

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
5 August 2004 (05.08.2004)

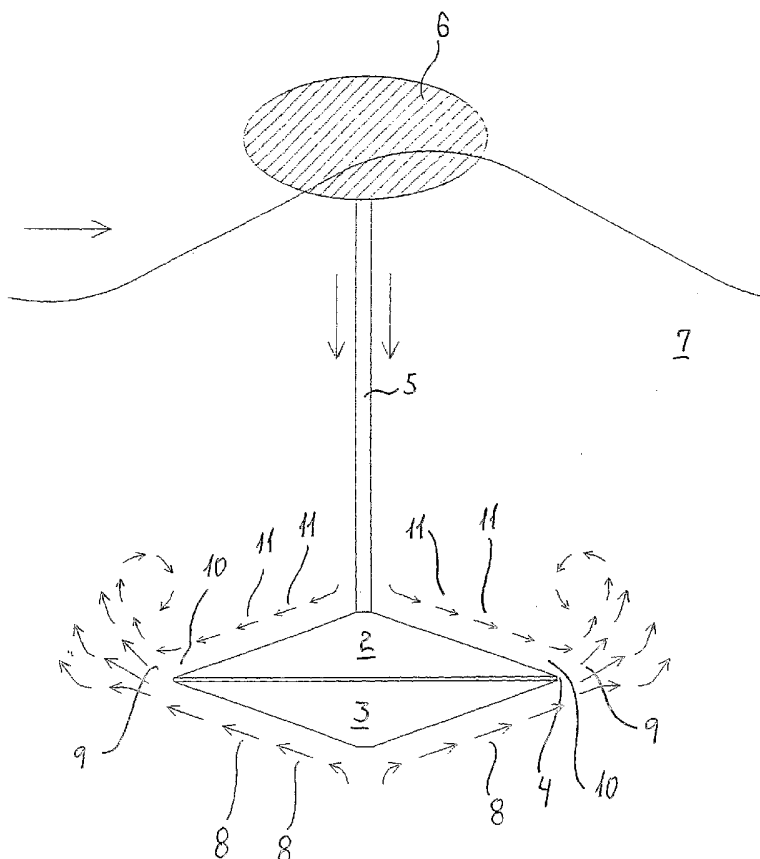
PCT

(10) International Publication Number
WO 2004/065785 A1

- (51) International Patent Classification⁷: F03B 13/20, 13/18
- (21) International Application Number: PCT/DK2004/000031
- (22) International Filing Date: 20 January 2004 (20.01.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: PA 2003 00050 20 January 2003 (20.01.2003) DK
- (71) Applicant and
- (72) Inventor: MOGENSEN, Torben, Veset [DK/DK]; Grevens Dal 19, DK-3760 Gudhjem (DK).
- (74) Agent: PATENTGRUPPEN ApS; Arosgaarden, Aaboulevarde 31, DK-8000 Aarhus C (DK).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: SEA WAVE ENERGY CONVERTER



(57) Abstract: An apparatus is disclosed for converting energy from the motion of sea waves into transmissible power, preferably electrical power. The invention utilises the surface waves to drive a subsurface, flow generating body in a reciprocating motion by connecting the body to a buoyancy member, i.e. a float. This motion generates a water flow along the surface of the body, and the water flow may be converted into a transmissible power, e.g. by driving a rotation of the flow generating body or by driving one or more rotors arranged in the generated water flow. The flow direction near the upper as well as the lower surface of the submerged flow generating body for most operational conditions is the same for both directions of movement in the reciprocating motion, and the generated water flow may be utilised to drive a rotation of the body or a rotor in a constant direction, regardless of the direction of movement. Thus, the surface waves may be utilised at both directions of movement without requirement of repeatedly adjustment of blades or other flow engaging parts.

WO 2004/065785 A1



Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SEA WAVE ENERGY CONVERTER

The present invention relates to an apparatus for converting energy from the motion of sea waves into transmissible power, preferably electrical power.

5

The invention utilises the surface waves to drive a subsurface, flow generating body in a reciprocating motion by connecting the body to a buoyancy member, i.e. a float. This motion generates a water flow along the surface of the body, and the water flow may be converted into a transmissible power, e.g. by driving a rotation of the flow generating body or by driving one or more rotors arranged in the generated water flow.

10

It has been found that the flow direction near the upper as well as the lower surface of the submerged flow generating body for most operational conditions is the same for both directions of movement in the reciprocating motion, and the generated water flow may be utilised to drive a rotation of the body or a rotor in a constant direction, regardless of the direction of movement. This effect is found even for a flat plate body, but it is preferred that the outline of a vertical cross-section of the body generally follows a triangular shape with respect to the upper as well as to the lower surface.

20

BACKGROUND

Many attempts have been made at utilising the motion of the sea waves to generate transmissible power by driving floats up and down. One specific type of devices uses a float at the water surface to drive a reciprocating, vertical motion of a submerged body, so that the relative motion between the submerged body and the surrounding sea water can be used to drive a power generating device, such as a rotor coupled to an electrical generator.

25

US-A-4 359 868 discloses such device, in which a float drives a reciprocating motion of a bucket wheel or a bucket chain which will rise and fall in the water in

30

accordance with the surface waves, causing the wheel or chain to rotate or circulate in one direction, regardless of the direction of motion. However, the efficiency of the bucket wheel is limited by the drag by the water on the backside of the buckets as they move through the water.

5

DE 35 08 780 A1 discloses another device, in which a float drives a reciprocating motion of a propeller-like turbine that is arranged horizontally in a radial direction with propeller shaft perpendicularly to the normal water line. The propeller blades automatically adjust the pitch to the change in direction of incident flow on the propeller with the change of direction of movement of the propeller. Thereby, the propeller always has the same direction of rotation, which improves the efficiency of the device as compared to one, where the direction of rotation changes. A drawback of the disclosed device is that the mechanism for changing the pitch of each of the blades is complicated and expensive to manufacture and is sensitive to the severe environment of the sea.

10
15

DE 199 32 004 A1 and US 4 447 740 both disclose other devices with a horizontally arranged propeller-like turbine, in which the pitch of the blades is changed by the change in relative direction of flow of the water. In DK 94 00381 U it is claimed that a propeller-like turbine with the same direction of rotation regardless of the direction of the movement is obtained with wedge-shaped vanes, but no details are given in the document.

20

Although the efficiency of power converting is quite good for the devices with horizontally arranged propeller-like turbines with adjustable blades, the mechanisms for adjusting the blades cannot be realised without being complicated and expensive to manufacture, and the mechanisms will be sensitive to the severe environment of the sea, both with respect to the physical forces in high waves and with respect to the corrosive sea water, that may enter sealed openings around axels for turning the blades. Also, the repeated adjustments of the blades expose the mechanisms to wear, in particular because the adjustment movements are started and stopped twice for

25
30

each cycle of the reciprocating motion, each stop requiring to the mechanism to absorb the kinetic energy of the pitching blades. The wear can be fatal to the practical use of the device for producing power from sea waves, as any repairing of maintenance of sea based plants is complicated and expensive to perform, and the operational reliability of the plant is therefore crucial.

Thus, it is an object of the present invention to provide a device for converting sea wave energy into transmissible power, such as electrical power, with a float driving a reciprocating motion of a submerged body, in which a high efficiency is obtained with a simpler mechanical design that does not require repeatedly adjustment of blades or other flow engaging parts.

This object is reached by the present invention, in which the submerged body has one upper, closed surface generally facing the float when the device is placed in water, and one lower, closed surface generally facing away from the float. The closed upper and lower surfaces will generate a near-surface water flow relative to the submerged body in the direction towards the edge of body when moving in both directions of the reciprocating movement of the submerged body, and the device comprises flow converter means arranged for converting this water flow into transmissible power, preferably electrical power. The converter means may e.g. comprise vanes on the submerged body to make it rotate or turbine rotors arranged in the generated water flow. Thus, the device may convert wave energy during the full cycle of the reciprocating movement without any adjustment to the change in direction of movement.

25

BRIEF DESCRIPTION OF THE INVENTION

Thus, the present invention relates to a wave energy converter apparatus comprising a buoyancy member, i.e. a float, an underwater, flow-generating member, which is submerged in the seawater during operation of the apparatus,

30

connection means connecting the buoyancy member and the flow-generating member, so as to transfer the movement of the buoyancy member to the flow-generating member,

said flow-generating member defining one upper, closed surface and one lower,
5 closed surface, the apparatus further comprising

flow converter means arranged for converting water flow generated along at least one of said surfaces by the reciprocating, preferably substantially vertical movement of the flow-generating member caused by surface waves acting on the buoyancy member, into transmissible power.

10

The upper surface is for most embodiments of the present invention generally facing the buoyancy member when the apparatus is placed in water, whereas the lower surface is generally facing away from the buoyancy member. However, this is not the case for certain embodiments as shown below.

15

The connection means may be a chain or a wire and only transmit the upward pull from the buoyancy member to the flow-generating member, so that the downward movement of the flow-generating member is effectuated by the force of gravity on the flow-generating member. Alternatively, the connection means may be a stiff
20 connection that links the buoyancy member and the flow-generating member together to a single unit, or the stiff connection may have one or more cardan joints so that torque may be transmitted through the connection means.

The transmissible power is preferably electrical power, but hydraulic power,
25 pneumatic power as well as mechanical power could alternatively be utilised.

In a preferred embodiment, the flow-generating member is rotational symmetrical with respect to a vertical centre axis, and the distance of the upper surface, respectfully the lower surface, from the meeting plane of said two surfaces, is non-
30 increasing from the centre axis and outwardly. Preferably, the distance is decreasing in most of or all of the area from the centre axis and to the edge of the surfaces, so

that the near-surface water flow is assisted. It is particularly preferred that the upper surface is defined by a smooth curve, i.e. with a continuous derivative, rotated about said axis. One preferred curve is a straight line, forming a conical upper surface, but also hyperbolic curves, logarithmic curves, polynomial curves, circular arcs and elliptic arcs may be employed together with other smooth curves. The purpose of the shape of the upper surface is to assist the near-surface flow with as few losses as possible, in particular by preventing the formation of separated zones of the flow for both directions of movement of the flow-generating member. The Reynolds number of the flow-generating member controls the tendency to separation and depends on the product of the diameter of the member and the flow velocity. The tendency to separation of the flow is proportional to magnitude of the Reynolds number.

Likewise, the lower surface may be defined by a smooth curve rotated about said axis. The lower surface may mirror the upper surface, but the two surfaces may also vary in shape, depending on the operational conditions, i.e. on whether the velocities in the upward motion and the downward motion of the flow-generating member are similar.

The two surfaces meet in a plane that under operational conditions is substantially horizontal. The edge is preferably sharp or thin compared to the other dimensions of the flow-generating member so as to prevent formation of eddies near the edge.

The flow converter means may according to one, preferred embodiment comprise vanes arranged on the flow-generating member to drive a rotation of said member by means of said water flow, in particular of rotational symmetrical members as previously discussed. The rotation of the member is then transformed to a transmissible power, either in the flow-generating member or in the buoyancy member. It is required that a counter-torque is provided, e.g. via the anchoring of the device to the ground and/or by fins on the buoyancy member.

Alternatively, the apparatus may comprise a plurality of flow-generating members with opposite directions of rotation and coupling means for mutual coupling of said flow-generating members to outbalance the torque. Thereby, the plurality of flow-generating members constitutes a unit that may be in balance with respect to torque,
5 which the connecting means does not have to be able to transfer torque to the buoyancy member.

Alternatively or additionally, the connection means may be suitable for transmitting a torque between the buoyancy member or members and the flow-generating
10 member, from either an unbalanced buoyancy member or from a plurality of only partly torque-balanced buoyancy members.

In particular, the connection means may be suitable for transmitting the rotation of the flow-generating member to the buoyancy member, and the buoyancy member
15 may comprise means for converting said rotation into transmissible power, in particular into electrical power. It is preferable that such apparatus comprises a plurality of flow-generating members with opposite directions of rotation and coupled to the same buoyancy member, so as to outbalance the torque.

20 In a second embodiment, the apparatus according to the present invention comprises a flow-generating member, which has a substantially constant cross-sectional outline along a longitudinal direction of said member and is symmetrical with respect to a vertical centre plane extending in the longitudinal direction, wherein the distance of the upper surface, respectively the lower surface, from the meeting plane of said two
25 surfaces, is non-increasing from the centre plane and outwardly. The outline of such flow-generating member will typically be quadratic or rectangular as exemplified in the accompanying figures. The flow-generating members of this second embodiment of the present invention are not rotating, but the reciprocating movement thereof generates a water flow of a constant direction, which can be utilised. The upper
30 surface of the flow-generating member is preferably defined by a smooth curve, such as a straight line, extending perpendicularly from the centre plane, and likewise is the

lower surface is also preferably defined by a smooth curve, such as a straight line, extending perpendicularly from the centre plane.

5 The flow converter means for the second embodiment of the present invention comprises in a preferred embodiment means for deflecting and collecting said generated water flow to a common flow converter device. Various examples are given in the detailed description of some examples of embodiments of the invention below.

10 Alternatively, the flow converter means for an apparatus according to the second embodiment of the present invention may comprise a plurality of rotors arranged in said generated water flow.

The length of the path of the movement through the water of the flow-generating member should be long as compared to the maximum diameter thereof, preferably at 15 least three times the maximum diameter, in order to obtain a high efficiency of the apparatus. The flow is unstable at the beginning of an upward or downward movement and the efficiency in that part of the path is consequently low. With an elongation of the path, the effect of this instability is diminished and the overall 20 efficiency of the apparatus is improved. Also, the speed with which the flow-generating member moves through the water along its path should exceed a lower threshold value to ensure that the advantageous flow pattern near the surfaces of the member is established correctly and the efficiency of the apparatus has shown to be generally proportional to the speed of the flow-generating member.

25

Thus, it is advantageous that a gearing is arranged between the buoyancy member and the flow-generating member so that the length of the path the flow-generating member moves through the water is longer than the path of the buoyancy member, preferably with a factor of 1.5 to 8, and most preferred with a factor of 2 to 5. The 30 gearing may advantageously be constituted by a hinged lever arm to which the buoyancy member as well as the flow-generating member is connected.

A flow pattern in the water originating from other sources than the flow-generating member, e.g. a current in the water and/or wave-induced vortices below the water surface may have a negative effect on the efficiency of the apparatus as it disturbs the
5 desired flow pattern near the surfaces of the flow-generating member. In order to delimit this negative effect, a shielding member may be arranged around the flow-generating member.

Thus, the apparatus may further comprise a shielding member with an inner wall
10 substantially parallel to the path of the flow-generating member through the water and enclosing the flow-generating member along at least a substantial part of said path. The area of the cross-sectional opening of the shielding member enclosing the flow-generating member is preferably within the range of 1.2 to 2 times the maximum cross-sectional area of the flow-generating member, most preferred within
15 the range of 1.3 to 1.7.

The shielding member may be arranged to follow the movements of the flow-generating member along said path. The shielding member may comprise funnel-shaped end openings at one or both ends thereof, as shown also in US 4 447 740, of
20 an opening area of 1.2 to 5 times the area of the cross-sectional opening of the shielding member enclosing the flow-generating member, preferably 1.5 to 3 times that area. Alternatively, the shielding member may be stationary, so that the flow-generating member moves reciprocally within the shielding member.

25 BRIEF DESCRIPTION OF THE FIGURES

A number of examples of embodiments of the present invention are given in the accompanying drawing, of which

Fig. 1 shows a flow-generating member as seen from the side,

30

Fig. 2 shows a rotational-symmetric flow-generating member with the outline as shown in Fig. 1,

5 Fig. 3a is a first section of the flow-generating member as shown in Fig. 2 along the line A-A,

Fig. 3b is a second section of the flow-generating member as shown in Fig. 2 along the line B-B,

10 Fig. 4 is a schematic view of the flow generated around the flow-generating member of Fig. 1 connected to a buoyancy member and moving upwards,

Fig. 5 is a schematic view of the flow generated around the flow-generating member of Fig. 4 moving downwards,
15

Fig. 6 is a side view of the flow-generating member of Figs. 1 and 2 having vanes on the upper surface as well as the lower surface,

Fig. 7 is a view of the flow-generating member of Fig. 6 as seen from C-C,
20

Fig. 8 shows six examples of the arrangement of vanes on rotational-symmetrical flow-generating bodies as seen from above,

Fig. 9 is a cross-section of a rotational-symmetrical flow-generating body with vanes and guide plates for directing and stabilising the generated flow,
25

Fig. 10 is a view from above of the flow-generating body of Fig. 9, in which the section shown in Fig. 9 is indicated as D-D,

30 Fig. 11 shows a side view of a rotational-symmetrical flow-generating body with vanes, in which the upper surface is conical and the lower surface is flat,

Fig. 12 shows the flow-generating body of Fig. 11 as seen from above, indicated as E-E,

- 5 Fig. 13 shows a side view of a rotational-symmetrical flow-generating body with vanes, in which the upper surface as well as the lower surface is flat,

Fig. 14 shows the flow-generating body of Fig. 13 as seen from above,

- 10 Fig. 15 shows an embodiment of a flow-generating member as seen from the side,

Fig. 16 demonstrates the design of a flow-generating body of the type shown in Fig. 15,

- 15 Fig. 17 demonstrates a second design of a flow-generating body of the type shown in Fig. 15,

Fig. 18 is a side view of a rotational-symmetrical flow-generating body of the type shown in Fig. 15 arranged with vanes,

20

Fig. 19 is the flow-generating body of Fig. 18 as seen from above,

Fig. 20 is a perspective view of the flow-generating body of Figs. 18 and 19,

- 25 Fig. 21 is a side view of a rotational-symmetrical flow-generating body of the type shown in Fig. 15 arranged with vanes and guide plates for directing and stabilising the generated flow,

Fig. 22 is the flow-generating body of Fig. 21 as seen from above,

30

Fig. 23 is a cross-section of the flow-generating body of Figs. 21 and 22 along A-A on Fig. 22,

Fig. 24 is a perspective view of the flow-generating body of Figs. 21-23,

5

Fig. 25 is a top view of a rotational-symmetrical flow-generating body of the type shown in Fig. 15 arranged with vanes on a flat annular plate extending from the periphery of the body,

10 Fig. 26 is a side view of the flow-generating body of Fig. 25,

Fig. 27 is an illustration of the design of the vanes of the flow-generating body of Fig. 25,

15 Fig. 28 is a side view of an apparatus with the flow-generating body of Figs. 18-20 connected to an elongated buoyancy member,

Fig. 29 is the apparatus of Fig. 28 as seen from below,

20 Fig. 30 is a perspective view of the apparatus of Figs. 28 and 29,

Fig. 31 shows an embodiment of a flow-generating member as seen from the side,

Fig. 32 shows five embodiments a-e of cross-sections of buoyancy members,

25

Fig. 33 is a side view of an apparatus with eight rotational-symmetrical flow-generating members of the type shown in Fig. 15,

Fig. 34 is the apparatus of Fig. 33 as seen from F-F,

30

Fig. 35 is a side view of an apparatus with three rotational-symmetrical flow-generating members of the type shown in Fig. 15,

Fig. 36 is the apparatus of Fig. 35 as seen from F-F,

5

Fig. 37 is a side view of three apparatuses a-c with different embodiments of the section connecting the buoyancy member and the flow-generating body,

Fig. 38 is a side view of an apparatus, in which the connecting part between a buoyancy member and a plurality of flow-generating bodies forms a rigid structure,

10

Fig. 39 is a side view of an apparatus with a plurality of flow-generating bodies mutually connected to a torque-balancing body, with a common torque-transmitting connection to the buoyancy member with a flexible link,

15

Fig. 40 is a side view of two apparatuses with different longitudinal extension between the buoyancy member and the flow-generating body,

Fig. 41 is a side view of an apparatus with a non-rotating flow-generating body,

20

Fig. 42 is the flow-generating body of the apparatus of Fig. 41 as seen from above from H-H,

Fig. 43 is a side view of a second apparatus with a non-rotating flow-generating body,

25

Fig. 44 is the flow-generating body of the apparatus of Fig. 43 as seen from above from K-K,

Fig. 45 is the flow-generating body of the apparatus of Fig. 43 as seen from the side from L-L,

30

Fig. 46 is a cross-section of an apparatus with a non-rotating flow-generating body and comprising means for deflecting and collecting the generated water flow to a common flow converter device,

5

Fig. 47 is the flow-generating body of the apparatus of Fig. 46 as seen from above; the cross-section shown in Fig. 46 is indicated with the line M-M,

Fig. 48 is a cross-section of a second apparatus with a non-rotating flow-generating
10 body and comprising means for deflecting and collecting the generated water flow to a common flow converter device,

Fig. 49 is the flow-generating body of the apparatus of Fig. 48 as seen from above; the cross-section shown in Fig. 48 is indicated with the line N-N,

15

Fig. 50 is a cross-section of a third apparatus with a non-rotating flow-generating body and comprising means for deflecting and collecting the generated water flow to a common flow converter device,

20 Fig. 51 is the flow-generating body of the apparatus of Fig. 50 as seen from above; the cross-section shown in Fig. 50 is indicated with the line N-N,

Fig. 52 is a side view of an apparatus having one buoyancy member and five rotational-symmetrical flow-generating members of the type shown in Figs. 18-20,

25

Fig. 53 is the apparatus of Fig. 52 as seen from below,

Fig. 54 is a perspective view of the apparatus of Figs. 52 and 53,

30 Fig. 55 is a side view of an apparatus having a flow-generating member enclosed in a tubular shielding member fastened to the buoyancy member of the apparatus,

Fig. 56 is a cross-section of a shielding member and a flow-generating member of the apparatus of Fig. 55,

- 5 Fig. 57 is a side view of a shielding member and a flow-generating member of the apparatus of Fig. 55 with indication of flow pattern,

Fig. 58 is a side view of a first apparatus, in which a lever arm hinged to a stationary construction connects the buoyancy member and the flow-generating member,

10

Fig. 59 is a side view of a second apparatus, in which a lever arm hinged to a stationary construction connects the buoyancy member and the flow-generating member,

- 15 Fig. 60 is an end view of the apparatus of Fig. 59,

Fig. 61 is a side view of a modification of the apparatus of Figs. 59 and 60, and

- 20 Fig. 62 is a side view of a third apparatus, in which a lever arm hinged to a stationary construction connects the buoyancy member and the flow-generating member.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE PRESENT INVENTION

A number of different embodiments of the present invention are presented in the
5 figures.

Figs. 1 and 2 shows a rotational-symmetric flow-generating member 1 with the
outline of two cones or frustro-cones, defining an upper surface 2 and a lower surface
3, the base planes of which meets in a horizontal plane 4. The upper and lower
10 surfaces 2, 3 are in this embodiment symmetrical with respect to the meeting plane 4,
but this is not necessarily the case, cf. Figs. 11 and 31. The optimal shape of the
surfaces 2, 3 depends on the operational conditions, which again to a large extent
depend on the magnitude of the buoyancy forces and gravity forces acting on the
apparatus, i.e. whether the design of the apparatus will cause the flow-generating
15 member 1 to move fastest in the upward motion, the downward motion or with equal
magnitudes of speed. The flow-generating member 1 of this embodiment is designed
to be driven in a rotational motion by the generated water flow, and the torque is
transmitted to the buoyancy member 6 by a shaft 5 connecting the flow-generating
member 1 and the buoyancy member 6. An electrical generator is situated in the
20 buoyancy member 6 to convert the torque to electrical power.

Cross-sections of the flow-generating member 1 along the lines A-A in the meeting
plane 4 and B-B in the upper surface 2 are shown in Figs. 3a and 3b.

25 The quality of the flow-generating member 1 is that the flow generated near its
surfaces 2, 3 has the same direction whether the member 1 moves upwards or
downwards in the water, as demonstrated in Figs. 4 and 5. This feature is present for
the rotational-symmetrical flow-generating members 1 as shown in Fig. 1 as well as
for the members 1 with a constant cross-section along a longitudinal direction as
30 shown later in Figs. 41-51.

Fig. 4 is a schematic view of the flow generated around the flow-generating member 1 with the outline of Fig. 1 connected to a buoyancy member 6 and moving upwards, driven by the buoyancy of the buoyancy member 6 caused by the surface wave rising the level of the water surface. The illustrated flow is in cross-section almost identical for the rotational-symmetrical embodiments of the member 1 and for the members 1 with a constant cross-section in a longitudinal direction. The surrounding water 7 is generally substantially stationary, at least as compared to the speed of motion of the reciprocating vertical movement of the flow-generating member 1. The upwards movement of the member 1 generates a relative flow of water past the upper surface 2 and the flow of water will take a radial path near the surface 2 as illustrated with arrows 8. At the outer edge 9 of the upper and lower surface in their meeting plane 4, the speed of the generated water flow will create a high dynamic pressure and a corresponding low static pressure as described by Bernoulli's equation. The displacement of the lower surface 3 upwards creates a low pressure below it, which causes a recirculation of water to be formed as large eddies (not shown). The low static pressure at the outer edge 9 drives a water flow from the edge-near area 10 near the lower surface 3, which stabilises the formation of the large eddies in the water below the lower surface 3. These relatively stable large eddies will form a radial water flow 11 along and near the lower surface 3 towards the outer edge area 9 thereof. Thus, the water flow 8, 11 has the same radial direction towards the outer edge area 9 near the upper 2 as well as the lower surface 3. The water flow 8, 11 is indicated relatively to the member 1 and not to the surrounding water 7. The flow pattern shown in Fig. 4 is the one occurring in the middle part of an upward movement of the member 1 as the flow pattern is much more complex at the beginning and the end of such movement.

