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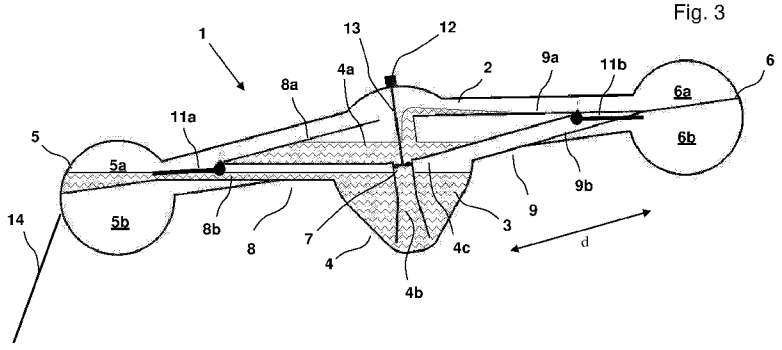
Fig. 3



(57) Abstract: A method and a device for transforming energy of water waves into electric energy by providing a closed container (2) arranged to float on a water surface, with its longitudinal axis mainly in a transmission axis of the waves occurring on the water surface, where the container (2) is supplied with compartments (5a, 6a) that can communicate with each other and said compartments located one at each end of the container (2), and wherein the container (2) is filled with a liquid (3) to a predetermined aliquot, whereby when one of said compartments (5a, 6a) at one end of the container (2), due to wave motion is at a predetermined higher level than the second compartment (5a, 6a) in the other end of the container (2), liquid (3) which is located in the higher compartment (5a, 6a) flows over to the lower situated compartment (5a, 6a) and then passes a turbine (7) in a flow path which, because of the container's (2) inclination, connects the two compartments (5a, 6a) whereby the turbine (7) is rotated and electrical energy being generated in a generator (12) coupled to said turbine (7) and wherein said flow movement is arranged mainly to take place in a vertical level through the container's longitudinal axis.

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DEVICE AND METHOD TO TRANSFORM WAVE ENERGY INTO ELECTRIC ENERGY

TECHNICAL FIELD

[0001] The invention relates to a device and a method of transforming energy of water waves into electric energy.

BACKGROUND ART

[0002] One technology field that has recently attracted increasing interest consists of devices and methods to extract energy from water waves, particularly from waves at sea. This form of energy source is characterized by movements that are relatively slow but still, within a limited area, holding large amounts of energy. Over the years, great efforts have been made in order to resolve the difficulties in utilizing this rich and renewable form of energy commercially and in particular to transform the energy of water waves in an area into electrical energy using generators that produce electricity.

[0003] In many of the proposed known solutions floating buoys are used to receive the energy in the waves. The buoys which are repeatedly raised and lowered by the waves are usually anchored to a seabed. The slow repeated movement of the waves in relation to the anchor is then converted to a high working speed of an electric generator by means of some form of switch. An example of such a device is given in the document US 6 388 342.

[0004] In still other variations of solutions, as in US 4 204 406, a buoy is shown represented by a platform having a plurality of hydraulic pumps intended during operation to pump sea water into a tank containing compressed air, where it serves to pressurize the sea water . The compressed air then passes then the sea water further to a turbine connected to an electric generator.

[0005] Common to all these devices is that they have a complex and thus expensive construction. Furthermore, they are rather sensitive to the influence of flora and fauna occurring in the managed sea water, which must be handled by means of filtration and measures in the form of regular supervision.

[0006] Another principle for the use of wave energy is known from the document EP 0 483 357 A1, in which a weight is aligned to rotate about a horizontal axis of rotation at a distance from the weight, as it moves up or down in a frame that stands on the seabed. This converts the repeated motions of the waves into rotational motion which can be transferred into electrical energy.

[0007] Document U.S. 4392061 discloses an apparatus which utilizes a liquid contained in a compartment where the liquid is moved back and forth in a rocking motion in pace with a wave motion. The liquid powers means to convert energy in the wave motion. The apparatus consists in this case of a large, eg. in a sea area anchored, container arranged to float on the surface and to rocking following the rhythm of the water waves at the location. The container has chambers containing a liquid that moves along the container with the same frequency as the container's rocking motion. Furthermore, the apparatus comprises means, such as turbines, which are positioned along the path of liquid movements in the container in order to seize energy from the wave motion. Said energy is extracted during horizontal movement of water masses between said chambers.

[0008] The device of FR 2499161 A2 discloses a container holding compartments in several levels, where a certain amount of water is enclosed in the container. The idea of this known device appears to be to arrive at a high potential energy of the water which in several steps is carried upwardly to a higher compartment due to undulations by means of a number of flaps which open and close in pace with the wave motions, whereupon the water flows downwardly through a turbine during conversion of potential energy of water into kinetic energy with the turbine. This stepwise upward transport of water takes place in compartments that are located on the same side of the turbine. A device of this kind is a slow and complex assembly. The known device should require a great height of the waves on the surface so as the bottom of the container shall not prevent the rocking movement if there isn't an undulation at the container's lower part in phase with the waves at the surface. Moreover, the arrangement of the device in a plurality of floors result in a high complexity. According to the embodiment, a large number of flaps at different heights are required. This implies a greater risk of malfunction and further major difficulty in implementing service.

DESCRIPTION OF THE INVENTION

[0009] The present invention relates to a method and a device to transform energy of water waves into electric energy. The invention is based on the use of a closed container which is arraanged to float on a water surface, usually in a sea area, in order to utilize the energy of waves at the surface. The container is anchored at a particular position and thus rocks back and forth vertically with the same frequency as the waves at the surface. The rocking motion is achieved by the waves lifting the one or the other end of the container. The container is furthermore filled with liquid to a predetermined subset of its volume, where the contained liquid flows back and forth between its both ends in line with the container's rocking motion caused by the undulation at the surface. Hereby, the container is positioned so that it floats on the water surface and rocks in the direction of propagation of the waves. The container floats on the water because of the proportion of air contained inside it.

