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(54) Title: WATER SUPPLY NOZZLE FOR SUBMERSIBLE FISH FARM

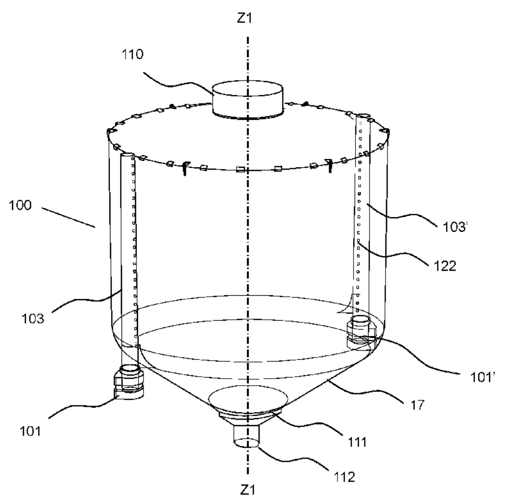

FIG. 1

(57) Abstract: The present invention concerns a water supply nozzle 122 for conducting a water flow into a closed submersible fish rearing tank 100. A first nozzle portion 800 is connectable to an inside surface of the tank 100 and a second nozzle portion 801 is connected to and extending from the first nozzle portion 800. The second nozzle portion 801 is made of a flexible material that is adapted to collapse if the water flow stops or is reduced to prevent reverse flow through the nozzle 122.

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Water supply nozzle for submersible fish farm

Field of the invention

The invention relates to a closed submersible fish farm with a fluid retention mechanism, more specifically a collapsible water supply nozzle.

Background

One of the goals of the aquaculture industry is environmentally sustainable development. The industry is therefore producing solutions that achieve energy efficiency, reduction of fossil fuels and reduced climate footprint.

The spread of salmon lice and other disease infections is a major issue for the aquaculture industry. Escape of fish is also a problem especially for the wild salmon stock - and is often due to technical failure, incorrect use of equipment and vessels, or storms.

In addition, emissions in the aquaculture industry have increased, and the industry accounts for large amounts of seabed waste along coastal areas. The waste largely consists of waste from feed and faeces, but also waste from medical treatments and delousing. The environmental impact because of the waste is largest below or in the immediate vicinity of the fish farms, and the discharges could potentially affect life on the seabed and affect the environmental conditions near the sites.

The above-mentioned issues create a need for closed fish farms that reduce the environmental problems, and which ensure growth and sustainability in the future. To increase production, there is also a need for new locations in more weather-exposed areas at sea. Closed and semi-closed fish farms have been deployed to remedy the above problems. Some companies produce land-based facilities, but such plants require considerable land areas, increased energy and water consumption. Handling of sludge production yield significant costs. Rigid fish tank structures are also costly to produce, and large tanks may be extremely heavy and hard to transport and deploy.

It is therefore an object of the invention to provide an easy to transport, energy efficient, closed, submersible fish rearing facility with low weight and that is cost efficient, easy to deploy and easy to maintain.

The environment from which the fish is sought to be separated from is mainly the upper water layer to avoid lice and other pathogens, while the waste substances are released into the bottom as in traditional cages. Disadvantages of these solutions include that they are cumbersome to operate, and they do not sufficiently reduce sea-bed pollution. It is therefore an object of the invention to provide an easy to transport, energy efficient, closed, submersible fish rearing facility with low weight and that is cost efficient, easy to deploy and easy to maintain. It is also an object of the invention to provide a facility that is adapted to be submerged below the upper water layers of the sea to avoid sea-lice, harsh weather conditions and floating debris. It is also an object of the invention to provide controlled water treatment, evenly distributed water flow within the facility, and controlled waste discharge to obtain ideal fish rearing conditions and environmentally friendly production.

For closed submersible fish farms having a flexible tank structure, it’s important to keep the tank completely water inflated at all times during operation, providing a maximum water volume for the fish. This may be solved by supplying water to the tank at a certain rate while providing a flow restriction through a water outlet of the tank.

However, if the water supply malfunctions, shuts down of if the water supply is significantly reduced the internal water will seek to flow out of the tank. This may result in pressure loss and cause the tank to collapse. This will dramatically affect the fish welfare causing cramped conditions and reduced water quality, which furthermore cause stress amongst the fish. A reduced tank volume naturally results in a reduced amount of oxygen available to the fish.

It is therefore an object of the invention to provide a mechanism for preventing flowback and automatically maintaining the tank water pressure in case a tank water supply shuts down. Is also an object of the invention to prevent a closed submersible tank having a flexible closure from collapsing due to reduction or loss of water supply.

Summary of the invention

The invention relates to a water supply nozzle for conducting a water flow into a closed submersible fish rearing tank including a first nozzle portion connectable to an inside surface of the tank, a second nozzle portion connected to and extending from the first nozzle portion. The second nozzle portion is made of a flexible material which is adapted to collapse if the water flow stops or is reduced to prevent reverse flow through the nozzle.

The invention further relates to said water supply nozzle, wherein the first nozzle portion is curved to redirect the water flow.

The invention further relates to said water supply nozzle, wherein the second nozzle portion is elongated.

The invention further relates to said water supply nozzle, wherein the second nozzle portion is tunnel shaped and attached to an inside surface of the tank.

The invention further relates to said water supply nozzle, wherein in the first nozzle portion is made of a rigid material.

The invention further relates to said water supply nozzle, wherein in the first nozzle portion is made of a flexible material.

