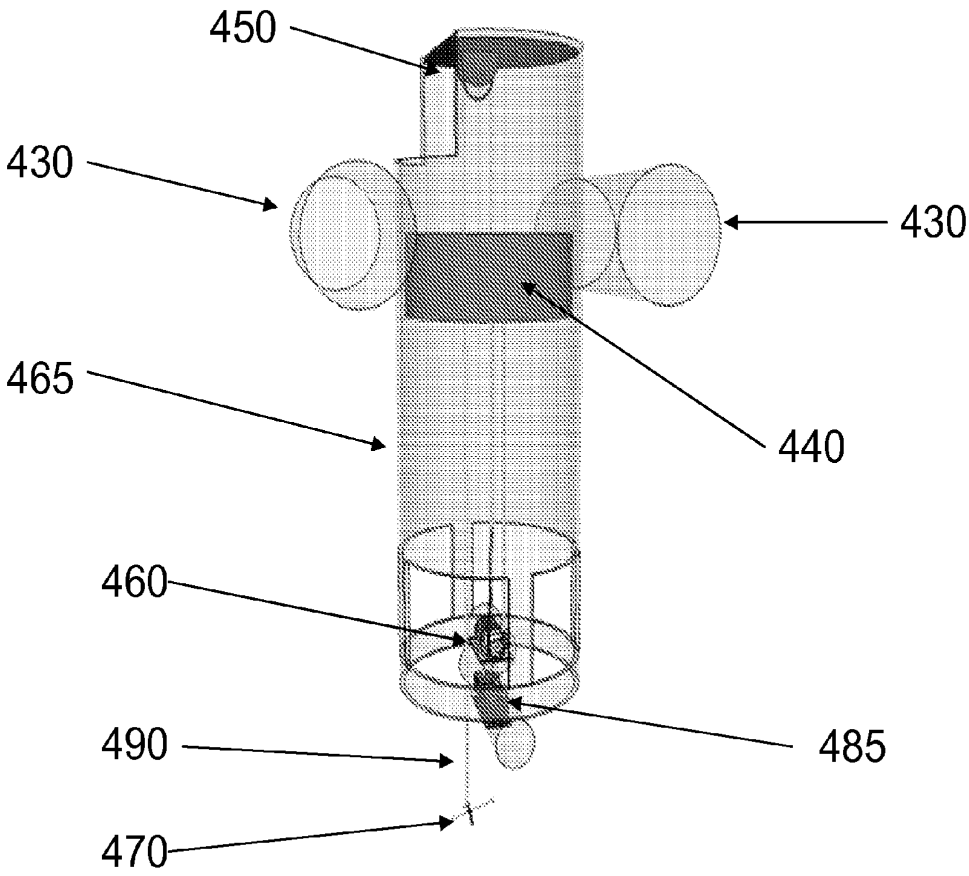


FIG. 4A

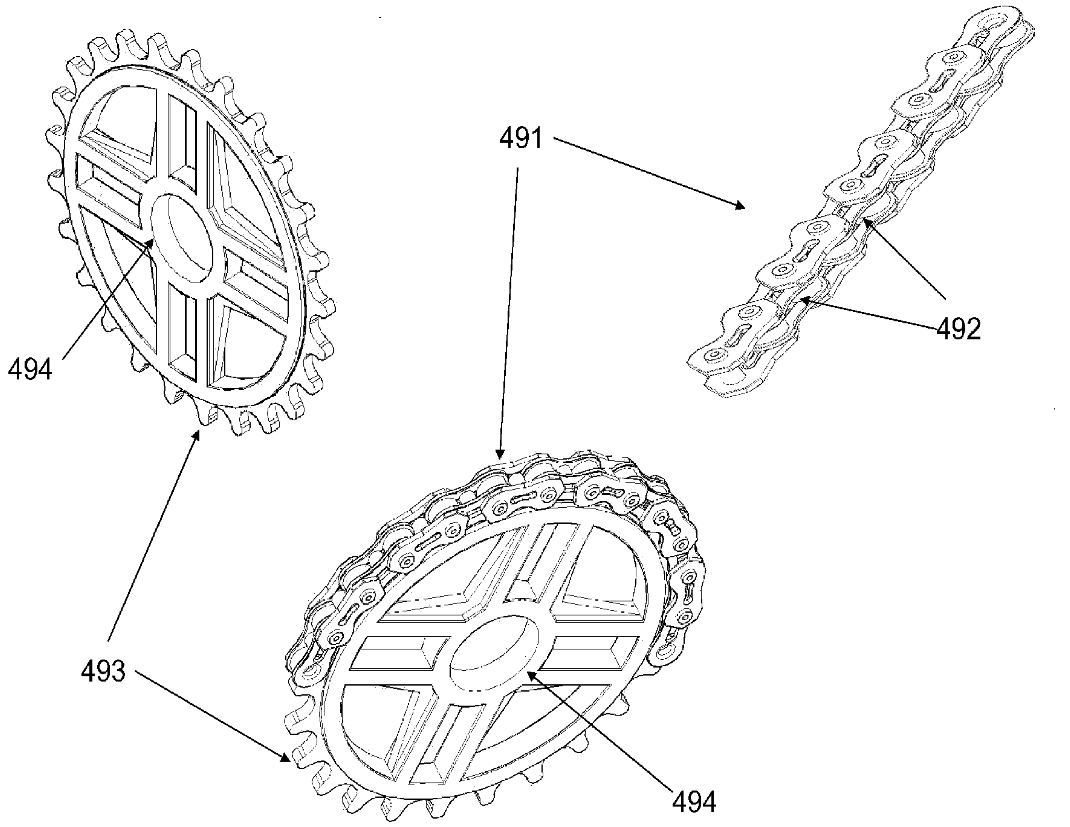


FIG. 4B

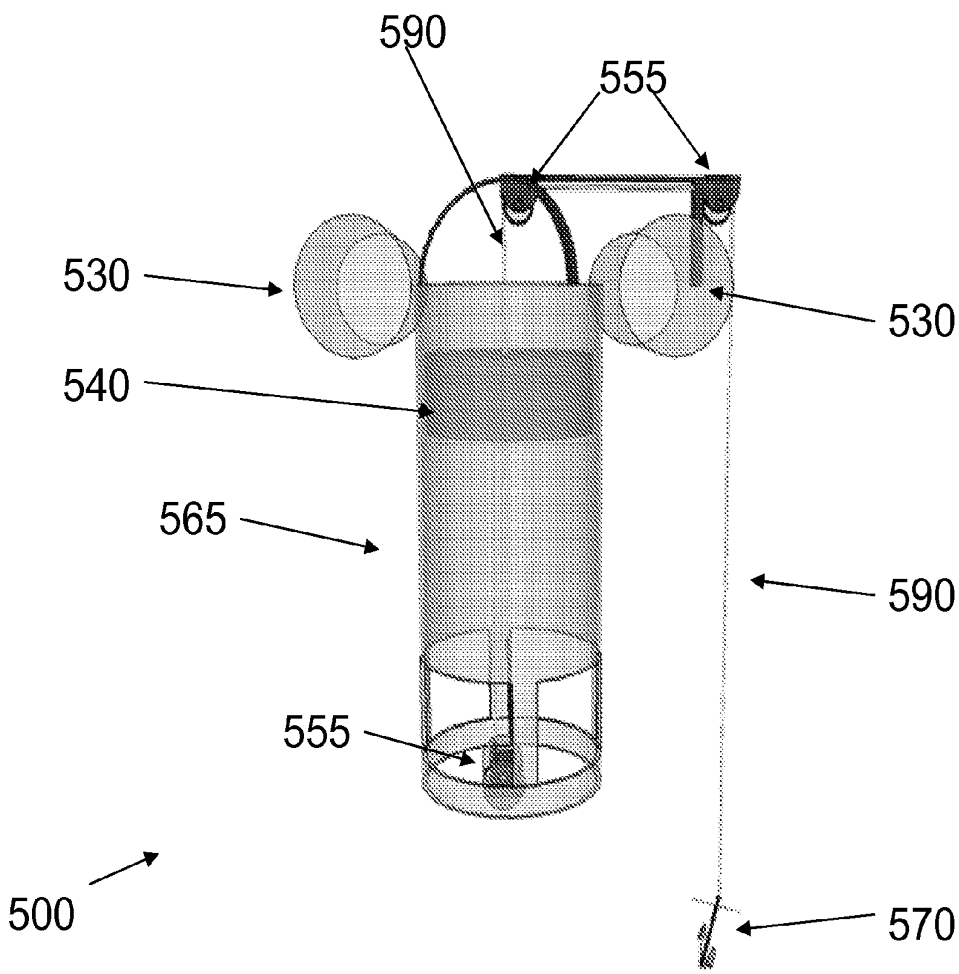


FIG. 5

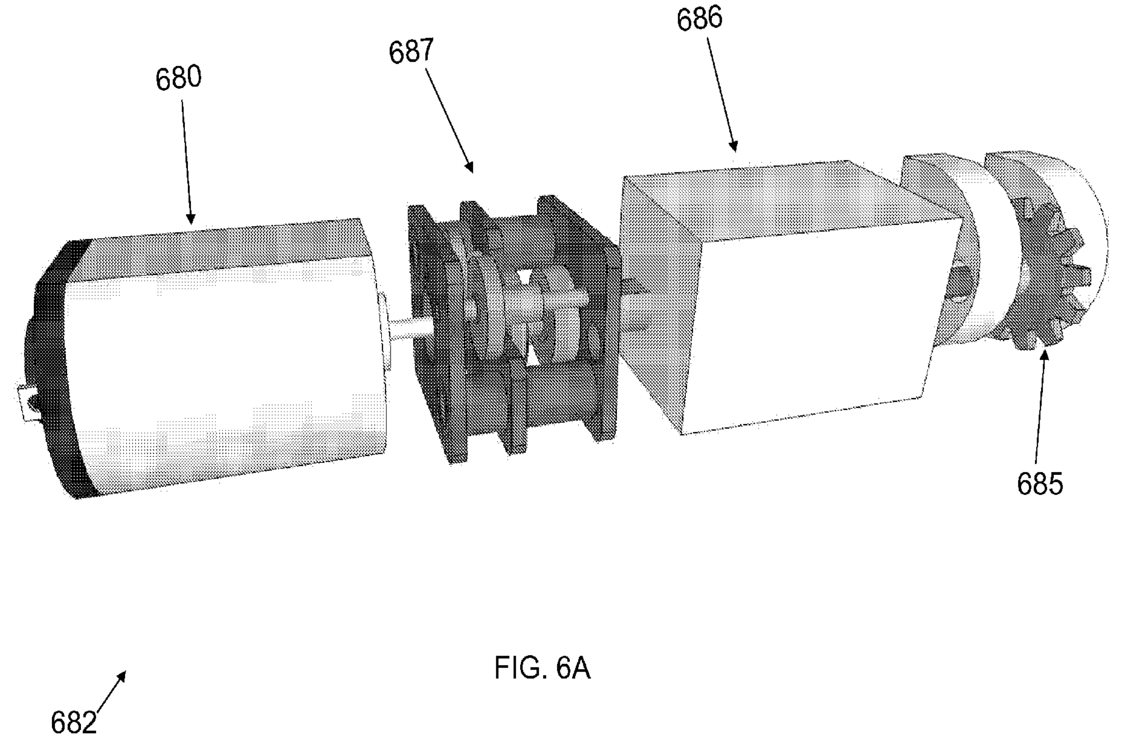


FIG. 6A

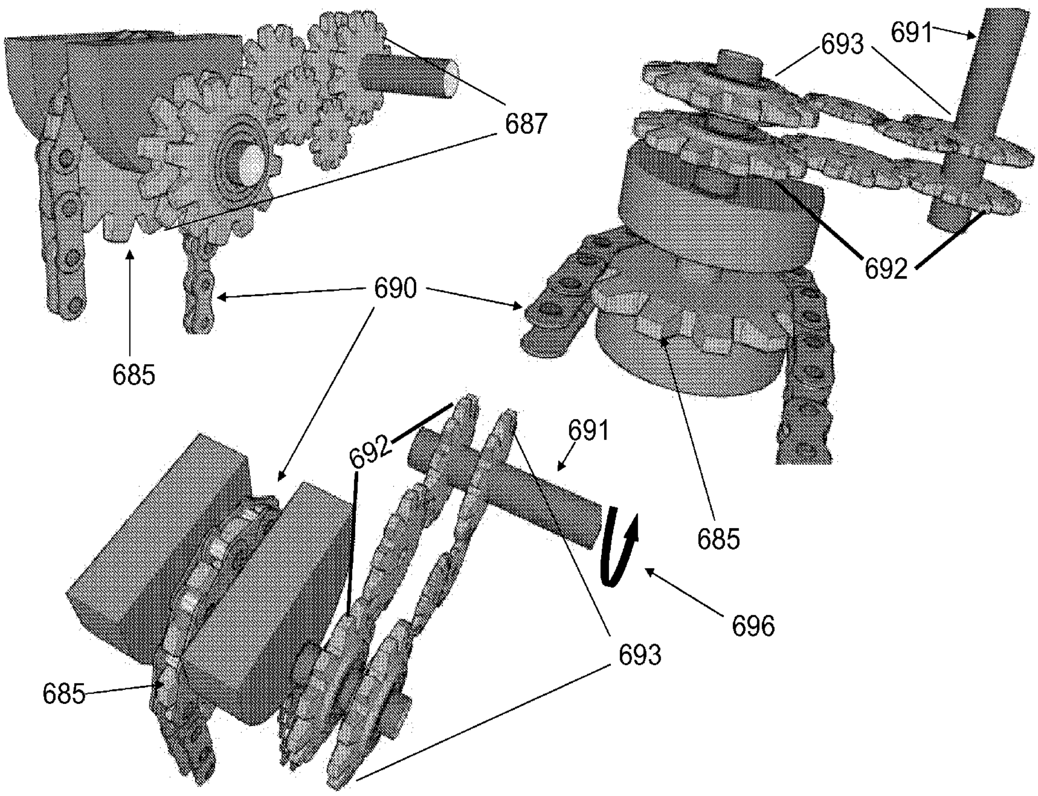


FIG. 6B

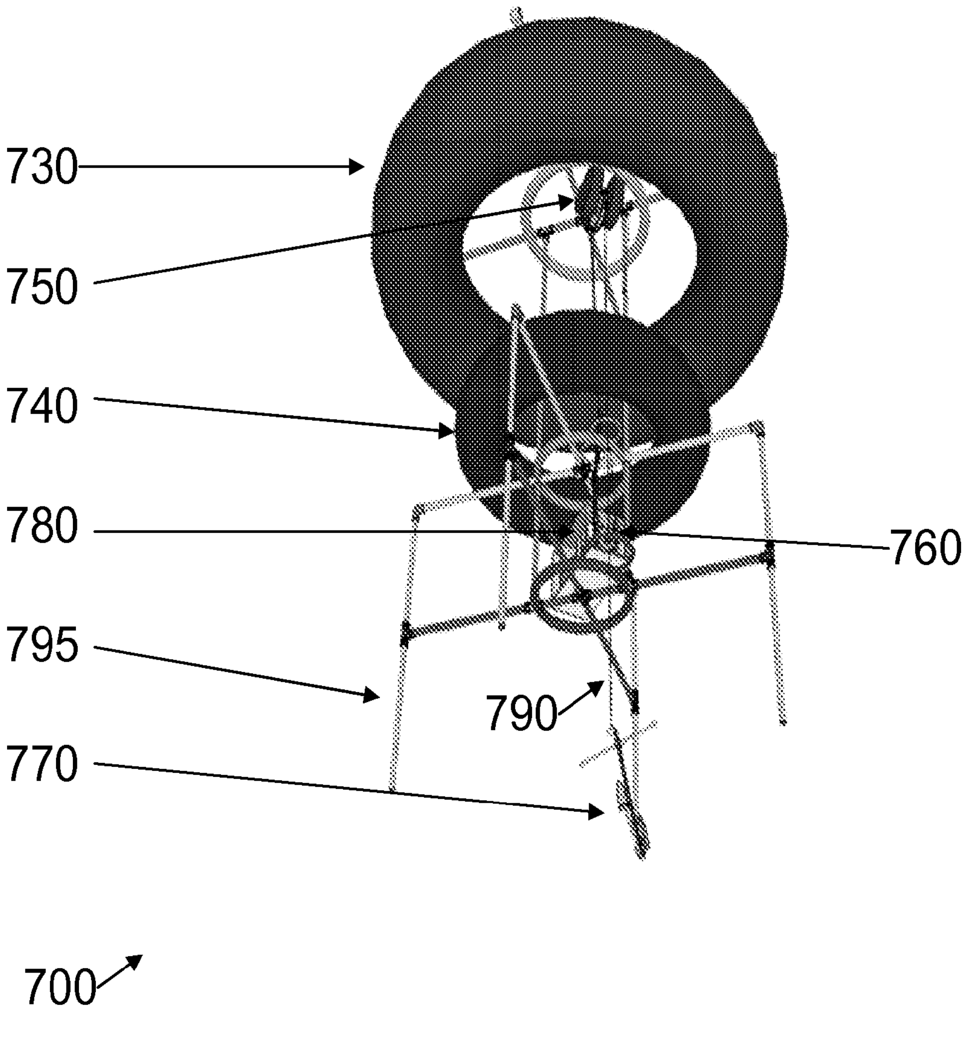


FIG. 7

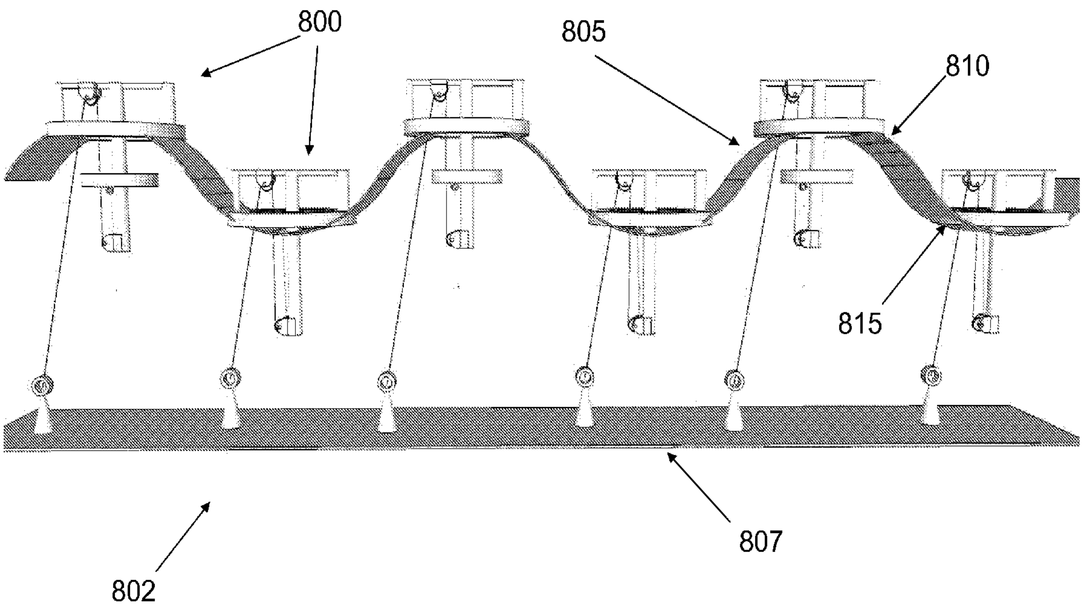


FIG. 8

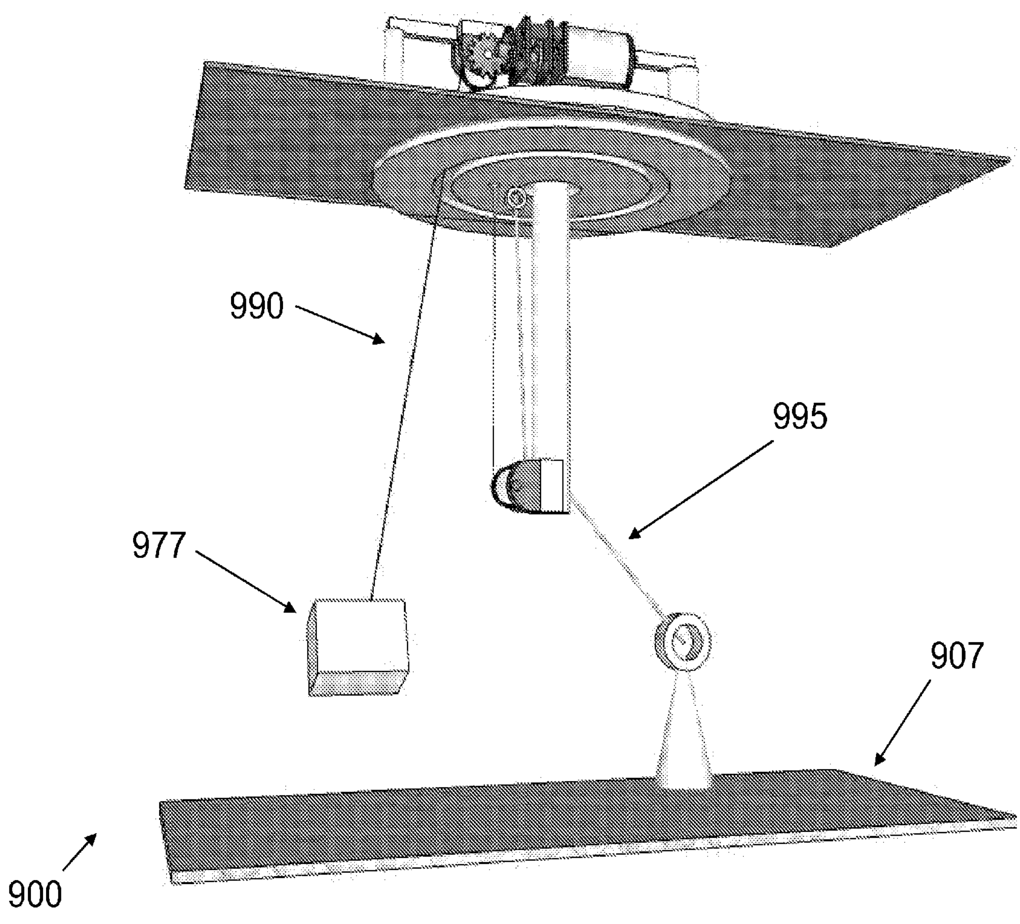


FIG. 9

providing a buoy having a first flotation element including an upper wheel assembly and a lower wheel assembly, the lower wheel assembly being below water level, a second flotation element, smaller than and motion independent of the first flotation element and, a cable, wherein the cable is attached at a first end to the second flotation element and is attached at a second end to a water bed, and wherein the cable is adapted to pass above and rotate said upper wheel assembly and pass beneath and rotate the lower wheel assembly

↓

placing the buoy into a body of water so that the first flotation element and the second flotation element are on the surface of the body of water

↓

anchoring the buoy through the cable to the bed of said body of water

↓

allowing action of waves to raise the first flotation element and concomitantly sink the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly

↓

allowing action of the waves to lower the first flotation element and concomitantly raise the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly.

FIG. 10

METHODS AND DEVICES FOR CONVERTING WAVE ENERGY INTO ROTATIONAL ENERGY

FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention, in some embodiments thereof, relates to devices and methods for efficiently converting energy associated with water waves into rotational energy, but not exclusively, to methods for effectively producing electrical energy from wave action.

[0002] There is a tremendous push in the world toward "renewable" energy sources. While solar and wind have been of the dominant varieties of alternative electricity sources, waves from the oceans could power a significant portion of the world electrical demand (see for example: http://peswiki.com/index.php/Directory:Ocean_Wave_Enemy). As with any form of energy supplied to the world public, wave-based electricity must be price competitive with other energy sources. Creating electricity is not the same as providing electricity in quantities and at prices that allow for its use in the electrical grid.

[0003] Wave-based electrical generators have been prepared and different versions have been used in sea trials, though none is commercially in use. While each system has unique features as well as performance specifications, most use the same basic physics of a wave driving either a linear or rotary element to eventually create electricity.

[0004] U.S. patent application Ser. No. 12/221,407 to Kim, et al describes electricity generation from the ocean wave by use of mechanical systems, submerged or on surface, collecting energy day and night regardless weather condition in a way similar to the way of collecting energy by use of solar panels or wind mills, without contacting the salty ocean water. The principal mechanism invented is as follows. Swinging of a heavy mass due to the ocean wave generates torque that sways gear wheel in clockwise or counterclockwise, thus transmitting the torque energy to two gear wheels that separate clockwise swing and counterclockwise swing via two sets of spring-piston clutching system and by use of gear chain, either converting clockwise swing to counterclockwise swing or vise versa such that the back and forth motion of the mass transforms into unidirectional rotation that rotates the rotor of electricity generator.

[0005] U.S. patent application Ser. No. 12/248,575 to Rasmussen teaches systems and methods are disclosed for harnessing wave energy. In one embodiment, a wave energy conversion device comprises a buoyant component connected to a generator such that wave energy is transferable from the buoyant component to the generator. A restricting mechanism connected with the buoyant component, is configured to selectively restrict the buoyant component from rising strictly along with passing waves. The restricting mechanism may be selectively released at an optimal time during a passing wave. In some embodiments, a system may include an array of wave energy conversion devices and a communications network. The communications network may allow for each of the buoyant components in the array to be released at an optimal time in sequential fashion

[0006] U.S. patent application Ser. No. 12/867,431 to Sidenmark describes a wave energy converter including a buoy and a transmission unit. In the transmission unit there is a driveshaft, which is driven to rotate either when the buoy rises or sinks, yet always in the same direction. The driveshaft is mechanically coupled to one of the rotating parts of an electric generator and drives this to generate electric current. Further on there is an energy accumulation device, which is also coupled to the driveshaft to accumulate energy when the buoy rises or sinks and the driveshaft rotates and which is then used to drive the generator at the other of the rising and sinking motions. The coupling between the energy accumulation device and the driveshaft can go by the generator's second rotatable part, the air gap between the generator's parts and the generator's first part. The coupling over the air gap gives a torque, which drives the second part to rotate along and which also counteracts the rotation of the driveshaft. The generator's second part is driven by the energy accumulation device to rotate in the other direction, when the torque from the driveshaft does not exceed the counteracting torque.

[0007] U.S. Pat. No. 4,568,836 to Reenberg teaches an apparatus for converting wave energy to electrical energy in a sea environment comprises a flotation duck anchored to the sea bottom and a turbine assembly pivotally connected thereto comprising an air chamber partially filled with liquid and/or granular particles having a turbine mounted on the upper portion thereof. The turbine is either self-rectifying or with a flap valve controlled entrance to the air chamber. A generator is coupled to the turbine and driven thereby. In operation, the motion of the waves causes the liquid and/or granular particles to compress the air within the chamber which is then used to drive the turbine. The spent air is fed back into the air chamber from the turbine as wave motion continues. In alternate embodiments the turbine generator assembly is mounted to the upper portion of an air chamber open to the sea on the bottom in an apparatus which rotates about a fixed or stable central axis. Gearing arrangements to drive the generator either alone or in combination with a liquid or air turbine drive are also disclosed. Compression of the air within the chamber or liquid, as the case may be, drives the turbine. Multiple assemblies may be readily coupled together to generate electrical energy in commercially practical quantities.

[0008] U.S. patent application Ser. No. 12/698,779 to Bender describes a power generating device comprising a weight suspended from a buoy via a zip-line and at least two gears disposed on said zip-line which are coupled to drives shafts, which in turn are couple to electric generators. The device converts the mechanical power of oscillating ocean waves into electricity.