[0010] At each end of the container there is a compartment, arranged for reception and delivery of the contained liquid in response to the rocking motion of the container. Said compartment is thus used as a liquid depot. Between the two compartments there is a central compartment which the contained liquid passes on its way from one compartment at one end of the container to the other compartment at the other end of the container.

[0011] When one of said compartments at one end of the container due to wave motion is at a predetermined higher level than the second compartment at the other end of the container, liquid which is in the higher situated compartment flows through the central compartment to the lower located compartment and then passes a turbine located in a channel which is arranged to combine the two compartment whereby the turbine is rotated and electrical energy is generated by a generator connected to said turbine. The liquid flow inside the closed container is arranged to take place in a substantially vertical plane through the container's longitudinal axis, wherein said longitudinal axis should be construed as the direction between the two at each end of the container's located compartments.

[0012] The container of the device can be designed geometrically in many ways. Characteristic for the device is that it is provided with a centrally disposed water reservoir which is situated above a turbine. Under the turbine there is a drain to receive the liquid passing through the turbine. The principle is such that liquid flows cyclically in pace with the cyclic wave motion:

- from the drain to one compartment,
- then to the water reservoir,
- down through the turbine to the drain,
- thence to the other compartment,
- again to the water reservoir,
- thence again through the turbine and back to the drain.

In reality it is not granted that all the contained liquid over a period of undulation flows exactly as scheduled, because external factors may affect the flow, such as wind, irregular wave motion, etc..

[0013] According to one aspect of the invention a method is presented having the characteristics as specified in claim 1.

[0014] Further, a device for performing the method is presented in the independent device claim..

[0015] Further embodiments of the invention are presented in the dependent claims.

[0016] By means of the ports which open and close during the movement of the liquid within the container, the two compartments are filled at least partly, alternately, by the back and forth moving liquid mass in the container. The ports are arranged so as to create a channel from one compartment to the other, wherein at least one turbine is passed by the liquid in the channel, as the liquid flows over from one compartment to the other. The ports, also referred to as flaps, may be arranged to be opened and closed automatically by the force of the flowing water. As a preferred alternative, counterweights may attached to the ports, so that these are opened, almost by themselves, under the influence of the container's inclination and the force of gravity. Thus, there is no loss of power of the flowing mass of water.

[0017] An advantage of the device and method of the invention is that it utilizes very few components and a minimum of moving parts.

[0018] Further, the liquid inside the container is arranged to flow mainly in a pattern back and forth in a vertical level through the container's longitudinal axis. Hereby, as an example,

turbines can be arranged for mainly vertical flows of the liquid flowing through the turbine or turbines. The closest prior art, according to US 4392061, where the horizontal water flow is applied, the liquid passes the turbines horizontally from a horizontally placed reservoir in relation to the turbine. This results in an uneven load on the turbine blades, because the water level decreases during the output of energy. By allowing liquid to pass through a vertically arranged turbine from a water reservoir located vertically above the turbine, power is distributed from the liquid evenly over the turbine blades.

DESCRIPTION OF THE FIGURES

Fig. 1 depicts a schematic representation of a side view of the inventive device in a horizontal rest position.

Fig. 2 depicts a side view of the device of figure 1, which describes how the trapped liquid will move when the container rocks over to the left from the rest position.

Fig. 3 shows in a side view corresponding to that of figure 2 the flow of the contained liquid when the container rocks over to the left during normal operation.

Fig. 4 shows in a diagram corresponding to figure 3, the flow of the contained liquid when the container rocks over to the right during normal operation.

Fig. 5 depicts a very generalized a perspective view where the container of the invention due to wave sinks at its left end and is pushed up at its right end.

Fig. 6 depicts in a way corresponding to that of figure 6 how the container of the invention due to wave motion is pushed up at its left hand end and sinks into at its right end.

Fig. 7 shows an alternative embodiment of a device according to the invention, wherein a flow to a compartment at the end of the container, and the flow from the same compartment occur via channels which in a vertical plane are arranged parallel to each other.

DESCRIPTION OF EMBODIMENTS

[0020] The following describes a number of embodiments of the invention with the aid of the accompanying drawings. The drawings show only schematically the principle of the device and do not purport to show any scale ratios between the various elements thereof.

[0021] Figure 1 shows a device 1 according to the invention's aspect of a container 2 in the rest position, ie. under a condition where the container flows horizontally. The container 2 is mentioned to be placed for example at sea, where energy from ocean waves can be recovered and converted into electrical energy by means of the present device. For this purpose the container 2 is closed and designed to partially, ie. to a particular aliquot, be filled with a liquid 3. In the embodiments described herein are used water, preferably fresh water, as the liquid with which the container 2 is partially filled. In this regard, the reference numeral 3 should also be interpreted as it can be any liquid, although it is herein referenced only as water. The water aliquot 3 with which the container 2 is partially filled, can be determined by the environmental conditions in which the container is used. The aliquot may thus depend on the average wave height occurring on the location, the wavelength which is considered to be the dominant one, and the depth at which the container will flow into the water, as some examples.

[0022] The container is also provided with anchor. This anchoring can be a rope or chain fixed to one end of the container and attached to the seabed, the container will flow in the wave direction of movement from the anchoring 14.

[0023] The container 2 is further divided into different sections. Thus the container comprises, in a variant, three tanks connected by tubes, wherein the container is divided into a structure of compartments and channels. Said tanks consist according to the example a centre tank 4 and at the respective end of the container 2, a first tank 5 and a second tank 6. The central tank 4 harbours reservoir 4a, turbine 7 and drain 4b. A first tube 8 connects in the example the central tank 4 to the first tank 5 and a second tube 9 connects the central tank 4 to the second tank 6. The connection between the central compartment 4 and the two tanks 5 and 6 could of course as an alternative be arranged by a plurality of first tubes 8, resp. several other tubes 9.