The invention also relates to a submersible fish rearing tank including an exterior enclosure including water supply means adapted to pump water into the tank for providing a pressure inside the submersible fish rearing tank exceeding a pressure acting on the outside of the submersible fish rearing tank. The water supply means is in fluid connection with at least one nozzle according to any of the preceding claims.

The invention relates to said fish rearing tank, wherein the exterior enclosure is made of a flexible material.

The invention relates to said fish rearing tank, wherein the water supply means comprises at least one inlet water supply column adapted to provide water into the submersible fish rearing tank and at least one pump unit adapted to pump water into the tank through the water supply column via the nozzles.

The invention relates to said fish rearing tank, wherein the nozzles are arranged in a vertical array in fluid connection with the water supply column.

The invention also relates to a water supply device including a water supply column, a pump unit connected to an upper or lower end of the water supply column, a vertical array of said nozzles connected to the water supply column, wherein the nozzles are in fluid communication with the inner volume of the water supply column.

Brief description of drawings

Fig. 1 is a transparent perspective view of a submersible fish farm according to the invention deployed in water;
Fig. 2 shows a perspective view of a plurality of nozzles according to the invention during operation;
Fig. 3 is a perspective view of a nozzle according to the invention in an inflated state;
Fig. 4 is a perspective view of a nozzle according to the invention in a collapsed state;
Fig. 5 is a cross-sectional view of a nozzle according to an embodiment of the invention in an inflated state;
Fig. 6 is a cross-sectional view of a nozzle according to Fig. 5 in a collapsed state.

Detailed description of embodiments

Fig. 1 is a transparent perspective view of a submersible fish farm according to the invention deployed in water. The submersible fish farm includes an underwater fish rearing tank 100.

The tank 100 further includes an exterior enclosure 17, an upper utility transition element 110 and a lower utility transition element 111 forming a closed habitat for fish. The habitat is sufficiently closed to allow a pressure to build up inside the tank 100. The internal hydrodynamic pressure forces the exterior enclosure 17 to maintain its shape as illustrated in Fig. 1 during operation.

The exterior enclosure 17 is preferably a membrane made of a flexible material such as PE, PVC, latex, nylon or any impermeable or semi-permeable, flexible plastic or fabric material. The exterior enclosure 17 may have elastic properties. The exterior enclosure 17 may also be made of a rigid material forming a rigid tank structure.

Although the tank is closed, the tank 100 may receive seawater (fresh or saline), fluids such as air and oxygen, feed, and furthermore discharge used water and waste. The term “closed” used in this application does therefore not exclude the presence of inlets and outlets, but is used to distinguish the invention from fish farms with permeable net cages, open-air basins etc.

Intake and discharge may be autonomously controlled by a controller connected to a plurality of sensors and cameras installed in the tank 100, thereby allowing controlled water treatment and flow for achieving optimal fish rearing conditions and optimal power usage. The pressure inside the tank 100 prevents ingress of unwanted elements in the event of a leak.

Incoming and outgoing water may be filtered to prevent sea lice from entering the tank 100, and from polluting the surrounding environment, although the tank water may be replaced in such a rate that sea lice would not be able to latch on to the fish.

The exterior enclosure 17 is fixed to the upper utility transition element 110 and to the lower utility transition element 111. The utility transition elements 110, 111 may be rigid and preferably made of metal, plastic or composite materials.

The exterior enclosure 17 may be equipped with a zipper (not shown) for opening the enclosure 17 for accessing the inside of the tank 100, e.g. for cleaning, replacing or performing maintenance on internal components.

The submersible fish farm may be deployed and operated offshore, in coastal areas or in freshwater lakes.

Fig. 1 further shows that the underwater fish rearing tank 100 includes a first water supply column 103 and a second water supply column 103’ attached to the exterior enclosure 17 on diametrically opposite sides. Each water supply column 103, 103’ can be a rigid or flexible tubular and elongated structure, preferably cylindrical but may have a rectangular or elliptical cross-section, extending vertically along the exterior of the tank 100 in parallel with the vertical centre axis Z1 of the tank 100. The first water supply column 103 and a second water supply column 103’ attached to the exterior enclosure 17 may be curved to accommodate the shape of the submersible fish rearing tank 100 and may be integrated into a wall exterior enclosure 17.

Each water supply column 103, 103’ includes nozzles 122 aligned in a vertical array along a surface of the water supply column 103, 103’. The nozzles 122 have outlets inside of the tank 100. The nozzles 122 may be oriented at an angle with a tangential component to create rotational flow inside the tank 100. The nozzles 122 of each of the supply columns 103, 103’ may be oriented in the same direction to create the rotational flow inside the tank 100. The nozzles 122 may also be aimed in different directions to create any desired flow inside the tank 100.

The tank 100 may include additional water supply columns (not shown) attached to the exterior enclosure 17, preferably having the same circumferential distance between each other. The water supply columns 103, 103’ are preferably made of a light-weight and rigid or flexible plastic or metal material. Suitable materials include PE, PVC, latex, nylon or any impermeable and flexible plastic or fabric material.

The upper utility transition element 110 includes a buoyancy element (not shown), such as a dynamic ballast tank, keeping the tank afloat at a desirable depth. The lower utility transition element 111 may include a weight element, such as a heavy solid material. The upper utility transition element 110 provides buoyancy while the lower utility transition element 111 provides gravity, counteracting any tilting movement and ensures that the tank always returns to an upright position aligned in parallel with a vertical axis Z. The tank 100 may also be moored to the sea-bed without the need for a lower utility transition element 111.

