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(54) AN APPARATUS FOR UTILIZING KINETIC ENERGY STORED IN THE SWELL OR WAVE MOVEMENT OF WATER

(71) We, KAJ-RAGNAR LOQVIST, of Regnbägsvägen 40, S-773 00 Fagersta, Sweden; MANFRED WALLACE GUSTAFSON, Malmvägen 6 G, S-773 00 Fagersta, Sweden; and SVEN ANDERS NORÉN, Klövervägen 3, S-161 36 Bromma, Sweden, all three of Swedish nationality do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The present invention relates to an apparatus for utilizing kinetic energy stored in the wave movement or swell of water.

Known apparatus of this kind comprises at least one buoyant body at the water surface anchored in such a way that it can move freely, without limitation, in conjunction with the wave movement, and substantially vertically. Connected to the buoyant body, the apparatus has at least one flow inhibiting and energy converting means comprising a propeller device.

Known installations for utilizing the kinetic energy in the wave movement of water give low power per unit of the energy converting system because of the comparatively low flow speeds. If greater quantities of energy are to be utilized, the installation requires large dimensions with associated high investment costs and difficult handling.

A not inconsiderable improvement of the power per unit can be achieved if the propeller device is provided with inlet and outlet funnels of the venturi type, giving velocity increase. Such arrangements can give power increases of from 5 to 10 times, but the power per unit is however still too low in relation to construction costs for use other than in special cases where investment and operating costs are of minor importance.

The present invention has the object of providing an apparatus for utilizing energy stored in the wave movement of the water, wherein there is obtained a considerable pressure difference in the part of the apparatus where the propeller device is situated, and thereby increasing considerably the power delivered by a given size of propeller device.

According to the present invention there is provided apparatus for utilising kinetic energy stored in the swell or wave movement of water, comprising a buoyant body located at the water surface and anchored in a way which permits substantially unrestricted movement thereof in an essentially vertical direction in conjunction with the wave movement; energy-converting means carried by the buoyant body and comprising a substantially vertical open-ended elongate tube rigidly secured to said body, both ends of said tube being beneath the water surface; and propeller means mounted in said tube adjacent the upper end thereof.

In the present invention the tube performs an oscillating movement in the vertical direction. The water column enclosed within the tube is then carried by the tube in its movement due to the resistance exerted by the propeller means and constriction of the tube bore, if any, against the through flow. If, for example, the tube with its propeller means is accelerated upwards an overpressure is generated under the water column lying above the propeller means and an underpressure above the water column lying under the impeller. The total of these pressures imparts the driving force to the propeller means. The pressure difference Δp is then:

$$\Delta p = \rho \, l \, a$$

where

ρ = density of water

l = total length of acceleration tube

a = acceleration of water column.

For a wave having a height of 2 m the

maximum acceleration is about 1 m/s^2. A tube having a length of 25 m imparts then a pressure difference of 25 000 N/m^2. This corresponds to a conventional water turbine plant having a height of fall of 2.5 m. The propeller means which in a similar manner oscillates up and down in free water (i.e. not confined by a tube) is able to utilize only the dynamical pressure which amounts maximally only to 500 N/m^2 for waves having a height of 2 m. This corresponds to a height of fall of only 0.05 m. It is thus seen that a tube having reasonable dimensions is able to increase the power output by 50 times for a given size of propeller means; or expressed in other terms the diameter of the propeller means can be reduced to 1/7 for the same power output.

The propeller means in the apparatus according to the invention can thus be given smaller dimensions, thus facilitating the constructional embodiment of the apparatus, while its constructional costs can be reduced at the same time.

The invention will be described in the following while referring to the attached drawings, on which embodiments of the invention are schematically illustrated as examples.

On the drawings,

Figure 1 shows perspectively an apparatus according to the invention, with a buoyant body and two tubes, while

Figure 2 is a part longitudinal section view of Figure 1.

Figures 3 and *4* show alternative forms of a detail of the apparatus.

The chief components of the apparatus shown in Figure 1 are two elongate open-ended tubes 1 and a buoyant body 2, all rigidly mounted on a frame 3 which is attached to the sea floor by a mooring 4 in a way which permits substantially unrestricted movement of the body 2 in an essentially vertical direction in conjunction with the wave movement. The buoyancy of the body 2 is so chosen, and the length of each tube 1 is so arranged, that the upper ends of the tubes come under the water surface 6.

In the part sectional view shown in Figure 2 of the apparatus in Figure 1 there may be seen energy converting means 7 with propeller means 8 and an electrical generator 9 mounted in each of the tubes 1. The propeller means 8 are incorporated into a constriction 10 in the bore of the tube and are placed in the upper ends of the tubes for ease of accessibility when repairing or servicing. The directions of rotation of the propeller means 8 in both means are suitably arranged so that the whole apparatus does not rotate about its vertical axis in the water.