[0024] By use of the tanks 5 and 6 are formed compartments 5a and 6a, one at each end of the container 2. Preferably, but not necessarily, the container 2 is elongated, thereby referred ends of the container are equated with the ends of the container which flow towards or with the waves surrounding the container 2. In a first embodiment of the invention sealed air bulkheads 5b and 6b are arranged below each of the compartments 5a, 6a at the ends of the container. These air bulkheads 5b, 6b are arranged to balance the container in the water in an advantageous manner. From the first compartment 5a at one end of the container, a first channel 8a runs through the first tube 8 up to and opens into the arranged water reservoir 4a, where the lower partition wall, ie. its bottom 4c, is arranged just above the drain 4b. Similarly, a second channel 9a runs from the second compartment 6a in the container. The second channel 9a also opens into the water reservoir 4a. The turbine 7 is provided in the central portion of the water reservoir's 4a bottom. This turbine 7 is adapted to be rotated when the water in the water reservoir 4a flows down through the turbine 7 towards the drain 4b of the container's 2 central portion.

[0025] A third channel 8b connects the drain 4b with the first compartment 5a. Similarly, a fourth channel 9b connects the drain 4b with the second compartment 6a.

[0026] It is also clear from the figure that the water 3 fills up a certain aliquot of the container 2. Flaps 11a, 11b can close or open the said channels 8a, 8b, 9a, 9b in the manner described below. It may further be mentioned that the flaps 11a, 11b are a kind of ports which are hinged along one of their edges and thus can rotate an angle around the hinge. Said hinges are marked as small filled black circles in the figures. Other edges of the flaps can, in order to supply a stop and seal, be arranged so that the flap by its own weight or by water pressure fits firmly against a strip, folding, elevation or equivalent in the flap adjoining wall. These details are not shown in the figures.

[0027] The turbine 7 is connected to a generator 12 by a shaft 13, in which the generator 12 is arranged inside or outside of the container 2. If the container is designed so that the compartment that represents the water reservoir 4a has a raised section, the generator 12 is mounted on the inside. When the turbine 7 is rotated, electrical energy is induced in the generator, from which the electrical energy can be distributed in a manner not described here.

[0028] With the aid of figures 2 to 4 the performance of the device according to the invention is described while it is ongoing. The first of these, figure 2, illustrates the start of the movement pattern of the entrapped water 3 when this is put in motion by the lifting force of a wave, which in this case in the figure moves to the right and with its wave crest lifts the right end of the container 2. When the container has thus rocked over to the left, meaning that its left end has fallen to a level lower than its right end, the flap 11a opens because of the container's inclination in combination with the gravity and/or by the flowing water flowing forwards from the right end of the channel 8b to the left in the figure. The water 3 will then because of the inclination of the container 2 flow from the drain 4b along the channel 8b through the opened flap 11a, whereby the compartment 5a is filled with water until the container 2 rocks over to the right when a new wave crest reaches the left end of the container.

[0029] When the container 2 rocks over to the right, according to figure 4, because of a new wave crest from the subsequent wave, it affects the left end of the container with an upward force the flap 11a will close due to changes in the container's inclination and the left compartment 5a starts to be emptied. The water from the compartment 5a hereby flows along the channel 8a, and falls into the water reservoir 4a. Also in this case, this flow happens when the container's inclination exceeds said predetermined angle. The water fills again the water reservoir 4a, so that the water in the reservoir 4a can be continuously flowing down and passes through the turbine 7, so that it continuously rotates. The water that has fallen through the turbine 7 during the container's inclination to the right, falls first into the drain 4b and flows further to the right in the channel 9b. In the channel 9b flap 11b opens because of the container's inclination so that the water from the channel 9b begins to fill the compartment on the right, ie. the second compartment 6a. The water flow through the turbine 7 has been achieved by an open second flow path which in this situation, when the container rocks over to the right, is made up of channel 8a, water reservoir 4a, the drain 4b and the channel 9b. This second flow path 8a, 4a, 4b, 9b thus consists of a path with which the compartments 5a and 6a communicate directly when the container is inclined to one side, in this example to the right in figure 4.

[0030] When the container 2 again rocks over to the left according to figure 2 as described above, because of a wave crest affecting the right end of the container with an upward force, the flap 11b is closed due to the changing inclination of the container and the

second compartment 6a starts to be emptied. The water flows from the compartment 6a herein along channel 9a to the left and falls into the water reservoir 4a, as shown in figure 3, in which the second compartment 6a has already been emptied into the channel 9a and the water reservoir 4a. Naturally, this flow occurs only when the container's inclination exceeds a predetermined angle which is dependent on the height of the water reservoir 4a. A typical inclination angle is within the range of 5 ° - 20 °. The water collected in a reservoir 4a can flow further down and pass through the turbine 7, so that it is rotated. Hereby the transformation of energy of water waves into electric energy is achieved, as the turbine 7 powers the generator 12. The water that has fallen through the turbine 7 flows further to the left in the channel 8b, as shown above. The water flow through the turbine 7 is accomplished by an open first flow path which in this situation, when the container rocks over to the left, consists of the channel 9a, the water reservoir 4a, the drain 4b and the channel 8b. This first flow path 9a, 4a, 4b, 8b thus constitutes a path by which the compartments 6a and 5a communicate directly, when the container is inclined more to one side, in this example to the left.

[0031] It should here be mentioned that the container 2 may contain multiple bulkheads, created by means of walls arranged in the longitudinal axis of the container 2. The flow in each of the bulkheads will hereby be represented by the flow pattern described above. In the case of several parallel bulkheads, a turbine can be arranged per bulkhead. There is also nothing to stop that a bulkhead, or when using multiple bulkheads, that each of the bulkheads are equipped with more than one turbine 7, i.e. the use of the concept turbine shall hereby be understood by that it also can refer to a turbine group.

[0032] Figures 5 and 6 illustrate in very schematic figures in a simplified perspective how the device according to the invention acts in water under the influence of water waves. In figure 5, a wave has lifted the right end of the container 2, whereas in figure 6, the wave has lifted the left end of the container.