[0009] U.S. Pat. No. 7,012,340 to Yi teaches an ocean wave energy conversion apparatus including a float adapted to ride on the surface of the ocean in reciprocal vertical motion in response to ocean wave front action and a lever adapted to ride on the surface of the ocean. The lever has one end coupled to the float. A fulcrum pivotally supports the lever. A magnet is coupled to the other end of the lever. Parallel stator cores having electric coils wound thereon together with the magnet form a magnetic circuit. Springs are adjacent the magnet and interconnected to the lever and the magnet. A barrier is disposed between adjacent stator cores. The upward motion of the float caused by impact of waves will move the magnet downward by the lever and compresses the springs. Downward motion of the float will move the magnet upward by the lever and expand the springs. Repeated movement of the magnet will induce a voltage in the electric coils.

[0010] The prior art generally describes production of electrical energy through the movement of weights with concomitant generation of electrical energy.

SUMMARY OF THE INVENTION

[0011] It is therefore a purpose of the present invention, in some embodiments, to describe methods and devices for converting wave energy into rotational energy, the rotational energy being, in some embodiments, being further converted to electricity.

[0012] The invention includes a device for converting wave energy into rotational energy, including the following: a first flotation element including an upper wheel assembly and a lower wheel assembly, the lower wheel assembly being below water level during action of the device; a second flotation element, smaller than and independent in individual motion of the first flotation element; a chain, wherein the chain is attached at a first end to the second flotation element and is adapted to rotate the lower wheel assembly and transfer change in potential energy of the first floatation element to mechanical rotational energy, and the chain further passing the upper wheel assembly; and, an anchor, wherein the anchor is attached to a second end of the chain and remains effectively unmoved during the action of the device.

[0013] In one aspect of the device, the rotational energy is employed in the generation of electricity.

[0014] In another aspect of the device, the device is a plurality of devices.

[0015] In another aspect of the device, there is additionally a motor being associated with a wheel assembly.

[0016] In another aspect of the device, the anchor sits on a water bed.

[0017] In another aspect of the device, the anchor is realized as a weight.

[0018] In another aspect of the device, there is additionally an electrical cable for dispatching electricity generated by the motor to an electrical grid.

[0019] In another aspect of the device, the device is realized as a buoy.

[0020] In another aspect of the device, the wheel assembly includes teeth adapted for interaction with the chain.

[0021] In another aspect of the device, the rotational energy is employed in water pumping.

[0022] In another aspect of the device, the rotational energy is employed in the compression of liquid or gas.

[0023] In still another aspect of the device, the device could be part of a raft or ship.

[0024] In another aspect of the device, there is additionally an electrical system for local off-grid uses.

[0025] In another aspect of device, there is additionally a light and adapted for use as lighthouse or marking buoy.

[0026] In another aspect of the device, there is additionally a gear system to convert turns of the wheels to larger turns of a component associated with a motor.

[0027] In another aspect of the device, there is a load on a shaft associated with the motor.

[0028] In another aspect of the device, there is no load on the motor.

[0029] In another aspect of the device, the chain may be comprised of a cable and a chain in a row.

[0030] In another aspect of the device, there is further included a system adapted to convert rotation in two directions to rotation in a single predetermined direction rotation.

[0031] The invention additionally includes a device for converting wave energy into rotational energy, including the following: a first flotation element including an upper wheel assembly and a lower wheel assembly, the lower wheel assembly being below water level during action of the device; a second flotation element, smaller than and independent in individual motion of the first flotation element; a chain, wherein the chain is attached at a first end to the second flotation element and is adapted to rotate the upper wheel assembly and transfer change in potential energy of the first floatation element to mechanical rotational energy, and wherein the chain is attached at a second end to the sea floor.

[0032] In one aspect of the device, the cable is attached to a cement block on the sea floor.

[0033] In another aspect of the device, the device is used in the production of electricity.

[0034] In another aspect of the device, the device is a plurality of devices.

[0035] The invention additionally provides for a method for converting wave energy to rotational motion, including the following: providing a buoy having a first flotation element including an upper wheel assembly and a lower wheel assembly, the lower wheel assembly being below water level, a second flotation element, smaller than and motion independent of the first flotation element and, a cable, wherein the cable is attached at a first end to the second flotation element and is attached at a second end to a water bed, and wherein the cable is adapted to pass above and rotate the upper wheel assembly and pass beneath and rotate the lower wheel assembly; placing the buoy into a body of water so that the first flotation element and the second flotation element are on the surface of the body of water; anchoring the buoy through the cable to the bed of the body of water; allowing action of waves to raise the first flotation element and concomitantly sink the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly; and, allowing action of the waves to lower the first flotation element and concomitantly raise the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly.

[0036] In one aspect of the method, the lower wheel is associated with an electric motor.

[0037] In another aspect of the method, there is an additional step of generating electricity from the rotation of the upper wheel assembly and the lower wheel assembly.

[0038] In another aspect of the method, there is an additional step of transferring the electricity from the buoy to an electrical grid.

[0039] In another aspect of the method, the buoy is realized as a plurality of buoys.

[0040] In another aspect of the method, the electricity is used to power the buoy.

[0041] In another aspect of the method, the cable is realized as a chain adapted to rotate teeth associated with the upper wheel assembly and the lower wheel assembly.

[0042] In another aspect of the method, there is additionally a system placed between the wheel and motor for conversion of two directions of rotation of said wheel to one direction of rotation and could optionally to a higher rate of revolution.

[0043] In another aspect of the method, the cable may be comprised of a cable and a chain in a row.

[0044] In another aspect of the method, there is additionally included a system adapted to convert rotation in two directions to rotation in a single predetermined direction rotation.

[0045] Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. "Buoy", "flotation element", "gear", "cable", "chain", "motor", "anchor", "wheel assembly", "sprocket", and other relevant terms may have their standard meanings as applied in the appropriate arts, unless otherwise defined in the instant invention. A chain may include a chain and a cable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced. It is noted that similar elements in various drawings will have the same number, advanced by the appropriate multiple of 100.