Turning now to Fig. 5, the apparatus of Fig. 4 is shown in a downward movement of the flow-generating member 1 caused by the gravity force on the apparatus and the reduced buoyancy force of the buoyancy member 6 caused by the surface wave lowering the level of the water surface. The flow near the surfaces 2, 3 of the flow-generating member 1 is now driven by the opposite causes as discussed relating to

Fig. 4, and the reference numbers 8, 10 and 11 now refer to the same phenomena as in Fig. 4 but for the opposite surface 2, 3. The water flow 8, 11 generated in the near-surface areas as well as in the near-edge area 9 has generally the same radial direction relative to the flow-generating member 1 for both directions of movement in the reciprocation vertical motion of the flow-generating member 1, which allows for utilisation of said flow to generate transmissible power with flow converter means that are of a simpler mechanical design that does not require repeatedly adjustment of blades or other flow engaging parts when the direction of movement of the flow-generating member 1 is altered in the reciprocating vertical motion. In Fig. 5, more of the flow pattern near the outer edge 9 is illustrated with the arrows and the formation of a large eddy above the upper surface 2 is indicated, which has a stabilising effect on the direction of the flow 11 near the upper surface 2.

One type of flow converter means are shown in the embodiment in Figs. 6 and 7, where Fig. 6 is a side view of the flow-generating member 1 of Figs. 1 and 2 having vanes 12 on the upper surface 2 as well as the lower surface 3, and Fig. 7 is a view of the flow-generating member 1 of Fig. 6 as seen from C-C. The vanes 12 will interact with the generated water flow near the surfaces 2, 3 to drive a rotational motion of the flow-generating member 1 about its vertical centre axis. The rotational motion may be transmitted to the buoyancy member 6 for conversion into a transmissible power as described previously, or the connecting member 5 may be stationary and provide the necessary holding torque for allowing conversion means within the flow-generating member to produce a transmissible power, such as electrical power or a water flow, e.g. inside the connecting member 5, to be utilised exterior to the apparatus.

Fig. 8 shows six examples of the arrangement of vanes 12 on rotational-symmetrical flow-generating bodies 1 as seen from above, wherein only a selected number of vanes 12 are marked with reference number. The vanes 12 of the example to the left in the lower row extend beyond the actual edge 13 of the upper and lower surfaces 2, 3 to utilise the flow in the near-edge area 9. Thereby, an improved efficiency of the

apparatus is obtained, but the distal ends of the vanes 12 are not supported on the flow-generating member 1 and the mechanical construction therefore requires a more complex design. The vanes 12 may be manufactured as separate items from e.g. stainless steel and be fastened to the body of the flow-generating member 1, or the
5 vanes 12 may be formed integral with the surfaces 2, 3, e.g. moulded in a plastics material or a fibre-reinforced matrix of resin or cast in concrete.

The embodiment in Figs. 9 and 10 comprises such vanes 12 extending beyond the edge 13 of the flow-generating member 1 as well as guide plates 14 for directing and
10 stabilising the generated flow towards the near-edge area 9, where it interacts with the distal part 15 of the vanes 12. The guide plates 14 further improve the efficiency of the apparatus and partly support the distal part 15 of the vanes 12.

Fig. 9 is a cross-section of the an rotational-symmetrical flow-generating body 1 with
15 vanes 12 and guide plates 14 and Fig. 10 is a view from above of the flow-generating body 1, in which the section shown in Fig. 9 is indicated as D-D,

Yet another example is shown in Figs. 11 and 12, where Fig. 11 shows a side view of a rotational-symmetrical flow-generating body 1 with vanes 12 on the upper surface
20 2 alone, in which the upper surface 2 is conical and the lower surface 3 is flat, and Fig. 12 shows the flow-generating body 1 of Fig. 11 as seen from above, indicated as E-E. The constructional design is much simpler than that of ones with a conical shape of the lower surface 3 as well, but the efficiency is only lowered slightly if the whole apparatus is designed so that the most energy is collected in the upward movement of
25 the reciprocating flow-generating body 1.

The fundamental and probably most simple design of a flow-generating body 1 is shown in Figs. 13 and 14. Fig. 13 shows a side view of a rotational-symmetrical flow-generating body 1 with vanes 12, in which the upper surface 2 as well as the
30 lower surface 3 is flat, and Fig. 14 shows the flow-generating body 1 of Fig. 13 as seen from above. The efficiency of this embodiment is lower than that of the more

streamlines designs, due to the tendency to formation of unstable separation of the water flow relatively to the flow-generating means 1, but the shown embodiment is fully operating in accordance with the present invention and producing transmissible power.

5

A different outline of the flow-generating member 1 is shown from the side in Fig. 15, in which the upper and lower surfaces 2, 3 follow a decreasing curve from the centre and towards the outer edge 13 being different from the straight line shown previously. The slope of the tangent to the surface 2, 3 decreases smoothly as well
10 from the centre towards the outer edge 13, which at the same time reduces the tendency to separation of the flow, as known from the flat plate shown in Figs. 13 and 14, and reduces the losses of turning the direction of the radial water flow to a horizontal flow as compared to the straight outline of the flow-generating bodies of a triangular cross-section. The curve may e.g. be an arc of a circle as illustrated in Fig.
15 16, an arc of an ellipsis as illustrated in Fig. 17, a polynomial curve, a parabolic or hyperbolic curve, etc.

A rotational-symmetrical flow-generating body 1 with the outline of the type shown in Fig. 15 and arranged with vanes 12 is shown in a side view in Fig. 18, as seen
20 from above in Fig. 19 and in a perspective view in Fig. 20. This embodiment is similar to the one shown in Figs. 6 and 7.

A rotational-symmetrical flow-generating body 1 with the outline of the type shown in Fig. 15 arranged with vanes 12 and guide plates 14 for directing and stabilising the
25 generated flow is shown in a side view in Fig. 21, as seen from above in Fig. 22, in Fig. 23 in a cross-section of the flow-generating body 1 along A-A on Fig. 22, and in a perspective view in Fig. 24. This embodiment is similar to the one shown in Figs. 9 and 10.

30 A preferred embodiment of a rotational-symmetrical flow-generating body 1 arranged with vanes 12 is shown in Figs. 25 and 26 in a top view and a side view,

respectively. The central part of the body 1 is of the type shown in Fig. 15, of which the periphery in the horizontal centre plane is extended as a flat annular plate extending from the periphery of the body 1, on which the vanes 12 are arranged. The central part of the body 1 extends over about a third of the total diameter of the body 1 and has the function of guiding the correct direction of the flow near the shaft 5, which is the most critical part of the flow. The vanes 12 are designed as illustrated in Fig. 27 so that the curvature of the vane 12 at the end A closer to the shaft 5 is larger than the curvature of the vane 12 at the end B near at the outer edge of the body 1. The height of the vane 12 above the body 1 increases from the inner end A towards the outer end B thereof, in particularly as shown with a height of zero at A, increasing with a constant slope along the vane 12 to the outer end B. However, other starting heights than zero may be employed and the slope may e.g. be parabolic, exponential etc. The low vane 12 at the inner end A directs the flow path along the surface 2, 3 with a minimum of friction between the vane 12 and the water 7, whereas the high vane 12 at the outer end B transfers the kinetic energy from the water flow into rotation of the body 1 with a high degree of efficiency and utilisation. Thus, by increasing the height of the vane 1 from the inner end A thereof to the outer end B, a balance between frictional losses and gain of energy is obtained.

Fig. 28 is a side view of an apparatus with the flow-generating body 1 of Figs. 18-20 connected to an elongated buoyancy member 6, Fig. 29 is the apparatus of Fig. 28 as seen from below and Fig. 30 is a perspective view of the apparatus of Figs. 28 and 29. However, the vanes 12 extend beyond the edge 13 of the flow-generating body 1 and have free, distal ends 15. The elongated shape of the buoyancy member 6 helps providing the holding torque for the apparatus to produce transmissible power from the rotation of the flow-generating body 1. The buoyancy member 6 may also be fastened to anchoring means, e.g. situated on the bottom of the sea, or to similar buoyancy members 6 to provide the necessary holding torque.

Yet another outline of a flow-generating body 1 is shown in Fig. 31 as seen from the side, in which the shape of the upper surface 2 and the lower surface 3 deviates,

which is advantageous for apparatuses of a design, where the speed of the flow-generating body 1 in the upwards and the downwards direction deviates strongly.

Fig. 32 shows five embodiments a-e of cross-sections of buoyancy members 6, note
5 that the embodiment shown in Fig. 32c is designed for carrying two rotating flow-generating bodies 1, of which one rotates clockwise whereas the other rotates counter-clockwise to provide torque-balance of the apparatus.

An apparatus with one buoyancy member 6 carrying eight rotational-symmetrical
10 flow-generating members 1 of the type shown in Fig. 15 is shown in a side view in Fig. 33 and as seen from F-F in Fig. 34. Every second flow-generating member 1 rotates clockwise and the remaining rotates counter-clockwise to provide a total torque-balance of the apparatus.

15 An apparatus with one buoyancy member 6 carrying three rotational-symmetrical flow-generating members 1 of the type shown in Fig. 15 is shown in a side view in Fig. 35 and as seen from F-F in Fig 36. One of the three flow-generating members 1 rotates opposite the other two to provide a partly outbalancing of the torque of the apparatus.

20

Fig. 37 is a side view of three apparatuses a-c with different embodiments of the section 16 supporting the connection 5 between the buoyancy member 6 and the flow-generating body 1,

25 Fig. 38 is a side view of an apparatus, in which the connecting part 16 between a buoyancy member 6 and a plurality of flow-generating bodies 1 forms a rigid structure, and Fig. 39 is a side view of an apparatus with a plurality of flow-generating bodies 1 mutually connected to a torque-balancing body 17, with a common torque-transmitting connection 5 to the buoyancy member 6 with a flexible
30 link 18, such as a cardan joint, so that the inevitable sideways forces between the

flow-generating bodies 1 and the buoyancy member 6 during operation will not stress the connection 5, which therefore may be of a lighter design.

Fig. 40 is a side view of two apparatuses with different longitudinal extension
5 between the buoyancy member 6 and the flow-generating body 1. It is advantageous for the efficiency of the apparatus that the flow-generating member 1 is positioned in water strata where the surrounding water is substantially at rest and unaffected by the surface waves and the air bubbles that are mixed into the surface water, and it is also advantageous that the distance of the flow-generating member 1 from the
10 surface, that growth of weed on the flow-generating member 1 due to daylight is substantially none. However, the longer the distance between the buoyancy member 6 and the flow-generating body 1, the larger is the magnitude of the torque on the connecting construction 16 due to sideways forces on the flow-generating bodies 1 and the buoyancy member 6. The most advantageous distance will have to be found
15 for the individual installation of an apparatus according to the present invention.

A number of embodiments of the present invention in which the apparatus comprises a flow-generating member 1 with a substantially constant cross-sectional outline along a longitudinal direction of said member 1 and which is symmetrical with
20 respect to a vertical centre plane extending in the longitudinal direction are shown in Figs. 41-51. A generally preferred feature is, that the distance of the upper surface 2, respectively the lower surface 3, from the meeting plane 4 of said two surfaces 2, 3, is non-increasing from the centre plane and outwardly. However, this is not a requirement for the apparatus according to the invention to be operational, a flat plate
25 similar to the one shown in Figs. 13 and 14 but without the vanes 12 could also function according to the invention. The outline of such flow-generating member 1 will typically be quadratic or rectangular.

Fig. 41 is a side view of an apparatus with a non-rotating flow-generating body 1,
30 and Fig. 42 is the flow-generating body 1 of the apparatus as seen from above from H-H. The flow-generating body 1 is equipped with a plurality of turbines 19 arranged

along the edge 13 thereof so that they are situated in the generated water flow in the near-edge area 9. The turbines 19 are hydraulically coupled via the connection 5 to a common turbine driving an electrical generator situated in the buoyancy member 6.

5 A similar construction is exemplified in Figs. 43-45, of which Fig. 43 is a side view of the apparatus with a non-rotating flow-generating body 1, Fig. 44 is the flow-generating body 1 of the apparatus as seen from above from K-K, and Fig. 45 is the flow-generating body 1 of the apparatus as seen from the side from L-L. The upper and lower surfaces 2, 3 of the flow-generating body 1 are equipped with vertical
10 screens 20 to concentrate the generated flow near the surfaces 2, 3 towards the turbines 19 to enhance the efficiency of the apparatus.

Another apparatus with a non-rotating flow-generating body 1 and with screens 21 for deflecting and collecting the generated water flow to a common flow converter
15 device is shown in cross-section in Fig. 46 and as seen from above in Fig. 47; the cross-section shown in Fig. 46 is indicated with the line M-M. The flow generated along the surfaces 2, 3 of the flow-generating body 1 is directed into a central channel 22 within the flow-generating body 1 by means of the two screens 21 arranged in the near-edge area 9 of the body 1.

20 A similar apparatus with a non-rotating flow-generating body 1, wherein the generated flow in the near-edge area 9 is deflected and collected within screens 23 arranged in the area 9, is shown in cross-section in Fig. 48 and as seen from above in Fig. 49; the cross-section shown in Fig. 48 is indicated with the line N-N. The
25 collected flow is directed from the channel 24 within the screens to a common flow converter device.

Yet another apparatus with a non-rotating flow-generating body 1 and comprising means 23 for deflecting and collecting the generated water flow to a channel 24 that
30 directs the flow to a common flow converter device, as well as vertical screens 26 for preventing cross-flow longitudinal of the flow-generating body 1 is shown in Fig. 50

in a cross-section and in Fig. 51 as seen from above; the cross-section shown in Fig. 50 is indicated with the line N-N.

An apparatus having one buoyancy member 6 and five rotational-symmetrical flow-generating members 1 of the type shown in Figs. 18-20 is shown in Fig. 52 in a side view, in Fig. 53 as seen from below, and in a perspective view in Fig. 54. In order to partly outbalance the torque of the apparatus, the first, third and fifth flow-generating members 1 rotate in one direction, whereas the second and fourth flow-generating members 1 rotate in the opposite direction. The rotation of the flow-generating members 1 is transmitted to the buoyancy member 6 by means of the connecting rods 5, where a common electrical generator is arranged.

Flow 27 in the water 7 surrounding the flow-generating member 1 may have a negative effect on the efficiency of the apparatus. Such flow 27 may be a current in the water 7 and/or be generated by the waves, which induces vortices below the water surface. In order to delimit this effect, a shielding member 28 may be arranged around the flow-generating member 1 as illustrated in Figs. 55-57 for rotational-symmetrical flow-generating members 1, but the shielding member 28 may as well be applied to other types of flow-generating members 1.

20

Fig. 55 is a side view of an apparatus having a flow-generating member 1 enclosed in a tubular shielding member 28, which is fastened to the buoyancy member 6 of the apparatus, so that the shielding member 28 moves up and down with the buoyancy member 6 and the flow-generating member 1. The shielding member 28 may in another embodiment have a funnel-shaped opening at the upper and lower end, so that more water is forced through the shielding member 28. Thereby, a better efficiency may be obtained or the diameter of the flow-generating member 1 may be reduced. As an alternative solution the flow-generating member 1 may be enclosed in a stationary tubular shielding member 28 supported on the bottom of the sea. The stationary shielding member 28 may be used to provide the counter-rotational force on the buoyancy member 6 so that other measures are superfluous. However, this

25
30

solution is mainly feasible at lower distances between the bottom of the sea and the water surface or in cases where the apparatus is combined with other off-shore constructions, such as oil production platforms and wind turbines. A cross-section of a shielding member 28 and a flow-generating member 1 of the apparatus is shown in Fig. 56, and it is seen that the cross-sectional area of the flow-generating member 1 is about 2/3 of the total inner cross-sectional area of the shielding member 28. The relative flow pattern around the flow-generating member 1 is illustrated in Fig. 57 for a downward movement of the flow-generating member 1 with the reference numbers used in Figs. 4 and 5. The proximity of the inner wall of the shielding member 28 on the outer edge of the flow-generating member 28 diverges the generated relative flow in a vertical direction and enhances the formation of the large eddies above the upper surface 2 of the flow-generating member 1, thereby further stabilising the advantageous flow pattern near the surface 2. A similar advantage is obtained with the flow near the lower surface 3 at the upward movement of the flow-generating member 1.

It is advantageous for the efficiency of the apparatus that that the length of the path of the movement through the water of the flow-generating member 1 is maximised and that the length preferably is at least three times the maximum diameter of the flow-generating member 1. The flow is unstable at the beginning of an upward or downward movement and the efficiency is consequently low. With a longer path, the effect of this instability is diminished and the overall efficiency is improved. Also, the speed with which the flow-generating member 1 moves through the water should preferably be maximised to ensure that the advantageous flow pattern near the surfaces 2, 3 is established correctly, and the efficiency of the apparatus is proportional to the speed of the flow-generating member.

In order to obtain these advantages, a gearing between the movement of the buoyancy member 6 and the flow-generating member 1 may be established as exemplified in the embodiments in Figs. 58-62. The gearing has the effect that minor

wave heights may be more efficiently utilised and/or that flow-generating members 1 with a larger diameter may be employed for wave heights within a given range.

In Fig. 58 a first apparatus, in which a lever arm 29 is hinged 30 to a stationary construction 31 connects the buoyancy member 6 and the flow-generating member 1 is shown in a side view. A secondary arm 32 is hinged 33 to the construction 31 at a lower position than the first hinge 30, and the shaft 5 of the flow-generating member 1 is hinged 34, 35 to both arms 29, 32 so that the up- and downwards movements of the buoyancy member 6 is transferred to generally up- and downwards movements of the flow-generating member 1. The distance between the hinge 30 of the lever arm 29 and the flow-generating member 1 is three times the distance between the hinge 30 and the buoyancy member 6, so that the speed and path length of the flow-generating member 1 will be three times those of the buoyancy member 6. A transmission system (not shown) for the rotary motion of the flow-generating member 1 to the construction 31 is arranged in one of the arms 29, 32.

A second apparatus, in which a lever arm 29 is hinged 30 to a stationary construction 31 connecting the buoyancy member 6 and the flow-generating member 1 is shown in Figs. 59 and 60 in a side view and an end view, respectively. Only one arm 29 is used, so that the path of the flow-generating member 1 is a circular arc. The arm 29 is furthermore angled at the hinge 30, so that the flow-generating member is positioned well below the flow patterns near the water surface generated by the waves. In fig. 61, a modification of the apparatus of Figs. 59 and 60 is shown in a side view, in which a wave-enhancing member 36 is situated below the path of the buoyancy member 6. The wave-enhancing member 36 has the effect that the wave height is locally enlarged, similarly to the well-known phenomena when sea waves move over an area of lower water depth, and the length of the path of the buoyancy member is consequently enlarged as well. The member 36 has a curved surface 37 where the lowest position 38 points towards the main direction from which the waves arrive. This arrangement is mainly advantageous in areas in which such main direction exists.

Alternatively, the buoyancy member 6 and the flow-generating member 1 may be situated on the lever arm 29 on the same side of the hinge as illustrated in Fig. 62, which is a side view of a third apparatus, in which the lever arm 29 is hinged 30 to a stationary construction 31 connecting the buoyancy member 6 and the flow-generating member 1.

If the apparatuses described above are utilised to generate electrical power, by means of synchronous or asynchronous generators, the frequency of the actuating current AC will vary as power of the flow generated by the flow-generating members 1 varies with the reciprocating motion. Consequently, the torque produced by the flow-generating members or the turbine or turbines driven by the generated water flow will vary. One known solution, similarly to sea-based wind power plants comprising a plurality of wind turbines with variable rotational speed, is to convert the power to a high voltage and rectify the current, where after it can be transmitted by a high-voltage DC connection (HVDC) to a land-based station. The connection may preferably be a supra-conducting connection.

The materials used for manufacturing of the apparatuses must be durable to the corrosive environment of the salt seawater as well as to the stress from the various forces on the construction. Steel with anodic corrosion protection or stainless steel may be used, as well as concrete, various types of plastics material and natural and artificial resins reinforced with fibres, such as glass fibres, carbon fibres and natural fibres, e.g. hemp or tree fibres.

Elements from the embodiments given above may be combined by the skilled person within the present invention, such as the different methods of transforming the power generated by means of the generated water flow into a transmissible power.

PATENT CLAIMS

1. A wave energy converter apparatus comprising
a buoyancy member (6),
5 an underwater, flow-generating member (1),
connection means (5) connecting the buoyancy member (6) and the flow-
generating member (1),
said flow-generating member (1) defining one upper (2), closed surface, and one
lower (3), closed surface, the apparatus further comprising
10 flow converter means arranged for converting water flow generated along at
least one of said surfaces (2, 3) by the reciprocating, preferably substantially vertical
movement of the flow-generating member (1) caused by surface waves acting on the
buoyancy member (6), into transmissible power.
- 15 2. An apparatus according to claim 1, wherein the flow-generating member (1) is
rotational symmetrical with respect to a vertical centre axis, and the distance of the
upper surface (2), respectively the lower surface (3), from the meeting plane of said
two surfaces, is non-increasing from the centre axis and outwardly.
- 20 3. An apparatus according to claim 2, wherein the upper surface (2) is defined by a
smooth curve, such as a straight line, rotated about said axis.
4. An apparatus according to claim 2 or 3, wherein the lower surface (3) is defined
by a smooth curve, such as a straight line, rotated about said axis.
- 25 5. An apparatus according to any of the preceding claims, wherein the flow converter
means comprises vanes (12) arranged on the flow-generating member to drive a
rotation of said member (1) by means of said water flow.

6. An apparatus according to claim 5, comprising a plurality of flow-generating members (1) with opposite directions of rotation and coupling means for mutual coupling of said flow-generating members (1) to outbalance the torque.
- 5 7. An apparatus according to claim 5, wherein the connection means are suitable for transmitting a torque between the buoyancy member (6) and the flow-generating member (1).
8. An apparatus according to claim 7, wherein the connection means are suitable for
10 transmitting the rotation of the flow-generating member (1) to the buoyancy member (6).
9. An apparatus according to claim 8, wherein the buoyancy member (6) comprises means for converting said rotation into electrical power.
- 15 10. An apparatus according to claim 8 or 9, comprising a plurality of flow-generating members (1) with opposite directions of rotation and coupled to the same buoyancy member (6), so as to outbalance the torque.
- 20 11. An apparatus according to claim 1, wherein the flow-generating member (1) has a substantially constant cross-sectional outline along a longitudinal direction of said member and is symmetrical with respect to a vertical centre plane extending in the longitudinal direction, wherein the distance of the upper surface (2), respectfully the lower surface (3), from the meeting plane of said two surfaces (2, 3), is non-
25 increasing from the centre plane and outwardly.
12. An apparatus according to claim 11, wherein the upper surface (2) is defined by a smooth curve, such as a straight line, extending perpendicularly from the centre plane.

13. An apparatus according to claim 11 or 12, wherein the lower surface (3) is defined by a smooth curve, such as a straight line, extending perpendicularly from the centre plane.
- 5 14. An apparatus according to claim 1 or any of claims 11-13, wherein the flow converter means comprises means for deflecting and collecting said generated water flow to a common flow converter device.
- 10 15. An apparatus according to claim 1 or any of claims 11-13, wherein the flow converter means comprises a plurality of rotors arranged in said generated water flow.
- 15 16. An apparatus according to any of the preceding claims, wherein the upper surface (2) is generally facing the buoyancy member when the apparatus is placed in water and the lower surface (3) is generally facing away from the buoyancy member.
- 20 17. An apparatus according to any of the preceding claims, wherein a gearing is arranged between the buoyancy member (6) and the flow-generating member (1) so that the length of the path the flow-generating member (1) moves through the water is longer than the path of the buoyancy member (6), preferably with a factor of 1.5 to 8, most preferred with a factor of 2 to 5.
- 25 18. An apparatus according to claim 17, wherein the gearing is constituted by a hinged lever arm (29) to which the buoyancy member (6) as well as the flow-generating member (1) is connected.
- 30 19. An apparatus according to any of the preceding claims, further comprising a shielding member (28) with an inner wall substantially parallel to the path of the flow-generating member (1) through the water and enclosing the flow-generating member (1) along at least a substantial part of said path.