[0033] Naturally, it is possible to design the container and its internal structure in different ways with different geometries. Characteristic for the device in different embodiments, however, is that it is provided with a central compartment, which from a higher to a lower level comprises water reservoir, turbine and drain with operation as described above. Further, the central compartment communicates with a liquid depot at each end of the container. The

liquid depots are represented in the given example by the first compartment 5a and the second compartment 6a. The principle is that the liquid depot at one end of the container communicates directly via an open flow path through a turbine with the liquid depot at the other end of the container. The way of the open flow path depends on which one of the two liquid depots that is being located at a higher level, such as disclosed in the described embodiment example.

[0034] A further embodiment of the invention is shown in figure 7, where the channels between the various compartments are arranged in an alternative manner. In this example, the channels 8a, 9a for emptying one of the first 5a or second 6a compartments disposed between duplicated channels 8b, 9b for filling either the first 5a or second compartment 6a. Hereby, e.g. apertures for those emptying and filling channels can be configured in different geometric ways compared to what is possible by use of the embodiment according to Fig. 1. For example, the inlet and outlet of said channels can be provided in an optimum way to utilize the energy of waves of lower wave height. In this embodiment, the check valve 13 is duplicated, in which each of the duplicated check valves 13 is placed in the flow path of the discharge channels 8a, 9a.

[0035] For the device to be able to function in an optimal way, the container 2 in the direction along its longitudinal axis should be provided with a span in which the energy of wave motion is captured in the most efficient manner. The span is the total extension of the device in the direction of its longitudinal axis, ie. in the direction of wave movement past the device. The channels 8a, 8b resp. 9a, 9b can be given a certain length d. This length d will hereby be the distance between the central compartment 4 and the first 5a and the second compartment 6a respectively. The adaptation to the dominant wavelengths of the site can be achieved by setting the total span of the container to correspond to the order of magnitude of half the average wavelength λ of the said location. If, in the direction of the longitudinal axis of the device, the width of the central compartment 4 is set to W and the width of each of the first compartment 5a and the second compartment 6a is set to w, there is thus a relation as follows: $W+2w+2d \approx \lambda/2$. This relationship is only approximate and should not be considered as to be binding to the invention. The distance d between the different compartments 4, 5a, 6a is designed to have an extension being determined by: $\lambda/4>d>\lambda/16$ or preferred: $\lambda/4> d> \lambda/8$.

[0036] Dimensions of containers, tubes, compartments and channels, and the turbines' throughflow areas respectively, should be adapted to the wave characteristics at the anchor position in question. Wave data for the dimensioning can be for example the wave length, the average height and period.

[0037] The dimensions of the container in the device may vary depending on the wave conditions at the location where it is placed. For the embodiment of Fig. 1 may, as an example, the ratio of length, width and height be 12m, 10m, resp. 3m.

Example:

Theoretical calculations indicate that a device according to any of the proposed embodiments can provide about 1 kW per meter width of the container. This effect can be achieved already at one-meter wave height. A total power of 10 kW is obtained from a container which has a width of 10 m and 12 m length in a wave period of 4 seconds in the open sea, where the whole water volume collected at one end of the container flows through the turbine (turbine group) during 2 seconds. With a fully open channel, a depot at one end of the container would be emptied during approximately half a second, but since the arranged turbine provides a flow resistance, it can be arranged so that the depot is emptied during said 2 seconds, so that the depot is empty or nearly empty even when the container rocks over to the other direction. In this example, the calculations have been performed for a container which encloses approximately 15 m^3 of liquid. Further conditions are a medium drop height of 0.78 m

[0038] A wave with a wavelength of about 24 m, which is one meter high as counted from the trough to the wave crest, gives a total power of 10 kW.

Definition

[0039] By the longitudinal axis of the container 2 means the direction between the compartments 5a and 6a at the ends of the container.

CLAIMS

1. Method for transforming energy of water waves into electric energy, comprising the steps of:
- supplying a closed container (2) which is arrange to float on a water surface.
- providing a first (5a) and second (6a) with each other communicable compartments located one at each end of the container (2) and between the first (5a) and the second (6a) compartment, a central compartment (4).
- arranging the container (2) to be oriented so that the first (5a), the second (6a) and the central (4) compartment in relation to each other are aligned mainly along a propagation direction of waves occurring on the water surface.
- arranging the central compartment (4) to contain, from a higher to a lower level, a liquid reservoir (4a), a turbine (7) and a drain (4b).
- filling the container (2) with a liquid (3) to a predetermined sub volume,
characterized in that:
- when one of said compartments (5a, 6a) at one end of the container (2), due to wave motion is at a predetermined higher level than the other compartment (5a, 6a) at the other end of the container (2), liquid (3) located in the higher situated compartment (5a, 6a) flows via an open flow path (9a, 4a, 4b, 8b, resp. 8a, 4a, 4b, 9b) over to the lower situated compartment (5a, 6a) and thereby passes the turbine (7) provided in the open flow path arranged to unite said two compartments (5a, 6a) wherein the turbine (7) is rotated and electrical energy generated in a generator (12) coupled to said turbine (7),
- said first compartment (5a), alternatively said second compartment (6a) is, for a period of the wave motion, the higher, resp. the lower compartment,
- said flow is arranged to take place mainly in a vertical plane through the container's longitudinal axis.

2. Method according to claim 1, comprising the step of:
- said compartments (5a, 6a) are arranged to communicate with each other by means of flaps (11a, 11b) which alternately open: a) a first flow path (8a, 4a, 4b, 9b) from the first (5a) of said compartments to the second (6a) of said compartments, and b) a second flow path (9a, 4a, 4b, 8b) from said second compartment (6a) to said first compartment (5a), wherein the flow paths are designed so that said turbine (7) is in both the first (8a, 4a, 4b, 9b) and the second flow path (9a, 4a, 4b, 8b).