[0047] In the drawings:

[0048] FIG. **1** is a schematic representation of wave energy amenable to conversion to rotational energy;

[0049] FIG. **2**A is a schematic representation of an embodiment of the instant invention;

[0050] FIGS. **2**B-**2**D show schematic views of the steps of energy transduction of an embodiment of the present invention;

[0051] FIG. **3** is a schematic representation of an alternative embodiment of the present invention;

[0052] FIGS. **4**A & **4**B are schematic representations of still another embodiment of a wave to rotational energy device;

[0053] FIG. **5** is a schematic representation of another embodiment of the present invention;

[0054] FIG. **6**A shows details of an electricity generating module associated with an embodiment of the present invention;

[0055] FIG. **6**B shows further detail of the mechanism for converting rotational energy to a single direction;

[0056] FIG. **7** is a schematic representation of electricity generation according to an embodiment of the present invention;

[0057] FIG. **8** is a schematic representation of a field of devices according to an embodiment of the present invention for the purpose of generating MW levels of electricity;

[0058] FIG. **9** shows a schematic representation of an embodiment of the present invention with a weight in place of anchor; and,

[0059] FIG. **10** shows a flowchart associated with a method of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

[0060] The present invention, in some embodiments thereof, relates to converting the energy associated with waves into rotational energy and, more particularly, but not exclusively, to methods and devices for producing grid-deliverable electricity from wave energy.

[0061] For purposes of better understanding some embodiments of the present invention, as illustrated in FIGS. **1-10** of the drawings, reference is first made to FIG. **1** which shows a general conceptual schematic for a wave that could be used for production of rotational energy. Water waves have associated energies and are produced by a variety of factors; their intensity and frequency, critical for energy extraction, are related to these factors (http://en.wikipedia.org/wiki/Water_waves):

[0062] The great majority of large breakers one observes on a beach result from distant winds. Five factors influence the formation of wind waves:

- **[0063]** Wind speed
- **[0064]** Distance of open water that the wind has blown over (called the fetch)
- **[0065]** Width of area affected by fetch
- **[0066]** Time duration the wind has blown over a given area
- **[0067]** Water depth

[0068] All of these factors work together to determine the size of wind-generated water waves. The greater each of the variables, the larger the waves. Waves are characterized by:

- **[0069]** Wave height (from trough to crest)
- **[0070]** Wavelength (from crest to crest)
- **[0071]** Wave period (time interval between arrival of consecutive crests at a stationary point)
- **[0072]** Wave propagation direction

[0073] Waves in a given area typically have a range of heights. For weather reporting and for scientific analysis of wind wave statistics, their characteristic height over a period of time is usually expressed as significant wave height. This figure represents an average height of the highest one-third of the waves in a given time period (usually chosen somewhere in the range from 20 minutes to twelve hours), or in a specific wave or storm system. Given the variability of wave height, the largest individual waves are likely to be about twice the reported significant wave height for a particular day or storm.

[0074] FIG. **1** shows a wave **110** heading towards a shore **120**. The wave has a wave height and groups of waves have an associated wavelength. Energy stored in the moving wave is delivered to shore (often as sound and froth) and then the remaining return wave heads out to sea, thus creating a trough. Energy associated with a wave is most closely associated with wave height, wave speed and the wave period.

First Embodiment

[0075] Attention is turned to FIG. **2**A, which shows a schematic view of an embodiment of the instant invention. A wave energy transducer **200** includes a first flotation element **230**, a second flotation element **240**, an upper wheel assembly **250**, a lower wheel assembly **260**, and an anchor **275**. At a resting state between or in the absence of waves, both flotation elements sit on the face of a body of water **205** where the transducer **200** is present. The wave energy transducer **200** works on a unique concept in which a passing wave (not shown) will necessarily raise the first flotation element **230**, as floating materials generally rise with each passing wave. The second flotation element **240** is significantly smaller than the first flotation element **230** and is also attached via a chain or cable **290** to said anchor **275**. Thus, when a wave passes the wave energy transducer **200**, the first flotation element **230** is raised with the height of the wave, while the smaller second flotation element **240** is transiently sunken into the water. The second flotation element **240** is necessarily sunken into the water due the presence of a cable **290** attached anchor **275** which may rest on a seabed **207**. Thus during a wave event, the first flotation element **230** goes up, while concomitantly the second flotation element **240** goes down. The associated chain or cable **290** associated with the second flotation element **240** turns the upper wheel assembly **250** and the lower wheel assembly **260**. It is thus through the wave action that wave energy is efficiently converted to rotational energy, primarily associated with the action of the at least two wheel assemblies **250** & **260**.

[0076] In FIG. **2**A, the upper wheel assembly **250** is attached to gear wheels **285** that may be further attached to generator **280**. It is noted that either wheel assembly may stand as an independent element, may be associated with an electricity production apparatus or may be associated directly or otherwise with elements that make benefit from rotation of a wheel assembly such as but not limited to a propeller screw or other rotational element.

[0077] It is appreciated that additional elements not shown in FIG. **2**A may be associated with the wave energy transducer **200**. For example, GPS transponder, computer, lighting, armament, power cables, buoy markings, and other elements may optionally be associated with a transducer.

[0078] It is stressed that in the present invention, there is no requirement for enormous counterweights which are often used in prior art systems. Rather, the differential size of the at least two flotation elements in association with an anchor or attachment to the ocean floor guarantees that only one flotation element rises with the impending wave, while the other, smaller, flotation element necessarily sinks. The first flotation element **230** is generally at least twice the size of the second flotation element **240**, though this ratio can be higher or lower, according to needs of the transducer **200**. After the wave has passed, the rotation elements return to their prior positions, namely the first flotation element **230** "comes down" on the back side of the wave crest to the original sea level, while the second flotation element **240** comes back up from the depths to again return to sea level. This return to position also drives the cable **290** through the upper wheel assembly **250** and lower wheel assembly **260**, thus guaranteeing additional rotational energy transduction with each passing wave. It is noted that the lower wheel assembly **260** is always beneath sea level, whereas the upper wheel assembly **250** can be either above sea level, at sea level or at times beneath sea level.

[0079] Attention is now turned to FIGS. **2**B-**2**D which show the "lifecycle" of a wave energy transducer **200** in its interaction with a wave. FIG. **2**B shows a wave energy transducer **200** at rest in water **205**, namely the first flotation element **230** and the second flotation element **240** are at rest, floating in the water. An anchoring element **275** is solidly attached to the ocean floor **207**. Cable **290** is attached to said anchoring element **275**, passes over upper wheel assembly **250** and under lower wheel assembly **260** before terminating at the smaller second flotation element **240**. The cable **290** is of a length to allow the two flotation elements to rest in flat water, with the cable being taught in its disposition.

[0080] Attention is turned to FIG. **2**C, which shows the wave energy transducer **200** during its interaction with a wave **210**, wherein the transducer **200** sits in this view on the wave **210** crest. As expected, the first flotation element **230** rises with the impending wave **210**. Under other conditions, the second flotation element **240** would also rise with the wave **210**; in the present invention, the intentionally smaller second flotation element **240** necessarily sinks in the wave due to the cable **290** connecting the second flotation element **240** to the anchoring element **275**. Thus, as shown in the figure, a separation space **295** is created between the first flotation element **230** and the second flotation element **240**. During the time when this separation space **295** is created, cable **290** rotates the upper wheel assembly **250** or a portion thereof and the lower wheel assembly **260** or a portion thereof. Thus, by separating flotation elements according to size and the connection of one flotation element **240** to a fixed anchoring element **275**, wave energy is converted to rotational energy in the wheel assemblies. One can use the rotational energy either directly or indirectly to generate electricity or rotational mechanical energy.

[0081] Attention is turned to FIG. **2**D, which shows the wave transducer **200** after the wave **210** has passed and the wave energy transducer **200** is sitting in a trough **215** between waves **210**. The larger first flotation element **230** has gone down and sits on the trough **215**. The smaller second flotation element (not visible in figure) has risen from the depths of the sea (or other water source) and is again floating, this time in the trough **215**. The movement of the flotation elements towards the trough **215** again turns the upper wheel assembly **250** and lower wheel assembly **260** via the cable **290**, this time the rotation being in a direction opposite that when the transducer **200** passed over the wave (see FIG. **2**C). The invention thus creates rotational energy both in reaching the crest of a wave **210** and in coming back down into the trough (FIG. **2**D, **215**) after a wave **210**. As discussed in a further embodiment, the rotation of the wheel assemblies in opposite directions during a full wave cycle can be converted to rotation in a single direction and alternatively at a higher rate of rotation through appropriate gears and other elements.

[0082] It is noted that the length of the cable may be important for efficient energy conversion by the wave energy transducer. The cable **290** is generally attached to the seabed or other water bed. It is strung through the wheel assemblies and finally attached to the smaller second flotation element. If the cable **290** is too short, the second flotation element will be partially submerged and will have limited travel distance when a wave passes. If the cable **290** is too long, wave passage will not lead to sinking of the smaller flotation element. Thus, cable **290** should be of a length to allow both flotation elements to sit on a calm water surface but should generally not be significantly shorter or longer, unless there is a reason for such a modification. The cable **290** will be adapted to be easily modified for length based on changing water conditions such as tides.

[0083] At the end of the process, the energy transducer **200** returns to its starting condition as shown in FIG. **2**B.

Second Embodiment

[0084] Attention is turned to FIG. **3** which shows a schematic view of an alternative embodiment of the present invention. A wave energy transducer **300** is shown in its resting position when the sea **305** is "flat" and not encountering waves. Conical first flotation element **330** is outside of and significantly larger than conical second flotation element **340**. The first flotation element **330** (or alternatively a collection of flotation elements that collectively serve as a first flotation element **330**) is generally twice as large as the second flotation element **340**, though the specific size ratio may vary according to application and specific embodiment. Anchor

370 rests on sea floor **307** and is attached to cable **390** which is further threaded through upper wheel assembly **350** and lower wheel assembly **360** before being finally attached to said second flotation element **340**. As shown in FIG. **3**, in its resting state, the wave energy transducer **300** has first flotation element **330** and second flotation element **340** both floating on the sea **305**. When a wave passes by (not shown), the flotation elements move in opposite directions: the larger first flotation element **330** rises with the wave, while the smaller, anchored second flotation element **340** is driven into the body of the sea. Cable **390** rotates upper wheel assembly **350** and lower wheel assembly **360**, thus converting energy associated with a propagated water wave into rotational energy. The rotating wheel assemblies can be associated with elements that convert the rotational energy into motion, electricity, or any other desired energetic outcome. In FIG. **3**, a battery **385** for the wave energy transducer **300** is associated with the lower wheel assembly **360** and powers the device which can serve as a buoy or beacon for shipping.

[0085] One will note that the wave energy transducer **300** includes a shaft **365** which houses the lower wheel assembly **360**, portions of the cable **390** that run through the lower wheel assembly **360** and the battery **385**. The shaft may be open or partially sealed, may float or may either rest or be anchored to the sea floor **307**.

Third Embodiment

[0086] Attention is turned to FIG. **4**A which shows an alternative embodiment of the present invention. A wave energy transducer **400** includes a shaft **465** that is open to water around it both at its top and its bottom. A second flotation element **440** is located inside the shaft **465** and may move down and up inside the shaft **465** as a function of wave interaction with the transducer **400**. The first flotation element **430** is actually realized as two unique flotation elements **430** placed on either side of the partially submerged shaft **465**. An anchor **470** is located at the end of cable **490** running from the second flotation element **440** and passing through the upper wheel assembly **450** and lower wheel assembly **460**. Cable **490** could alternatively be attached to a large weight or the seabed itself (neither shown in figure). The cable **490** is adapted to pass around both wheel assemblies and to thus rotate the wheel assemblies as second flotation element **440** initially is sunk by wave presence and then elevated after a wave has passed. A battery **485** associated with lower wheel assembly **460** receives energy generated through the wave-specific rotation of lower wheel assembly **460**.

[0087] Cable **490** may be realized as a chain that allows for spokes from the wheel assemblies to pass through it (FIG. **4**B). The chain **491** includes spacing **492** for receiving spokes **493** from a sprocket **494** associated with a wheel assembly. Chain **491** dressed around sprocket **494** of wheel assembly is adapted to rotate sprocket **494** and thus wheel assembly (not shown) and any associated rotational elements including but not limited to a rotating element of an electrical generator.

Fourth Embodiment

[0088] Attention is now turned to FIG. **5** which shows a schematic view of an additional embodiment of the present invention. A wave energy transducer **500** includes a plurality of wheel assemblies **555** which are adapted to be rotated by a cable **590** whose penultimate ends are an anchor **570** and a second flotation element **540** which is half the size or less than a first flotation element **530**. Multiple wheel assemblies **555** aid in more efficient cable motion and potentially higher efficiencies of energy conversion between wave motion and rotational energy realized in the wave energy transducer **500**.

Fifth Embodiment

[0089] Attention is now turned to FIG. **6**A which shows a gear system **682** that may be associated with an embodiment of the present invention. Gear **685** is rotated by chain or cable (not shown for purposes of clarity) as described in previous embodiments. The gear **685** is associated with a two-way to one-way rotation converter **686**, as the gear rotates in both clockwise and counterclockwise directions during a single wave pulse. The converter **686** converts all gear **685** rotation into a single direction of rotation for conversion of wave to rotational energy. The converter **686** is connected to a step-up gear **687** that typically has a ratio of 50:1 or 100:1 to increase the percentage of wave energy that is realized as usable rotational energy. Finally, the step-up gear **687** is connected to a motor/generator **680** that can generate electricity through the appropriate rotation of magnet, rotor or the like to allow for production of electricity from rotational energy. The gear system **682** thus takes wave energy via a wheel assembly-associated gear **685** and allows for conversion of said energy into electricity which can be used on-site or transferred elsewhere. Rotation of gear **685** is specifically dependent on wave action as described in the first embodiment of the instant invention.

[0090] FIG. **6**B shows greater detail of the gear **685** function in transduction of wave energy to rotational energy. With movement of flotation elements (not shown), chain **690** rotates gear **685** associated with wheel assembly **655**; gear **685** in turn rotates a plurality of gears **687** associated with a backstop freewheel system. As depicted in FIG. **6**B, the upper gears **693** rotate shaft **691** only when chain **690** rotates gear **685** in a clockwise direction; lower gears **692** do not function at all. When chain **690** rotates gear **685** in a counterclockwise direction, lower gears **692** rotate shaft **691** in the same direction **696** as before, while upper gears **692** do not function. The plurality of gears **687** aids in efficiently converting the wave-specific rotation of wheel assembly **655** gear **685** into single-direction rotational energy as shown in FIG. **6**A.

Sixth Embodiment

[0091] Attention is turned to FIG. **7** which shows an embodiment of the invention used for production of electricity. A wave energy transducer **700** is shown with separation of first flotation element **730** and second flotation element **740** that occurs when the transducer **700** is lifted by a wave (not shown). Cable **790** attached to an anchoring element rotates a lower wheel assembly **760** which is associated with an electrical generator **780**. Electricity generated by the electrical generator **780** is sent by a transmission cable to an electrical grid (not shown). Optional stabilizers **295** are also shown.

Seventh Embodiment

[0092] Attention is turned to FIG. **8** which shows an embodiment of the present invention. A plurality of wave energy transducers **800** are placed in the sea **805**, wherein said transducers **800** are anchored to the seabed **807**. Waves passing through the field **802** of transducers **800** will cause the action of each transducer **800** to convert wave energy into rotational energy and optionally into electricity which can be taken from the field **802** with an appropriate set of transmission wires (not shown). Note that different transducers **800** can be in wave crest **810** or trough **815** at the same time.

Eighth Embodiment

[0093] Attention is turned to FIG. **9** which shows a schematic view of an embodiment of the present invention. The wave energy transducer **900** includes a weight **977** in place of anchor, said weight either resting on seabed **907** or being suspended in the sea, as a function of the cable **990** length. In such an embodiment, the transducer **900** may be held in place by a separate line **995** or other means. It is assumed that the transducer will remain generally in a single location during the time of its use.

Ninth Embodiment

[0094] FIG. **10** shows a method of the present invention. The method includes providing a buoy having a first flotation element including an upper wheel assembly and a lower wheel assembly, the lower wheel assembly being below water level, a second flotation element, smaller than and motion independent of the first flotation element and, a cable, wherein the cable is attached at a first end to the second flotation element and is attached at a second end to a water bed, and wherein the cable is adapted to pass above and rotate said upper wheel assembly and pass beneath and rotate the lower wheel assembly; placing the buoy into a body of water so that the first flotation element and the second flotation element are on the surface of the body of water; anchoring the buoy through the cable to the bed of said body of water; allowing action of waves to raise the first flotation element and concomitantly sink the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly; and, allowing action of the waves to lower the first flotation element and concomitantly raise the second flotation element, wherein the motion of the second flotation element allows for the rotation of the upper wheel assembly and the lower wheel assembly.

[0095] It is expected that during the life of a patent maturing from this application, additional wave-based energy systems will be developed, and the scope of the term of the invention is intended to include all such new technologies a priori.

[0096] As used herein the term "about" refers to ±10%.

[0097] The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

[0098] The term "consisting of means "including and limited to".

[0099] The term "consisting essentially of" means that the, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

[0100] As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

[0101] Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0102] Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges from" a first indicate number "to" a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

[0103] Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. The present invention could be employed for a wide variety of embodiments with differentially sized flotation elements as herewith described.