20. An apparatus according to claim 19, wherein the area of the cross-sectional opening of the shielding member (28) enclosing the flow-generating member (1) is within the range of 1.2 to 2 times the maximum cross-sectional area of the flow-generating member (1), preferably within the range of 1.3 to 1.7.
- 5
21. An apparatus according to claim 19 or 20, wherein the shielding member (28) is arranged to follow the movements of the flow-generating member (1) along said path.
- 10
22. An apparatus according to claim 21, wherein the shielding member (28) comprises end openings at one or both ends thereof of an opening area of 1.2 to 5 times the area of the cross-sectional opening of the shielding member (28) enclosing the flow-generating member (1), preferably 1.5 to 3 times that area.

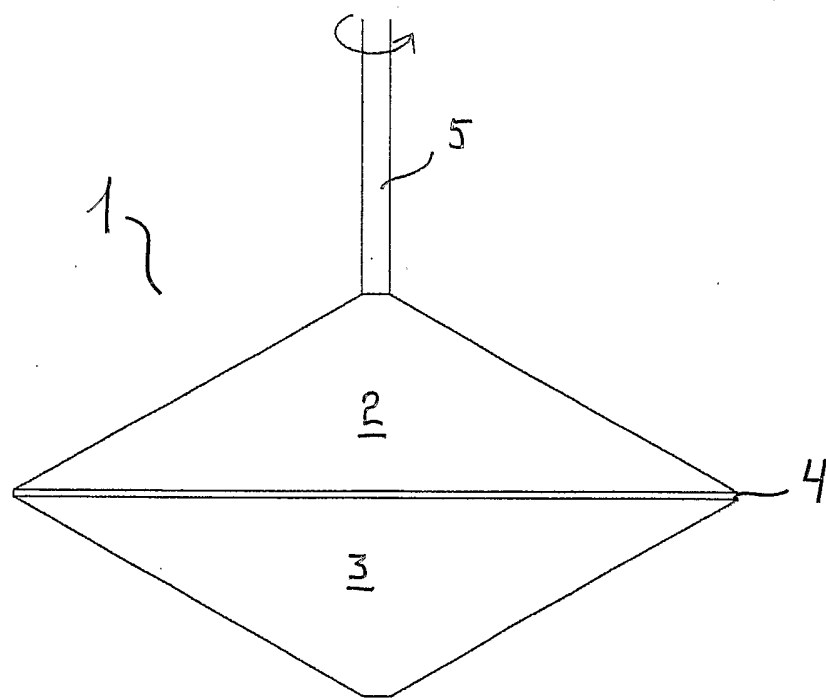


Fig. 1

2/38

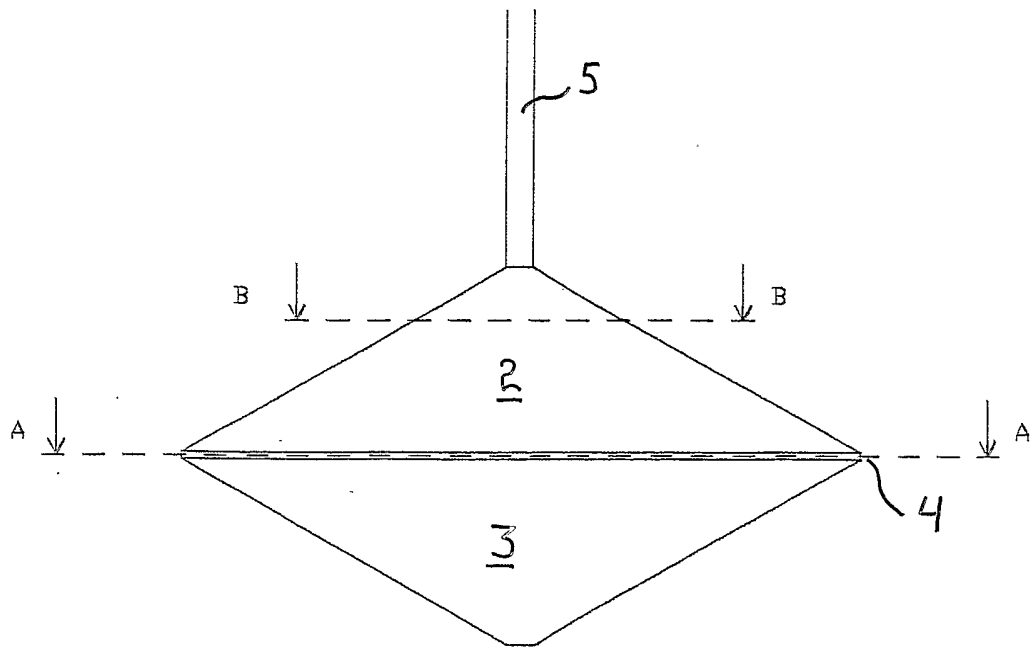


Fig. 2

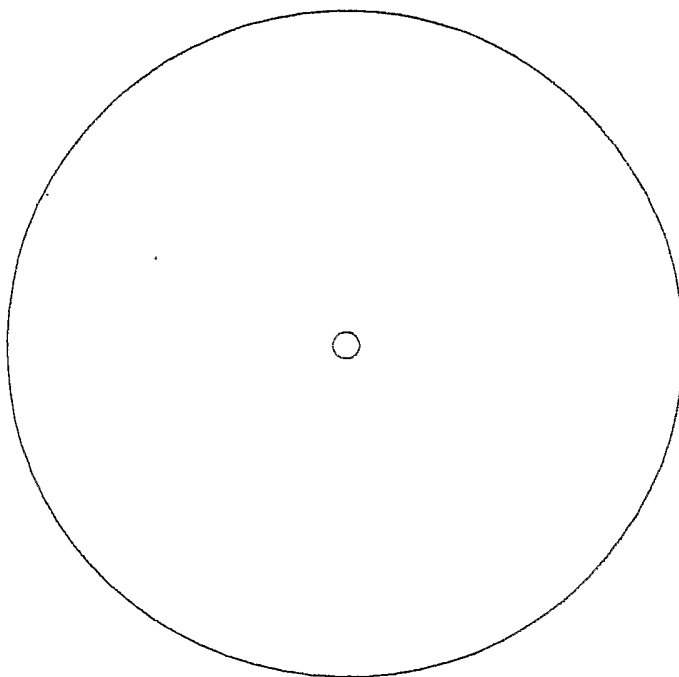


Fig. 3a

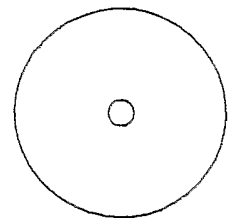


Fig. 3b

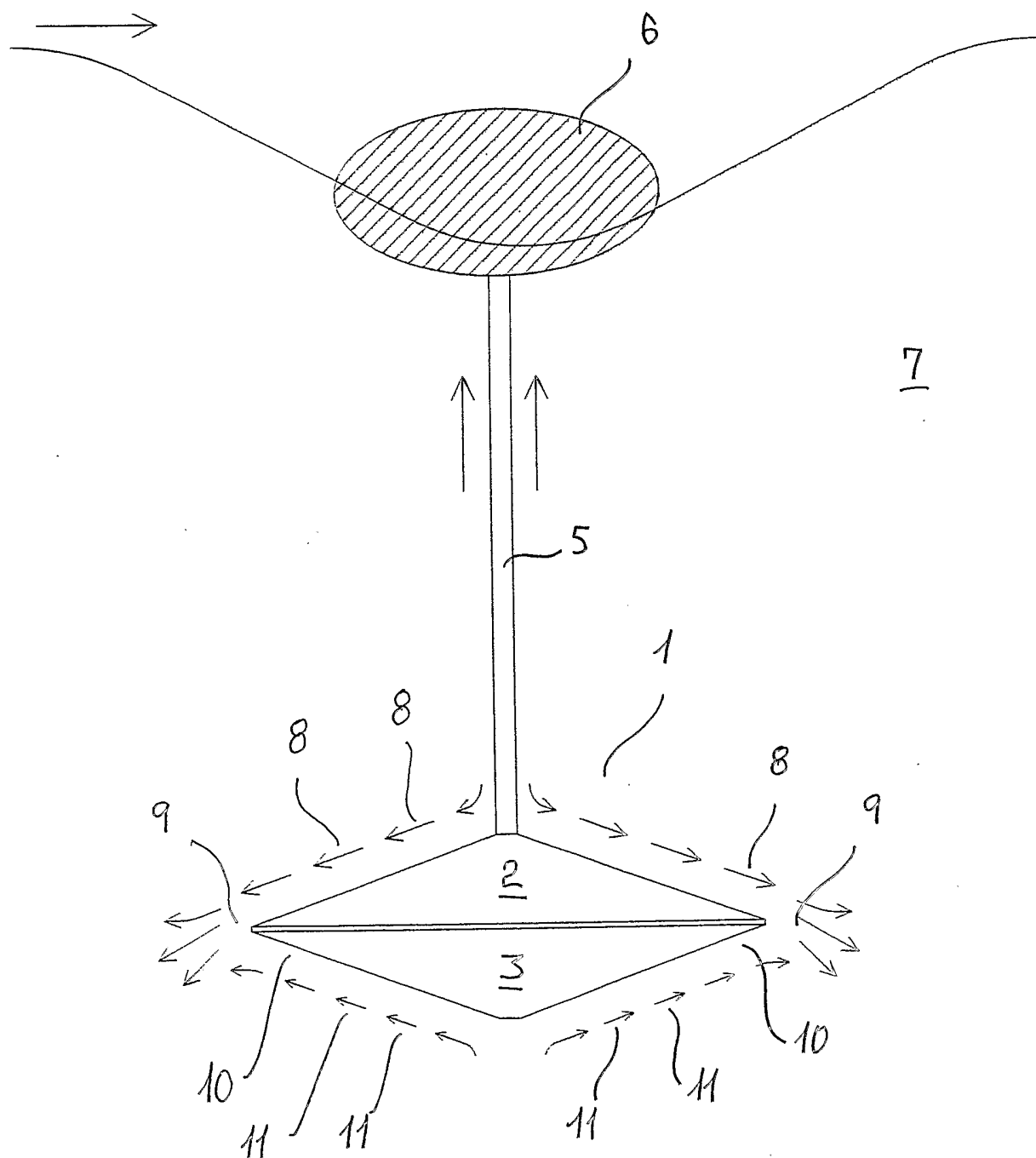


Fig. 4

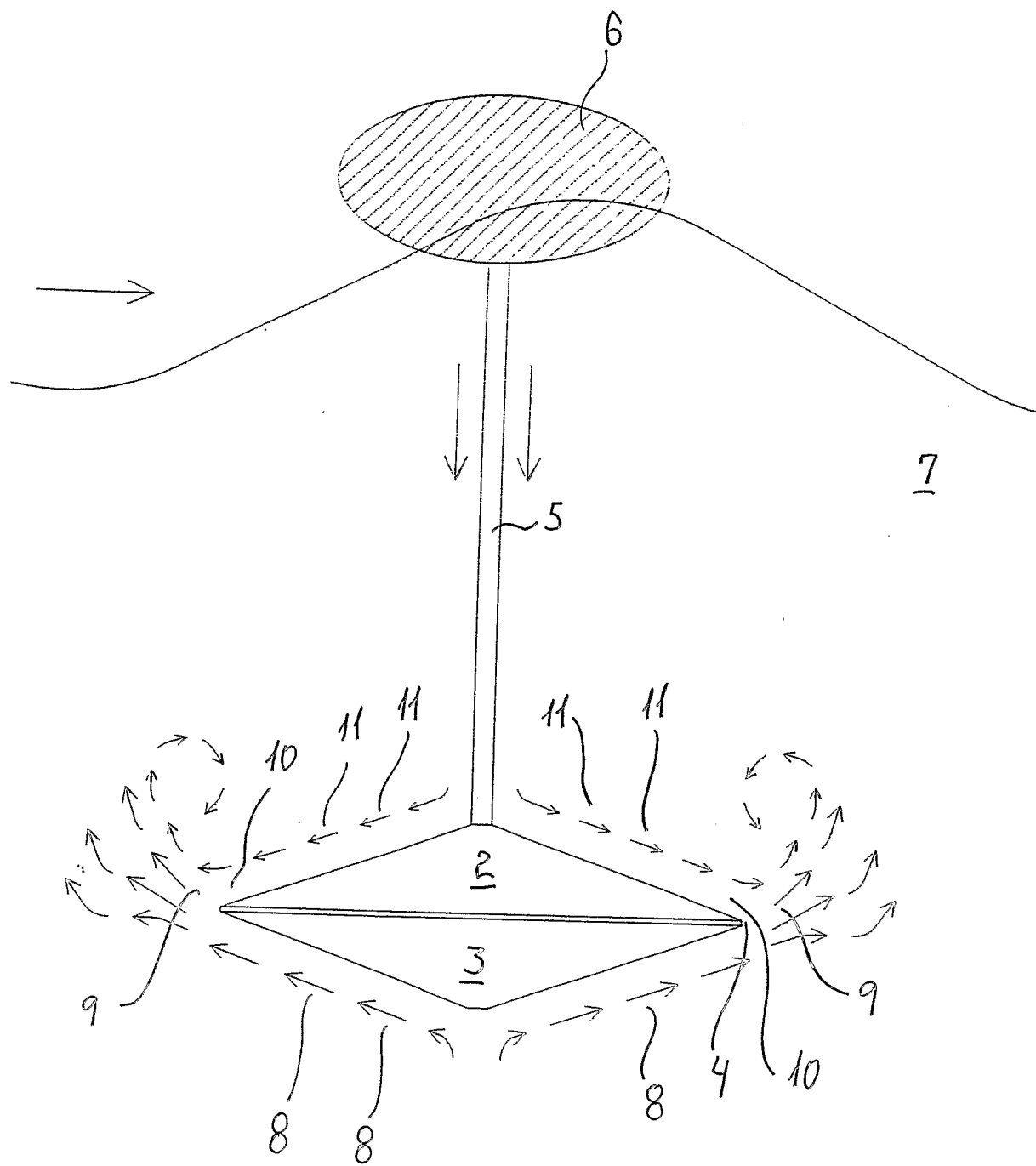


Fig. 5

5/38

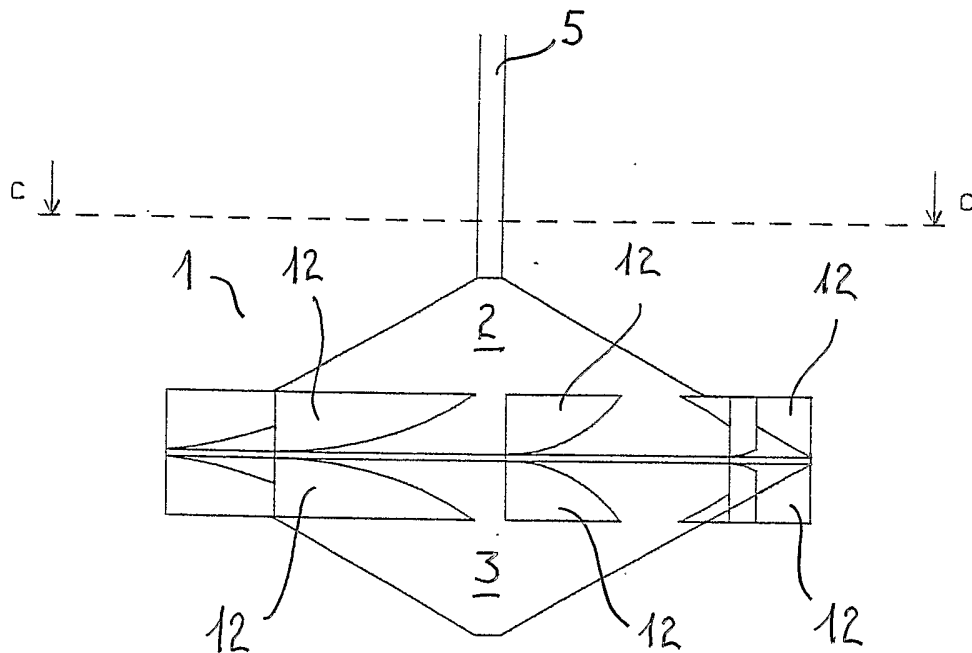


Fig. 6