3. A device transforming energy of water waves into electric energy, comprising a closed container (2) arranged to float on a water surface with its longitudinal axis mainly in a direction of propagation of the waves occurring on the water surface,
characterized in that:
- the container (2) is supplied with a central compartment (4), which from a higher to a lower level comprises a liquid reservoir (4a), a turbine (7) and a drain (4b)
- said central compartment (4) communicates with a liquid depot (5a, 6a) at each end of the container (2), where the liquid depot (5a, 6a) at one end of the container (2) communicates via an open flow path (9a, 4a, 4b, 8b, resp. 8a, 4a, 4b, 9b), in which the turbine (7) is mounted, with the liquid depot (5a, 6a) at the other end of the container (2),
- a liquid (3) enclosed in the container (2) generates the electrical energy when a wave on the surface brings the liquid (3) to flow from a higher-located liquid depot (5a, 6a) to a lower-located liquid depot (5a, 6a) along the flow path and thereby rotates the turbine (7) which is coupled to a generator (12).

4. Device according to claim 3, wherein the container (2) is adapted to be partially filled with liquid (3), preferably water, in particular fresh water.

5. Device according to claim 4, wherein one of said liquid depots comprises a first compartment (5a) and the second liquid depot, a second compartment (6a) and said first and second compartments being connected to the central compartment (4) via tubes (8, 9), wherein the tubes' lengths corresponds to a distance d between the first compartment (5a) and the central compartment (4), as well as between the second compartment (6a) and the central compartment (4), in the order of: wavelength/4>d>wavelength/16.

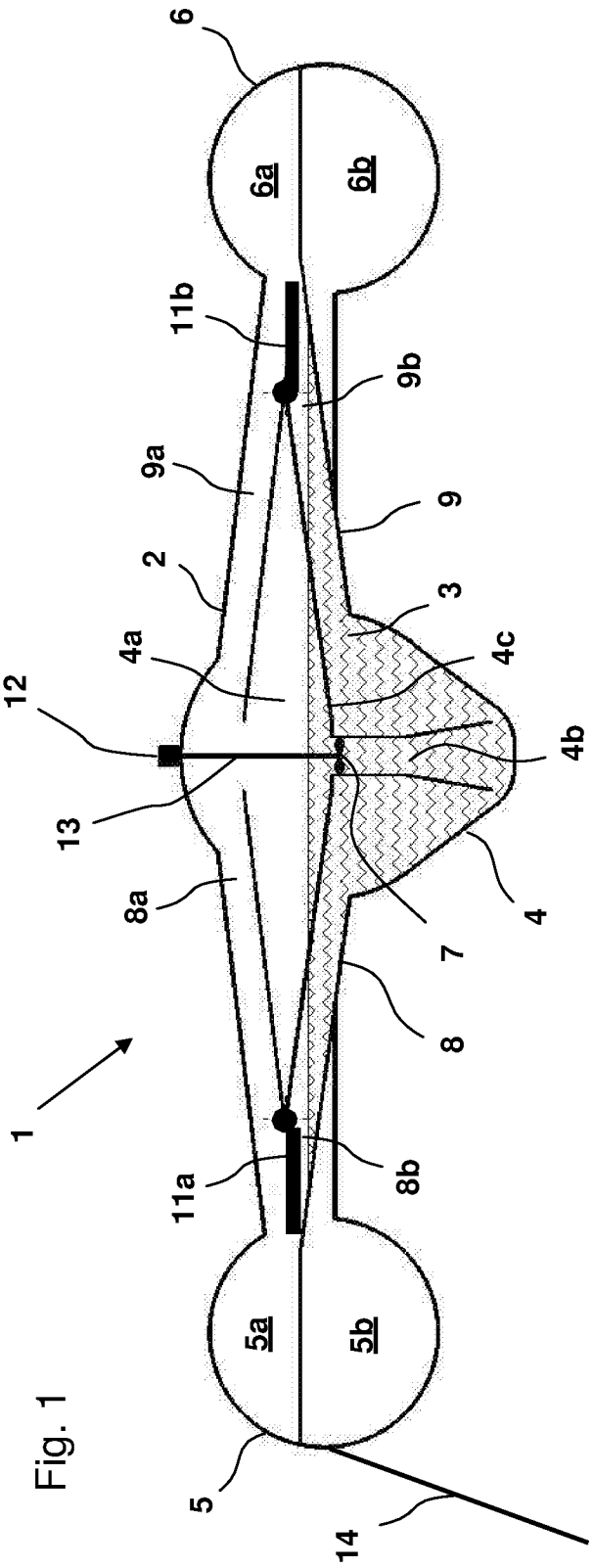
6. Device according to claim 5, wherein said open flow path comprises:
- a first channel (8a) of the first tube (8), water reservoir (4), drain (4b) and a second channel (9b) of the second tube (9), when the container (2) is inclined a predetermined angle to one direction.
- a first channel (9a) of the second tube (9), water reservoir (4a), drain (4b) and a second channel (8b) of the first tube (8), when the container (2) is inclined a certain angle in the other direction.

7. Device according to claim 6, wherein the container's inclination determines which of said said flow paths that is open through flaps (11a, 11b) which opens or closes the flow paths.

8. Device according to claim 7, wherein the flaps (11a, 11b) comprise lids which are rotatably arranged in horizontally and transverse to the container's longitudinal axis arranged hinges, about which hinges the lids can rotate and by its own weight be opened or closed under the influence of the container's (2) inclination in cooperation with the force of gravity and/or by the force effected by the liquid (3) flowing towards the flaps (11a, 11b).

9. Device according to any of claims 3 - 8, wherein said turbine (7) is positioned at the bottom (4c) of the water reservoir (4a) which is filled with water when the container (2) repetitively rocks up and down at a minimum inclination angle in the range of 5 ° - 10 °.