[0104] It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

[0105] All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

What is claimed:

1. A device for converting wave energy into rotational energy, including the following:

a first flotation element including an upper wheel assembly and a lower wheel assembly, said lower wheel assembly being below water level during action of said device;

a second flotation element, smaller than and independent in individual motion of said first flotation element;

a chain, wherein said chain is attached at a first end to said second flotation element and is adapted to rotate said lower wheel assembly and transfer change in potential energy of said first floatation element to mechanical rotational energy, and said chain further passing the upper wheel assembly; and, an anchor, wherein said anchor is attached to a second end of said chain and remains effectively unmoved during the action of said device.

2. The device according to claim **1**, wherein said rotational energy is employed in the generation of electricity.

3. The device according to claim **2**, wherein said device is a plurality of devices.

4. The device according to claim **1**, further including a motor, said motor being associated with a wheel assembly.

5. The device according to claim **1**, wherein said anchor sits on a water bed.

6. The device according to claim **1**, wherein said device is realized as a buoy.

7. A device for converting wave energy into rotational energy, including the following:

a first flotation element including an upper wheel assembly and a lower wheel assembly, said lower wheel assembly being below water level during action of said device;

a second flotation element, smaller than and independent in individual motion of said first flotation element;

a chain, wherein said chain is attached at a first end to said second flotation element and is adapted to rotate said upper wheel assembly and transfer change in potential energy of said first floatation element to mechanical rotational energy, and wherein said chain is attached at a second end to the sea floor.

8. The device according to claim **7**, wherein said cable is attached to a cement block on said sea floor.

9. The device according to claim **7**, wherein said device is used in the production of electricity.

10. The device according to claim **7**, wherein said rotational energy is employed in the compression of liquid or gas.

11. The device according to claim **7**, wherein said device could be part of a raft or ship.

12. The device according to claim **4**, further including an electrical system for local off-grid uses.

13. The device according to claim **4**, further including a light and adapted for use as lighthouse or marking buoy.

14. The device according to claim **1** wherein said device includes a gear system to convert turns of said wheels to larger turns of a component associated with a motor.

15. The device according to claim **4**, wherein there is a load on a shaft associated with said motor.

16. The device according to claim **4**, wherein there is no load on said motor.

17. A method for converting wave energy to rotational motion, including the following:

providing a buoy having a first flotation element including an upper wheel assembly and a lower wheel assembly, said lower wheel assembly being below water level, a second flotation element, smaller than and motion independent of said first flotation element and, a cable, wherein said cable is attached at a first end to said second flotation element and is attached at a second end to a water bed, and wherein said cable is adapted to pass above and rotate said upper wheel assembly and pass beneath and rotate said lower wheel assembly;

placing said buoy into a body of water so that said first flotation element and said second flotation element are on the surface of said body of water;

anchoring said buoy through said cable to said bed of said body of water;

allowing action of waves to raise said first flotation element and concomitantly sink said second flotation element, wherein the motion of said second flotation element allows for the rotation of said upper wheel assembly and said lower wheel assembly; and,

allowing action of said waves to lower said first flotation element and concomitantly raise said second flotation element, wherein the motion of said second flotation element allows for the rotation of said upper wheel assembly and said lower wheel assembly.

18. The method according to claim **17**, furthering including the step of generating electricity from said rotation of said upper wheel assembly and said lower wheel assembly.

19. The method according to claim **17**, wherein said cable may be comprised of a cable and a chain in a row.

20. The method according to claim **17**, wherein there is further included a system adapted to convert rotation in two directions to rotation in a single predetermined direction rotation.

* * * * *

US 20100032950A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2010/0032950 A1**

(43) **Pub. Date: Feb. 11, 2010**

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(54) **DEVICE FOR WAVE-POWERED GENERATOR**

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(21) Appl. No.: **12/528,948**

(22) PCT Filed: **Mar. 3, 2008**

(86) PCT No.: **PCT/NO08/00076**

§ 371 (c)(1),
(2), (4) Date: **Aug. 27, 2009**

(30) **Foreign Application Priority Data**

Mar. 16, 2007 (NO) 20071410

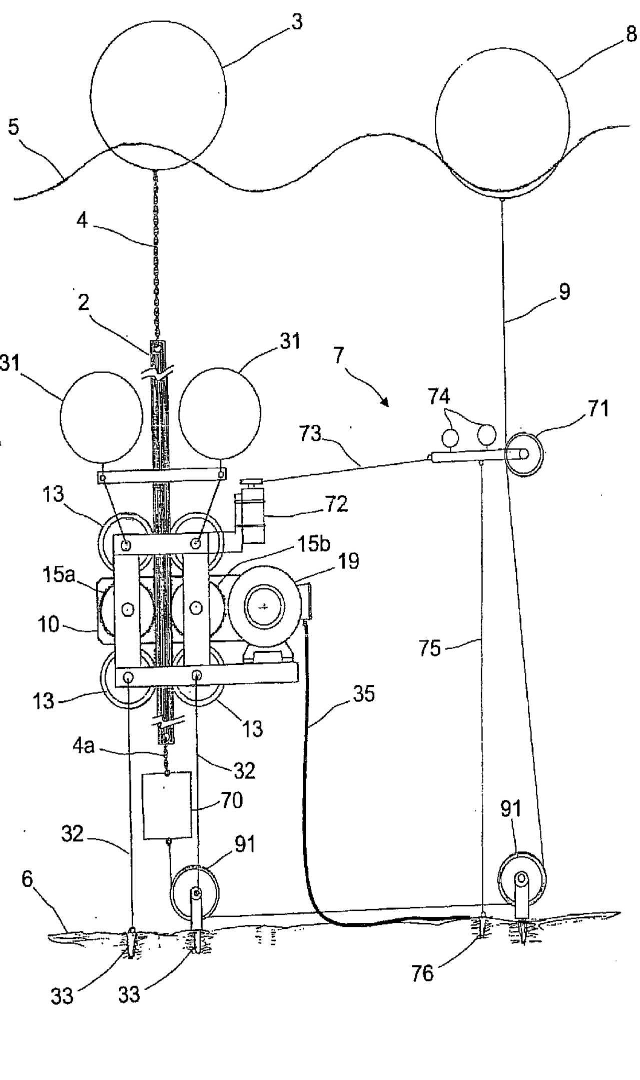
Publication Classification

(51) **Int. Cl.**
F03B 13/18 (2006.01)
F04B 17/00 (2006.01)

(52) **U.S. Cl.** **290/53**; 417/330

(57) **ABSTRACT**

A device for a wave-powered generator which is provided with at least one energy generator and lines for transferring energy to a consumer, the wave-powered generator comprising a main module provided with a running rod which is substantially vertical in its longitudinal extent, several supporting devices arranged around a portion of the running rod and arranged for sliding or rolling movement on surface portions extending in the longitudinal direction of the running rod, at least one sheave which is arranged to roll on the running rod, and transmission means which are arranged to translate the rotating motion of the at least one sheave into rotation of the drive shaft of the at least one generator; and a first float which is floatingly disposed in an area affected by waves and which is connected to the running rod by a primary driving line substantially of tensile strength.



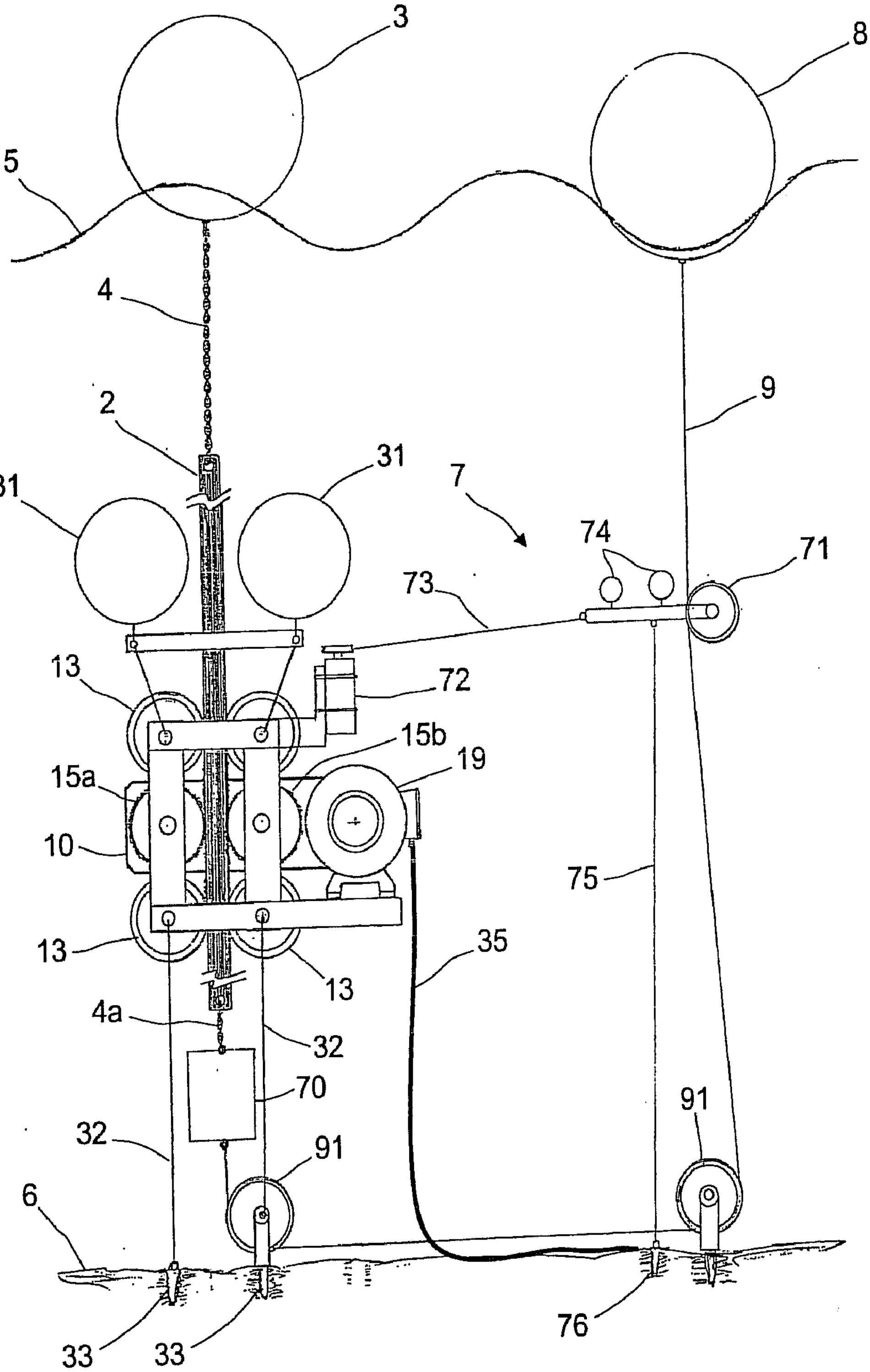

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Fig. 1

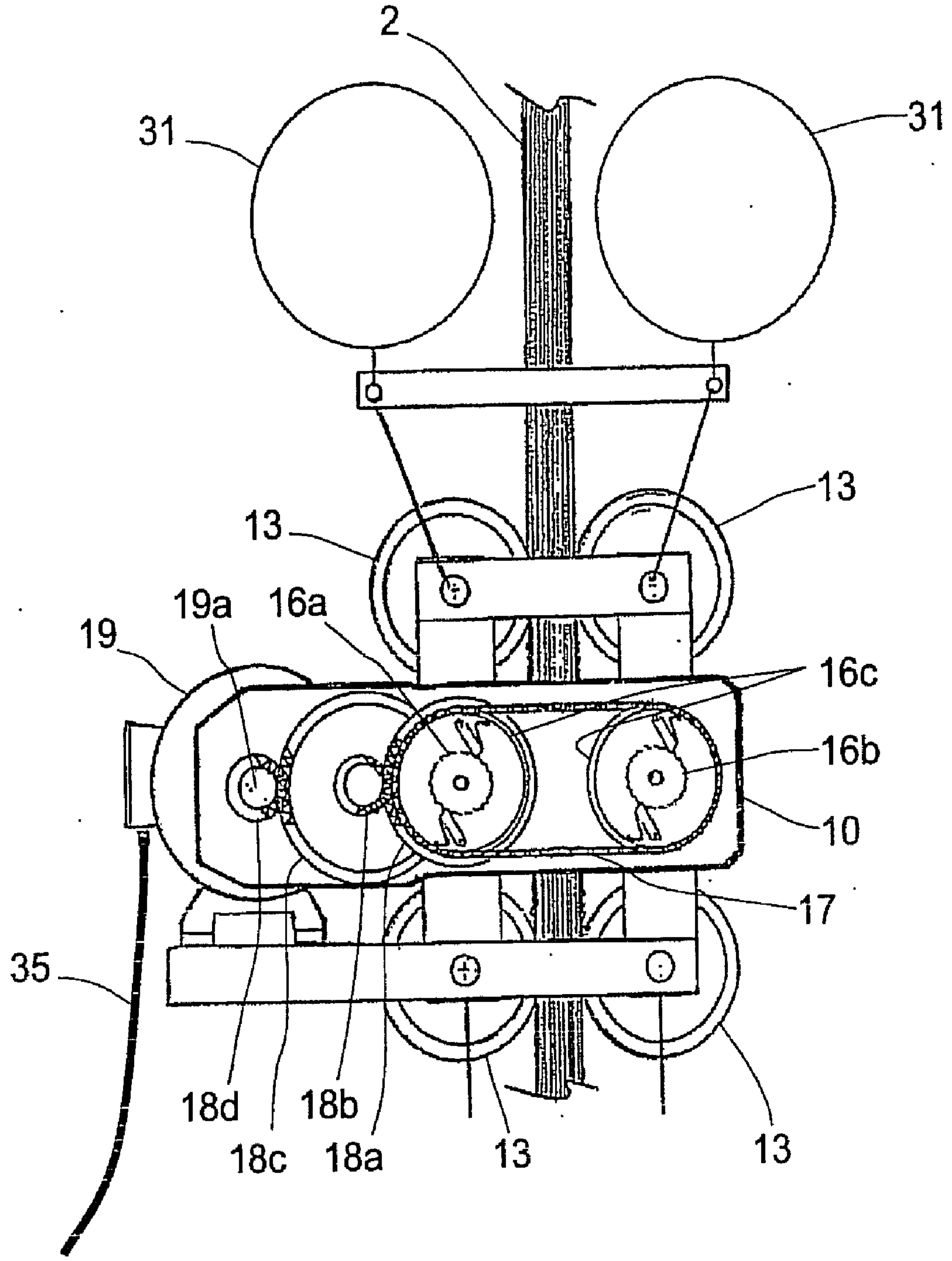

Fig. 2

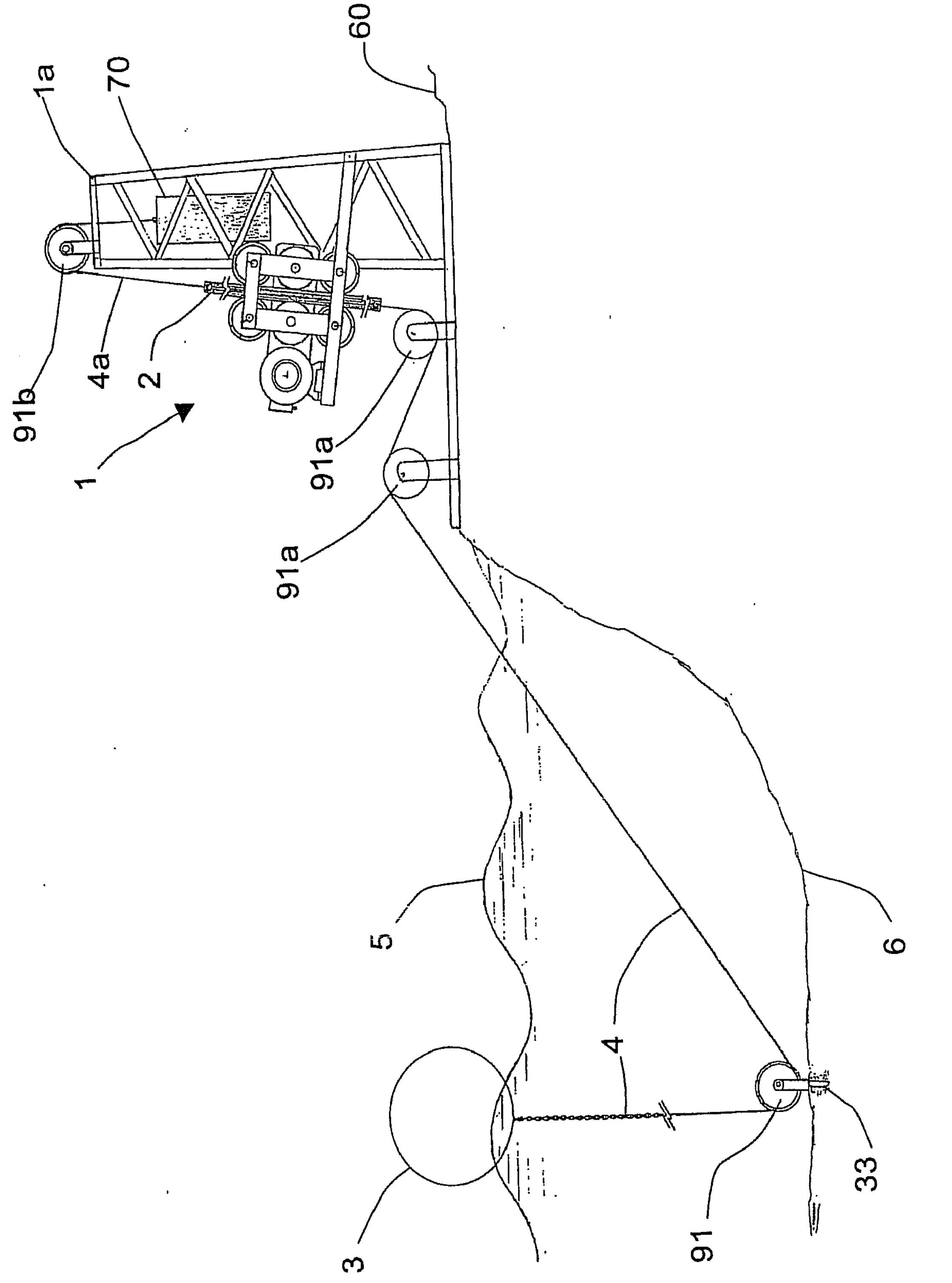

Fig. 3

DEVICE FOR WAVE-POWERED GENERATOR

RELATED APPLICATIONS

[0001] The present invention claims priority under 35 U.S.C. §119 to Norwegian Patent Application No. NO 20071410, filed on Mar. 16, 2007, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The invention relates to a driving device for converting a linear movement induced by wave motion on a water surface into a unidirectional, rotational motion, more specifically a stationary main module comprising means for sliding or rolling movement of a running rod engaged in a drive which drives an energy generator through the wave-induced vertical movement of the running rod, the running rod extending substantially in a vertical direction. Transmission means provide a unidirectional direction of rotation in the energy generator when the moving direction of the running rod changes.