In Fig. 1, the upper utility transition element 110 is coupled with the lower utility transition element 111 via the flexible enclosure 17 thereby providing a submersible spar structure. The utility transition elements 110, 111 may additionally be connected by means of a column or a flexible element such as wire, chain or rope (not shown).

Each water supply column 103, 103’ is attached and sealed onto the outside of the exterior enclosure 17 by ways of being sown, glued or melted into the exterior enclosure 17 over an attachment length. In operation, the attachment length is shorter than the distance between the utility transition elements 110, 111. Consequently, as shown in Fig. 1, the exterior enclosure 17 forms a cylindrical mid-section along the said attachment length, a conical top-section and a conical bottom-section. At least one hole in the exterior enclosure 17 is provided to ensure fluid communication between each water supply column 103 and the tank 100 volume via nozzles 122.

Each water supply column 103, 103’ may include a lower water inlet pump unit 101 located on its lower end. Each water supply column 103, 103’ may also include an upper water inlet pump unit (not shown). Each water inlet pump unit 101, 101’ includes a water inlet (see Fig. 1) and a water pump mechanism for drawing clean ambient water into the water supply column 103 and into the underwater fish rearing tank 100 via nozzles 122 in the water supply column 103 with nozzle outlets inside the tank 100. The pump may be actuated by a topside controller (not shown) manually or autonomously based on data retrieved from sensors included in the tank 100. The lower water inlet pump unit 101 serves to increase hydrodynamical pressure within the tank and to create a rotational fluid flow inside the tank 100 and allow water replacement so that the fish is provided with clean water.

The lower utility transition element 111 includes a water outlet 112 for discharging water from the tank 100.

The water outlet 112 may include a passive or actuatable flow restrictor/reducer or throttle to reduce or restrict or completely close the outlet water flow from the water outlet 112 to maintain the pressure inside the submersible fish rearing tank 100 above the pressure acting on the outside of the submersible fish rearing tank 100.

The pressure difference between the outside and the inside of the tank allows the water outlet 112 to passively expel water from inside the tank 100.

The utility transition elements 110, 111 may provide a transition for at least one of a water inlet, a water outlet, a gas outlet, an air inlet, and connections for instrumentation, fixed to the exterior enclosure 17.

Fig. 2 shows a perspective view of a plurality of nozzles 122 according to the invention during operation. The nozzles 122 are impermeably fixed to each water supply column 103, 103’. The nozzles 122 are oriented at an angle with a tangential component to create rotational flow inside the tank. In Fig. 2, the nozzles of each of the supply columns 103, 103’ are oriented in the same direction to create the rotational flow inside the tank. The nozzles 122 may however be directed in any direction to obtain a desired flow within the tank 100.

The nozzles 122 may be placed above each other, preferably with a constant distance between each other.

Fig. 3 is a perspective view of a nozzle 122 according to the invention in an inflated state. Fig. 3 shows a nozzle 122 seen from a side. The nozzle 122 includes a first nozzle portion 800. The first nozzle portion 800 may be of a rigid material (e.g. plastic, composite or metal) or a flexible material such as the material of the second nozzle portion 801. The first nozzle portion 800 may be curved and semi-circular to redirect water flowing inside the nozzle 122. The first nozzle portion 800 may be cubical or cylindrical or any other tubular or annular shape.

In an embodiment where the first nozzle portion 800 is rigid, consideration is given to selecting a material for the first nozzle portion 800 having suitable materials properties and a suitable thickness that meet the necessary rigidness to prevent it from collapsing when the internal tank water pressure exceeds the internal nozzle water pressure. This enables the rigid component to remain open consistently, despite variations in water pressure.
The nozzle 122 further includes a second nozzle portion 801 connected to the first nozzle portion 800 as an extension of the first nozzle portion 800. The second nozzle portion 801 may have a cross-sectional shape of a semi-circle and fixed to the inside of the tank 100 at two sides of the nozzle 122 forming a tunnel. The second nozzle portion 801 may also have a rectangular cross section. The second nozzle portion 801 may be elongated or oblong. The second nozzle portion 801 is made of a flexible material such as PE, PVC, latex, nylon or any impermeable and flexible plastic or fabric material.

Consideration is given to selecting a material having suitable materials properties and a suitable thickness that meet the necessary flexibility requirements to ensure that the second nozzle portion 801 collapses during a decrease in dynamic water pressure inside the nozzle, i.e. when the internal tank water pressure exceeds the water pressure within the second nozzle portion 801.

The first nozzle portion 800 is curved, slanted, or skewed to orient the fluid flowing within the nozzle 122 at an angle so that the fluid is dispensed at an angle into the tank 100 volume.

The nozzles 122 may be directed with a tangential component inside the tank to generate a circular or spiral shaped waterflow inside the tank 100.

The first nozzle portion 800 is extended by the second nozzle portion 801 which extends in parallel with the inside of the tank 100 and/or the enclosure 17. The second nozzle portion 801 may be substantially longer than the first nozzle portion 800.

In Fig. 3 the pump unit 101 (see Fig. 1) is operational and water flows at a normal rate through the nozzle 122. The hydrodynamic pressure acting on the inside the nozzle 122 is thereby higher than the pressure acting on the outside of the nozzle 122 by immediate surrounding water. By way of this pressure differential, the second nozzle portion 122 is held completely stretched out and water inflated, thereby providing its maximum cross-sectional flow area.