10. Device according to any of claims 3-8, wherein the first compartment (5a) is included in a tank (5) which also houses a first air bulkhead (5b) and the second compartment (6a) is included in a tank (6) which also accommodates a second air bulkhead (6b).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6b
11b
9b
9a
9
2
3
4a
4c
12
4b
13
8a
4
7
8
1
11a
8b
5a
5b
5
14

Fig. 1

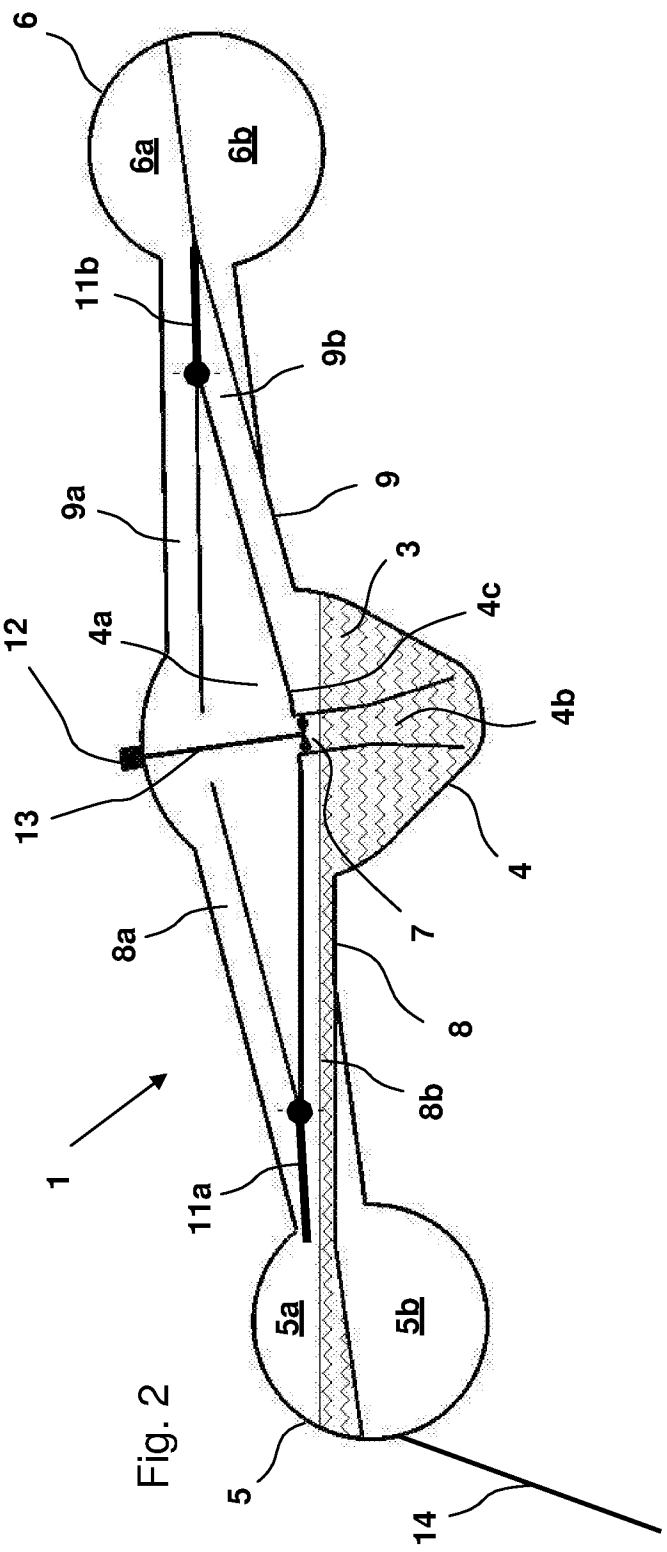
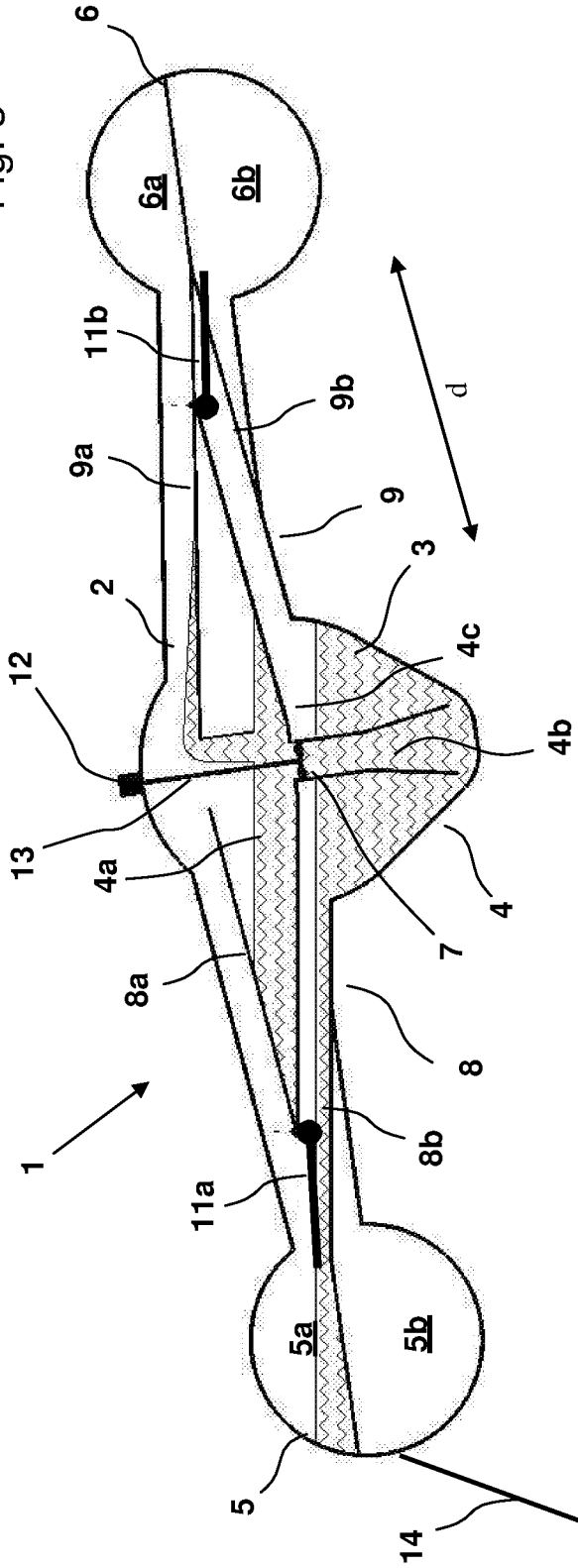