[0003] In the following description the terms "wave-powered generator" and "generator" are used in part for devices which are arranged to produce electrical current. It is within the scope of the invention that the "wave-powered generator" and the "generator" may just as well produce energy of some other form, for example by a pump supplying liquid under pressure. Therefore, the terms "wave-powered generator" and "generator" should be understood to be broader than the narrow sense, that is to say related to electrical energy, that these expressions have in everyday language.

[0004] There are known many different systems for exploiting wave and tidal force for the production of energy, for example electrical current. The problems within this field have been that the technical equipment has not been able to withstand the heavy loads inflicted on a wave-powered generator by the waves, and the efficiency has been too poor. To prevent a breakdown, it has been attempted to move the wave-powered generator to areas with "calmer" sea and weather conditions. Naturally, this has led to poorer wave power exploitation and efficiency.

[0005] The invention has for its object to remedy or reduce at least one of the drawbacks of the prior art.

[0006] The object is achieved through features specified in the description below and in the claims that follow.

SUMMARY

[0007] For maximum utilization of a wave- and tide-powered generator it is necessary to place the equipment in areas that are exposed to storms and powerful waves. It is an object of the invention to provide a wave-powered generator, in which only one of the main elements of the wave-powered generator, a float, is located in the area in which the wave power is effective, whereas the rest of the wave-powered generator, a main module, is placed submerged below the sea surface and at a depth at which the wave substantially do not propagate, possibly on land, the float and the main module being connected, with tensile strength, by stays and/or wires, chains or similar, for transmitting wave motion from the float to the main module.

[0008] The invention relates, in particular, to a device for a wave-powered generator which is provided with at least one energy generator, in what follows also referred to as a generator, and lines for transferring energy to a consumer, for example electrical current or liquid under pressure, the wave-powered generator comprising a main module preferably anchored sub-merged in water, and a running rod disposed substantially vertically, provided with longitudinal, continuous side surfaces, being connected to the main module, the running rod being supported in a rolling or sliding manner by several means arranged on the main module, and at least one sheave being arranged to roll on one of the side surfaces of the running rod as the running rod moves in its longitudinal direction. Furthermore, the device includes transmission means which are arranged to translate the rotating motion of the at least one sheave into rotation of the at least one generator; and a float which is floatingly disposed in an area affected by waves and is connected to the running rod by a driving line substantially of tensile strength. Alternatively, the main module is placed on land.

[0009] In a first aspect the invention relates in particular to a device for a wave-powered generator which is provided with at least one energy generator and lines for transferring energy to a consumer, characterized by the wave-powered generator comprising:

- **[0010]** a main module provided with
  - **[0011]** a running rod which is substantially vertical in its longitudinal extent,
  - **[0012]** several supporting devices arranged around a portion of the running rod and arranged for sliding or rolling movement on surface portions extending in the longitudinal direction of the running rod,
  - **[0013]** at least one sheave which is arranged to roll on the running rod, and
  - **[0014]** transmission means which are arranged to translate the rotating motion of the at least one sheave into rotation of the drive shaft of the at least one generator; and
- **[0015]** a first float which is floatingly disposed in an area affected by waves and which is connected to the running rod by a primary driving line substantially of tensile strength.

[0016] The transmission means are advantageously arranged to translate the rotating motion of the at least one sheave into rotation of the drive shaft of the at least one generator in a predetermined direction.

[0017] The transmission means comprise transmission elements which are arranged to maintain the predetermined direction of rotation of the at least one generator Independently of the direction of rotation of the at least one sheave.

[0018] The transmission means comprise at least two freewheels.

[0019] The opposite contact surfaces of the at least one sheave and running rod are provided with means which are arranged to prevent or reduce the risk of slippage during the rotation of the at least one sheave on the running rod.

[0020] The opposite contact surfaces of the at least one sheave and running rod are preferably cogged.

[0021] Advantageously, the main module is disposed submerged in water and is floatingly disposed above the seabed as it is provided with buoyancy elements and also anchoring means secured to the sea floor.

[0022] Alternatively, the main module is disposed on land.

[0023] Preferably, the running rod is provided with ballast.

[0024] Advantageously, the generator is an electric generator or a pump.

[0025] In a second aspect the invention advantageously relates to a second float which is floatingly arranged in an area affected by waves and is connected to the primary driving line via a secondary driving line and positioned at a distance from the first float.

[0026] Preferably, the distance between the first and second floats substantially corresponds to the wave frequency and wave length, so that when the first float is on a wave crest, the second float is in a wave trough.

[0027] In a third aspect the invention advantageously relates to a device for adjusting the distance between the first and second floats, the device comprising a positioning guide for the secondary driving line, means for registering the speed and direction of motion of the first driving line, means for calculating a desired distance between the first and second floats and means which are arranged to adjust the distance between the positioning guide and the running rod.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In what follows, there is described a non-limiting example of a preferred embodiment which is visualized in accompanying drawings, in which:

[0029] FIG. **1** shows a principle drawing of a wave-powered generator with a vertical running rod according to the invention, viewed from the side;

[0030] FIG. **2** shows, on a larger scale, a principle drawing of a section of the wave-powered generator according to the invention, viewed from the opposite side relative to FIG. **1**; and

[0031] FIG. **3** shows a wave-powered generator, in which the main module is placed on land.

DETAILED DESCRIPTION

[0032] A main module **1** is anchored to a sea floor **6** by means of stays **32** and anchors **33**. The main module **1** is provided with buoyancy elements **31** in order to float in a submerged state. Further, the main module is provided with a generator **19**.

[0033] A running rod **2** is arranged vertically, extending through the main module **1**. The main module **1** is provided with several supporting devices for the running rod in the form of guiding sheaves **13** which are arranged to roll on one of the side surfaces of the running rod **2**. By means of a driving line **4**, the **5** running rod **2** is connected to a float **3** floating on a water surface **5**. The main module is further provided with two sheaves **15***a*, **15***b*.

[0034] The main module **1** comprises transmission means **10** in the form of two free-wheels **16***a*, **16***b*, each coaxially connected to a sprocket **16***c* and to the sheaves **15***a*, **15***b*, and interconnected by a drive chain **17** via the two sprockets **16***c*. One free-wheel **16***a* is also connected to a gear **18***a* which is connected via gearwheels **18***b*, **18***c*, **18***d* to the drive shaft **19***a* of the generator **19**. The sheaves **15***a*, **15***b* are arranged to engage a cogged portion (not shown) on the running rod **2**, the cogged portion extending along substantially the entire longitudinal extent of the running rod **2**. The transmission means **10** provide for the drive shaft **19***a* of the generator **19** to be rotated when the drive **10** is set into rotation by the vertical movement of the running rod **2** relative to the main module **1**.

[0035] It is obvious to a person skilled in the art that the length of the running rod **2** must be adapted for the dimensioning wave height in the area in which the wave-powered generator is to be disposed.

[0036] The free-wheels **16***a*, **16***b* are arranged to be drivingly engaged in a first direction of rotation. By the fact that the freewheels **16***a*, **16***b* are each connected to a respective one of the sheaves **15***a*, **15***b* which are arranged on respective sides of the running rod **2**, one particular direction of motion of the running rod **2** will provide one particular direction of rotation of one sheave **15***a*, whereas the other sheave **15***b* rotates in the opposite direction. By the interconnection of the free-wheels **16***a*, **16***b* by way of the drive chain **17**, the first and second free-wheels **16***a*, **16***b* will alternately provide for the drive shaft **19***a* of the generator **19** to be kept in a unidirectional direction of rotation as the running rod alternates between the upward and downward directions of motion.

[0037] To the running rod **2** ballast **70** is connected via an extension **4***a* of the driving line **4**.

[0038] The generator **19** is connected to a distribution grid (not shown) for energy via lines **35** extended along the sea floor **6** to a consumer, for example a switching and transformer station (not shown) in the event of the generator **19** being an electric generator.

[0039] In an AC power station the generator **19** comprises means (not shown) known per se, to maintain a prescribed frequency on the alternating voltage produced.

[0040] At the first driving line **4** for the first float **3** there is arranged a second driving line **9**, this being connected to the ballast **70** and being connected at an opposite end to a second float **8** floating on the water surface **5** at a distance from the first float **3**. The second driving line **9** is passed over several sheaves **91** which are anchored to the sea floor **6**.

[0041] For the second driving line **9** there is arranged a device **7** for adjusting the distance between the first and the second floats **3**, **8**. The device **7** comprises a driving line guide **71**, an actuator **72** attached to the main module **1**, means (not shown) for registering the speed of the running rod **2**, means (not shown) for calculating the wave frequency at the first float, a connection **73** of tensile strength between the driving line guide **71** and the actuator **72** and also buoyancy means **74** and anchoring means **75**, **76**.

[0042] FIG. **3** shows an exemplary embodiment, in which the main module **1** is placed on land **60**, the primary driving line **4** being extended via sheaves **91**, **91***a* to one end of the running rod **2** which is connected, at its other end, to the ballast **70** via the driving line extension **4***a*. The driving line extension **4***a* is passed over a sheave **91***b* which is arranged on a tower **1***a*, and here the ballast is hangingly disposed in the tower **1***a*. Beyond that, this exemplary embodiment is arranged as described for corresponding elements above.

[0043] By the upward movement of the first float **3** by the waves **5**, the runnning rod **2** is lifted as the sheaves **15***a*, **15***b* rotate on the side surfaces of the running rod **2**. Because of the orientation of the free-wheels **16***a*, **16***b* and the interconnection of the sprockets **16***c* via the drive chain **17**, the rotation of only one of the sheaves **15***a*, alternatively **15***b*, will be transmitted to the drive shaft **19***a* of the generator **19** via the gearwheels **18***a*, **18***b*, **18***c*, **18***d* as the free-wheel **16***a*, alternatively **16***b*, on the other one of the sheaves **15***a*, alternatively **15***b*, is running freely. As the float **3** begins to fall into a wave trough, the running rod **2** is lowered by means of gravity and the ballast **70** as a downward movement reverses the direction of rotation of the sheaves **15***a*, **15***b* rolling on the side surfaces of the running rod **2**. In this situation the other one of the sheaves **15***a*, alternatively **15***b*, takes over the operation of the generator **19**, as the free-wheel **16***a*, alternatively **16***b*, of this sheave **15***a*, alternatively **15***b*, engages, whereas the other one of the freewheels **16***a*, alternatively **16***b*, runs freely. Thereby a uniform direction of rotation is maintained in the generator **19**.

[0044] There are other possibilities for maintaining a uniform direction of rotation in the generator **19** by an alternating direction of motion of the running rod **2**. For example, sheaves may be used only on one side of the running rod **2**, this/these being provided with two free-wheels (not shown) arranged in such a way that, for example, one free-wheel is rotating r clockwise and the other one is rotating anti-clockwise, and one free-wheel is transmitting rotation via an intermediate wheel, so that the opposite direction of rotation of the sheave is turned into the right direction.

[0045] When the distance between the first and second float **3**, **8** is adjusted to the wave frequency and length in such a way that when the first float **3** is on a wave crest, and the other float **8** is, at the same time, in a wave trough, the movements of the floats **3**, **8** will cooperate to enable the production of larger amounts of energy than if the running rod **2** is to be pulled down only by means of gravity and the weight of the ballast **70**.

[0046] The distance between the floats **3**, **8** is adjusted to the wave frequency and length by the device **7** registering the movement of the running rod **2**, calculating the frequency and, by means of the actuator **72**, adjusting the driving line guide **71** in such a way that the second float **8** takes a distance to the first float **3**, such that it is in an opposite phase to the movement of the first float **3**.

[0047] By arranging the main module **1** as shown in FIG. **3**, some structural and operational problems caused by water, especially sea water, will be reduced or eliminated.

[0048] To a person skilled in the art it is obvious to combine a wave-powered generator with floats **3**, **8** in opposite phases with a main module **1** placed on land **60**.

What is claimed is:

1. A device for a wave-powered generator which is provided with at least one generator and lines for transferring energy to a consumer, wherein the wave-powered generator comprises:

a main module provided with a running rod which is substantially vertical in its longitudinal extent, several supporting devices arranged around a portion of the running rod and arranged for sliding or rolling movement on surface portions extending in the longitudinal direction of the running rod, at least one sheave which is arranged to roll on the running rod, and transmission means which are arranged to translate the rotating motion of the at least one sheave into rotation of the drive shaft of the at least one generator; and

a first float which is floatingly disposed in an area affected by waves and which is connected to the running rod by a primary driving line substantially of tensile strength, wherein the transmission means further comprises at least two free-wheels and in that, when the main module is floatingly above the sea floor, it is provided with buoyancy elements and anchoring means secured to the sea floor.

2. The device in accordance with claim **1**, wherein the generator is an electrical generator or a pump.

3. The device in accordance with claim **1**, wherein it comprises a second float which is floatingly arranged in the area affected by waves, being connected to the primary driving line via a secondary driving line and positioned at a distance from the first float.

4. The device in accordance with claim **1**, wherein it comprises a device for adjusting the distance between the first and second floats, which comprises a positioning guide for the secondary driving line, means for registering the speed and direction of motion of the first driving line, means for calculating a desired distance between the first and second floats and also devices which are arranged to adjust the distance between the positioning guide and running rod.

5. The device in accordance with claim **1**, wherein the distance between the first and second floats corresponds substantially to the wave frequency and wave length, so that when the first float is on a wave crest, the second float is in a wave trough.

* * * * *

US 20100064679A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2010/0064679 A1
Straume (43) Pub. Date: Mar. 18, 2010

(54) DEVICE FOR A WINCH-OPERATED WAVE-POWER PLANT

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(21) Appl. No.: 12/596,111

(22) PCT Filed: Jan. 29, 2008

(86) PCT No.: PCT/NO08/00028

§ 371 (c)(1),
(2), (4) Date: Nov. 25, 2009

(30) Foreign Application Priority Data

Apr. 17, 2007 (NO) 20071963

Publication Classification

(51) Int. Cl.
F03B 13/18 (2006.01)
B66D 1/50 (2006.01)

(52) U.S. Cl. 60/507; 254/274; 254/277

(57) ABSTRACT

A device for a wave-power plant includes a self-tightening winch with a winch wire. The winch wire is connected to a wave-power-operated absorption element at one end and to a cable drum of the self-tightening winch at the other end. The cable drum is connected via a transmission system to an outgoing axle which is further connected to an energy-storing restructuring machinery. Movement of the absorption element results in rotation of the cable drum and transmission of mechanical energy from the cable drum to the rotating outgoing axle and to the restructuring machinery. The transmission system includes a slip clutch connected to the outgoing axle, which protects the components in the wave-power plant, particularly the components in the restructuring machinery, against overload in the event of large wave amplitude. The engagement of the slip clutch varies depending on the rotational speed or torque of the outgoing axel, thereby providing a maximum threshold for how great an amount of energy per time unit can be transmitted to the outgoing axle and to the energy-storing restructuring machinery.