Fig. 4 is a perspective view of a nozzle 122 according to the invention in a collapsed state. Fig. 4 shows the nozzle 122 in operation in a situation where the accommodating water pump unit 101 (see Fig. 1) shuts down. This situation may be caused intentionally by shutting down the water pump 101. In another situation the pump unit 101 may malfunction and stop completely, or water may otherwise be prevented from entering the nozzles 122 from the outside. Both situations result in reduced or zero flow through the nozzle 122, and since hydrodynamic water pressure inside the tank 100 during operation is constantly higher than the hydrodynamic pressure acting on the tank 100 from the outside, the internal water will seek to flow out of the tank 100 through a water outlet 112 (see Fig. 1). This results in a relative pressure loss, and in that the inside pressure and the outside pressure is equalized, causing the tank 100 to at least partly collapse. This may dramatically affect the fish welfare causing cramped conditions and reduced water quality, which furthermore cause stress amongst the fish. A reduced tank volume naturally results in a reduced amount of oxygen available to the fish. It is therefore important to keep the tank 100 completely inflated at all times during operation, providing a maximum water volume for the fish habitat.

The tank 100 normally receives water which is more saline than its surrounding water. Therefore, the water inside the tank 100 is more dense than the water outside the tank 100. The density differential puts pressure on the inside of the tank 100, causing the internal water to seek a out of the tank 100 even with no water supply.

To prevent the internal water from flowing out of the tank 100 when the water supply shuts down or is reduced, any water outlet present in the tank 100 must be closed or restricted. In a specific situation, a water pump unit 101 may at least partly shut down, while another pump unit 101’ may still be functioning.

When the water supply shuts down or is reduced, the hydrodynamic water pressure acting on the inside of the nozzle 122 is lower than the hydrodynamic water pressure acting on the outside of the nozzle 122. The pressure differential causes at least the second nozzle portion 801 to collapse, preferably against an inner surface if the tank 100. This flattens the second nozzle portion 801 and reduces its cross-sectional flow area, preferably to zero. Also, the mentioned salinity difference may create yield a force, also causing at least the second nozzle portion 801 to collapse.

Thus, the nozzles 122 are adapted to automatically collapse and prevent flowback when water supply is shut down or reduced.

In a situation where every water pumps shuts down, the water outlet 112 (see Fig. 1) may be closed. The enclosure 17 (see Fig. 1) may have some elastic properties, which facilitates keeping the tank 100 completely water inflated even after water supply shuts down. The nozzles 122 would automatically collapse in this situation.

The tank 100 may also stay water inflated in situations where the water supply is not completely shut down.

By way of providing a flexible material property to the second nozzle portion 801 of the nozzle, the second nozzle portion 801 will collapse when the water supply shuts down due to pressure loss within the nozzle 122. The hydrodynamic pressure within the tank 100 therefore forces the second nozzle portion 801 to collapse, and therefore completely preventing water from flowing back through the nozzle 122 and out to the ambient water.

The second nozzle portion 801 may be elongated to provide a long flat part in the collapsed state, which ensures that the risk of flowback is reduced.

Fig. 5 is a cross-sectional view of a nozzle 122 according to an embodiment of the invention in an inflated state. As stated above, both the first and second nozzle portions 800, 801 may be made of flexible materials. In Fig. 5 both the first and second nozzle portions 800, 801 are made of flexible materials adapted to collapse to prevent reverse water flow through the nozzle 122. In Fig. 5 water flow is active and flows through the water supply column 103, 103’, the nozzle 122, the first nozzle portion and the second nozzle portion 801, and lastly into the tank 100 volume. In Fig. 5 the hydrodynamical pressure acting on the inside of the first nozzle portion 800 is named p2, while the hydrodynamical pressure acting on the external surface of the first nozzle portion 800 is named p1. In Fig. 5 p2 is greater than p1, thereby keeping the first and second nozzle portions 800, 801 open for transporting fluid into the tank 100. The tank 100 may include a plurality of nozzles 122 according to the embodiment of Fig. 5.

Fig. 6 is a cross-sectional view of a nozzle 122 according to Fig. 5 in a collapsed state. In Fig. 5 water supply is shut down or reduced substantially, and thereby leaving p1 greater than p2, thereby forcing the flexible first and second nozzle portions 800, 801 to collapse preventing reverse flow out of the tank 100. The first nozzle portion 800 is introverted and forced a distance inside the water supply column 103, 103’. In addition, the second nozzle portion 801 is collapsed and forced against the inside surface of the tank 100 preventing water from flowing in reverse. The first nozzle portion 800 abuts and seals against the perimeter of the opening 1221. This provides an additional sealing effect compared to the embodiment of Fig. 4 where only the second portion 801 collapses and seals against the inside surface of the tank 100.

PATENT CLAIMS

1. Water supply nozzle (122) for conducting a water flow into a closed submersible fish rearing tank (100) comprising:

a first nozzle portion (800) connectable to an inside surface of the tank (100); and

a second nozzle portion (801) connected to and extending from the first nozzle portion (800);

wherein the second nozzle portion (801) is made of a flexible material which is adapted to collapse if the water flow stops or if the water flow is reduced to prevent reverse water flow through the nozzle (122).

2. Water supply nozzle (122) according to claim 1, wherein the first nozzle portion (801) is curved to redirect the water flow.

3. Water supply nozzle (122) according to any preceding claim, wherein the second nozzle portion (801) is elongated.

4. Water supply nozzle (122) according to any preceding claim, wherein the second nozzle portion (801) is tunnel shaped and attached to an inside surface of the tank (100).