The tube 11, 21 shown in Figures 3 and 4 is cylindrical and has considerable length in relation to its diameter, the ratio of length to diameter being between 5:1 and 20:1. Inside the tube 11, 21, and with its center coinciding with the axis of the tube, there is arranged the propeller means 12, 22, its axis of rotation coinciding with the axis of the tube. The tube 11, 21, may thus be said to form a turbine housing open at both ends. Fairings 13, 23 and 13′, 23′, respectively, extending upwards and downwards from the propeller means are formed to constrict the flow of water through the tube 11, 21. The ratio between the diameter of the constriction to the diameter of the tube is between 1:1.25 and 1:2.5. The constriction, of course, increases the flow velocity of the water past the propeller means 12, 22. In the embodiment according to Figure 3, both constriction fairings 13, 13′ are fixedly attached to the tube 11, and form at the same time a casing for one or more electricity generators 14, coupled to the rotor shaft 15 rotating in the bearings 16, 17. In the embodiment according to Figure 4 the lower constriction fairing 23 is rigidly connected to the tube 21 and contains bearing 26 for the lower end of the rotor shaft 25. The upper fairing 23′ is either fixedly (i.e. as illustrated) or rotatably connected to the rotor shaft 25 via the bearing 27 and rotates with the shaft or is stationary. The generator coupled to the shaft 25 is in Figure 4 placed within the buoyant body at the water surface, and is thus not shown on the drawings. The propeller means 12, 22 is so designed that its blades are pivotal between two pitch settings and are automatically moved from one setting to the other by the water when the latter changes its direction of flow in the tube. This resetting is indicated by the dashed lines 18′, 28′ on the respective figures.

WHAT WE CLAIM IS:-

1. Apparatus for utilising kinetic energy stored in the swell or wave movement of water, comprising a buoyant body located at the water surface and anchored in a way which permits substantially unrestricted movement thereof in an essentially vertical direction in conjunction with the wave movement;

energy-converting means carried by the buoyant body and comprising a substantially vertical open-ended elongate tube rigidly secured to said body, both ends of said tube being beneath the water surface; and

propeller means mounted in said tube adjacent the upper end thereof.

2. Apparatus as claimed in claim 1, wherein the bore of the tube is constricted at the location of the propeller means for increasing the flow velocity of the water past the propeller means.

3. Apparatus as claimed in claim 2, wherein the ratio between the diameter of

the constriction to the diameter of the tube is between 1:1.25 and 1:2.5.

4. Apparatus as claimed in any preceding claim, wherein the ratio between the length of the tube and its diameter is between 5:1 and 20:1.

5. Apparatus as claimed in claim 2, wherein the constriction is provided by two fairings rigidly attached to the tube and forming casings for one or more electricity generators driven by said propeller means.

6. Apparatus as claimed in claim 2, wherein the constriction is provided by two fairings of which one is rigidly attached to the tube and the other is rigidly attached to said propeller means.

7. Apparatus as claimed in any preceding claim, wherein said propeller means comprises a plurality of blades which are pivotal between a first pitch setting and a second pitch setting and are automatically positioned in one of said settings according to the direction of water flow past the propeller means, whereby the propeller means rotates unidirectionally.

8. Apparatus for utilizing kinetic energy stored in the swell or wave movement of water substantially as hereinbefore described with reference to any one of the embodiments illustrated in the accompanying drawings.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1

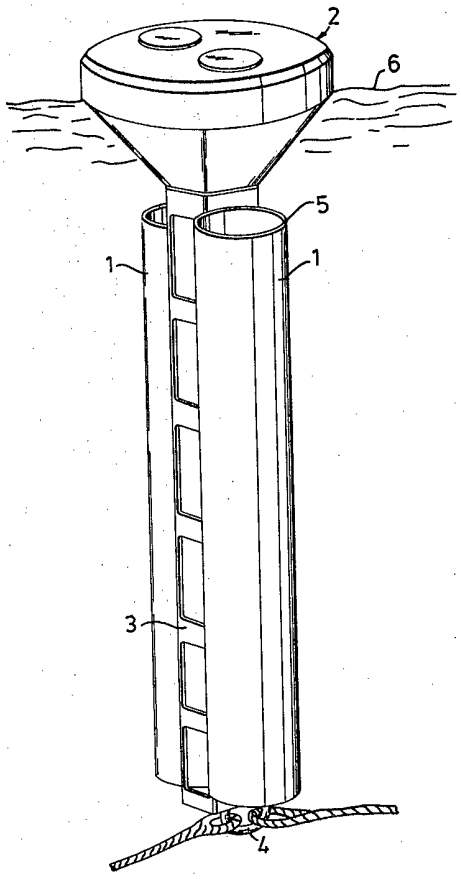
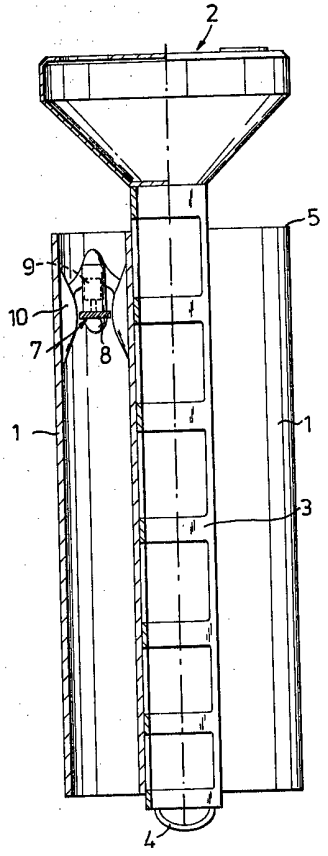


Fig. 2



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Sheet 2

Fig. 3

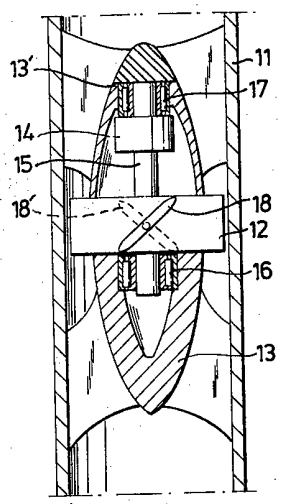

Fig. 4