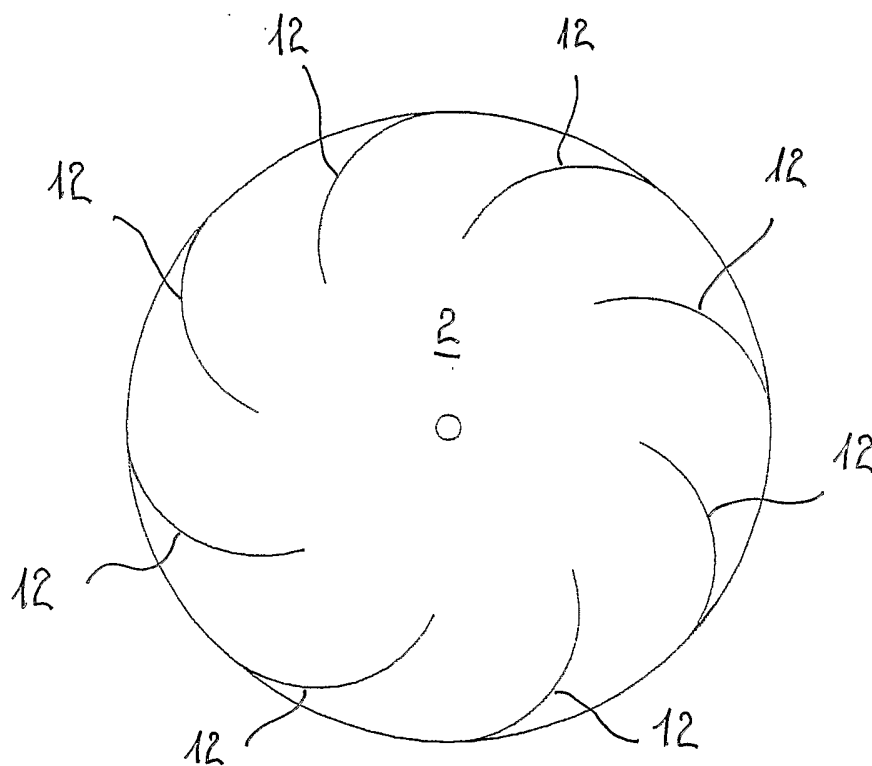


Fig. 7

6/38

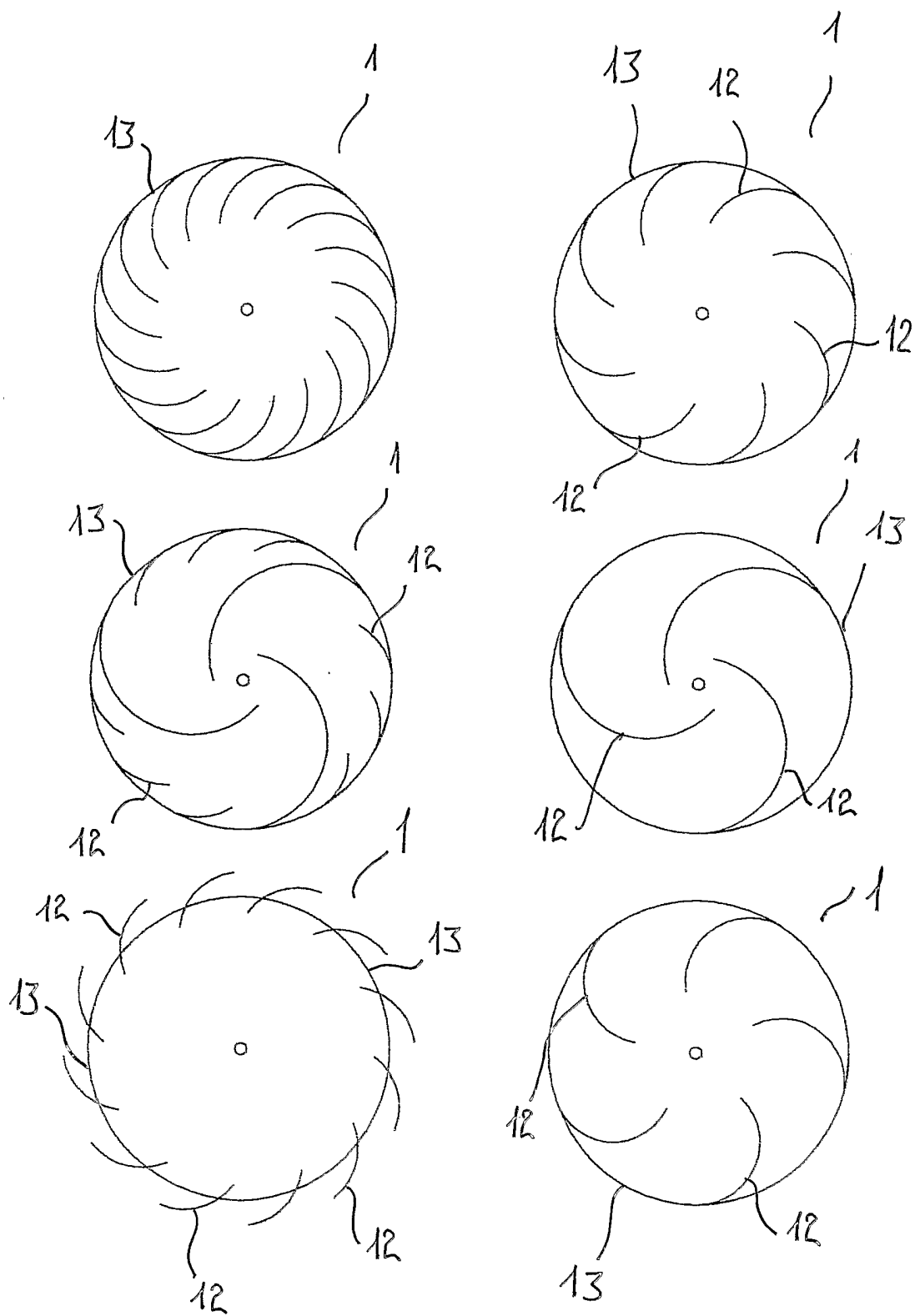


Fig. 8

7/38

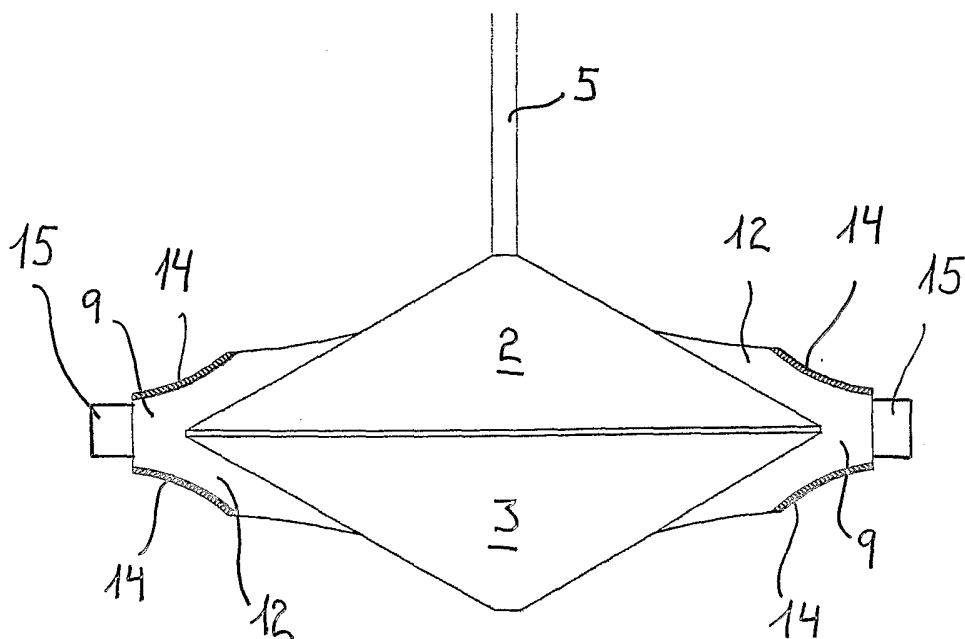


Fig. 9

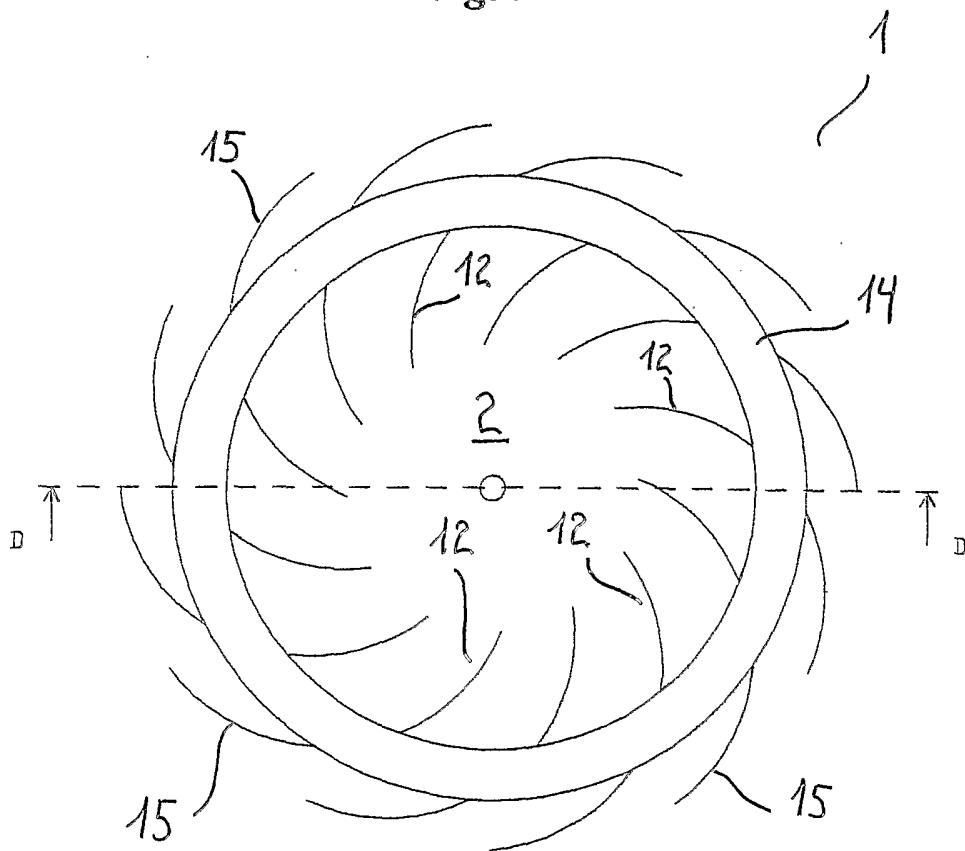


Fig. 10

8/38

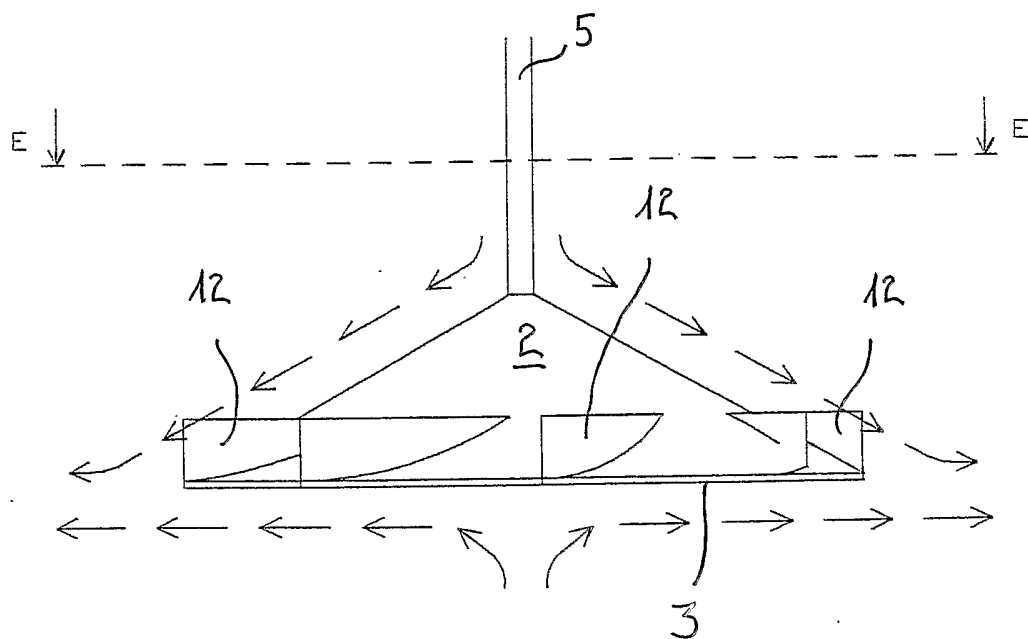


Fig. 11

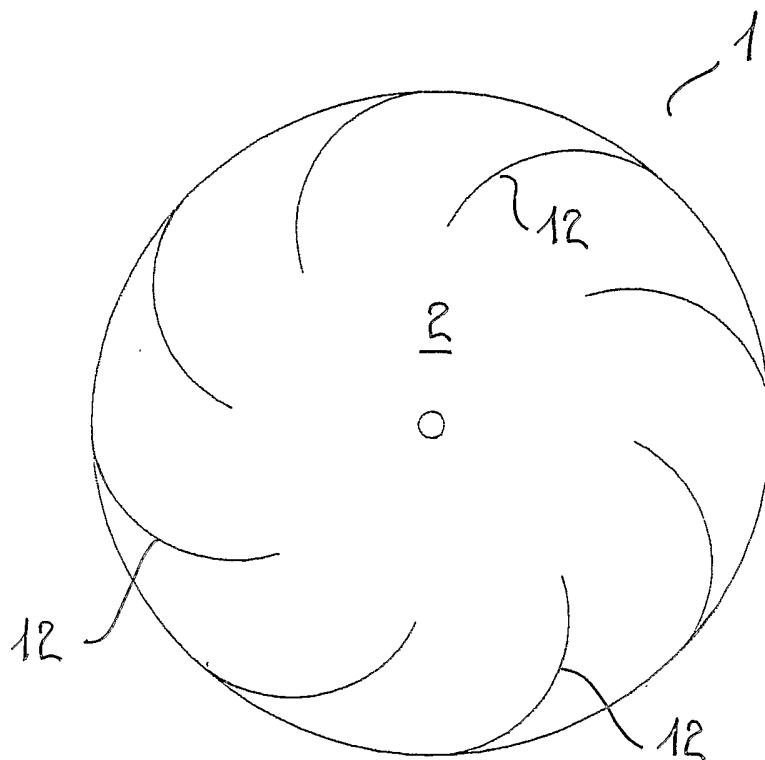


Fig. 12

9/38

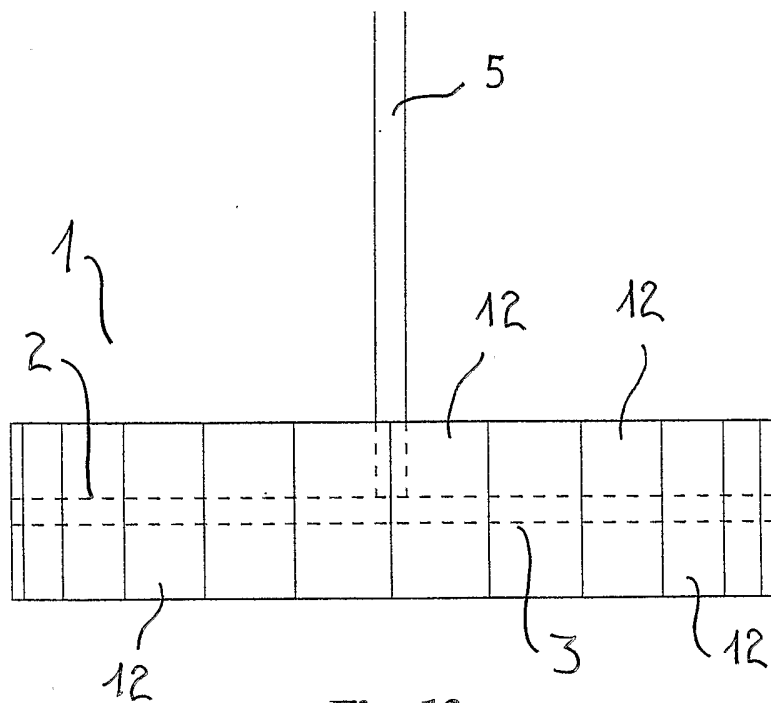


Fig. 13

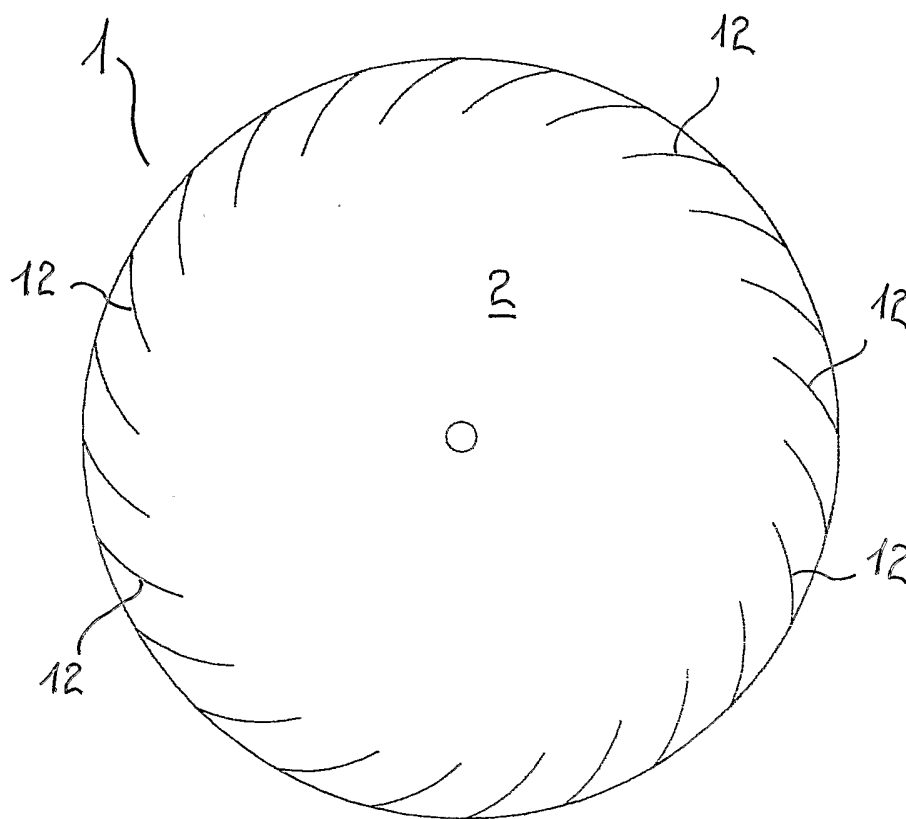


Fig. 14

10/38

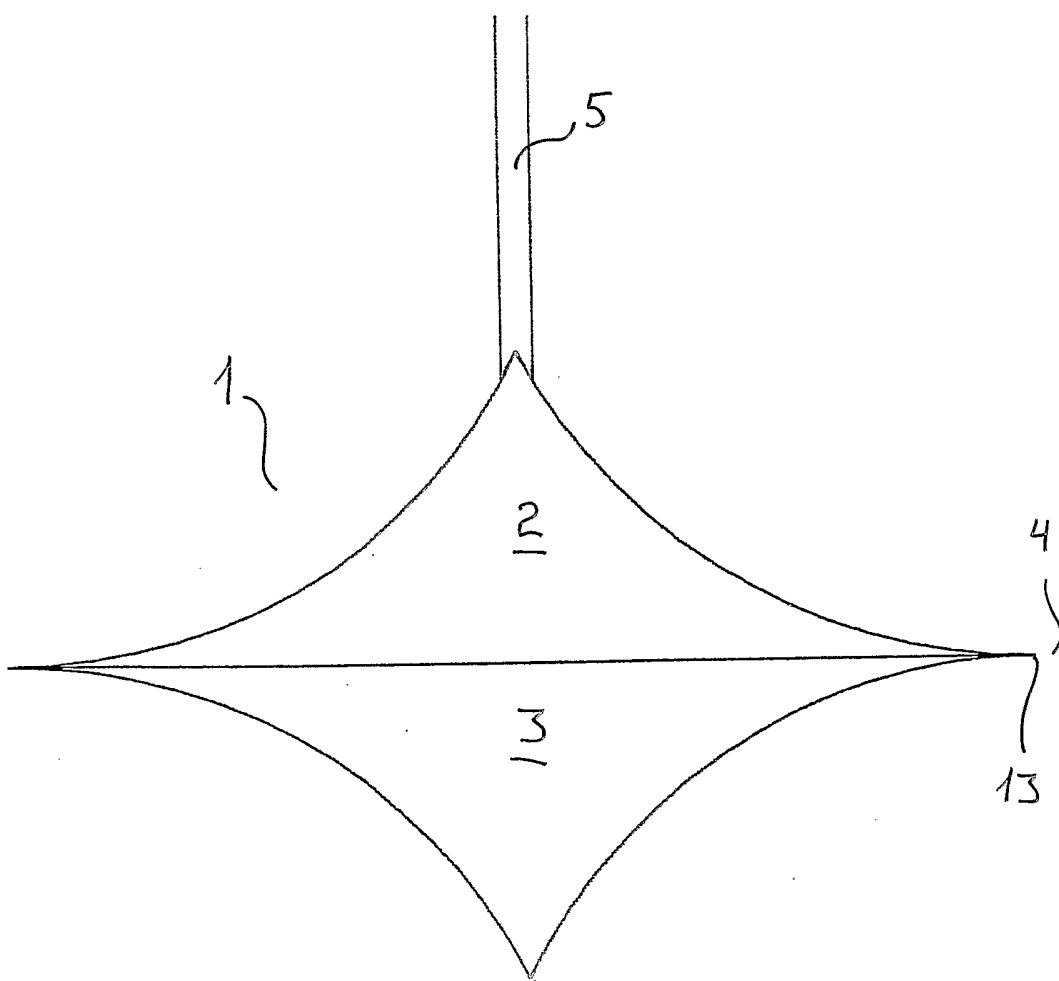


Fig. 15

11/38

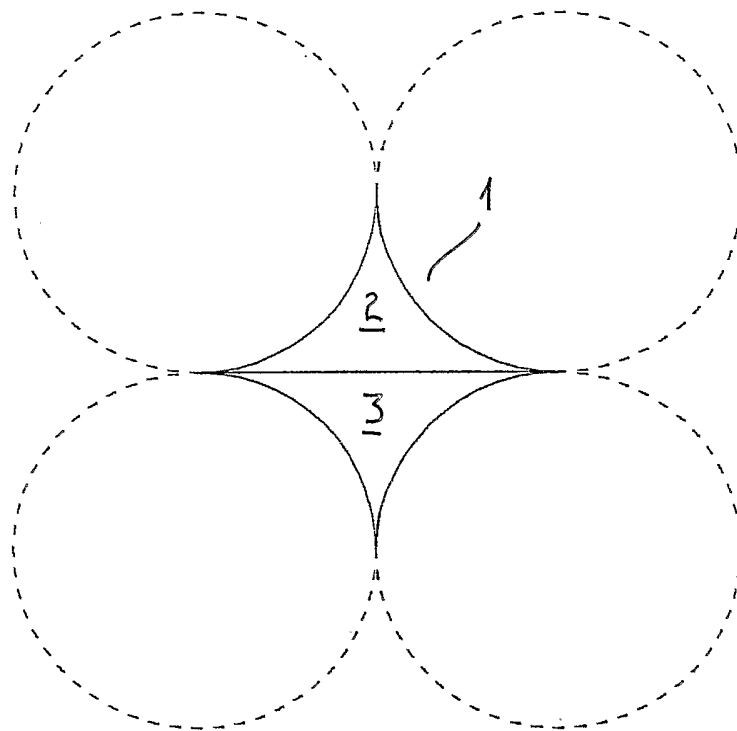


Fig. 16

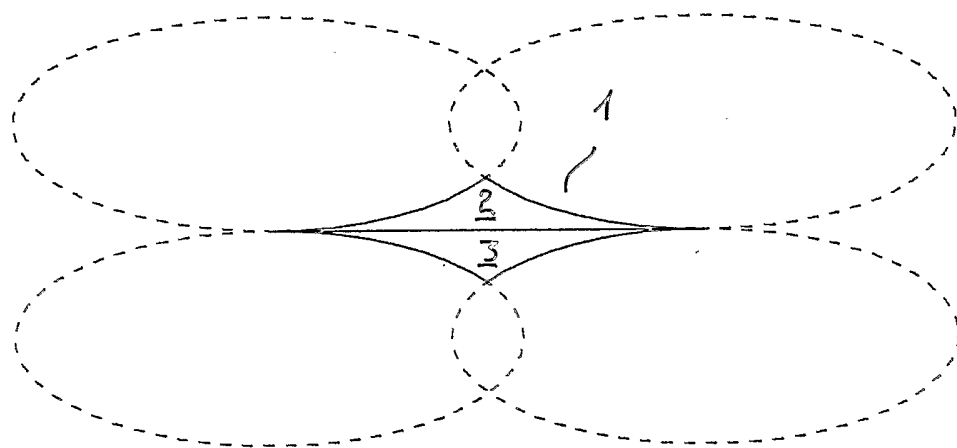


Fig. 17

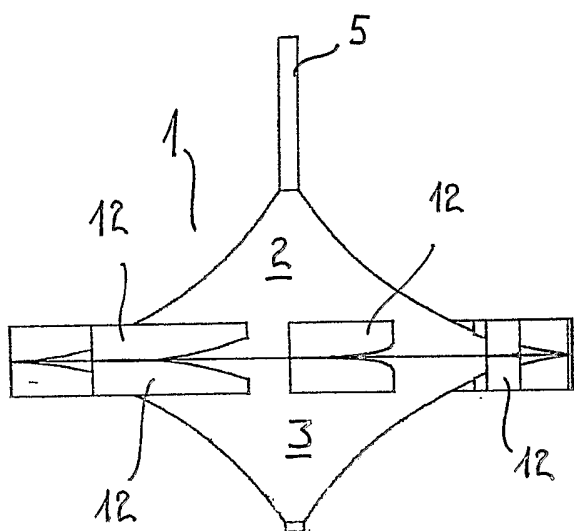


Fig. 18

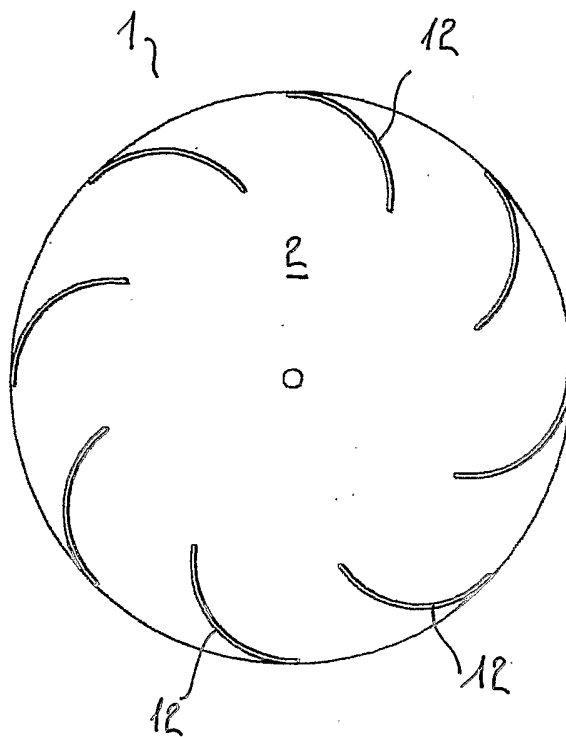


Fig. 19

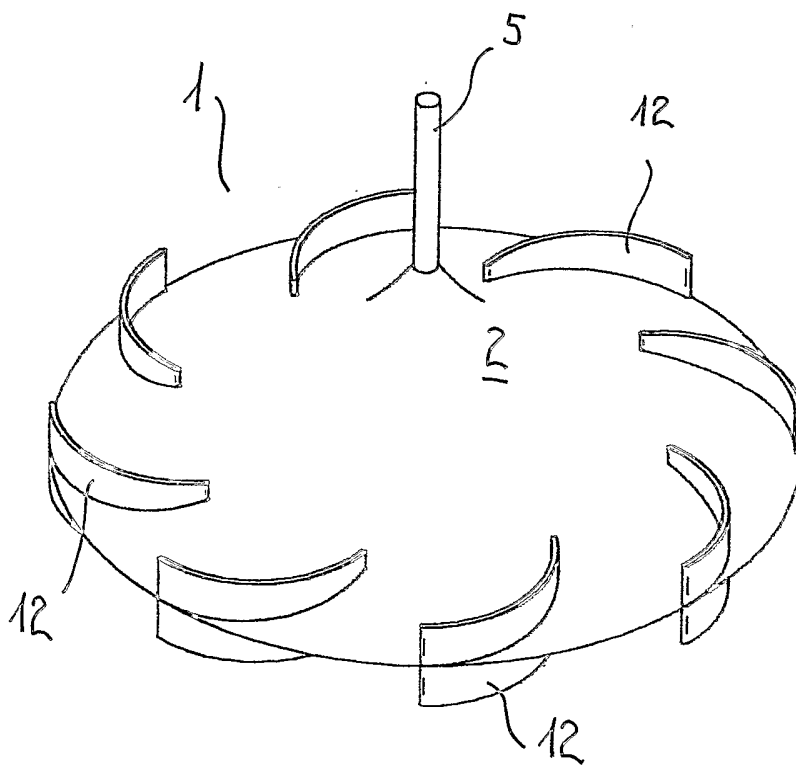


Fig. 20

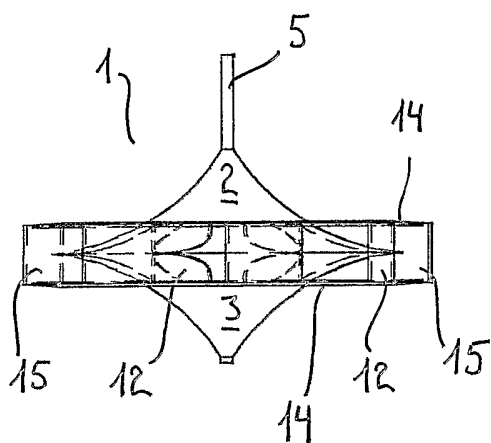


Fig. 21

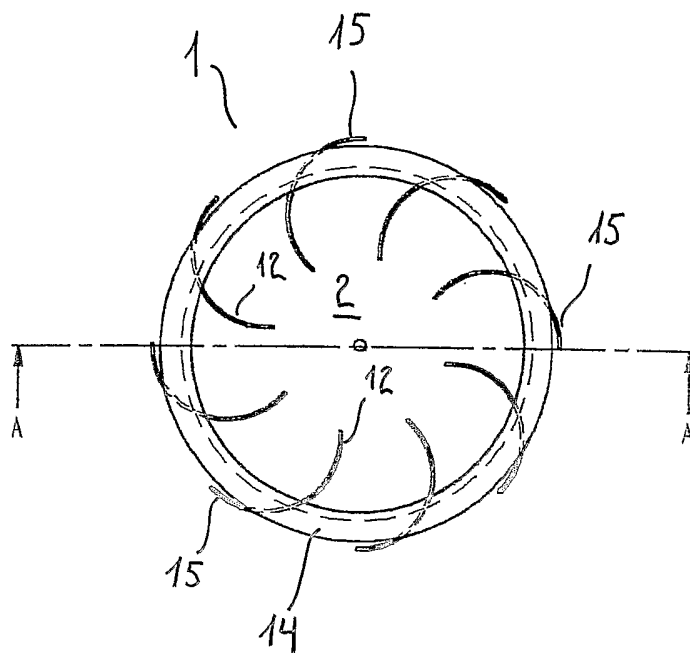


Fig. 22

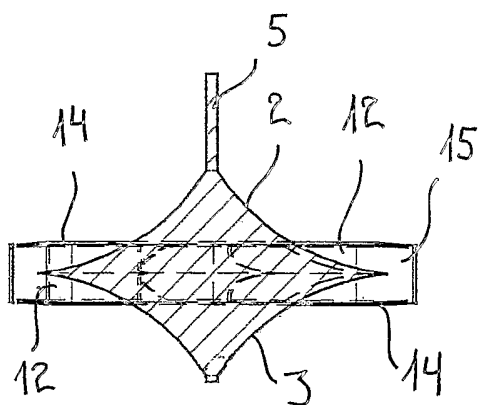


Fig. 23

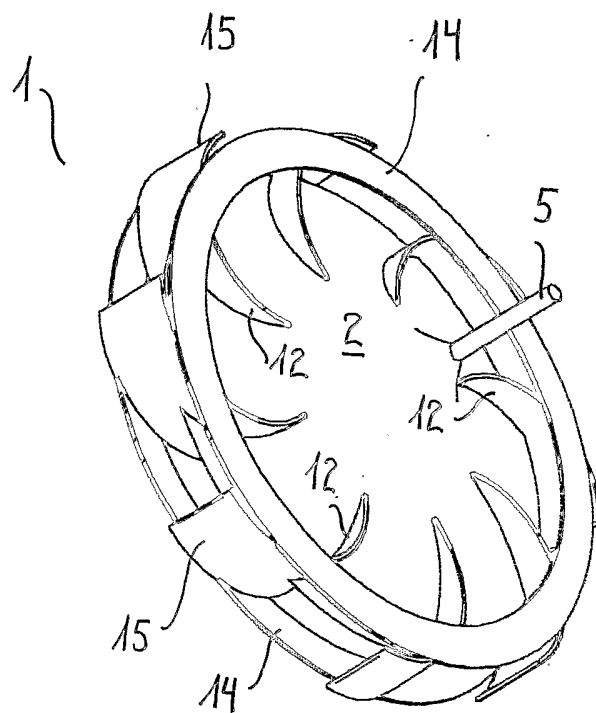


Fig. 24

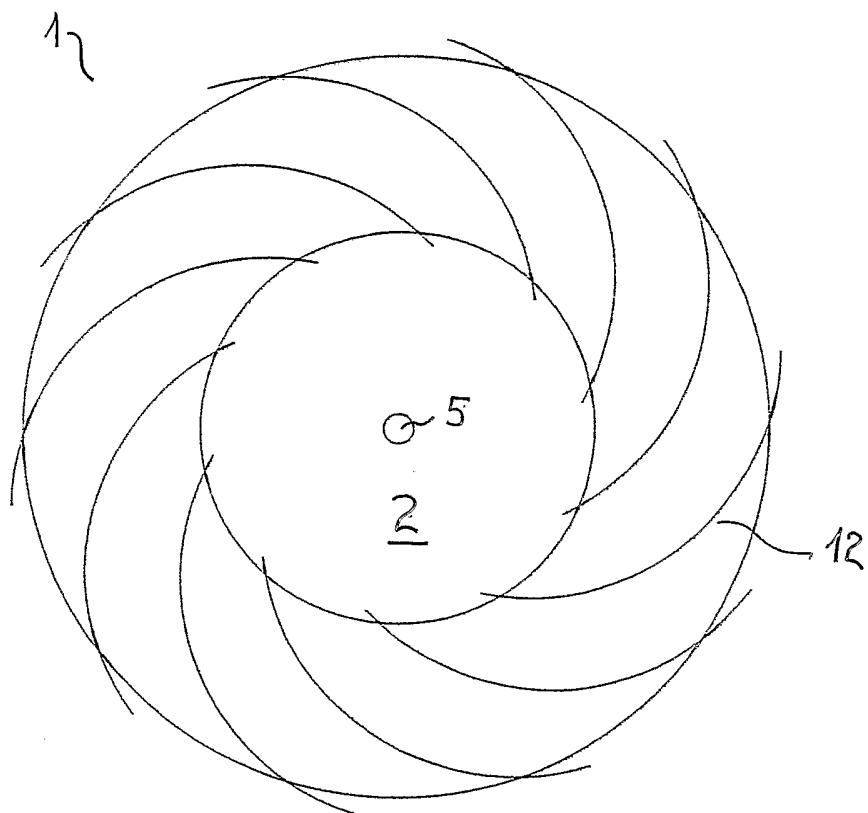


Fig. 25

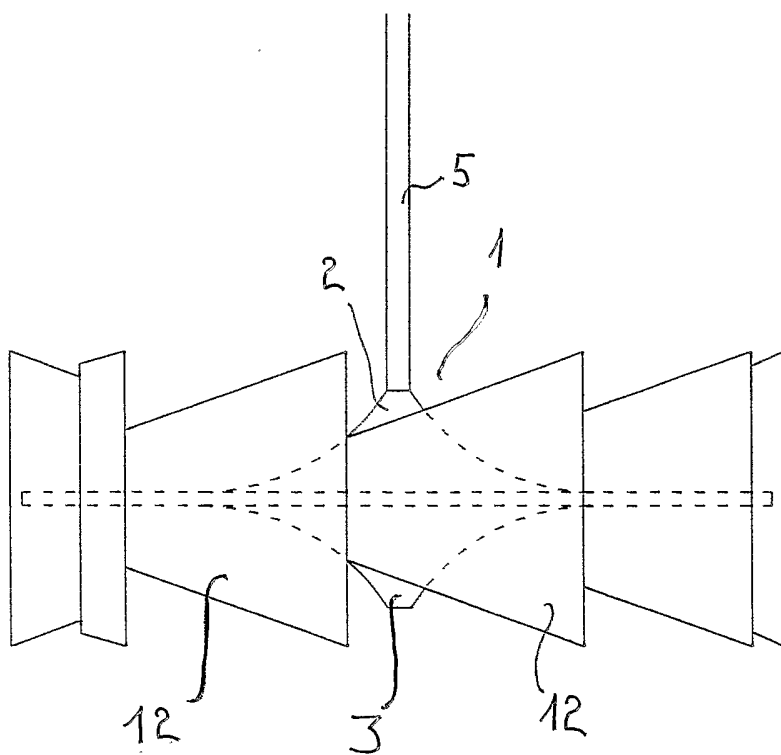


Fig. 26

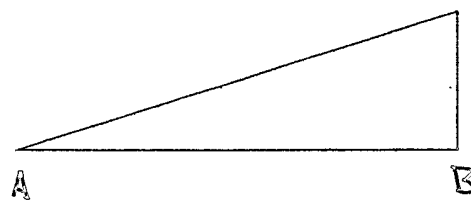
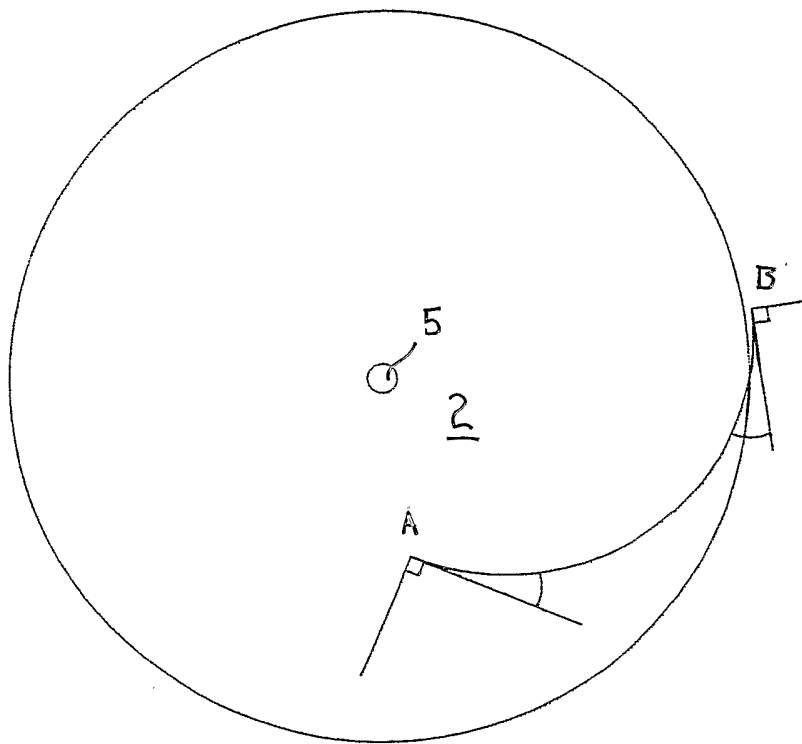