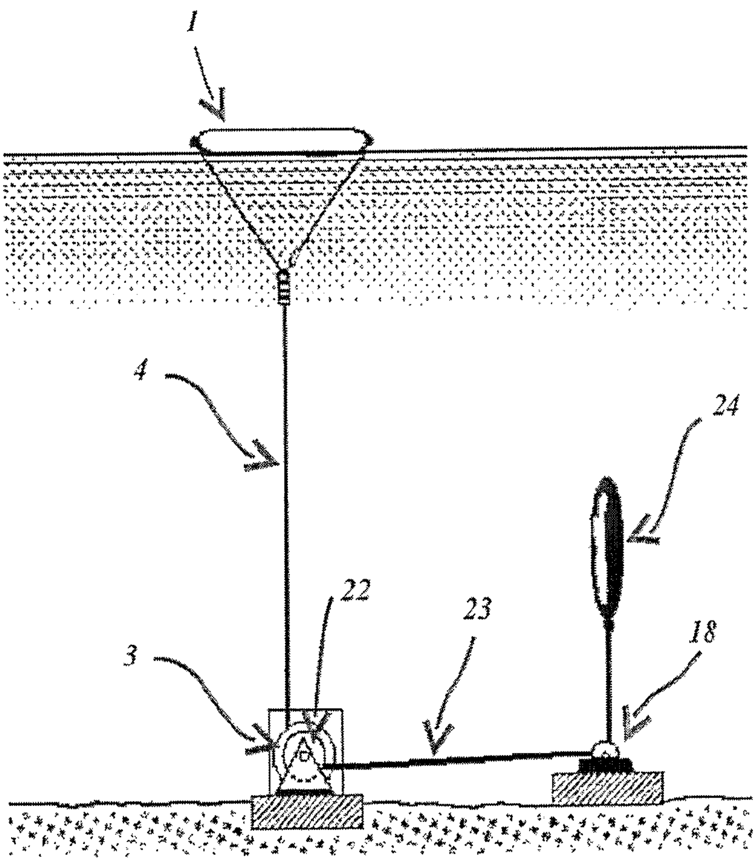


Fig. 1a

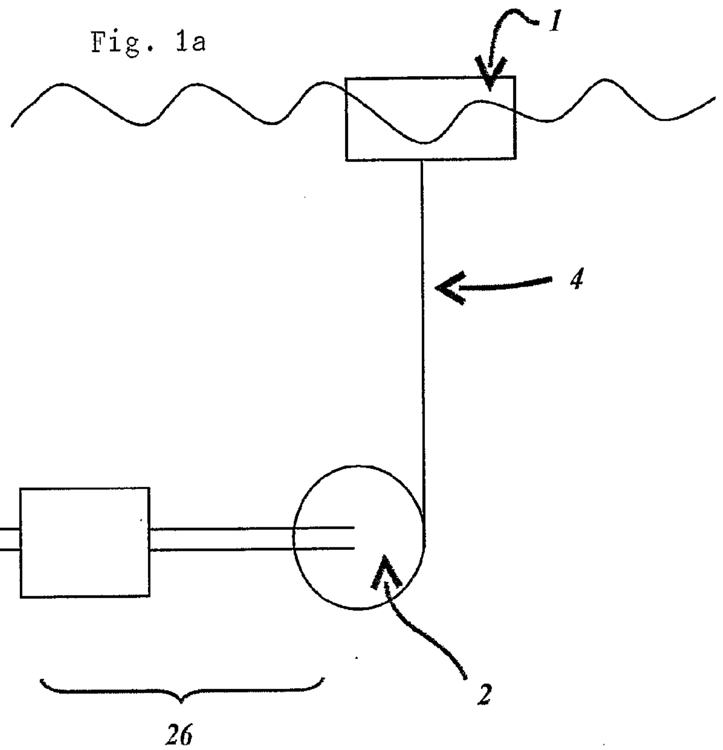


Fig. 1b

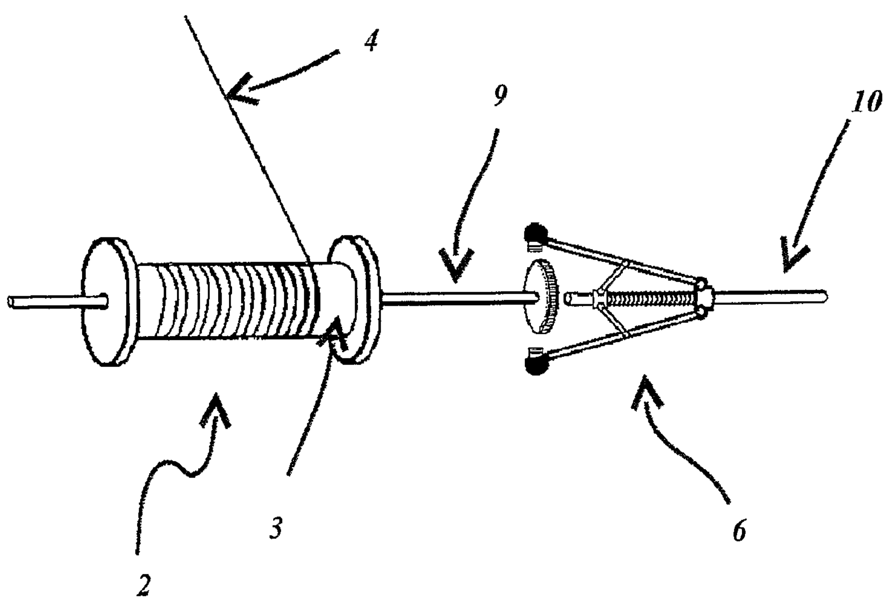


Fig. 2

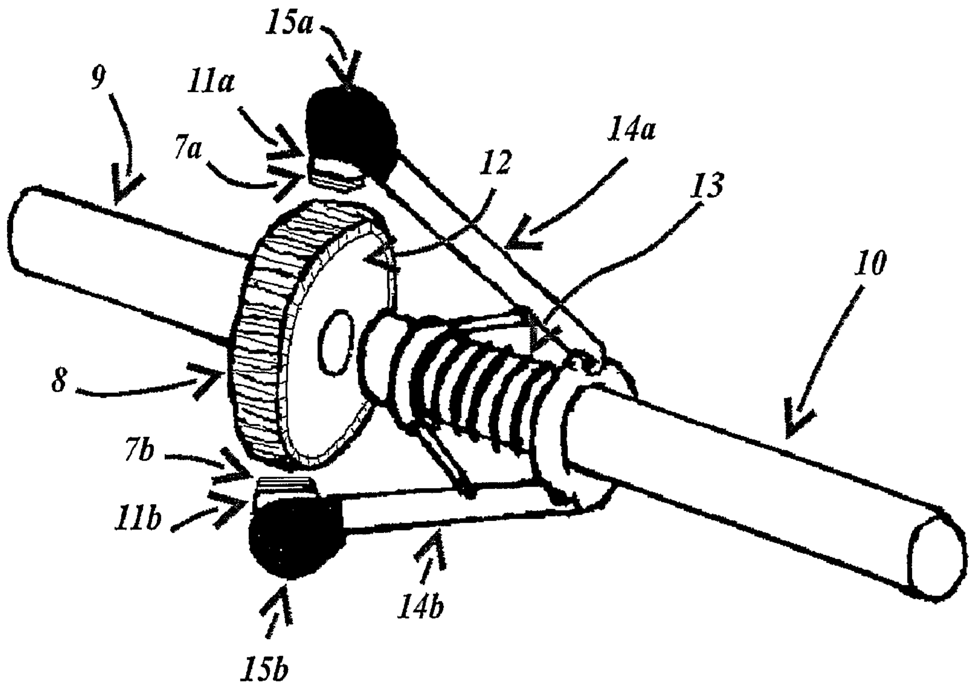


Fig. 3

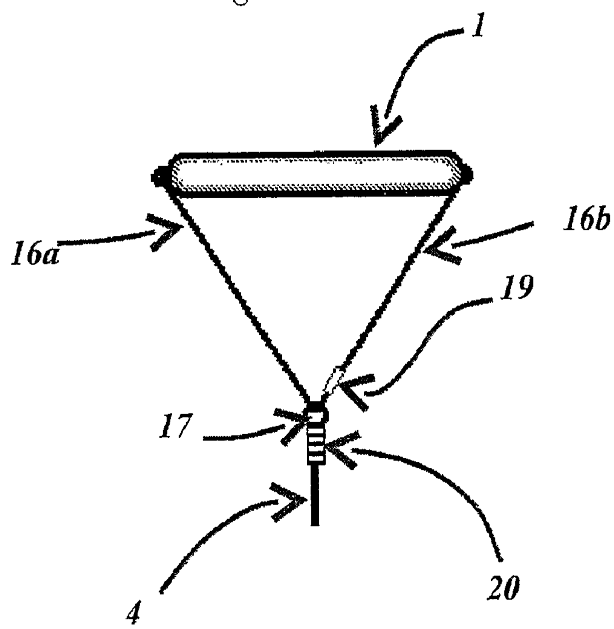


Fig. 4

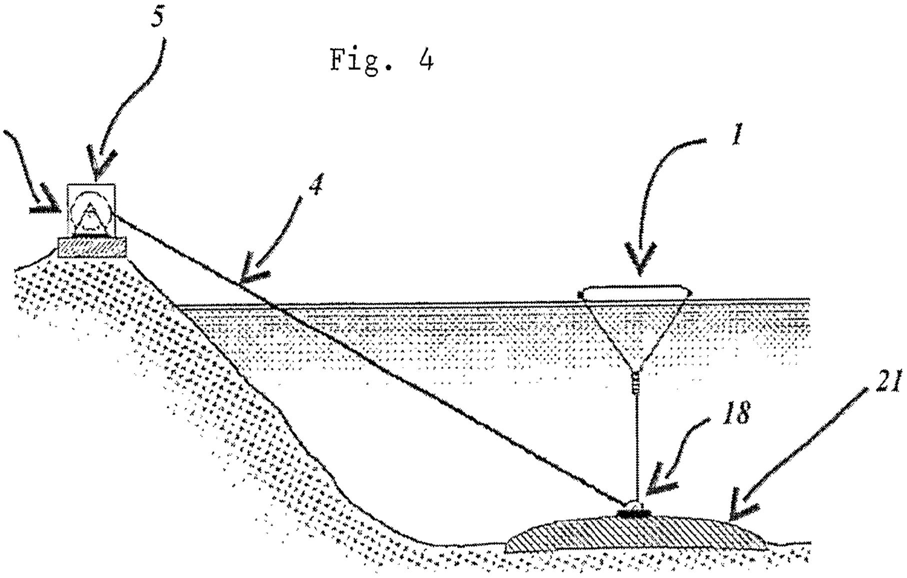


Fig. 5

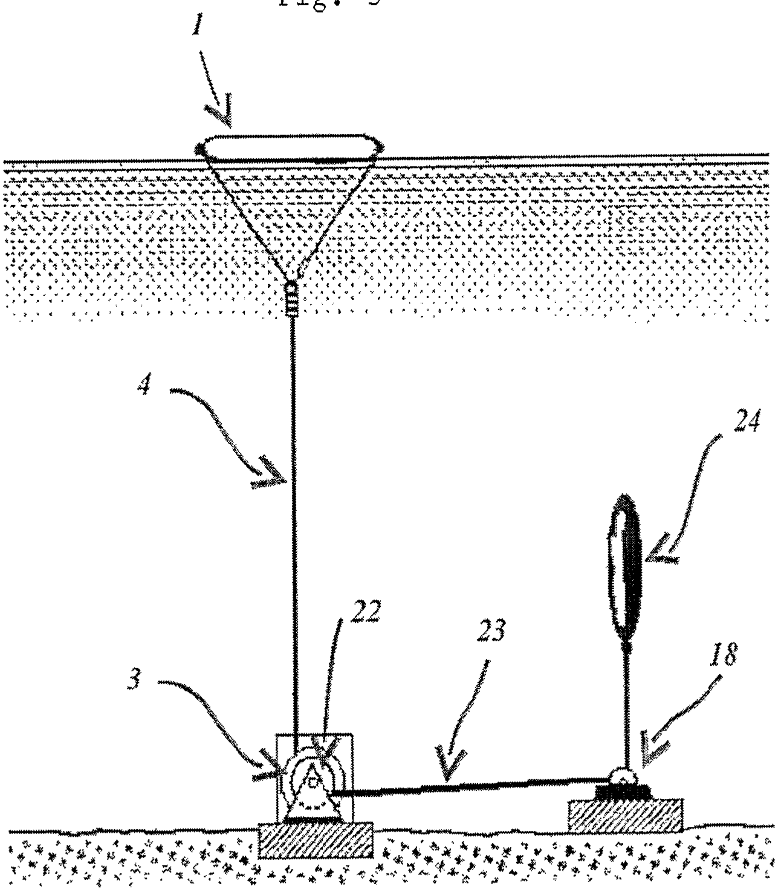


Fig. 6

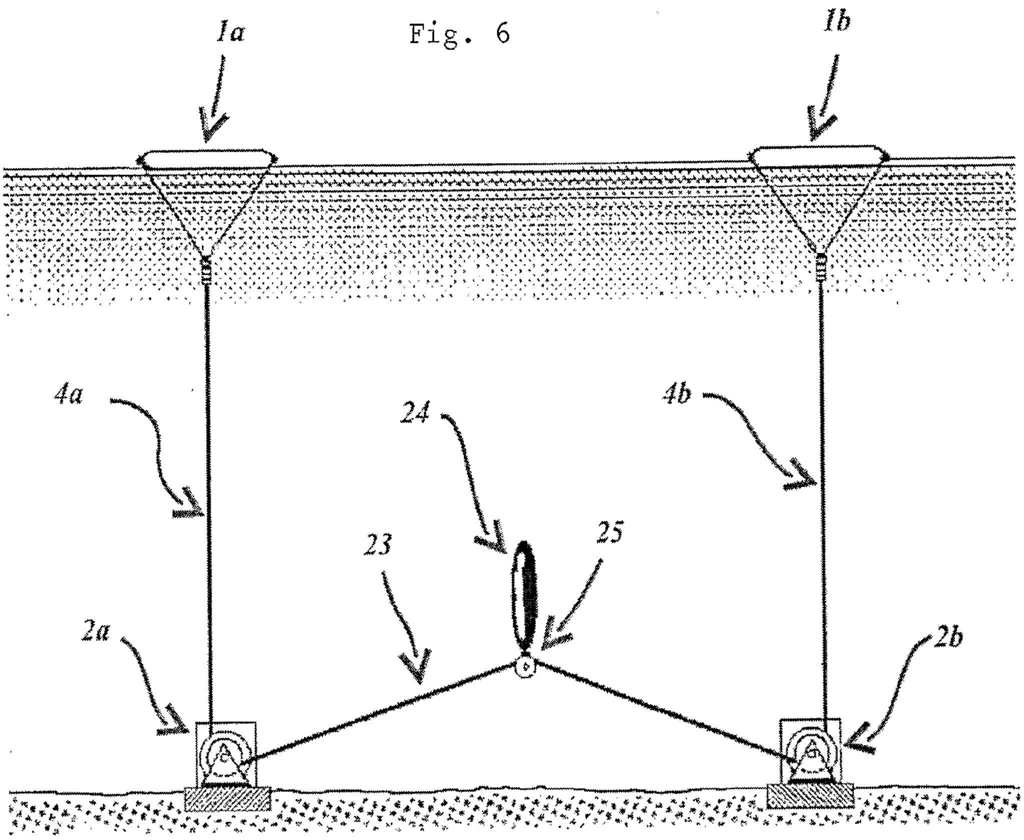
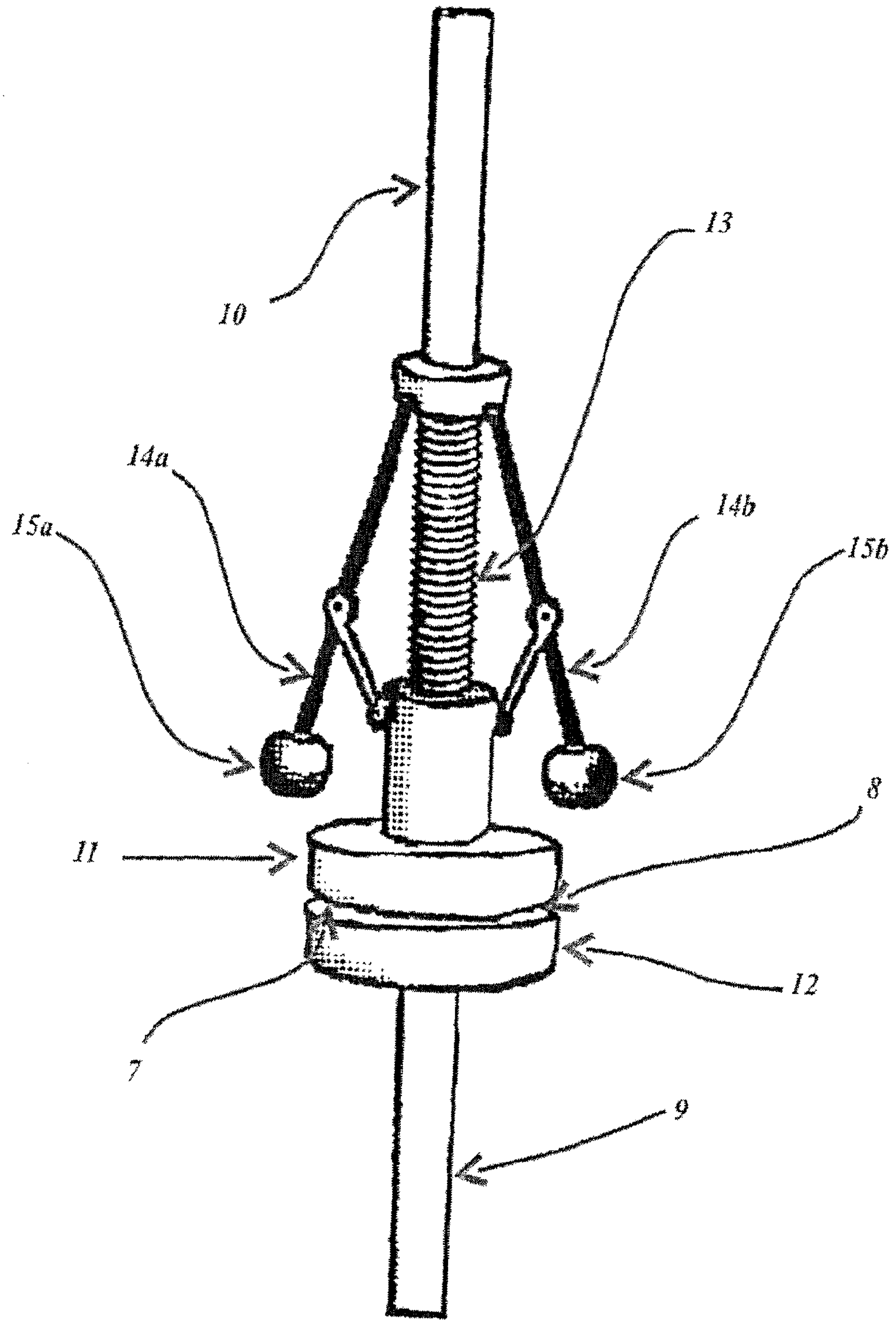