6
6a
6b
11b
9b
9a
9
3
4a
4c
12
4b
13
4
8a
7
8
1
8b
11a
5a
5b
5
14

Fig. 2

Fig. 3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6b
11b
9b
9a
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d
2
3
4c
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4
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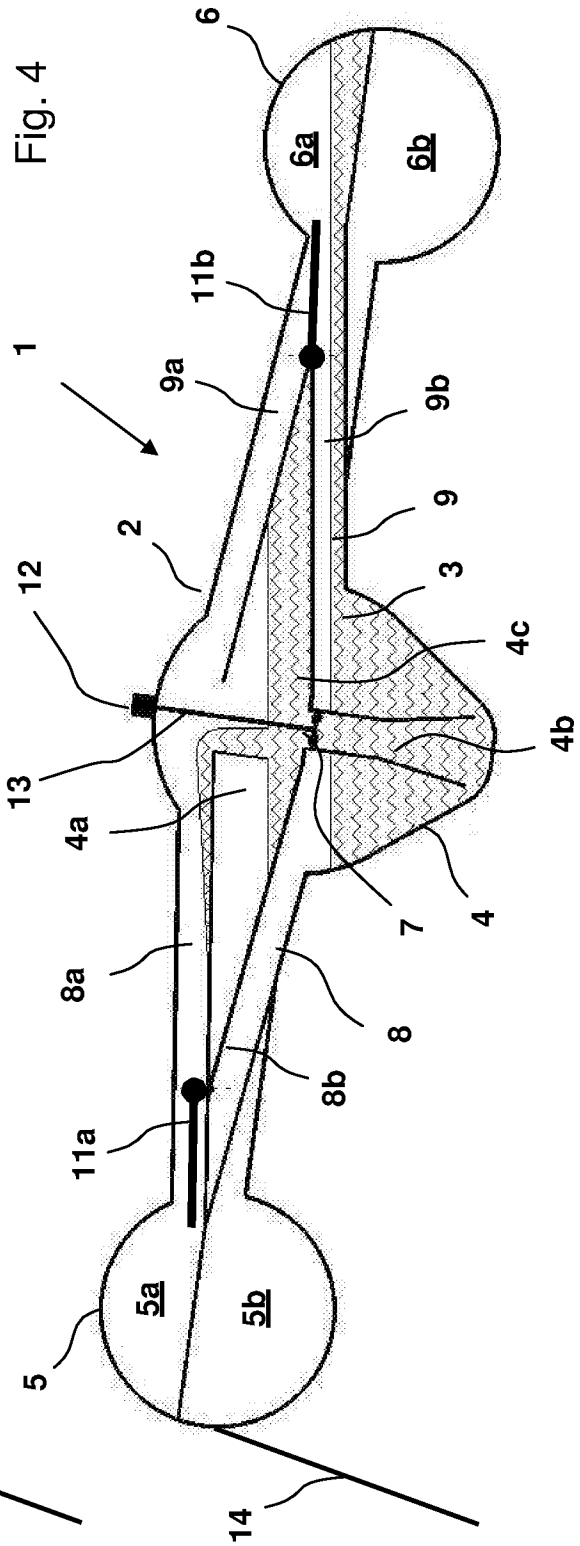
8
8b
1
11a
5a
5b
5
14

Fig. 4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11b
1
9a
9b
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3
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4b
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8b
11a
5a
5b
5
14