Fig. 27

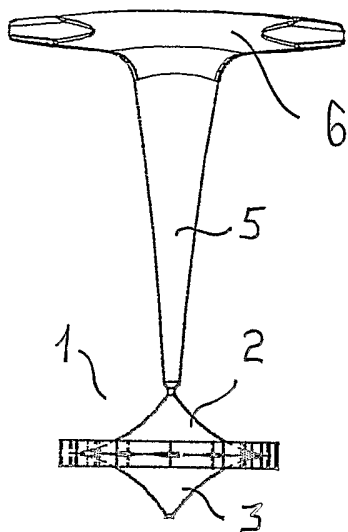


Fig. 28

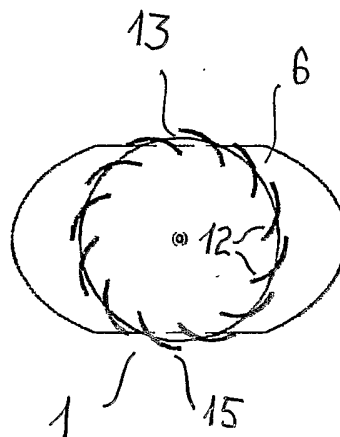


Fig. 29

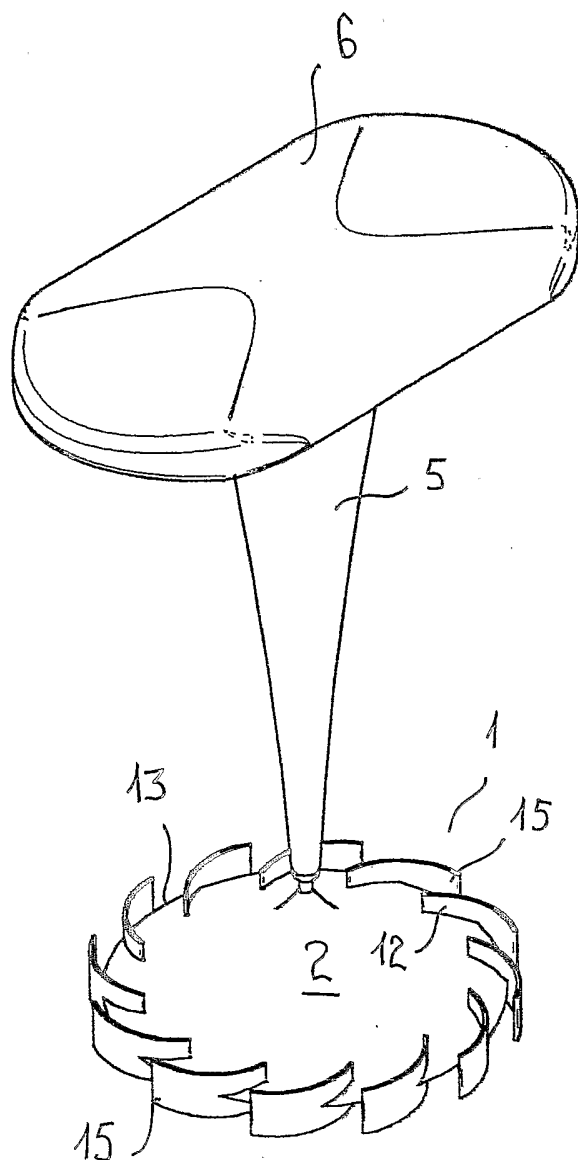


Fig. 30

17/38

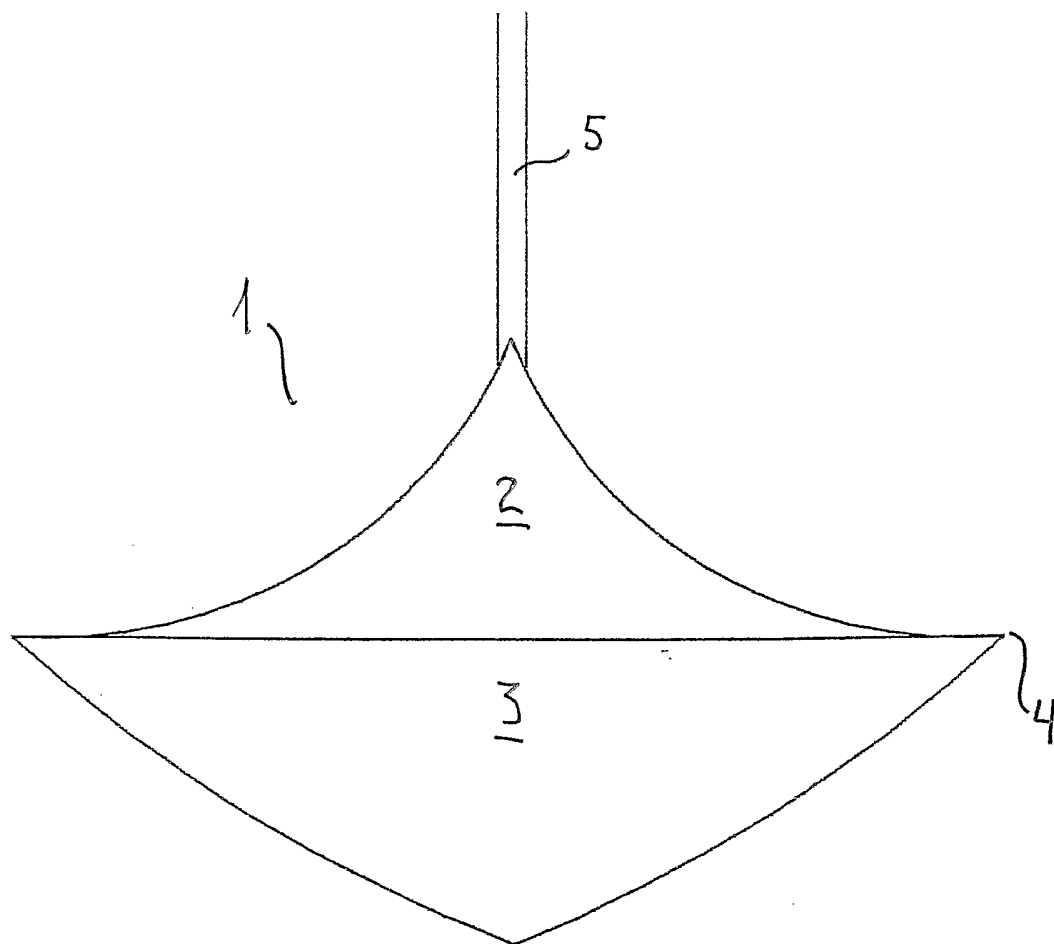


Fig. 31

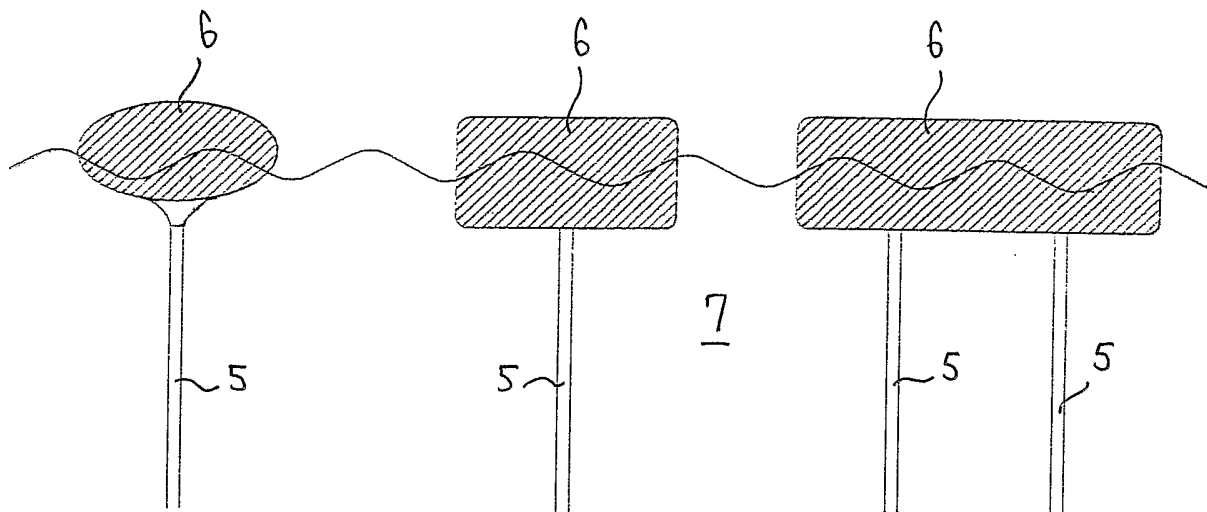


Fig. 32a

Fig. 32b

Fig. 32c

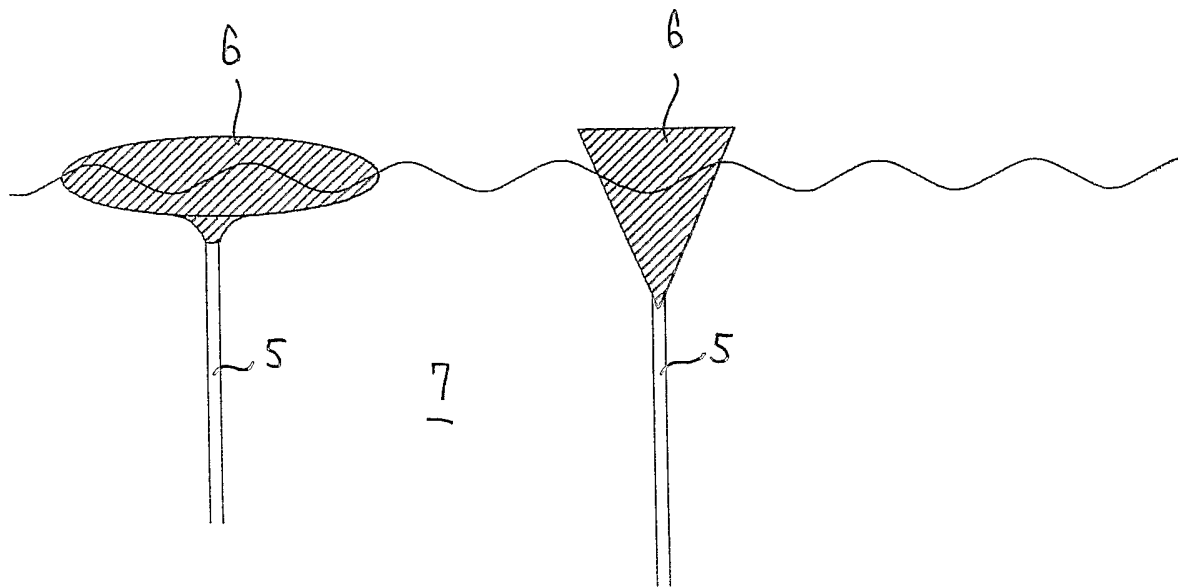


Fig. 32d

Fig. 32e

19/38

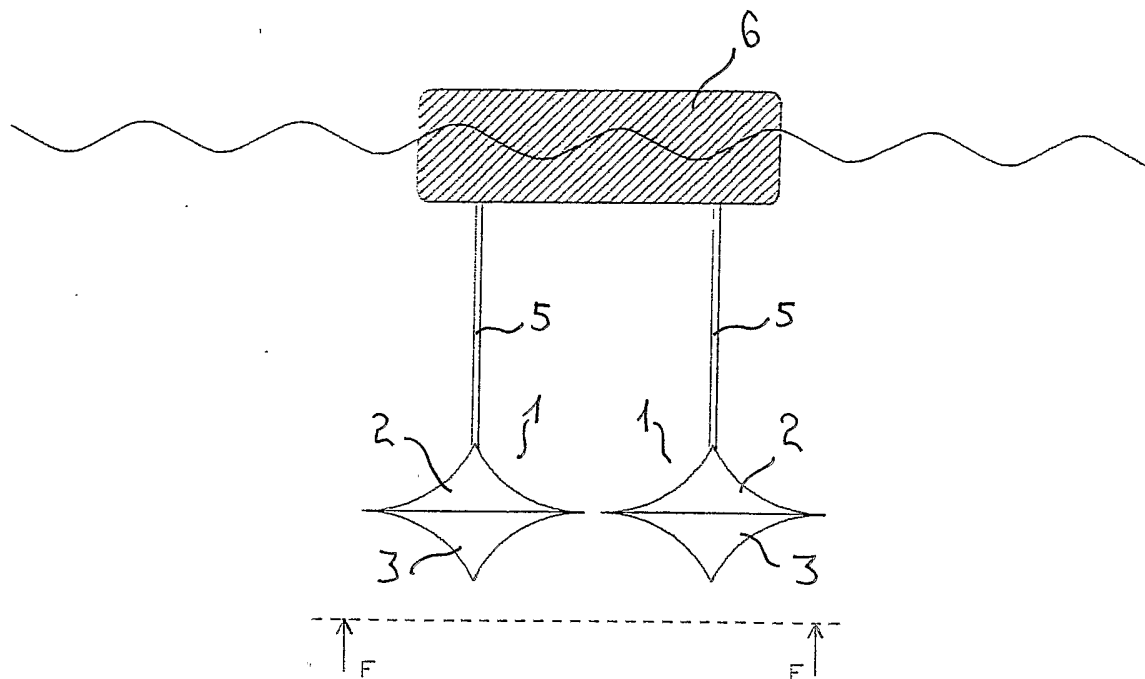


Fig. 33

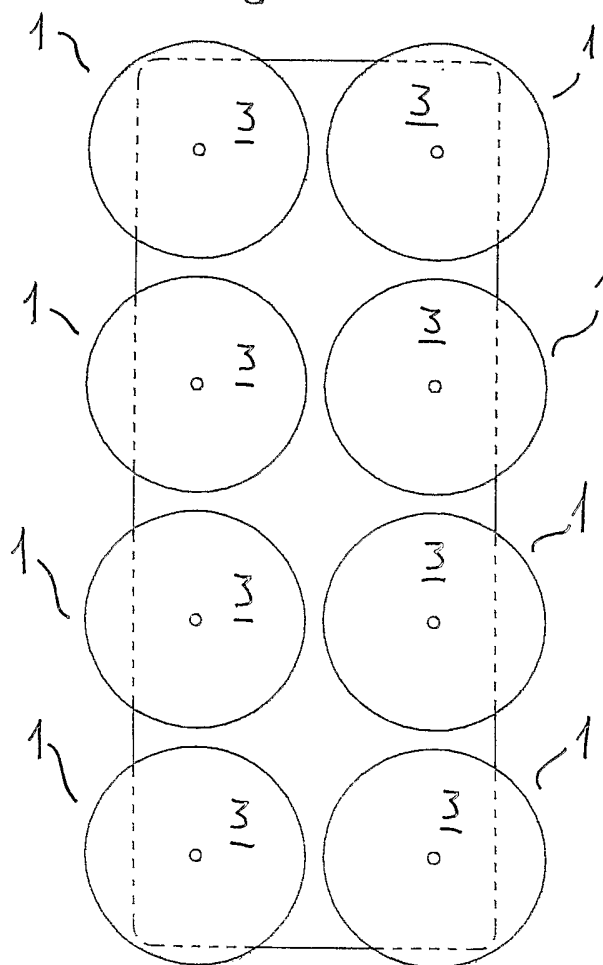


Fig. 34

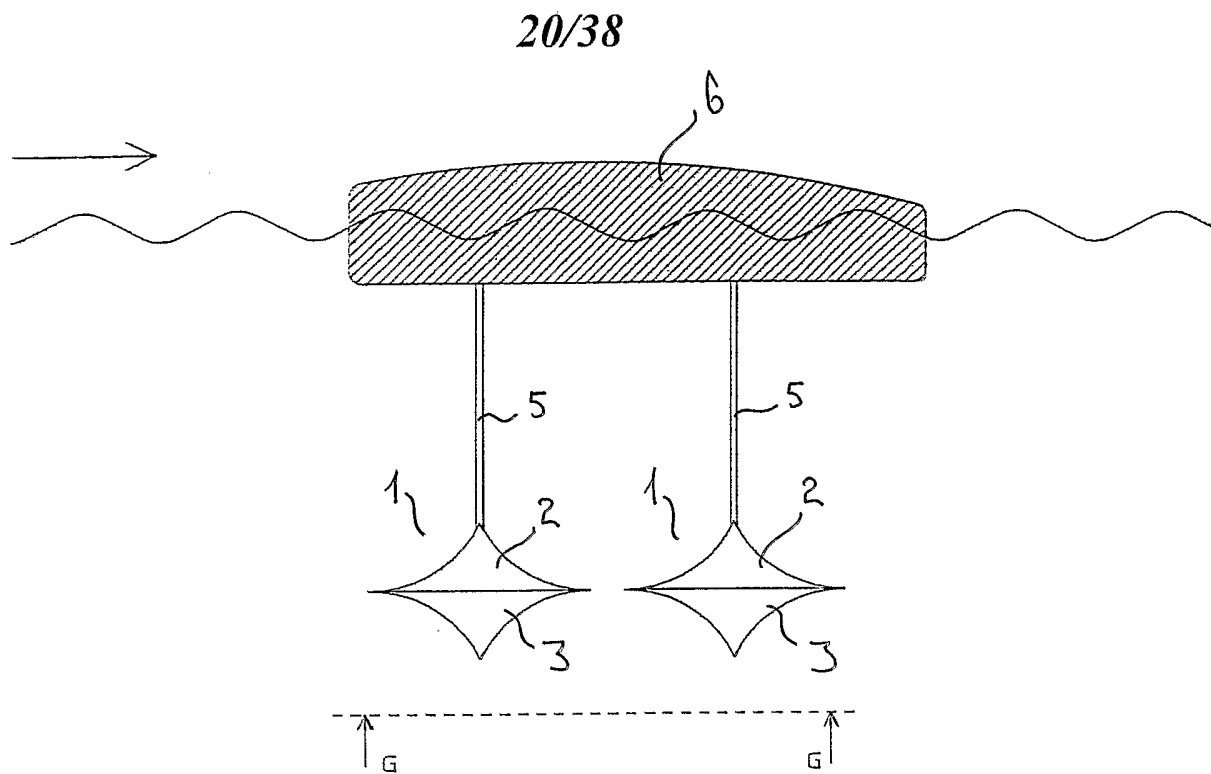


Fig. 35

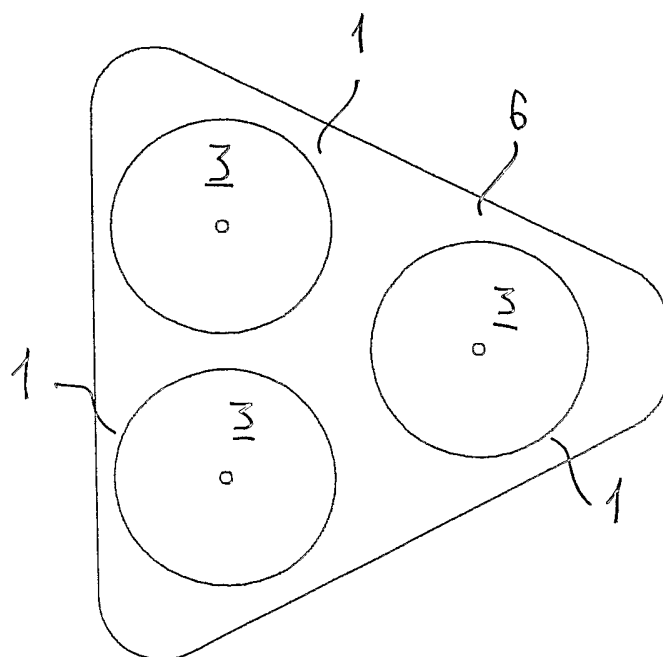


Fig. 36

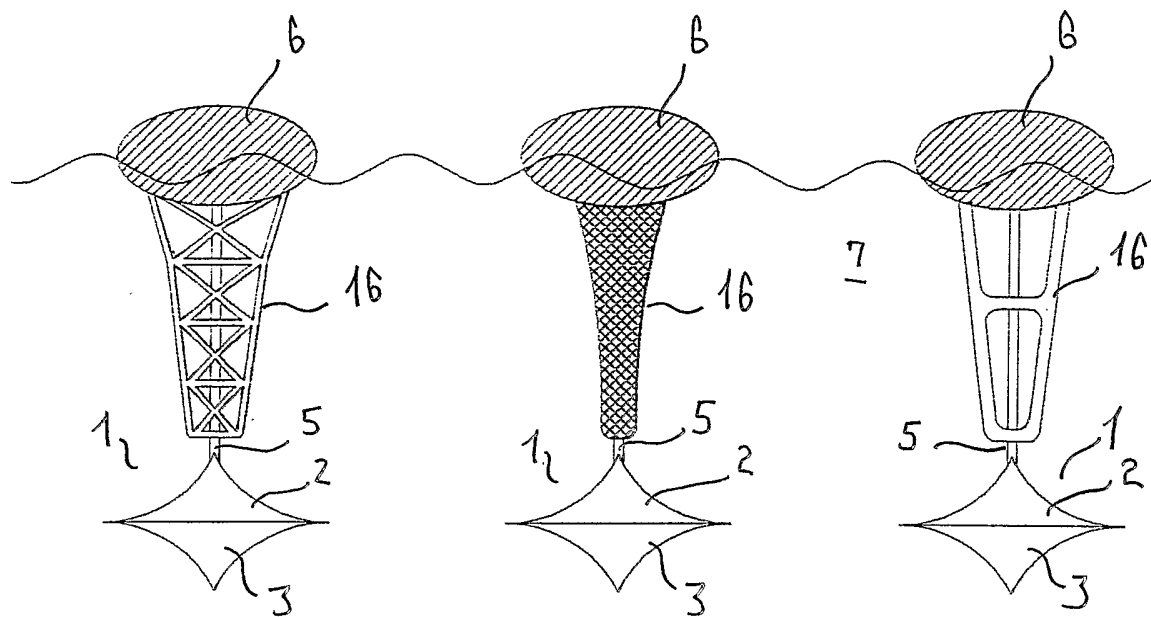


Fig. 37a

Fig. 37b

Fig. 37c

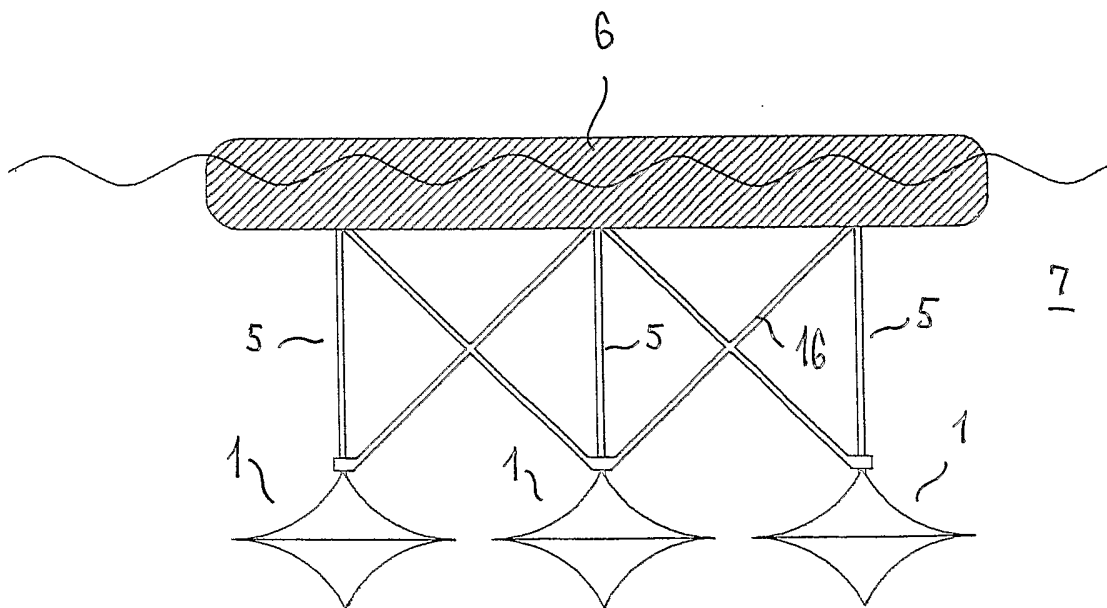


Fig. 38

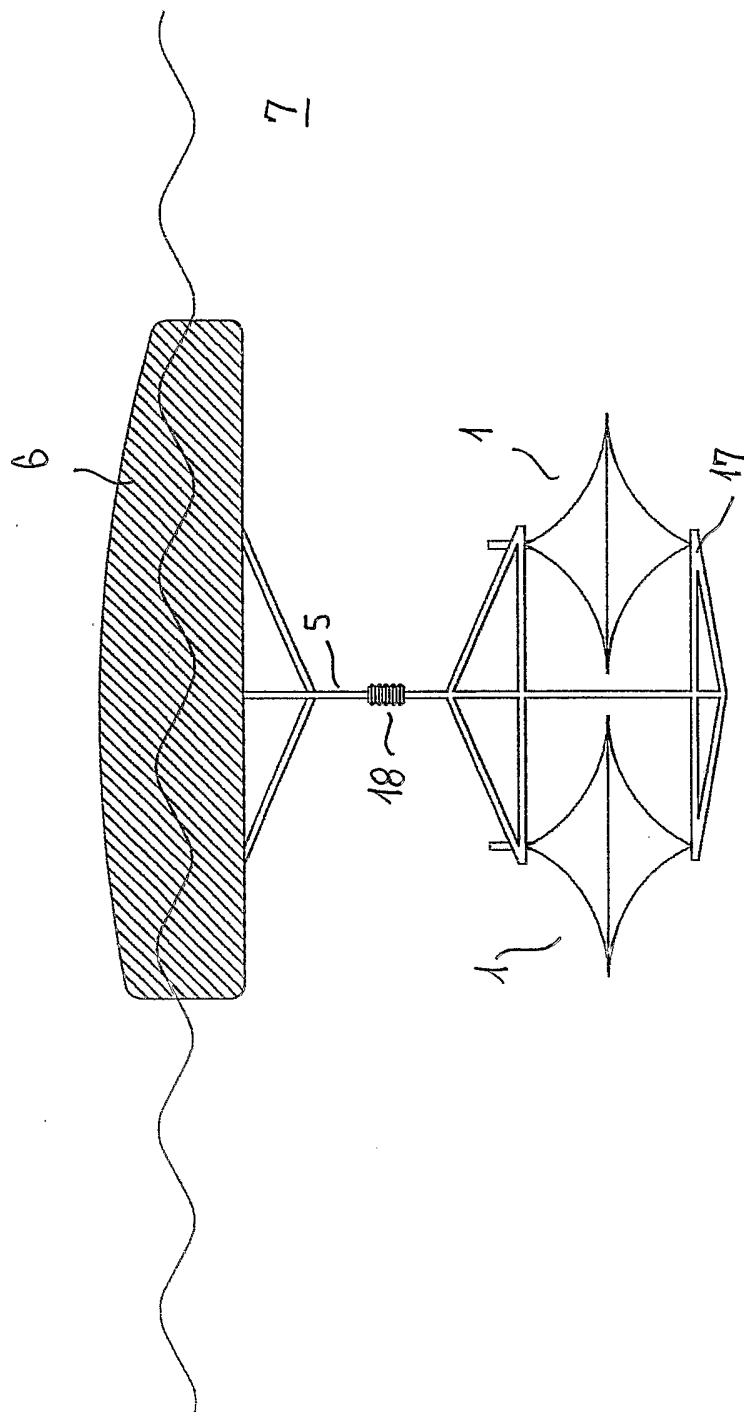


Fig. 39

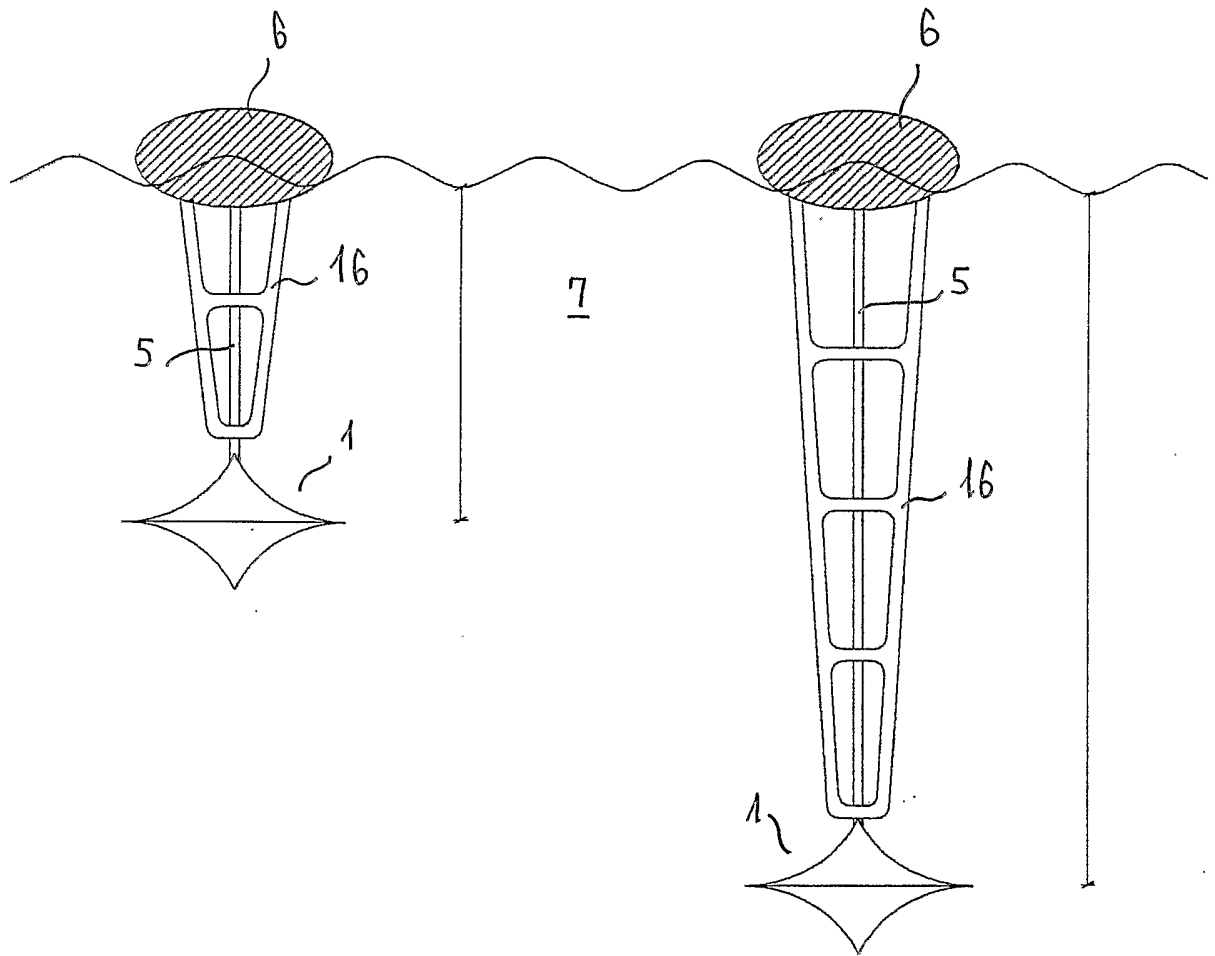