Fig. 7



DEVICE FOR A WINCH-OPERATED WAVE-POWER PLANT

[0001] In the patent literature over 1000 devices are described for exploitation of ocean-wave energy. At one time it was not realized that a successful commercial exploitation of energy from ocean waves requires the plants to have one (or more) inherent or ancillary overload protection mechanism (s). Amongst developers of newer wave-power systems, however, more and more operators have been beginning to take this essential factor into consideration: in one way or another, the plants must include a strategy for tackling the encounter with the most extreme waves. The traditional manner of tackling this problem has been to provide the plants and the components therein with an extremely robust design. This has proved to be difficult, and insofar as it has succeeded, it has produced unprofitable wave-power plants. Some of the newer wave-power technologies, including mechanisms for overload protection, are as follows: Pelamis from the Scottish company Ocean Power Delivery Ltd. (www.oceanpd.com), Danish Wave Dragon (www.wavedragon.dk) and U.S. Pat. No. 5,808,368. The common feature of the overload protection mechanisms in these is that they are based on registration of sea state prior to implementation of overload protection measures, which have to be controlled manually or by means of computer technology, and that the overload protection measure can be described as analogous to what tortoises do when they withdraw their heads into their shell. These "tortoise strategies" involve the plant's energy-producing parts being reinforced, contracted or submerged under water, with the result that they no longer (or to a lesser extent) are exposed to the wave forces. At the same time the energy production comes to a stop or is greatly reduced.

[0002] In contrast to this, the type of wave-power plant described herein has an instant-acting overload protection mechanism based on simple mechanical principles, which does not require manual or computer control, and which does not put the plant temporarily out of operation. The overload protection mechanism makes the plant type robust, thereby permitting the plants to be designed for a greater degree of direct interaction with the waves (compared with e.g. Pelamis). This provides improved efficiency.

Known Technology on which the Invention is Based.

[0003] The invention is based on three elements:

[0004] 1. Wave-power plant with floating body/bodies which absorb wave energy.

[0005] 2. Winch characterised in that the end of the winch wire is secured to the cable drum in a manner which enables the wire to be wound out and in without there being any counter-corresponding wire end which has to be correspondingly wound in and out.

[0006] 3. Overload-protection slip clutch which slips when the output which is being attempted to be channelled/directed into the system reaches the maximum level which the components in the system are designed to withstand.

[0007] Individually or only together in twos, the elements are not capable of solving the problem addressed by the invention described herein: to exploit energy from ocean waves with sufficiently low cost design of the plants without the plants and the components therein being destroyed by extreme waves. All three elements must be present in order to provide profitable exploitation of wave power. A combination of this kind will offer a substantial cost reduction for the plants, a cost reduction which is so great that it will probably involve a technical-commercial breakthrough for wave power as energy supply.

[0008] Some known technical solutions will now be listed where some of the above-mentioned elements are represented.

Winch-Operated Wave-Power Plants

[0009] There are a number of wave-power systems where accumulation (absorption) of wave energy is conducted by floating bodies and where transmission of this energy is effected by wires attached to and wound in on a winch. See, e.g. US 2005/0121915 and GR 990100030. However, these lack the overload-protection slip clutch/connection or the like which is necessary to allow the plants to survive the encounter with the most extreme waves in the worst stormy episodes without requiring to have such a robust design that they become unprofitable.

Slip Clutch

[0010] The overload-protection slip clutch is a basic component in the invention. In principle such a slip clutch can be constructed in two ways:

[0011] Slip clutch type I: where the clutch slips when a specific angular velocity with regard to the clutch's rotation is exceeded.

[0012] Slip clutch type II: where the clutch slips when a specific torque is exceeded.

[0013] Since transmitted output is equal to the product of transmitted angular velocity and torque, both of these clutch types individually will act in such a manner that they set a threshold for the maximum amount of output that can be transmitted—provided that the machinery to which the output is transmitted is of such a commonplace nature that torque and angular velocity are functions of each other, with the result that the torque is constant at constant rotational velocity.

Slip Clutch (Type I) for Setting the Threshold for Rotational Speed

[0014] Two similar variants of the slip clutch type where the slipping is determined by the angular velocity are depicted in FIG. **2** and FIG. **7**. In principle a slip clutch of this kind is a negative feedback mechanism composed of a speedometer and a clutch. It has a function which is closely related to the function of the flywheel governor in James Watt's original steam engine, where rotational speed over a specific precalibrated value resulted in the steam pressure from the boiler being discharged another way, thereby protecting the rotating parts (piston, crankshaft, flywheel, etc.) in the steam engine against overload in the form of too high speed.

[0015] There are components on the market, viz. a type of cam clutches, which amongst other things have the ability to disengage when the rotational speed is too high. At low speed a spring system ensures that the clutch is locked. Disengagement is determined by the centrifugal force on the cams which at high rotational speed overrides the spring force. Tsubakimoto Chain Co. is a supplier of such cam clutches, series type designation: BREU. See http://tsubakimoto.com and http://tsubakimoto.com/tem/pdf/CAM_BREU.pdf.

Winch with Slip Clutch (Type II) for Setting the Threshold for Torque

[0016] Connecting a winch to a transmission system containing a slip clutch which slips when the torque transmitted from the incoming axle exceeds a predetermined value is a technique used in sports fishing rods. A standard sports fishing rod reel has this particular functionality built into it: it slips if the line is jerked too hard. (In principle a sports fishing rod reel can be regarded as a winch). However, there is no known clutch which slips when the torque transmitted exceeds a specific threshold value, used or proposed for use in a winch-operated wave-power plant where the winch has the wire wound in on and secured to it.

Wave-Power Plant with Slip Clutch (Type II) for Setting the Threshold for Torque

[0017] The idea of making a wave-power plant containing a slip clutch which slips when the torque exceeds a specific threshold value is mentioned in a German patent application from 1978: DE 2850293. The wave-power plant described in the German patent application is not winch-operated, but operated by a wire running one single time over a pulley, without the wire being attached to the pulley and without one being able to say that the wire is wound into the pulley as in the case of a winch. A substantial difference is involved herein. This substantial difference is based on the fact that, in contrast to a winch-secured wire, a wire which runs loosely over a pulley is dependent on a counterweight in the opposite end of the wire in order for the wire to be kept in position over the pulley. It also involves the wire being wound into the opposite end of the wire when the end which is connected to the wave absorption body is unwound, and vice versa. The physical dimensions of the system therefore necessarily become considerably larger, in at least one dimension. Whether the wire dangles loosely with a counterweight at the end, or the wire and the counterweight are built into a cylinder housing as in DE 2850293, the system will have a long, projecting movable part which is exposed to wind and waves, thereby making the system more vulnerable. Consequently it will be more expensive to design in a way that enables it to withstand the encounter with the forces of nature. On the other hand, a wire which is secured to and wound in on a cable drum permits a much more compact design at a lower cost, where the system is better protected against wind and waves.

Other Disengagement Mechanisms used in Connection with Wave Power

[0018] A patent publication, WO 96/30646, describes a wave-power plant with two floats (**22** and **32**) which are moved by the waves, each transmitting this movement via wires/cables (**17** and **36**) to a drum (**16/28**). From each of the drums two wire ends extend, each with a counterweight, a hanging weight (**20/34**). The arrangement is such that the weights have to be raised when the float pulls out its pair of wire ends, and vice versa: the weight is lowered, pulling back with it the pair of wires when the forces which caused the float to pull out the pair of wires at the opposite end become less than the mass of the weights. With such an arrangement it is impossible to wind all the wire in on the drum, as opposed to the winch described under patent claim **1** in the present patent application. The sum of the lengths of the pieces of wire attached to the weight (**20/34**) and the pieces of wire ending in the float (**22/32**) is constant. As in the case of DE 2850293, therefore, it can be established that such an arrangement does not result in the compact solution achieved with a winch where one end of the wire is attached to the cable drum (see patent claim **1**), and which is necessary in order for a wave-power plant, without incurring unreasonably large design costs, to be capable of surviving the encounter with the at times extreme forces of the ocean waves in the event of storms and hurricanes. The arrangement in WO 96/30646 is at no point referred to as a winch. In this connection it may be described as an anchor windlass with a hanging weight at the opposite end of the wire, in the same way as DE 2850293.

[0019] WO 96/30646 mentions "slip clutches or other mechanical means" as a possible arrangement between shaft (**12**) and alternating current generator, alternator (**54**). No further description or account is given of these "slip clutches", neither of their design or arrangement. Only the purpose is mentioned. This purpose is quite different from overload protection, namely: to assist in keeping the rotational speed in the alternator (**54**) constant "regardless of the drive power produced by floats **22** and **32**", in order that the current delivered by the alternator should be of such a quality with regard to switching frequency (±1 Hz, see line 3, page 6) that it can be fed directly into the electricity grid. Thus it is not a question of trying to limit the output from the waves into the restructuring machinery to any specific maximum threshold value, as is the object and function of the overload-protection slip clutch in the present patent application. Instead the object is to attempt to prevent the waves' varying motion from causing variable rotational speed in flywheel (**52**) and alternator (**54**). It is also clear that the author of WO 96/30646 has in no way considered the theme of overload protection.

[0020] Another patent publication, U.S. Pat. No. 4,228,360, discloses a winch-operated wave-power plant with a self-tightening winch, containing a clutch (**70**) in the transmission system between cable drum (**12**) and a mechanical energy-storage system. The mechanical energy-storage system in U.S. Pat. No. 4,228,360 comprises the following components in connection order from the cable drum:

[0021] transfer gear (**18**)

[0022] energy storage element (**20**) with related part components

[0023] step-up gear system (**42**)

[0024] flywheel (**50**)

[0025] The flywheel (**50**) is further connected to a generator. The flywheel is also connected to a flywheel governor (**80**) which regulates a clutch control (**82**). The clutch control (**82**) is an agent for disengaging the clutch (**70**), controlled by the flywheel governor (**80**). The cable drum (**12**) is therefore disengaged from the energy-storage system if the speed of the flywheel (**50**) exceeds a predefined threshold speed determined by the flywheel governor (**80**).

[0026] The purpose of the disengagement system in U.S. Pat. No. 4,228,360 is not to ensure overload protection by providing a maximum threshold for how much output (energy per time unit) or how much power (mass or inertia multiplied by acceleration) the waves can impose on the wave-power plant and its components. U.S. Pat. No. 4,228,360 does not mention overload protection of float and winch system and energy-storage system. Overload protection is only considered for the flywheel (**50**), and only in the form of protection against being supplied with more energy when the energy content in the flywheel exceeds a certain limit and not in the form of overload protection against being supplied with too great an output (energy per time unit) or from being influenced by excessive forces.

[0027] The fact that the disengagement mechanism in U.S. Pat. No. 4,228,360 deals with limiting the amount of stored energy in the flywheel is directly expressed in patent claim **4** (page 10, line 41 and following):

[0028] "4. The apparatus as defined in claim **1** which further comprises: clutch means (. . .); and clutch control means connected to said clutch means and responsive to said flywheel governor means do disengage said clutch means when a selected amount of energy is stored in said energy storage flywheel."

[0029] The disengagement mechanism in U.S. Pat. No. 4,228,360 sets a limit for how much energy, in the form of rotating kinetic energy, the flywheel (**50**) may contain. It sets no limit for how great an output or how great forces it is possible for the waves to channel into the mechanical energy store. Under given circumstances it may lead to overload. The disengagement mechanism only comes into effect after any overload forces and overload output have been channelled into and through the mechanical energy store. U.S. Pat. No. 4,228,360 protects the flywheel (**50**) against the storage of too much rotating kinetic energy. However, neither the flywheel nor any of the energy-transmitting components in the system, from float assay (**2**) to and including flywheel (**50**) are in any way protected against excessive forces or excessive output transmission from the waves. Disengagement of the clutch (**70**) only occurs when the flywheel has been pre-saturated with energy according to the disengagement velocity of the flywheel determined by the flywheel governor (**80**).

[0030] Nor does the system described in U.S. Pat. No. 4,228,360, as it is proposed to be designed, give any inadvertent overload protection, for before the flywheel governor (**80**) can come into operation, the whole mechanical restructuring and energy-storage machinery has to be accelerated to a given disengagement velocity. Since it is proposed that this machinery should contain a heavy mechanical spring: "heavy-duty spiral spring" (page 5, line 19) with energy-storage capacity for half the wave cycle, together with several gears, one of which is proposed with a gear-up factor of 1 to 40 (page 7, line 14) and a flywheel on the fastest rotating axle, there is an enormous inertia in the system from the cable drum (**12**) up to and including the flywheel (**50**). Before the flywheel has reached the disengagement velocity, the waves will have had abundant opportunity to subject wire, winch and the mechanical energy store to forces and output influxes which in practice are only limited by the potential in the waves themselves.

[0031] Thus the components in the power plant (wire, winch, axles, gear etc.) must be of sufficiently robust design to withstand the extreme forces and the enormous energy flux which such a system can and will absorb from an extreme wave.

DESCRIPTION OF WAVE-POWER TECHNOLOGY

[0032] The invention will now be described in more detail by means of examples of embodiments and with reference to the accompanying figures.

[0033] FIG. **1***a* illustrates the principle of the device according to the invention.

[0034] FIG. **1***b* illustrates an exemplary embodiment according to the invention of winch, winch axle and slip clutch for setting the threshold for maximum transmissible output.

[0035] FIG. **2** illustrates an embodiment of a slip clutch type I, designed with two arms.

[0036] FIG. **3** illustrates an embodiment of an absorption element (floating buoy).

[0037] FIG. **4** illustrates an embodiment of a winch unit with wire, anchor construction on seabed and absorption element.

[0038] FIG. **5** illustrates an embodiment of a winch unit with submerged buoyancy body and an embodiment of a tightening system.

[0039] FIG. **6** illustrates a second embodiment of a tightening system with two winch units with submerged buoyancy body.

[0040] FIG. **7** illustrates a second embodiment of a slip clutch type I with plate clutch surfaces.

TRANSMISSION SYSTEM WITH BUILT-IN SLIP CLUTCH

[0041] FIG. **1***a* illustrates the principle of the device according to the invention. An absorption element **1**, which is a floating body, is anchored by wire **4** to a winch **2** with a cable drum **3** in such a manner that the cable drum **3** is forced to rotate when the wave forces move the absorption element **1** in the winch wire's **4** longitudinal direction. The winch **2** may, for example, be anchored to the seabed, be located on land or floating in the water integrated in an absorption element **1**. The energy absorbed from the waves in this manner is transmitted in the form of rotating motion from the cable drum to restructuring machinery **5**, converting the absorbed energy into mechanical stored energy. This mechanical stored energy may, for example, be in the form of m×g×h (the product of mass, acceleration due to gravity and vertical height), p×V (pressure multiplied by volume), or $\frac{1}{2}\times I\times\omega^2$ (moment of inertia multiplied by the square of angular velocity divided by 2). The restructuring machinery is not discussed further below as this is not the subject of the patent.