5. Water supply nozzle (122) according to any preceding claim, wherein in the first nozzle portion (800) is made of a rigid material.

6. Water supply nozzle (122) according to one of the claims 1-4, wherein in the first nozzle portion (800) is made of a flexible material adapted to collapse if the water flow stops or if the water flow is reduced to prevent reverse flow through the nozzle (122).

7. A submersible fish rearing tank (100) comprising:

an exterior enclosure (17);

water supply means (103, 101) adapted to pump water into the tank (100) for providing a pressure inside the submersible fish rearing tank (100) exceeding a pressure acting on the outside of the submersible fish rearing tank (100);

wherein the water supply means (103, 101) is in fluid connection with at least one nozzle (122) according to any of the preceding claims.

8. The submersible fish rearing tank of claim 7, wherein the exterior enclosure (17) is made of a flexible material.

9. The submersible fish rearing tank of claim 7 or 8, wherein the water supply means (103, 101) comprises at least one inlet water supply column (103) adapted to provide water into the submersible fish rearing tank (100) and at least one pump unit (101) adapted to pump water into the tank (100) through the water supply column (103) via the nozzles (122).

10. The submersible fish rearing tank of claim 9, wherein the nozzles (122) are arranged in a vertical array in fluid connection with the water supply column (103).

11. Water supply device comprising:

a water supply column (103);

a pump unit (101) connected to an upper or lower end of the water supply column (103);

a vertical array of nozzles (122) according to any of the preceding claims 1-5 connected to the water supply column (103);

wherein the nozzles (122) are in fluid communication with the inner volume of the water supply column (103).