Fig. 40

24/38

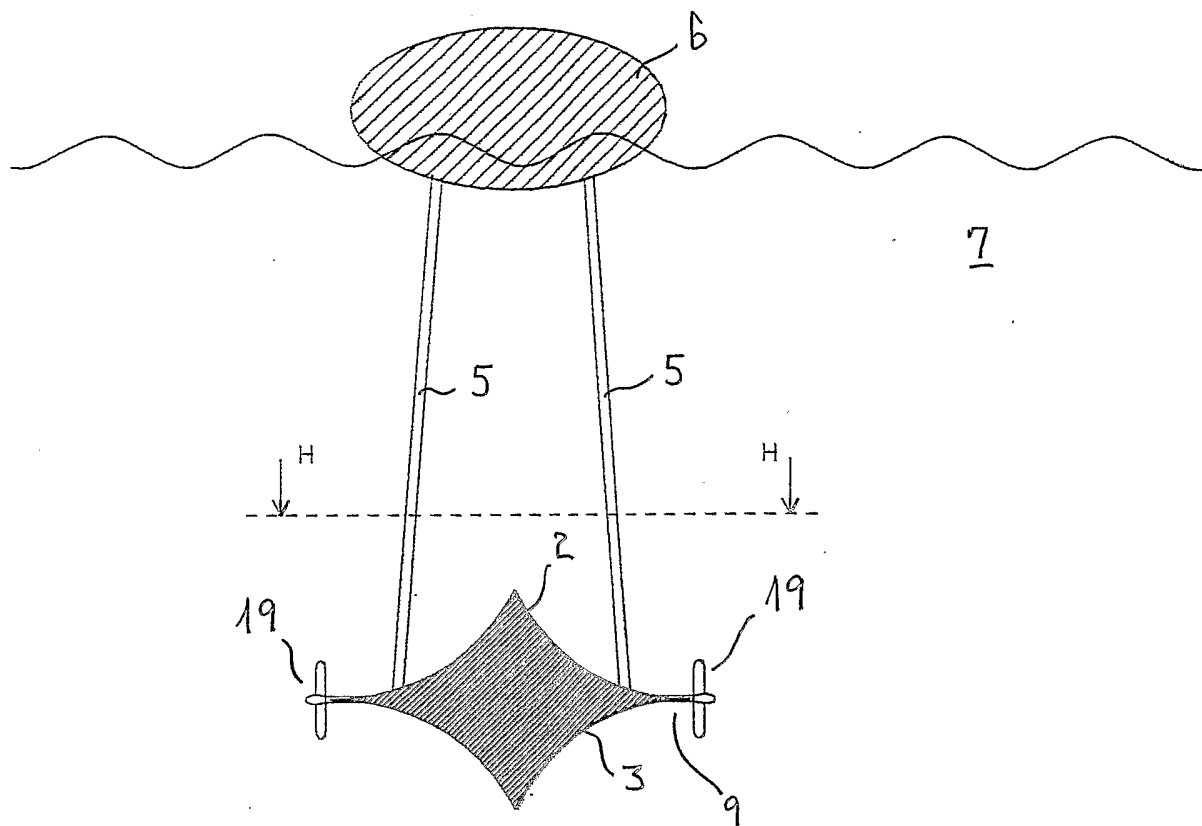


Fig. 41

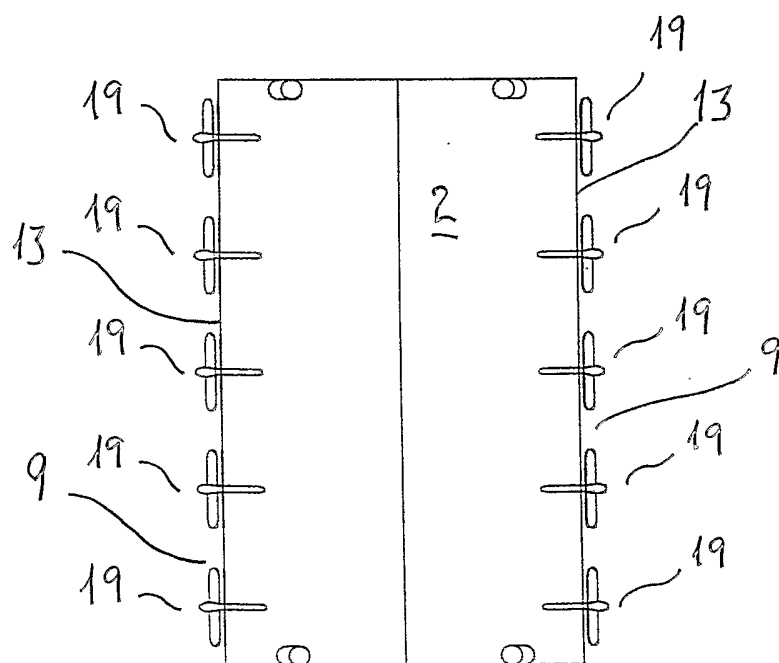


Fig. 42

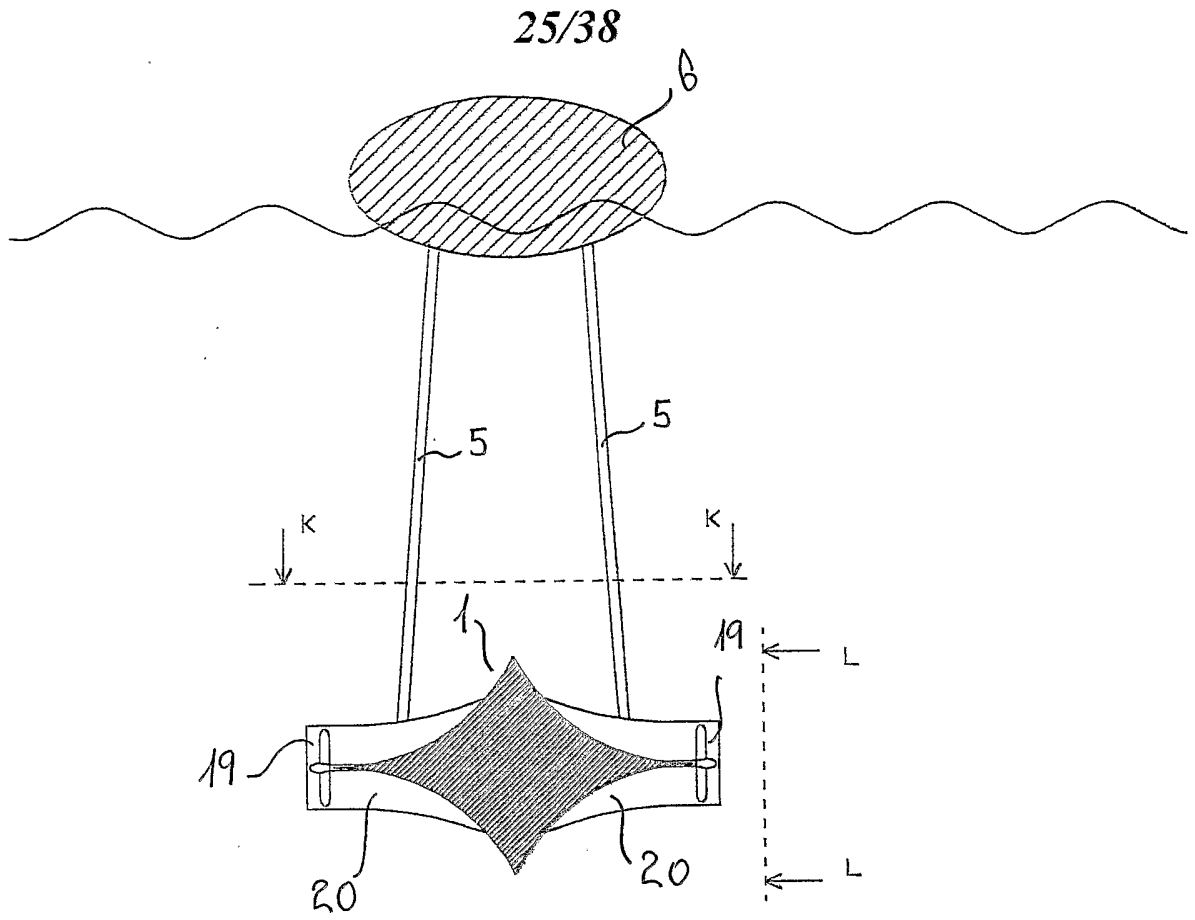


Fig. 43

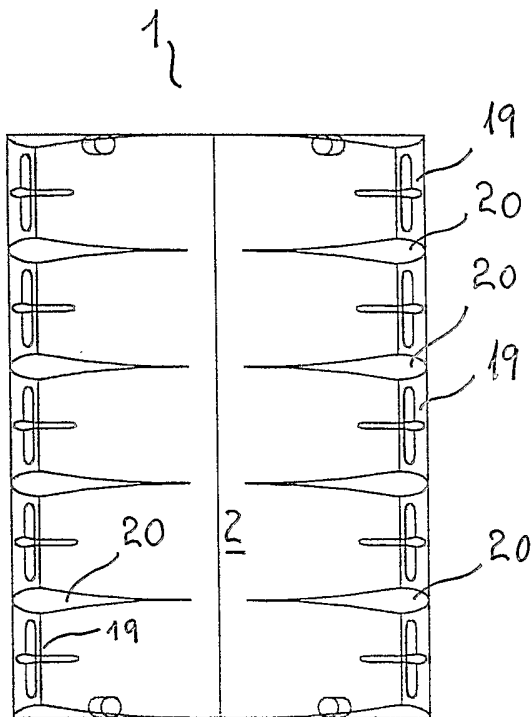


Fig. 44

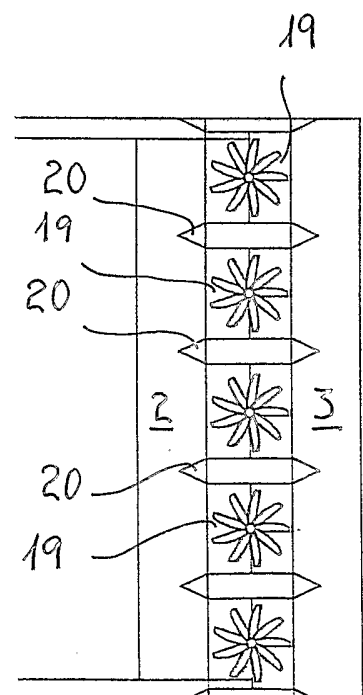


Fig. 45

26/38

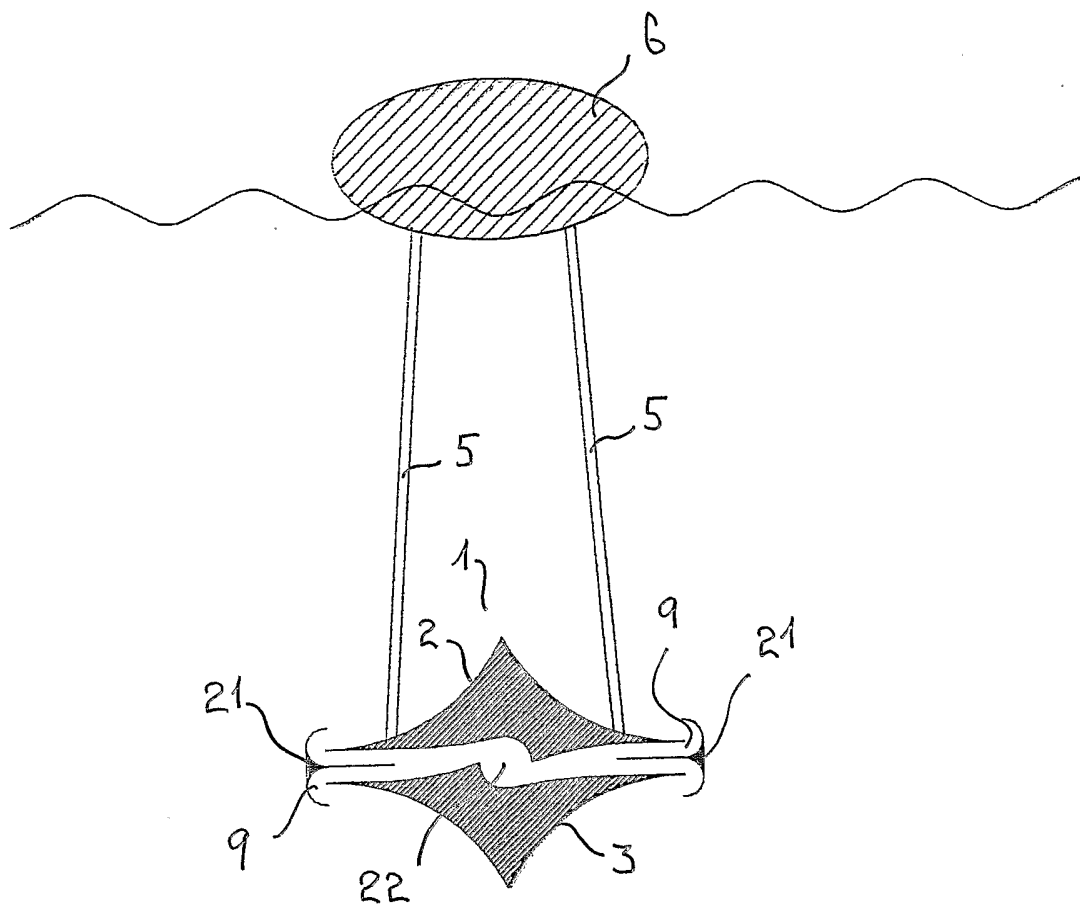


Fig. 46

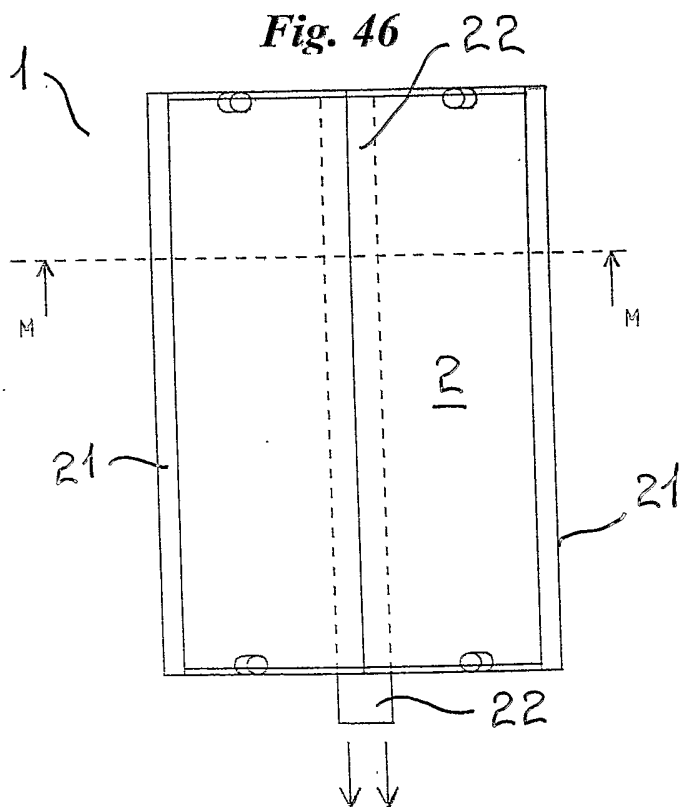


Fig. 47

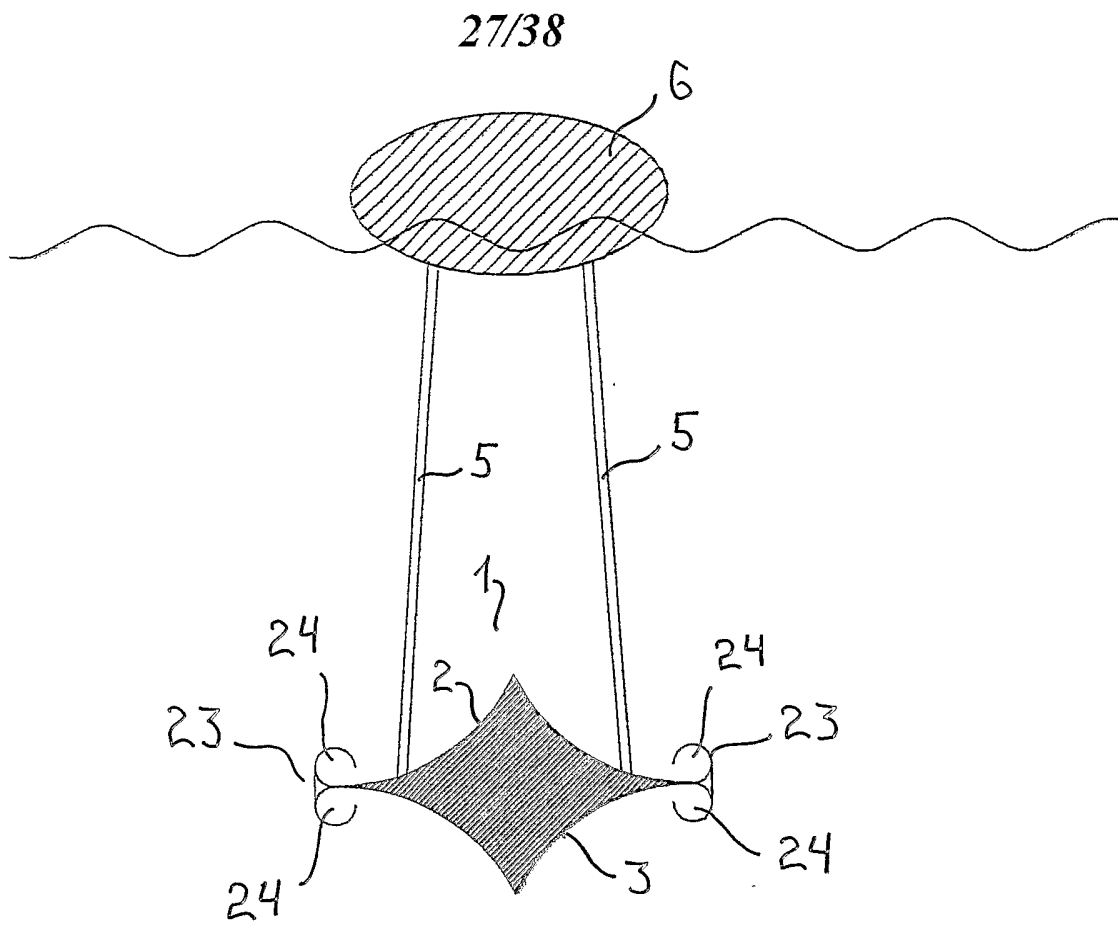


Fig. 48

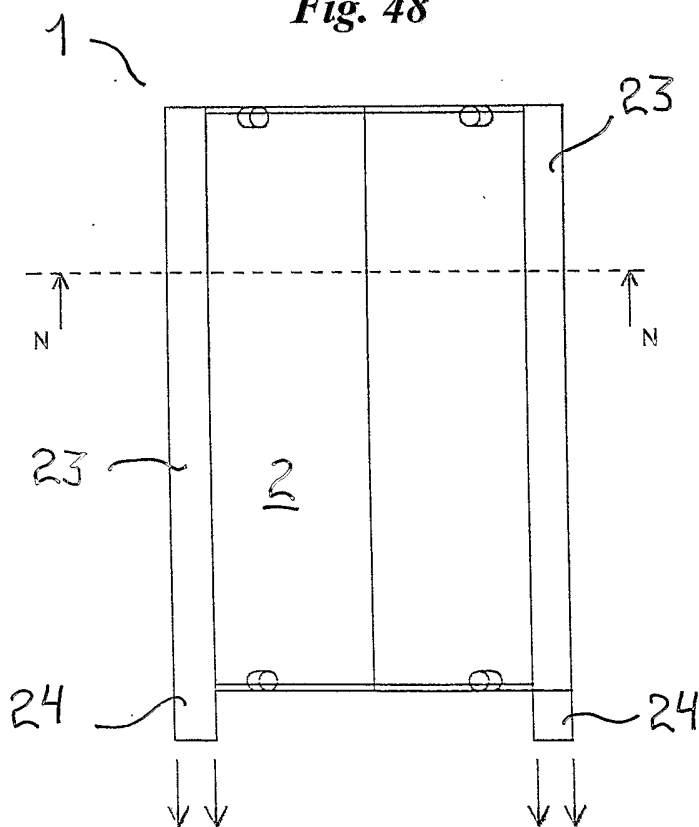


Fig. 49

28/38

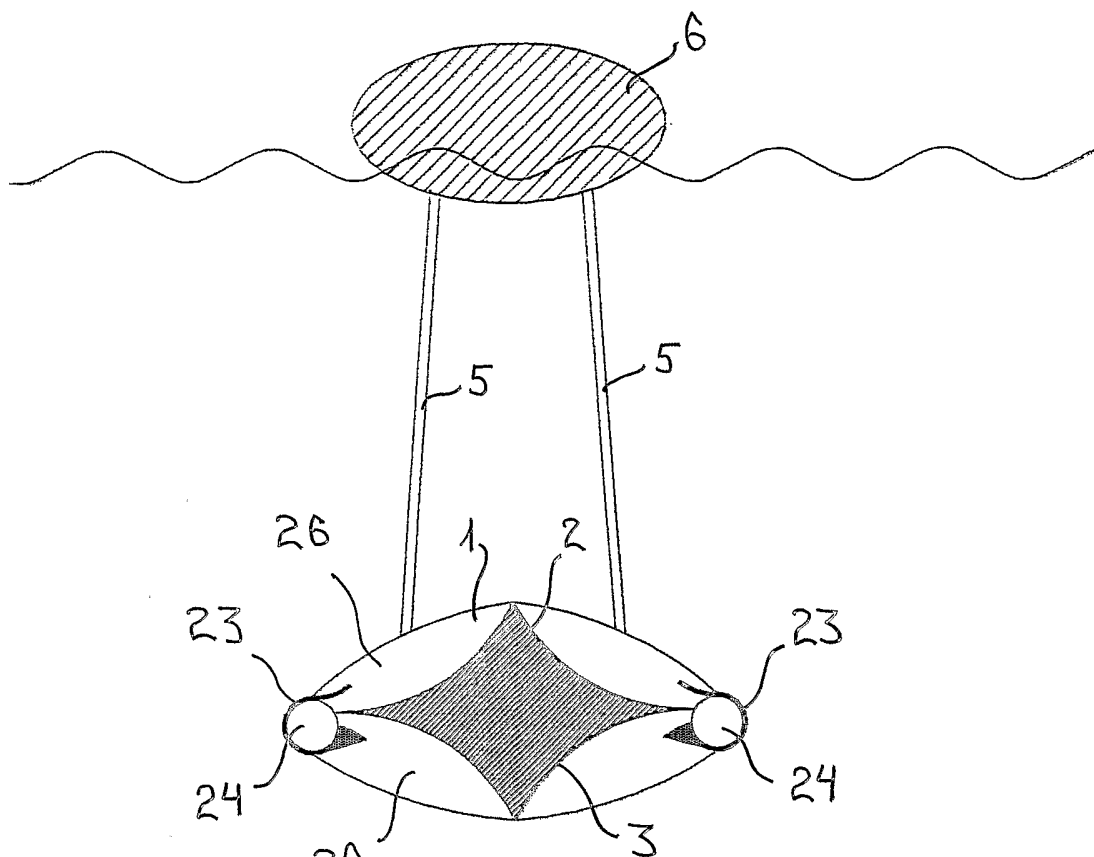


Fig. 50

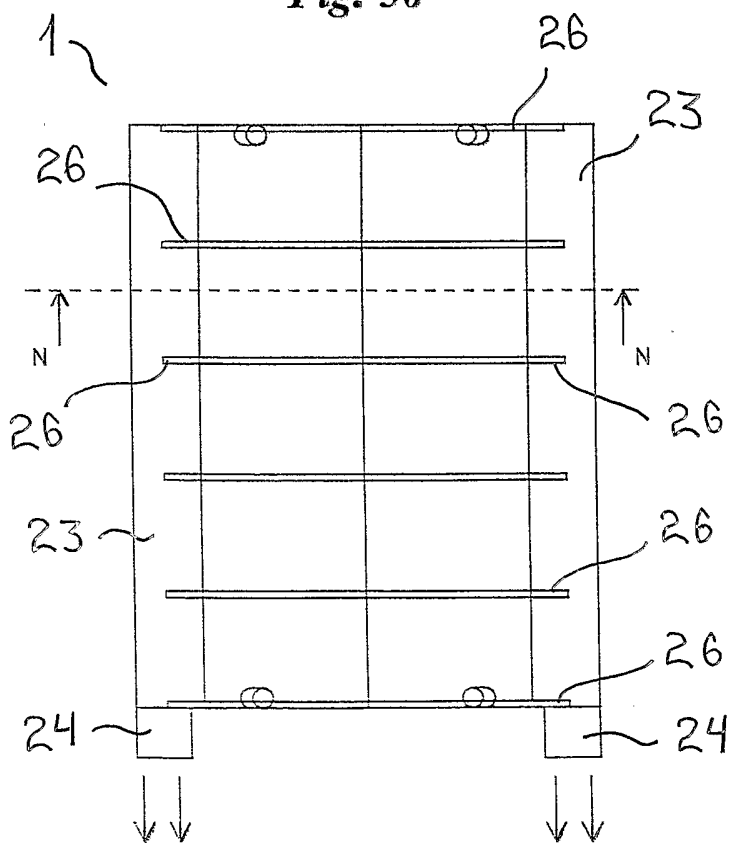


Fig. 51

29/38

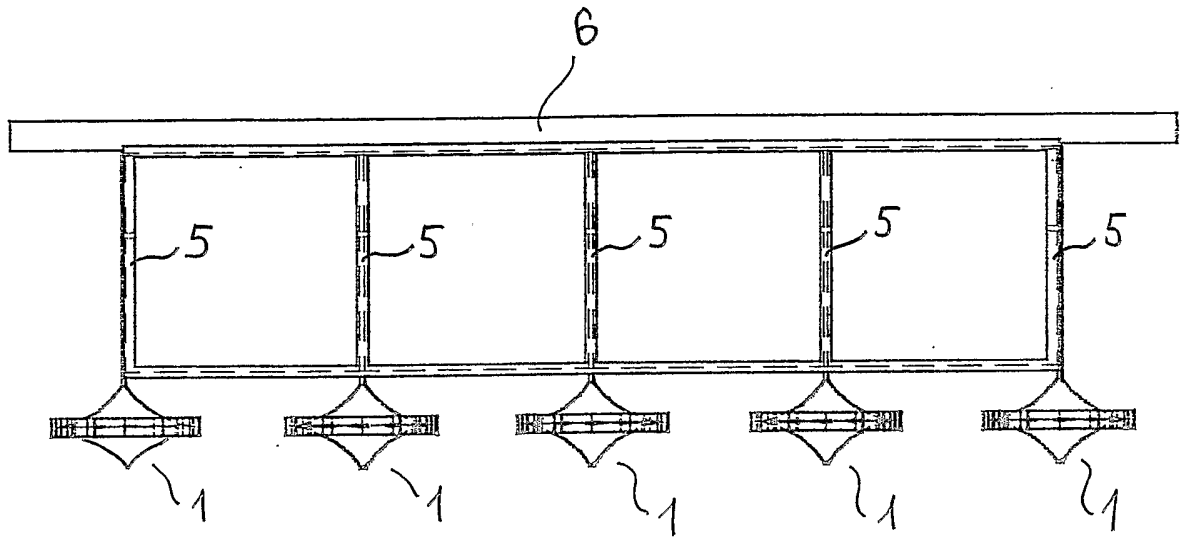


Fig. 52

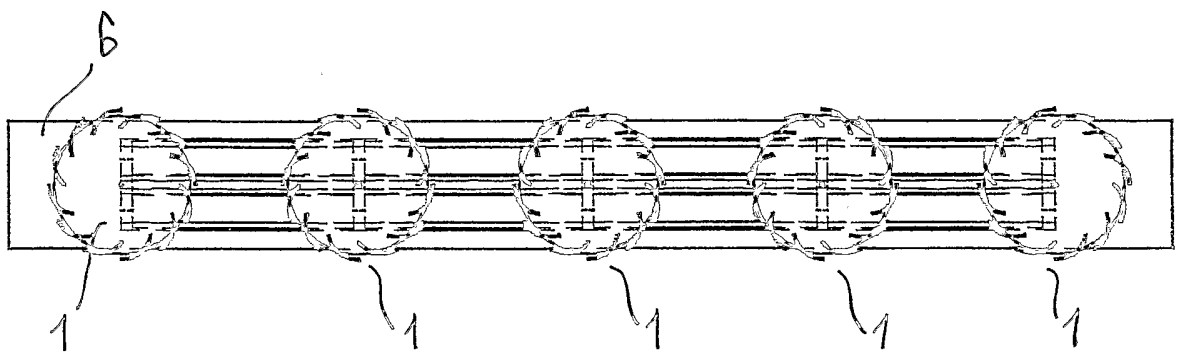


Fig. 53

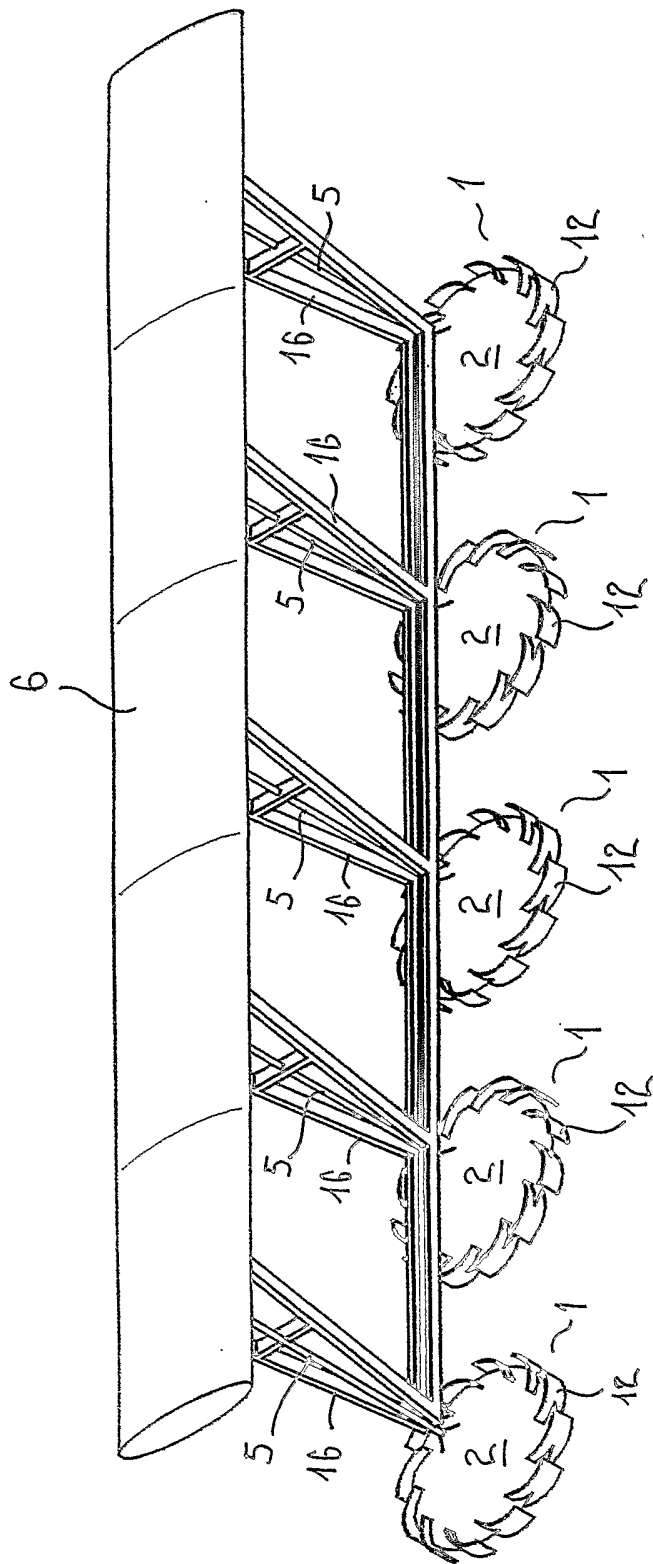


Fig. 54

31/38