[0042] The transmission of energy from the winch **2** to the restructuring machinery is conducted via a transmission system **26** and an outgoing axle **10** which are interconnected.

[0043] The transmission system **26** comprises a clutch (not illustrated in FIG. **1***a*) which slips if the output, in the form of the product of rotating speed and torsional force (angular velocity multiplied by torque), which is being attempted to be transmitted from the cable drum to the restructuring machinery, exceeds a certain value. This means that output will always be transmitted to the restructuring machinery, but that this output will not exceed the threshold value/limit of tolerance of the restructuring machinery.

[0044] A principle for design of such a slip clutch for limiting maximum permitted transmitted output involves allowing the clutch to slip as the rotational speed (angular velocity) of the clutch's outgoing axle reaches a certain level. The slip clutch thereby provides an upper limit for how fast the rotating motion which is directed into the restructuring machinery can be. FIGS. **1***b*, **2** and **7** illustrate examples of embodiments of slip clutches according to this principle.

[0045] In these embodiments the slip clutch **6** comprises adjacent friction surfaces **8**, **7***a*-*b* on an incoming axle **9** and an outgoing axle **10** respectively, and these adjacent friction surfaces are pressed against each other. The compressive force, however, is not constant. It is regulated as a function of the outgoing axle's rotational speed by means of the centrifugal forces acting on the clutch when it rotates. When the rotational speed on the outgoing axle exceeds a certain, precalibrated threshold value, the centrifugal forces will ensure that the adjacent friction surfaces are disengaged from each other, but only just, with the result that the transmitted rotational speed remains equal to the threshold value as long as the incoming rotational speed is higher than or equal to the threshold value. While the rotational speed is lower than the threshold value, the slip clutch will act as a fixed clutch.

[0046] The adjacent friction surfaces will become worn down over time when the wave-power plant is in operative condition. They should therefore be replaceable like the plates on a car clutch. The robustness of the system is further reinforced by the mechanism which presses together the replaceable friction surfaces **7***a-b*, **8** coming to a stop when the distance between the pedestal surfaces **11***a-b* and **12** on which the replaceable friction surfaces are attached becomes smaller than a certain number of millimetres. When/if the friction surfaces then become completely worn down, the clutch will slip so much that virtually no transmission takes place of rotational motion to the outgoing axle.

[0047] The effect of the above-described robustness-reinforcing arrangement is as follows: as the friction surfaces become worn, the efficiency of the system will gradually be reduced, instead of the system being exposed to even greater wear due to the wear. In other words: the arrangement causes wear to become wear-limiting.

[0048] In practice a slip clutch which slips when the rotational speed is too high could be constructed in various ways. In the examples in this document, the feedback mechanism which provides varying coupling/degree of disengagement is specified as a flywheel governor, inspired by the famous rotating steam pressure governor which James Watt used in his epoch-making steam engine in the 18th century, and which before that was employed to regulate the compressive force between the millstones in windmills (although coupled in the opposite manner in this case, so that the compressive force between the millstones increased when the windmill's speed increased). It is essential for this flywheel governor to be mounted in such a way that its rotational speed is dependent on the outgoing axle's rotational speed, and not the incoming axle's rotational speed. (The outgoing axle is the axle to which the output is transmitted. The incoming axle is the axle from which the output is transmitted). In this document "disengagement" refers to a mechanism for varying coupling. A possible design involves allowing a spring device **13** to press the clutch surfaces **7***a-b*, **8** against each other, see FIG. **2** and FIG. **7**. Two or more raisable arms **14***a-b* with a certain mass, possibly with a lead weight **15***a/b* at the end of each arm, are attached on opposite sides of outgoing axle **10**. When the arms are lifted up from the outgoing axle, the clutch surfaces are pulled away from each other. In this way the centrifugal forces will cause the clutch to slip when the outgoing axle's rotation reaches a specific threshold velocity. With this relevant design, an additional functionality is achieved: the raisable arms **14***a-b* help to stabilise the outgoing axle's rotational speed when the threshold velocity has been achieved. This is because the angular velocity of the rotating mass is altered as a function of the variation of the radius when the arms are raised and lowered.

[0049] It is also possible to envisage an electronically controlled feedback mechanism, where a motor or an electromagnet with variable strength arranges for the compressive force in the clutch to be adjusted according to the rotational speed which the outgoing axle has at any time.

[0050] A wave-power-operated winch with slip clutch for setting the threshold of maximum transmissible output will be able to be constructed in a great many different variants. In addition to the slip clutch **6**, the transition between cable drum **3** and outgoing axle **10** may contain one or more axles with associated clutches, for example a free-wheel (one-way clutch), and possibly one or more gears in some form or other.

[0051] The clutch types described above, both the mechanically designed slip clutch and the electronically controlled feedback mechanism, are slip clutches whose mode of operation is characterised in that they set an upper limit for how fast the outgoing axle can rotate. Transmitted output is equal to the product of transmitted angular velocity and transmitted torque. By setting a threshold for how high velocity is permitted to be transmitted in the rotating clutch, a threshold is simultaneously set for many watts of power output can be channelled into the restructuring machinery, given that the resistance offered by the restructuring machinery (the torque acting on the outgoing axle **10**) is constant when the rotational speed is constant.

[0052] A simpler, though less wear-resistant alternative, involves the use of an ordinary slip clutch where the compressive force between the clutch surfaces is fixed, thereby setting an upper limit for how powerful rotation (how great torque) can be transmitted. For the restructuring machinery the outcome of this will be the same, viz. that the output channelled into the restructuring machinery cannot be greater than the threshold value determined by the product of transmitted angular velocity and torque.

[0053] Regardless of the design, the basic concept is that the wave-power plant should be capable of withstanding the worst extreme waves because it does not try to resist the waves when the wave forces therein become too great, but instead gives way and allows most of the output in the extreme waves, the destructive energy peaks, to pass and remain in the sea.

Design of the Absorption Element

[0054] The absorption element is anchored at the end of the wire **4** which runs in and out on the aforementioned winch **2**. Amongst the multitude of possible designs of the absorption element, the following is a suitable example: a tubular or sausage-shaped floating body **1** is anchored by two equally long upper wires **16***a-b*, one at each end of the floating body, see FIG. **3**. The opposite ends of the upper wires (the ends which are not anchored to the floating body) meet at a central connecting point **17**. When the wave-power plant is in operative condition, the central connecting point will be located below the ocean surface. From the central connecting point a main wire descends towards the seabed. (This main wire is the same as the winch wire **4**). The actual winch may be located on the seabed. The winch wire **4** will then run directly from the winch vertically upwards to the central connecting point **17**. Alternatively, the winch may be located on shore, in which case the winch wire may run from the winch through a pulley **18** anchored on the seabed before extending up to the central connecting point.

[0055] With a tubular or sausage-shaped floating body of this kind, doubly moored by two upper wires attached to a central connecting point further anchored by the main wire, the floating body will normally be positioned with the broadside along the wave front, regardless of wave front direction. This provides the greatest possible energy absorption. In one embodiment, in one of the upper wires a weak link **19** is inserted, which is weaker than the other elements in the wire and mooring system. The weak link **19** may be formed by changing the diameter of one of the upper wires, connecting one of the upper wires to a material with different breaking strength, etc. The effect of this is as follows: if the wave forces become too violent, causing something to break, it is this weak link that breaks first. The floating body will then take up a position with the broadside across the wave front. The floating body's capability—and possibility—of absorbing energy from the ocean waves thereby becomes substantially less. This should have the effect of reducing the extent of the damage in the event of sea damage.

[0056] In one embodiment of the invention, between main wire **4** and central connecting point **17**, a strong shock-absorbing spring **20** is inserted which is intended to take up the strain of powerful jerks in the wire during start-up, i.e. at the beginning of a wave cycle during periods of violent waves. The shock-absorbing spring is designed so as to compensate for undesirable inertia in the system due to movable mass elements which are set in motion at the start of each wave cycle: wire, cable drum, axles, any gears, slip clutch, etc.

Design of a Wave-Power Plant with Winch, Transmission System and Restructuring Machinery Located on Shore

[0057] See FIG. **4**. In this design, the wave-power plant consists of the following parts:

[0058] A floating wire-anchored absorption element **1**.

[0059] A pulley **18** attached to an anchor **21** on the seabed.

[0060] A winch **2** which arranges for the transmission of power motion absorbed by the absorption element to restructuring machinery **5** via a transmission system containing a slip clutch as described under the section "Transmission system with built-in slip clutch" above.

[0061] The absorption element may be designed as described in the section "Design of absorption element" and as illustrated in FIG. **3**, or it may take any form whatever as long as it floats and is wire-anchored. The pulley **18** is attached to an anchor base **21** located on the seabed. The winch wire **4** extends slantingly downwards from the shore out into the water, down to the seabed where it runs through the pulley **18** and subsequently vertically upwards towards the surface where it anchors the absorption element **1**.

Design of the Winch Tightening System

[0062] A wave-power-operated winch as described in this document will not work without a system for tightening the winch. There are several different system solutions to choose among. A hydraulic accumulator will be a suitable alternative. Other possible system solutions are as follows (not listed in order of priority):

[0063] 1. Tightening of winch wire by means of self-tightening mechanical spring device.

[0064] 2. Tightening of winch wire by means of reverse-wound tightening wire with a buoyancy body submerged in water attached to the end. See FIG. **5**.

[0065] 3. Based on **2**, but where two winches share the same buoyancy body. See FIG. **6**.

Tightening System Solution 1 (Not Shown)

[0066] The winch is tightened by an inbuilt/integrated mechanical spring device which is arranged so that the spring is tightened as the winch wire is pulled out. When the force/forces pulling out the winch wire cease or decrease sufficiently, the spring system will arrange for the winch to be rewound. The spring is strong enough to keep the winch wire **4** taut.

Tightening System Solution 2 (FIG. 5)

[0067] This system solution is most practical if the winch is placed on the seabed, see FIG. **5**, but it is not essential for the winch to be placed in this manner. The winch may also be located on shore. A tightening wire **23** is reeled in on a tightening drum located on the same axle as the cable drum. The tightening drum has a smaller radius than the cable drum. The tightening wire **23** and the main wire **4** are wound in on their respective drums in the opposite direction to each other: if the main wire is wound in in a clockwise direction, the tightening wire has to be wound in in an counterclockwise direction, and vice versa. The tightening wire runs through a pulley **18** anchored to the seabed. The pulley is fixed to an anchor base **21** which, if the winch is placed on the seabed, is horizontally displaced some distance from the winch. From there the tightening wire extends vertically for some distance upwards in the water where its end is attached to a buoyancy body **24**, which is pure and simply an oblong bouy or hose-shaped body whose specific weight is lighter than sea water. The buoyancy body is completely submerged in the water, and located so far below the surface that it is not appreciably influenced by the wave motion. If the main wire **4** is pulled out as a result of the wave motion in the ocean surface, this will cause the buoyancy body to be pulled down, but on account of its buoyancy it will attempt to float up towards the surface, thereby forcing the main wire to be reeled in again when the wave forces abate.

Tightening System Solution 3 (FIG. 6)

[0068] Two winches **2***a-b* are placed on the seabed some distance from each other, each operating an absorption element **1***a-b*. Each has a tightening winch, but share tightening wire **23**, as illustrated in FIG. **6**. In the same way as for tightening system solution **2**, the tightening wire is reeled in on the tightening drums in the opposite direction to the main wires **4***a-b*. The tightening wire is tightened by a submerged buoyancy body **24** with a pulley **25** attached to the bottom. The tightening wire runs through this pulley. Having two winch units sharing a buoyancy body in this manner saves on building materials, thereby enabling costs to be cut.

REFERENCE TERMS USED IN THE FIGURES

[0069] **1**—absorption element (floating body)

[0070] **2**—winch

[0071] **3**—cable drum

[0072] **4**—winch wire (main wire)

[0073] **5**—restructuring machinery

[0074] **6**—slip clutch for setting threshold of maximum transmissible output

[0075] **7**—(*a-b*) friction surface(s) attached to outgoing axle

[0076] **8**—friction surface attached to incoming axle

[0077] **9**—incoming axle/winch axle/axle ahead of outgoing axle

[0078] **10**—outgoing axle

[0079] **11**—(*a-b*) pedestal surface(s) attached to outgoing axle

[0080] **12**—pedestal surface attached to incoming axle

[0081] **13**—spring device

[0082] **14**—(*a-b*) raisable arms on outgoing axle

[0083] **15**—(*a-b*) lead weight on the raisable arms

[0084] **16**—(*a-b*) upper wires

[0085] **17**—central connecting point

[0086] **18**—pulley on the seabed

[0087] **19**—weak link

[0088] **20**—shock-absorbing spring

[0089] **21**—anchor construction on the seabed/anchor base

[0090] **22**—tightening drum

[0091] **23**—tightening wire

[0092] **24**—buoyancy body

[0093] **25**—pulley attached to the buoyancy body

[0094] **26**—transmission system

1. A device for a wave-power plant comprising a self-tightening winch with a winch wire,

wherein the winch wire is connected to a wave-power-operated absorption element at one end and to a cable drum of the self-tightening winch at the other end and the cable drum is connected via a transmission system to an outgoing axle which is further connected to an energy-storing restructuring machinery,

wherein movement of the absorption element results in rotation of the cable drum and transmission of mechanical energy from the cable drum to the rotating outgoing axle and to the restructuring machinery,

wherein the transmission system comprises a slip clutch connected to the outgoing axle, which protects the components in the wave-power plant, particularly the components in the restructuring machinery, against overload in the event of large wave amplitude,

wherein the engagement of the slip clutch varies depending on the rotational speed or torque of the outgoing axel, thereby providing a maximum threshold for how great an amount of energy per time unit can be transmitted to the outgoing axle and to the energy-storing restructuring machinery.

2. A device according to claim **1**, wherein the axle of the cable drum is connected to an intermediate axle through one or more gears, and possibly a free-wheel before or between or after the gears, and where the intermediate axle is further connected to the outgoing axle via the slip clutch.

3. A device according to claim **1**, wherein the slip clutch is of such a nature that it slips if the angular velocity which is being attempted to be transmitted to the outgoing axle exceeds a predetermined threshold value.

4. A device according to claim **1**, wherein the slip clutch is of such a nature that it slips if the torque which is being attempted to be transmitted exceeds a predetermined threshold value.

5. A device according to claim **1**, wherein the slip clutch comprises adjacent clutch surfaces on an incoming axle and an outgoing axle respectively which are pressed against each other by means of spring force from a spring device, and in connection with the outgoing axle a clutch mechanism consisting of two or more raisable arms attached to the outgoing axle, each with a lead weight outermost at the end, which is pressed in towards the axis by means of the force from the said spring device, whereby the compressive force between the adjacent clutch surfaces is adjusted as a function of the centrifugal forces acting on the arms and the weights in such a manner that the compressive force in the clutch decreases when the rotational speed of the outgoing axel increases.

6. A device according to claim **1**, wherein the slip clutch is a clutch mechanism where the degree of engagement is adjusted by means of an electronic regulating system connected to the outgoing axle, with the result that the compressive force between the clutch surfaces decreases as the rotational speed of the outgoing axel increases.

7. A device according to claim **5**, wherein the adjacent clutch surfaces are replaceable and attached to respective pedestal surfaces, and where the mechanism which presses the clutch surfaces against each other contains a blocking means which prevents the pedestal surfaces from coming into contact with each other if the replaceable clutch surfaces become completely worn down.

8. A device according to claim **1**, wherein the absorption element is connected via a shock-absorbing spring to the wire which is reeled in on the cable drum, whereby the shock-absorbing spring has the effect of taking up the strain of jerks in the wire.

9. A device according to claim **1**, wherein the absorption element is a sausage-shaped floating absorption element doubly moored at each end by two upper wires which are attached with their opposite wire ends in a central connecting point which is further connected via a shock-absorbing spring to wire which is reeled in on the winch.

10. A device according to claim **9**, where there is incorporated in one of the two upper wires a weak link which is weaker than the other mooring elements, with the result that it is this weak link and nothing else which is the first to break in the event of overloading.

11. A device according to claim **1**, wherein the absorption element is connected by wire via a pulley attached to an anchor on the seabed, to the winch located on shore connected to a transmission system.

12. A device according to claim **1**, wherein the winch is self-tightening, being tightened by an inbuilt mechanical spring system or the like.

13. A device according to claim **1**, wherein the winch is self-tightening, being tightened by a submerged buoyancy body attached to a tightening wire reeled in on a tightening drum whose radius is smaller than that of the cable drum, where the tightening drum is fixed to the same axle as the cable drum and where the tightening wire is reeled in on the winch in the opposite direction of the winch wire, the tightening wire running from the winch through a pulley attached to an anchor on the seabed, before extending vertically up to the buoyancy body.

14. A device according to claim **1**, wherein two winches are provided located on the seabed horizontally displaced some distance from each other, both winches being tightened by one and the same buoyancy body with a pulley, where a reverse-wound tightening wire, which is common to the two winches, runs through the pulley, thereby ensuring that both the winch wires are kept taut.

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