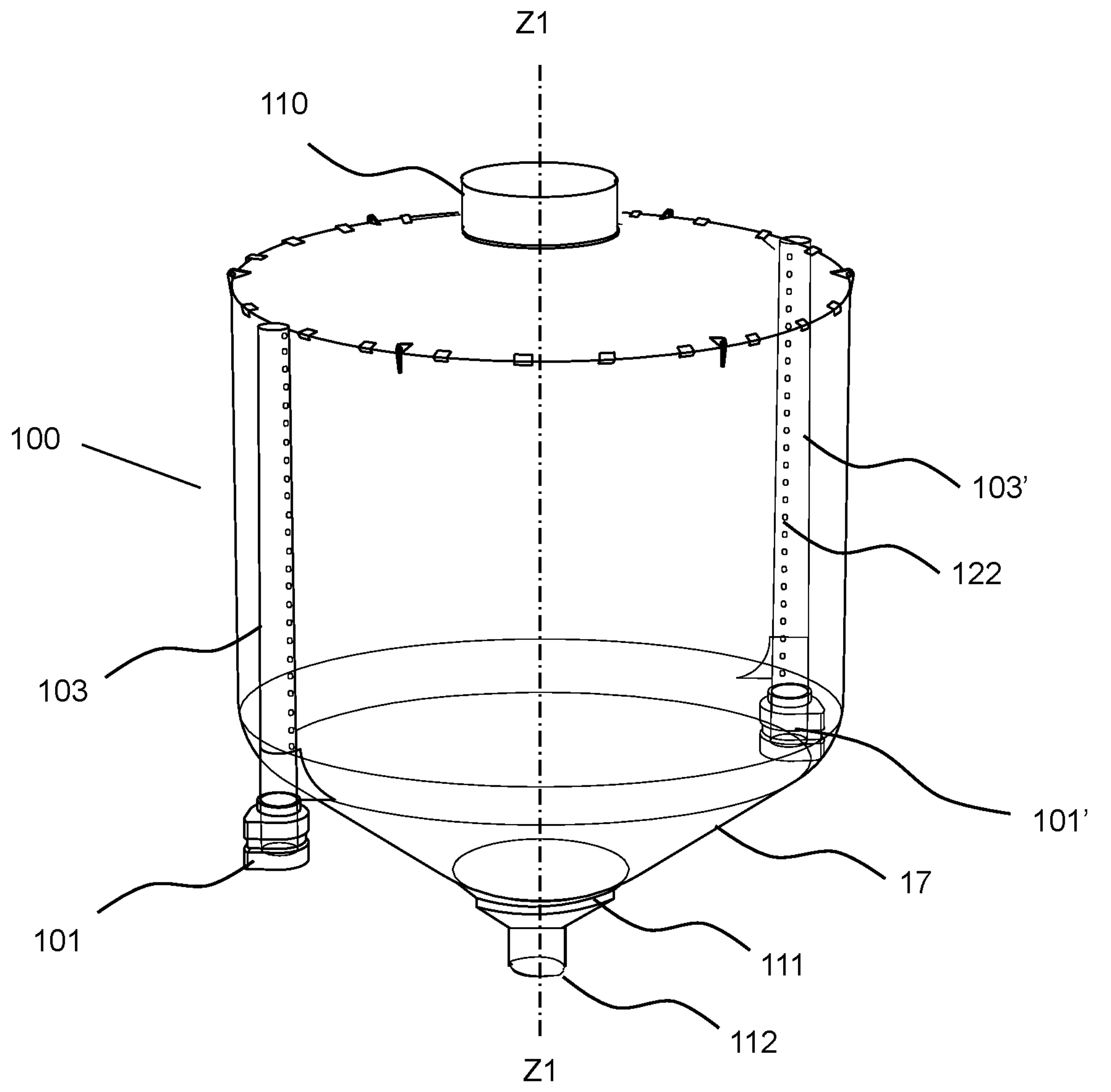

FIG. 1

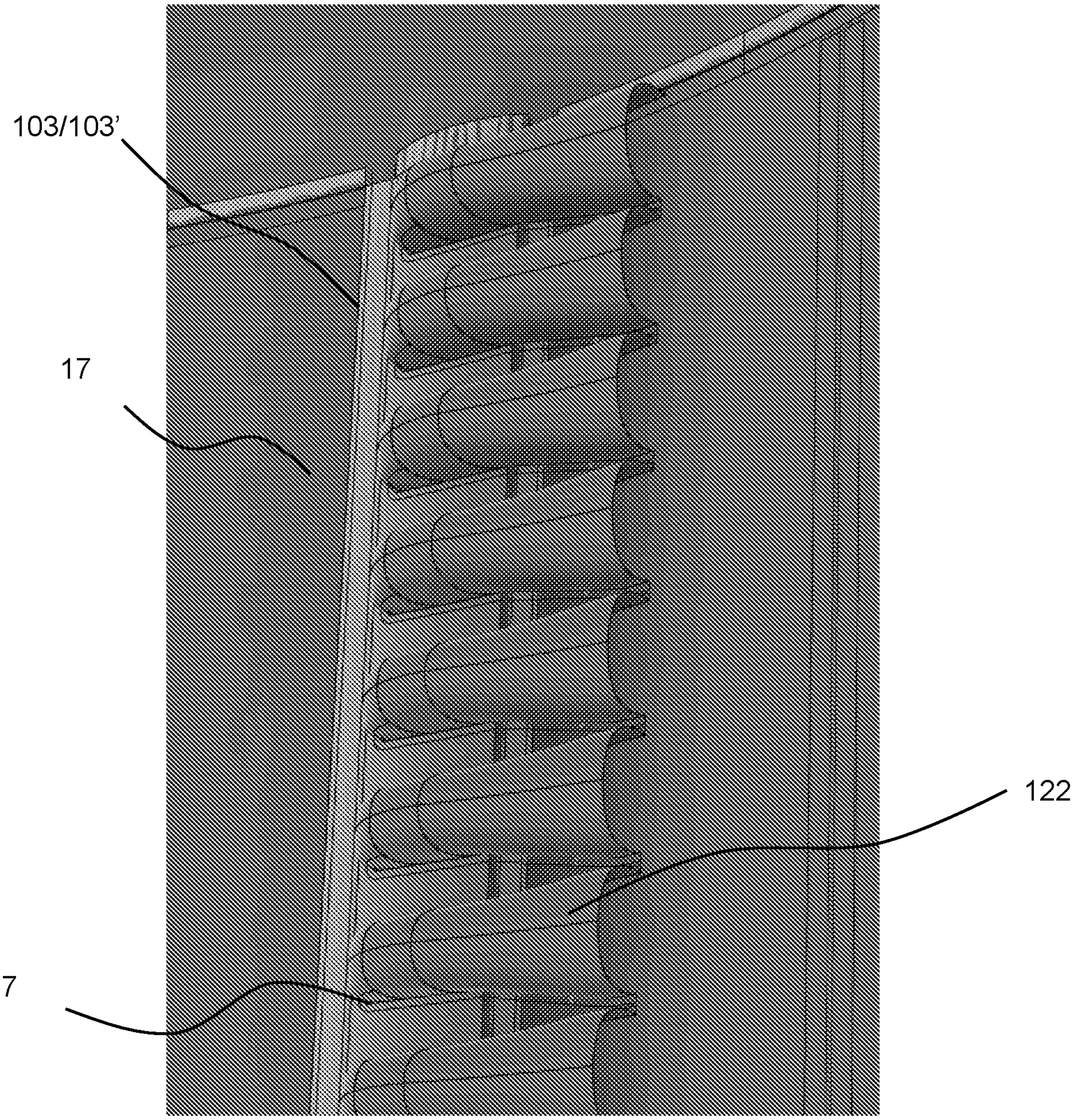

FIG. 2

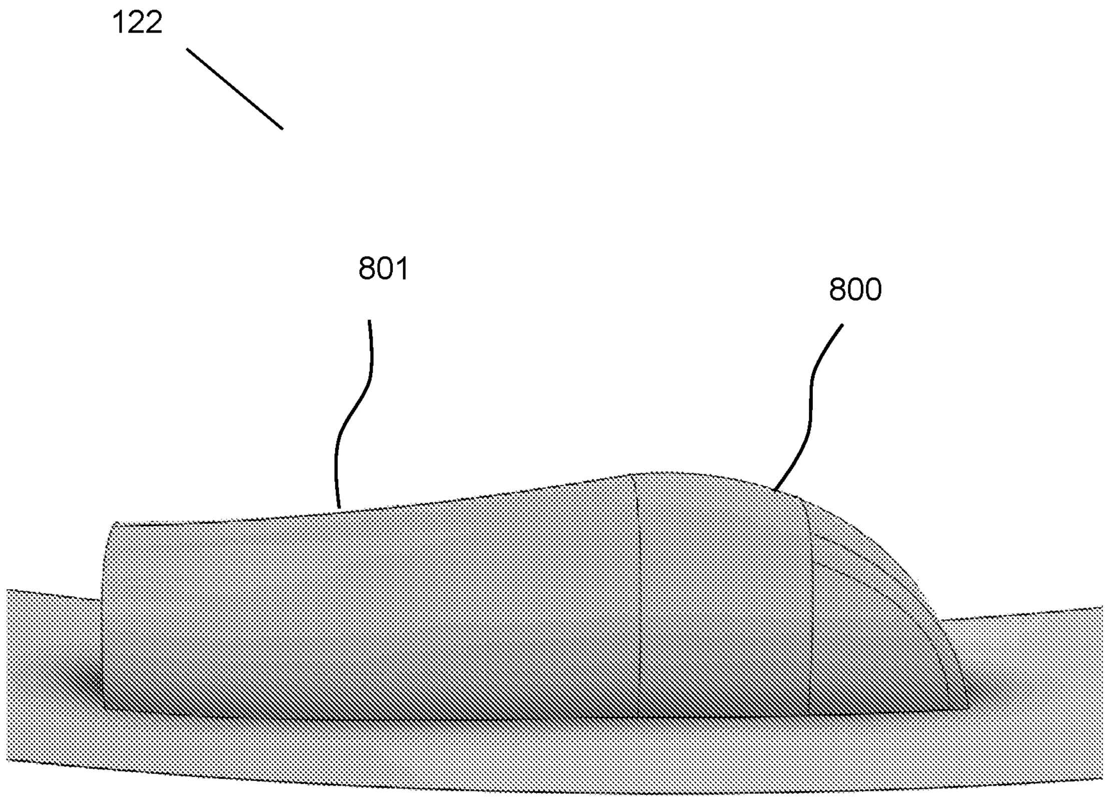

FIG. 3

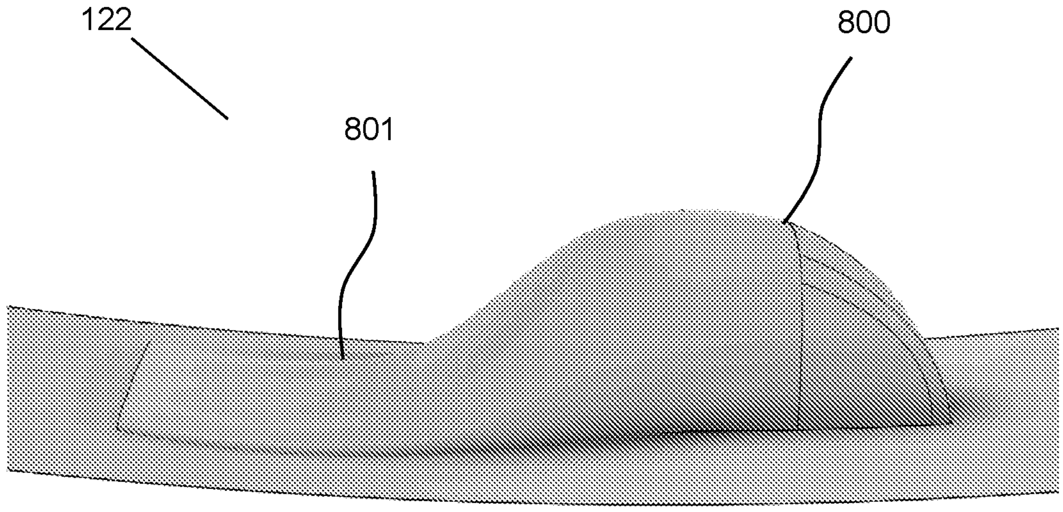

FIG. 4

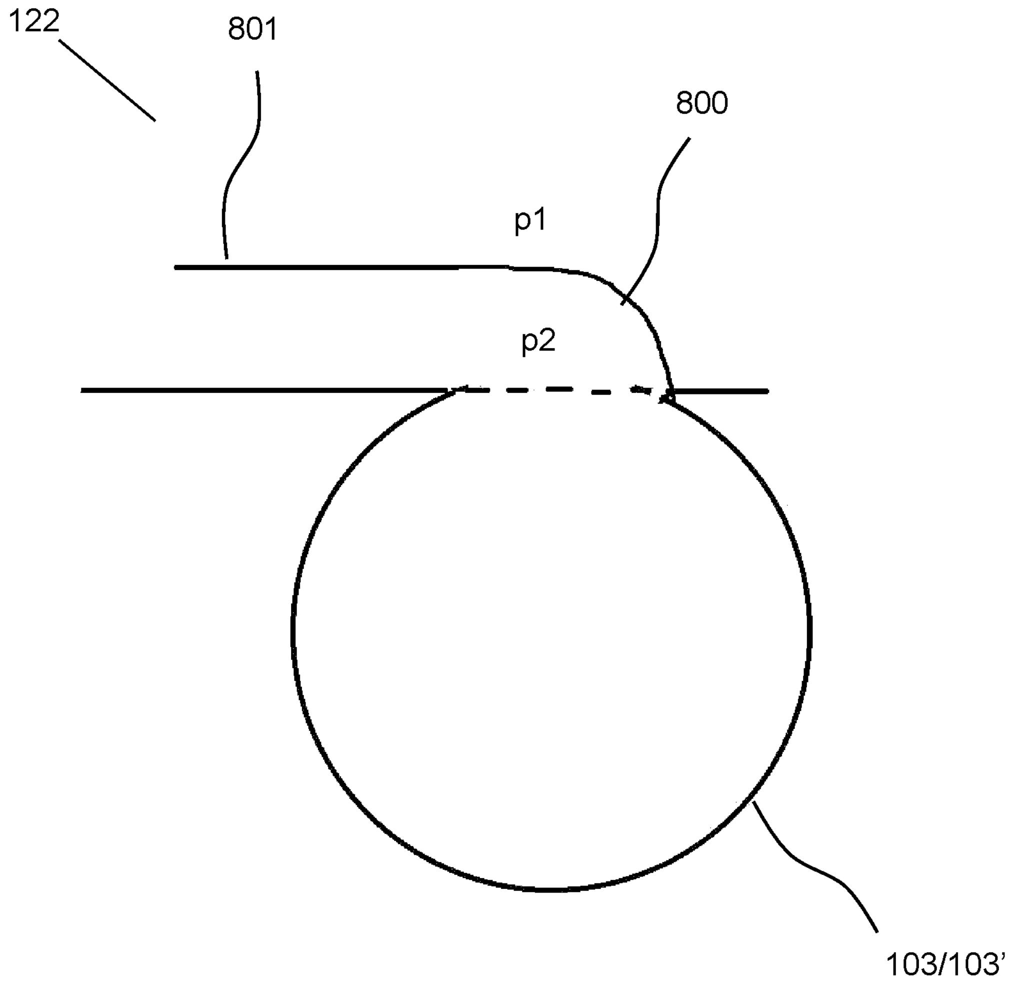

FIG. 5

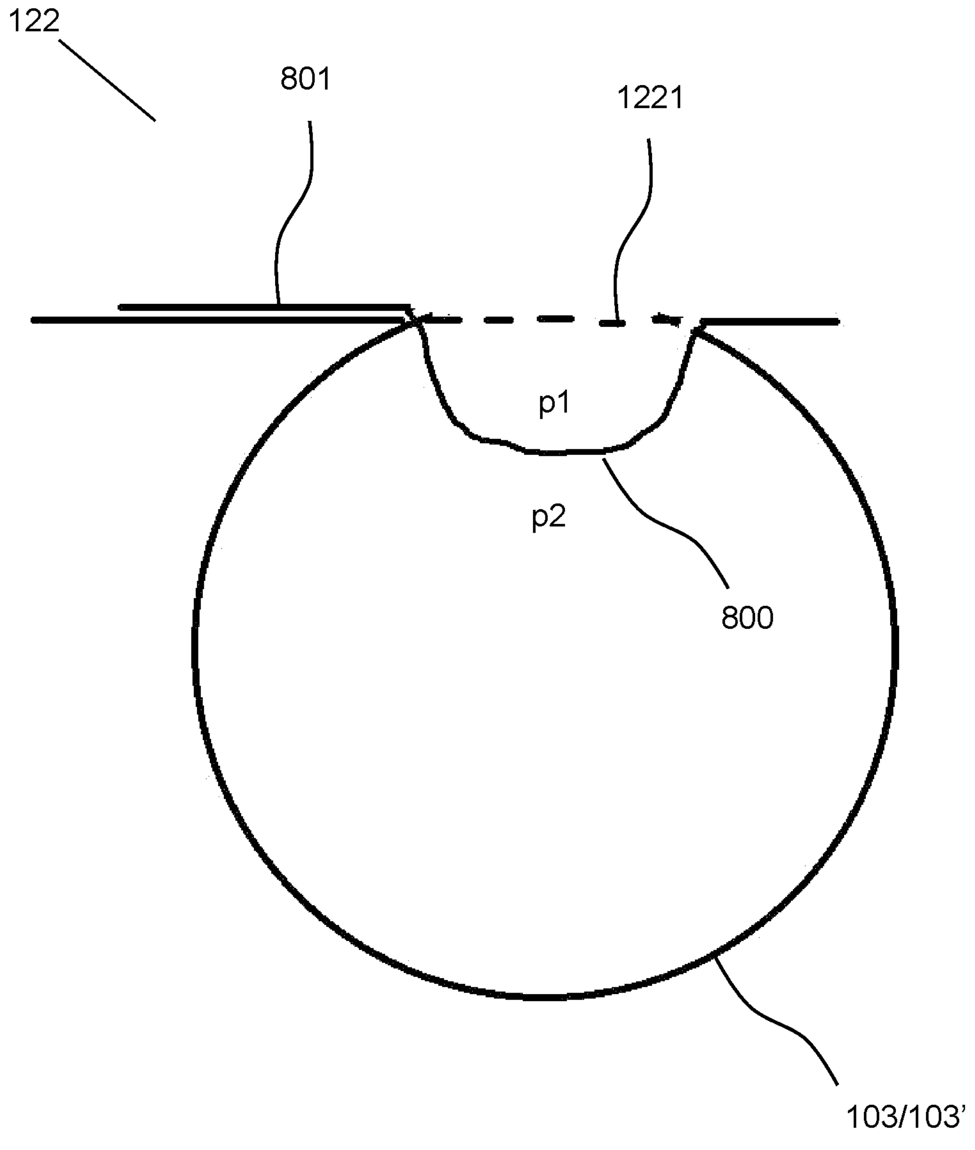

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/NO2023/060018

A. CLASSIFICATION OF SUBJECT MATTER
INV. A01K61/10 A01K63/04
ADD.

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)
A01K

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 practicable, search terms used)

EPO-Internal, 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	WO 2017/155414 A1 (KYRKJEBØ JAN ERIK [NO]) 14 September 2017 (2017-09-14) page 6, line 1 - page 10, line 2; figures 1-10 -----	1-11
A	NO 20 210 776 A1 (ECOMERDEN AS [NO]) 27 June 2022 (2022-06-27) page 4, line 21 - page 8, line 21; figures 1-6 -----	1-11

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

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Pacevicius, Matthias

INTERNATIONAL SEARCH REPORT

Information on patent family members

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WO 2017155414 A1	14-09-2017	NO 341377 B1	23-10-2017
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