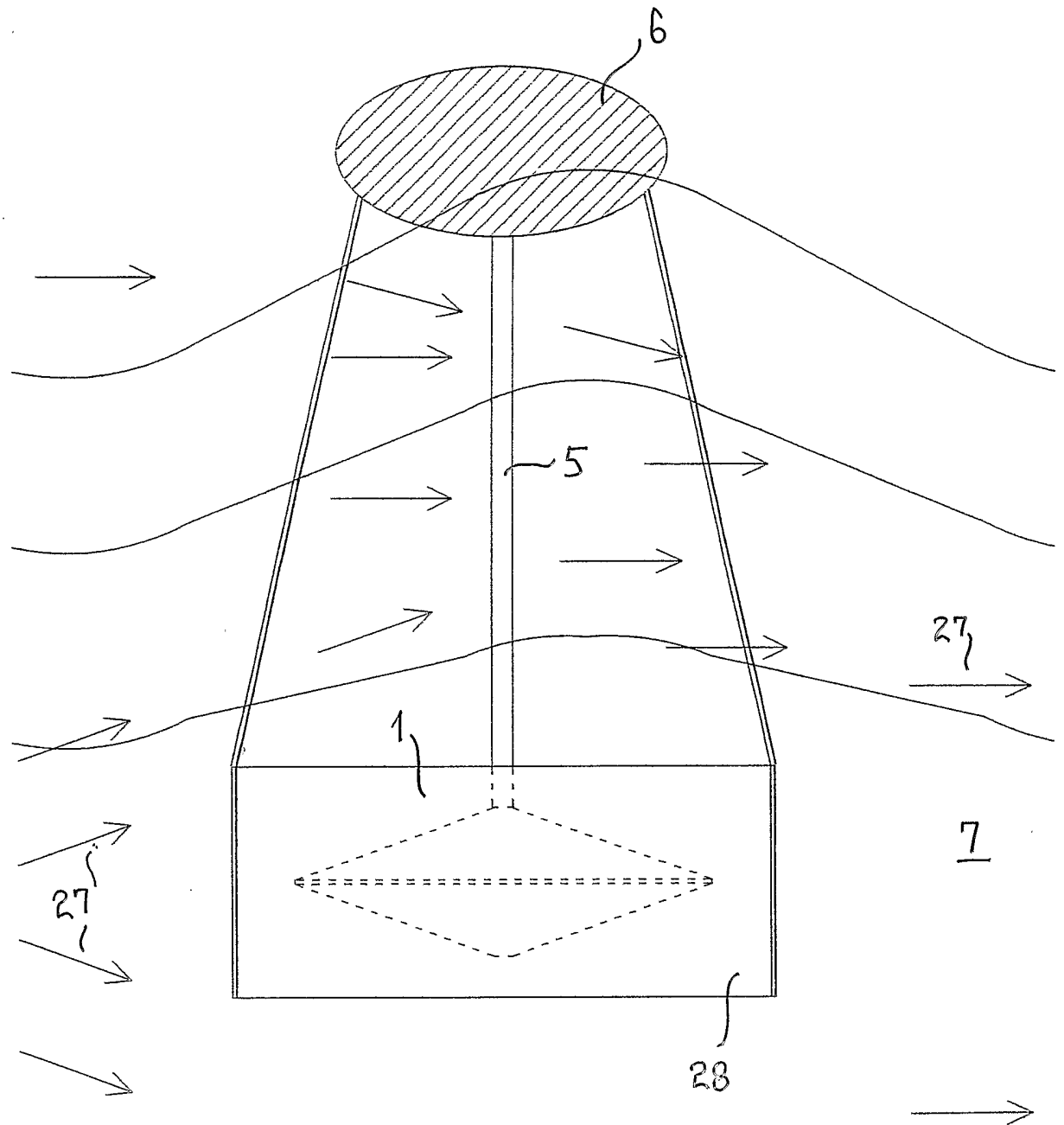


Fig. 55

32/38

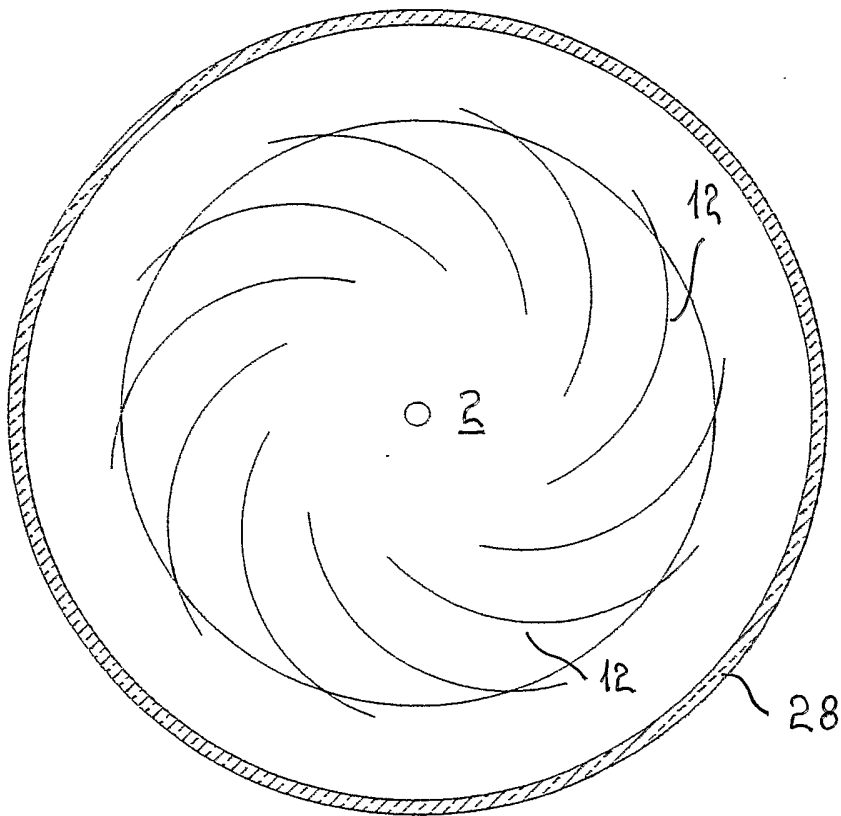


Fig. 56

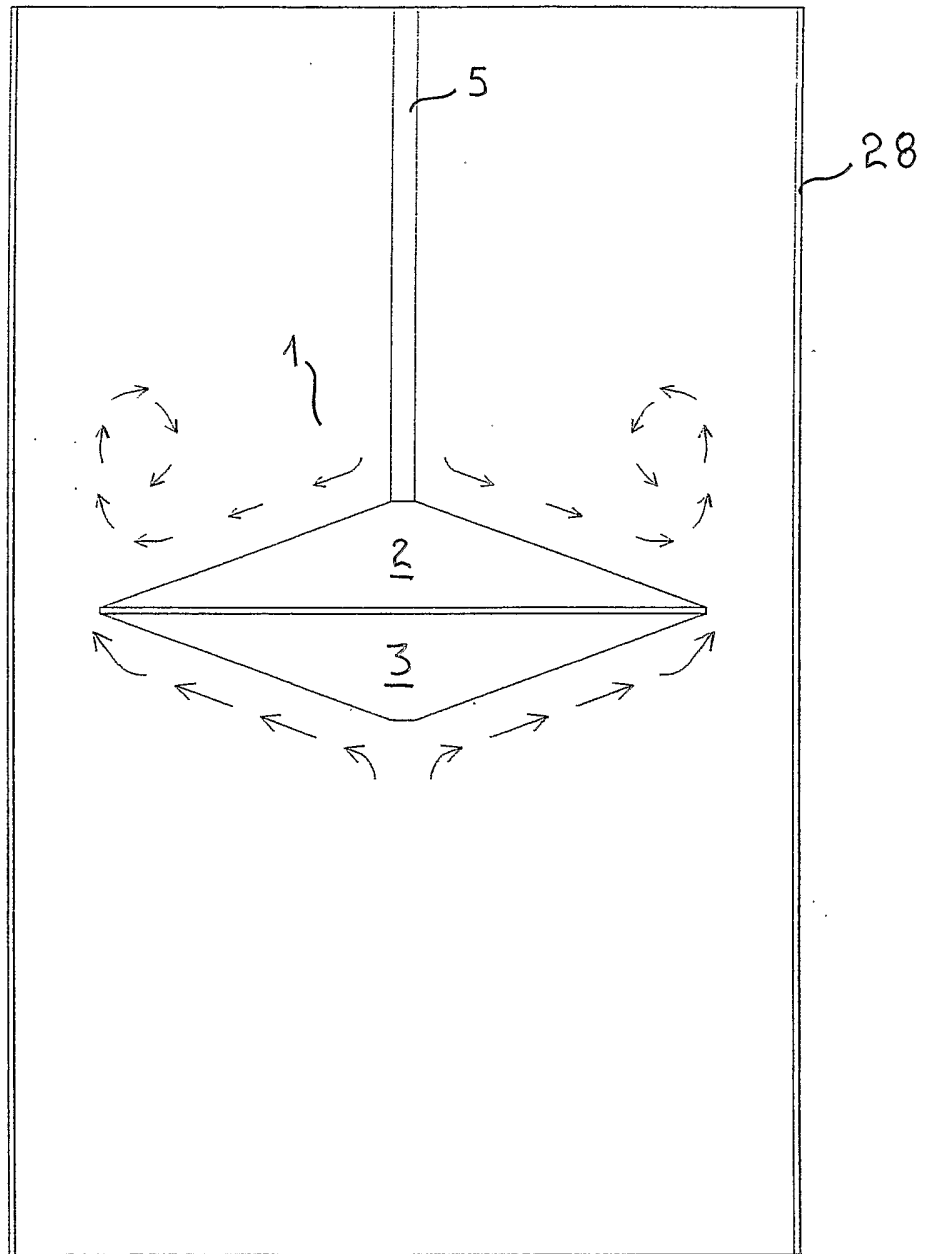


Fig. 57

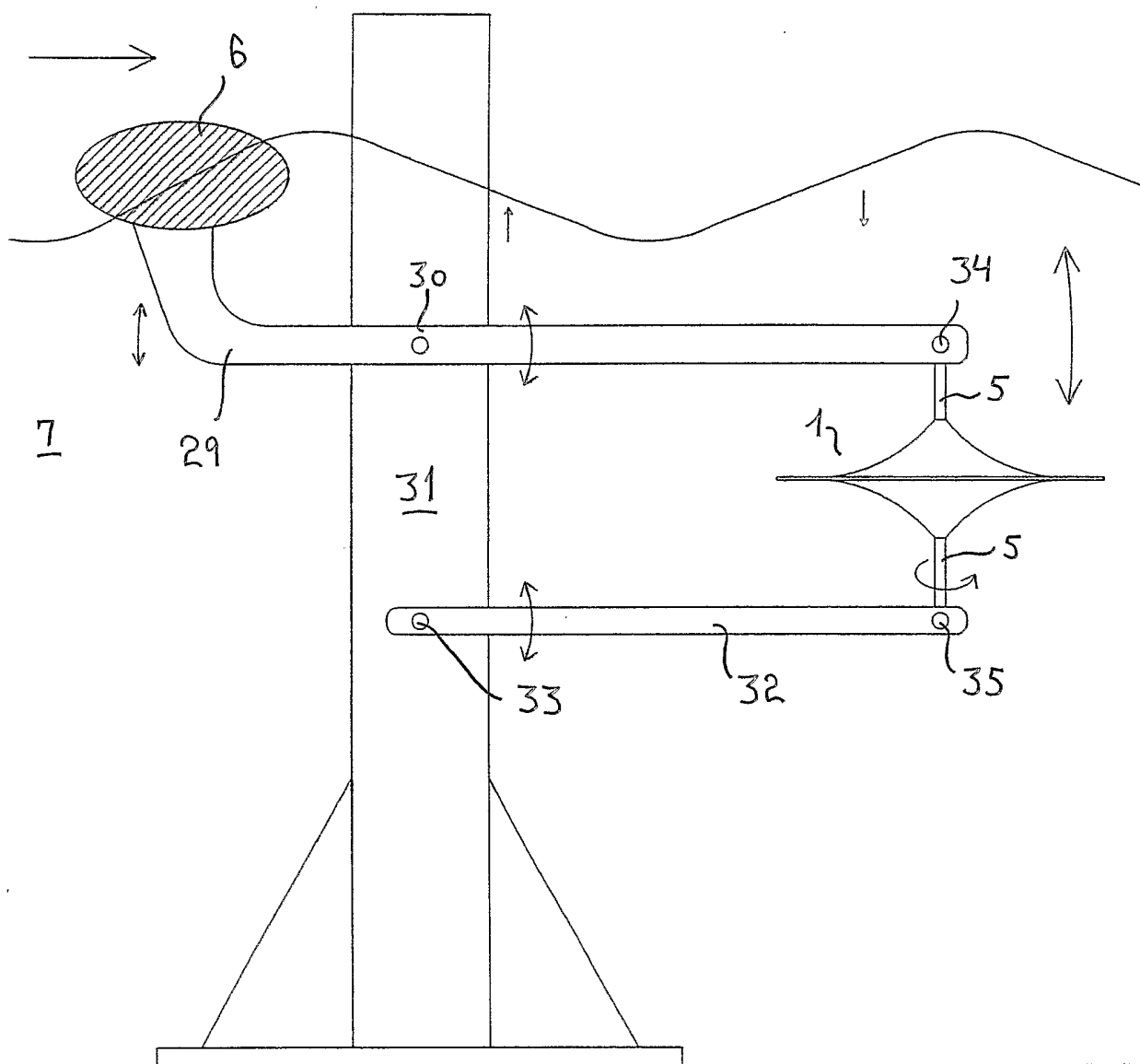


Fig. 58

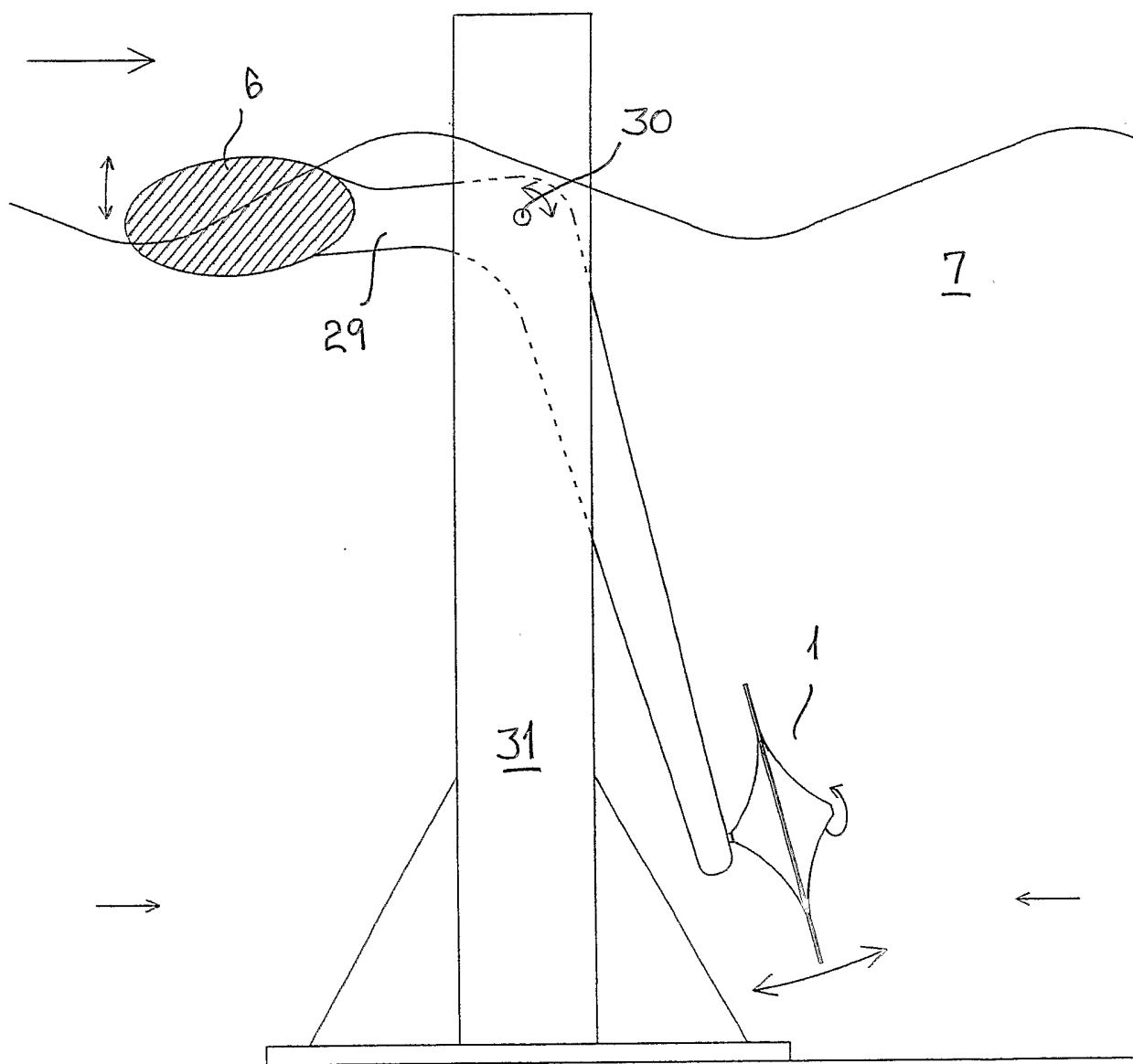


Fig. 59

36/38

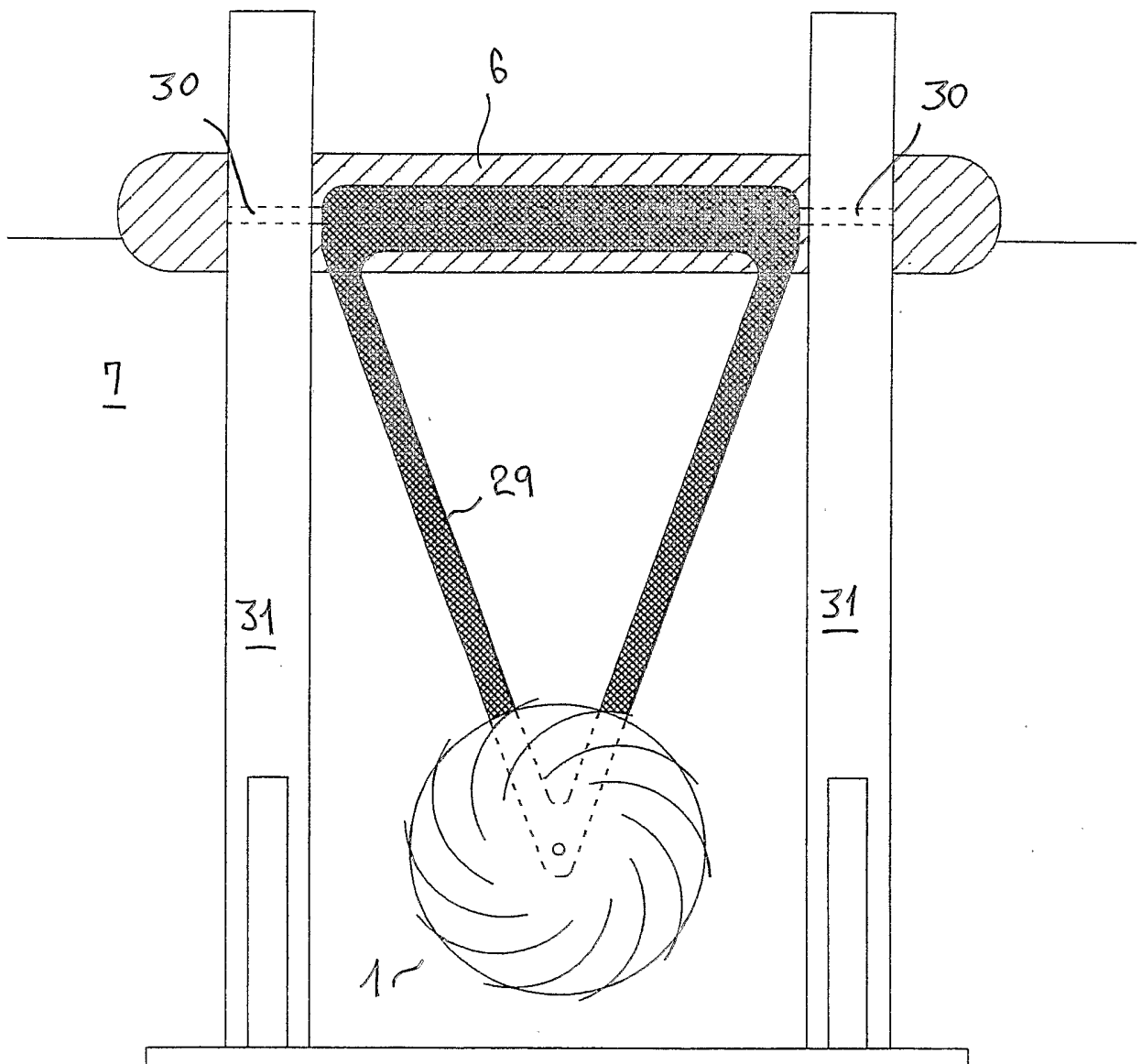


Fig. 60

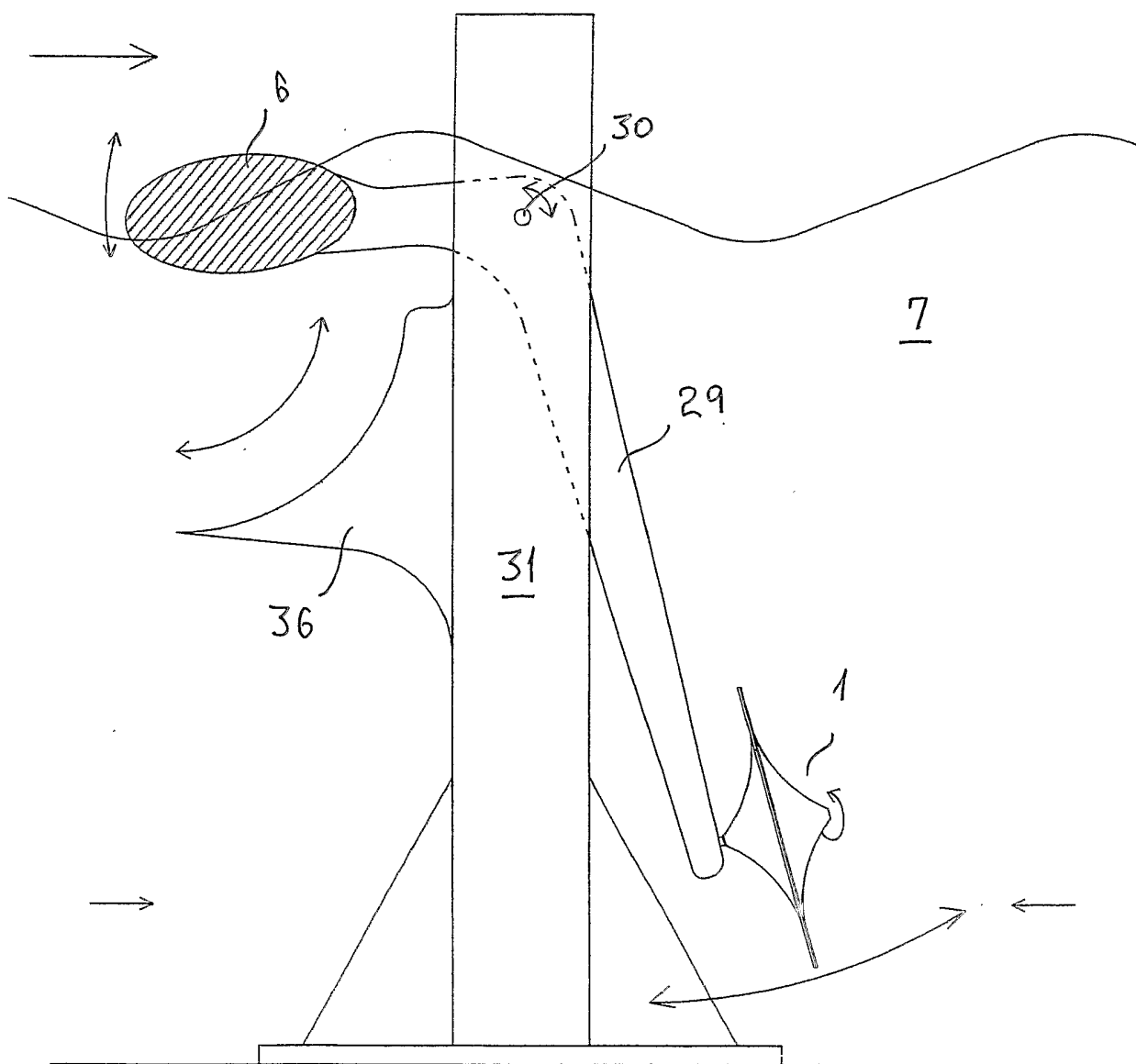


Fig. 61

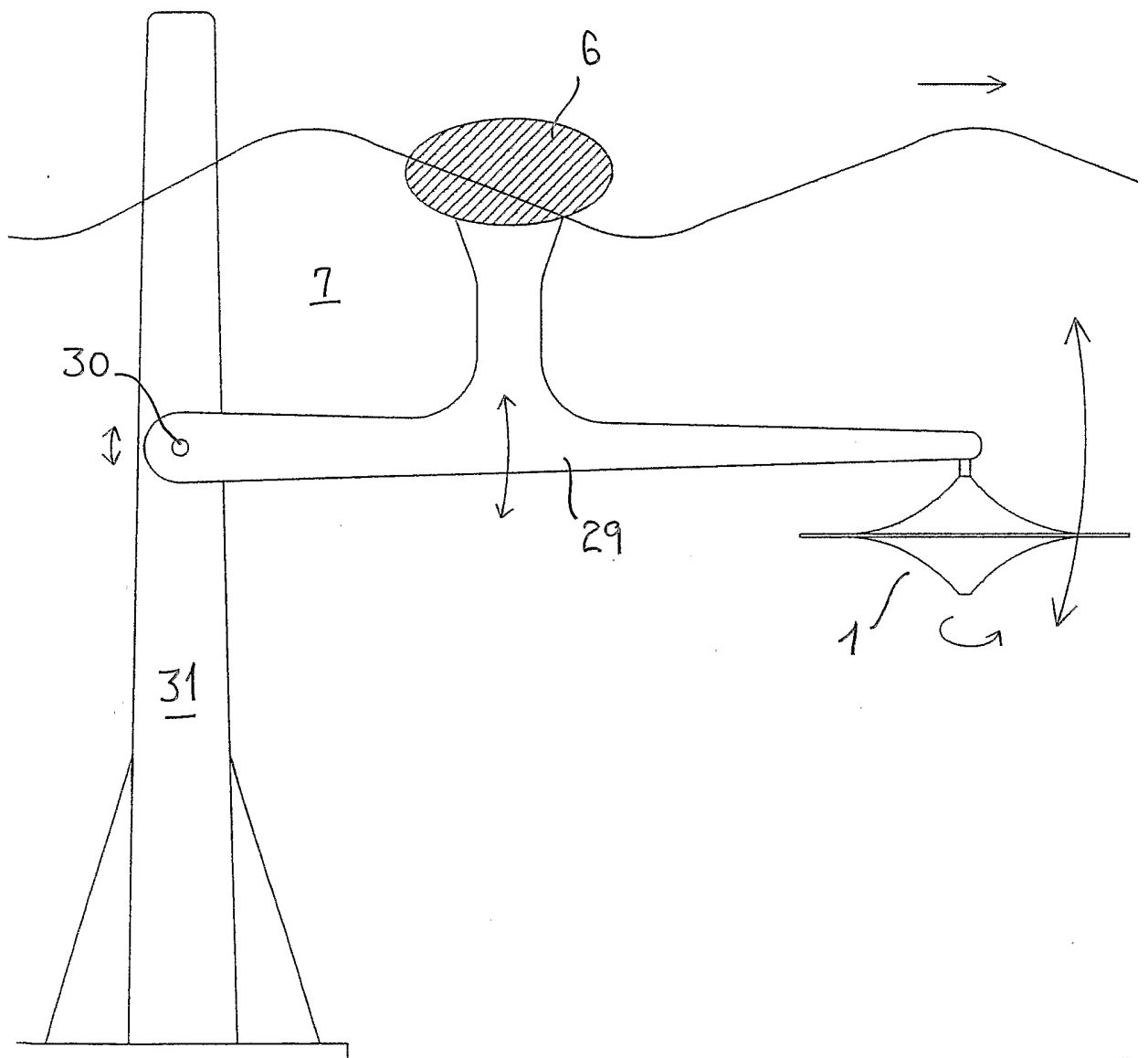


Fig. 62

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK2004/000031

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03B13/20 F03B13/18

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 7 F03B

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

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

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 485 642 A (BEZARD AUGUSTE) 31 December 1981 (1981-12-31)	1-10, 16
Y	page 1, line 5 - line 7 page 2, line 14 - line 18 figures	17-22
Y	----- US 4 447 740 A (HECK LOUIS J) 8 May 1984 (1984-05-08) cited in the application figures 1,16,17	17-22
A	----- DK 9 400 381 U (RINGGAARD BENT) 23 December 1994 (1994-12-23) cited in the application figures	1, 11

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

12 May 2004

Date of mailing of the international search report

21/05/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Angelucci, S

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/DK2004/000031

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
FR 2485642	A	31-12-1981	FR	2485642 A1	31-12-1981
US 4447740	A	08-05-1984	NONE		
DK 9400381	U	23-12-1994	DK	9400381 U3	23-12-1994