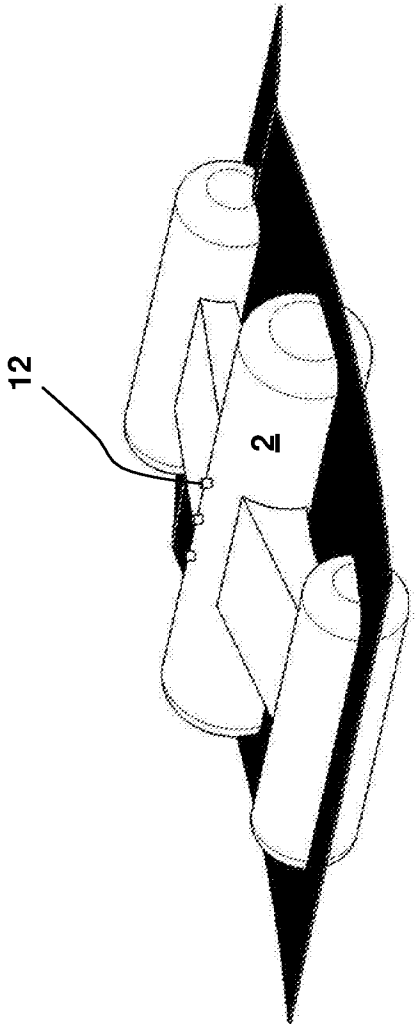

Fig. 5

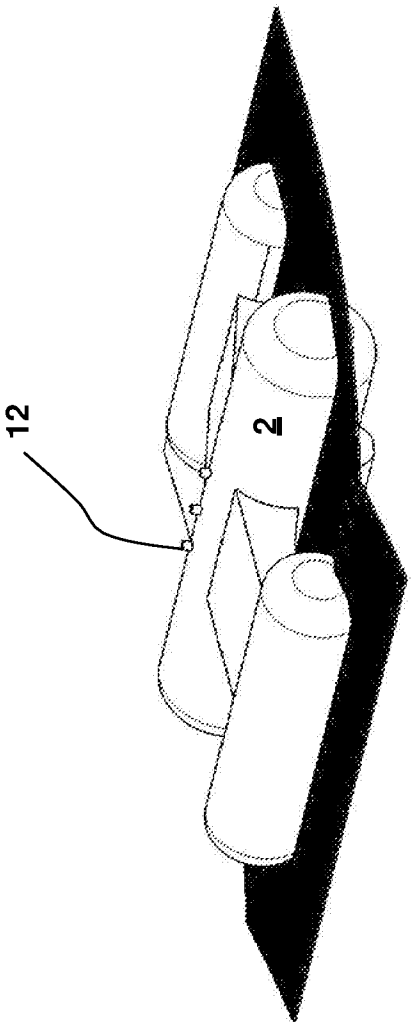

Fig. 6

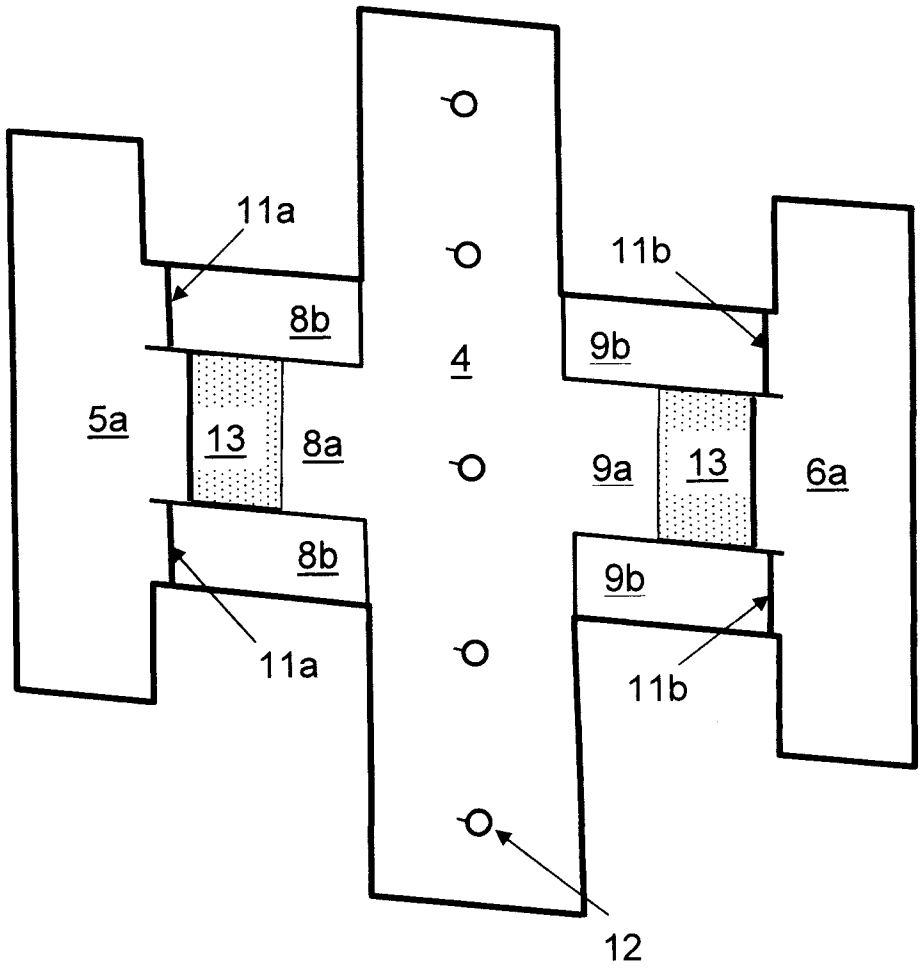

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/050273

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B63H, F03B, F03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4392061 A (DUBOIS YVES ET AL), 5 July 1983 (1983-07-05); abstract; column 1, line 35 - column 7, line 62; column 2, line 13 - column 2, line 26; column 4, line 39 - column 5, line 7; figures --	1-10
A	FR 2499161 A2 (RODRIGUEZ ANDRE), 6 August 1982 (1982-08-06); abstract; page 2, line 9 - page 2, line 12; page 2, line 16 - page 2, line 29; figures --	1-10

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27-06-2012	29-06-2012
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Claes Weyde Telephone No. + 46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2012/050273

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4179886 A (TSUBOTA JUNJIRO), 25 December 1979 (1979-12-25); abstract; column 1, line 65 - column 2, line 5; column 2, line 35 - column 2, line 41; column 2, line 62 - column 2, line 68; column 6, line 52 - column 7, line 23; figures 4-5, 13-15	1-10
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A	AU 2010101355 A4 (CHEN SHIH-HSIUNG), 13 January 2011 (2011-01-13); abstract; page 5, line 10 - page 6, line 10; page 7, line 7 - page 7, line 24; page 8, line 7 - page 9, line 5; page 9, line 14 - page 9, line 25; figures	1-10
	--	
A	EP 2133555 A1 (MOLLOY PADRAIG), 16 December 2009 (2009-12-16); abstract; paragraphs [0004], [0020], [0021]; figures; claim 1	1-10
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A	US 4207739 A (SCARPI BRUNO D), 17 June 1980 (1980-06-17); abstract; column 2, line 39 - column 3, line 25; figures	1-10
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A	GB 2311565 A (COOK ANDREW PAUL), 1 October 1997 (1997-10-01)	1-10
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T	WO 2012056167 A1 (GEPS INNOV ET AL), 3 May 2012 (2012-05-03); page 2, line 7 - page 2, line 24; page 3, line 4 - page 3, line 7; page 4, line 5 - page 4, line 13; page 8, line 3 - page 9, line 27	1-10
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International application No.
PCT/SE2012/050273

Continuation of: second sheet

International Patent Classification (IPC)

F03B 13/22 (2006.01)
F03G 7/08 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

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				FR	2500887	B1	05/10/1984
				IT	1154481	B	21/01/1987
FR	2499161	A2	06/08/1982	NONE			
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				WO	2009149918	A1	17/12/2009
US	4207739	A	17/06/1980	FR	2375463	B1	13/04/1979
GB	2311565	A	01/10/1997	NONE			
WO	2012056167	A1	03/05/2012	NONE			